IASPEI

Regional Assembly Latin-American and Caribbean Seismological Commission – LACSC

Seismology for Science and Science for Society

SCIENTIFIC PROGRAMME

June 20th to 22nd, 2016 - San Jose, Costa Rica

esencial COSTA RICA

GRUPO ICE

Academia Nacional de Ciencias

LABORATORIO DE INGENIERÍA SISMICA
INSTITUTO DE INVESTIGACIONES EN INGENIERIA
UNIVERSIDAD DE COSTA RICA

OVSICORI–UNA
INSTITUTO DE INVESTIGACIÓN OBSERVATORIO VULCANOLÓGICO Y SISMOLÓGICO DE COSTA RICA

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PRESENTATION

El Comité Organizador Local (LOC) de la II Asamblea Regional de la Comisión Latinoamericana y del Caribe de Sismología (LACSC) con mucho orgullo presenta este volumen de resúmenes de las ponencias , tanto en modalidad oral como en posters, de más de 200 científicos de 37 países que asisten a esta edición LACSC2016. Son 287 presentaciones, distribuidas en 41 sesiones y desarrolladas durante 3 días, del 20 al 22 de junio del 2016, en el Centro de Convenciones del Hotel Windham-Herradura en San José, Costa Rica.

La Comisión Latinoamericana y del Caribe de Sismología (LACSC) en una de las cuatro Comisiones Regionales de la Asociación Internacional de Sismología y Física del Interior de la Tierra (IASPEI). IASPEI a su vez es una de la ocho Asociaciones Internacionales de la Unión Internacional de Geodesia y Geofísica (IUGG).

Esta Unión Internacional fue fundada, en 1919, justo después de la I Guerra Mundial y se dedica al estudio científico del planeta Tierra para poner ese conocimiento al servicio de la sociedad. Somos una de las tres primeras uniones científicas en conformar el Concilio Internacional de Uniones Científicas (ICSU por sus siglas en inglés); ICSU lo conforma ahora 32 de estas uniones científicas.

La Asociación Internacional de Sismología y Física del Interior de la Tierra (IASPEI) cuenta con 4 Comisiones Regionales para África, Europa, Asia y para América Latina y El Caribe (LACSC).

Nuestra Comisión fue propuesta durante un Simposio Sismológico en Lima, Perú, en septiembre del 2012 y fue formalmente aprobada por el Concilio de IASPEI en su Asamblea general realizada en Gothenburg, Suecia, en julio del 2013. La primera Asamblea General de LACSC se llevó a cabo en Bogotá, Colombia en el 2014 y esta es su segunda Asamblea General.

La Misión de LACSC es promover la ciencia de la sismología en América Latina y el Caribe estimulando estudios de investigación, ampliando la cooperación científica y facilitando entrenamiento a los científicos jóvenes. La organización de estas Asambleas Regiones bi-anuales es una de sus principales tareas.

PRESENTATION

En los últimos años la región latinoamericana y del Caribe ha tenido un gran desarrollo sismológico, tanto en la densificación de las redes locales de observación, como en la producción de una gran cantidad de conocimiento y desarrollo teórico de la disciplina. Las redes sismológicas individuales de los países comienzan a ser integradas en grandes redes regionales, continentales y mundiales, permitiendo la obtención de una gran cantidad de registros sísmicos en tiempo real. Redes de control geodinámico locales en volcanes y para sismología urbana están abriendo nuevas ventanas para el conocimiento de procesos generadores de desastres y para la mitigación de sus efectos.

Esta segunda asamblea de LACSC agrupa a científicos de más de tres decenas de países y de muy diversas áreas del conocimiento geofísico que surge alrededor de la sismología. Participamos aquí, entre otros, sismólogos teóricos, instrumentalistas, sismólogos volcánicos, paleosismólogos, ingenieros de la comunidad de construcción sismoresistente, desarrolladores de software sismológico, geodestas de deformación cortical, modeladores de fuentes sísmicas, desarrolladores de instrumentación sismológica, tomógrafos sísmicos y otros científicos interesados en contribuir y aprender del desarrollo actual y futuro de la sismología.

Este evento científico ha sido logísticamente organizado tanto por la Academia Nacional de Ciencias de Costa Rica, la institución huésped de IUGG en Costa Rica, como por la Universidad Nacional, cede del Observatorio Vulcanológico y Sismológico de Costa Rica (OVSICORI-UNA). El LOC lo conforma además científicos de la Universidad de Costa Rica y del Instituto Costarricense de Electricidad.

LACSC2016: Sismología para la Ciencia y Ciencia para la Sociedad

Marino Protti
Presidente
LACSC

DECLARATION OF PUBLIC INTEREST

La Gaceta No. 110
08 de junio,2016

EL PRESIDENTE DE LA REPÚBLICA

Y EL MINISTRO DE CIENCIA, TECNOLOGÍA

Y TELECOMUNICACIONES

Con fundamento en las atribuciones conferidas en los artículos 140 incisos 3) y 18) y 146 de la Constitución Política; 25 inciso 1) y 28 inciso 2.b) de la Ley N° 6227 "Ley General de la Administración Pública", publicada en el Diario Oficial La Gaceta N° 102, Alcance N° 90, del 30 de mayo de 1978; y el artículo 8 de la Ley N° 7169 "Ley de Promoción del Desarrollo Científico y Tecnológico", publicada en el Diario Oficial *La Gaceta* N° 144, Alcance N° 23, del 01 de agosto de 1990, y;

Considerando:

I.—Que en los últimos años la región latinoamericana y del Caribe ha tenido un gran desarrollo sismológico tanto en la densificación de las redes locales de observación, como en la producción de una gran cantidad de conocimiento y desarrollo teórico de la disciplina. Las redes sismológicas individuales de los países comienzan a ser integradas en grandes redes regionales, continentales y mundiales, permitiendo la obtención de una gran cantidad de registros sísmicos en tiempo real. Redes de control geodinámico locales en volcanes y para sismología urbana están abriendo nuevas ventanas para el conocimiento de procesos generadores de desastres y para la mitigación de sus efectos.

II.—Que los días 20 al 22 de junio de 2016 se llevará a cabo la *"II Asamblea General de la Comisión Latinoamericana y del Caribe de Sismología"*, la cual constituye una reunión académica internacional de alrededor de trescientos científicos de la región y de otras partes del mundo que trabajan haciendo investigación en todas las disciplinas de la sismología. Dicha actividad se realizará en el Hotel Windham Herradura del 20 al 22 de junio de 2016.

III.—Que la II Asamblea pretende reunir a todos los países de la región de América Latina y el Caribe, contando con la participación de especialistas científicos de diversos campos del área de geofísica: sismólogos teóricos, instrumentistas, sismólogos especialistas en volcanes, paleosismólogos, ingenieros en terremotos, programadores de software sismológicos, modeladores de fuentes sísmicas, desarrolladores de instrumentos sísmicos, tomógrafos sísmicos y cualquier geofísico interesado en aportar y aprender sobre el futuro de la sismología.

IV.—Que de conformidad con el artículo 8º de Ley N° 7169, "Ley de Promoción del Desarrollo Científico y Tecnológico", se declaran de interés público todas las actividades científicas y tecnológicas sin fines de lucro, realizadas por las entidades que forman parte del Sistema Nacional de Ciencia y Tecnología. **Por tanto,**

ACUERDAN:

Declaratoria de Interés Público de la "II Asamblea General de la Comisión Latinoamericana y del Caribe de Sismología"

Artículo 1°—Con fundamento en el artículo 8º de la Ley Nº 7169 "Ley de Promoción del Desarrollo Científico y Tecnológico", se declara de interés público la *"II Asamblea General de la Comisión Latinoamericana y del Caribe de Sismología*", que se llevará a cabo los días 20 al 22 de junio de 2016, en el Hotel Windham Herradura ubicado en San José, Costa Rica.

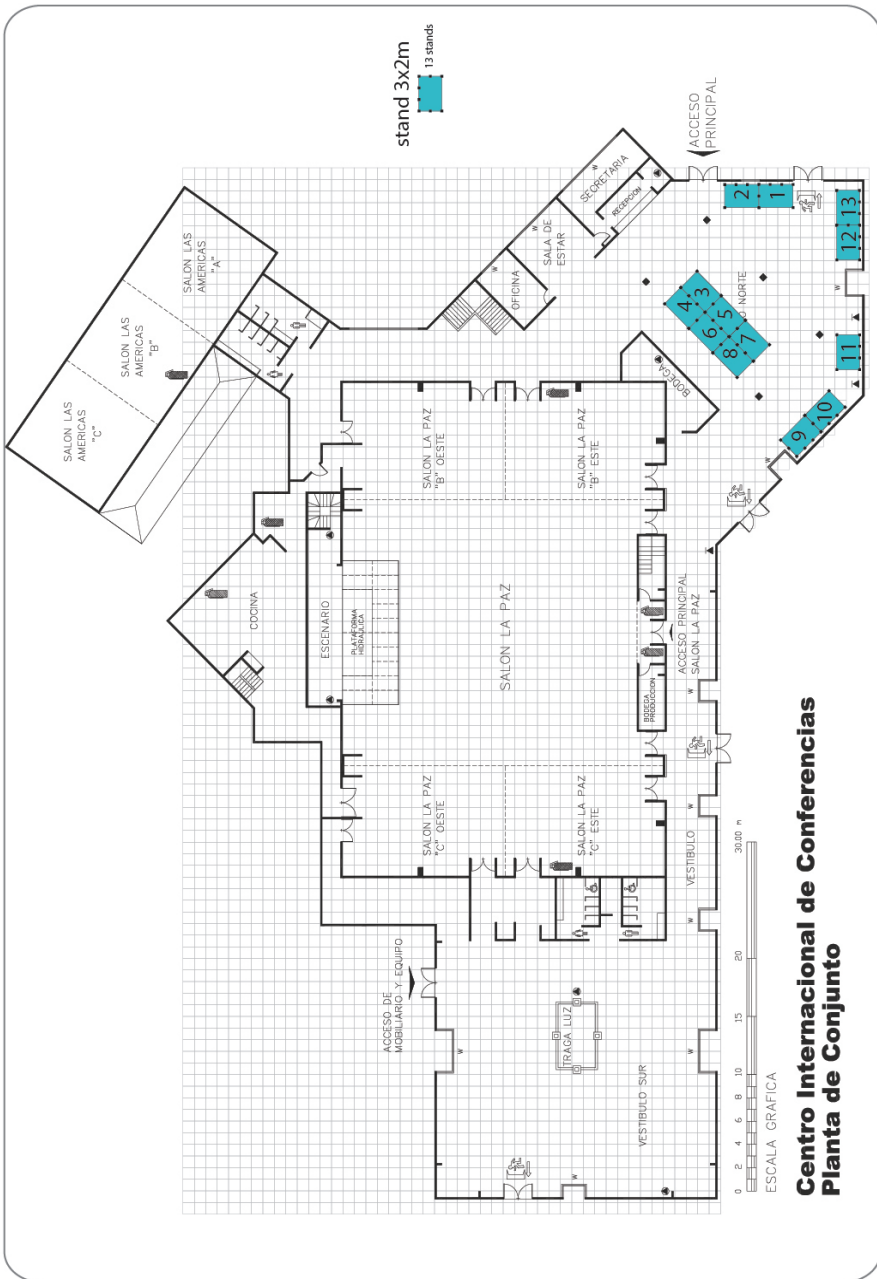
Artículo 2°—Se insta a las entidades públicas y privadas, para que en la medida de sus posibilidades y dentro de la normativa jurídica vigente, contribuyan con el aporte de recursos económicos, logísticos y técnicos para la exitosa realización de la actividad mencionada.

Artículo 3°—Rige del 20 al 22 de junio del 2016.

Dado en la Presidencia de la República. San José, a los veintiocho días del mes de marzo del dos mil dieciséis.

LUIS GUILLERMO SOLÍS RIVERA. —El Ministro de Ciencia, Tecnología y Telecomunicaciones, Marcelo Jenkins Coronas. —1 vez. —O. C. N° 3400027211. —Solicitud N° 54021. —(IN2016029105).

CONVENTION CENTER FLOOR PLAN



MEETING AT A GLANCE

Sunday June 19, 2016

16:00-18:30	Registration
18:30-19:30	Ice Breaker

Monday June 20,2016

	Plenary Room	Salon La Paz "B" Este	Salon La Paz "B" Oeste	Salon La Paz "C" Este	Salon La Paz "C" Oeste
08:00-09:00	Registration				
09:00-10:00	Opening Ceremony				
10:00-10:30	Coffee Break				
10:30-12:00		Caribbean Tectonics, Plate Montion and Plate Boundaries	Slow Slip Events, Very Long Period Events and Tectonic Tremors	Advances in Seismic Network Opertations and Offshore Instrumentation	Volcano Seismicity
12:00-13:30	Lunch				
13:30-15:15		Caribbean Tectonics, Plate Montion and Plate Boundaries	Anthropogenic Seismicity	Advances in Seismic Network Opertations and Offshore Instrumentation	Volcano Seismicity
15:15-15:45	Coffee Break				
15:45-17:15		Caribbean Tectonics, Plate Montion and Plate Boundaries	Anthropogenic Seismicity	Advances in Seismic Network Opertations and Offshore Instrumentation	
17:00-18:30	Poster Session				
18:45-20:00		Meeting of LACSC`s Executive Committee			
20:00-21:45	Welcoming Concert				

MEETING AT A GLANCE

Tuesday June 21,2016

	Salon La Paz "B" Este	Salon La Paz "B" Oeste	Salon La Paz "C" Este	Salon La Paz "C" Oeste
08:00-10:00	Active Seismology for Deep Crustal Studies in Central and South America	Seismology Applications in Engineering	Subduction Zone Processes and Science	Seismic Interferometry Monitoring Of The Earth's Background Seismic Field, Seismic Tomography And 3D Models For Earthquake Locations
10:00-10:30	Coffee Break			
10:30-12:00	Geodynamic Control Networks in Latin America and the Caribbean	Landscape Records of Earthquakes and Tsunami Tectonic Geomorphology and Paleoseismology	Subduction Zone Processes and Science	Seismic Interferometry Monitoring Of The Earth's Background Seismic Field, Seismic Tomography And 3D Models For Earthquake Locations
12:00-13:30	Lunch			
13:30-15:15	Advances in Tsunami Disaster Risk Reduction in Latin America and the Caribbean	Landscape Records of Earthquakes and Tsunami Tectonic Geomorphology and Paleoseismology	Subduction Zone Processes and Science	Regional Moment Tensor Solutions:Advances and New Applications
15:15-15:45	Coffee Break			
15:45-17:15	Advances in Tsunami Disaster Risk Reduction in Latin America and the Caribbean	Forum on the Costa Rica Seismic Code	Subduction Zone Processes and Science	Regional Moment Tensor Solutions:Advances and New Applications
17:00-18:30	Poster Session			
19:30-20:45	Official meeting of the Latin American and Caribbean Seismologial Commission to elect the new Executive Committee and the host country for LACSC2018.			

MEETING AT A GLANCE

Wednesday June 2,2016

	Salon La Paz "B" Este	Salon La Paz "B" Oeste	Salon La Paz "C" Este
08:00-10:00	Advances in Tsunami Disaster Risk Reduction in Latin America and the Caribbean	Seismic Hazards in Latin America and the Caribbean	General Contributions
10:00-10:30	Coffee Break		
10:30-12:00	Advances in Tsunami Disaster Risk Reduction in Latin America and the Caribbean	Seismic Hazards in Latin America and the Caribbean	General Contributions
12:00-13:30	Lunch		
13:30-15:15	Advances in Tsunami Disaster Risk Reduction in Latin America and the Caribbean	Seismic Hazards in Latin America and the Caribbean	General Contributions
15:15-15:45	Coffee Break		
15:45-16:45			General Contributions
15:45-17:15	Special Session on the April 2016 , Pedernales , Ecuador , Earthquake.		
17:15-17:45	Closing Remarks		

SCIENTIFIC PROGRAMME

Sunday , June 19th

16:00-18:30 Registration

18:30-19:30 Ice Breaker

Monday, June 20th

08:00- 09:00 Registration
09:00- 10:00 Opening Ceremony
10:00- 10:30 Coffee Break

10:30-12:00
Salon La Paz "B" Este- Caribbean Tectonics, Plate Motion and Plate Boundaries
Chairs: Jay Pulliam and Andres Gorki Ruiz.

10:30 **O001 Current Kinematics of the Caribbean Plate and its Margins from GPS Measurements**
Eric Calais, Steeve Symithe, Jean-Bernard de Chabalier, Richard Robertson, Machel Higgins

11:00 **O002 Tectonic inversion in the Caribbean-South American plate boundary: GPS Geodesy,Seismology, and Tectonics of the Mw 6.7 April 22,1997 Tobago earthquake**
John Weber, Halldor Geirsson, Joan Latchman, Kenton Shaw, Peter La Femina, Shimon Wdowinski, Machel Higgins, Christopher Churches, Edmundo Norabuena

11:15 **O003 Panama Arc-North Andes Collision: "Broken Indenter" model from new GPS velocity field**
James Kellogg, Héctor Mora

11:30 **O004 GPS Velocity Field of the Circum-Caribbean Region**
Jeffrey Freymueller

11:45 **O005 Investigating the Post-Seismic Deformation of 2012 Nicoya Earthquake from cGNSS data**
Rui Fernandes, Ronnie Quintero, Machiel Bos

10:30-12:00
Salon La Paz "B" Oeste- Slow Slip Events, Very Long Period Events and Tectonic Tremors
Chairs: Ana Cristina Aguiar and Nicholas Voss

11:00 **O018 Investigation of Triggered Non-Volcanic Tremor in the USA and Latin America Cancelled**
Hector Gonzalez-Huizar, Sandra Hardy
O019 Slow Slip Events and the earthquake cycle beneath Nicoya Peninsula, Costa Rica
Nicholas Voss, Timothy Dixon, Zhen Liu, Rocco Malservisi, Marino Protti, Victor Gonzalez, Susan Schwartz

11:15 **O020 Waveform modeling of very-low-frequency earthquakes off the coast of Nicoya Peninsula, Costa Rica**
Stephen Hernandez, Susan Schwartz

11:30 **O021 Slow Slip Events in Guerrero, Mexico**
Vladimir Kostoglodov, Allen Husker, Jose Antonio Santiago, Nathalie Cotte, Andrea Walpersdorf

11:45 **O022 Contrasting behavior of very low frequency earthquakes(VLFEs) in Cascadia**
Abhijit Ghosh, Alexandra Hutchison

10:30-12:00
Salon La Paz "C" Este-Advances in Seismic Network Operations and Offshore Instrumentation
Chairs: Yoshiyuki Kaneda, Carlos Vargas

10:30 **O033 Development of real-time tsunami inundation forecast system using offshore ocean-bottom pressure data from S-net**
Yoshiyuki Kaneda, Shin Aoi, Naotaka Yamamoto, Wataru Suzuki, Kenji Hirata, Hiromitsu Nakamura, Takashi Kunugi

11:00 **O034 Real time monitoring for Earthquakes and Tsunamis -For disaster mitigation of earthquakes and tsunamis**
Yoshiyuki Kaneda, Narumi Takahashi, Toshitaka Baba, Takane Hori, katsuyoshi Kawaguchi, Eiichiro Araki, Hiroyuki Matsumoto, Takeshi Nakamura, Shinichiro Kamiya, Keisuke Ariyoshi, Mamoru Hyodo, Masaru Nakano, Takashi Yokobiki, Jin-Kyu Choi, Shuhei Nishida, Shin Aoi

11:15 **O035 Instrumentation of expandable and replaceable submarine cabled real-time seafloor surveillance system "DONET".**
Katsuyoshi KAWAGUCHI, Eiichiro ARAKI, Narumi TAKAHASHI, Yoshiyuki KANEDA

11:45 **O036 Aspectos Sismotectónicos del Sandra Ridge – Cuenca de Panamá**
Carlos Alberto Vargas Jimenez, Eduardo Pulido

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10:30-12:00
Salon La Paz "C" Oeste- Volcano seismicity
Chairs: Javier Pacheco and Mauricio Mora

10:30 **O050 Actividad sísmica asociada con la erupción efusiva-explosiva del Volcán de Colima desde el 2013 al presente**
Raúl Arámbula Mendoza , Gabriel Reyes Dávila, Miguel González Amezcua, Carlos Navarro Ochoa, Dulce Vargas Bracamontes, Carlos Ariel Ramírez Vázquez, Alejandro Martínez Fierros

11:00 **O051 Seismic analysis of the 2015 eruptive activity of Volcán de Colima, Mexico**
Dulce Vargas Bracamontes, Alejandro Nava, M. en C. Gabriel Reyes Dávila, Raúl Arámbula, Alejandro Martínez, Ariel Ramírez, Miguel González

11:15 **O052 Seismic monitoring of the 2015-16 eruption of Momotombo volcano, Nicaragua**
Virginia Tenorio, Martha Navarro, Wilfried Strauch

11:30 **O053 Enjambres de sismos tipo LP y VT en el volcán Masaya, como indicio de la actividad eruptiva del lago del lava**
Martha Navarro, Greyving Arguello, Wilffied Strauch, Virginia Tenorio

11:45 **O054 Locating the 13 October 2012 Te Maari, New Zealand lahar using the amplitude source location and active seismic source methods and their implications on mass flow monitoring**
Braden Walsh, Arthur Jolly, John Procter

12:00-13:30 –Lunch

13:30-15:15
Salon La Paz "B" Este- Caribbean Tectonics, Plate Motion and Plate Boundaries
Chairs: Eduardo Camacho and James Kellogg

13:30 **O006 Strain evolution of the Salvadoran Volcanic Arc. An structural and experimental approach**
Jorge Alonso-Henar, José Antonio Álvarez-Gómez, Guido Schrdreurs, José Jesús Martínez-Díaz

14:00 **O007 What moves the Central American forearc sliver?**
Jose A. Alvarez-Gomez, Alejandra Staller, Jose J. Martinez-Diaz, Jorge Alonso Henar, Carolina Canora, Juan Miguel Insua Arevalo, Marta Béjar Pizarro

14:15 **O008 El cinturón deformado del norte de Costa Rica-Colombia: ¿Desde una faja de empuje-plegamiento hasta una zona de subducción incipiente dentro de un bloque o microplaca?**
Guillermo E. Alvarado

14:30 **O009 Updated geologic mapping in the western Azuero Peninsula**
Camilo Montes

14:45 **O010 Western Azuero-Panamá, Mapping and Structural Geology**
Carolina Ortiz

15:00 **O011 Paleomagnetic Interpretation from Northwestern Part of Azuero Peninsula, Panama**
Luis Alejandro Rodriguez-Parra, Camilo Esteban Gaitán, Camilo Montes, German Bayona, Augusto Rapalini

13:30-15:15
Salon La Paz "B" Oeste- Anthropogenic Seismicity
Chairs: José Eduardo Anderson Nascimento and Carlos Alberto Vargas

13:30 **O023 Relación de la actividad sísmica local, operaciones de explotación y fallas activas, en los campos geotérmicos de México**
Javier Lermo

14:00 **O024 Sismicidad inducida en los campos geotérmicos de Costa Rica**
Waldo Taylor

14:15 **O025 Identifying earthquake families of induced seismicity in The Geysers geothermal field by means of the transformation to equivalent dimensions**
Stanislaw Lasocki, Beata Orlecka-Sikora, Constantinos Leptokaropoulos, Grzegorz Kwiatek, Patricia Martínez-Garzón

14:30 **O026 Characterization of the seismic activity in the oil zone of Puerto Gaitán, Llanos Orientales Basin (Colombia)**
Daniel David Siervo, María Daniela Reyes, Cristina Dimaté

14:45 **O027 Estimación de atenuación de ondas de coda para la cuenca de los Llanos Orientales de Colombi**a
Carlos Eduardo Fajardo Zarate, Carlos Alberto Vargas Jiménez

15:00 **O028 Anthropogenic Seismicity in Colombia: a qualitative and quantitative probabilistic approach.**
Sebastian Gomez Alba, Carlos Vargas

13:30-15:15
Salon La Paz "C" Este Advances in Seismic Network Operations and Offshore Instrumentation
Chairs: Dmitry Storchak and Wilfred Strauch

13:30 **O037 The National Seismological Center and rapid characterization of the September 16 2015 M8.4 Chile earthquake**
Sergio Barrienos

13:45 **O038 The Brazilian Seismographic Network current developments and outcomes**
Marcelo Bianchi, Marcelo Assumpção, Hans Agurto-Detzel, Bruno Collaço, José Roberto Barbosa, Cleusa Barbora, Jackson Calhau, Luis Gualhardo, Felipe dos Anjos Neves, Emília Brasilio

14:00 **O039 Avances y perspectivas a futuro: modelos de instalación y organización de la Red Sismológica Uruguaya (RSU)**
Hernan Castro, Martín Rodríguez, Enrique Latorres, Leda Sánchez Bettucci

14:15 **O040 Renovation of the National Seismological Network of Costa Rica: improving station coverage and earthquake monitoring**
Lepolt Linkimer, María Cristina Araya

14:30 **O041 Status of the Nicaraguan Seismic Network - 2016**
Wilfried Strauch, Antonio Acosta, Fernando García, Ulbert Grillo, Elvis Mendoza, Allan Morales, Domingo Ñamendi, Javier Ramírez, Wesley Sang, Emilio Talavera, Virginia Tenorio

14:45 **O042 The Mexican National Seismological Service: An overview**
Xyoli Perez-Campos

15:00 **O043 The ISC Products and Services for Latin America and the Caribbean Region**
Dmitry Storchak, James Harris, Domenico Di Giacomo

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13:30-15:15
Salon La Paz "C" Oeste Volcano seismicity
Chairs: Dulce Vargas Bracamonte and Henriette Bakkar Hindeleh

13:30 **O055 Precursors and Seismic Evolution of Cotopaxi 2015 eruption, Ecuador**
Mario Ruiz, Stephen Hernández, Guillermo Viracucha, Patricia Mothes, Alexandra Alvarado, Gabriela Arias, Gabriela Ponce, Morgan Plain

14:00 **O056 Actividad sísmica asociada a los procesos eruptivos del volcán Rincón de la Vieja,Costa Rica, durante el período 2014-2015**
Henriette Bakkar Hindeleh, Mauricio Mora Fernández, Waldo Taylor Castillo

14:15 **O057 Seismic precursors evolution along the eruptive stages from 2010-2016 at Turrialba volcano, Costa Rica**
Mauricio M. Mora, Javier Fco. Pacheco

14:30 **O058 Seismic signals associated to explosive activity at Turrialba volcano, Costa Rica**
Javier Pacheco, Mauricio Mora

14:45 **O059 A first tomographic study of Baru Volcano, Chiriquí, Southwestern Panama.**
Daphne Sagel, Eduardo Camacho, Inmaculada Serrano

15:00 **O060 Regularly reoccurring seismic swarms at Guagua Pichincha, Ecuador**
Stephen Hernandez, Mario Ruiz

15:15-15:45–Coffee Break

15:45-17:15
Salon La Paz "B" Este- Caribbean Tectonics, Plate Motion and Plate Boundaries
Chairs :Jeff Freymueller and Guillermo Alvarado.

15:45 **O012 Sismicidad superficial en el extremo nororiental de Colombia y su relación con la convergencia entre la Placas Caribe y Suramérica**
German Chicangana

16:00 **O013 Receiver function imaging beneath the Northeast Caribbean**
Jay Pulliam, Gift Ntuli, Mohit Agrawal, Eugenio Polanco Rivera, Victor Huerfano Moreno

16:15 **O014 Focal Mechanisms of Intermediate-Depth Earthquakes Beneath the Northeast Caribbean**
Jay Pulliam, Hannah Mejía, Eugenio Polanco Rivera, Víctor Huérfano Moreno

16:30 **O015 The seismicity at the Gulf Of Chiriqui, southwestern Panama**
Eduardo Camacho, Néstor Luque

16:45 **O016 The Panama –Colombia border sequence of July 29,2015**
Eduardo Camacho, Nestor Luque

17:00 **O017 The change of dip of the subducted cocos plate in southern Mexico: is it related to the north America-Cocos-Caribbean triple junction?**
Marco Guzman-Speziale

15:45-17:15
Salon La Paz "B" Oeste- Anthropogenic Seismicity
Chairs: Waldo Taylor and Stanisław Lasocki

15:45 **O029 E-research platform of EPOS Thematic Core Service anthropogenic hazards**
Beata Orlecka-Sikora, Stanislaw Lasocki, Jean Robert Grasso, Jean Schmittbuhl, Grzegorz Kwiatek, Paolo Gasparini, Alexander Garcia, Nigel Cassidy, Tomasz Szepieniec

O030 New seismicity in the Açu reservoir,NE Brazil,and implications for fault hydraulic variability Cancelled
Aderson Nascimento, Pedro Rodrigues, Francisco Bezerra, Joaquim Ferreira, Heleno Neto, Eduardo Menezes

16:30 **O031 Reservoir-Triggered Seismicity in Brazil: characteristics and new cases**
Lucas Vieira Barros, Marcelo Assumpcao, Monica G. Von Huelsen, Vinicius Martins Ferreira, Juraci Carvalho, Daniel Caixeta

15:45-17:15
Salon La Paz "C" Este Advances in Seismic Network Operations and Offshore Instrumentation
Chairs: Lepolt Linkimer, Marcelo Assumpcao

15:45 **O044 The real-time strong motion monitoring network of the Lesser Antilles Island Arc**
Lloyd Lynch, Jean-Marie Saurel, Daniel McNamara, André Anglade

O045 La Red Acelerográfica en México "Una Retrospectiva" Cancelled
Leonardo Alcántara, David Almora, Leonardo Ramírez-Guzmán, Citlali Pérez

16:15 **O046 Red de Monitoreo acelerográfico y sistema de reporte automatizado del Instituto Costarricense de Electricidad (ICE)**
Alvaro Climent, Rosey Piedra

16:30 **O047 The scope for Earthquake Early Warning in Nicaragua and Central America**
Wilfried Strauch, John Clinton, Yannik Behr, Emilio Talavera, Virginia Tenorio

16:45 **O048 Completeness of the RSN earthquake catalog, Costa Rica**
Kevin Godínez, Mario Arroyo, Lepolt Linkimer

17:00 **O049 Minimum 1D P wave velocity model for the Guanacaste Volcanic Arc, Costa Rica**
María Cristina Araya, Lepolt Linkimer, Waldo Taylor

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17:15-18:30- Poster Session

MO_P001 Observations of Remotely Triggered Seismicity in Salton Sea and Coso Regions, Southern California, After Big (Mw>7.8) Recent Earthquakes
Raul Ramon Castro, Robert Clayton, Egill Hauksson, Joann Stock

MO_P002 Coulomb Failure Stress modeling of past destructive earthquakes in El Salvador, forecasting the next one
Jose A. Alvarez-Gomez, Marta Béjar Pizarro, Jose J. Martinez-Diaz, Jorge Alonso Henar, Carolina Canora, Juan Miguel Insua Arevalo

MO_P003 Dynamic earthquake triggering of long period events in the San Miguel Volcano
David Soto, Aaron Velasco, Ezer Patlan, Richard Alfaro-Diaz

MO_P004 Near Surface shear wave velocity increase trend estimation from dispersion curve and its utilization for H/V curve technique at a sediment filled crater site, Sao Paulo Brazil
Irfan Ullah, Renato Luiz Prado

MO_P005 Intraplate seismicity in mid-plate South America: Correlations with geophysical lithospheric parameters
Hans Agurto-Detzel, Marcelo Assumpção, Marcelo Bianchi, Marlon Pirchiner

MO_P006 Electromagnetic signals and seismicity on the central region of Colombia
Juan Manuel Solano , Carlos A Vargas , Alexander Caneva

MO_P007 Análisis de la deformación actual del Valle Central a partir de mecanismos focales y mediciones GPS entre el 2010 – 2015, Costa Rica
Hernan Porras, Ronnie Quintero, Cyrill Muller

MO_P008 Integrated Static and Dynamic Stress Modeling for Investigating Tremor Source Regions in the San Andreas Fault
Ms. Sandra Hardy, Hector Gonzalez - Huizar, Bridget Konter

MO_P009 Automatic Earthquake Solutions - Quality Assessment and Dissemination
Billy Burgoa, Marino Protti, Joan Latchman, Chandradath Ramsingh

MO_P010 Differences in the lithosphere seismic structure along the Brazilian continental margin from travel time seismic tomography
Marcelo Rocha, Paulo Azevedo, Marcelo Assumpção, George França, Giuliano Marotta

MO_P011 Actividad sísmica en Sandra Ridge – Cuenca de Panamá
Jose Eduardo Pulido, Carlos Alberto Vargas

MO_P012 Seismic Anisotropy in the Paraguay-Araguaia Fold Belt, Brazil
Monique Costa, George Sand Franca, Polyanna Moro

MO_P013 Getting Ground Truth events from quarry blasts knowing location, but not the origin time
Lucas Vieira Barros, Juraci Carvalho, Marcelo Rocha, Daniel Caixeta, Vesna Resende Barros

MO_P014 Mantle discontinuities images across stable South American continent
Marcelo Bianchi, Marcelo Assumpção, Jordi Julià

MO_P015 The South – Eastern Brazilian Seismological Network and the Brazilian Seismological Portal
Thiago Sant'Anna, Sergio Fontes**MO_P016 Waveform cross correlation to discriminate natural and artificial events**
Ms. Vesna Barros, Lucas Vieira Barros, Juraci Carvalho, Daniel Caixeta
MO_P017 Sinkholes on natural ground in plateau region currency, iron quadrangle, itabirito - mg: Caused by earthquakes natural?
Gomes Jr AntôNio Augusto Seabra
MO_P018 Determination of magnitude and epicenter of historical earthquakes in Brazil by inversion techniques using intensity attenuation curves: application to the 1861 and 1950 events
Ana Paula Trindade Souza, Leonardo Yoshiaki Kamigauti, Marcelo Assumpção
MO_P020 Upper mantle transition zone underneath Southern Peru
Xyoli Pérez-Campos, Robert W. Clayton
MO_P021 Subsurface boundaries of the San Francisco and Amazonian cratons from travel time seismic tomography
aulo Azevedo, Marcelo Rocha
MO_P022 Studying Active Faults in Colombia using High Precision Geodetic Tecniques: A new challenge
Héctor Mora-Páez, Hans Diederixd, Olga Patricia Bohorquez Orozco, Jair Ramirez Cadena
MO_P023 Morphology tectonic and seismotectonic of Agua Caliente and Navarro faults
Nathalie Chavarría,, Oscar Lücke, Lepolt Linkimer, Walter Montero
MO_P024 Relación entre estructuras-esfuerzo y sismicidad en los sectores de Puriscal-La Guácima, Costa Rica
Mario Arroyo, Juan Carlos Carranza, Marvin Moya, Hernan Porras
MO_P025 Morphotectonic signatures of active faulting and linked seismicity in Central Costa Rica
Allan López, Louis Andreani, Leomaris Domínguez
MO_P026 Morphotectonic analysis of seismic sources in El Salvador
Jorge Alonso-Henar, José Jesús Martínez-Díaz, José Antonio Álvarez-Gómez
MO_P027 Neotectónica de la Falla Cipreses y sus implicaciones en la zonificación del uso del suelo, cantones de Montes de Oca, Curridabat y La Unión
Evelyn Rodríguez Coto, Lepolt Linkimer
MO_P028_A Environmental effects triggered by January and February 2001 El Salvador earthquakes: Analysis for hazard assessment
Eliana Esposito, Crescenzo Violante, Giuseppe Giunta, Eutizio Vittori, Antonio Caprai, Miguel Angel Hernandez
MO_P028_B Archaeological evidence of tsunami deposits in the Lesser Antilles related with the 1755 Lisbon earthquake
Valerie Clouard, Jean Roger, Emmanuel Moizan
MO_P029 Intensity Attenuation Relationship in Costa Rica
Juan Porras
MO_P030 Ambient Seismic Noise Levels of OVSICORI-UNA Broadband Seismic Stations
Billy Burgoa, Marino Protti, Ronnie Quintero

MO_P031 Application of the double difference earthquake location algorithm with HypoDD to four seismic sequences at Central Costa Rica
María Cristina Araya
MO_P032 Detection Threshold OVSICORI-UNA Seismic Network
Billy Burgoa, Javier Pacheco, Marino Protti
MO_P033 Depth-dependent periodic change in the interplate coupling at NE Japan inferred from spatial gradient of velocity field
Takeshi Iinuma
MO_P034 Crustal Kinematics Driven by Aseismic Ridge Collision: Cocos Ridge
Gorki Andres Ruiz,, Peter La Femina, Eduardo Camacho, Arkin Tapia, Hector Mora-Paez, Javier Cornejo, Omar Espinoza
MO_P035 Present day kinematics of El Salvador Fault Zone
Alejandra Staller, José A. Álvarez-Gómez, José J. Martínez-Díaz, Belén Benito
MO_P036 The 1976 Guatemala earthquake case study: A contribution to the seismic hazard evaluation
Sabina Porfido, Efisio SPIGA
MO_P037 Volcanic tremor associated to the eruptive activity between 2014 and 2016 at the Turrialba volcano (Costa Rica)
Amalia Gutiérrez, Juan Luís Porras, María Fernanda Jiménez, Mauricio Mora, Paulo Ruíz Cubillo
MO_P038 Análisis de la sismicidad ocurrida en el volcán de San Miguel en los años 2013 y 2014
Rosa Amelia García Castro, Griselda Marroquín, Nelson Gómez
MO_P039 Actividad sísmica durante crisis eruptiva del 01 al 09 de mayo del 2015. Volcan Telica, Nicaragua.
Virginia Tenorio, Martha Navarro, Amilcar Cabrera, Greyving Argûello
MO_P040 Seismicity of Ijaci, southern of Minas Gerais State, Brazil is caused by mining extraction, water extraction or reservoir impoundment?
Vinicius Ferreira, Lucas Barros, Paulo Coutinho

18:45-20:00 Salón La Paz "B" Este Meeting of LACSC`s Executive Committee

20:00-21:45 Welcoming Concert

Tuesday, June 21st

08:00- 10:00
Salon La Paz "B" Este- Active seismology for deep crustal studies in Central and South America
Chairs: Michael Schmitz and Jose Eduardo Soares.

08:30 **O062 Gross crustal structure of the Merida Andes, Venezuela, from seismic wide angle and gravimetric studies**
Michael Schmitz, Javier Sánchez, Fernando Mazuera, Luis Yegres, Jesús Ávila, Euries Gil, Nuris Orihuela,

08:45 **O063 Crustal structure beneath the inverted falcon basin,Merida Andes,and el Baul Massif, Venezuela, from deep seismic studies.**
Fernando Mazuera, Michael Schmitz, Alan Levander, Colin Zelt, Euries Gil

09:00 **O064 North São Francisco Craton seismic profile: NE Brazil**
Jose Eduardo Soares, Reinhardt Fuck, Marcus Vinicius Lima, Eduardo Freire, Vanessa Nascimento, Cintia Trindade, Leandro Moutinho

09:15 **O065 The PABBRISE profile,onshore SE Brazil**
Renato Bernardes, José Eduardo Soares, Cássia Luisa Peixoto, Camila Hanna Simões, Reinhardt Fuck, Marcus Vinícius Lima, Adriano Viana

09:30 **O066 Parnaíba Basin WARR,Brazil**
Vitto AraúJo, Fábio Rocha, Flavio Lima, Cíntia Trindade, Camila Simões, José Soares, Randell Stephenson, Reinhardt Fuck, Marcus Lima

09:45 **O032 Seismic model of Borborema Province,northeastern Brazil: NW-SE transect**
Marcus Vinicius Lima, José Eduardo Soares, Reinhardt Fuck, Jesús Berrocal, Edson Tavares, S. Noelia Mejía

08:00- 10:00
Salon La Paz "B" Oeste- Seismology applications in engineering
Chair: Carlos Aguirre

O085 A Probabilistic Methodology for Site Specific Response Analysis Cancelled
Atilla Ansal, Gökçe Tönük

08:15 **O199 Analysis of a small magnitude earthquake sequence and its possible relation to the recent collapse of a tailings dam in south-east Brazil**
Marcelo Assumpção, Marcelo Bianchi, Hans Agurto-Detzel, Martin Schimmel, Bruno Collaço, José Roberto Barbosa, Jackson Calhau

08:30 **O086 Efectos por directividad de la fuente sísmica del Terremoto de Sámara 7,6Mw,del 5 setiembre del 2012,Costa Rica**
Wilfredo Rojas

O088 Estimación de parámetros sísmicos. Una metodología neuronal Cancelled
Leonardo Alcántara , Silvia García

09:15 **O089 Modelación Probabilista de Escenarios de Riesgo Sísmico en Managua,Capital de Nicaragua**
Orlando Hernandez Rubio, Ana Izaguirre, Norwin Acosta, Wilfried Strauch

O090 Rupture characteristics of 2012 earthquake doublet in Ahar- Varzagan region,using Empirical Green Function method Cancelled
Hesaneh Mohammadi, Mohammad Reza Gheitanchi

O091 Generation A New Near Source Ground Motion Catalog for Tectonically Active Part of the Alp-Himalayan Belt Cancelled
Zoya Farajpour, Mehdi Zare, Shahram Pezeshk

SCIENTIFIC PROGRAMME

08:00- 10:00
Salon La Paz "C" Este- Subduction zone processes and science
Chairs: Tiegan Hobbs and Juliana Ayala

08:00 **O103 Spatial variation of the postseismic seafloor displacements associated with the 2011 Tohoku-oki earthquake (M9.0) based on repeated GPS/Acoustic observations**
Fumiaki Tomita, Motoyuki Kido, Yusaku Ohta, Ryota Hino, Takeshi Iinuma, Yukihito Osada

08:30 **O104 Unlocking Controls on Earthquake Behavior Along the Subduction Megathrust: Findings from the Nicoya Seismic Cycle Observatory**
Andrew Newman, Christodoulos Kyriakopoulos, Timothy Dixon, Susan Schwartz, Rocco Malservisi, Marino Protti

08:45 **O105 Postseismic Deformation Following the 2012 Mw 7.6 Nicoya Earthquake: What Can We Learn From a Dense Geodetic and Seismic Network Directly Above an Active Megathrust**
Tiegan Hobbs, Andrew Newman, Dongdong Yao, Marino Protti

09:00 **O106 The 2012 M7.6 Nicoya Peninsula, Costa Rica, earthquake sequence: Source scaling and energy budget**
Esteban Chaves, Thorne Lay

09:15 **O112 Forearc survival and the upper limit of the seismogenic zone**
Marino Protti, Floribeth Vega, Walter Jiménez

09:30 **O110 Rupture process of the 2012 Nicoya earthquake inferred from interseismic locking distributions**
Hongfeng Yang, Bing He, Huihui Weng

09:45 **O200 Detailed Spatio-Temporal Evolution of Aftershocks and Repeating Earthquakes Following the 2012 Mw7.6 Nicoya Earthquake**
Dongdong Yao, Marino Protti, Zhigang Peng, Meng Xiaofeng, Susan Schwartz, Jake Walter, Andrew Newman

08:00- 10:00
Salon La Paz "C" Oeste- Seismic interferometry monitoring of the Earth's background seismic field,seismic tomography and 3D models for earthquake locations
Chairs: Diego Quiros and Esteban Chaves

08:00 **O123 Very low velocity anomaly detected by analysis of CCF in a dense network**
Arturo Iglesias, Francisco Córdoba Montiel, Vala Hjörleifsdóttir, Víctor Manuel Cruz-Atienza, Shri Krishna Singh

08:30 **O124 Seismic and non-seismic regions of the Andean backarc crust above the flat-to-inclined slab subduction of Argentina (30-33°S) from ambient noise and regional seismic source analyses**
Patricia Alvarado, Kevin Ward, Agostina Venerdini, Jean Baptiste Ammirati, Susan Beck, Leplot Linkimer, Mario Araujo

08:45 **O125 Ambient noise tomography in the northwestern Andean region, Colombia**
Esteban Poveda, Jordi Julià, Martin Schimmel, Nelson Pérez

09:00 **O126 Seismic interferometry of railroad noise: body and surface wave imaging**
Diego Quiros, Larry Brown, Doyeon Kim

09:15 **O127 Academic "Treasure" from Industry "Trash"- From deep crustal imaging in 3D to high resolution surface wave mapping of the near- surface to detection of M<0 seismicity by processing of the normally discarded portions of large oil exploration datasets.**
Larry Brown, Doyeon Kim, Diego Quiros, Anastasija Cabolova

10:00- 10:30- Coffee break

10:30- 12:00
Salon La Paz "B" Este- Geodynamic control networks in Latin America and The Caribbean
Chair: Víctor Huérfano

10:30 O068 Seismic, geodetic and tsunami monitoring and data sharing in the Caribbean, the Puerto Rico case.
Victor Huerfano, Elizabeth Vanacore, Alberto Lopez
O069 Elastic Block Modeling of the GPS Velocity Field in Ecuador Cancelled
Paul Jarrin, Jean Mathieu Nocquet, Frederique Rolandone, Patricia Mothes

11:00 O070 Multiparameter stations: electric, magnetic, seismic, radon gas and GNSS data measurements on the central region of Colombia
Alexander Caneva, Carlos Alberto Vargas Jiménez, Juan Manuel Solano Fino

11:15 O071 GNSS space geodesy: a tool for the analysis and modeling of crustal deformation in Colombia
Hector Mora Paez, Hans Diederix, Olga Patricia Bohorquez Orozco, Sebastián Cardozo Giraldo, Leonardo Cardona Piedrahita, Yuli Corchuelo, Jair Ramírez Cadena, Gina Martinez Diaz, Leidy Giraldo Londoño, Sindy Lizarazo, Fredy Díaz Mila, Juan Peláez Gaviria, Richard Moreno, Carlos Alvarez
O072 Detectando actividad tectónica de la Falla de Cuiza y sus efectos sobre la Laguna de Cocinetas en Venezuela mediante la integración de la percepción remota y observaciones GPS Cancelled
Victor Cioce, Luz Sanchez-Arias, Darwins Valecillos, Joel Alvarado, Henio Briceño, Yajaira Torrealba, Juan Santamaria, Angel Daal, Miguel Barboza

11:45 O073 OVSICORI`s Southern Costa Rica Geodynamic Control Network: The opening of a Pandora`s Box
Marino Protti, Víctor González, Enrique Hernández, Cyril Muller, Daniel Rojas, Hairo Villalobos

10:30- 12:00
Salon La Paz "B" Oeste- Landscape records of earthquakes and tsunami: tectonic geomorphology and paleosismology
Chair: Jeff Marshall

10:30 O092 Tectonic geomorphology and paleoseismology of the Gatún fault in central Panamá
Eldon Gath, Tania Gonzalez, Thomas Rockwell, Pastora Franceschi

11:00 O093 First structural characterization of the Azuero-Sona Fault Zone
Lina Perez-Angel, Camilo Montes

11:15 O094 Use of electromagnetic geophysical methods for detecting neotectonic structures in the Azuero Peninsula, Panama.
Billy Revelo ,Andrea Jara, Camilo Montes
O095 Estudio paleosismológico de la falla Sabanalarga occidente del departamento de Antioquia-Colombia Cancelled
Albeiro Rendón Rivera, John Jairo Gallego Montoya

11:45 O096 The Navarro Fault System: left-lateral displacements along the Central Costa Rica deformed belt
Walter Montero Pohly, Lepolt Linkimer Abarca, Wilfredo Rojas Quesada

SCIENTIFIC PROGRAMME

10:30- 12:00
Salon La Paz "C" Este- Subduction zone processes and science
Chair: Eliana Gómez-Hurtado

10:30 **O107 Evolution of the Galapagos Hotspot from Oceanic Plateau to Seamounts: Evidence from Azuero, Panamá**
Edgar Alejandro Cortés Calderón, Marco Antonio Rodríguez Ruiz, Nathalia Andrea Pineda Rodríguez, Maria Margarita Ariza Acero, Maria Paz Urdaneta Urrea, Andrés Felipe Rodríguez Corcho, Camilo Montes Rodríguez, Idael Francisco Blanco Quintero

10:45 **O108 Bouguer anomaly model from Western Azuero Peninsula, Panamá**
Juliana Ayala, Camilo Montes , David Farris

11:00 **O109 Is Loma Iguana (Azuero Peninsula,Panama) a global example of transition from intraplate to arc-related magmatism?**
Laura Catalina Agudelo Motta, Carolina Rubiano Rodriguez, Idael Francisco Blanco Quintero, Camilo Montes Rodriguez

11:15 **O111 SKS and local S-Wave splitting evidence for sub-slab mantle flow in northwestern South America subduction zones**
Javier Idarraga-Garcia, Michael Kendall, Carlos A. Vargas

O113 Record of the evolutions from an oceanic arc to a young continent in the Central American Land-Bridge Cancelled
Esteban Gazel, Jorden Hayes

10:30- 12:00
Salon La Paz "C" Oeste- Seismic interferometry monitoring of the Earth's background seismic field, seismic tomography and 3D models for earthquake locations
Chairs: Ana Cristina Aguiar and Diego Quiros

10:30 **O128 SALSA3D: A Global 3D Velocity Model for Improved Seismic Event Location**
Sanford Ballard, Michael Begnaud, James Hipp, Christopher Young, Andre Encarnacao, W. Scott Phillips, Eric Chael

11:00 **O129 Reflection imaging using earthquake sources: Applications of RVSP (reverse vertical seismic profiling) and the need for dense arrays**
Diego Quiros, Larry Brown, Kathy Davenport, John Hole, Anastasija Cabolova, Chen Chen, Liang Han, Martin Chapman, Walter Mooney

11:15 **O130 Improvement of Epicenter Location in the offshore Campos Basin with RSTT 3D Model**
Marcelo Assumpcao, Felipe Neves, Frank Le Diagon, Atonio Ortolan, Rodrigo Rangel

12:00-13:30- Lunch

13:30-15:15
Salon La Paz "B" Este- Advances in Tsunami disaster risk deduction in Latin America and the Caribbean
Chairs: Néstor Luque and Paula Repetto

13:30 **O074 Tsunami-HySEA model validation for tsunami current predictions with Tohoku 2011 field data**
Jorge Macías Sánchez, Manuel J. Castro, Sergio Ortega-Acosta, José Manuel González-Vida

14:00 **O075 Software to forecast the tsunami parameters from pre-simulated seismic unit sources**
Cesar Omar Jimenez Tintaya

14:15 **O076 NTHMP Benchmarking of Tsunami-HySEA model for propagation and inundation**
Jorge Macías Sánchez, Manuel J. Castro, Sergio Ortega-Acosta, Cipriano Escalante, José Manuel González-Vida

14:30 **O077 Verification of a low resolution tsunami model system for Costa Rica North and Central Pacific Coast**
Silvia Chacon-Barrantes

14:45 **O078 Tsunamis on Colombia´s Pacific Coast**
Hansjürgen Meyer, Diana Patrica Mendoza Gonzalez

15:00 **O079 Evaluación del impacto de maremotos en el sur del Perú, caso de estudio: Maremoto del 13 de agosto de 1868 (Tacna)**
Nabilt Moggiano Aburto, César Jiménez Tintaya

13:30-15:15
Salon La Paz "B" Oeste- Landscape records of earthquakes and tsunami: tectonic geomorphology and paleosismology
Chair: Walter Montero

13:30 **O097 Morfotectonic and seismotectonic evidences of a large seismic source near San Salvador: the Guaycume Fault**
Jose Martinez-Diaz, Marcos Plaza Mulas, Jorge Alonso Henar, José Antonio Álvarez Gómez, Belén Benito Oterino, Carolina Canora-Catalan, Juan Miguel Insua Arevalo, Alejandra Staller Vazquez, Pilar Villamor

14:00 **O098 The nascent Caño Negro dextral fault system of northern Costa Rica and its relation to NW motion of western Costa Rica**
Walter Montero Pohly, Jonathan C. Lewis

14:15 **O099 Megathrust Earthquakes and Coastal Uplift at the Nicoya Peninsula, Costa Rica**
Jeff Marshall, Jim Spotila, Tom Gardner, Marino Protti, Eli LaFromboise, Shawn Morrish, Melissa Robinson, Andrew Barnhart, Amber Butcher, Fookgiin Khaw, Peter Piestrzeniewicz, Brent Ritzinger, John Utick, Kacie Wellington

14:30 **O100 Cocos Ridge indenter provides a regional understanding for the seismic hazard of the North Panama Deformed Belt,Caribbean Coast,Costa Rica**
Eldon Gath, Tania Gonzalez, Walter Montero

14:45 **O101 Ecological changes and overwash events at three coastal ponds of St. Thomas,U.S. Virgin Islands**
Zamara Fuentes, Martitia P. Tuttle, Wilford E. Schmidt

15:00 **O102 The Elusive Santa Monica - Hollywood fault zone of Southern California**
Tania Gonzalez, Eldon Gath

SCIENTIFIC PROGRAMME

13:30-15:15
Salon La Paz "C" Este-Subduction zone processes and science
Chair: Esteban Chaves

13:30 **O115 Subduction Zone Science – Seismological View of Nazca-South American Convergent Margin – New Results and Ongoing Questions**
Susan Beck, George Zandt, Alissa Scire, Daniel Portner, Kevin Ward, Brandon Bishop, Jamie Ryan, Lara Wagner, Maureen Long, Hernando Tavera

14:00 **O116 Rupture process of the 2015 Mw 8.3 Illapel,Chile earthquake constrained by strong-motion,high-rate GPS and teleseismic data**
Xiong Xiong, Yong Zheng, Chengli Liu, Bin Shan

14:15 **O117 The 2014 Iquique, Chile earthquake sequence: correlation between b-value and interseismic coupling**
Hans Agurto-Detzel, Hugo Soto, Andrés Tassara

14:30 **O118 Water Release from Cold Serpentinized Forearc Mantle During Subduction Associated with Warming Changes in Incoming Oceanic Plate Thermal Structure and Plate Boundary Kinematics: New Insights into Non-Volcanic Tremor (NVT)**
Stephen Kirby

14:45 **O119 Rupture parameters for the 16 September 2015,Illapel, Chile Mw 8.3 earthquake from modeling of seismic and tsunami waves**
Thorne Lay,Lingling Ye, Hiroo Kanamori, Keith Koper, Linyan Li, Kwok Cheung

15:00 **O120 Chile´s ever changing shape**
Sergio Barrienos, Francisco Del Campo

13:30-15:15
Salon La Paz "C" Oest - Seismic interferometry monitoring of the Earth's background seismic field, seismic tomography and 3D models for earthquake locationss
Chairs: Jiří Zahradník and Efthimios Sokos

13:30 **O131 Intraplate Stress Field in South America from Earthquake Focal Mechanisms: new data from waveform inversion of small regional events**
Fabio Luis Dias, Marcelo Assumpcao, Ivan Zevallos

14:00 **O132 Events relocation and source parameters of central Brazil micro-earthquakes**
Juraci M. Carvalho, Lucas Vieira Barros

14:15 **O134 Distribución espacial del centroide de las soluciones del tensor el momento sísmico a lo largo de la región central de las Antillas Menores en el periodo 2013-2015.**
O´Leary Fernando González Matos, Valerie Clouard, Jiri Zahradnik

14:30 **O135 Focal Mechanism solution for earthquakes in the Central part of Costa Rica**
Ronnie Quintero, Hernan Porras, Jiri Zahradnik

15:15-15:45 Coffee Break

15:45-17:15
Salon La Paz "B" Este- Advances in Tsunami disaster risk deduction in Latin America and the Caribbean
Chairs: Christa von Hillebrandt-Andrade and Wilfried Strauch

15:45 **O080 Potential tsunamis inundation maps in the F.W.I. from a bank of seismic scenarios**
Narcisse Zahibo, M. Bernard Dudon, Yann Krien
16:15 **O081 Tsunami scenarios and hazard assessment along the northern coast of Haiti**
Eric Calais, Audrey Gailler, Hélène Hébert, Emile Okal
16:30 **O082 Estimación de la peligrosidad por tsunami en San Andrés Isla utilizando herramientas numéricas y geoespaciales.**
Ronald Sanchez, Anlly Guerrero, Laura Vasquez
16:45 **O083 Tsunami modeling with ComMIT of the historic earthquake September 7,1882; and determination of areas of flood in the Province of Colon, Panama.**
Nestor Luque, Silvia Chacón, Yadira Echeverria, Eduardo Camacho
17:00 **O084 Numerical simulations of 1991 Limon tsunami based on two different seismic solutions**
Silvia Chacon-Barrantes, Natalia Zamora-Sauma

15:45-17:15
Salon La Paz "B" Oeste- Forum on the Costa Rica Seismic Code
Chairs: Carlos Aguirre

15:45 **O201 Aspectos Científicos y Filosóficos Para el Diseño Sismo-Resistente Considerado**
Miguel F. Cruz
16:15 **O207 Diseño Sismoresitente de viviendas en Costa Rica**
Álvaro Poveda
16:45 **O208 Seismic Risk Prevention in Costa Rica:A Successful 39 Year Experience**
Jorge Gutiérrez

15:45-17:15
Salon La Paz "C" Este- Subduction zone processes and science
Chairs:Sergio Barrientos and Susan Beck

15:45 **O121 Existing Instrumentation and Scientific Drivers for a Subduction Zone Observatory in Latin America**
Andrew Frassetto, Robert Woodward, Susan Beck, Sergio Barrientos
16:15 **O122 Building a Framework Earthquake Cycle Deformational Model for Subduction Megathrust Zones: Integrating Observations with Numerical Models**
Kevin Furlong, Rob Govers, Matthew Herman

15:45-17:15
Salon La Paz "C" Oeste-Regional moment tensor solutions: advances and new applications
Chairs: Marcelo Assumpcao and Ronnie Quintero

15:45 **O136 Rupture process of the Lefkada 2015 earthquake (Mw 6.4) using regional and local seismic data**
Efthimios Sokos, Jiří Zahradník, František Gallovič, Anna Serpetsidaki, Vladimir Plicka
16:15 **O137 Seismic source model of a deep Mw 7.6 earthquake, Nov. 24,2015, Brazil-Peru border**
Jiri Zahradnik, Jaromir Jansky, Hernando Tavera, Lucas Barros, Efthimios Sokos, Craig Bina
16:30 **O138 W-phase source inversion using high-rate regional GPS data for large earthquakes**
Sergio Barrientos, Sebastian Riquelme

17:15-18:30- Poster Session

TU_P001 The Seismic Strong Motion Array Project (SSMAP) and September 5, 2012 (Mw=7.6) Nicoya, Costa Rica Earthquake Investigation
Gerry Simila, Ehsan Mohammadebrahim, Ronnie Quintero, Karen McNally, Juan Segura

TU_P002 ShakeMap Implementation in Costa Rica
Ronnie Quintero, Billy Burgoa Rosso

TU_P003 Quality factor Q to model attenuation of seismic waves in Western Venezuela and further calibration of local magnitude MC with updated Mw magnitude values
Fernando Sorondo, Herbert Rendon

TU_P004 Seismic hazard assessment aimed at improving the building code in Haiti
Ing. Gaspard Pierristral, Maria Belén Benito, Jaime Cervera, Ing. Dwinell Belizaire

TU_P005 Simulación de escenarios sísmicos desfavorables en El Salvador
Jorge Alonso-Henar, Belén Benito Oterino, Alejandra Staller, Carolina Canora Catalán, José Jesús Martínez-Díaz, José Antonio Álvarez-Gómez

TU_P007 Estimation of the earthquake ground motion features in Tapachula (Mexico) from ambient noise and seismic data
Francisco Vidal, Gerardo Alguacil, Manuel Mavarro, Raul González, Alejandro Ruíz- Sibaja, Jorge Aguirre

TU_P008 New seismic hazard assessment in El Salvador
Alejandra Staller, Belén Benito, Jorge M. Gaspar-Escribano, Sandra Ruiz-Barajas

TU_P009 Cálculo de parámetros físicos del terremoto de Cúcuta de 1875 a partir de intensidades macrosísmicas actualizadas
Remy Galán, Augusto Antonio Gómez Capera, Ana Milena Sarabia, Alejandra Sánchez Vazquez, Luz Rodríguez, Marco Santulin

TU_P010 Receiver Function as a new methodology to model the Continental Crust - Tegucigalpa, Honduras
Luis Vargas

TU_P011Seismic characterization of the Sierra de Valle Fértil above the Pampean flat slab subduction in Argentina
Agostina Venerdini, Patricia Alvarado, Gustavo Ortiz, Mario Araujo,Leplot Linkimer

TU_P012 RomUkrSeis 2014
Randell Stephenson, RomUkrSeis 2014 Working Group,,,

TU_P013 Estructura de la corteza del Brasil central: Una aproximación por refracción sísmica y función receptora
Cíntia Trindade, José Soares, Reinhardt Fuck, Renato Bernardes
Universidad de Brasilia, Brasília, Brasil

TU_P014 Crustal structure across the northwestern region of Venezuela, Northern Andes profile, from wide-angle seismic data.
Lisfer Flores, Michael Schmitz, Jesús Ávila, Euries Gil, GIAME active seismic working group

TU_P015 Velocity model across the southern part of the Mérida Andes, Venezuela. From wide angle seismic profiles
Henderson Pinto, Michael Schmitz, Jesus Avila, Loveida Montilla, Euries Gil
TU_P016 BB-ASAP: BroadBand seismic experiment in the Area of Sergipe-Alagoas-Pernambuco, Brazil
D. Aslanian, A. Afilhado,, C. Corela, P. De Barros Correia, N. Dias,, J. Duarte, M. Evain, R. Fuck, M. Gorki, J. Julia, A. Loureiro, L. Matias, M. Moulin, A. Nascimento, S. Neves, P. Pelleau, M. Perrez-Guissente, M. Rabineau, P. Schnurle, Jose Eduardo Soares, G. Silveira
TU_P017 Ejercicio de respuesta ante tsunami local, dirigido a los escolares de nivel básico en la comunidad de Zipolite, Oaxaca, México
Hamblet Torija Morales, Francisco Reyes Hernández
TU_P018Modeling the CaribeWave2015 Tsunami Exercise Scenario: An initiative of a Caribbean-based Collaborative Modeling Group
Alberto López-Venegas, Silvia Chacón, Néstor Luque, Ronald Sánchez, Víctor Huérfano
TU_P019 Sensitivity of the tsunami hazard values to input parameters and assumptions: A case study in Central America
Natalia Zamora, Andrey Y. Babeyko
TU_P020 The relation between slip distribution and run-up: Comparison of recent Chilean tsunamis
Natalia Zamora, Juan González-Carrasco, Gabriel González
TU_P021 Percepción del riesgo ante tsunami y otros peligros de origen telúrico-meteorológico, por parte de los profesores de la Escuela Primaria Rural en Zipolite, Oaxaca, México
Hidrobiól. Francisco Reyes Hernández, David Alberto Salas de León, Ricardo Prieto-González, Hamblet Torija Morales, Pedro Joaquín Gutiérrez-Yurrita
TU_P022 Seismic Interferometry applied to fracture seismicity recorded at Planchón-Peteroa Volcanic Complex, Argentina-Chile
Micaela Maugeri,, Deyan Draganov, Victoria Olivera Craig, María Constanza Manassero, Gabriela Alejandra Badi, Luis Enrique Franco Marín, Martín Gomez, Elmer Ruigrok
TU_P023 Shear – wave velocity structure beneath northern South America from ambient noise rayleigh wave tomography
Lina Tatiana Auzaque, Mariano Simón Arnaíz - Rodríguez, Michael Schmitz,
TU_P024 Crustal Structure of North Peru from analysis of teleseismic Receiver Function
Cristobal Condori, George Sand Franca, Hernando Tavera
TU_P025 Moho depth and Vp/Vs estimates in the North and Central-West Brazil
Marcelo Peres Rocha, Diogo Albuquerque, George Sand Franca, Cristobal Condori
TU_P026 Group and Phase velocities of the Falcón Basin from Ambient Noise Correlation
Mariano S. Arnaiz-Rodríguez, Tatiana Auzaque, Michael Schmitz
TU_P027 MSNoise: A framework for Continuous Seismic Noise Analysis
Esteban J. Chaves, Thomas Lecocq, Raphaël De Plaen, Corentin Caudron, Aurélien Mordret

TU_P028 Improved Seismic Travel Times in Central and Northern Costa Rica for Accurate Earthquake Location
Ana C. Aguiar, Stephen C. Myers, István Bondár
TU_P031 Numerical modeling of initial slip and poroelastic effects of the 2012 Costa Rica earthquake using GPS data
Kimberly McCormack, Marc Hesse, Georg Stadler
TU_P032 Co- and Post- seismic ground deformation on the volcanoes of Costa Rica after the 5th September 2012 Mega Earthquake
Cyril Muller, Ana-Lucia Garita Fernendez, Marino Protti, Rodrigo Del Potro, Enrique Hernandez Rodriguez, Victor Gonzalez
TU_P034 Atenuación sísmica a partir de datos de redes temporales en el segmento de subducción horizontal de los Andes Centrales
Micaela Maugeri, Gabriela Alejandra Badi, María Constanza Manassero, José Augusto Casas,, Nora Sabbione, Jesús Ibáñez Godoy
TU_P035 Crustal structure and rheological performance beneath Eastern Cordillera, Colombia
Eliana Gómez-Hurtado, Carlos A. Vargas
TU_P037 Shape of subducting Nazca Plate and lithospheric structure in the Pampean Flat Slab Region of Argentina
Lepolt Linkimer, Susan Susan Beck, George Zandt, Patricia Alvarado, Megan Anderson, Hersh J. Gilbert, Haijiang Zhang
TU_P038 Samarray – proposal for a seismological backbone of a South American subduction zone observatory
Michael Schmitz, Mariano Arnaiz-Rodriguez, Herbert Rendon
TU_P039 Nanoseismic Monitoring an Attractive Choice for Civil Engineers
Yawar Hussain, Naomi Vouillamoz, Hernan Martinez-Carvajal,, Aderson Do-Nacimento
TU_P040 Caracterización del subsuelo utilizando el método geofisico de refracción por microtremores ReMi para segmento de la Avenida Circunvalar y Parque Central Simón Bolivar
Jessica Paola Pulido Vasquez,, Maria Daniela Rodriguez Gutierrez
TU_P041 Using GNSS data to monitor the National Geodetic Reference after the ocurrence of natural phenomena
José Francisco Valverde, Jorge Moya, Sara Bastos, Ana Lucía Garita, Daniela Ovares

19:30-20:45

Official meeting of the Latin American and Caribbean Seismologial Commission to elect the new Executive Committee and the host country for LACSC2018.

Wednesday, June 22nd

08:00- 10:00
Salon La Paz "B" Este- Advances in Tsunami disaster risk deduction in Latin America and the Caribbean
Chairs: Emilio Talavera and Natalia Zamora

08:00 **O139 Contribution of rogue events to tsunami danger in Central America**
Emile Okal

08:30 **O140 Influence of seismic source geometry over hydrodynamic processes on tsunamigenic events**
Juan González, Rafael Aránguiz, Gabriel González, Yuji Yagi, Ryo Okuwaki, César Núñez

08:45 **O141 Posibles peligros geológicos asociados a la Isla Del Coco**
Wilfredo Rojas

09:00 **O142 Breve historia de Tsunamis Marinos en México ¿Qué sabemos, cómo participamos y cómo podemos informarnos?**
Francisco Reyes-Hernández, Pedro Gutiérrez-Yurrita, David Alberto Salas de León, Gloria I. López

09:15 **O143 The Puerto Rico Tsunami Programa Component of the National Tsunami Hazard and Mitigation Program (NTHMP)**
Victor Huerfano, Elizabeth Vanacore

09:30 **O144 Tsunami Warning System for the Caribbean and Adjacent Regions: 10 Years Advancing Readiness**
Christa von Hillebrandt-Andrade, Carolina Hincapie Cardenas, Bernardo Aliaga

09:45 **O145 Local Tsunami Warnings: Perspectives from Recent Large Events**
Diego Melgar, Richard Allen

08:00- 10:00
Salon La Paz "B" Oeste- Seismic hazards in Latin America and the Caribbean
Chairs: Antonio Gomez Capera and Mark Petersen.

08:30 **O158 Probabilistic seismic hazard and site response assessments of cities in Panama**
Eduardo Camacho, Nestor Luque, Yadira Echeverría, Javier Lermo, Arkin Tapia, Eric Chichaco

08:45 **O159 New seismic zonation in Central America**
Guillermo Alvarado, Maria Belén Benito, Alejandra Staller, Alvaro Climent, Eduardo Camacho, Griselda Marroquin, Enrique Molina, Emilio Talavera, Wilfredo Rojas

09:00 **O160 Seismic hazard in Fonds-Parisien**
Sophia Ulysse

O161 Modelling the seismic risk in parts of the Caribbean Cancelled
Max Wyss, Philippe Rosset, Stavros Tolis

09:30 **O162 Seismic Hazard and Exposure assessments for South America, Central America, and the Caribbean Region**
Mark Petersen

09:45 **O163 Earthquake Parameter Estimation from Historical Macroseismic Data in Colombia**
Augusto Antonio Gomez Capera, Ana Milena Sarabia, Monica Arcila, Marco Santulin, Massimiliano Stucchi

SCIENTIFIC PROGRAMME

08:00- 10:00
Salon La Paz "C" Este- General contributions
Chairs: Julia Carolina Rivadeneyra and Waldo Taylor

08:00 **O176 Diverse Rupture Processes in the 2015 Peru Deep Earthquake Doublet**
Thorne Lay, Lingling Ye, Hiroo Kanamori, Zacharie Duputel

08:30 **O177 Determination of the Fault Plane And Rupture Size of the 2013 Santa Cruz earthquake,Bolivia,5.2Mw,by Relative Location of the Aftershocks**
Julia Carolina Rivadeneyra Vera, Marcelo Assumpcao, Estela Minaya, Percy Aliaga, Guido Ávila

08:45 **O178 Sismicidad de la cordillera volcánica de Guanacaste antes,durante y después del terremoto de Sámara de 2012 (periodo 2005-2015)**
Waldo Taylor

09:00 **O179 Identificación de estructuras sismogénicas corticales en el Bloque de Jalisco,México**
Juan Martín Gómez-González, Daniel Yela Portilla, Rosario Martínez López, Héctor López-Loera,Marco Guzmán Speziale, Stephen Grand

09:15 **O180 Microsismicidad en la Sierra Madre Oriental,México.**
Juan Martín Gómez-González,Vsevolod Yutsis, Angel F. Nieto Samaniego, Erika N. López Valdivia, Rodrigo A. León Loya

09:30 **O181 La aplicación de arrays sísmicos en el monitoreo del Volcán Ubinas-Peru**
Adolfo Inza, Edmundo Norabuena, HInda Miled

09:45 **O182 Dinámica de las principales Fallas Activas en el Perú inferida de mediciones GPS.**
Edmundo Norabuena, Yohel De la Cruz, Jhon Salazar

10:00-10:30 Coffee break

10:30-12:00
Salon La Paz "B" Este- Advances in Tsunami disaster risk deduction in Latin America and the Caribbean
Chairs: Víctor Huérfano and Jorge Macías

10:30 **O146 Tsunamigenic sources in the Middle America Trench off Central America.**
Jose Antonio Alvarez-Gomez, Iñigo Aniel Quiroga, Mauricio Gonzalez

11:00 **O147 Tsunamis recientes en Chile: que hemos aprendido para la alerta y la evacuación a partir de observaciones y modelación hidrodinámica**
Rodrigo Cienfuegos, Rafael Aránguiz, Patricio Catalán, Gabriel González, Juan González, Alejandro Urrutia

11:15 **O148 Resultados preliminares de la elaboración de un mapa de rutas de evacuación en un evento de tsunami en playa Sámara, Guanacaste (Costa Rica)**
Fabio Rivera, Isabel Arozarena-Llopis, Silvia Chacon-Barrantes, Gustavo Barrantes

11:30 **O149 Examining the role of urban form in supporting rapid and safe tsunami evacuations: a multi-scalar analysis in Iquique, Chile**
Jorge León, Eliana Guic, Rodrigo Cienfuegos, Marco Quiroz, Gonzalo Álvarez

11:45 **O150 Why should I stay? Study of the return process after a Tsunami evacuation**
Paula Repetto, Eliana Guic, Nicolás Bronfman

10:30-12:00
Salon La Paz "B" Oeste- Seismic hazards in Latin America and the Caribbean
Chairs: Antonio Gomez Capera and Mark Petersen

10:30 **O164 Building a Ground-Motion Prediction Equations Dataset for PSHA analysis in South America within the GEM-SARA project framework**
Stéphane Drouet, Luisa Fernanda Castillo, Cristina Dimaté, Gonzalo Antonio Fernández Marañon, Gonzalo Montalva, Cecilio Morales, Marlon Pirchiner, Juan Carlos Singaucho Armas, Graeme Weatherill

11:00 **O165 Updated earthquake Catalogue for South America suitable for PSHA: time window pre-1964**
Augusto Antonio Gómez Capera, Massimiliano Stucchi, Mónica Arcila, Mario Bufaliza, Choy Jose, Estela Minaya, Felipe Leyton, Marlon Pirchiner, Herbert Rendon, Leandro Rodriguez0, Ana Milena Sarabia, Hernan Tavera, Hugo Yepes

11:15 **O167 The South American Risk Assessment (SARA) Probabilistic Seismic Hazard Assessment Model: An Open Seismic Hazard Model for South America**.
Julio Antonio García, Graeme Weatherill, Marco Pagani, Luis Rodríguez, Valerio Poggi,

11:30 **O168 New hazard maps of Spain for the revision of the building code**
S. Ruiz, María Belén Benito , A. Rivas, J. Gaspar-Escribano

O169 The roadmap for updating the Italian seismic hazard model Cancelled
Carlo Meletti, Warner Marzocchi

10:30-12:00
Salon La Paz "C" Este- General contributions
Chairs: Vadin Levin and Lepolt Linkimer

10:30 **O183 Passive-Source Seismology in the Borborema Province of NE Brazil: Investigating Cenozoic Volcanism and Uplift**
Jordi Julià, Rosana M. N. Luz, Flodoaldo L. Simões Neto, Martin Schimmel, Ian D. Bastow

11:00 **O184 1-D seismic velocity structure of Colombia from constrained joint inversion of receiver functions and surface wave dispersion**
Anibal Sosa, Aaron Velasco

11:15 **0185 High resolution Double Seismic Zones in the Nazca subduction based on teleseismic depth phase arrival**s
German Prieto, Manuel Florez

11:30 **O186 3-D Local Earthquake Tomography of the Cocos Ridge Subduction at the Southeastern End of the Middle American Trench**
Lepolt Linkimer, Ivonne Arroyo, Ingo Grevemeyer, Guillermo Alvarado, Krista Thiele

11:45 **O187 Seismic anisotropy indicates mantle flow through the Central American Volcanic Gap**
Vadim Levin , Lepolt Linkimer

12:00-13:30 Lunch

SCIENTIFIC PROGRAMME

13:30-15:15
Salon La Paz "B" Este- Advances in Tsunami disaster risk deduction in Latin America and the Caribbean
Chairs: Silvia Chacón Barrantes and César Jiménez

13:30 **O151 Primaras Experiencias del Centro de Asesoramiento de Tsunami para América Central (CATAC) en INETER, Nicaragua.**
Emilio Talavera Martínez, Virginia Tenorio Bellanger, Wilfried Strauch, Javier Ramírez Zelaya

14:00 **O152 Tsunami risk and tsunami warning for Puerto Armuelle, Panama**
Wilfried Strauch, Gloria Hernández, Analisa Díaz

14:15 **O153 Propuesta de implementación de un Sistema de Cables Submarinos para detección de Tsunamis en el Centro de Alerta de Tsunamis del Perú**
Ceci Rodríguez Cruz, Nabilt Moggiano

14:30 **O154 SIPAT: Sistema de Soporte de Decisiones para la Alerta Temprana de Tsunamis de Chile**
Patricio Catalan, Javier Cañas, Carlos Zuniga, Cecilia Zelaya, Alejandra Gubler, Leonardo Pizarro, Carlos Valdés, Samuel Miranda

15:00 **O156 Tsunami-HySEA: An operational GPU-based model for Tsunami Early Warning Systems**
Jorge Macías Sánchez, Manuel J. Castro, José Manuel González-Vida, Marc de la Asunción, Sergio Ortega-Acosta

13:30-15:15
Salon La Paz "B" Oeste- Seismic hazards in Latin America and the Caribbean
Chairs: Antonio Gomez Capera and Mark Petersen

13:30 **O170 Present-day Shortening in Southern Haiti from GPS Measurements and Implications for Seismic Hazard**
Steeve Symithe, Eric Calais

O171 Probabilistic Seismic Hazard Evaluation of the Trans Mexican Volcanic Belt, Mexico, based on Instrumental and Historical Data Cancelled
Gerardo Suarez, José A. Bayona

14:15 **O172 El Sistema de Fallas de Algeciras, Colombia: Amenaza sísmica, tectonoestratigrafía y geomorfología tectónica**
German Chicangana

14:30 **O173 Updated Mw magnitude values for seismic events in eastern Venezuela, based upon an improved model for Q within the region. An empirical relation that converts former local MC values to Mw for homogenization purposes**
Gabriela Garcia, Herbert Rendon

14:45 **O174 Seismic hazard assessment in the continental Ecuador.**
Humberto Parra, María Belén Benito, Jorge Gaspar-Escribano

15:00 **O175 Estimación de la amenaza sísmica en Cumaná, Estado Sucre, Venezuela**
Jorge Rojas, Maria Belén Benito, Ligia Elena Quirós,Ysimar Rivera.

13:30-15:15
Salon La Paz "C" Este- General contibutions
Chairs: Krista Thiele Mora and Rui Fernandes

13:30 **O189 Present-day Shortening in Southern Haiti from GPS Measurements and Implications for Seismic Hazard**
Steeve Symithe, Eric Calais

14:00 **O190 Present-day GPS velocity field of South America**
Rui Fernandes, Hector Mora-Paez, Pete LaFemina, Machiel Bos

14:15 **O194 Rupture-Length x Magnitude for Intraplate Earthquakes in Brazil using Cross-Correlation of Regional LG Waves**
Caio Ciardelli, Marcelo Assumpcao

15:15-15:45 Coffee break

15:45-17:15 Salones La Paz "B" Este y La Paz "B" Oeste- Special Session on the April 2016 , Pedernales , Ecuador , Earthquake.
Chair: Marino Protti

15:45 **O202 Background Information and Main Characteristics of the April 16th 2016 Pedernales Earthquake**
Mario Ruiz

16:15 **O203 Interseismic velocity field and coupling along the Ecuador Subduction interface in relation with the 2016 Pedernales Earthquake**
Frederique Rolandone, Patricia Mothes, Paul Jarrin, Jean-Mathieu Nocquet

16:30 **O204 Rupture process of the Mw 7.8 2016 April 16 Pedernales earthquake from near field data**
M. Vallee, P. Mothes, J. M. Nocquet, P. Jarrin, F. Rolandone, B. Delouis

16:45 **O205 Focal Mechanisms and Spatio-temporal Distribution of the 16 April** 2016 **M7.8 Pedernales Ecuador Aftershock Sequence**
Frederique Rolandon, Stephen Hernandez, Mario Ruiz, Jean-Mathieu Nocquet, Paul Jarin

17:00 **O206 InSAR analysis of Ecuador Earthquake using Sentinel 1A imagery**
James Kellogg, Carlos A. Mendonça, Assumpção Marcelo, Gabriel Dicelis

15:45-16:45 Salon La Paz "C" Este- General contributions
Chairs: Richard Álfaro-Diaz and Aaron Velasco.

15:45 **O195 An automatic approach for sifting through large amounts of data for triggered phenomena**
Aaron Velasco, Richard Alfaro-Díaz

16:00 **O196 The Impact of Stress Orientation on Remote Dynamic Triggering in the** Coso Geothermal Field
Richard Alfaro-Díaz, Aaron Velasco, Debi Kilb, Kristine Pankow

16:15 **O197 Stress field in Costa Rica from focal mechanisms and wellbore breakouts: implications for fault reactivation**
Allan López, Birgit Müller, Wilfredo Rojas, Oliver Heidbach, Fernández Mario

16:30 **O198 Transferencia de esfuerzos de coulomb y escenarios de reactivación de fallas asociados al terremoto de Sámara-Nicoya,05-09- 2012 Mw 7.6,Costa Rica**
Allan López, Liu Chengli, Waldo Taylor

17:15-17:45 Closing Remarks

ABSTRACTS

ORAL COMMUNICATION

O001 Current Kinematics of the Caribbean Plate and its margins from GPS Measurements

Eric Calais[1], Steeve Symithe2, Jean-Bernard de Chabalier3, Richard Robertson4, Machel Higgins4

[1]Ecole Normale Supérieure, Paris, France, [2]Faculté des Sciences, Université d'Etat d'Haiti, Port-au-Prince, Haiti, [3]Institut de Physique du Globe, Paris, France, [4]Seismic Research Center, University of the West Indies, St. Augustine, Trinidad and Tobago

The Caribbean plate and its boundaries with north and South America, marked by subduction and large intra-arc strike-slip faults, are a natural laboratory for the study of strain partitioning and interseismic plate coupling in relation to large earthquakes. Here we use most of the available campaign and continuous GPS measurements in the Caribbean to derive a regional velocity field expressed in a consistent reference frame. We use this velocity field as input to a kinematic model where surface velocities results from the rotation of rigid blocks bounded by locked faults accumulating interseismic strain, while allowing for partial locking along the Lesser Antilles, Puerto Rico, and Hispaniola subduction. We test various block geometries, guided by previous regional kinematic models and geological information on active faults. Our findings refine a number of previously established results, in particular slip rates on the strike-slip faults systems bounding the Caribbean plate to the north and south, and the kinematics of the Gonave microplate. Our much-improved GPS velocity field in the Lesser Antilles compared to previous studies does not require the existence of a distinct Northern Lesser Antilles block and excludes more than 3 mm/yr of strain accumulation on the Lesser Antilles-Puerto Rico subduction plate interface, which appears essentially uncoupled. The transition from a coupled to an uncoupled subduction coincides with a transition in the long-term geological behavior of the Caribbean plate margin from compressional (Hispaniola) to extensional (Puerto Rico and Lesser Antilles), a characteristics shared with several other subduction systems.

O002 Tectonic inversion in the Caribbean-South American plate boundary: GPS Geodesy, Seismology, and Tectonics of the Mw 6.7 April 22, 1997 Tobago earthquake

John Weber[1], Halldor Geirsson[2], Joan Latchman[3], Kenton Shaw[1], Peter La Femina[2], Shimon Wdowinski[4], Machel Higgins[3], Christopher Churches[1], Edmundo Norabuena[5]

[1]Grand Valley State University, Allendale, United States, [2]The Pennsylvania State University Department of Geosciences, University Park, USA, [3]The University of the West Indies Seismic Research Centre, Ste. Augustine, Trinidad and Tobago, [4]University of Miami RSMAS-Geodesy Lab, Miami, United States, [5]Instituto Geofisica del Peru, Lima, Peru

On April 22, 1997 the largest earthquake recorded in the Trinidad-Tobago segment of the Caribbean-South American plate boundary zone (Mw 6.7) ruptured a shallow (~9 km), ENE-striking (~250° azimuth), shallowly dipping (~28°) dextral-normal fault ~10 km south of Tobago. We describe this earthquake and related foreshock and aftershock seismicity, derive co-seismic offsets using GPS data, and model the fault plane and magnitude of slip for this earthquake. Coseismic slip estimated at our episodic GPS sites indicates movement of Tobago 135±6 to 68±6 mm NNE and subsidence of 7±9 to 0 mm. This earthquake was anomalous and is of interest because: 1) its large component of normal-slip and ENE strike are unexpected given the active E-W dextral shearing across the Caribbean – South American plate boundary zone, 2) it ruptured a normal fault plane with a low (~28°) dip angle, and 3) it reactivated and inverted the preexisting Tobago terrrane-South America ocean-continent (thrust) boundary that formed during early Tertiary oblique plate convergence. ~1.5±1.0 mm/yr of active ~N-S extension between Trinidad and Tobago, the pre-existing Tobago terrane boundary, and gravitational forces resulting from the stacking of oceanic crust over continental crust acted together to drive the large component of normal dip-slip that occurred during this event. After a critical amount of elastic strain accumulated, the Tobago terrane probably exploited the pre-exiting weak fault and quickly slid NNE. Assuming that extension rates are constant, similar earthquakes could recur about once every ~500 years. Another good modern analogue of this sort of geodynamic process can also be found in the D'Entrecasteaux islands, Papua New Guinea.

ABSTRACTS

O003 Panama Arc-North Andes Collision: "Broken Indenter" model from new GPS velocity field

James Kellogg[1], Héctor Mora[2]

[1]*University of South Carolina, Columbia, United States*, [2]*Servicio Geologico Colombiano, Bogota, Colombia*

There is an apparent discrepancy between the small GPS measured margin-normal shortening in the Eastern Cordillera of Colombia and the apparent recent rapid shortening and uplift of the Cordillera. This apparent discrepancy may be explained with a "broken indenter" model for the Panama arc.
A new velocity field for northwestern South America and the southwest Caribbean is based on CORS (Continuously Operating Reference Stations) in Panama and Colombia (GEORED) with a minimum of 2.5 years of observations. The velocity field records margin-normal shortening of only 3-4 mm/yr in the Eastern Cordillera of Colombia. However, paleobotanical, fission-track, seismic reflection and well data from the range suggest rapid uplift (7 km) and shortening (120 km) in the last 10 Ma. This would imply an average rate of about 12 mm/yr for the last 10 Ma or about 3 to 4 times the present rate.
The initial collision of the Panama-Choco arc and the North Andes occurred between 12 and 40 Ma. However, paleoceanographic studies show a decrease in the transport of deep and intermediate Pacific waters into the Caribbean by 10 to 11 Ma, probably related to a closing Central American Seaway. Recorded changes in Caribbean water salinity and the Great American Biotic Interchange did not occur until 4.2 Ma and 3.5 Ma. The rigid Panama-Choco collision with the North Andes (20 mm/yr at present) produced rapid permanent deformation in the North Andes, especially after the closure of the Central American Seaway and formation of the land bridge in the last 10 Ma. The new GPS velocity field, however, shows that the Choco block is no longer part of the rigid Panama indenter. We propose that the break in the Panama-Choco indenter must have occurred very recently (in the last 1-2 Ma).

O004GPS Velocity Field of the Circum-Caribbean Region

Jeffrey Freymueller[1]

[1]*University of Alaska Fairbanks, Fairbanks, United States*

GPS measurements around the Caribbean date back to the late 1980s, when several projects aimed at studying the motion of the Caribbean plate and the tectonics of its boundaries. Until the last few years, these studies were dominated by campaign GPS measurements. Recently, with the development of CocoNet and several national GPS networks, a wealth of continuous GPS data has become available. Using a largely automated GPS data analysis system, we have analyzed the available continuous GPS data from the circum-Caribbean region. GPS time series are analyzed and fit with station trajectory models, and those with linear motions with time are used to define the motion of the Caribbean plate and the motions along its plate boundaries. Several large earthquakes have occurred within the region, and coseismic and postseismic displacements from these events must be isolated or modeled.

O005 Investigating the Post-Seismic Deformation of 2012 Nicoya Earthquake from cGNSS data

Rui Fernandes[1], Ronnie Quintero[2], Machiel Bos[1]

[1]*SEGAL (UBI/IDL), Covilhã, Portugal*, [2]*OVSICORI, Heredia, Costa Rica*

The OVSICORI (Observatorio Vulcanologico y Sismologico de Costa Rica) has installed and is maintaining a network of continuous operating GNSS stations in Costa Rica. Until 2012, the network consisted of 15 stations distributed in the entire country. Although some of the stations suffer some data gaps, they are providing an important contribution for the understanding of the geodynamics of Costa Rica that are mainly dominated by the subduction zone driven by the rapid convergence of Cocos towards the Caribbean tectonic plate.
In this work, we use HECTOR technique (Bos et al., 2013) to analyze the data from all available stations in Costa Rica, in order to investigate the post-seismic deformation signals caused by the 2012 September 5th Nicoya Earthquake. The earthquake of 7.6 (Mw) magnitude at a depth of 30 km and with centroid at 10.0559°N, 85.4778°W caused co-seismic displacements up to ~70cm in horizontal and ~50cm uplift in vertical (Protti et al., 2014; Quintero et al, 2014).
HECTOR allows us to estimate simultaneously the amplitudes of the co-seismic (offset) and post-seismic (exponential decay) signals. We investigate the optimal parameters that permit to obtain the best fit and we correlate our results with others recently published. Finally, we also try to determine the period of significance of the post-seismic deformation for the Nicoya earthquake in function of the distance to the epicenter.

ABSTRACTS

O006 Strain evolution of the Salvadoran Volcanic Arc. An structural and experimental approach

Jorge Alonso-Henar[1], José Antonio Álvarez-Gómez[1], Guido Schreurs[2], José Jesús Martínez-Díaz[1]
[1]*Universidad Complutense De Madrid, Madrid, Spain,* [2]*University of Bern, Bern, Switzerland*

In order to shed light on the recent strain history of northern Central America we have done a strain analysis based on structural data and analog modeling. We have reconstructed Miocene to Holocene strain ellipsoids from fault slips, dikes and fracture data and we modeled the Holocene faults along the Salvadoran volcanic arc (the El Salvador Fault Zone). We identified two deformation phases in the back arc zone: A first one of Miocene transpressional wrenching close to simple shearing regime; and a second one characterized by E-W extensional regime. Modeling results of the strain in the Holocene volcanic arc helped us to constrain the kinematic evolution of the ESFZ, being necessary an extensional stage followed by a dextral transtensional strike-slip phase, to reproduce the current structure of the ESFZ.
Based in our analyses, and bibliographical review about the deformation in the Chortís block and in the Central America Volcanic Arc, the Cocos slab subduction beneath the Caribbean Plate and the East Pacific Rise opening rates in front of Central America, we propose that: the transpressional Miocene deformation in the volcanic arc was related with a higher coupling stage (NW folding in Nicaragua and transpressional wrenching in El Salvador); a change in the subduction related conditions (decrease of the East Pacific Rise opening rates and a slab detachment of the Cocos slab) resulted in a roll-back process and a seaward migration of the volcanism (extensional phase and grabens opening in El Salvador and Nicaragua). This process controlled the coupling degree of the subduction interphase (decreasing towards its current state). The pure shear component of the strain, derived from the trench push decreased and evolved to a transtensional deformation controlled by the eastward drift of the Chortís Block and the subsequent neotectonic development of the ESFZ and intra-graben deformation in Nicaragua.

O007 What moves the Central American forearc sliver?

Jose A. Alvarez-Gomez[1], Alejandra Staller[2], Jose J. Martinez-Diaz[1], Jorge Alonso Henar[1], Carolina Canora[1], Juan Miguel Insua Arevalo[1], Marta Bejar Pizarro[3]
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One of the debates on deformation and tectonics in the Caribbean during last decades is the kinematic and dynamic behavior of the Central America forearc sliver. Since the arrival of the geodetic data, the forearc motion has been measured, a rate of about 10–14 mm/yr in WNW direction relative to the Caribbean plate. Different hypotheses have been advocated to explain its displacement. DeMets (2001) proposed the existence of slip partitioning due to the obliquity of the subduction. Lyon-Caen et al. (2006) showed, also with GPS data, that the coupling in the subduction interface was low, and therefore the potential for slip-partitioning were limited. Alvarez-Gomez et al. (2008), based on numerical finite element models, showed how the slip-partitioning in the Central American volcanic arc was impossible because of the weak coupling of the subduction interface. They suggested that the coupling between the North American Plate and the forearc block occurred in Guatemala and Mexico and the forearc sliver is dragged by the North American plate on a fixed Caribbean plate reference; or due to the eastward motion of the Caribbean on a fixed North American plate reference; supporting the model of Plafker (1976). Guzman-Speziale (2009) proposed a similar model based on analysis of focal mechanisms. Rodriguez et al. (2009) and Franco et al. (2012) come to the same conclusions based on GPS data. However, La Femina et al. (2009) proposed an alternative model based on GPS observations in Costa Rica and Nicaragua; for them the engine of the displacement is the subduction of the Cocos Ridge acting as an indentor, and pushing the forearc block towards the WNW. In this communication we discuss the different models proposed on a regional basis using geological, geodetic and seismic data, to assess the likelihood of the different hypotheses.

O008 El cinturón deformado del norte de Costa Rica-Colombia: ¿Desde una faja de empuje-plegamiento hasta una zona de subducción incipiente dentro de un bloque o microplaca?

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El cinturón de empuje-plegamiento del norte de Costa Rica se extiende a Colombia (Case & Holcombe, 1980; Ponce & Case, 1987). Se le ha llamado Cinturón deformado del norte de Limón, del norte de Panamá y del norte de Colombia. Claramente ha sido una zona de interés petrolero y sismológico. Recientes estudios sismológicos han evidenciado una zona de subducción en el cinturón deformado del sur del Caribe (NW colombiano) con un plano de Wadati-Benioff de bajo ángulo al inicio, pero muy empinado después, hasta alcanzar una profundidad de 180 km (Bowin, 1976; Pennington, 1981; Yarce et al., 2014). En el cinturón deformado del norte de Panamá se definió un plano de Wadati-Benioff hasta una profundidad de unos 80 km (Camacho et al., 2010). Pero hacia el lado de Costa Rica, el mismo sistema de fallamiento se continúa más bien como un sistema de fallas inversas, cuya traza se va perdiendo en un intrincado sistema de fallas entre el Valle Central y la cordillera de Tilarán. Ello define el cinturón deformado de Costa Rica Central (Montero, 1999, 2001; Marshall et al., 2000). Entonces, se pasa de una zona de subducción en Colombia y Panamá, a un sistema de falla de empuje-corrimiento del tras-arco costarricense. ¿Se está ante la presencia de una zona de subducción incipiente? Se define el bloque de Panamá (Bowin, 1976; Plafker, 1976;) o la microplaca de Panamá (Collins et al., 1995). ¿Será una microplaca incipiente? Parte de estos aspectos serán tratados durante la exposición.

O009 Updated geologic mapping in the western Azuero Peninsula

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An updated geologic map of the western Azuero Peninsula brings into finer focus the structure, stratigraphy and tectonic affinities of the trailing edge of the Caribbean Plate. Two seasons of geologic mapping were complemented with a battery of analytical data. This included geophysical techniques such as a new gravity survey along the western margin of the Peninsula, and detailed ground-penetrating radar and resistivity surveys along the Azuero-Sona fault zone (ASFZ). These surveys reveal that the ASFZ is not the main tectonic boundary (also confirmed by mapping), and also that recent deposits are offset by the fault and may be used to date its activity. Geologic mapping confirms that the offset along the ASFZ is left-lateral, approximately 14km, and new microstructural analyses of fault-rocks along the fault reveal a complex older history of ductile deformation. Paleomagnetic analyses in basaltic sequences reveal large vertical-axis rotations in blocks north and south of the ASFZ, and large contrasts in the inclination of sites along the western edge of the Peninsula. New stratigraphic observations and measurements reveal the presence of Oligocene and Miocene marine sequences containing a rich fossil flora. The relationship with underlying basement is non-conformable, but also modified by later faulting. Basement is made by plateau-affinity and proto-arc basaltic sequences covered
by hemi-pelagic limestone units of probable Late Cretaceous age, and intruded by a late basaltic dyke suite. This basement is recognized south of the ASFZ and is amalgamated with a similarly basaltic basement that has been correlated to oceanic islands. Accretion took place before the intrusion of the mafic dyke suite. Overall, this new map and analytical data can be used to test current hypothesis regarding the evolution of this complex subduction/accretion margin in the trailing edge of the Caribbean Plate.

ABSTRACTS

O010 Western Azuero-Panamá, Mapping and Structural Geology

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Only one mapping project has been done in the western Azuero Peninsula of Panamá; it took place several decades ago as a part of a mineral resources evaluation sponsored by the United Nations. According to this mapping, and also to several geochemical and geochronological sampling projects, Azuero's basement is composed by mafic and ultramafic rocks corresponding to two Paleogene oceanic islands and a Cretaceous Caribbean Large Igneous Province (CLIP) in an ancient subduction zone. The tectonic model shows the accretion of the islands from the Santonian until the middle Eocene, covered by a post-collisional Cenozoic clastic sequence. Accretion would have taken place along the Azuero-Sona fault zone (ASFZ), which is located in the south-west part of the Azuero Peninsula and is a strike-slip left lateral fault. This suture would separate basaltic homogeneous basement and a heterogeneous volcanic arc. Nonetheless, this hypothesis contradicts field, geophysical, and laboratory observations collected in two field seasons in 2014-2015, that suggest that the suture might be found south from ASFZ, in an ophiolitic complex, accreted to the Caribbean Plateau, which might have been emplaced and deformed following the oceanic islands´ accretion. Structural data and field mapping provide the key arguments for presenting a detailed structural cross-section and tectonic reconstruction showing the main features of Panama´s south western tectonics.

O011 Paleomagnetic Interpretation from Northwestern Part of Azuero Peninsula, Panama

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The Isthmus of Panama is located in the southern part of the Caribbean Plate and its study is important to understand the tectonic evolution of the Central American seaway. However, the geology of the Caribbean Plate is still a matter of debate, especially on its origin models. Therefore, paleomagnetic studies are an important tool to understand more about tectonics of the Caribbean, because it provides important information of paleolatitudes and vertical axis rotation of the different blocks on the plate. The Azuero Peninsula is located in Southwestern part of Panama, and some authors suggest that it is separated in two different terrains by the Azuero-Soná Fault Zone (ASFZ). We collected two hundred forty oriented cores in twenty different localities as result of two months of fieldwork in the southwestern part of the Azuero Peninsula. The studied localities comprise basalts interlayed with limestones, pillow basalts interlayed with cherts, and tabular basalt flows. In each core were demagnetized two pilot samples per site, by alternating fields and thermally. Additionally, anisotropy and magnetic susceptibility measurements were also made to determine flow directions and magnetization in the thermal process. As a result, we suggest 1) that the principal ferromagnetic mineral in the studied rocks is Magnetite (Fe_3O_4) or other mineral of Titanomagnetite group, 2) all studied sequences have directions of primary magnetization, and 3) that the rotation of the blocks in Azuero Peninsula was independent to the principal activity of the ASFZ, because all blocks present similar magnitude of vertical- axis rotation (ca. 80^0). In consequence, the structural element that divides the blocks in the peninsula is not the ASFZ but Cerro Honda Fault, that is located south of the ASFZ and can be observed by gravimetric methods and field relations. The data also preliminarily suggests that paleolatitudes were close to the equatorial line.

O012 Sismicidad superficial en el extremo nororiental de Colombia y su relación con la convergencia entre la Placas Caribe y Suramérica

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En la medida que la Red Sismológica Nacional de Colombia (RSNC) ha desplegado estaciones en la plataforma continental de la región Caribe colombiana se ha ido mejorando el registro de la microsismicidad en esta región. En su sector nororiental la sismicidad superficial registrada se asocia aquí a las zonas por donde se presentan grandes fallas como Oca y Perijá - El Tigre. Estas fallas de orden cortical definen grandes sistemas orogénicos como la Serranía de Perijá y la Sierra Nevada de Santa Marta (SNSM), que obedecen junto con la la Península de La Guajira (PLG) al norte de estos, a procesos de deformación relativamente recientes en términos de tiempo geológico. Con la verificación de las estaciones que pertenecen al proyecto de posicionamiento global - GEORED del Servicio Geológico Colombiano, se ha demostrado la movilidad hacía el Este de la PLG con respecto a la SNSM. Esto se interpreta como el empuje que la placa Caribe ejerce sobre el margen suramericano, y este fenómeno sería la causa de la sismicidad superficial (h < 30 km) que registra la RSNC en esta región de Colombia. En este trabajo se muestra el registro sísmico de la RSNC, los resultados del proyecto GEORED, y la interpretación sismotectónica para indicar las posibles sismofuentes que produce esta sismicidad superficial. Con este análisis se busca revalorar la amenaza sísmica y de esta manera incentivar estudios de amenaza sísmica locales para ciudades con gran densidad de población de esta región de Colombia, teniendo presente que en esta se presentó el sismo del 22 de mayo de 1934 que destruyo a la ciudad de Santa Marta, el cual es un antecedente histórico muy importante en este sentido.

O013 Receiver function imaging beneath the Northeast Caribbean

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Due to its tectonic history, the Caribbean plate contains complex fault systems that are likely to have disrupted the Moho. To study the region's subsurface structure we computed a 3D image of the Northeast Caribbean via "velocity analysis" with Ps receiver functions. In this technique we simultaneously find, via an optimization procedure, depths to major discontinuities (in this case the Moho) and P and S velocity profiles beneath each seismic station. Ps receiver functions are time series computed from three-component seismograms that identify waves converted from P- to S-type at velocity discontinuities, such as the Moho and subducting lithosphere. Velocity analysis and effective migration are feasible only when station spacing is relatively dense, which limits its success in this region to the islands of Puerto Rico and Hispaniola. However, individual receiver functions were computed for isolated stations in the NE Caribbean, as well.
Moho depths beneath Puerto Rico range from 24 km, in the north, to 37 km, in the south. Moho depths beneath Hispaniola range from 23 km to 36 km but exhibit a more complex pattern of variation than beneath Puerto Rico, with the Moho generally shallower in the east, deepening in central and western Dominican Republic, and shallowing again in the southwest, although values beneath Haiti are poorly constrained. The interpretation of the images places constraints on the structure of the subsurface and may elucidate the causes and styles of deformation occurring in the region.

O014 Focal Mechanisms of Intermediate-Depth Earthquakes Beneath the Northeast Caribbean

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The Caribbean-North American plate boundary transitions from normal subduction beneath the Lesser Antilles to oblique subduction at Hispaniola before becoming almost exclusively transform in nature at Cuba. In the Greater Antilles, large earthquakes occur all along the plate boundary at shallow depths but intermediate-depth earthquakes (70-200 km focal depth) occur almost uniquely beneath the eastern Hispaniola. Previous studies have suggested that the these earthquakes may be associated with, for example, opposing slabs subducting beneath the Muertos Trough (northward-dipping) and the plate boundary (southward-dipping), tearing of the subducting North American slab, or the westward drift of a subduction transform edge propagator (STEP) fault. A few of the larger-magnitude earthquakes have had centroid moment tensors computed for them but the great majority of events have uncertain mechanisms.
Seismic stations in the region have historically been sparse, so constraints on earthquake depths and focal mechanisms have been poor. In an effort to understand more about the tectonics of the region, fifteen broadband sensors were deployed in the Dominican Republic in 2014, increasing the number of stations to twenty-two. To determine the roles deep earthquakes play in regional tectonics, a catalog was created of events recorded jointly by our stations and by other broadband and short period stations in the region for which hypocentral depths are greater than 50 km and earthquake magnitudes greater than 3.5. All events have been relocated and focal mechanisms will be computed for as many events as possible. The earthquake's locations and mechanisms will help constrain a subducted slab edge and lithospheric tearing, if present.

O015 The seismicity at the Gulf of Chiriqui, Southwestern Panama

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We present results based on earthquake locations and focal mechanisms for events occurred at the Gulf of Chiriqui, offshore southwestern Panama, obtained during the last 10 years and from the newly upgraded Panama Seismic Network. Seismicity alignments confirm the existence of some offshore strike slip faults which run parallel to the coast line up to at least 10 km depth (Okaya and Ben Avraham, 1983). The majority of these focal mechanisms are consistent with left-lateral strike-slip motion. Events greater than about 10 km depth closer to the Burica peninsula, like the December 6, 2014 (Mw6.0), and December 8, 2014 (Mw6.6) earthquakes, however, exhibit thrust-faulting mechanisms, perhaps reflecting oblique subduction of the Nazca plate below the Panama microplate or the convergence of the Cocos Ridge, which causes the uplift of the Burica penisula. Right lateral strike-slip mechanisms are observed along the subducting Panama and Balboa Fracture Zones. Around Coiba Island and the mouth of the Gulf of Montijo it is observed a very active seismicity.
Key words: Gulf of Chiriqui, subducting fracture zones, Coiba Island.

ABSTRACTS

O016 The Panama –Colombia border sequence of July 29, 2015

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On July 29, 2015 a sequence of earthquakes near CerroTacarcuna, in the Serrania del Darien, in the Panama Colombia border region began. The first event and main event occurred at 00:10 UTC with epicenter at 8.15 ° N, 77.36 ° W, with a depth of 8 km and a magnitude Mw5.8. This earthquake caused minor damage in the town of Ungía, Colombia, where it reached an intensity of MM VI and in Meteti, Panama caused some cracks in school buildings. These damages occurred in poorly built structures made of poor construction materials. The seismic sequence continued until the middle of August along a fault with a north south bearing. The focal mechanism of the main event corresponds to a left lateral strike slip fault. There are no instrumental or historical records of an earthquake of this type in the northeastern region of Darien so it is important to take into account this seismogenic source for seismic hazard studies for future life lines between Panama and Colombia as the next electric transmission line between these two countries.
Keywords: Panama-Colombia border, seismic sequence, strike slip fault, seismic hazard.

O017 The change of dip of the subducted cocos plate in Southern Mexico: Is it related to the North America-Cocos-Caribbean triple junction?

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It is now clear that the subducted Cocos plate undergoes a change in dip in southern Mexico. To the northwest, west of about longitude -96°, the dip is very shallow, in some instances 10° to 15°. To the east, the dip is a more uniform 45° to 50°. There is also a noticeable difference in age of the slab on either side.

Several mechanisms have been previously proposed to explain this change, notably a tear within the subducted slab. In this work, we explore the possibiltiy that the two modes of subduction actually belong to two different realms: the Mexico realm (MR) to the East, and the Central America realm (CAR), to the west. Within the CAR, the subducted slab forms a continous and regular surface, from Costa Rica to southern Mexico. The isodepth curves are concave to the NW, mostly parallel to the trench, but they curve until they become perpendicular to the trench, in Mexico. The curvature of the subducted CAR is mimicked in the overiding plate by the reverse-faulting Vista Hermosa fault (VHF) and the Sierra de Juárez range. We thus suggest that the CAR represents an older subduction episode sutured along the VHF, and the Sierra de Juarez being the exposed accretionary prism. Later, both realms became one. There is seismic evidence that, at present, the VHF acts as a left-lateral, strike-slip fault. Hence, we propose that the Polchic fault cuts across southern Chiapas, Mexico, along the Tonalá fault and continues to the northwest into the VHF.

ABSTRACTS

O019 Slow Slip Events and the earthquake cycle beneath Nicoya Peninsula, Costa Rica

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Slow Slip Events (SSE) beneath the Nicoya Peninsula in Costa Rica have been occurring regularly (recurrence interval ~21 months) since the installation of continuous GPS stations in 2002. This recurrence interval continues unchanged past the September 5th, 2012 Nicoya M 7.6. Following the earthquake, an SSE occurred 'right on time' in February of 2014, 20 months after the preceding SSE, despite ongoing postseismic deformation. This Mw=7.0 event is located downdip of the coseismic slip area, at a depth between 25 and 45 km, coincident with the location of prior deep SSEs. Further, a new event appears to have begun in the fall of 2015 and is ongoing as of submission of this abstract. It appears that the recurrence of SSEs in the Nicoya was unaltered by the 2012 earthquake. We present time-dependent slip histories of all known events beneath the Nicoya Peninsula. We will discuss the relationship between SSE and the earthquake cycle as observed in Nicoya. Both in terms of late interseismic SSEs and the eventual earthquake, and the effect of the earthquake on SSE behavior.

O020 Waveform modeling of very-low-frequency earthquakes off the coast of Nicoya Peninsula, Costa Rica

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The Nicoya Peninsula is a unique peninsula composed of obducted ophiolites in northwest Costa Rica. This peninsula abuts seaward to within 60 km of the Middle America trench and has experienced 4 large earthquakes of ~Mw7.5 since 1852 at approximate 50-year intervals. Close proximity to the trench has enabled dense instrumentation of seismic and geodetic instruments for the purposes of monitoring deformation of an active subduction zone. Over the years, this network has captured a variety of shallow slow-slip events (SSE), tremor, and very-low-frequency earthquakes (VLF). In this study, we perform moment tensor inversions of multiple VLF events over several SSE episodes and spanning 6 years of data (2008 - 2014). Inversions are performed using acceleration time series recorded on broadband seismometers, where waveforms are typically filtered between 10 and 30 seconds. For each event, we search over a grid of spatial points with depths fixed to the estimated plate interface (Kyriakopoulos et. al., 2015). Waveform modeling indicates VLF events have long durations (>20 seconds), moment centroids that locate very close to the trench, and moment magnitudes greater than 3.0. Variance reductions of our best solutions are of order ~60 - 70%. However, due to azimuthally restricted station geometry and band-limited/low signal to noise waveforms, even in the best-recorded events minor double couples can constitute up to 50% of the total moment. Solutions are very sensitive to choice of origin time and half duration of the event, meaning cycle slips either convert a normal mechanism to thrusting, or vice versa. In general, we obtain nodal planes with dips close to 45° and northeast-trending strikes that are inconsistent with underthrusting on the plate interface. This work builds on previous results by expanding the number of events and introduces the possibility of normal (extensional) mechanisms being present in the shallow overriding plate.

O021 Slow Slip Events in Guerrero, Mexico

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Slow slip events (SSE) of three different types are occurring in Guerrero, Mexico. Those are long- and short-term subduction events, and recently discovered SSE on the La Venta – Chacalapa fault (LVC). Large long-term, LT-SSEs, (Mw~7.5) are happening on the subduction interface in Guerrero every ~4 years. Short-term, ST-SSEs, of smaller (Mw<6) magnitude occur about every 3 months and are accompanied by the non-volcanic tremor. The crustal slow slip events on the LVC fault are not well studied so far.
The secular GPS velocities in the Pacific coast of Mexico are oblique to the Middle America trench (MAT). The along-trench GPS velocities abruptly change across the LVC fault zone, which is striking at ~105 km inland from the MAT along the Pacific coast for ~650 km. This velocity slump reveals a partitioning of the oblique convergence between the Cocos and North America (NA) plates with a sinistral motion (wrt NA) of the Xolapa forearc sliver.
GPS displacement records in Guerrero provide clear evidence that the left lateral dislocation on the LVC fault occurs mainly during periodic episodes of strike-slip slow slip (SS-SSE), which coincide in time and duration with large slow slip events on the subduction interface (LT-SSE). In the inter-LT-SSE periods (~3 years) the LVC fault is locked, and the shear strain rate distributed across it is constant, about of ~14 nrad/year. During the LT-SSEs there is a noticeable increase of lateral sinistral displacement of the GPS stations located on the coast, south off the fault, meanwhile the stations to the north off the LVC undergo minor dextral displacements. The secular shear train rate drastically changes across the fault, which means that it is currently active but slow accumulation of the shear strain on it is periodically interrupted with the SS-SSEs, which are highly synchronized with the subduction LT-SSEs.

O022 Contrasting behavior of very low frequency earthquakes (VLFEs) in Cascadia

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Very low frequency earthquakes (VLFEs) are considered to be a seismic manifestation of slow slip along fault (slow earthquakes). VLFEs are rich in energy between 20 and 50s compared to local regular earthquakes. They are associated with episodic tremor and slip (ETS) event at the base of the seismogenic zone and release most of the seismic moment during ETS events. We detected and located VLFEs in Cascadia using a grid-search moment tensor inversion algorithm [Ghosh et al., 2015, GRL]. Their magnitude ranges between Mw 3.3 and Mw 4.1, with focal mechanisms consistent with slip on the plate boundary fault. So far, we have analyzed two ETS events, and observe contrasting behaviors of VLFE activities in relation to tremor. During an ETS event in August 2011, VLFEs are detected during strong tremor bursts, are located in an area of intense tremor activity, and migrated with tremor along the strike. This is consistent with an idea of tremor and VLFEs represent different part of the seismic spectrum of same event, i.e. slow earthquake. Interestingly, VLFEs during ETS event in December 2014 in the same general area show remarkably different behavior. In this case, VLFEs are detected during low level of tremor activity near the VLFEs, are located in an area of little to no strong tremor activity, and clustered in a relatively small area. This suggests that tremor and VLFEs may behave independently during an ETS. The fault patches generating VLFEs and tremor may have their own seismic cycles characterized by independent stress dynamics and become unstable separately in space and time even during a large ETS event.

ABSTRACTS

O023 Relación de la actividad sísmica local, operaciones de explotación y fallas activas, en los campos geotérmicos de México

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En las últimas décadas de explotación y aprovechamiento de los recursos energéticos contenidos debajo de la superficie terrestre, se ha observado numerosa actividad sísmica a través de las diferentes redes fijas y temporales en los campos geotérmicos de México, relacionando la sismicidad, las operaciones de explotación y el sistema hidrotermal, se distinguen las actividades de mayor impacto en la generación de eventos y cambio de esfuerzos. En Los Humeros desde el año 1997 hasta el 2008, se concentraron numerosos sismos en la traza de las fallas NE-SW y alrededor de los pozos inyectores, localizados en la periferia de la zona de mayor temperatura en el yacimiento, lo que sugiere una estrecha relación entre la sismicidad y el ingreso de fluidos por conducto de los pozos inyectores. Adicional a la inyección y el fracturamiento hidráulico se observa actividad sísmica asociada al fracturamiento del esqueleto rocoso, fenómeno originado por la expansión y dilatación de los poros en la roca, debido a la variación en la presión y temperatura. Los Azufres, se analizó durante los años 2008 y 2009, complementando el modelo estructural se adiciona actividad sísmica asociada a las Falla La Cumbre y El Chino, se observa numerosa actividad relacionada los pozos inyectores y nula respecto a los pozos productores. En el campo Las Tres Vírgenes, se estudio la sismicidad desde el 2003 hasta el 2010, asociando gran parte de la actividad sísmica a la estimulación y pruebas de producción en dos pozos productores; se relaciona la mayor cantidad de sismos al sistema tectónico regional, fallas La Virgen, El Volcán, El Partido y la falla Cimarrón, con notorias acumulaciones en las fallas La Cuesta y el Partido, cercanas al pozo inyector y al pozo productor monitoreado durante su perforación

O024Sismicidad inducida en los campos geotérmicos de Costa Rica

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En el campo geotérmico de Pailas, el cambio de esfuerzos que se realizó con la inyección en agua en el pozo PGP-27 provocó un aumento del esfuerzo vertical. Como la presión no superó los 100 bares (esfuerzo máximo regional), no fue posible realizar la fractura hidráulica, en los alrededores del pozo. Sin embargo, la transferencia de esfuerzos hacia una falla que se encuentra por debajo, provocó que esta se moviera con una componente normal y con desplazamiento de rumbo lateral derecha. Este mismo comportamiento había sido observado cuando se realizaron las pruebas de inyección en el pozo PGP-09. La sismicidad se orientó con rumbo NNW-SSE, esto hace pensar que la poca permeabilidad del medio, junto con la dirección preferencial NE-SW del máximo esfuerzo regional, provocan que las fracturas se estén orientando según el mínimo esfuerzo, por lo tanto, debería pensarse en que para lograr un mejor rendimiento de los pozos, estos deberán perforarse perpendicularmente a la orientación de las fracturas, es decir con rumbos NE-SW. En el caso del Campo Geotérmico Miravalles (CGM), desde el 2010 y hasta el 2013, se nota una clara relación entre el aumento de la sismicidad y la disminución en la masa total inyectada en el mes de agosto de cada año. En el 2014 por el contrario, se aumentó o se mantuvo la inyección y el pico de sismicidad no se presentó. Esto quiere decir, que cuando se disminuye la producción por mantenimiento, se da un aumento en la sismicidad, muy posiblemente debido al efecto térmico y de hidrofracturación que ejerce el agua reinyectada y la explotación misma del yacimiento.

O025 Identifying earthquake families of induced seismicity in The Geysers geothermal field by means of the transformation to equivalent dimensions

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The transformation to equivalent dimensions (Lasocki, 2014, Geophys.J.Int. 197, doi:10.1093/gji/ggu062) is based on the assumption that the lengths of intervals of earthquake parameterizations are equivalent when the probability for earthquakes to take values from either interval is the same. For earthquake parameters {X}, the transformed parameters U=F(X), where F is the cumulative distribution of X, are uniformly distributed in [0, 1] and equivalent. The distance between earthquakes in the space of {U} is Euclidean. When the cumulative distribution of earthquake parameters are unknown, they are estimated from the sample data using the model-free kernel estimation method.
We investigate seismicity induced by geothermal energy production in the northwestern part of The Geysers geothermal field in California. The geothermal power production is performed there for more than 50 years. In order to maintain the desired energy production water is presently injected into the reservoir. The injection is accompanied by intense seismicity. We analyze samples from earthquake dataset related to 7 years of fluid injection into two wells located in the northwestern part of the field. The earthquakes have been parameterized by multiple high-resolution parameters including seismic moment, source radius, static stress drop, and focal mechanisms (Martínez-Garzón et al., 2014, J.Geophys.Res. 119, doi:10.1002/2014JB011385; Kwiatek et al., 2015, J.Geophys.Res. 120, doi:10.1002/2015JB012362). The selected parameter sets are transformed to equivalent dimensions and the Ward's hierarchical clustering is used to construct hierarchical trees. An analysis of the linkage distance of consecutive clustering steps makes it possible to identify the earthquakes being sequentially the closest linked by the values of all their parameters.
This work was supported by EPOS Implementation Phase project funded from Horizon 2020 – R&I Framework Programme, call H2020-INFRADEV-1-2015-1 and within statutory activities No3841/E-41/S/2015 of Ministry of Science and Higher Education of Poland.

O026 Characterization of the seismic activity in the oil zone of Puerto Gaitán, Llanos Orientales Basin (Colombia)

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The Colombian National Seismic Network (RSNC) noticed a sudden appearance of high seismic activity in the oil production zone of Puerto Gaitán (midcontinental Colombian Llanos Basin) in April 2013. This zone was known as almost aseismic (0.7 events/yr between 1995 and 2012) and it changed to generate about 130 events/yr, including 48 events with ML ≥ 3.5, the largest with ML 4.8. With the main goal of determining the origin and dimension of the ongoing activity, we analyze two months (April-June 2014) of seismological records gathered by the RSNC from two local stations located in the epicentral region and one regional station and we estimated MW for nine events with ML ≥ 3.5 based on far field records. We locate nearly 250 events that occurred during this period, with ML between 1.0 and 4.0. Our locations show two clusters, one on the Quifa Field, where most of the epicenters concentrate and the other on the Pirirí Field; both clusters coincide, within uncertainties, with residual water injection wells. Because seismic activity in this region is unusual and isolated from the known Andean seismic activity, no information on attenuation parameters was available; using a method proposed by Drouet (2008) we calculate the S-wave spectra of far field records of the RSNC and invert the low frequency range of the spectra with a linear regression to recover an average geometric attenuation parameter and the seismic moment, required to compute Mw. Our calculated MW magnitudes range between 3.0 and 4.5; they are comparable to those estimated by the RSNC and higher by 0.1 on average.

ABSTRACTS

O027 Estimación de atenuación de ondas de coda para la cuenca de los Llanos Orientales de Colombia

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En la cuenca de los Llanos Orientales de Colombia se presentó un fenómeno sismológico en el cual se registraron una serie de eventos localizados por el Servicio Geológico Colombiano (SGC) entre el periodo del año 2013 al 2015, la mayoría de los registros se ubicaron en el municipio de Puerto Gaitán en el departamento del Meta. Alrededor de 200 sismos de magnitud mayor a 2,8Mw hasta 4,4 Mw fueron localizados con profundidades entre superficiales hasta los 40 Km, para este trabajo se estimó a partir de los registros mencionados anteriormente la atenuación de Coda Qc para frecuencias entre 1Hz hasta los 16Hz con ventanas de tiempo entre 5s y 50s con pasos de 5s para las estaciones de la Red Sismológica Nacional de Colombia PTGC, GUA, VIL, MACC y TAM,que están sobre la cuenca de los Llanos Orientales y para las estaciones CHI, RUS,SPBC y ORTC ubicadas en la cordillera Oriental y la cuenca del Rio Magdalena.

O028 Anthropogenic Seismicity in Colombia: A qualitative and quantitative probabilistic approach

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It is know that tectonic stress, pore pressure, fluid migration and strain variations can be generated by human operations. The response of earth to these changes is manifested in the occurrence of earthquakes known as anthropogenic seismicity. This kind of seismicity can be induced or triggered and its discrimination from natural seismicity is a difficult task, and specific methods have not been well established yet. The first approaches to assess the probability of an earthquake is or not induced/triggered is given by a qualitative evaluation of some parameters related with historical seismicity and its relation in time and distance between plausible sources and events.
In order to make a more quantitative evaluation of anthropogenic seismicity, the objective of this work is to provide reasonable information about which events may be considered induced by analyzing the changes in parameter b over time. The methodology used consist of run some non-parametric distribution tests and evaluate the frequency – magnitude variations. Records are provided by the National Seismological Network of Colombia in areas close to the most productive oil fields in Colombia for the last 10 years.

ABSTRACTS

O029 E-research platform of EPOS Thematic Core service anthropogenic hazards

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EPOS Thematic Core Service ANTHROPOGENIC HAZARDS (TCSAH) creates new research opportunities for studies of anthropogenic hazards evoked by exploitation of georesources. TCSAH, based on the prototype built in the framework of the IS-EPOS project, financed from Polish structural funds (POIG.02.03.00-14-090/13-00), is further developed within EPOS-IP project (H2020-INFRADEV-1-2015-1, INFRADEV-3-2015). TCSAH is a functional e-research environment to ensure researchers the maximum possible liberty for experimentation by providing a virtual laboratory, in which the researcher can design own processing streams and process the data integrated on the platform. TCSAH integrates data gathered in the so-called "episodes", comprehensively describing a geophysical process, induced or triggered by industrial activity, which under certain circumstances can become hazardous for people and the environment and problem-oriented services to analyze correlations between technology, geophysical response and resulting hazard. Presently six episodes are available and new 20 episodes related to conventional hydrocarbon extraction, reservoir treatment, underground mining and geothermal energy production are being integrated within EPOS-IP project.
Implemented services are grouped within six blocks: (1) data integration and handling; (2) physical models of stress/strain changes over time and space as driven by geo-resource production; (3) analysing geophysical signals; (4) the relation between technological operations and observed induced seismicity; (5) probabilistic assessments of anthropogenic seismic hazard; (6) estimation of occurrence probability of chains of events or processes impacting the environment.
TCSAH platform: https://tcs.ah-epos.eu/ is open for the whole research community and the general public. The platform is also used in research projects. Presently, all episodes gathered in "Shale gas exploration and exploitation induced risks" project (Horizon 2020, call LCE 16-2014) are integrated on TCSAH.
This work was supported by EPOS Implementation Phase project funded from Horizon 2020 – R&I Framework Programme, call H2020-INFRADEV-1-2015-1 and within statutory activities No3841/E-41/S/2015 of Ministry of Science and Higher Education of Poland.

O031 Reservoir-Triggered Seismicity in Brazil: Characteristics and new cases

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We report here 23 cases of reservoir-triggered seismicity (RTS) in Brazil emphasizing the cases observed in the last few years. In worldwide terms, Brazil presents a relatively high number of RTS (23 in 110 cases). Not different from the rest of the world, Brazil´s interest for the RTS subject began around the 70's when the first case was identified by macroseismic observations and felt with intensity V-VI. This event was triggered 17 years after the first impoundment of a reservoir of only 20 m high with seismicity around the periphery of the lake, probably resulting from the slow diffusion of the water due to the low permeability of the rocks in the area.
Two magnitudes 4 RTS earthquakes were observed, the biggest being 4.2mb MMI VI. About 70% of the RTS cases present initial seismicity (reservoir with fast response - the events occur less than 1~2 years after the first impoundment), and the rest present delayed response with some cases having more than one main event.
The magnitude of triggered events is not directly proportional to the depth of the water column or to the total volume of the reservoir, although the triggered seismic activity has been more common in reservoirs with depth > 100 m (about half of the cases). However, there are reservoirs higher than 100 meters that have never presented RTS and others with height less than 50 m with triggered seismicity. Therefore, there is not a direct relationship between the maximum magnitude of a triggered earthquake, dam height and the volume of the reservoir, although the two earthquakes of magnitude 4 observed have happened in reservoirs with height above 100 m.
In this work we will discuss the Brazilian RTS features, highlighting the new cases, including the ones not yet reported.

ABSTRACTS

O032 Seismic model of Borborema Province, northeastern Brazil: NW-SE transect

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The NW-SE transect in the Borborema Province is a 900 km seismic profile crossing its north and central sub-provinces, in northeastern Brazil. It was acquired in 2008 under the auspices of the INCT for Tectonic Studies (MCTI/CNPq), and it is a historical line once it is the first line acquired with Brazilian equipment and because it initiated a new moment in applying refraction experiments to crustal studies in Brazil.
The NW-SE line was acquired with a vertical sensor every 2 km and a triaxial short-period sensor every 20 km, and shots of 1.4 tonne every 50 km and 2.8 tonne in the extremes. The dataset is of high quality and permitted the raytracing modeling of the P and S wave-fields and receiver function results. The receiver function helps to complement the model in the extremes and in the most structured parts.
Seismic results show that the Borborema Province has a thin crust with Moho depth varying from 29 to 35 km and a structured lithospheric mantle. The seismic data led to define crustal discontinuities not related to surface Neoproterozoic limits and shows that the lithosphere of the Borborema Province was deeply reworked by traction, thinning the crust by stretching, delamination and probably by mineral phase changes. The two most prominent structures are a simple shear stretching involving the lithospheric mantle that generated the Potiguar basin, and the crustal delamination associated with the uplift of the Borborema plateau.
As a whole, the lithosphere of the Province was subjected to significant extensional processes with subsequent reworking of the basal portion of the crust, controlled by the composition of the different crustal segments. The stretching is related to the opening of the South Atlantic Ocean in the Cretaceous, and imprinted new limits in the lithosphere of the province.

O033 Development of real-time tsunami inundation forecast system using offshore ocean-bottom pressure data from S-net

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Prompt and accurate tsunami forecast is essentially important to reduce the fatalities of onshore residences due to tsunami, and the 2011 megathrust Tohoku-oki earthquake reinforced the importance of offshore observation for warning of near-field tsunami. Under the sponsorship of MEXT, Japanese government, NIED is now constructing S-net (Seafloor Observation Network for Earthquakes and Tsunamis along the Japan Trench) where offshore observations were insufficient at the time of the Tohoku-oki earthquake. This network consists of 150 ocean bottom observatories linked by fiber optic cables and covers the wide area along the Japan Trench and the southernmost Kuril Trench from Kanto to Hokkaido. In this presentation, we develop a new methodology of real-time tsunami inundation forecast. We also construct tsunami scenario bank (TSB) prior to earthquakes which contains thousands of inundation scenarios generated using various earthquake source models. When tsunami occurs, forecast is carried out by comparing observed offshore ocean bottom pressure data and pre-calculated data. An advantage of our method is that tsunami inundation is estimated without any earthquake source information which is difficult to correctly estimate in real-time. Due to the high-cost calculation for the inundation simulations, the number of the tsunami scenarios stored in TSB is limited. We therefore perform sensitivity analyses to select the tsunami scenarios which efficiently cover possible tsunami scenarios affecting the coastal region where the real-time tsunami forecast will be issued. To select the appropriate scenarios from TSB, we propose an evaluation algorithm based on the combination of three different indexes calculated from maximum absolute values of continuously observed pressure changes. As S-net is under construction and not in operation, performance of our algorithm is examined using simulated tsunami waveforms.

O034 Real time monitoring for Earthquakes and Tsunamis -For disaster mitigation of earthquakes and tsunamis-

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For early earthquake and tsunami detection, the real time monitoring using ocean floor observatories is effective. DONET1 and DONET2 are in operation and being under constructing around the Nankai trough seismogenic zone SW of Japan, respectively. These systems have multi kinds of sensors such as the accelerometer, broadband seismometer, pressure gauge, difference pressure gauge, hydrophone and thermometer for earthquakes and tsunamis monitoring. DONET1 and DONET2 with 51 observatories will be deployed along the Nankai Trough SW of Japan by the end of March 2016.
At the Tohoku earthquake in 2011, 10 observatories of DONET1 have already been in operation, and they could detect tsunamis. Comparing the data by DONET1 to those by the tide gauges nearby, tsunami amplification process could be revealed. Furthermore, we developed tsunami database which will provide the early estimation of tsunami for appropriate tsunami evacuations and quick initial responses.
Tsunami studies focusing on its early detection by using hydro-acoustic data are being developed. For example, we examine hydro-acoustic data and develop new approaches to detect tsunami precursory. This approach may be useful in the view point of tsunami disaster mitigation. For tsunamigenic events, however which cannot be detected by the seismic network, such as tsunami earthquakes, landslides, volcanic eruptions, hydro-acoustic data may help to detect such non-seismogenic tsunamis. Recently, a paper mentioning ambient seafloor noise excited by earthquakes in the Nankai subduction zone has been published in Nature using real-time data. Thus, real-time monitoring data from the oceanfloor network is very important and indispensable for ocean science as well as disaster mitigation.

O035 Instrumentation of expandable and replaceable submarine cabled real-time seafloor surveillance system “DONET”

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DONET is a submarine cabled seafloor observatory network for seismogenic zone monitoring in western Japan. Development of original system “DONET1”has been begun in 2006 and in operation from 2011. Second generation system “DONET2” is being construction at present and completion is scheduled within 2016. A total of 51 locations of observatory is planned to deploy in the seafloor. To maintain this large scale system for more than 20 years, observatory network consists of three separable components of backbone cable, seafloor concentration (named node), and observation instrument package (called observatory). Each component is connected through an underwater mateable connector (UMC) to realize the expandability, replaceability and maintanancability in operation life time. Backbone cable has been developed using telecommunication submarine cable technology to get the more than 20 years of lifetime without maintenance. Node is a kind of hub system for power feeding and data transmission between landing station and observatories, and key device of DONET development. Twelve nodes are equipped on the DONET1 and 2 network, and each node has eight UMC interfaces for observatories. Total 96 interfaces are prepared for observation, 51/96 interfaces are reserved for DONET standard observatory, two interfaces are reserved for borehole observatories maintained by IODP program and 43 interfaces can be used for future expansion. DONET standard observatory consists of ground motion sensing system and pressure sensing system and each sensing system consist of more than single sensor. The subsea construction of DONET is carried out by cable laying ship, research ship and work class ROV for science research. Approximately 5monthes of cable laying ship operation and 700 days of research cruise ship time (including ROV operation) are spent for DONET construction. DONET2 expected to move to operation phase by the end of 2016 and related researchers start to discuss the utilization of expansion interfaces.

ABSTRACTS

036 A spectos Sismotectónicos del Sandra Ridge – Cuenca de Panamá

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Al sur de la Cuenca de Panamá emerge el Sandra Ridge, un centro de expansión oceánico que se acopla a la placa Nazca y que converge con dirección W-E hacia el occidente de la Costa Pacífica de Colombia. Estimaciones paleomagnéticas del Sandra Ridge indican edades de formación que oscilan entre 9-12 Ma; sin embargo, su convergencia bajo la placa Suramericana, sugiere una posible actividad que se puede explicar por al menos tres hipótesis: a) su emplazamiento gracias al movimiento diferencial de la placa Nazca y que permite su actual actividad, así como la movilidad del Arco de Panamá dentro del territorio Colombiano; b) conforma el límite sur de la placa Caribe mediante una estructura con cinemática dextral; c) una combinación de las dos hipótesis anteriores y la conformación de un escenario de slab-window que promueve subducción plana de la placa Caribe al norte y subducción normal de la placa Nazca al sur. En este trabajo se presenta evidencia sismológica de actividad del Sandra Ridge como producto de una campaña de despliegue de OBS en el marco del proyecto OSCAR, así como del uso de datos de varias redes sismológicas (Colombia, Panamá, Costa Rica, Ecuador y Nicaragua) entre enero y marzo de 2015. Dicha evidencia será apoyada por datos batimétricos, magnéticos, gravimétricos y de flujo térmico.

O037 The National Seismological Center and rapid characterization of the September 16 2015 M8.4 Chile earthquake

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The task of a rapid evaluation of large earthquakes -for tsunami potential evaluation and estimation of areas of severe shaking- is accomplished through a network of sensors being implemented by the National Seismological Center (CSN) of the University of Chile. The network is composed by 100 broad-band and strong motion instruments connected in real time. 130 GNSS devices are being established, 40 of them with real time absolute location capabilities.
Hypocentral locations and magnitudes are estimated by automatic software based on seismic waves; for magnitudes less than 7.0 the rapid estimation works within acceptable bounds. For larger events, automatic detectors and amplitude estimators of displacement are being developed.
On September 16, 2015 at 19:54 hrs (local time) a magnitude 8.4 (W-phase) earthquake took place off the coast of central Chile. This earthquake is the largest in the country since the February 27, 2010 event and the third largest since May 22, 1960, surpassing in size the one that took place off the coast of Iquique- Pisagua on April 1, 2014. Unlike the later, the 2015 earthquake showed no recognizable immediate precursor activity in the epicentral area. Estimates of the slip distribution, based on GNSS data, indicate that the rupture length reaches about 200-220 km with a maximum displacement of the order of 6 to 8 m.
Historical seismicity in the region is examined to understand the possible future scenarios of large earthquakes. To the north, the 1922 (Mw=8.4) has been the last to rupture this zone; to the south, the sequence of the events of 1971 and 1985 (Mw=7.8) are the last ones to take place. These earthquakes, together with the Mw8.2 1906 event apparently ruptured only the downdip section of the contact zone, implying that there is significant equivalent deformation accumulated to generate a 8.5+ event in the area.

O038 The Brazilian Seismographic Network current developments and outcomes

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The Brazilian Seismographic Network (RSBR) has evolved today to be a fully open, nation-wide network of more than 80 broadband seismographic stations transmitting in real-time. Data is being archived and distributed from four different institutions, each of them developing its own tools, services and research projects on top of the shared infrastructure.
Picks for local and teleseismic events are routinely sent to the International Seismological Centre (ISC). Local and regional seismicity is now evaluated in realtime, allowing institutions working in Brazil to give a rapid response to the population, as it was the case for several events during the first year of full operation. The data availability and open standards in data distribution is allowing national and international researchers to use RSBR records to complement global datasets in their studies of South American events, filling the gap of station coverage in the distance range 5°-35°. Furthermore, national institutions are already using the newly acquired RSBR data, working towards updating past studies of seismic tomography (body, surface and noise correlation), receiver functions (for crustal and mantle structure), SKS splitting, focal mechanisms and stress maps, etc.
Considering the quality and amount of the data generated, the University of São Paulo Seismological Center started to reformulate its own services, offering a new set of web tools for accessing the events catalog, and the first interactive macroseismic tool in Brazil, in which intensities are automatically calculated from the population responses to an internet-based questionnaire.
Next year, the RSBR is expected to grow with the addition of 4 more stations (covering the Amazon and Western Brazil), the relocation of one station to better adjust the station distribution, and a sensor re-orientation following a study concluded last year about the RSBR sensor orientation directions.

O039 Avances y perspectivas a futuro: Modelos de instalación y organización de la Red Sismológica Uruguaya (RSU)

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El Uruguay no contó con una red sismológica, hasta la instalación de la primera estación hace solamente 4 años atrás, en marzo del 2013. Al comienzo el apoyo fue nulo, y el descreimiento de la actividad sísmica en el Uruguay.
El Observatorio Geofísico del Uruguay ha hecho un gran esfuerzo en comunicar, educar y promover la concientización sobre la geofísica, la sismología, y la evaluación y prevención de riesgos, además de la investigación en estas áreas.
A partir de la colaboración con DINAMIGE (Dirección Nacional de Minería y Geología), que ha retomado el interés en la geofísica, se planifica la instalación de 14 estaciones acelerométricas repartidas por todo el país. A su vez participaremos en un proyecto con la Universidad de Sao Paulo (FAPESP Thematic Project, Pantanal-Chaco-Paraná Basins (PCPB): Crust and Upper Mantle Seismic Structure and Evolution) con lo que contaremos con dos estaciones de banda ancha. Un convenio con ANCAP (empresa petrolera estatal) nos permitirá contar con otras dos estaciones banda ancha más, sumada a la estación de banda ancha actual (SDYD). Esto representa un avance en todo sentido respecto al estado actual de la sismología y la geofísica en el País.
En este sentido se hace más que urgente la necesidad de formación de científicos que puedan analizar e interpretar los datos adquiridos por dichas estaciones. Esto dará un gran aporte al conocimiento geológico y tectónico del área. Asimismo, estos trabajos y sus resultados servirán como catalizadores para la formación y estudio de nuevas líneas de investigación en el área de la Sismología
Se detallan los procedimientos y el plan de acción para la instalación de las 18 estaciones previstas, como así también las perspectivas a futuro que tiene el equipo de trabajo.

ABSTRACTS

O040 Renovation of the National Seismological Network of Costa Rica: improving station coverage and earthquake monitoring

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The National Seismological Network of Costa Rica (RSN) is a joint effort between the Seismology Laboratory of the School of Geology at the University of Costa Rica (UCR) and the Seismology Division of the main Costa Rican Electric Company (ICE). Since 1973, the RSN has continuously monitored the seismic and volcanic activity of Costa Rica. In this presentation, we addressed some efforts performed by the RSN since 2012, separated in three groups: growing the station network, improving earthquake locations, and developing newer ways for disseminating the information generated to society. In 2015, 70 new short-period seismometers have been installed to provide a new coverage configuration with higher station density in the central part of the country where most of the population and economic activities are concentrated and where we intent to locate more and smaller earthquakes. Also, earthquake locations have been improved by setting, automatizing, and integrating earthquake location routines from the SeisComp, Earthworm, and SeisAn software packages. We implemented the automatic earthquake triggering and location of SeisComP and Earthworm by acquiring data from a unique waveform buffer that both systems could read. We re-locate the initial locations using SeisAn and report the earthquake locations through an automatized web portal, which have resulted in reducing the time of earthquake notification of a revised location. We also have developed newer ways for disseminating the information. The RSN is using Facebook and Twitter to report felt earthquakes and scientific information. Additionally, a new website was created in 2012 and an application for smartphones is been released in 2015. We see these new channels as opportunities to engage non-science audiences and encourage the population to participate in reporting seismic observations and thus providing intensity data for felt earthquakes.

O041 Status of the Nicaraguan Seismic Network - 2016

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We report about the status and the progress of the Nicaraguan Seismic Network. The Network is used for seismic and volcano monitoring, tsunami warning and lahars and landslide warning. The network counts around 100 stations. Many stations are multisensor stations and count also with webcams, continuous GPS or other sensors. All field stations are digital with 24 bit A/D and time synchronization with GPS. Data transmission is performed via WIFI, Internet, optical fiber of the National Electricity Company, 3G cellular network. Data acquisition and automatic processing is done with SeisComP3, Eartworm and Early Bird. Besides the Nicaraguan stations the data center processes also real time data coming in from the Central American countries and from the global seismic network. In 2015-2016, we have corrected constructional problems at field stations to reduce their seismic noise, added additional stations to improve the geometry of the network, reduced processing time per event, accelerated the reporting to the civil protection institutions. Extensive maintenance was guaranteed and problems were solved with stations in harsh or hostile environments as in the volcanoes, with high tropical temperatures and humidity, insects, vandalism, robbery, saturation or interruption of communication services. The volcano-seismic monitoring was improved extending the local seismic networks around the volcanoes and we succeeded to emit warnings on pending eruptions or explosions on active volcanoes in Nicaragua. Additional temporary stations were installed in areas affected by seismic swarms. The staff working in the 24x7 shift was extended and its members capacitated. The results of the seismic monitoring are published in monthly and yearly bulletins in our website http://webserver2.ineter.gob.ni/sis/bolsis/bolsis.html . Regional cooperation within Central America was improved and our data center started to serve the region as the Central American Tsunami Advisory Center (CATAC).

O042 The Mexican National Seismological Service: An overview

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The Servicio Sismológico Nacional (SSN, Mexican National Seismological Service) was created in 1910. It was in the late twentieth century that a process of modernization started, this involved the installation of the broadband network and collaboration with other Mexican networks. A major renovation process started on 2015, with the construction of a new building that hosts the central facilities; and the acquisition of more powerful servers. On this work we will present the networks operated by the SSN, from site selection and installation to general capabilities and current station status. Also, we will present communication and system architecture, as well as monitoring and reporting processes, which include the use of social networks and a mobile app. Furthermore, we will show new products based on the regional moment tensor inversion, both, from surface waves and W fase, and future projects and challenges, such as lowering the magnitude threshold of detection nation wide by increasing the number of stations in the country, implementation of methodologies developed by the research community in order to provide new seismic products, and installation of a mirror site to guarantee a 99% operability.

O043 The ISC Products and Services for Latin America and the Caribbean Region

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The main mission of the International Seismological Centre (ISC) is to provide the definitive information on past earthquakes and other seismic events by collecting, processing and integrating seismic bulletins from more than 130 seismic networks worldwide, including 20 permanent networks within the Latin America and the Caribbean region.
The ISC Bulletin is the most complete long-term source of seismic bulletin information in this region. The data from the EHB bulletin – a groomed subset of the ISC Bulletin – provide a high-precision view of seismicity. Jointly with NEIC, the ISC runs the International Seismograph Station Registry. Registered station codes and ISC event hypocenters are used by the IRIS DMC for providing seismic waveform data. The ISC also updates and maintains the IASPEI Reference Event List (GT) used for calibration of newly developed velocity models and earthquake location methods. The ISC-GEM Catalogue is a highly homogeneous dataset primarily designed for global and regional studies of seismic hazard and risk. The ISC Event Bibliography is an interactive facility that enables searches for references to scientific articles devoted to specific natural and anthropogenic seismic events that occurred within a region and time period of interest. The ISC also runs the registry of international contacts in Seismology that becomes useful when urgent professional contact information is required following a recent destructive earthquake.
In this presentation we demonstrate the improvement of the ISC products in Latin America and the Caribbean region during the recent years.

ABSTRACTS

O044 The real-time strong motion monitoring network of the Lesser Antilles Island Arc

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A real-time network of strong motion monitoring stations has been established in the Lesser Antilles Island Arc. It comprises over 40 installations deployed on sixteen islands from Barbuda to Trinidad, including the French dependent territories. Currently, more than a half of the installations are free field deployments at which the accelerometers are collocated with broadband seismometers in surface vaults. These were primarily designed to meet the requirements of real-time tsunami monitoring and are linked to network hubs operated by the Seismic Research Centre (SRC) and/or the Institut de Physique du Globe de Paris (IPGP) and/or the US Geological Survey's Global Seismic Network (USGS-GSN) via satellite transmission. Data are further relayed to a tsunami warning centre and other repositories such as IRIS. Although the remaining installations also meet the minimum qualifying requirements to contribute data to a regional tsunami early warning system, they were established with the goal of extending the capability of the network to study the effects of strong earthquakes. Several of these are collocated intermediate-period seismometers and there are several deployments that are standalone digital accelerometers housed in buildings. This subset of stations are linked to the monitoring hubs via Internet and/or last mile technologies such as spread spectrum radios. The digital infrastructure of the seismic network was built during the last ten years since the de-liberalization of the regional telecommunications industry. Financing for the network came from regional governments, international donor agencies and the private sector. High level collaboration among the principal monitoring agencies has contributed to lower cost of ownership, lower operating costs and improved performance. This poster highlights the key attributes that are linked to the sustainability of the network as well as some early results.

O046 Red de Monitoreo acelerográfico y sistema de reporte automatizado del Instituto Costarricense de Electricidad (ICE)

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El instituto Costarricense de Electricidad (ICE) es una institución pública, dedicada a desarrollar y proveer los servicios de telecomunicaciones y electricidad en Costa Rica. Los proyectos mayores para el suministro eléctrico en el país han sido desarrollados por el ICE. Dadas las condiciones sismo-tectónicas del país, estos han sido monitoreados sísmicamente por la institución durante las diferentes etapas de su desarrollo, construcción y operación.

Desde 1984 el ICE mantiene un Programa de Seguridad Sísmica de los Proyectos y Presas del Sector Electricidad, por medio de la instalación de equipos para el registro de los movimientos sísmicos fuertes, conocidos como acelerógrafos. Estos equipos instalados principalmente en presas.

La instalación de este tipo de instrumentación en presas, es de suma importancia en zonas o regiones altamente sísmicas. La ocurrencia de eventos sísmicos y su medición ha permitido conocer y entender mejor los procesos sismo-tectónicos y su efecto sobre este tipo obras. Además que permite cumplir con recomendaciones nacionales e internacionales sobre seguridad sísmica de presas.

El ICE opera un total de 32 acelerógrafos digitales de tres componentes y dos registradores multi-canal con siete acelerómetros. Estos se encuentran distribuidos en 15 sitios a todo lo largo del país. Toda esta instrumentación conectada, vía internet, a un centro de registro único, localizado en San José.

La tecnología actual de los instrumentos acelerográficos, y su plataforma de trabajo, permite automatizar los procesos relacionados con su operación, control y registro, así como el procesamiento y reporte de la información en tiempo real.

Se presenta en este trabajo una descripción de la red ICE, así como del sistema automatizado de reporte acelerográfico desarrollado en esta institución, el cual es utilizado para la toma de decisiones sobre la seguridad sísmica en los centros de producción y particularmente de las presas, cada vez que un sismo sentido ocurre.

O047 The scope for Earthquake Early Warning in Nicaragua and Central America

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We will provide an analysis of the scope for Earthquake Early Warning (EEW) in Nicaragua and the Central American region based on 1) The existing seismic network, data sharing and communications practice, data processing and 2) The existing network with assumed improved communications and EEW algorithms that may become available.
This work is part of a cooperation project between Nicaragua and the Swiss Confederation supported by the Swiss Agency for Development and Cooperation.

O048 Completeness of the RSN earthquake catalog, Costa Rica

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This study evaluates the stability of the mean rate earthquake occurrence and the spatial and temporal distribution of seismicity in Costa Rica, in order to calculate the completeness magnitude for the RSN seismic catalog and the Gutenberg-Richter relationship for 1975-2014. The results show that the completeness magnitude for the catalog is 5.0, but it could be as low as 3.0 Mw for certain periods of time. The "b" value and maximum likelihood magnitude obtained for this catalog are 0.96, and 7.8, respectively. The geographic distribution of seismicity highlights the main active tectonic structures. In particular, clusters of seismicity revels highly deformed crustal areas, which are located along the inland projected path of seamount chains and the Panama Fracture Zone. These clusters do not correlate exactly with the largest energy released zones.

O049 Minimum 1D P Wave Velocity Model for the Guanacaste Volcanic Arc, Costa Rica

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In this study a minimum 1D model for the Guanacaste Volcanic Arc (CVG) is derived from 950 manually located events, and then filtered to 475 good quality local earthquakes registered between January 2006 and July 2014 by the Arenal-Miravalles Seismological and Volcanic Observatory (OSIVAM). The events were then processed with VELEST to obtain the 1D velocity model and the stations corrections for the stations used to locate the events.
This velocity model has six layers and covers from the surface to a depth of 80 km. The model has velocities from 3.96 to 7.79 km/s from top to bottom. The station corrections obtained range between -0.28 and 0.45. These corrections show a trend with positive values located over the volcanic arc and negative values located on the forearc, in agreement with the crustal thickness. Three main seismicity clusters were identified from the earthquake relocations, which may be associated with activity on inferred faults.
The obtained one dimensional velocity model displays a simplified version for the crustal structure and aim to improve the earthquake location processes performed by the OSIVAM.

ABSTRACTS

O050 Actividad sísmica asociada con la erupción efusiva-explosiva del Volcán de Colima desde el 2013 al presente

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El Volcán de Colima inició un nuevo periodo eruptivo en enero del 2013 con explosiones moderadas. Durante el 2013 un nuevo domo de lava, así como flujos de lava hacia el W fueron emitidos. Para el 2014, la efusión de lava disminuyó hasta casi terminar en junio, para julio un nuevo pulso de magma formó un nuevo domo y generó derrumbes y flujos de lava hacia el W y SW. La actividad explosiva se intensificó entre enero y marzo del 2015 como consecuencia de la destrucción del domo anterior. Para mayo del 2015 se observa un nuevo domo. Durante los primeros días de julio se acelera la tasa de efusión generando derrumbes y flujos de lava hacia el N, SW y S. El viernes 10 de julio se observan flujos piroclásticos hacia el Sur, el mismo viernes ocurre un colapso de domo de lava el cual genera grandes flujos piroclásticos hasta una distancia de 9 km. El 11 de julio se presenta un mayor colapso del domo, con flujos piroclásticos hasta 10.2 km de distancia. Después del colapso, un flujo de lava se emplazó hacia el S. Al momento solo existen explosiones de baja a moderada intensidad.
Parte del monitoreo sísmico incluye la localización de los diferentes eventos. Además se ha cuantificado la energía sísmica. Hasta la fecha (5/02/2016), la energía sísmica acumulada de 8437 explosiones es de 2.63 e+10 Joules. VLPs también han sido registrados en las mayores explosiones, su localización por medio del movimiento de partícula han sido obtenidos. Adicionalmente al cálculo del RSEM y su variación temporal, se ha incluido el conteo de eventos sísmicos de forma automática por medio de un programa basado en Modelos Ocultos de Markov, dicho algoritmo ha permitido ver variaciones temporales en el número de eventos en este periodo eruptivo.

O051 Seismic analysis of the 2015 eruptive activity of Volcán de Colima, Mexico

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Volcán de Colima is an andesitic stratovolcano located in western Mexico. It is considered the most active volcano in Mexico, with activity characterized mainly by intermittent effusive and explosive episodes. On July 10th-11th 2015, Volcán de Colima underwent its most intense eruptive phase since its Plinian eruption in 1913. A partial collapse of the dome and of the crater's wall generated several pyroclastic flows, the largest of which reached 10.3 km to the south of the volcano. Lava flows along with incandescent rockfalls descended through various flanks of the volcanic edifice, and the ashfall affected people up to 40 km from the volcano's summit. Inhabitants from the small villages closest to the volcano were evacuated and authorities sealed off a 12 km area.
We present an analysis of the precursory, eruptive and post-eruptive seismicity related to the July 2015 volcanic crisis at Volcán de Colima. In particular, we focus on the search of temporal information within the spectral content of volcanic signals. We employ common time-frequency representations such as Fourier and wavelet transforms, but also more recent techniques proposed for the analysis of non-stationary signals, such as empirical mode decomposition and the synchrosqueezing transform. We present results of their performances and discuss the potential use of each technique to characterize and quantify spectral changes which could be used to forecast future eruptive events and to evaluate the course of volcanic processes during ongoing eruptions.

O052 Seismic monitoring of the 2015-16 eruption of Momotombo volcano, Nicaragua

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Momotombo volcano, Nicaragua, erupted on December 1, 2015, after 110 years of inactivity. We present the results of the seismic monitoring of the volcano before and during the eruption. The eruption was preceded by a seismic swarm and seismic tremor several days and hours before the beginning of the activity. Seismic tremor increased drastically when the lava fountaining began in the central crater. The lava flow which reached a distance of 3 km from the crater was accompanied by strong seismic tremor. Lava fountaining and flow ceased on December 8. In January and February 2016, the volcano presented several strong explosion in the crater followed by pyroclastic flows which reached distances up to 2.2 km. The occurrence of volcano-tectonic (VT) seismic events and chracteristic patterns of the tremor permitted the prediction of the explosiones and the emission of warnings to the civil protection authorities.

O053 Enjambres de sismos tipo LP y VT en el volcán Masaya, como indicio de la actividad eruptiva del lago del lava

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A partir del 15 de abril 2015, se comenzó a observar un aumento del número de sismos de tipo LP que duró hasta el mes de junio, con frecuencias bajas de 0.9Hz. La amplitud sísmica (RSAM) se mantuvo casi constante en 14 unidades, durante esta actividad.
En noviembre se inicia una fase de sismos de tipo VT con magnitudes menores a 3.5, con profundidad entre 1 y 8 km. Durante esta fase se inicia a observar incandescencia en el fondo del intercráter Santiago, los sismos VT continúan aumentándose, las frecuencias de los sismos alcanzaron 25 Hz.
El tremor de fondo del volcán aumento de amplitud con frecuencias 0.5, 2 y 5 Hz. El RSAM se incremento alcanzando 1100 unidades a partir del mes de febrero. El lago de lava se hizo más visible llegando a producir pequeñas explosiones de gases cenizas y fontanas de lava.

O054 Locating the 13 October 2012 Te Maari, New Zealand lahar using the amplitude source location and active seismic source methods and their implications on mass flow monitoring

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Volcanic mass flows are amongst the most dangerous and destructive naturally occurring events and hazards to populated areas. Real time monitoring and warning systems are becoming more important as people and infrastructure creep closer and closer to volcanic mass flow prone areas. Two emerging methods show promise in determining the location and dynamics of volcanic mass flows, the amplitude source location (ASL) and active seismic source methods. Both of these methods have been used to determine the dynamics and location of the 13 October 2012 Te Maari, New Zealand lahar. The lahar occurred at 11:30 UTC about 10 minutes after a debris flow dam was breached remobilizing the older debris flow deposits and water down channel. Both seismic approaches used a common frequency band range of 3-10 Hz to compute amplitudes for four near field seismic stations. We acquired amplitude distributions from the lahar that match best with locations within ~0.5 km away from the dam breakout location. The methods and routines created in this study are contributing to techniques of automation for real time warning and location prediction.

ABSTRACTS

O055 Precursors and Seismic Evolution of Cotopaxi 2015 eruption, Ecuador

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Cotopaxi volcano is one of the largest and more dangerous volcano in Ecuador. It is covered by a glaciar cap, that provides enough water to feed lahars. In past eruptions (VEI 3-4), huge lahars descended by all three drainages affecting areas nowadays covered by villages, agriculture lands and industrial facilities.
A clear increase of seismic activity was detected at Cotopaxi since April 2015, 4 months before the initiation of eruptive activity. In May 2015, around 3000 events were recorded by the seismic monitoring network of the Instituto Geofisico, some of them exhibited energy in the vlp band (periods larger than 1.2 sec.). At the end of May, and particularly in June, spindle shape tremor episodes became the dominating feature (it reached 150 tremor episodes a day). It suggested an alteration of hydrothermal system.
After a subtle decrease of activity in July 2015, interpreted as a drying phase of the hydrothermal system, a swarm of volcano tectonic events on August 13, anticipate the occurrence of phreatic explosions on the dawn of August 14 (04h02 and 04h07 local time). Other explosion signals with infrasound component were recorded at 10h25, 13h45 and 14h29. Tremor with high frequency content increased in the following days and they was related to ash emissions. A large number of VT events detected since mid September accompanied a second period of ash emissions in October 2015. Afterwards, all seismic parameters except the number and size of VT events showed a decreasing trend up to January 2016.
Cotopaxi seismic monitoring system also has been very useful for early detection of small secondary lahar events that occurred especially on the western drainage. Lahars events on September 28, October 25, November 28, 2015, and January 14, 2016 had the largest seismic amplitudes. Rapid evaluation of these signals allowed to issue warning notifications.

O056 Actividad sísmica asociada a los procesos eruptivos del volcán Rincón de la Vieja, Costa Rica, durante el período 2014-2015

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El volcán Rincón de la Vieja es un volcán andesítico localizado en la Cordillera Volcánica de Guanacaste, Costa Rica. Durante el siglo XX generó varias erupciones freáticas y freatomagmáticas siendo las últimas de ese siglo, las ocurridas en febrero de 1998 las cuales fueron del primer tipo. Durante el presente siglo el Rincón de la Vieja ha generado actividad principalmente freática durante el 2011 y 2010. Durante el periodo 2014-2015 se han observado cambios en la sismicidad que se tornaron más conspicuos entre finales de setiembre, octubre y principios de noviembre del 2015 y que se acompañaron de actividad eruptiva freática. Este trabajo se enfoca en la revisión y caracterización detallada de las señales sísmicas de este periodo, complementado con el uso de métodos análisis tiempo-frecuencia con el objetivo de buscar patrones sísmicos que pudieran ser utilizados como precursores de actividad eruptiva e investigar cambios en la dinámica interna y del volcán. Una de las señales más relevantes analizadas durante este periodo y que podrían constituir un precursor interesante se trata de señales tipo tornillo caracterizadas por una coda armónica con frecuencia fundamental que varía entre los 5 y 8 Hz. Estas señales presentan una muy larga duración con un decaimiento lento de la coda. Los tornillos en Rincón de la Vieja tienen duraciones entre 90 – 300 segundos. Estos son asociados a cambios en el sistema hidrotermal, previos a erupciones freáticas, en los cuales las frecuencias dominantes cambian con respecto a los valores normales.

O057 Seismic precursors evolution along the eruptive stages from 2010-2016 at Turrialba volcano, Costa Rica

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Turrialba volcano is located at the eastern end of the central volcanic range of Costa Rica. Since 1997, it shows a slow awakening which turned conspicuous in 2007. A first phreatic eruption occurred in January 5th 2010 that opened a new vent on the inner crater wall. Subsequent eruptions took place in 2011, 2012 and 2013. The eruption on October 29th 2014 established a breakpoint in the eruptive dynamics of the volcano that turned from isolated annual eruptions to well defined eruptive cycles. The present work focus on the precursory activity of the main eruptive stages at Turrialba volcano since 2010, in order to understand the evolution of the eruption dynamics along the slow awakening of the volcano. Close inspection of seismic records and different time-frequency analysis have been used in order to characterize the changes on seismicity and extract the different types of events involved previous to each stage and analyze their changes on characteristics and rates. The 2010 eruption was preceded by a sustained increasing seismic activity since 2007 reflecting the first opening of paths for magma to move upwards. Overall seismicity comprises a wide variety of signals with frequency ranges from 1-4 Hz and some energy up to even 10 Hz. 16 days before the 2010 eruption seismicity clearly shifted to only two well defined families of LP events, one with clear harmonic tremor with glidding and the other without it. 30 minutes before those families disappeared and gave way to 1,5 Hz harmonic episodes and a high frequency tremor just before the onset of the eruption. After this eruption overall seismicity at Turrialba volcano changed and precursory behaviour evolved at each stage reflecting as well an evolution on eruptive dynamics and the internal state of the system, conditioned by the slow magma ascent to the surface.

O058 Seismic signals associated to explosive activity at Turrialba volcano, Costa Rica

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Turrialba volcano, in Costa Rica, a stratovolcano with basaltic-andesitic composition, locates to the southeastern end of the Cordillera Volcánica Central. First signs of awakening, after 150 years of relative quiescence, began to appear after mid 1990s. However, the most important seismic activity was recorded in 2007, probably associated with a breakage of the quartz seal, and the ascend of a small magma body. The first phreatic eruption was recorded in 2010. After this first rupture of the crater inner wall, other phreatic eruptions followed, one every year until a change in eruptive behaviour occurred during the October-December 2014 eruptive cycle. Throughout this eruptive sequence and the following ones that took place in March-June 2015 and October 2015, two types of seismic signals were recorded associated with some of the eruptions, mainly those that were explosive and shoot ballistic fragments. First type of seismic events look like a regional event, and is characterized by two clear phases; one with a small amplitude, very emergent (resembling the arrival of an emergent P wave and the P coda) and the second phase with larger amplitude (resembling the arrival of an S wave and the following coda). When eruptions are located very close to the surface of the crater, the seismic signature corresponds to the arrival of the second phase. The second type of signals are VLP (Very Long Period) events, that are recorded between 60 and 90 seconds before the ash plume is observed at the surface. Although both type of signals are associated to explosive eruptions, their different frequency content and waveform shape implies a very different source mechanism. This work focus on the nature of the sources that produce these events by studying the relationship between the seismic signature of the explosive eruption and visual characteristics of the event.

ABSTRACTS

O059 A first tomographic study of Baru Volcano, Chiriquí, Southwestern Panama

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The objective of this research is to determine the location of the magma chamber inside the Baru volcano. The seismic tomography methodology used for this research was the developed by Zhao (1992, 1994); using the first arrivals (P waves) with local earthquakes. 3D model of Zhao (1992) 2D discontinuities inversion was used.
The seismological data used was provided by the University of Panama Instituto de Geociencias for the period 2011-2015. A total of 1057 earthquakes and 418 (83 national and 335 international) seismic stations were used. The seismic data was analyzed using the Analysis System Program (SEISAN). The main parameters for selecting the data were those earthquakes that occur in at least 5 seismic stations; seismic stations that reach at least 5 earthquakes and waste less time traveling to 0.150 s.
Data on inversion: flat layers are selected (2, 4, 6, 8, 10, 15, 20, 25 km deep) and two discontinuities (Vp of 8.2 km to 5.1 km / s, 20 km with Vp of 6.7 km / s in the semi space with Vp of 7.3 km / s). To set a parameter of trust and reliability we use the method of Hit Counts (coverage rays) obtaining a total of 1359 nodes. The number of data before and after inversion is: 4187 and 2895 which are determined by the quality parameters such as time of travel less than 0.150 s.
The results obtained in this research show a strong negative anomaly at 2 km deep which can indicate the magma chamber west of Baru Volcano, which extends southwest from the region extending to the 15-20 km depth.

O060 Regularly reoccurring seismic swarms at Guagua Pichincha, Ecuador

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Guagua Pichincha is an active stratovolcano of dacitic composition located 12 km west of nearly 2 million urban inhabitants. Guagua Pichincha is currently monitored by seismic, geodetic, and infrasound sensors. Since March 2014, and possibly earlier, seismic activity at Pichincha has been characterized by short duration (< 1 day) seismic swarms with recurrence intervals between swarms that vary over time. Two small phreatic explosions occurred in mid-April of 2015 and attests to the still active nature of this volcano. To assess the repeatability of these seismic events, we apply a waveform similarity analysis using a single vertical component short period station located at the volcano rim. A template event was chosen at random and cross correlated through 19 months of continuous data. At a threshold of 0.7, greater than 7800 events organized into >80 seismic swarms were identified. Cultural noise as the source of this activity is ruled out by the random start and end times of these swarms. The high coherence between events additionally suggests a relatively stationary source location. However, for events large enough to register at multiple stations, hypocentral locations delineate a vertically elongated (>10 km) column of events directly beneath the volcano summit. At times, these swarms coincide with small transients (<10 microradians) at a single tilt meter located ~600 m from the crater domes. During any single swarm, events show a progressive rise and subsequent decay in their maximum amplitudes, where the highest amplitudes are usually associated with the highest instantaneous rates as well. This observation is intriguing and may provide some semblance of magnitude predictability using knowledge of the current average rate of events at a particular time in the swarm. The significant historical activity and large nearby population reinforces the need for intense monitoring and detailed analysis of any seismic and geodetic trends.

O062 Gross crustal structure of the Merida Andes, Venezuela, from seismic wide angle and gravimetric studies

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Seismic wide angle and gravimetric measurements were done from 2013 to 2015 along three main profiles across the Merida Andes, with a perpendicular profile in the Falcon basin in the north. The objective of these measurements, done in the scope of the GIAME project, was the determination of the crustal structure of the mountain chain, and its relation to the development of the adjacent sedimentary basins. The mountain chain was sampled along three segments, the southernmost with a poorly developed vergence to the northwest, the central segment with a well-developed vergence to both flanks, and the northernmost, which only exhibits vergence to the southeast. Most striking result is an asymmetry in the crustal root along the southern segment, derived from the profile perpendicular to the Andes mountain chain, as well as from along strike observations, with a maximum Moho depth of 52 km, shifted about 50 km to the northwest compared to topographic profile. This asymmetry seems to vanish towards the north, is still present in the central segment with a Moho depth of about 50 km, whereas in the northern segment, asymmetry seems to be shifted to the southeast with maximum crustal thickness of 44 km towards El Baul massif. Analysis of new, high resolution gravity data and 2-D gravity forward models confirm this asymmetry. Strong variations of the thickness of the crustal root out of the main strike of this feature is necessary to achieve a good fit of the observed Bouguer anomaly. In the Falcon area, crustal thickness is reduced to about 30 km, as a result of the crustal thinning. Further members of GIAME active seismic working group are: Manuel Bolivar, Mariano Arnaiz-Rodriguez, Henderson Pinto, Lisfer Flores, Jorge Alcala, María Saavedra, Loveida Montilla, Christian Jimenez, Yoana Maldonado, Kenny Garcia, Gabriela Gil, Joaquin Requena.

O063 Crustal structure beneath the inverted Falcon Basin, Merida Andes, and El Baul Massif, Venezuela, from deep seismic studies

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Falcon basin and Merida Andes in western Venezuela are related to a complex geological zone, due to the interactions between the Caribbean and South American plates. During last 60 years several models regarding the shallow and deep structure from this region, have been proposed. Nevertheless, most of these studies are based on minor-scale observation windows, and they do not represent a regional frame of deep structure. As a part of the GIAME Project, we will try to solve various uncertainties regarding to lithospheric structure, since a wide-angle seismic transect was acquired across the three major geological zones (Falcon inverted basin, Merida Andes, and El Baul massif). In this contribution we present a 2-D model along the 560 km long Northern Andes profile, with 13 controlled explosive (200-1600 kg) blasts, recorded by more than 600 portable seismometers (Texan), provided by IRIS-PASSCAL and FUNVISIS. The spacing between receivers ranged from 0.5 to 1 km. We recognized seismic energy from Pg phases until 190 km distance; Pn phases ranged from 125 to 545 km; intra-crustal reflections (Pi) from depth ranges of 20 to 30 km, and PmP reflections from depths of 33 to 44 km. Vp-velocities of the crust ranged between 3.2 and 5.7 km/s for the sedimentary cover; 6.1 to 6.5 km/s for the upper crust, and 6.7 to 7.2 km/s, and 7.8 to 8.4 km/s for lower crust and upper mantle, respectively. The most prominent features imaged by the seismic survey were a crustal thinning beneath Falcon basin which is related to a rift origin for this inverted basin, and a deeper reflected phase interpreted to be derived from the downgoing Caribbean slab. The velocity model made by a first-arrival seismic tomography shows remarkable velocities structures associated to the Andes crystalline core, and Pre-Cambrian and Paleozoic rocks from El Baul massif.

ABSTRACTS

O064 North São Francisco Craton seismic profile: NE Brazil

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The North São Francisco Craton seismic refraction profile is the third seismic transect supported by the research program of the INCT for Tectonic Studies (MCTI/CNPq) in NE Brazil, scheduled to be acquired in May 2016.
The São Francisco Craton is part of an amalgam of Archean-Paleoproterozoic terrains supported by an ultra-depleted lithospheric root, which confers them a block framework behavior. During formation of West Gondwana, the São Francisco Craton was linked to the Congo Craton, which were individualized in the Cretaceous with the opening of the South Atlantic Ocean. From west to east it displays a Neoproterozoic-Cretaceous cover, a central Mesoproterozoic cover, and an eastern Paleoproterozoic cover. The seismic profile crosses the domains in the northern part of the craton, almost perpendicular to their limits. It is a 700 km W-E profile, with one vertical station every 2 km and a shot of 1.5 tons every 50 km. Additionally, as part of the seismic experiment, a line array of forty triaxial short-period seismic stations (one every 20 km) was deployed for receiver function studies. The first results show a felsic and thick crust (42-47 km) in the western cratonic domain and a felsic and thinner crust (38-40 km) in the central and eastern domains. The Moho behavior suggests that the crust of the central and eastern domains was bended upwards, probably do to an isostatic rebound imposed by the South Atlantic opening. As a consequence, the Neoproterozoic and Cretaceous sediments, currently exposed in the western domain, were removed from the other domains. Receiver function results and a qualitative analysis of the seismic profiles of the north São Francisco Craton will be shown.

O065 The PABBRISE profile, onshore SE Brazil

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The PABBRISE profile consists of a ca. 700 km wide-angle reflection/refraction seismic experiment crossing the northeastern Paraná Basin, southern Brasilia belt, and Ribeira belt, adjacent to the SE Brazilian continental margin. The experiment was funded by Cenpes/Petrobras.
Modelling of P-wave travel-times and regularly spaced receiver function results provide a seismic model in which the Moho discontinuity is shown as a structured and heterogeneous interface, with three major steps (43 km, 40 km and 32 km), getting shallower to the southeast, near the continental margin. The obtained geometry suggests three different seismic domains in the continental crust. In all of them the lower crust was modified in some way: by mafic intrusions, ductile stretching or delamination. Near the Paraná River, the lower crust (Vp=6.70–7.05 km/s) shows discontinuous seismic reverberations interpreted as mafic sill-like intrusions. In the central domain, the upper crust is almost three times thicker than the lower crust. The latter is associated with a strong positive velocity gradient, indicating the occurrence of a mafic underplate along the Moho (Vp=7.10–7.25 km/s). The lower crust near the continental margin shows anomalous low velocities (Vp=6.48–6.65 km/s). This area is associated with the prominent elevations of the Serra do Mar and Mantiqueira ranges. It also displays the thinnest crust under the profile (32 km) and a Bouguer anomaly in phase with the topography and the Moho. Altogether, these data suggests that delamination, possibly related to the South Atlantic opening, removed the mafic portion of the lower crust. This was followed by regional flexural uplift and prominent alkaline magmatism. That event helped to mold the current geometry of the northeastern flank of the Paraná Basin. The lithospheric mantle displays Vp=7.88–7.92 km/s near the continental margin and Vp=8.25 km/s to the northwest, under the basin, revealing two main lithospheric mantle domains.

O066 Parnaíba Basin WARR, Brazil

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The Parnaiba Basin is a Paleozoic sag basin, roughly circular in shape, occupying a 660,000 km2 area of north Brazil. It has tectonic contact with the Amazon Craton (westwards) and with the São Luis Craton (to the north), and an erosive contact with the Borborema Province (eastwards) and the São Francisco Craton-Tocantins Province (southwards). Close to the eastern border, hidden by sedimentary cover, the basin-basement is cut by the Transbrasiliano lineament.
With the aim to detail the structure of the Parnaiba Basin and its basement and to better understand the genesis of sag basins, BP has promoted a Program of Study of the Parnaíba Basin (PABIP), supporting a multidisciplinary approach involving geological and geophysical studies, including a WARR (Wide Angle Reflection and Refraction) experiment.
The WARR line is an E-W, 1,200 km long profile crossing the basin and its western and eastern limits, following the path of the previously acquired PABIP deep reflection line, done in 2013.
Thirty-six short-period three-component seismic stations were deployed along the refraction transect in August 2015, covering (mainly) the extremes of the line and the western and eastern limits of the basin. The objective is to complement the analysis of the WARR data with receiver function results. These stations worked in continuous mode until January 2016. Another six hundred one-component stations were installed along the profile in September-October 2015 and, during four nights, twenty two shots, comprising 1.5 tonne of explosives each, were performed.
The refraction data have been pre-processed and are of very good quality. The three-component stations have just been recovered and the data are under analysis. This paper proposes to present a preliminary model of the Moho interface under the PABIP profile from receiver functions and a preliminary image of crustal velocity distribution obtained by tomography of first-break WARR data.

ABSTRACTS

O068 Seismic, geodetic and tsunami monitoring and data sharing in the Caribbean, the Puerto Rico Case

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The Caribbean Region (CR) has a documented history of large damaging earthquakes and tsunamis that have affected our countries (1692, 1867, 1918, 1946 and 2010). The CR is monitored jointly by national/regional/local seismic, geodetic and Sea Level networks, all networks and monitoring institutions are participating in an initiative to improve the real time (RT) data sharing, warning and data collection capabilities. Currently, more than 120 broad-band seismic, more than 50 sea levels channels and more than 20 GPS high rate stations are being received in the Puerto Rico Seismic Network (PRSN) in real time. These RT streams are used by the EarthWorm/EarlyBird/TideView/PR-DANIS packages to locate and determine the size of events in the Caribbean with magnitudes greater than 4.5 as well as the sea level evaluation, the solutions are provided in a timely framework to our emergency managers.
This initiative is motivated both by research and natural hazard monitoring and warning; it will allow to define the structure of the Caribbean region to a high detail, to study properties of the seismic source for intermediate and large events, and to apply this knowledge to procedures of civil protection. To reach its goals, the CR virtual network has been designed following the highest technical standards. In addition countries are working together to improve the sea level and geodetic monitoring capabilities. All data generated by this virtual network are also shared with international geodetic, seismic and tsunami centers under the UNESCO ICG CARIBE EWS framework.
The need to establish a system of rapid notification for earthquake/tsunami alerting in the CR has been recognized by emergency managers and the scientific community. The goal of this presentation is to describe the PRSN system, including the real time earthquake and tsunami monitoring as well as the specific protocols used to broadcast earthquake/tsunami messages locally.

O070 Multiparameter stations: Electric, magnetic, seismic, radon gas and GNSS data measurements on the central region of Colombia

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The tectonic convergence process, which takes place in the north-west part of South America, due to Nazca, Cocos, South American and Caribbean Plates interaction has been aim of study with different methods; however, most of them have been applied one after another, but not simultaneously, resulting on an extended in time set of data, but, which includes contributions from different methods applied in different time periods.
Such methods have been applied in the central region of Colombia, particularly in the Piedmont of the Eastern Cordillera. This region is of great interest because of the significant race of the number of seismic events of different magnitudes in recent times. This phenomenon requires additional studies in order to clarify, which is the influence of the particular natural tectonic processes, and, which the intense petroleum exploitation activity developed nowadays.
A number of multi-parameter stations are being deployed in the central region of Colombia. The measurements are beginning to provide electric, magnetic, seismic, radon gas, and GNSS data. Here we will show the preliminary results of instrumental deployment, as well as, we will discuss the repercussion of the intense petroleum exploitation activity developed nowadays in the Piedmont of the Eastern Cordillera in Colombia.
This work is supported by the Administrative Department of Sciences, Technology and Innovation of Colombia – COLCIENCIAS (project No. 0361-2013), and co-supported by the Antonio Nariño University, the National University of Colombia, and Tigo mobile provider.

O071 GNSS Space Geodesy: A tool for the analysis and modeling of crustal deformation in Colombia

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Colombia is currently in the process of expansion of its research capabilities in the field of the Earth Sciences that includes the application of various technologies oriented towards the study of crustal dynamics of its territory. The Colombian Geological Survey-CGS, the erstwhile INGEOMINAS, is actively promoting the expansion of its seismic network, volcanological and seismological observatories and, more recently, the inclusion of a GNSS Space Geodetic Network. The present geodetic infrastructure, known as GeoRED (Geodesia: Red de Estudios de Deformación, in Spanish) consists of 82 permanent stations and 323 campaign-style stations. The localization of the permanent stations as well as the field stations arrays, has been determined by the repartition of the Colombian territory in crustal blocks limited by identified presumably active faults along which stress is being transferred in shear zones. This permits the segmentation of the North Andean Block within Colombia into 20 tectonic sub-blocks as a first conceptual model and working hypothesis. Complementary neotectonic surveys along these fault zones are carried out concurrently to validate this model. An important aspect that has risen as a by-product of these activities has been the creation of institutional cooperation efforts within the framework of international projects, initially in the form of the GPS CASA Project during the decade of the nineties and more recently as the COCONet Project. Likewise there is also active interchange and sharing of data between researchers of Colombia and the USA, Venezuela, Panama, Ecuador and Peru. All data are being processed using the GIPSY-OASIS II v 6.3 scientific software developed by JPL-NASA-CALTECH, whereas the time series are being generated using the HECTOR software (Bos et al., 2012). A GPS velocity field wrt to South American plate is showed, and constitutes an essential input for the determination of the state of crustal deformation of the Colombian territory.

O073 OVSICORI`s Southern Costa Rica Geodynamic Control Network: The opening of a Pandora`s Box

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With the expectation of repeating the success in Nicoya, the Costa Rica Volcanological and Seismological Observatory at the National University (OVSICORI-UNA) decided to improve the coverage and gain of its geodynamic control network in southern Costa Rica. What started as an attempt to anticipate the rupture of the next Osa-Burica earthquake, is growing now into a multi purpose network. Although understanding all processes that occur in that region requires several years of recordings, we will show preliminary results of very well recorded earthquakes. Our expectations now are to use this network to address the following issues: 1) geometry and distribution of inhomogeneous coupling along the Cocos-Panama subduction interface; 2) forearc response to the subduction of the Cocos Ridge and other smaller bathymetric features; 3) characteristics of the subducted portion of the Panama Fracture Zone under Burica peninsula; 4) the geometry and speed of faults along which the Coastal Range overthrusts the forearc; 5) the internal deformation of both, Cocos and Panama plates, as a response of sub-flat subduction; and 6) mapping of small shallow local faults that could represent a threat to local communities; among others.

O074 Tsunami-HySEA model validation for tsunami current predictions with Tohoku 2011 field data

Jorge Macías Sánchez[1], Manuel J. Castro[1], Sergio Ortega-Acosta[1], José Manuel González-Vida[1]
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Model ability to compute and predict tsunami flow velocities is of importance in risk assessment and hazard mitigation. Substantial damage can be produced by high velocity flows, particularly in harbors and bays, even when the wave height is small. Besides, an accurate simulation of tsunami flow velocities and accelerations is fundamental for advancing in the study of tsunami sediment transport. These considerations made the National Tsunami Hazard Mitigation Program (NTHMP) proposing a benchmark exercise focused on modeling and simulating tsunami currents. Until recently, few direct measurements of tsunami velocities were available to compare and to validate model results. After Tohoku 2011 many current meters measurement were made, mainly in harbors and channels. In this work we present a part of the contribution made by the EDANYA group from the University of Malaga to the NTHMP workshop organized at Portland (USA), 9-10 of February 2015. We have selected three out of the five proposed benchmark problems. Two of them consist in real observed data from the Tohoku 2011 event, one at Hilo Habour (Hawaii) and the other at Tauranga Bay (New Zealand). The third one consists in laboratory experimental data for the inundation of Seaside City in Oregon. For this model validation the Tsunami-HySEA model, developed by EDANYA group, was used. The overall conclusion that we could extract from this validation exercise was that the Tsunami-HySEA model performed well in all benchmark problems proposed. The greater spatial variability in tsunami velocity than wave height makes it more difficult its precise numerical representation. The larger variability in velocities is likely a result of the behaviour of the flow as it is channelized and as it flows around bathymetric highs and structures. In the other hand wave height do not respond as strongly to channelized flow as current velocity.

O075 Software to forecast the tsunami parameters from pre-simulated seismic unit sources

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In this research we have implemented a software to forecast the parameters of a tsunami, such as the arrival time of the first wave and the maximum wave height in tidal stations of the Peruvian coast, from a database of synthetic marigrams (or Green functions) obtained from numerical simulation of seismic unit sources (dimension: 50×50 km2) for subduction zones from southern Chile to northern Mexico, with a bathymetry resolution of 30 s (927 m). The resulting tsunami waveform is obtained from the superposition of synthetic marigrams corresponding to several seismic unit sources contained in the rupture geometry. The numerical model was applied to the Chilean tsunami of April 1, 2014 with satisfactory results, in the case of the Arica tidal station an error of 3.5% was obtained.

O076 NTHMP Benchmarking of Tsunami-HySEA model for propagation and inundation

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According to the 2006 Tsunami Warning and Education Act, all inundation models used in NTHMP projects must meet benchmarking standards and be approved by the NTHMP Mapping and Modeling Subcommittee (MMS). To this end, a workshop was held in 2011 by the MMS, and participating models whose results were approved for tsunami inundation modeling were documented in the "Proceedings and results of the 2011 NTHMP Model Benchmarking Workshop". Since then, other models have been subjected to the benchmark problems used in the workshop, and their approval and use subsequently requested for NTHMP projects. For those currently wishing to benchmark their tsunami inundation models, a first step consists in completing benchmarks problems 1, 4, 6, 7, and 9 in the former report. The aim of the present contribution is to present NTHMP model validation for propagation and inundation for the case of the Tsunami-HySEA model.

Thus, Tsunami-HySEA numerical model is verified and validated using NOAA standards and criteria for inundation. The numerical solutions are tested against analytical predictions (BP1, solitary wave on a simple beach), laboratory measurements (BP4, solitary wave on a simple beach; BP6, soliary wave on a conical island; and BP7, runup on Monai Valley beach), and against field observations (BP9, Okushiri island tsunami). We will show how the Tsunami-HySEA model performs well in all the tests, producing good results fulfilling MMS/NTHMP requirements.

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O077 Verification of a low resolution tsunami model system for Costa Rica North and Central Pacific Coast

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RONMAC Program is building tsunami evacuation maps for some locations along the North and Central Pacific Coast of Costa Rica. To identify locations with higher hazard a low resolution model has been setup covering the mentioned coastline. The same model can be used for real-time forecast purposes. To ensure realistic results, it is required verification of the model through comparison with records of real tsunamis. Quepos tidal gauge, on the Central Pacific Coast of Costa Rica, has been operating since 1957 and has registered seven far-field and one local tsunami. Only marigrams from four of those tsunamis are available: 2015 Chile Mw 8.3, 2011 Japan Mw 9.0, 2010 Chile Mw 8.8 and 1990 Cóbano (Costa Rica) Mw 7.0. Here, a 3arcsec grid covering Quepos was nested to the low resolution model to compare the existing marigrams with model results. Far-field tsunamis were simulated using PMEL-NOAA initial condition obtained from DART buoy data inversion. For the local tsunami it was considered pure dip-slip rupture over a single plane, not validated with DART data. In all cases ComMIT (MOST) tsunami numerical model was employed. The nearshore bathymetric data was obtained after digitized old nautical charts. The model results agreed well with tsunami records, except for 2015 Chile tsunami. On December 2014, the tidal gauge was relocated in a new dock, being very likely the reason for the model underestimation of the tsunami records of the latest tsunami. Updated higher resolution bathymetric data would be desirable to have a more reliable model setup for Quepos. High resolution bathymetric data is required to determine the evacuation area at the locations where evacuation maps are going to be built. However, the performance of the low resolution model is considered acceptable for the identification of priority locations.

ABSTRACTS

O078Tsunamis on Colombia´S Pacific Coast

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Colombia has two coasts on tsunami-prone basins, Pacific and Caribbean, with significant differences in terms of occurrences, hazard, exposure, as well as complexities of their tectonic and seismogenic conditions. Here we present a brief compilation of advances towards hazard and risk assessments for the Pacific coast, until recently mainly focused on the coastal segments with historic tsunami disasters and larger exposed populations. While the Caribbean coast has more and larger cities (and densely populated islands), but no historic events nor notorious sources nearby, the Pacific coast has a record of large and disastrous events and most of its coastline is barely above sea level.
Along the Colombian Pacific coast – more than 800 km – runs the northern segment of the South America subduction zone, with historic events of up to M8.6 (1906). While its southern part – source of very large events since 1906 - is rather well studied, including one of the first modern and comprehensive studies of large earthquakes and tsunami, the northern one is still a rather white area in all published results, and its potential for tsunamigenic events is still unknown. We attempt a first estimate, based on integration of results from many authors; its preliminary conclusion is towards a significantly lower potential, based on seismicity, morphology, convergence velocity variations, and other features.
We also present tsunami propagation models, to estimate maximum wave heights for a distant source and for several historic and inferred near sources along the subduction zone. Finally, we present our conclusions regarding data and knowledge needs and future priorities to improve hazard and exposure models for the Colombian Pacific coast.

O079 Evaluación del impacto de maremotos en el sur del Perú, caso de estudio: Maremoto del 13 de agosto de 1868, Tacna-Peru

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Se realizó el estudio del maremoto histórico ocurrido el 13 de agosto de 1868 frente a las costas del sur de Perú. Mediante la elaboración de un modelo de fuente sísmica homogénea para un escenario sísmico de Mw=9.0, se modeló la propagación e inundación del maremoto usando el modelo numérico TUNAMI en su forma lineal y no lineal. Se obtuvieron como resultados mareogramas simulados que indican tiempos de arribo de la primera onda de 10 min para las localidades de Mollendo e Ilo y de 15 min para las localidades de Camaná y Santa Rosa. Las máximas alturas de olas según el mareógrafo virtual de Ilo es de 8.0 m y en Mollendo es de 10.0 m, los cuales son valores bastante cercanos al registrado históricamente en 1868. En cuanto a la evaluación del impacto de maremotos, la máxima distancia de inundación horizontal obtenida fue en la localidad de Camaná (Arequipa), con un valor de 2.68 km, lo cual inunda parcialmente el poblado y terrenos de cultivos en esta ciudad. Estos resultados permiten concluir que la localidad de Camaná sería la más afectada ante el impacto de un maremoto con características similares al evento histórico de 1868.

O080 Potential tsunamis inundation maps in the F.W.I. from a bank of seismic scenarios

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We present here a case study of tsunamis modeling in Guadeloupe and in Martinique (F.W.I.) in an aim of an operational valuation. Among about thirty tsunamis of multiple origins (seismic, volcanic and teletsunamis) that have hit the Lesser Antilles these last 400 years, some were generated by extreme seismic scenarios: 1867 Virgin Island scenario, Mw 7.3; 1839 and 1843 scenarios, both of Mw 8.5. The consequences of these extreme events over our islands in terms of tsunamis are not well known. What could it be today where the human and economic stakes turn out to be very important in our coastal zones?
The purpose of the study is to build a bank of seismic tsunamis scenarios, from historical and potential seismic sources to characterize the potential inundation zones for extreme events, in order to study the vulnerability of the coastal zones and to bring a decision-making support to the authorities, mainly to the municipalities. In total, 1961 combinations of scenarios were created and classified in four categories: Mw ≤ 7.5; 7.5 < Mw ≤ 8.0; 8.0 < Mw ≤ 8.5; Mw ≥ 8.5.
By using the numerical modeling code of the national tsunami warning center of France, CENALT (witch monitors the Western Mediterranean Sea and the northwestern Atlantic Ocean) we have produced different types of modeling data from all the 1961 scenarios: travel time, inundation map for each coastal zone, maps of maximum of maximum, maps of minimum of minimum, evaluation of the hold of the tsunami wave on the stakes of the municipalities, action maps of tsunami management for the municipalities, study of the vulnerability of coastal zones, etc.

O081 Tsunami scenarios and hazard assessment along the Northern Coast of Haiti

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The northeastern Caribbean island arc, which materializes the boundary between the North American and Caribbean plates, is particularly exposed to large earthquakes and tsunamis. We show tsunami inundation results for northern Haiti based on three earthquake scenarios: a M8.0 earthquake on the Septentrional strike-slip fault (possibly similar to the 1842 earthquake), a M8.1 earthquake on the offshore thrust fault system north of Haiti, and an earthquake rupturing a large portion of the offshore thrust fault system north of Haiti and the Dominican Republic. We find that the rupture of the offshore North Hispaniola thrust fault could result in wave heights up to 10 m with inundation up to 4 km inland, with only 10-15 minutes between ground shaking and the first wave arrivals. The city of Cap Haitien is particularly exposed, with potential flooding of most of the city and its suburbs, including the international airport. We compare our results with a similar study performed by a private consortium for a UNESCO tsunami ask reduction program. We find significant differences in the geometry of the source scenarios chosen and the resulting run-up heights, in particular for the heavily populated city of Cap Haitien. We argue that a careful review is in order before important operational decisions are taken, such as the location of shelters and safe population-gathering areas in case of a large regional earthquake.

ABSTRACTS

O082 Estimación de la peligrosidad por tsunami en san andrés isla utilizando herramientas numéricas y geoespaciales

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Con base en el escenario CaribeWave 2015, es posible que se generen sismos precursores de tsunami con afectación en la costa Caribe y Áreas insulares de Colombia. Por su ubicación geográfica y número de habitantes que superan los 75.000, sumados a la población flotante que se estima en 600.000 en temporada turística, es necesario, estimar la peligrosidad por tsunami en San Andrés Islas. Se utilizó información batimétrica de detalle de 15 m de resolución espacial e información Light Detection and Ranging (LiDAR) que permite representar la altimetría del terreno del área de estudio con una exactitud posicional de ±30 cm en el plano vertical y ±30 cm en el plano horizontal de acuerdo con los datos adquiridos por Dimar, la cual se integró al modelo Non-Hydrostatic Evolution Of Ocean Wave (NEOWAVE), y se realizó un análisis con ArcGIS 11.0, para determinar el grado de afectación por el tsunami. Como resultados se obtuvieron alturas de ola de 0 m a 5.0 m, y tiempo de llegada del tsunami de 40 minutos, además se determinó la efectividad de la barrera natural de coral como elemento protector, toda vez que disminuye la altura de ola en un 60%. La inundación en promedio es de 3.5 m en la zona nor-occidente de la isla, donde se concentra el comercio, el turismo y desarrollo de la misma. El tiempo de llegada del tsunami permite con preparación de la población, una evacuación a zonas altas o de menor exposición, la barrera de coral es un elemento protector solo para la zona centro-occidental. Se concluye que San Andres Isla presenta amenaza por tsunami. Por lo que se recomienda generar planes locales de prevención y contingencia ante tsunami que permitan reducir la vulnerabilidad de la población.

O083 Tsunami modeling with ComMIT of the historic earthquake September 7, 1882; and determination of areas of flood in the Province of Colon, Panama

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The first work of tsunami modeling with ComMIT and mapping of tsunami inundation with a view to comprehensive disaster risk management is presented for Panama. Historical tsunami of September 7, 1882 (meaning throughout the territory of the Isthmus of Panama, the first of the four big waves came to the region of Guna Yala between 15 to 30 minutes after the earthquake). The model is considered a seismic source which produced a bidirectional rupture, a magnitude 8.5 Mw and inundation maps Panama's Caribbean coast are generated in the province of Colon to the towns of Viento Frio and Palenque. For the modelling work ComMIT computational tool developed by NOAA was used. Bathymetry was obtained from scanning nautical charts and topography the shores of a digital elevation model of 30 m. For the preparation of the maps ArcGIS computational tool of ESRI was used. Tsunami height maps, flood depth, current speed, and safe areas, on a scale that allows to give an overview for the civil protection authorities of Panama the size of a tsunami event end were obtained. Based on the results obtained it is proposed future studies of paleotsunamis in the Caribbean and Pacific coasts of Panama, acquiring bathymetric and topographic data of higher resolution to improve performance, advance training activities of coastal communities in the plans evacuation to flooding by tsunami.

ABSTRACTS

O084 Numerical simulations of 1991 Limon tsunami based on two different seismic solutions

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On April 22nd, 1991, an earthquake with magnitude Mw 7.6 ruptured along the thrust faults that form the North Panama Deformed Belt (NPDB). The earthquake triggered a tsunami that affected within few minutes the Caribbean coast of Costa Rica and Panamá, generating two casualties. These are the only deaths reported to be caused by a tsunami in Costa Rica. Co-seismic uplift up to 1.6 m, and run-up values larger than 2 m were measured along some coastal sites. On the 25th anniversary of the event, we model the tsunami considering two solutions for the seismic source model as initial conditions, each considering a single rupture plane based on Plafker and Ward (1992). We performed numerical modeling of the tsunami propagation and run-up using NEOWAVE numerical model, on a system of nested grids from the entire Caribbean Sea to Limon city. Unfortunately, there was no tidal gauge near the source region. Nonetheless, the modeled surface deformation and tsunami run-up agreed with the measured data, indistinctly for both solutions along most of the coastal sites. The model results are useful to determine how the 1991 tsunami could have affected regions where tsunami records were not preserved and to simulate the effects of the coastal surface deformations as buffer to tsunami. Such simulations considering historical events and maximum credible scenarios are useful for prevention and mitigation purposes.

O086 Efectos por directividad de la fuente sísmica del Terremoto de Sámara 7,6Mw, del 5 setiembre del 2012, Costa Rica

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El 5 de setiembre del 2012 se produjo un terremoto frente a la Península de Nicoya, Mw 7,6. Fue sentido en todo el país y produjo daños en algunas poblaciones de la zona. Generó una concentración de efectos y daños en una región distante entre 120 a 150 km, en los municipios de Sarchí y Naranjo. Esos efectos se podrían explicar en alguna medida por la directividad de la energía sísmica, influenciado por la geometría y características de la fuente sísmica.
El terremoto fue originado por subducción de la placa del Coco bajo la placa Caribe. La zona de ruptura tendría un largo aproximado de 55 km, un ancho en profundidad de unos 40 km, hasta debajo de la zona de Cerro Azul y Juan de León de Jicaral. Se estima un área de ruptura de aproximadamente 2200 km2. El deslizamiento a lo largo del plano de falla es de 2,2 m. La energía total liberada sería de 1,58 x 1023 ergios, que equivale a una potencia de 158 bombas atómicas similares a la detonada en Hiroshima en 1945.
Dado que teóricamente la fuente sísmica durante el proceso de ruptura tienden a enfocar las ondas "P" a 45° del plano de deslizamiento y en este caso al estar dicho plano inclinado unos 30° al NE, tiende a enfocar el tren de ondas en dirección NE, de manera que se proyectan con su eje central del óvulo mayor de ondas a unos 120 a 150 km de distancia en esa dirección. Siendo allí donde ese mayor tren de ondas se encuentra con los poblados de Sarchí y Naranjo, donde aunado a las condiciones de terreno volcánico alterado y de laderas, provocó severos daños en esa región

ABSTRACTS

O089 Modelación probabilista de escenarios de riesgo sísmico en Managua, Capital de Nicaragua

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La Ciudad de Managua ha sido afectada en varias ocasiones por terremotos que le han ocasionado grandiosas pérdidas económicas y de vidas humanas. Como capital de Nicaragua, es el principal centro urbano, político y económico de la nación. Esta combinación de alta amenaza sísmica, concentración de bienes y de población, hacen de ella la ciudad con mayor riesgo sísmico del país; de ahí la necesidad de evaluar las pérdidas debidas a sismos empleando técnicas avanzadas. En este sentido, empleando la herramienta CAPRA, se llevó a cabo una evaluación probabilística del riesgo sísmico a los portafolios de viviendas, educación y salud. Esta herramienta permite la evaluación de pérdidas en elementos estructurales expuestos utilizando métricas probabilistas. El estudio comprendió: el cálculo de la amenaza sísmica empleando modelos probabilistas y utilizando ordenadas espectrales como medidas de intensidad; la definición de funciones de amplificación del suelo para la ciudad; la estimación del valor físico de los elementos expuestos en estudio (viviendas, escuelas y hospitales), su distribución geográfica y clasificación en tipologías estructurales; el estudio, selección y modificación de funciones de vulnerabilidad. Finalmente se obtuvieron los resultados del riesgo expresado en términos de las principales métricas para cada una de los grupos de edificaciones evaluadas: pérdida anual promedio, curva de excedencia de pérdidas y pérdida máxima probable. Los datos aportados por el estudio pueden ser usados por los tomadores de decisiones para la gestión del riesgo sísmico de Managua. Basados en ellos pueden ser diseñados instrumentos de transferencia de riesgo, se pueden realizar evaluaciones de relaciones probabilistas de beneficio-costo de reforzamiento de estructuras. Por otro lado también pueden servir en la planeación de la ciudad y en los planes de emergencia ante terremotos.

O092 Tectonic geomorphology and paleoseismology of the Gatún fault in Central Panamá

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The Gatún fault, a primary east-west structural feature in central Panamá, has a strong geomorphic signature that can be readily observed in aerial photographs and digital elevation models. The fault forms an abrupt southern margin to the Sierra Maestra Mountains, and all rivers and streams that cross the fault are affected at the fault crossing. Most large rivers are left-laterally deflected, and all streams that cross the fault have a 1- to 2-meter, and locally as high as 5-meter near-vertical knickpoint at or immediately upstream of the fault. Paleoseismic trenching of the Gatún fault east of Gatún Lake has shown that this fault has experienced at least two, and possibly three, surface-rupturing earthquakes since 1490 AD. Based on 3-D trenching of an ~3 ka channel thalweg that is offset 19-20 m, the left-lateral slip rate on the Gatún fault is 6-9 mm/yr with a maximum of 20% north-side up normal slip, and the most recent earthquake in the mid-late 1800s generated at least 0.7+0.2 meters of left-lateral surface offset that apparently went unnoticed at the time. Our best estimate is that this 40 km segment of the Gatún fault has a recurrence interval of ~M6.8 earthquakes every 110-170 years based on the last three events, but if the fault is capable of multi-segment, less-frequent ruptures, the earthquakes could potentially be as large as M7.4 if the entire 120 km fault were to rupture. We suspect, but cannot prove, that triggered slip resulted in soil fracturing on the Gatún fault during the 1991 M7.6 earthquake on the North Panamá Deformed Belt off the Caribbean coast of eastern Costa Rica. These findings are important for the seismic stability analysis of the AD 1913 Gatún Dam across the Chagres River, one of the most critical structures in the Panamá Canal.

O093 First structural characterization of the Azuero-Sona Fault Zone

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This work presents the first structural characterization of the Azuero-Sona fault zone with ground mapping and microstructural analyses. Of the three samples analyzed in laboratory, one may correspond to a pseudotachylite and the other two to phyllonites. The protolith of these rocks are a basalt and a mafic lava flow with vesicles and blocks. The thin sections analyzed show a dextral shear sense, which once translated to the original foliation plane where the sample was taken, indicates a normal displacement. A folded sequence of carbonates within the fault zone has an average fold axial plane dipping 22 degrees towards the southwest. The shear zone is at the zeolite metamorphic facies. A strain determination was performed for the volcanic vesicles present in the phyllonite. The orientation of the maximum elongation axis has an azimuth of 196 degrees and a plunge of 44 degrees. In thin section the rocks only register one event of deformation. However, field cross-cutting relationships suggest two events, first ductile shearing and then a brittle event. If pseudotachylites are indeed present, it may indicate the record of large earthquakes.

O094 Use of electromagnetic geophysical methods for detecting neotectonic structures in the Azuero Peninsula, Panama

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The Azuero Soná Fault Zone (ASFZ) is a sinistral strike slip fault, extending from southeast to northwest in the Azuero and Sona peninsulas (Panama). Both geomorphological and GPS measurements suggest that this fault is an active fault.
Three recent sedimentary deposits in the peninsula were located along the fault trace: Playa Malena, Sapotal and Quebro Rivers. All three locations were surveyed with ground penetrating radar (GPR) and resistivity survey methods during the field season of June, 2015. In all locations the ground was composed of Quaternary sequences of gravels and muds as part of alluvial terraces. 26 surveys totaling 1500 meters were performed perpendicular to the fault's main strike with the GPR and 100 m with resistivity, which led to vertical profiles showing the subsurface.
The GPR profiles at Quebro River location showed vertical discontinuities in the otherwise horizontal bedding, while the resistivity method showed vertical discontinuities at both Quebro and Sapotal River locations. The younger terraces of the Quebro River show that both upper and lower layers are displaced vertically by a fault. GPR profiles at the older terrace of Quebro River show a fault that cuts the lower layers only, while a second fault (younger) cuts both lower and upper layers. These ruptures and discontinuities in the fluvial stratigraphy of the Quebro River terraces are interpreted here as a result of neotectonic activity along the Azuero fault. No concluding evidence was found in Playa Malena locality.

ABSTRACTS

O096 The Navarro Fault System: left-lateral displacements along the Central Costa Rica deformed belt

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In this study, the Navarro fault system is identified based on geologic, geomorphologic, and seismological observations as one of the main left-lateral strike-slip faults of the Central Costa Rica Deformed Belt. This fault system is located between the northern slopes of the Talamanca cordillera and the southern and southeastern slopes of the Irazu and Turrialba volcanoes. The Navarro fault system trends between east-west and northeast-southwest and includes the following fault segments: Tarrazu, Navarro, Cachi, Urasca, Paraiso, and Maravilla. There are two transtensional structures along the fault system: the step over Estrella and the Ujarras tectonic depression. Two damaging historical earthquakes might be related to the Navarro fault system: the Paraíso earthquake of August 22, 1951 (5.4 Ms) and Frailes earthquake of August 9, 1991 (Mw 5.2). Earthquakes occurred during 1973-2015 were relocated illuminating the fault segments of the southwest portion of the system. The focal mechanisms calculated mainly correspond to strike-slip faults in agreement with morphotectonic observations. The Navarro fault system represents an important seismic hazard for the infrastructure and population of Central Costa Rica.

O097 Morfotectonic and seismotectonic evidences of a large seismic source near San Salvador: The Guaycume Fault

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From the analysis of the geological map, neotectonic field observations and morphotectonic analysis of aerial photography, digital elevation models, and fluvial network geometry, we have identified the existence of an active fault poorly known so far. Such a tectonic feature, referred as Guaycume fault, is located just 15 km north of San Salvador.
The Guaycume fault is divided into two segments, a western segment 10 km long composed of several parallel faults that distribute the deformation. The eastern segment, separated from the western one by the Cerro del Ojo del Agua, is characterized by a main fault plane with a sharp fault escarpment of 20 Km in length. The analysis of large offsets affecting the river network leads us to calculate a horizontal accumulated displacement of 1750 ± 50 m, and an average vertical displacement of 80 ± 5 m. Using the ages of geological formations on which the network is developed we calculate an average minimum slip rate of 1.08 ± 0.2 mm/yr. This value is significantly lower than the slip rate obtained from geodetic GNSS data probably due to the high uncertainty of the age of the fluvial network.
We have revisited the available information regarding the damage distribution generated by the 1917 seismic crisis. We have re-evaluated the spatial distribution of damage. We conclude that Guaycume fault could be the source responsible for the 8 June 1917 Mw 6.4 earthquake, one of the most destructive in the history of San Salvador. We have developed a simulated seismic scenario considering a seismic rupture of the complete Guaycume fault with a Mw 6.8 earthquake. For an event of Mw 6.8 on Guaycume fault, accelerations exceeding 0.6 g are obtained in the region nearest to the source, and greater than 0.2 g in the northern part of San Salvador.

ABSTRACTS

O098 The nascent Caño Negro dextral fault system of northern Costa Rica and its relation to NW motion of western Costa Rica

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Analyses of digital elevation data, GPS velocities, earthquake focal mechanisms and geomorphology suggest the existence of an immature fault system in northern Costa Rica. The Caño Negro fault system consists of a series of likely active, northwest-striking dextral slip faults, extending more than 130 km along northwestern Costa Rica and southwestern Nicaragua. The fault system includes the Haciendas and Caño Negro dextral faults. A right step between the Haciendas and Caño Negro faults defined the Cuatro Bocas pull-apart. The faults show typical strike-slip tectonic landforms including m-to km-scale river deviations. To the south, the Caño Negro fault likely links with the Chiripa fault and with faults of the Central Costa Rica Deformed Belt (CCRDB) including the Esparza and the Atirro-Rio Sucio dextral faults. To the north, the Haciendas fault disappears at Nicaragua Lake and may be a conjugate to the sinistral fault that accommodated earthquakes of August 3, 2005 (Mw 6.3 and Mw 5.3). We suggest that the Caño Negro fault system may accommodate differential velocity suggested by GPS data across western Costa Rica. Although escape of the Central American forearc sliver may stem from collision of the Cocos ridge with southern Costa Rica, the nature of the boundaries of the sliver remain elusive. The Caño Negro fault may be the easternmost extension of a young fault system that defines the margin of the sliver. The relation between this system of dextral strike slip faults and the NE-trending CCRDB remains an important question. Recent plate reconstructions provide constraints on possible drivers of forearc motion and on the timing of faults that might be required to accommodate forearc translation.
Unraveling the geometry and kinematics of such structures will complement additional geodetic work.

O099 Megathrust earthquakes and coastal uplift at the Nicoya Peninsula, Costa Rica

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The Nicoya Peninsula, Costa Rica forms a prominent morphologic high along the Middle America forearc. This emergent coastal landmass overlies the megathrust along a seismogenic zone that produces frequent major earthquakes. Quaternary marine and fluvial terraces record a net uplift pattern consistent with the peninsula's overall topographic form. Terrace mapping, surveying, and geochronology (14C, OSL, TCN) reveal uplift variations that coincide with three domains of subducting seafloor (EPR, CNS-1, CNS-2), with uplift rates of 0.1-0.2 m/ky inboard of older EPR crust in the north, 0.2-0.5 m/ky inboard of younger CNS-1 crust along the central coast, and 1.5-2.5 m/ky inboard of CNS-2 seamounts impacting the peninsula's southern tip. GIS digital terrain analyses show a deformation pattern consistent with field geomorphic and geologic observations. The two most recent large Nicoya earthquakes (1950 Mw7.8; 2012 Mw7.6) generated decimeter-scale coseismic uplift along the central coast. The 2012 uplift pattern coincides with the area of mainshock slip, pre-event locking, and prior 1950 coseismic uplift. Most of the 1950 uplift was recovered by interseismic subsidence during six decades of strain accumulation leading to the 2012 rupture. Paleoseismic sediment coring in Nicoya coastal wetlands reveals fragmentary stratigraphic evidence consistent with earlier Holocene seismic-cycle land level changes. While elastic strain accumulation and release produce short-term cycles of uplift and subsidence, long-term net uplift results in gradual coastal emergence and the growth of topographic relief. Net uplift along the central Nicoya segment may be the product of irrecoverable seismic-cycle strain (shortening), coupled with tectonic erosion near the trench and subsequent underplating of eroded material at depth beneath the peninsula. Our results are consistent with geophysical observations that indicate along-strike segmentation of the Nicoya seismogenic zone and the presence of three principal earthquake source areas: 1) Papagayo (1916, M>7.0), 2) Nicoya (1950, Mw7.8; 2012 Mw7.6), and 3) Cobano (1990 Mw7.3).

ABSTRACTS

O100 Cocos Ridge indenter provides a regional understanding for the seismic hazard of the North Panama Deformed Belt, Caribbean coast, Costa Rica

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As part of a Probabilistic Seismic Hazard Assessment (PSHA) for a new harbor development, we were able to quantitatively investigate the paleoseismic history of the western North Panama Deformed Belt (NPDB) because that history is expressed as a suite of coseismically uplifted coral platforms on the Caribbean coast of Costa Rica, between Moín and Limón. The NPDB is an 800-km long offshore thrust fault zone that runs westward from Colombia, along the northern coast of Panama, before stepping ashore at Moín, Costa Rica on the left-lateral Río Blanco tear fault, where it continues west as the Siquirres-Matina reverse fault. We interpreted and dated as many as 12 earthquake events spanning the last 7000 years, including the AD 1991 and 1822 events. The NPDB is accommodating incipient subduction of the Caribbean plate under the Panama microplate. In the project area, the NPDB is accommodating backarc thrusting of the northeast-directed 72 - 90 mm/yr subduction of the Cocos Plate under eastern Costa Rica. The Cocos Ridge, a NE-trending seamount chain on the subducting plate, is impacting the isthmus as an indenter, resulting in the transfer of ~7 mm/yr northward into the crust because of the ridge's difficulty in subducting. At Limón, we determined that 3.8 ± 0.3 mm/yr of this convergence slip is occurring on the NPDB, as measured from the 1.9 ± 0.2 mm/yr uplift rate of the coral platforms. Numerous crustal faults onshore may be accommodating the residual strain of ~3 mm/yr; assigning this differential to a regional strain field simplifies the PSHA calculations without having to define fault-specific slip rates. Thus, an understanding of the regional context of tectonic deformation can provide valuable constraints on otherwise unconstrained seismic hazard models and rates.

O101 Ecological changes and overwash events at three coastal ponds of St. Thomas, U.S. Virgin Islands

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Six overwash deposits record atypical events in pond-bottom sediments along the northeast and south coast of St. Thomas, USVI. Amongst three ponds - Cabrita, Smith, and Perseverance, sand and shell deposits correlate with the A.D. 1867 tsunami event that originated in the Anegada Passage and the A.D. 1650-1800 and A.D. 1200-1450 tsunami events previously recognized on Anegada, BVI. In addition, we discovered three older events, two between B.C. 450 - A.D. 1150 and another before B.C. 2900. Two events between B.C. 450 - A.D. 1150 were recorded at all three ponds; whereas, the event before B.C. 2900 was only observed at Cabrita Pond at the northeast end of the island where there is a longer sediment record. Pond-bottom sediment was obtained by piston-coring along transects roughly perpendicular to the shoreline. Cores were logged using a GEOTEK multi-sensor core logger (MSCL) and an XYZ point sensor, split, scanned and described. Representative units were analyzed with a grain-size analyzer and organic material was sampled for AMS 14C dating. Criteria used to identify tsunami deposits include mixed composition of sediment derived from multiple environments of deposition; presence of broken shells, microbial mats fragments, mixed or disturbed sediment, and substantial change in environment of deposition. The present study: 1) recognizes a greater geographic impact of the A.D. 1650-1800 and A.D. 1200-1450 inferred tsunamis from Anegada southwest to the island of St. Thomas; 2) describes an overwash deposit related to the A.D. 1867 tsunami; and 3) identifies three older inferred tsunami overwash events, increasing the tsunami record in the region to B.C. 3000. Additional study is planned to improve age estimates of the prehistoric tsunami deposits and to further map the geographic distribution of tsunami deposits to better understand the earthquake potential of offshore faults.

O102 The Elusive Santa Monica - Hollywood fault zone of Southern California

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The Santa Monica and Hollywood faults form the southern boundary to the Santa Monica Mountains, and from west to east, extend through the cities of Santa Monica, Beverly Hills, West Hollywood and the Hollywood area of Los Angeles. The faults were first inferred in the 1920s, and typically mapped as buried under the alluvial fan sediments that have eroded off the mountains. In the early 1990s, researchers conducted a detailed geomorphic analysis of the region and strongly suggested that the faults have moved in the Holocene, and are thus active by California definitions. Subsequent studies by the same researchers reportedly exposed active fault traces, or secondary active elements of these faults, in large-diameter bucket augers and trenches, respectively. More recently, partly in response to "Not In My Backyard" outcries from parties opposed to new development in these cities, the California Geological Survey zoned the Hollywood fault.
Geological studies designed to locate the fault must now be conducted for any property that is to be developed or re-developed within the zone of required investigation. As a result, several new investigations have been conducted in the area by various geological consulting firms. These studies have consisted of borehole and cone penetration test transects drilled approximately perpendicular to the inferred strike of the fault, with trenching where possible. To date, none of these studies have exposed an active trace of the fault putting into question the activity of this fault system. This presentation will summarize the most recent available information on these faults, and will discuss the methods used to evaluate faults in a highly urban environment.

O103 Spatial variation of the postseismic seafloor displacements associated with the 2011 Tohoku-oki earthquake (M9.0) based on repeated GPS/Acoustic observations

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Postseismic deformation associated with the 2011 Tohoku-oki earthquake (M9.0) has been occurring, and it is detected by means of terrestrial and seafloor geodetic observations. Significant landward movements on the seafloor above the main coseismic rupture area (MCRA) are mainly accounted for by the viscoelastic relaxation, while trechward movements in the north and south to the MCRA may be caused by the afterslip on the subducting plate interface. However, we can not grasp entire spatial pattern of the postseismic deformation near the Japan Trench, because seafloor observation network were not dense enough. Therefore, we have performed GPS/acoustic (GPS/A) observation at 20 stations near the Japan Trench since 2012 [Kido et al., 2015, IAGS]. We estimated a horizontal seafloor displacement rate at each site with the estimation error of the rates is averagely ~3 cm/yr. The calculated displacement rates at the sites south to the MCRA (36~37°N) show high trenchward displacement rates (5~15 cm/year), which can be interpreted as the effect of afterslip. Moreover, we also found out that highest trenchward movement have been occurring off Fukushima Prefecture near the trench. High landward displacement rates (~10 cm/year) are observed above the MCRA, which strongly support the occurrence of the viscoelastic relaxation, but some stations nearest to the trench show lower landward displacement rates (~7 cm/year). In north of 39.5°N, the observation sites show low landward displacement rates (~5 cm/year). Comparing the observation with the model of Sun et al. [2014] suggests that additional coseismic slip in the northern MCRA (39~39.5°N) near the trench and aseismic fault slip and/or the revision of the viscoelastic structure in the area nearest to the trench above MCRA are necessary. Our GPS/A observation results revealed overall spatial characteristics of the postseismic deformation of the Tohoku-oki earthquake and suggest re-examination of the viscoelastic relaxation model.

O104 Unlocking controls on earthquake behavior along the subduction megathrust: Findings from the Nicoya Seismic Cycle Observatory

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Unlike most subduction environments that exist mostly or entirely offshore, the Nicoya Peninsula's location in Costa Rica allows for unique land-based observations of the entire down-dip extent of coupling and failure along the seismogenic megathrust. Because of this geometry and approximately 50-year repeat cycle of mid-magnitude 7 earthquakes here, numerous geophysical studies have taken place. Most notably of these are the dense seismic and GPS networks cooperatively operated by UC Santa Cruz, Georgia Tech, U. South Florida, and OVSICORI, collectively called the Nicoya Seismic Cycle Observatory (NSCO). The megathrust environment below Nicoya is notable, additionally for strong along-strike transitions in oceanic crust origin and geometries, including massive subducted seamounts, and a substantial crustal suture well documented in recent work by Kyriakopoulos et al. [JGR, 2015].
Using GPS data collected from campaign and continuous sites going back approximately 20 years, a number of studies have imaged components of the seismic cycle, including late-interseismic coupling, frequent slow-slip events, coseismic rupture of a moment magnitude 7.6 earthquake in 2012, and early postseismic response. The derived images of interface locking and slip behavior published for each of these episodes use different model geometries, different weighting schemes, and modeling algorithms limiting their use for fully characterizing the transitions between zones. Here, we report the first unified analysis of the full continuum of slip using the new locally defined 3D plate interface model. We focus on evaluating how transitions in plate geometry control observed locking and slip, and quantifying how well pre-seismic images of megathrust locking and slow-slip events dictate coseismic and postseismic behavior.
Without the long-term and continuous geodetic observations made by the NSCO, this work would not have been possible.

O105 Postseismic deformation following the 2012 Mw 7.6 Nicoya Earthquake: What can we learn from a dense geodetic and seismic network directly above an active megathrust

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When studying subduction zone deformation one is often forced to consider a region significantly landward of the trench. The Nicoya Peninsula in Costa Rica presents a unique environment to obtain rich datasets from land in close proximity to an active megathrust. A recent moment magnitude (Mw) 7.6 earthquake in September 2012 on this portion of the Middle America Trench affords an opportunity to constrain ongoing postseismic deformation on the subduction interface between the Cocos and Caribbean plates.

GPS campaigns occupying 22 sites were undertaken immediately following the earthquake in September-December 2012 with subsequent measurements taken in 2015 and 2016. Combined with data from 17 continuous GPS in the region, we analyze the spatial and temporal changes in the postseismic displacement field. Another campaign is planned for 2017, which may directly measure the early relocking signal. Between 2012-2015, campaign GPS results indicate significant trenchward motion of at least 6 cm, relative to a fixed Caribbean plate, for all sites up to the volcanic chain. Maximum values of 21 cm are observed above and updip of the coseismic rupture zone. Our preliminary, elastic slip inversion using a smoothed, 2D geometry indicates up to 175 cm of well-resolved postseismic motion on the subduction interface over the first 2.5 years since the earthquake. The majority of the slip locates within three patches updip and downdip of the region of strongest coiseismic rupture, including a zone which was identified as strongly-coupled prior to the 2012 rupture. A fourth patch of slip is colocated with an inferred 2012 slow slip event, and possibly exhibits significant margin-parallel motion.
We will report on these results and initial findings of our 2016 fieldwork. Postseismic slip measurements will be compared against independent estimates of afterslip, obtained using repeating earthquakes recorded by 26 seismic stations on and around the Nicoya Peninsula.

O106 The 2012 M7.6 Nicoya Peninsula, Costa Rica, earthquake sequence: Source scaling and energy budget

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Due to the advantageous location of the Nicoya Peninsula in northwestern Costa Rica, extending seaward over the seismogenic zone where the Cocos plate subducts underneath the Caribbean plate at a rate of ~85 mm/yr, regional broadband seismic stations provide unusually good coverage of megathrust activity. The September 5, 2012 MW7.6 Nicoya plate boundary thrust earthquake was followed by thousands of aftershocks located in four clusters distributed along strike. We estimate source parameters and earthquake focal mechanisms for more than 300 events. We perform regional full waveform moment tensor inversions for all of aftershocks with Mw > 3.5 located along the plate interface. For smaller events, we use P wave first motion polarities to estimate faulting geometries. We analyse scaling relationships of the source parameters, energy budget and self-similarity of the earthquake source spectra for the four clusters of aftershocks. We correct spectra of larger events for attenuation using the empirical Green's function (EGF) method and define criteria for selection of EGF earthquake pairs and for the evaluation of the obtained EGF spectral ratio.

O107 Evolution of the Galapagos Hotspot from Oceanic Plateau to Seamounts: Evidence from Azuero, Panamá

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Two different terrains have been suggested for the geology of the Azuero Peninsula. A terrain that comprises an uplifted part of the Caribbean Oceanic Plateau (i.e COP) overlaid by sedimentary and arc sequences, and a younger accreted terrain composed by fragments of seamounts. These terrains are divided by the Azuero-Soná Fault Zone (ASFZ) that represents the major structural element of the area. However, recent studies to the southwest of the ASFZ show volcano-sedimentary sequences and intrusive bodies with different petrographic features (basalts, gabbros, breccia, cherts and limestones) and field relations in comparison with the rest of the accretionary complex. The Ocú Formation and some intrusive bodies found in the study area suggest that the ASFZ does not separate the terrains proposed for the Azuero geology. Moreover, this rock association could be considered as a fragment of the forearc due to its composition and mineralogy. Some magmatic rocks are coarse grained (ca. 2-4 mm) and have equigranular olivine + clinopyroxene + orthopyroxene ± plagioclase grains that show different rock textures from the previously reported picritic basalts in the study area. Additionally, mineral analysis of these volcanic rocks reveals high Mg-rich minerals (i.e. #Mg>80) such as forsterite and pyroxenes, Ca-rich plagioclase (Xan=0.55-0.70) and refractory Cr-spinel (i.e. #Cr=0.56-0.72), ilmenite and magnetite. These minerals suggest a mantle genesis for the melt. We propose according to petrological features and field relations of the study area that these sequences could represent a middle step between the COP and the accreted seamounts in Azuero from the Galapagos Hotspot. This step is important because it could increase the knowledge about the subduction initiation process in the southern part of the Caribbean Plate and the evolution of mantle plumes such as the Galapagos Hotspot.

O108 Bouguer Anomaly Model from Western Azuero Peninsula, Panamá

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The Azuero peninsula, located on the southern part of Panamá has a complex geological history dominated by oceanic floor subduction and accretion of seamounts from Galapagos. The peninsula has three tectonic boundaries, with the Azuero-Soná regional fault as major structure that separates the main lithologies, Cenozoic sediments and limestones, Late Creataceous carbonates, and igneous rocks and intrusions with ultramafic, mafic and intermediate compositions.
In 2014, a gravimetric survey was made along the western side of the Azuero peninsula, along with a geologic map with 1:25000 scale. The survey had 142 stations with gravity reading and exact coordinates and elevation.

During the first semester of 2015 reductions for drift, tides and elevation were made on the acquired data; also the selection of relevant samples and the measurement of their density, in order to create a final model that resemble a schematic cross-section on the geologic map which shows the different lithologies mention before. The Azuero-Soná fault zone divides the model created, and within it, all the lithologies are represented by blocks or polygons and it presents three main boundaries. Each side of fault zone suggested by the geologic map (made on the field) has different gravity affinity. The model creates a hypothesis of the implications of this difference in the geology of the peninsula, and it defines a new main structure creating the change in signatures.

O109 Is Loma Iguana (Azuero Peninsula, Panama) a global example of transition from intraplate to arc-related magmatism?

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In the region of Loma Iguana (NW Azuero Peninsula, Panama), there are important stratigraphic groups that correspond to an apparently continuous volcanism, which covers sequences formed in three different environments: Plateau (Caribbean Large Igneous Province-CLIP), Proto-arc and Volcanic arc, representing a change from intraplate to arc-related magmatism; however, the differentiation between these units is poor and their relationship with a tectonic setting is unclear. In this work we performed a geochemical characterization of the volcanic rocks in the region in order to determine how the transition from plateau to volcanic arc was, and thus associate these rocks with a tectono-magmatic framework.
The volcanic sequences in our study zone correspond to subalkaline basalts/andesitic basalts, as indicate by the major element compositions. However, the trace geochemical signatures (REE and spider normalized diagrams) are not characteristic of volcanic arcs and show MORB affinity (flat patterns in the geochemical signatures), with depletion in Nb and enrichment in Ba, which disagrees with previous descriptions in the area. According with the geochemical data, we suggest that this sequence could correspond to the Proto-Arc group, which could be part or locate close to the arc root, and could be interpreted as the volcanism at the early stages of subduction.

O110 Rupture process of the 2012 Nicoya earthquake inferred from interseismic locking distributions

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Interseismic locking distributions derived from geodetic observations in subduction zones are often used to qualitatively evaluate the potential for future megathrust earthquakes. Due to the long recurrence intervals between large earthquakes, it is inherently difficult to perform direct quantitative field evaluations of locking and eventual coseismic slip. Here we report our quantitative estimates of coseismic slip of the 2012 Mw7.6 Nicoya earthquake from the interseismic locking distributions using numerical simulations of dynamic ruptures. We first set up a planar subduction fault embedded within a homogeneous three dimensional domain. We then compute static stress drop, assuming that the total slip deficit since last characteristic megathrust event in 1950 will be released in the 2012 earthquake. By assuming a uniform strength and dynamic friction coefficient on the fault, we can estimate the initial stress distribution. Next we perform spontaneous rupture simulations under the framework of a linear slip-weakening law. The rupture nucleates at the epicenter of the 2012 earthquake and then extends over the entire locked patch if the entire fault has identical strength and the characteristic slip distance (Dc). We have also set the nucleation zone at different positions and find that the final coseismic slip and seismic moment are generally consistent with the geodetic locking distributions and seismic observations, regardless of epicenter locations. However, in all preliminary scenarios the entire locked patch will be ruptured if the fault has uniform strength and Dc. Since the 2012 event only ruptured approximately half of the locked patch, our numerical results indicate that the frictional strength and/or the characteristic slip distance on the fault are heterogeneous on the subduction fault, in addition to the non-uniform initial stress. The results can not only validate frictional parameters on subduction faults, but also present a framework to quantitatively link interseismic locking with eventual coseismic slip.

O111 SKS and Local S-Wave splitting evidence for sub-slab mantle flow in northwestern South America subduction zones

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In order to investigate the subduction dynamics between the South America continent and the oceanic Nazca and Caribbean plates, we measured SKS and slab-related local S splitting at 38 seismic stations. Comparison between the delay times of both phases shows that most of the SKS splitting is due to entrained mantle flow beneath the subducting Nazca and Caribbean slabs. On the other hand, the fast polarizations of local S-waves are consistently aligned with regional faults, which implies the existence of a lithosphere-confined anisotropy, and that the mantle wedge is not contributing significantly to the splitting. Also, we identified a clear change in SKS fast directions at the trace of the Caldas tear (~5°N), which represents a variation in the subduction style. To the north of ~5°N fast directions are consistently parallel to the flat subduction of the Caribbean plate-Panama arc beneath South America; while to the south fast polarizations are subparallel to the Nazca-South America subduction dip direction. Our results support the idea of Caribbean subduction beneath northwestern Colombia, a hotly debated topic in recent years. Fast directions south of the Caldas tear are subparallel to the direction of Nazca-South America convergence. A new change in the SKS splitting pattern is detected at ~2.8°N, which is related to another variation in the subduction geometry marked by the presence of a lithosphere-scale tearing structure, named here as Malpelo tear; in this region, NE-SW-oriented SKS fast directions are consistent with the general dip direction of the underthrusting of the Carnegie Ridge beneath South America. Further inland, this NE-SW-trending mantle flow continues beneath the Eastern Cordillera of Colombia and Merida Andes of Venezuela. Finally, our results suggest that the sub-slab mantle flow in northwestern South America is strongly controlled by the presence of lithospheric tearing structures

ABSTRACTS

O112 Forearc survival and the upper limit of the seismogenic zone

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What presents as an evident visual correlation between the morphology of the a chewed-up foreacr and the seismicity pattern, off the west coast of Costa Rica, could have very important implications in the understanding of what controls the upper limit of seismogenesis along subduction zones. Areas of the plate interface beneath scars and cannons on the slope, along the southern terminus of the Middle America Trench, left by the subduction of small seamounts (5-40 km wide), are lacking of interplate seismicity. The few earthquakes that plot under these features are all ourter rise events. Deposits that fill the space left after the seamount is subducted are too weak to deform elastically. Thus, the upper limit of the seismogenic zone correlates very well with depth contours along the slope of the forearc. Where larger and parallel ocean floor bathymetric highs subduct, the uplift they induce of the forearc, produces decoupling of the megathrust in the region between them, reducing the potential for the genesis of large earthquakes and even microseismicity. We will show several examples of these conditions using over 30 years of continuous seismicity recorded by the Costa Rica Volcanological and Seismological Observatrory at the National University.

O115 Subduction zone science – seismological view of Nazca-South American Convergent Margin – new results and ongoing questions

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The subduction of the Nazca plate beneath the South America plate constitutes the largest present day ocean-continent convergent margin system and has built the Andes, one of the largest actively growing mountain ranges on Earth. This active margin is characterized by along-strike variations in arc magmatism, upper crustal shortening, crustal thickness, and slab geometry that make it an ideal region to study the relationship between the subducting slab, the mantle wedge, and the overriding plate. After 20 years of portable seismic deployments in the Central Andes seismologists have combined data sets and used multiple techniques to generate seismic images spanning ~3000 km of the South American subduction zone to ~900 km depth with unprecedented resolution. For example, using teleseismic P- waves we have imaged the Nazca slab penetrating through the mantle transition zone (MTZ) and into the uppermost lower mantle. Our tomographic images show that there is significant along-strike variation in the morphology of the Nazca slab in the upper mantle, MTZ, and the lower mantle, including tears, folding, and internal deformation. Receiver function studies and surface wave tomography have revealed major changes in lithospheric properties in the Andes. Improved seismic images allow us to more completely evaluate the role of many tectonic processes in the formation and uplift of the Andes including: (1) overthickened continental crust, (2) changes in slab dip and coupling with the overlying plate (3) localized lithospheric foundering, and (4) large-scale mantle and crustal melting leading to magmatic addition and/or crustal flow. Although we have made significant progress in understanding subduction there are many processes for which we need improved data of all types (ie. the role of fluids and mantle convection). For a transformative improvement in our understanding of subduction zones and upper plate processes we need an interdisciplinary, collaborative approach.

O116 Rupture process of the 2015 Mw 8.3 Illapel, Chile earthquake constrained by strong-motion, high-rate GPS and teleseismic data

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On 16 September 2015, a magnitude Mw 8.3 interplate thrust earthquake occurred in Illapel, a region in central Chile that covered by dense seismological and geodetic instruments. The abundant datasets near and around the rupture zone provide a unique opportunity to study the detailed source process of this megathrust earthquake. We investigated the spatial and temporal distributions of the mainshock rupture slip by a joint inversion of teleseismic records, GPS offsets and strong motion data. Our optimized model shows that the primary slip zone is located in the north of the hypocenter with a maximum slip of ~ 6.0 m, and the rupture scale extends ~150 km along strike and ~120 km along dip. Considering the strain accumulation, this Illapel earthquake released the most strain that accumulated in the region since the 1943 M8.3 event. The total seismic moment is 2.6×10^{21} N·m, equivalents to Mw 8.3. Most seismic moment was released within 160 s. The rupture propagated in main slip asperity with a velocity of ~2.0 km/s, which is relatively slower than ordinary thrust event, thus it is one of the reason that caused the strong tsunami in the Pacific Ocean. We also find that the aftershocks distributions have a clear complementary distribution with the co-seismic rupture pattern, aftershock clusters are found at the edge of unbroken barriers, and regions of rapid transition from high to low slip within the main fault area.

O117 The 2014 Iquique, Chile earthquake sequence: Correlation between b-value and interseismic coupling

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On the 1st of April 2014, a Mw=8.2 tsunamigenic megathrust earthquake struck the coast of North Chile, causing six fatalities, vast material damages, and prompting the preventive evacuation of around one million people along the coastal area of North and Central Chile. The earthquake nucleated at the center of a well known seismic gap existent since 1877. In this paper we use a published high-quality catalog of seismicity preceding the mainshock (Schurr et al., 2014) and a geodetic interseismic locking model (Metois et al. 2013) to compute b-value variations prior to the earthquake and establish possible correlations with the mapped interseismic locking. We found that the overall b-value tends to decrease within the future rupture area prior to the earthquake as the mainshock day approaches. Also, an inverse correlation (R = -0.6) is observed when comparing b-value and interseismic locking, with areas of low b-value related to areas of high interseismic locking and vice versa. Using a linear regression we modeled the relationship between b-value and geodetic coupling values, and then used the obtained curve to forward model an interseismic coupling map using as input our b-values dataset. We found that the map of seismically obtained coupling greatly resembles the geodetically-obtained locking map.
Our results highlight the convenience of using b-value as a 'stressmeter' capable of mapping zones of increased interseismic coupling with potential for future large ruptures. The use of seismic data and b-values as a proxy for interseismic locking represents an advantage in comparison with land-based geodetic methods that can be difficult to carry out in areas with difficult or none land access (such as the offshore area of subdution zones). In addition, fewer modeling assumptions are taken into account in the computation of b-values in comparison with geodetic methods which can also suffer of excessive smoothing.

O118 Water Release from Cold Serpentinized Forearc Mantle During Subduction Associated with Warming Changes in Incoming Oceanic Plate Thermal Structure and Plate Boundary Kinematics: New Insights into Non-Volcanic Tremor (NVT)

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Kirby, Wang, and Brocher (Earth Planets and Space, 2014) show how the change in kinematics of the California margin from subduction motion to continental transform motion with the birth and growth of the San Andreas Fault System (SAFS) beginning at about 33 Ma BP likely led to a warming of the former forearc mantle and the release of water from serpentinized mantle by dehydration and a likely increase in fluid pressures along the SAFS. Such a mantle sources of pressurized water gives insights into both the low sliding resistance for the SAFS and the mobilization and ascent of some serpentinized mantle peridotites through the crust. Thermal modeling by others has also shown that changes in the incoming plate age and subduction rate can also lead to warming of the forearc mantle during subduction and subsequent water release. Recent mineralogical and geochemical observations of serpentinite blocks in serpentinize mélange bodies in the San Francisco Bay Area (Uno and Kirby, 2015; Lewis and Kirby, AGU 2015) suggest that these rocks sustained multiple stages of serpentinization that are broadly consistent with this model.
A recent paper by McCrory, Hyndman and Blair (GGG, 2014) suggest that NVT in Cascadia and other subduction systems tends to occur along the inter-plate thrust boundary just up dip of serpentinized forearc mantle during the subduction of lithosphere of Tertiary age. Kirby (AGU Abstract, 2015) argues that subduction systems heat up and dewater under certain subduction inputs or changes in interplate kinematics, such as when spreading centers approach trenches, a condition that applies to much of the Pacific margins of the Americas. Such a rapid flux of water up dip of warming serpentized forearc mantle may lead to high fluid pressures and low effective normal stresses, low friction, and NRT as a means of accommodating interplate motions.

O119 Rupture parameters for the 16 September 2015, Illapel, Chile Mw 8.3 earthquake from modeling of seismic and tsunami waves

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On 16 September 2015, a great (Mw 8.3) interplate thrust earthquake ruptured offshore Illapel, Chile, producing a 4.7 m local tsunami. The last great rupture in the region was a 1943 Mw ~8.1 event. The source moment tensor was obtained robustly by W-phase inversion. Short-period teleseismic P wave back-projections indicate generally northward rupture expansion from the hypocenter at a modest rupture expansion velocity of 1.5-2.0 km/s. Finite-fault inversions of teleseismic P and SH waves using that range of rupture velocities and a range of dips from 16° to 22°, consistent with long-period moment tensor inversions, indicate a 180 to 240 km bilateral along-strike rupture zone with larger slip northwest to north of the epicenter (with peak slip of 7-10 m). Iterative modeling of tsunami recordings from DART stations and tide gauge stations establish that very little slip occurred to the south, so the rupture is located primarily offshore, extending to the trench with up to 10 m slip, with a smaller amount of slip below the coast. The total source duration is about 94 s. The seismic moment estimate is about 2.6 ×10^21 Nm, the static stress drop estimates range from 3.1-3.2 MPa, and the radiated seismic energy, up to 1 Hz, is about 2.8 × 10^16 J. Aftershocks surround the peak slip zone and extend to the south where little if any coseismic slip occurred.

O120 Chile´s ever changing shape

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Faults generate earthquakes and produce significant deformations around them. With the emergence of GNSS positioning technology it is now possible the detection and accurate determination of small horizontal changes.
Chile presents a high productivity rate of large earthquakes and hosts some of the largest earthquakes recorded worldwide therefore it is an ideal laboratory to observe these changes. The oldest historical reports of coastal elevation changes associated with subduction earthquakes date from 1822. We analyze the inter-seismic as well as several co-seismic observed changes within the Nazca-facing portion of Chile. These changes reveal an average contraction of the order of 26 mm/yr of the western portion of the South American continent. This amounts to 8.4 ha of yearly decrease of the area of the continent that lies above sea level. With each earthquake, the area of the continent is augmented according to Log A = -9.59 + 1.32*MW, where A is in hectares and Mw is moment magnitude.
Regarding vertical changes, according to the observed co-seismic coastal elevation changes and the location of the "zero-crossing" axis, we can forecast whether the coast will be subjected to uplift or subsidence at the time of a large earthquake. Our estimation is that most of the coast within 21°-35°S will be subjected to uplift with the possible exception of the coastal areas around 25°S and 30°S. Uplift is also forecasted for the coastal segment around Arauco Peninsula (37°S-38°S) and the islands of Guafo and Guamblin at 43.5°S and 45°S, respectively. The model forecasts that the coastal elevation changes in other places of Chile should be very close to zero or present subsidence at the time of large earthquakes. Larger amounts of co-seismic subsidence are expected for the coastal regions of Valdivia (39.5°S) and Arica (18.5°S).

O121 Existing Instrumentation and Scientific Drivers for a Subduction Zone Observatory in Latin America

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The subduction zones along the western shore of the Americas provide numerous societally relevant scientific questions that have yet to be fully explored and would make an excellent target for a comprehensive, integrated Subduction Zone Observatory (SZO). Furthermore, a review of present-day geophysical networks in Latin America indicates that existing stations that could serve as a backbone for an SZO. Such preexisting geophysical infrastructure commonly plays a vital role in new science initiatives, from small PI-led experiments to the establishment of the USArray Transportable Array, Reference Network, Cascadia Amphibious Array, and the redeployment of EarthScope Transportable Array stations to Alaska. Creating an SZO along the western coast of the Americas could strongly leverage the portfolio of existing seismic and geodetic stations across regions of interest.In this presentation, we will discuss the concept and experience of leveraging existing infrastructure in major new observational programs, outline the state of geophysical networks in the Americas (emphasizing current seismic networks but also looking back on historical temporary deployments), and provide an overview of potential scientific targets in the Americas that encompass a sampling of recently produced research results and datasets. Additionally, we will reflect on strategies for establishing meaningful international partnerships, such as the recent IRIS-Chilean collaboration to assist in the development of a new Chilean National Seismic Network, and associated capacity building needed for a successful SZO initiative.

O122 Building a framework earthquake cycle deformational model for subduction Megathrust Zones: Integrating observations with numerical models

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Over the past decades our abilities to observe the build-up in slip deficit along subduction plate boundary zones has improved substantially. One result from these observations is a range of present-day behavior along the boundaries. Some regions show displacements that are consistent with elastic deformation of a fully locked plate interface, while other plate boundary segments show little or no plate-motion directed displacements - often interpreted to reflect little or no coupling along the interface. What is unclear is whether this spatial variation in apparent plate boundary behavior reflects true spatial differences in plate interface properties and mechanics, or rather reflects temporal behavior of the plate boundary during the earthquake cycle.
Observations include:

1. Coseismic displacements are enhanced in “near-trench” region
2. Post-seismic relaxation varies with position landward
3. Continued coseismic-like displacements immediately post-EQ.
4. The post-EQ transient can last for decades after a major event

We have integrated the observed patterns of upper-plate displacements (and deformation) with numerical models of subduction zone evolution that allow us to investigate the transient behavior associated with post-earthquake viscous re-equilibration and the underlying long term elastic strain accumulation. Numerical modeling of the earthquake cycle over numerous earthquake cycles allows us to develop a framework model for the megathrust cycle. Our results indicate that the observed patterns of co-, post-, and inter-seismic deformation are largely controlled by interplay between elastic and viscous processes. Displacements (and associated deformation) represent the competition between steady elastic-strain accumulation driven by plate boundary coupling, and post-earthquake viscous behavior in response to the coseismic loading of the system by the rapid elastic rebound. This framework model allows us to develop improved assessments of the slip deficit accumulating within the seismogenic zone, and the earthquake potential of segments along the plate boundary.

O123 Very low velocity anomaly detected by analysis of CCF in a dense network

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Tomographic studies have been recently published showing a clear shallow-crust low-velocity anomaly close, but not below, to an active volcanic field called “Los Tuxtlas” or Tuxtla Volcanic Field (TVF) in the east of Mexico. These studies show that the extension of anomaly has a radius of ~100km and is detected in tomographic images computed for periods between 5 and 10s. In this work we used data from VEOX experiment (an array of more than 40 broad-band stations deployed along the Tehuantepec Isthmus) and from the broad-band network of the Mexican National Seismological Service (SSN). The vertical component of seismic noise was processed, in a standard way (e.g. Bensen et al., 2007), to obtain cross correlation functions (CCF) between pairs of stations. The low-pass filtered CCF (< .1Hz) show a clear Rayleigh pulse propagating along the profile with an approximate constant velocity; however the high-pass filtered CCF (> .1Hz) show strong differences especially in the region just to the south of TVF. By using different structures, we made numerical simulations of seismic records, trying to explain the observed seismograms.

O124 Seismic and non-seismic regions of the Andean backarc crust above the flat-to-inclined slab subduction of Argentina (30-33°S) from ambient noise and regional seismic source analyses

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In the last two decades, seismic monitoring in Argentina has increased observations in the flat-slab subduction region between 30°S-33°S. This region has caused the most damaging earthquakes in Argentina in the past century and seems to provide an efficient mechanism for mountain building along a more than 600 km horizontal east-west orientation. Continuously recorded data from permanent seismic stations from INPRES, UNSJ (Argentina) and global networks (CTBTO, GSN), as well as temporary IRIS-PASSCAL broadband deployments cover four main morphostructural geological units and accreted Paleozoic terranes. We use: 1) Ambient noise (AN)showing Rayleigh wave tomographic images at different levels of the continental crust, which clearly define regions of low seismic velocities associated with basins surrounding others of high seismic velocities beneath the Precordillera and Sierras Pampeanas(SP) outcrops. 2) A joint inversion of receiver functions and AN-Rayleigh wave dispersion curve showing that adding a small percentage (15%) of AN-surface wave information greatly improves the 1-D lithosphere seismic velocity structure beneath each seismic station. 3) Relocations and focal mechanisms of 514 crustal earthquakes. From west to east, our results indicate Moho depths of approximately 70 km beneath the main Andean cordillera, 66 km in the thin-skinned Precordillera, 47 km in the thick-skinned western SP and 41 km in the eastern SP. Mid-crustal discontinuities in seismic velocities at about 21-km and 35-km depths correlate well with suggested decollements and compositional changes at depth for more mafic lithologies. The lower crust exhibits similar properties to those of the uppermost mantle likely related to partial eclogitization beneath the western terranes. The most seismically active Precordilleran and SP region, shows mainly reverse fault focal mechanisms. No earthquakes are observed beneath the Bermejo basin or in the lower crust. In summary, combining different types of seismic analysis allows us to significantly improve our understanding of the crust.

ABSTRACTS

O125 Ambient noise tomography in the northwestern Andean region, Colombia

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We present new group- and phase-velocity maps of the fundamental-mode of Rayleigh waves for the northwestern most corner of South America. The new maps have been developed in the 6 - 42 s period range from the cross-correlation of seismic ambient noise recorded at 52 broadband stations operated by the Colombian Geological Survey, providing a good coverage of the Andean region. Over 1300 empirical Green's functions with raypaths between 100 and 1300 km were extracted from inter-station cross-correlations, obtained after normalizing the ambient seismic noise recordings in both the frequency and time domains and stacking up to 32 months (2012-2014) of normalized data. The group-velocity curves from the various paths were then inverted to produce maps in a 0.5˚ x 0.5˚ grid using a non-linear, iterative, 2-D tomographic scheme that updates the propagation paths using the Fast Marching Method. Dispersion maps show good correlation with surface geology down to 20 s. Low-velocity anomalies correlate with Cenozoic sedimentary rocks and Quaternary deposits around the Caribbean and Pacific coast and, in the Eastern range, with de Cenozoic and Cretaceous sedimentary cover. High velocity anomalies along the Central range and the Sierra Nevada of Santa Marta seem to be related to igneous metamorphic Jurassic and Cretaceous structures and with Precambrian and Paleozoic basement. We also inverted group- and phase-velocity measurements simultaneously for a 1-D shear wave velocity structure at each grid point and generate S-wave velocity maps at different depths. The models show a thick sedimentary cover around of ~7 km in the Caribbean region, the Magdalena Valley and the Cordillera Oriental. Also we estimate a crustal thickness on the Pacific and Caribbean region less than ~30 km which correlates with previous studies.

O126 Seismic Interferometry of railroad noise: Body and surface wave imaging

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The anthropogenic contribution to the ambient seismic field has been addressed by only a few interferometry studies. The work presented here reports our attempt to use the ambient seismic field generated by trains to produce virtual records of surface and body waves for imaging the subsurface.
Seismic interferometry applied to 120 hr of railroad traffic recorded by an array of vertical component seismographs along a railway within the Rio Grande rift has recovered surface and body waves characteristic of the geology beneath the railway. Linear and hyperbolic arrivals are retrieved that agree with surface, direct and reflected P waves observed by nearby conventional seismic surveys. Train-generated Rayleigh waves span a range of frequencies significantly higher than those recovered from typical ambient noise interferometry studies. Direct P-wave arrivals have apparent velocities appropriate for the shallow geology of the survey area. Significant reflected P-wave energy is also present at relatively large offsets. A common midpoint stack produces a reflection image consistent with nearby conventional reflection data. We suggest that for sources at the free surface (e.g. trains) increasing the aperture of the array to record wide angle reflections, in addition to longer recording intervals, might allow the recovery of deeper geological structure from railroad traffic. Frequency-wavenumber analyses of these recordings indicate that the train source is symmetrical and that deeper refracted energy is present although not evident in the time-offset domain. These results confirm that train-generated vibrations represent a practical source of high-resolution subsurface information, with particular relevance to geotechnical and environmental applications.

O127 Academic "Treasure" from Industry "Trash"- From deep crustal imaging in 3D to high resolution surface wave mapping of the near- surface to detection of M<0 seismicity by processing of the normally discarded portions of large oil exploration datasets

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The rapidly expanding use by the oil and gas industry of "nodal", large channel capacity areal arrays that record continuously for extended periods of time is generating large volumes of data in excess of that needed for the conventional CMP reflection imaging that is the primary goal of such surveys. These excess data, once considered as simply "noise", have recently been recognized to have utility not only for the exploration seismologist but also for addressing a diverse range of phenomena. The most widely recognized use for these "noise" records is surface wave tomographic imaging of near surface velocity structure via seismic interferometry of ambient natural noise. Such results are proving to be of great value in enhancing conventional 3D exploration imagery, but they should be appreciated in their own right for the information they provide on the shallow subsurface to the hydrologist, engineer and tectonicist. Another relatively dramatic application is the delineation of local structure by tracing the propagation of body and surface waves from local and teleseismic events across these dense arrays. Here I would like draw attention to three other promising uses for such data: a) detection and mapping of microseismicity below the detection thresholds of conventional earthquake monitoring networks, especially in areas of low conventional seismicity; b) body wave and surface wave imaging of structure using cultural, as opposed to natural, energy sources, and c) systematic mapping of the basement in 3D using the existing exploration sources recorded at travel times longer than that typically harvested for resource purposes. We conclude by emphasizing that these potentially invaluable "extras" are now being recorded routinely around the world, but there is as yet no mechanism in place to ensure they are exploited rather than simply deleted.

O128 SALSA3D: A Global 3D Velocity Model for Improved Seismic Event Location

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The SALSA3D global, 3D velocity model of the Earth's mantle has been developed to improve the accuracy and precision of seismic travel time predictions for a wide suite of regional and teleseismic phases. Improved travel time predictions lead directly to significant improvements in the accuracy and precision of seismic event locations as compared to locations computed using standard 1D velocity models like ak135, or 2½D models like RSTT. A key feature of SALSA3D is that path-specific model uncertainty of travel time predictions are calculated using the full 3D model covariance matrix computed during tomography, which results in more realistic uncertainty ellipses that directly reflect tomographic data coverage. Recent improvements in the model include the generation of an S velocity model to compliment the P velocity model and development of capability to compute travel times for core phases, reflections off the core-mantle boundary and underside reflections off the Moho and the surface of the Earth. For use in routine operations, travel time predictions and prediction uncertainties are precomputed and stored in station-phase-specific 3D lookup tables, which allows fast, reliable retrieval of information needed by locators. The lookup capabilities are based on the open-source GeoTess software package available at http://www.sandia.gov/geotess.

ABSTRACTS

O129 Reflection imaging using earthquake sources: Applications of RVSP (reverse vertical seismic profiling) and the need for dense arrays

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Large-scale, continuously recording seismic arrays are now commonplace in oil and gas exploration. This technology has the potential to transform how we image and monitor deep structure and tectonic processes as well. Here we demonstrate how such arrays might be used to image the subsurface by VSP processing of microearthquake clusters, in this case comprised of aftershocks.
Following the Mw 5.8 2011 central Virginia earthquake, unusually dense arrays were deployed over the epicentral region. One of the objectives of this study was to demonstrate how unaliased recordings of aftershocks can be used to image geologic structures using reflection techniques. However, applying standard common reflection point processing to earthquake sources is inappropriate because the sources are not at the surface. An earthquake occurring several kilometers beneath a surface receiver array has a more natural analog: an offset reverse vertical seismic profiling (RVSP) survey. Processing the recorded aftershocks with VSP techniques results in a 3D reflection image. The reflection image shows a southeast dipping reflector that we interpret to be part of a complex imbricate thrust sequence at 5-7 km depth previously imaged 6 km southwest by a deep crustal reflection survey.
An illumination analysis was done prior to stacking via VSP methods. The analysis used the geometries of the receiver array and of the aftershock sources (hypocenters) in conjunction with a 3D structural model derived from the interpretation of the nearby reflection survey. The results indicate that although partial illumination of geological structures is achieved by our array, a true 2D surface receiver array is critical to compensate the sparse distribution of the earthquake sources.

0130 Improvement of Epicenter Location in the offshore Campos Basin with RSTT 3D Model

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Locating epicenters in the continental shelf has two main difficulties: a) the large azimuthal gap when using only onshore stations, and b) the large variation in crustal structure (ranging from ~40 km thick continental crust onshore, through extended crust in the continental shelf, and ~5-10 km thick oceanic crust further out), making average 1D models unsuitable. Thus the use of 3D models, such as RSTT, is necessary to improve earthquake location offshore. Here we tested the current RSTT model for South America by relocating a small magnitude event (mb=3.8) in the Campos Basin, SE Brazil, in 2010-07-01, which was also recorded by seismic streamers during a seismic reflection survey. The data recorded in the streamers during two shots of the seismic survey give an additional control on the epicenter making this event a good test of the RSTT model. The epicenter obtained with the RSTT model is 100 km further from the coast, and is much more consistent with the data of the seismic survey, compared with the previoulsy available epicenter that had been calculated with an average 1D model. This indicates that the 3D RSTT model is useful for improving earthquake locations offshore SE Brazil.

O131 Intraplate Stress Field in South America from Earthquake Focal Mechanisms: New data from waveform inversion of small regional events

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We updated the previous compilation of earthquake focal mechanisms in Brazil and in the sub-Andean region. For Brazil, about ten new focal mechanisms were determined by waveform inversion using path-specific velocity models derived from group velocity inversion of Rayleigh and Love waves, checked against P-wave polarity data. The new dataset is used to derive the stress tensor orientation in mid-plate South America.
Most events in the sub-Andes show reverse or strike-slip mechanisms. Focal mechanisms in Brazil are also mainly reverse and strike-slip faulting. In the sub-Andes, stresses are compressional with the principal major compression (S1) E-W, on average. A slight rotation of S1 is observed, controlled by the orientation of the Andean plateau. In the sub-Andes the intermediate principal stress (S2) is also compressional.
In mid-plate South America, stresses vary in nature and orientation. In SE Brazil and near the Chaco-Pantanal basins, S1 is oriented roughly E-W with S2 approximately equal to S3. This stress pattern changes to purely compressional (compressional SHmax and Shmin) in the north of the São Francisco craton. A rotation of SHmax from E-W to SE-NW is suggested towards the Amazon region. Along the Atlantic margin, the regional stresses are affected by coastal effects, which tend to make SHmax parallel to the coastline and Shmin (usually S3, extensional) perpendicular to the coastline. The few breakout data and in-situ measurements in Brazil are generally consistent with the pattern derived from the focal mechanisms. Although ~E-W trending SHmax is usually well explained by global and regional numerical models of plate stresses, the SE-NW orientation across the Amazon craton has not been explained by any current numerical model of intraplate stresses.

O132 Events relocation and source parameters of central Brazil micro-earthquakes

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In this work we focus on the relocation and moment-tensor determination of events occurred in Central Brazil within the Goiás-Tocantins Seismic Zone (GTSZ). The GTSZ is a part of the Tocantins Geological Province which includes, among others, the large geological structure (Lineament Transbrasiliano-LTB). The region is characterized by low magnitude seismicity (M < 3.5) distributed along a belt parallel to the LTB but not exactly coincident. Most of the events are recorded by few stations from the Brazilian Seismograph Network (RSBR) recently deployed and these events are too weak to have their Focal Mechanisms (FM) obtained by the traditional method using only the phase P polarities. To overcome this limitation, for some events, we used the ISOLA software for the centroid-moment tensor solution together with the CSPS tool (Cyclic Scanning of the Polarity Solutions) which makes use of the full waveform inversion to constrain the non-unique focal mechanism solutions obtained by the FOCMEC program from a set of a few available polarities.
The first task was to work on the improvement of the location of events from the Brazilian seismic catalog to lower their horizontal and vertical errors allowing for events screening (erh < 10 km) and enabling attempts to establish a possible correlation between the GTSZ seismicity and the LTB large scale regional structure. Secondly we performed, with the help of ISOLA (and CSPS), the waveform inversion of some events to obtain the focal mechanisms.
Determining the moment tensor of such small earthquakes is quite challenging, but necessary to obtain the crustal stress orientation, which is fundamental to understand the tectonics and seismicity, particularly at the intraplate regions. The focal mechanism solutions of the events obtained so far, Mara Rosa-GO (Oct-2010), Formoso-GO (Jan-2011) and Peixe-TO (Nov-2015) are all in agreement with previous studies.

O134 Distribución espacial del centroide de las soluciones del tensor el momento sísmico a lo largo de la región central de las Antillas Menores en el periodo 2013-2015

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Using waveform data gathered from the seismological networks of the Lesser Antilles, we calculate new moment tensors for earthquakes with M ≥ 3, from 2013 to middle of 2015 by full waveform inversion. 10 of these moment tensor solutions are in good agreement with those previously reported by other institutions and provide validity for processing 25 new moment tensor for the central region of the Lesser Antilles. For earthquakes within the upper Caribbean lithosphere, our results evidence that, extensional or strike-slip focal mechanisms are predominant, resulting from of the intra-plate deformation produced by the subduction of the American Plate, whereas very few thrust events are observed. For deeper earthquakes, our results compare well with older focal mechanisms from previous studies. However the inversion procedure for most of them are less precise due to their larger condition number (CN) and Kagan angle distribution. We use the new moment magnitudes obtained to estimate the scaling relation with the local magnitude MLv computed by the regional seismic operators. The two magnitudes are consistent for earthquakes with magnitudes M > 4, with a slope close to unity. Nevertheless, for M < 4 the relationship is sparse and furtherworks are needed to extrapolate or precise it.

O135 Focal Mechanism solution for earthquakes in the Central part of Costa Rica

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The majority of the Costa Rica population lives in the central part of the country. This zone has experienced strong to major earthquakes in the past that had caused strong damages, with earthquakes reaching Modified Mercalli intensity IX. The latest earthquakes in the zone that caused strong damages were the Puriscal, December 22, 1990, 17:27 UTC, Mw 5.9 and the Cinchona, January 8, 2009, 19:21 UTC, Mw 6.1. The OVSICORI-UNA seismographic network has been operating since the 1980's, and recently has been upgraded with broadband seismometers, accelerometers, and software for acquisition and archiving. Special emphasis of the deployed permanent and temporary seismic stations of the OVSICORI-UNA network is in the Central Valley. One of the network's outputs are focal mechanisms, normally obtained using first-motion polarities; additionally, in this work we used data from 2010 to the present for the full waveform inversion to obtain Moment Tensor solutions for moderate to small earthquakes in the central part of the country, and compare results with mechanism obtained using first-motion polarities.

O136 Rupture process of the Lefkada 2015 earthquake (Mw 6.4) using regional and local seismic data

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On November 17th, 2015, a strong earthquake (Mw 6.4) occurred on Lefkada island, western Greece. Structural damage and earthquake effects, i.e. landslides, rock falls, liquefaction etc, were concentrated at the southern part of the island. Two people died and four were injured. The damage was confined mainly to non-reinforced buildings in the epicentral area. The dextral Cephalonia Transform Fault (CTF) that runs along the western coast of Lefkada was immediately identified as the causative fault. We studied the rupture properties of the earthquake using broad band and strong motion data at regional and local distances, using full waveform inversion methods. After extensive spatial grid search the centroid position was found at the depth of 5 km, shifted with respect to epicenter by 10 km southward and 5 km westward. The focal mechanism solution indicated a strike slip fault (strike/dip/rake, 24°/80°/-149°) compatible with CTF. Source complexity was investigated using iterative deconvolution at frequencies 0.03-0.08 Hz. Results indicated two main subevents: the first, smaller one and close to hypocenter (Mo[sub]1[/sub]=0.17e19 Nm) and the second, major one (Mo_2=0.28e19 Nm) that occurred ~ 3-4 seconds later, as far as 15 km from epicenter in the SSW direction. Focal mechanisms of the two subevents (s/d/r = 189°/77°/146° and 27°/79°/-150° for the first and second, respectively) were basically right-lateral strike slips with a small thrust component, similar to the centroid solution. The finite fault slip inversion provided similar results, with maximum slip of about 1.5 m. The SSW directivity was also confirmed by the patch method based on empirical Green's functions. Results of our analysis indicate that this earthquake ruptured a part of the Cephalonia-Lefkada strike-slip fault that didn't rupture during the last events, i.e., the Lefkada 2003 (Mw 6.2) and the two Cephalonia 2014 events (Mw 6.1, and 6.0).

O137 Seismic source model of a deep Mw 7.6 earthquake, Nov. 24, 2015, Brazil-Peru border

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Two Mw 7.6 earthquakes occurred within five minutes on November 24, 2015 at Brazil-Peru border; we studied the first. Using pP-P arrival times, hypocenter depth was first constrained to 600+/-10 km. Then, using P waves from 18 stations at distances ~340-1560 km, epicenter was located at 10.59°S, 70.98°W. Same stations were used for full-waveform inversion. Centroid position was found at 10.65°S, 70.95°W, 600+/-5 km, shifted ~20 km from GCMT solution. Strike, dip, and rake angles 2°/40°/-64° (Plane 1), 150°/55°/-110° (Plane 2), Mw 7.6, Mo=2.8x1020 Nm, and DC>95%, were similar to those of GCMT. Using iterative deconvolution at 0.02-0.10 Hz, the source appeared to be composed of three subevents, tightly clustered to each other (<15 km), with total duration of 15-20 s, featuring almost identical focal mechanisms and high DC%. When grid-searching in Planes 1 and 2 for two major subevents and their moment-rate time functions simultaneously (non-negative least-squares), the source appeared less compact, indicating rupture propagation from hypocenter at azimuth of ~140°, either horizontally (in Plane 2), or slightly downward, with plunge -30° (in Plane 1). This direction is nearly perpendicular to slip vector. The same was confirmed by directivity effects derived from angular variation of P-wavegroup duration at 8-16 Hz, and by kinematic location of the stopping point of rupture. The latter resolved the rupture length (40+/-10 km), and provided rupture speed of 1.5-2.5 km/s, as low as 40% of shear-wave speed. The event is consistent with regional stress model calculated from 16 GCMT focal mechanisms of nearby deep events at Lat 5°S to 14°S: Sigma 1 and 3 axes with (azimuth, plunge) = (61°, 77°) and (256°, 13°), respectively, and low friction (0.1-0.2). These results may elucidate processes involving buoyancy forces and metastable mineral phases, upon further analysis with an appropriate thermo-mechanical model.

ABSTRACTS

O138 W-phase source inversion using high-rate regional GPS data for large earthquakes

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W-phase moment tensor inversion has proven to be a reliable method for rapid characterization of large earthquakes. For global purposes it is used at the USGS (United States Geological Survey), PTWC (Pacific Tsunami Warning Center) and IPGS (Institut de Physique du Globe de Strasbourg). These implementations provide moment tensors within 30-60 min after the origin time of moderate and large worldwide earthquakes. Currently, the method relies on broadband seismometers, which clip in the near field. To ameliorate this, we extend the algorithm to regional records from high-rate GPS data and retrospectively apply it to six large earthquakes that occurred in the past five years in areas with relatively dense station coverage. These events show that the solutions could potentially be available 4-5 minutes from origin time. Continuously improving GPS station availability and real time positioning solutions will provide significant enhancements to the algorithm.

O139 Contribution of rogue events to tsunami danger in Central America

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Most assessments of tsunami risk are based on earthquake sources occurring at subduction plate boundaries, and following seismic scaling laws. However, a significant risk exists, or is enhanced by, "rogue" events failing those characteristics.
In the context of tsunami risk in Central America, we first consider the case of the so-called "tsunami earthquakes", featuring anomalous slowness in their source process. We are motivated by the classic 1992 Nicaragua tsunami earthquake, and the smaller event of 2012 in El Salvador, which featured similar source
characteristics. We surmise that the tsunami of 27 February 1902 in Guatemala and Western El Salvador may also have belonged to this family. This strongly suggests a regional trend of tsunami earthquakes along at least the Western part of the Central American subduction zone, which should be kept in mind in the local development of tsunami mitigation, notably in regard to education of populations at risk.
We next discuss the case of the 1856 earthquake on the northern coast of Honduras, which led to considerable destruction from Belize to Trujillo, and to definitive tsunami flooding and damage at both Omoa and Laguna Criba, 350 km to the East. The favored explanation of this tsunami following what had to be a major strike-slip earthquake on the Swan Transform Fault, is its generation by a series of landslide sources triggered by the earthquake.
We also recall the presence of Holocene terraces on the Northwestern coast of Colombia, notably at Tierra Bomba (Cartagena), which may suggest the occurrence of rare, catastrophic earthquakes capable of inflicting tsunami damage throughout the Southern Caribbean. Finally, we draw attention to events occurring outside main plate boundaries, such as the cluster of small earthquakes defining the Hess escarpment (M < 5.4 since 1963). We update results on a larger event along this feature (tentative M = 6.9 in 1926) and speculate about possible maximum earthquakes carrying tsunamigenic risk.

O140 Influence of seismic source geometry over hydrodynamic processes on tsunamigenic events

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During the last decades, major tsunamigenic events as Mw 9.2 Sumatra – Andaman, 2004, Mw 8.8 Maule, Chile and Mw 9.0 Tohoku – Oki, Japan have provided valuable information to the scientific community about predominant processes in the generation, propagation and impact of a tsunami on far and near – field coastal zones. In this context, new insights have emerged for estimation of tsunami threat with a comprehensive analysis of the seismic source and its relationship with hydrodynamic processes of tsunami propagation, such as shelf and harbor resonance, coseismic displacement heterogeneity and coastal morphological effects. Finite-fault models are strong technique to know a slip distribution of a megathrust earthquake, additionally can be used as seismic source input in tsunami numerical models. Simulated tsunami sea level records show hydrodynamic parameters, as wave height, directivity and resonant periods, to assess a tsunami hazard in coastal areas. The main objective of this contribution is to analyze the influence of seismic source geometry over main hydrodynamic processes, i.e. shelf and harbor resonance, of tsunamigenic events occurred in coastal areas of southern Peru and northern Chile. To test our hypothesis we select available finite-fault models of tsunamigenic earthquakes (Mw > 7.5) to know slip distribution and characterize the geometry of maximum slip patches (MSP). Subsequently, we simulate tsunami behavior using MSP as input to construct tsunami sea level time series and evaluate using spectral analysis on main coastal cities of study area.

O141 Posibles peligros geológicos asociados a La Isla Del Coco

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Isla del Coco, único afloramiento subaéreo de la Cordillera Submarina Coco donde poco se conoce sobre los peligros geológicos. Es parte emergida de un volcán submarino complejo, compuesta por rocas volcánicas del Pleistoceno, con suelos, coluvios y depósitos de playas, en una zona de topografía abrupta. Se le asignó el nombre de dorsal asísmica, pero desde el punto de vista geográfico y vulcanológico, es mejor llamarla Cordillera de Coco.
Las principales amenazas geológicas son los deslizamientos disparados por la alta precipitación y por sismos regionales, seguido por tsunamis, luego en menor grado sismicidad y por último el vulcanismo. Se registran efectos de sismos regionales que han causado deslizamientos, como en 1972. Los datos analizados, indican alguna actividad sísmica alrededor de la Isla, que sugieren potencial sísmico bajo. Hay Fallas geológicas, como la falla en tijera presente entre Bahía Wafer y Punta Presidio, con una traza de 6 km, no muestra signos de actividad o movimientos recientes, pero es zona de debilidad que podría sufrir futuras rupturas y no se puede excluir que sea potencialmente activa.
Algunos pequeños tsunamis históricos y prehistóricos han afectado la isla. También es propensa a fenómenos de licuefacción en las playas arenosas.
Dataciones radiométricas en la Cordillera Coco, dan edades entre 14.4 hasta 0.6 Ma y la isla está circundada por volcanes submarinos anómalamente jóvenes (0,6-1,3 Ma). Se sugiere que la isla es producto de una anomalía térmica del manto, manifestada por vulcanismo a través de una zona de debilidad cortical. No presentó actividad histórica o en los últimos 10000 años, pero, su relativa juventud geológica y la falta de investigaciones, no permite excluir la probabilidad de formación de un nuevo volcán, en algún sector aledaño a la Isla dentro del presente periodo geológico, donde la posibilidad es remota pero no nula.

ABSTRACTS

O142 Breve historia de Tsunamis Marinos en México ¿Qué sabemos, cómo participamos y cómo podemos informarnos?

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Los episodios telúricos que sacudieron de forma importante la Ciudad de México los días 19 y 20 de Septiembre de 1985, generaron tsunamis perceptibles cerca de sus respectivas zonas epicentrales en los litorales del Pacífico Mexicano. Dichos macrosismos fueron la justificación para que la Protección Civil se considerara asunto prioritario en México y por ello, se creó el Sistema Nacional de Protección Civil (Sinaproc) hacia el año 1988. Con el apoyo del Gobierno de Japón, se instaura en la UNAM el Centro Nacional de Prevención de Desastres en 1990 y se elabora el primer Atlas Nacional de Riesgo. Luego del tsunami local derivado del sismo de Jalisco-Colima del 9 de octubre de 1995, el Comité Científico Asesor sobre Riesgos Geológicos del Sinaproc propuso una recomendación para atender este tipo de eventos, pero ante el devastador Terremoto y Tsunami de Sumatra-Andamán de 2004, se revisa dicha recomendación y se actualiza, aunque inexplicablemente pronto queda archivada. Sin embargo, el primer programa de prevención de riesgo de desastre mediante un sistema de alerta por tsunami dirigido a la población costera del Pacífico Mexicano, surge de una iniciativa del Gobierno Estatal de Jalisco en 2010. Posterior al Sismo y Tsunami de Tohoku, Japón en 2011, el Gobierno Mexicano por fin atiende el tema y funda el Centro de Alerta de Tsunamis y el Sistema Nacional de Alerta de Tsunamis de México. En septiembre de 2015, varias comunidades costeras plantean de manera incipiente simulacros de respuesta ante la ocurrencia de tsunamis. Así, el objetivo de este estudio fue realizar una búsqueda historiográfica, con material consultado durante el Siglo XX y lo que va del XXI, el cual es referente para comunicar la severidad de estos eventos y transmitir la cultura de la prevención y la autoprotección, para reducir en lo posible algún desastre socioeconómico.

O143 The Puerto Rico Tsunami Program, a Component of the National Tsunami Hazard and Mitigation Program (NTHMP)

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The Caribbean region has a documented history of damaging tsunamis that have affected coastal areas. In particular, the Puerto Rico – Virgin Islands (PRVI) region, where the proximity of the coast to prominent tectonic faults would result in near-field tsunamis. Tsunami hazard assessment, detection capabilities, warning, education and outreach efforts are common tools intended to reduce loss of life and property. It is for these reasons that the PRSN is participating in an effort with local and federal agencies to develop tsunami hazard risk reduction strategies under the NTHMP and the NWS TsunamiReady program, which is the base of the tsunami preparedness and mitigation in PR. In order to recognize threatened communities in PR as TsunamiReady, sources for local, regional and tele-tsunamis shall be identified and modeled and the results have been used to develop tsunami response plans. The main goal of the PR-NTHMP is to strengthen resilient coastal communities.
Evacuation maps were generated using the worst-case scenario based on the Maximum of Maximums (MOM) for all the modeled sources. Inundation and evacuation zones were drawn on GIS referenced maps and aerial photographs. These products are being used by emergency managers to educate the public and develop mitigation strategies. Maps and related evacuation products, like evacuation times, can be accessed online via the PR Tsunami Decision Support Tool. Based on these evacuation maps, tsunami signs were installed, vulnerability profiles were created, communication systems to receive and disseminate tsunami messages were installed in each TWFP, and tsunami response plans were approved. Also, the existing tsunami protocol and criteria in the PR/VI was updated.
This paper describes the PR-NTHMP recent outcomes, including the real time monitoring as well as the protocols used to broadcast tsunami messages. The paper highlights tsunami hazards assessment, detection, warning, education and outreach efforts in Puerto Rico.

O144 Tsunami Warning System for the Caribbean and Adjacent Regions: 10 Years Advancing Readiness

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Over 75 tsunamis have been documented in the Caribbean and Adjacent Regions over the past 500 years with 4484 people associated deaths. The most recent devastating tsunami occurred in 1946 in Dominican Republic; almost 2000 were reported to have died. With the explosive increase in residents, tourists, infrastructure, and economic activity along the coasts, the potential for human and economic loss is enormous. It has been estimated that on any day, upwards of more than 500,000 people could be in harm's way just along the beaches, with hundreds of thousands more working and living in the tsunamis hazard zones.

In 2005 the UNESCO Intergovernmental Oceanographic Commission established the Intergovernmental Coordination Group for the Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG CARIBE EWS) to coordinate tsunami efforts among the 48 participating countries in territories in the region from Bermuda thru Brazil. Significant progress has been made in tsunami monitoring, tsunami services, hazard and risk assessment, evacuation mapping, as well as community preparedness, readiness and resilience. The presentation will provide an update on the status of the CARIBE EWS, as well as future areas of focus and development.

O145 Local tsunami warnings: Perspectives from recent large events

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Local tsunami warning requires rapid assessment and communication of the tsunami hazard for communities immediately adjacent to large earthquake. Here, the warning times are typically of minutes to tens of minutes. Local warning remains a challenging problem with very few systems worldwide capable of issuing such alerts. Here, we demonstrate a flexible strategy for local tsunami warning that relies on regional geodetic and seismic stations. Through retrospective analysis of four recent tsunamigenic events in Japan and Chile, we show that rapid earthquake source information, provided by methodologies developed for earthquake early warning, can be used to generate timely estimates of maximum expected tsunami amplitude with enough accuracy for tsunami warning. We validate the technique by comparing to detailed models of earthquake source and tsunami propagation as well as field surveys of tsunami inundation. Our approach does not require deployment of new geodetic and seismic instrumentation in many subduction zones, and could be implemented rapidly by national monitoring and warning agencies. We illustrate the potential impact of our method with a detailed comparison to the actual timeline of events during the recent 2015 Mw8.3 Illapel, Chile earthquake and tsunami that prompted the evacuation of 1 million people.

O146 Tsunamigenic sources in the Middle America Trench off Central America

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The Pacific coast of Central America has been hit by several tsunamis throughout its recent history. Since 1539 Central America has suffered 39 tsunamis in the Pacific coast, where the subduction zone of the Cocos plate under the Caribbean plate is the main source of damaging tsunamis for the area. These events have had destructive nature leading to significant economic losses and human lives. The tsunami risk reduction in the region goes through a better understanding of risk, improved resilience, improved mitigation measures, and strengthening of intergovernmental collaboration. The basic support of any risk management system undergoes a precise knowledge of causative sources of hazard and an estimation of its occurrence probability. We present a compilation of tsunamigenic seismic sources in the Middle America Trench off Central America, with analysis of their capacity to generate tsunamis and their probability of occurrence. Along with the presentation of the sources and their potential, we also present tsunami hazard maps at regional scale.

O147 Tsunamis recientes en Chile: Que hemos aprendido para la alerta y la evacuación a partir de observaciones y modelación hidrodinámica

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El tsunami ocurrido el 27 de Febrero de 2010 irrumpió en forma dramática, luego de un silencio tsunamigénico de 50 años, causando numerosas muertes y cuantiosos daños económicos. Las fallas observadas en los sistemas oficiales de detección, alerta y comunicación de mensajes para la evacuación evidenciaron serias limitaciones en recursos humanos, conocimiento científico y técnico, además de dificultades tecnológicas de captura de datos y comunicaciones. Este diagnóstico hizo que se pusieran en marcha diversos esfuerzos, desde la sociedad civil, la academia y los servicios técnicos del Estado, para mejorar las capacidades nacionales de alerta y evacuación. Estas mejoras han sido puestas a prueba en otros dos tsunamis ocurridos el 2014 en el norte grande y el 2015 en el norte chico, que aunque de menor intensidad que el del 2010, produjeron importantes daños y 8 fallecidos por inmersión el 16 de Septiembre de 2015.
En esta presentación, entregaremos un resumen del conocimiento hidrodinámico que las observaciones y modelaciones nos han permitido sistematizar a partir los 3 últimos tsunamis destructivos ocurridos en Chile. En ellos se comprueba la presencia característica de ondas de orilla y fenómenos resonantes que pueden amplificar localmente el fenómeno en ciertas bahías y explicar el arribo tardío de ondas secundarias peligrosas. Por otro lado, la comprobación del breve tiempo disponible entre el terremoto y las primeras inundaciones en las zonas inmediatamente adyacentes a la ruptura exigen reforzar los esfuerzos de educación y preparación de la población para la auto-evacuación.

O148 Resultados preliminares de la elaboración de un mapa de rutas de evacuación en un evento de tsunami en Playa Sámara, Guanacaste (Costa Rica)

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Se ha diseñado una metodología con el objetivo de elaborar una cartografía de rutas de evacuación en caso de tsunami a escala 1:10.000 para las localidades del Pacífico Norte y Central de Costa Rica identificadas como prioritarias. Dicha metodología está basada en el modelado numérico determinista de 35 escenarios de posibles tsunamis usando ComMIT, la exposición de la población de estos lugares (vulnerabilidad física), de acuerdo con los datos con los que cuenta el país. Dentro de las localidades seleccionadas para elaborar la cartografía, se analizó playa Sámara, en el Pacífico Norte. Las diferentes capas de información utilizadas en el análisis de rutas de evacuación fueron: red vial, pendiente, distribución de población y otros elementos que interactúan en el espacio al momento de la evacuación. Esta información se obtuvo a través de la recolección, geoprocesamiento y levantamiento de datos, todo ello validado en el campo. A través de la herramienta SIG, se construyó una superficie de costo que considera los elementos espaciales que dificultan la evacuación por las diferentes vías a fin de determinar la vía óptima para cada zona habitacional que se dividió en área de estudio, en el momento que se produce una alerta por tsunami. Los resultados preliminares del análisis de rutas de evacuación en Playa Sámara, muestran que las diferentes condiciones morfológicas del terreno condicionan diferentes modalidades de evacuación; en algunos sitos, la pendiente es suficientemente pronunciada como para permitir acceder a la zona segura con rapidez, mientras que en otras la excesiva pendiente impide el acceso por las rutas más próximas hacia las zonas seguras. Por último, algunos sectores del área de estudio presentan grandes distancias hasta la zona segura por lo que pueden evaluarse otras alternativas a la evacuación horizontal.

O149 Examining the role of urban form in supporting rapid and safe tsunami evacuations: A multi-scalar analysis in Iquique, Chile

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Large populated coastal areas in Latin America and the Caribbean are exposed to destructive near-field tsunamis. Globally, long-term changes in the urban built environment have been proposed to mitigate this type of risk (e.g. large civil-engineered defences, land-use regulations, and building codes). Moreover, the role of physical urban forms in supporting populations' rapid responses to tsunamis, such as evacuation and sheltering, has been increasingly recognized. Thorough analysis methods have been applied to this area of research, such as agent-based modelling, network analyses and 'what-if' scenarios. Nevertheless, much of these efforts remain focused on the large-scale of the urban configuration, i.e. the system of linked spatial elements (streets, squares, parks, etc.) through which people move during an emergency. The critical micro-scale of the evacuees' experience within the built environment (usually in deteriorated conditions after a tsunamigenic earthquake) is not commonly examined.
In this presentation we describe a study undertaken in the Chilean city of Iquique, affected by a large earthquake and minor tsunami on April 1st, 2014. By using a mixed-methods approach including computer models, fieldwork, and surveys for evacuation behaviour, we overlaid the large- and micro-scale levels of analysis and compare their results. For certain parts of the city, significant differences were found between the evacuation times as predicted by large-scale approaches (e.g. agent-based models) and those experienced by evacuees. When examining the micro-scale conditions of these areas, we found a large concentration of built environment's vulnerabilities that might have affected the evacuees' performance, including design, maintenance and usage-related problems.
These findings pose significant implications for authorities, urban planners/designers and emergency managers, as they underline the necessity of refine current evacuation strategies. This is particularly important in developing contexts such as Latin America and the Caribbean, as their built environments usually lack appropriate conditions for supporting rapid and safe evacuations.

O150 Why should I stay? Study of the return process after a Tsunami Evacuation

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Fast and effective evacuation can be a life-saving decision for people who are exposed to natural disasters, such an earthquake and tsunami. From previous research we know that evacuation is a collective behavior, performed with close relatives and friends, and that is closely related to the perception of risk and the need to search for safety. Quarantelli (1980) has proposed that this a four stages process, starting with the warning and ending with the return. Researchers have focused on understanding the first stages, however very few studies have focused on the return stage. This is the problem that is being addressed in the present study. Using surveys we studied the evacuation process of a sample of 281 adults living in Iquique who had to evacuate after the earthquake and tsunami that affected this area in April 1st, 2014. Our results show that over 40% of the participants returned to their homes before the warning was cancelled. Perceiving that the threat was over and observing others return were among the main reasons to return early. Sociodemographic factors were also predictors of early return. Discussion focuses on the need to defining a successful evacuation and how the citizens should be informed about this process.

O151 Primaras Experiencias del Centro de Asesoramiento de Tsunami para América Central (CATAC) en INETER, Nicaragua

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Grandes terremotos en el océano pacífico y mar caribe de América Central, han generado más de cincuenta tsunamis que han afectado las costas del Pacífico y del Caribe en América Central en los últimos 500 años. El tsunami más destructivo fue el de Nicaragua en 1992 que generó olas de hasta 10 metros de altura. Ante la necesidad de salvaguardar la vida de las personas, en las zonas costeras, el Instituto Nicaragüense de Estudios Territoriales (INETER), propuso en la tercera reunión del grupo de trabajo regional para América Central del grupo Intergubernamental de Coordinación del Sistema de Alerta contra los Tsunamis y Atenuación de sus Efectos en el Pacífico (ICG/PTWS), la creación de un centro regional de asesoramiento de tsunamis para América Central, con el apoyo de Japón. Los representantes de los países acordaron agradecer la cooperación técnica de la Agencia de Cooperación Internacional de Japón (JICA) otorgada a Nicaragua para el establecimiento de un Centro Regional de Asesoramiento de Tsunamis en América Central (CATAC) y el fortalecimiento del sistema a nivel regional, incluyendo la capacitación técnica. El Grupo decidió apoyar los esfuerzos y avances de Nicaragua para el establecimiento de un Centro Regional de Asesoramiento de Tsunamis de América Central (CATAC) en el marco del ICG/PTWS y del ICG/CARIBE-EWS. Se han fortalecido los sistemas de localización automática de sismos, envío de información a tomadores de decisiones, generación de información a la población, intercambio de datos sísmicos con observatorios homólogos de la región de América Central y coordinación de procedimientos se ha avanzado en el marco del proyecto de creación del Centro de Asesoramiento de Alerta de Tsunami con la participación de los homólogos de todos los países.

O152 Tsunami risk and tsunami warning for Puerto Armuelle, Panama

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We elaborated a tsunami risk map for Puerto Armuelle located in the Gulf of Chiriquí, Western Panama. The town is endangered mainly by local tsunamis caused by large earthquakes 1) in the Gulf of Chiriquí and the Pacific coast of Southwestern Panama; 2) near the Pacific Ocean of Southern Costa Rica and 3) near the Pacific coast of Colombia and Ecuador which might struck the town within a few minutes, around 20 minutes and within about one hour, respectively. The Gulf of Chiriquí was affected historically by large earthquakes and tsunamis. Smaller tsunamis with wave heights of less than 5 m would affect only the areas near the beach and additionally some low areas near smaller rivers flowing into the Gulf. Larger tsunamis could hit an extended part of the town. But there are high grounds with altitudes above 20 m which the people can reach within a few minutes. We identified important buildings under risk, evacuation ways, save zones and points of concentration. Tsunami warning must be given by the National Civil Protection Authority in Panama (SINAPROC) based on information obtained from national, regional and international tsunami warning agencies. The population has to hurry to higher ground immediately when they feel extremely strong seismic shaking. We discussed with the local authorities and groups of habitants of Puerto Armuelles about our findings and discussed the need for information, capacitation and training on tsunamis risk and mitigation.
This work was supported by the Secretaría Nacional de Ciencia y Tecnología (SENACYT, Panama) by UNACHI, SINAPROC (National Office in Panama City and regional office in David) and by OSOP.

O153 Propuesta de implementación de un Sistema de Cables Submarinos para detección de Tsunamis en el Centro de Alerta de Tsunamis del Perú

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El Centro Nacional de Alerta de Tsunamis, ubicado en la Dirección de Hidrografía y Navegación de la Marina de Guerra del Perú, cuenta con diversos equipos y sistemas de comunicación cuya finalidad es la detección, vigilancia y monitoreo de tsunamis que ocurren frente a las costas peruanas. Sin embargo, es de gran importancia poder contar con un sistema de detección rápida para tsunamis de origen cercano que permita disminuir los tiempos en la emisión de un boletín de alarma y/o alerta de tsunami respectiva. Para optimizar este sistema, en esta investigación se presenta un contraste entre los sistemas más actuales en el mundo en cuanto a detección de tsunamis: El sistema de boyas detectoras de tsunamis (tipo DART) y el sistema de cables submarinos (DONET y NEPTUNE) con el fin de determinar el mejor sistema de detección rápida de tsunamis para ser implementado en el Perú y fortalecer de esta manera el Sistema Nacional de Alerta de Tsunamis en el Perú.

O154 SIPAT: Sistema de Soporte de Decisiones para la Alerta Temprana de Tsunamis de Chile

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El presente trabajo describe el Sistema Integrado de Predicción y Alerta de Tsunamis (SIPAT) desarrollado en Chile y pronto a ser implementado en el Sistema Nacional de Alerta de Maremotos.
Este es un Sistema de Soporte de Decisiones compuesto por una plataforma tecnológica (software + hardware), la cual entrega la evaluación del peligro asociado a tsunamis ante la ocurrencia de un sismo real de manera rápida, precisa y de forma sectorizada para toda la costa de Chile Continental, Insular y Antártico, luego de contar con información sísmica de bajo orden (magnitud y ubicación hipocentral).
La filosofía de diseño sigue el modelo de base de datos de tsunami originalmente desarrollado en Japón, sin embargo, permite la flexibilidad para integrar nuevos desarrollos como por ejemplo soluciones rápidas de la fuente sísmica y modelado en tiempo casi real.
El sistema ha sido probado de manera preliminar en el terremoto de Illapel, de Septiembre de 2016, arrojando una excelente capacidad de pronóstico.
El relativo bajo costo de implementación, y filosofía modular, pueden hacer de este sistema un modelo atractivo para otros países de la Cuenca del Pacífico.

O156 Tsunami-HySEA: An operational GPU-based model for Tsunami Early Warning Systems

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The Tsunami-HySEA numerical model for the simulation of earthquake generated tsunamis is presented. The initial sea surface deformation is computed using Okada model. Wave propagation is computed using nonlinear shallow water equations in spherical coordinates, where coastal inundation and run-up are suitable treated in the numerical algorithm. Generation, propagation and inundation phases are all integrated in a single code and computed coupled and synchronously when they occur at the same time. Inundation is modelled by allowing cells to dynamically change from dry to wet and reciprocally when water retreats from wetted areas. Special effort is made in preserving model well-balanced (i.e. capturing small perturbations to the steady state of the ocean at rest). The GPU model implementation allows faster than real time (FTRT) simulation for real large-scale problems. The large speed-ups obtained make Tsunami-HySEA code suitable for its use in Tsunami Early Warning Systems. The Italian TEWS at INGV (Rome) has adopted Tsunami-HySEA GPU code for its National System. The model is verified by hindcasting the wave behaviour in several benchmark problems. Numerical results for an earthquake-generated tsunami in the Mediterranean Sea is presented and computing time analysed. The interest of using higher order methods, analysing numerical schemes from first order up to order five, in the context of TEWS, is also addressed. Tsunami codes do not usually use higher than second order methods. It is demonstrated that this should idea should be revised.
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O158 Probabilistic Seismic Hazard and site response assessments of cities in Panama

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The results of probabilistic seismic hazard (PSHA) and site response assessments in the cities of Colon, Puerto Armuelles, David and southwestern Panama City are presented. The PSHA were performed based on the methodology employed by Benito et al., (2012). For the site response assessment at the first three cities we analyzed strong motion records from earthquakes and ambient noise. In the case of southwestern Panama City we used broad band seismometer records. Transfer functions average response spectra were obtained for the four cities studied and spectral ratio for each of the spectral ordinates were calculated to determine natural frequencies of vibration of the soils. In the cases of Puerto Armuelles, Colon and David the soils were divided into soft and firm. For Panama City the Geotechnical studies of the metro line 1, were very helpful and the its soils were subdivided into four microzones (1) stable region with no relative amplification; (2) high frequency area, isoperiods between 0.1 and 0.2 s; (3) transition area, isoperiods between 0.2 s., and 0.3 s. and (4) low frequency area, isoperiods between 0.4 s and 05 s. These results provide valuable information to improve the Panamanian Structural Code (REP2014) and future seismic hazard assessments in these four cities.
Key words: probabilistic seismic hazard, site response, spectral ratios, isoperiods.

O159 New seismic zonation in Central America

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A new seismic zonation of Central America is proposed in this work, based on a detailed analysis of data regarding the seismotectonic framework, seismic catalogue, geological context and other geophysical and geodetic evidences (gravimetric maps, GPS observations). We try to define zones with similar patterns of faulting, seismicity, and rupture mechanism inside each one. The tectonic environment required taking into account zones in three particular seismological regimes: a) crustal faulting (including, local faults, major fracture zones of plate boundary limits, etc), b) subduction interplate and c) subduction intraplate inslab. As an important difference regarding previous zonations, we pay now particular attention in the change of the subduction angle along the trench located in the boundary Coco´s –Caribbean plates. The seismicity each one being associated with particular ranges in depth, which are variables taking into account the change in the subduction angle along the Trench. In fact the angle decreases in Costa Rica, involving different depth for the subduction zones of the north CA (Guatemala, El Salvador and Nicaragua) with respect the southern zones (costa Rica and Panama) and this is the main novelty of the new zonation. The seismicity of each zone is associated with the particular ranges in depth taking into account the variations in the angle. Finally, the seismic parameters of recurrence and Mmax has been estimated.
The results may be useful for futures seismic hazard studies in the region

O160 Seismic hazard in Fonds-Parisien

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The republic of Haiti, the western part of the Hispaniola Island, is crossed by two active major faults: the Septentrional fault to the north and the Enriquillo Plantain Garden fault to the south. This tectonic context involves an important seismic hazard for this country with several lethal earthquakes during the last four centuries. The last one is the January 12, 2010 earthquake whose epicenter was located to the southwest of Haiti and having made more than 230,000 deaths, nearly 300,000 wounded, rendered homeless 1.2 millions of persons and caused material damages evaluated between 8 and 14 billion dollars. Since then, several works were carried out along the portion of the fault zone that is located to the west of Pétion-Ville. Here we use a geophysical multi-method approach to evaluate the seismic hazard and the resulting seismic risk in Fonds-Parisien, an area located at the eastern part of the fault. To the north of this area is found a sedimentary basin boarding the Azuei lake and to the south, the foothills of the "Massif de la Selle". We performed Electrical Resistivity Tomography (ERT), Multichannel Analysis of Surface Waves (MASW), Horizontal to Vertical Spectral Ratio (HVSR) to the north and to the south of Fonds-Parisien and used microseismic data recorded by four seismic stations installed at that zone. The data shows that the sectors where there is a high seismic risk probability are mainly those located at the northern part. ERT cross-correlated through geological and microseismic data depicts the sedimentary basin and MASW associated with HVSR evidenced the thickness of the sedimentary basin.

O162 Seismic Hazard and Exposure assessments for South America, Central America, and the Caribbean Region

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The USGS has produced a seismic shaking hazard model for South America and seismic exposure assessments for South America, Central America, and the Caribbean region to help prioritize earthquake risk. We use USGS hazard models as well as the Global Seismic Hazard Map (GSHAP) along with population exposure information for these assessments. This seismic hazard model follows the probabilistic methodology that was developed by the USGS for the 2014 and earlier editions of the U.S. National Seismic Hazard Models. We developed a new earthquake catalog by combining several regional source catalogs. The earthquake source model includes a smoothed seismicity component applied across the entire continent that accounts for earthquakes with M 5-7, subduction zone sources on the northern and western coasts with M 7-9.5, and crustal faults M 7-8. We applied published global ground motion models for this analysis. Results of this analysis indicate high hazard in the western and northern coasts of the South American continent that exceed 1 g ground shaking for 1 Hz spectral acceleration at a 2% probability of exceedance in 50 year hazard level. Hazard is also high at inland sites where crustal faults or seismicity causes additional increased hazard. Our results indicate that high seismic hazard (peak ground accelerations exceeding 0.3 g) impacts roughly 50-100 million people in South America, 20 million people in Central America, and 8 million people across the Caribbean region. The hazard for these areas is still highly uncertain and should be improved to reduce future earthquake losses.

O163 Earthquake parameter estimation from historical macroseismic data in Colombia

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The location and magnitude of significant historical earthquakes are an important input in probabilistic seismic hazard assessment calculations. The aim of this effort is to calibrate in a homogeneous way the intensity attenuation relationship for the Bakun and Wentworth method (Bull. Seism. Soc. Am. 87:1502-1521, 1997), to determine earthquake parameters from EMS98 macroseismic data points (MDPs) of historical events in the Colombian territory.
The Bakun and Wentworth method requires an intensity attenuation relation as function of the moment magnitude and source distance from MDPs. To developed it, a training set of 8 shallow earthquakes of 20-21th centuries was selected (as example the 2008, 5.9Mw Quetame; 1999, 6.1Mw Armenia; 1995, 6.5Mw Tauramena; 1992, 7.1Mw Murindó earthquakes; Mw values from ISC-GEM catalogue). For this set there is a large number of macroseismic data points available (450MDPs from the Colombian Geological Survey) and covering the largest possible magnitude range [5.1-7.1Mw] for the territorial area and providing reliable instrumental Mw, its uncertainty and location. The model obtained is validated using 4 earthquakes (as example 1994, 6.8Mw Páez earthquake), which were not used in the calibration process and also have MDPs and instrumental data.
An overall agreement is found for the magnitude of these events with magnitudes uncertainties around ±0.3. The model was then applied to 34 historical Colombian earthquakes for the time windows 1644-1962 as example: 1743 Fómeque (6.5±0.2Mwl), 1785 Bogotá (7.0±0.2Mwl), 1805 Honda (6.0±0.2Mwl), 1834 Nariño (6.7±0.2Mwl), and 1875 Cúcuta (6.9±0.2Mwl) earthquakes. Confidence intervals of the location, intensity magnitudes and uncertainty are given. The results are encouraging but, at the same time, show the limitation when dealing with few MDPs, or partial distribution of MDPs.

O164 Building a Ground-Motion Prediction Equations Dataset for PSHA analysis in South America within the GEM-SARA project framework

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Within the framework of the GEM-SARA Project (http://www.globalquakemodel.org/what/regions/south-america/) aiming at building a hazard model for South America, a working group on strong ground motion data and selection of Ground-Motion Prediction Equations (GMPEs) has been created.
The team involves researchers from South America (Bolivia, Brazil, Colombia, Chile, Ecuador and Venezuela). In a first step strong ground motion data have been collected in each country. The same processing and metadata collection scheme has been used in order to build a homogenized database. In a second step, tools have been developed in order to benefit from OpenQuake and associated toolkits libraries to compare with GMPEs. Testing of the GMPEs is performed using three different approaches, the residuals statistics and likelihood of the normalized residuals, the average sample log-likelihood values (LLH), and the Euclidean Distance (EDR). Preliminary results of the GMPEs testing will be presented.

ABSTRACTS

O165 Updated earthquake Catalogue for South America suitable for PSHA: Time window pre-1964

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On the frame of SARA (The Seismic Risk in South America), the task 4 project goal was to compile an earthquake catalogue for South America, homogeneous as far as possible, in terms of Mw. The methodology has been development of a critical inventory of all public studies related to earthquakes of South America, incorporating the CERESIS available data, recent national and international studies and analysis conducted during the project. The main problem of the catalogue is the need to express the values of magnitude in terms of Mw. This task was performed:

i) adopting the Mw values already available from ISC-GEM, other catalogues and few macroseismic studies;
ii) converting to Mw the available Ms and mb values, by making use of global empirical relationships and relation for Brazil (low magnitudes) published in literature;
iii) using the method of Bakun and Wentworth calibrated regionally for some events that have a sufficient number of macroseismic data, based on what already has been worked out in Ecuador, Venezuela and recently in Colombia which was developed in SARA project
iv) determining Mw(Intensity) relationships to Argentina, Bolivia, Colombia, Peru and Chile, for those earthquakes which do not have magnitude assessment but a value of maximum intensity or epicentral intensity is available.

Finally, earthquake parameters are assessed for 2556 earthquakes in the time-window 1513-1963; the lower threshold is Mw=5[-0.2] for the Andean region. For Brazil is not applying a lower threshold. We have still more than 1700, low size earthquakes, for which the Mw(Intensity) relationships could not be applied, while for more than 200 earthquakes no size assessment is available.

O167 The South American Risk Assessment (SARA) probabilistic seismic hazard assessment model: An open seismic hazard model for South America

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Earthquake hazard in South America is dominated by the tectonic forces driving the subduction along the west coast, which, in addition, provides an important contribution to the tectonic stresses generating shallow on-shore earthquakes. In this complex tectonic framework, further challenges arise due to the current state of knowledge, with inhomogeneous characterization of seismicity, active faults and strong motions between the different countries. It is within this framework that the South American Risk Assessment (SARA) project established, as part of its core objectives, the creation of a new seismic hazard model for South America. The SARA Project encompassed several key goals for improving the state of seismic hazard assessment: a) harmonization of critical earthquake data sets (historical and instrumental earthquake catalogues, seismically active shallow faults, and strong motion recordings); b) construction of common standards for exchanging information amongst the scientists involved in the project; and c) development of open source tools for both data collection and interpretation. The SARA seismic hazard model was created using a compilation of updated and harmonized information, based on common standards and procedures for assimilation of data and creation of models, and relying on the knowledge and expertise of many South American scientists and engineers.
The resulting seismic hazard model can be used as the input for seismic risk studies across local, national and regional scales. It is also consistent with the requirements of internationally recognized seismic design codes. The completed model is an important result for the entire seismological community of the region; our wish is that the South American scientific community will use the results to continue and hopefully increase international collaboration in the Region. In this communication we will illustrate the main components of the hazard model, and the results achieved; and we will outline possible areas for future improvement.

O168 New hazard maps of Spain for the revision of the building code

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A new estimation of seismic hazard has been developed for the Spanish territory aimed at the revision of the Spanish Building Code. The study includes geologic, seismic and strong motion data gathered in the last years, being remarkable the use of: 1) the Data Base of Quaternary Active Faults of Iberia (QAFI,v2) an updated seismic catalogue homogenized to Mw, 3) a new area-source model compiling different geophysical data and 4) a ground motion prediction equation derived with local data, covering the magnitude Mw range (4-5.5). Its worthy to note the information and lessons derived from the Lorca 2011 earthquake, which has been the most destructive event in the last 120 years in Spain.
A probabilistic seismic hazard approach has been followed (PSHA) joining the consensus of the main specialists of the country who have participated in the decisions around the critical aspects, such as: source model and GMPE to be used for different magnitude ranges, values of maximum magnitude Mmax for each zone, logic tree and weighs for uncertainty quantification, etc. As result, hazard maps in terms of PGA and spectral accelerations SA (T) have been obtained for different return periods: 475, 975 and 2475 years. In addition a map for return period of 10.000 years have been derived, which may be oriented to critical facilities. Although the study over such long exposure times requires alternative methodologies and more exhaustive analysis about active faults, recurrence periods, paleoseismic data, etc, this map may be an starting point of specific assessments addressed to critical facilities.
The new hazard maps counts with the agreement of the Spanish seismological community and are presented in this communication.

O170 Present-day Shortening in Southern Haiti from GPS Measurements and Implications for Seismic Hazard

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The ~3 M inhabitant capital region of Haiti, severely affected by the devastating M7.0, 2010 earthquake, continues to expand at a fast rate. Accurate characterization of regional earthquake sources is key to inform urban development and construction practices through improved regional seismic hazard estimates. Here we use an improved Global Positioning System (GPS) data set and show that seismogenic strain accumulation in southern Haiti involves an overlooked component of shortening on a south-dipping reverse fault along the southern edge of the Cul-de-Sac basin in addition to the well-known component of left-lateral strike-slip motion. This tectonic model implies that ground shaking may be twice that expected if the major fault was purely strike-slip, as assumed in the current seismic hazard map for the region.

O172 El Sistema de Fallas de Algeciras, Colombia: Amenaza sísmica, tectonoestratigrafía y geomorfología tectónica

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Los sismos históricos acaecidos en los años 1785, 1827, 1917 y 1967 que fueron sentidos en Bogotá y que dejaron tanto pérdidas económicas como de vidas, se asocian por estudios previos sobre sismicidad histórica a la zona de influencia del Sistema de la Falla Algeciras (SFA). El impacto de estos sismos históricos para Colombia gracias a estudios previos de macrosísmica demuestra que en su ocurrencia han producido efectos fuertes no solo Bogotá, sino también para varias ciudades del occidente y suroccidente colombiano. Su magnitud de momento no es menor a 7.0 en ninguno de estos casos, por lo que teniendo en cuenta la gran densidad de población de Colombia para su región de influencia en la actualidad (más del 65%), la ocurrencia de un sismo de estas características dejaría un gran escenario de desastre y pérdida económica para el país. En este trabajo se hace un análisis histórico para cada caso, y para el SFA, se revisa la sismicidad instrumental superficial reportada por la Red Sismológica Nacional de Colombia (RSNC), se efectúa una revisión tectonoestratigráfica desde algunas apreciaciones de campo y se muestran aspectos morfotectónicos relacionados al sistema de fallas.

O173 Updated Mw magnitude values for seismic events in eastern Venezuela, based upon an improved model for Q within the region. An empirical relation that converts former local MC values to Mw for homogenization purposes

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In order to advance towards the creation of a homogeneous earthquake catalog for Venezuela, it is necessary to produce empiric relations between the various existing magnitude scales shown in the current catalog. In this regard, this work represents an effort that attempts to convert the given local magnitude, MC (C for Close) prior to the year 2000, to the most trustworthy and useful magnitude value Mw, based on seismic events registered by the National Seismic Network operated by FUNVISIS in eastern Venezuela during the time window 2010-2014. For this attempt, a total of 210 earthquakes were analyzed with a previously given magnitude value, Mw, ranging from 2.5 to 4.6.
Previous to the determination of the aimed empirical MC-Mw relation, we applied the CODA Q method, as presented in SEISAN (Havskov et al, 2010), to obtain a proper and adequate model for Q associated to an active seismic region with widespread fracturing and strong lateral in-homogeneities, which should substitute the inappropriate parameters of the existing Q model. The data was grouped by depth, having two groups: shallow earthquakes with depth < 30 km and deep earthquakes with depth > 30 km; and two frequency dependent Q relationships were achieved, one for shallow earthquakes Q(f)= (70±2) f (0.81±0.01) and other for deep earthquakes Q(f)= (89±5) f (0.84±0.03. This new model gave us the opportunity to better adjust the magnitude values Mw, of the working dataset of seismic events. Also, for the same data set of events, it was computed the magnitude values MC, applying the procedure described by Fiedler 1978 in the NOAA report for earthquake procedures in The Americas.
Finally, once all earthquakes had both MC an updated Mw values, a linear regression was executed to obtain the relation between these two parameters expressed in the following equation: Mw= (0.68±0.14)*MC+ (1.4±0.05).

O174 Seismic Hazard Assessment in the Continental Ecuador

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Ecuador is located in the northwest of South America and shows both, shallow and deep seismic activity, mainly caused by the subduction of the Oceanic Nazca Plate and the presence of a complex system of active faults that generate crustal earthquakes. The greatest magnitude event, that has already been registered during the instrumental period, occurred in 1906 with MW 8.8 and it was located on its shores. In the Andes Mountain Range, lesser magnitude, shallow events, have occurred involving significant human and material losses.
A seismic hazard assessment study of continental Ecuador is now presented. The study begins with a revision of the available information considering instrumental and historic data of seismic events and the posterior elaboration of a seismic catalog that covers 427 years, homogenized to magnitude Mw.
A new area-source model containing 21 seismogenetic zones grouped into three tectonic regimes (crustal, subduction interface and subduction in-slab) is proposed. The subduction dip is particularly analyzed to provide an area-source model consistent with the physical, geological and tectonic knowledge of the study region.
A Probabilistic Seismic Hazard Assessment (PSHA) approach is carried out, in terms of peak ground acceleration PGA and spectral accelerations SA(T) for periods T= 0.1, 0.2, 0.5, 1, and 2 s. The resulting hazard maps for continental Ecuador are presented for three return periods: 475, 975 and 2475 years, together with the uniform hazard spectra derived in four province capital cities: Quito, Esmeraldas, Guayaquil and Loja.
The study of each city is completed with a hazard disaggregation analysis for the target motions given by the expected PGA and SA (1s) values for return periods of 475 and 2475 years. As result, the controlling earthquakes with highest contribution to the hazard in every city, for short and long structural periods, are determined.

ABSTRACTS

O175 Estimación de la amenaza sísmica en Cumaná, Estado Sucre, Venezuela

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Cumaná es la ciudad de Venezuela que mas ha sufrido el impacto de terremotos en su historia. La amenaza sísmica es por tanto elevada, y también lo es su vulnerabilidad, por lo que la población está expuesta a un alto riesgo sísmico.

En este trabajo se ha estimado la amenaza sísmica de la ciudad para dos periodos de retorno (PR) de 475 y 975 años, elegidos habitualmente como referencia en normativas para edificaciones convencionales y de especial importancia, respectivamente. Los cálculos se han realizado para aceleraciones pico (PGA) y espectrales de corto y largo periodo, SA(0.1s) y SA (1s). El efecto local ha sido incluido haciendo uso de un mapa de microzonación de la ciudad. Se han generado así mapas de los movimientos esperados con 10 % y 5 % de probabilidad de excedencia en 50 años, que resultan ser máximos al norte y noroeste de la ciudad, debido a la influencia del sistema de fallas El Pinar y de la zona de subducción. Concretamente la PGA alcanza valores de 0.6 g y 0.75 g para PR de 475 y 975 años, respectivamente, disminuyendo la amenaza hacia el sur.

Con objeto de definir escenarios sísmicos para un posterior estudio de riesgo, se ha desagregado la amenaza para las dos probabilidades de excedencia manejadas. Se identifican así dos sismos de control que mas contribuyen a la amenaza, dados por los pares magnitud Mw - distancia R: (5.7, 0-10 km) y (6.7, 10-20 km). Estos escenarios se identifican con el sistema de fallas El Pilar y más específicamente con el tramo de falla Cumaná-Casanay, donde han ocurrido dos terremotos históricos en 1929 y 1997. Los correspondientes escenarios se han caracterizado por medio de espectros específicos de respuesta, que representarán las curvas de demanda en un posterior estudio de riesgo.

O176 Diverse rupture processes in the 2015 Peru Deep Earthquake Doublet

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Earthquakes in deeply subducted oceanic lithosphere can involve either brittle or dissipative ruptures. On 24 November 2015, a pair of deep (606 and 622 km) magnitude 7.5 and 7.6 earthquakes occurred 316 s apart, separated by about 55 km. The first event was a brittle rupture with a sequence of comparable size subevents extending unilaterally ~50 km southward with a rupture velocity of ~4.5 km/s. This earthquake triggered deep activity to the north including a second major event that had 40% larger seismic moment and the same duration, but smaller rupture area and lower rupture velocity, indicative of a more dissipative rupture. As for the nearby great 1994 Bolivia earthquake, dynamic stresses from brittle rupture may be essential to drive the onset of distinct dissipative failure processes in deep slabs.

O177 Determination of the fault plane and rupture size of The 2013 Santa Cruz Earthquake, Bolivia, 5.2Mw, by Relative Location of the Aftershocks

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The Central Andes of southern Bolivia is a highly seismic region with many active faults, that could generate earthquakes up to 8.5 Mw. Nevertheless most of them are shallow and have low magnitude. In 2013, a 5.2Mw earthquake occurred in Santa Cruz de la Sierra. The five largest aftershocks were registered by the International Seismological Centre (ISC) and 33 smaller aftershocks were recorded by the Observatorio San Calixto (OSC) in the two months after the mainshock. Distances between epicenters of the aftershocks and the mainshock were up to 34 km, which is larger than expected for an earthquake of this magnitude. Using data from South American stations and the relative location technique with Rayleigh waves (usually the clearest wave in noisy seismograms), the epicenters of the five largest aftershocks of Santa Cruz series, registered by the ISC, were determined in relation to the mainshock. This method enabled to achieve epicentral locations better than +/-2 km. Additionally, using data of three stations, two of the national network of Bolivia (MOC, and SIV), and LPAZ; the eight smallest aftershocks, recorded by the OSC, were relocated through correlation of P and S waves. The results show a N-S trend of the epicenters and an E dipping fault, the maximum distance between the aftershocks is less than 10 km, within the uncertainties of the fault subsurface rupture length, in accordance with the magnitude of the mainshock. Nevertheless the events are located away from the Mandeyapecua fault, one of the most important reverse fault in Bolivia; and present a different dipping, demonstrating that these events were generated by another fault of the area, that had not been well studied yet.
Keys words: Relative Locations, Mandeyapecua fault

O178 Sismicidad de La Cordillera Volcánica de Guanacaste Antes, durante y después del Terremoto de Sámara de 2012 (Periodo 2005-2015)

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El proceso de subducción que se lleva a cabo a lo largo de toda la costa pacífica de Centroamérica, controla la sismicidad que se produce en las cordilleras volcánicas. En este trabajo se hace un análisis del comportamiento de la sismicidad durante el periodo 2005-2015 (más de 12 mil sismos) en la Cordillera Volcánica de Guanacaste (CVG) y el comportamiento de la misma antes, durante y después del Terremoto de Sámara (MW 7,6) ocurrido en setiembre de 2012. La información sísmica muestra que antes del terremoto se produjo un aumento paulatino de la sismicidad en la CVG, con enjambres sísmicos en diferentes sectores, especialmente durante el periodo 2009-2011, que disparó las estadísticas a más de 950 sismos localizados anualmente. En las horas posteriores al evento principal, se produjo sismicidad inducida en varias fallas locales y se dio un cambio importante en el comportamiento del volcán Rincón de la Vieja, detectado incluso por inclinómetros electrónicos. En los últimos tres años, la sismicidad en la Península de Nicoya se mantuvo alta durante los años 2013 y 2014, con más de 550 sismos al año (lo normal son menos de 350 sismos al año), esto se debe principalmente por el reacomodo de los esfuerzos en las placas tectónicos. Por su parte, la sismicidad en la CVG se mantuvo baja y estable durante el 2013 y el 2014. En el 2015, tanto la Península de Nicoya así como la CVG muestran una disminución importante de la sismicidad y todo parece indicar que al finalizar el año tendrán niveles similares a los que tenían en el periodo 2007-2008.

ABSTRACTS

O179 Identificación de estructuras sismogénicas corticales en el Bloque de Jalisco, México

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Analizamos la distribución espacial de la sismicidad en el Bloque de Jalisco (BJ), México, para identificar estructuras sismogénicas corticales. Ésta es una de las regiones más complejas tectónicamente, la mayor parte de la sismicidad es generada por la subducción de las placas de Cocos y Rivera bajo la placa de Norteamerica. Ello es la causa del movimiento relativo en las fallas corticales. Se tienen cartografiadas las estructuras geológicas más mayores, pero aún faltan por clasificar otras de menor tamaño. Localizamos la sismicidad registrada por la red sísmica temporal MARS que operó de enero de 2006 a junio de 2007, compuesta de 50 sismógrafos digitales de banda ancha. La mayor parte de la sismicidad cortical somera ($h < 15$ km) con magnitudes de entre $1.8 \leq M \leq 5.5$. Construimos los mecanismos focales de los sismos más grandes con primeros arribos de onda P. Las orientaciones de las soluciones son variadas, ello refleja la heterogeneidad de las estructuras. También contrasta con la aparente homogeneidad de las soluciones reportadas por las agencias internacionales. Las localizaciones hacia el sur del BJ son de fallamiento inverso; las del interior del continente son de fallamiento normal, acorde con la tectónica extensional causada por el rift de Colima. Ampliamos la ventana temporal de análisis incorporando las soluciones reportados en otros catálogos (ISC y Engdahl) de 1996 a 2013. Hacia el SW del BJ, entre Manzanillo y Barra de Navidad, encontramos un alineamiento de epicentros que sugiere una estructura sin expresión en superficie que aún no ha sido cartografiada. Complementamos las localizaciones hipocentrales con información geológica, análisis de imágenes aeromagnética y topográficas. Otras zonas muestran comportamientos similares, nuestros resultados ayudan a mejorar el conocimiento sismotectónico del BJ, aunque aún requerimos acotar mejor las estructuras locales con estudios más específicos, ello facilitará la estimación de su potencial sísmico.

O180 Microsismicidad en la Sierra Madre Oriental, México

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Mostramos los resultados del registro de sismicidad en la Sierra Madre Oriental (SMOr), México, región intraplaca considerada sin riesgo sísmico, pese a que allí han ocurrido sismos de magnitud moderada (aprox. 5.5) y enjambres sísmicos de larga duración temporal y amplia distribución espacial. Actualmente dichos sismos podrían crear importantes estragos en la población. Desde 2001 iniciamos varios monitoreos sísmicos temporales con redes locales. Recurrimos a la localización mono-estación pues las bajas magnitudes de la microsismicidad no siempre es registrada en la mayoría de las estaciones. Uno de los periodos más destacados de actividad ocurrió de 2007 a septiembre de 2010. Registramos más de 3000 eventos y localizamos 299 epicentros (aprox. $h < 10$ km, $Ml < 3$) ocurridos en la parte central de la SMOr. Complementamos su estudio con geología, modelos digitales de elevación y perfíles geofísicos para restringir las zonas potencialmente activas. La sismicidad tiene una distribución espacial NW-SE paralela a los lineamientos estructurales contemporáneas de la SMOr, cuyo origen ocurrió durante la orogenia Laramide. Los modelos geológico-geofísicos sugieren una relación entre las capas sedimentarias y la estructura del basamento subyacente, donde identificamos tres conjuntos de fallas: las profundas, concentradas en el basamento; las que van desde la superficie al basamento; y las fracturas y fallas concentradas en la parte más somera. Los rasgos estructurales también sugieren la coexistencia de dos sistemas de fallas normales regionales, ambos perpendiculares entre sí, el más somero con orientación NW-SE y el más profundo NE-SW. En general el nivel de microsismicidad regional es alto y persistente en el tiempo con picos de magnitudes más grandes que percibidos por la población. La sismicidad de la SMOr es más continua de lo que se creía. Esta es probablemente la región intraplaca más activa de México.

O181 La aplicación de arrays sismicos en el monitoreo del Volcan Ubinas-Peru

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El volcán Ubinas es uno de los volcanes más activos del Perú y en su record histórico registra mas de 23 erupciones moderadas durante los últimos 500 años. Las estaciones sísmicas tradicionales que se tienen alrededor del volcán no han permitido localizar con alta precisión las fuentes sísmicas de tipo LP asociadas a su actividad magmática. En este sentido el uso de arrays sísmicos permite superar estas limitaciones. El 2015 se instalaron dos arrays sísmicos de 6 elementos cada uno en los flancos norte y oeste del edificio volcánico. Los datos colectados durante tres meses de operación fueron procesados utilizando métodos basados en la decomposición modal empírica (EMD) para obtener hipocentros de alta precisión y estimar trayectorias del flujo magmático en el volcán.

O182 Dinámica de las principales Fallas Activas en el Perú inferida de mediciones GPS

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A lo largo del territorio peruano se destacan importantes sistemas de fallas activas tanto de tipo normal como de tipo inverso. Estos sistemas de fallas han sido fuente de varios eventos sísmicos extremos con significativas perdidas económicas y sociales. Entre estas se encuentran la Falla del Alto Mayo-Región San Martin que fue epicentro de sismos de magnitud 6.6 y 6.9 Mw en 1990 y 1991 respectivamente; la falla de la Cordillera Blanca – Región Ancash y la Falla de Tambomachay - Región Cusco. Esta ultima fue la causante de un sismo de 5.8 Mw en 1986. El presente trabajo muestra resultados del campo de velocidad horizontal estimado alrededor de cada una de las fallas mencionadas en base a observaciones GPS realizadas los año 2014 y 2015.

O183 Passive-source seismology in the Borborema Province of NE Brazil: Investigating Cenozoic volcanism and uplift

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The Borborema Province of NE Brazil can be regarded as the remnant of a larger Proterozoic mobile belt that structured during the Brasiliano-Pan African orogeny at the end of the Neoproterozoic. The Province is scarred by a number of aborted rift basins that resulted from extensional stresses related to the opening of the Atlantic ocean. After continental breakup, the Province was affected by episodes of intraplate volcanism and uplift, as expressed through the Macau-Queimadas magmatic alignment (93-7 Ma) and the high-standing Borborema Plateau (~1000 m), respectively. A number of models have been proposed to explain this intraplate activity, which invoke mantle plumes, small-scale convection cells, lateral crustal flow, and/or anomalous bodies in the lithospheric mantle. With the aim at discriminating among these competing models, the deep structure of the Province was investigated through analysis of seismic waves passively recorded at permanent and temporary seismic stations. At crustal levels, joint receiver function and surface-wave dispersion analysis revealed a 4-5 km thinning of the crust surrounding the southern Plateau, from 36-38 km to 30-32 km, along with the presence of a marked intra-crustal discontinuity accompanying thin crust. Interestingly, the analysis also revealed the northern Plateau is a region of elevated thin crust. At upper mantle levels, SKS-splitting showed the mantle is surprisingly anisotropic at the heart of the Province, and body-wave tomography demonstrated the upper mantle under the northern half of the Province is slower than that under the southern half. We propose topographic variations are mostly the result of differential stretching during continental breakup - with Cenozoic uplift being restricted to the northern Plateau -, while Cenozoic volcanism is likely to have resulted from lithospheric mantle sources. The lack of anisotropy in the mantle is harder to explain, and might have resulted from two anisotropic layers with orthogonally oriented fast axes.

O184 1-D seismic velocity structure of Colombia from constrained joint inversion of receiver functions and surface wave dispersion

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We apply a constrained optimization approach for joint inversion of surface wave and receiver functions using seismic S-wave velocities as a model parameter. We introduce inequality constraints only over the model parameter to control the model space, therefore introducing intrinsic regularization to the inverse problem. We take advantage of the improved local broadband network density and its integration into global networks, to acquire a large amount and variety of seismic data. In particular, we compute receiver functions stacks based on ray parameter, and invert them jointly with collected surface wave group velocity dispersion observations. The inversions results estimate 1-D seismic S-wave velocity profiles up to 300 km depth beneath each station considered, which can be used to address important questions related to tectonic and lithospheric activity of the complex Colombian region.

0185 High resolution Double Seismic Zones in the Nazca subduction based on teleseismic depth phase arrivals

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The mechanism for intermediate depth and deep earthquakes is still under debate. The temperatures and pressures are above the point where ordinary fracture ought to occur. Key to constraining this mechanism using seismological data is the precise determination of hypocentral depth and the robust estimation of source parameters.
It is well known that depth phases can provide unique information, which not only allows for significant improvement in event depth determination, but also holds the key to better constraining source properties. Nevertheless, routinely and systematically picking such phases at teleseismic or regional distances is problematic due to poor signal-to-noise ratios around the pP and sP phases. To overcome this limitation we have started taking advantage of the availability of dense seismic arrays. We recently proposed a relative earthquake relocation algorithm based on the precise picking of the P and pP phase arrivals using array processing techniques.
We further improve our algorithm by implementing source deconvolution to enhance the signal to noise-ratio of the pP phase and our estimate of pP-P arrival times. We are thus able to precisely map intermediate-depth and deep seismicity in regions where it is tightly clustered. As a byproduct of our relocation scheme we get array-based estimates of the source time function for every event-pair in the cluster.
We explore the intermediate depth seismicity in the Nazca subduction zone in northern Chile and identify the double seismic zone (DBZ) using teleseismic waveforms only. Our results show low uncertainties and provide a new tool for the determination of the width of the DBZ in different subduction zones.

O186 3-D Local Earthquake Tomography of the Cocos Ridge Subduction at the Southeastern End of the Middle American Trench

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Southeastern Costa Rica remains as one of the less understood regions along the Middle America Subduction Zone. This highly complicated region includes the presence of the submarine Cocos Ridge, an exposed forearc, a ~190-km gap in the Quaternary volcanic arc, a lack of deep seismicity, and the outcrop of Pliocene-Pleistocene adakites. Using the VELEST and SIMULPS packages, we inverted travel times from ~500 selected local earthquakes recorded by Red Sismológica Nacional (RSN) since 1998, simultaneously determining hypocenters and the 3-D tomographic P-wave velocity structure of the shallow part of the subduction zone. The new tomographic data show a well-defined, thick steep slab (~55° at depths > 30 km), reaching depths of 65 km, 70 km landwards from the trench. The subducting slab is imaged as a high-velocity perturbation with a band of low velocities on top encompassing the intraslab seismicity deeper than ~20 km. The Wadati Benioff Zone is displayed from 40 to 65 km beneath the Fila Costeña Range. In the upper plate, we observe three main velocity anomalies: a high velocity anomaly beneath the Talamanca Cordillera and two low velocity anomalies beneath the Fila Costeña Range and the Limon Basin. An anomalously deep intracrustal seismicity (down to 40 km) in the Panama Block was detected below the thrust belt of Fila Costeña and the Talamanca Cordillera. These new results favor the presence of a steeply dipping subducted slab beneath Southeastern Costa Rica and a Wadati Benioff Zone seismicity extending to at least ~70 km depth. The velocity anomalies observed within the upper plate suggest a very heterogeneous crust. The geometry determined by our seismic tomography provides a new frame to interpret the driving mechanisms for the upper plate deformation and the presence of the volcanic arc gap.

O187 Seismic anisotropy indicates mantle flow through the Central American Volcanic Gap

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Between volcanoes Irazu in Costa Rica and Baru in Panama, the Central American subduction zone has a gap where most of subduction attributes (a deep trench offshore, a Wadati-Benioff zone extending to depths of 100s of km, explosive volcanism) are absent. We refer to this region as the Central American Volcanic Gap (CAVG).
Absence of volcanism and the lack of deep seismicity argue for either a change in the nature of subducting lithosphere, or the change in its configuration, or for no subduction at all. These scenarios predict very different upper mantle conditions beneath the CAVG. In particular, the nature of expected mantle flow depends strongly on the choice of the geodynamic scenario.
North of the CAVG trench-parallel orientation of fast shear wave propagation direction suggests lateral flow along the slab. If the deep slab continues beneath the CAVG, this flow will likely extend through it. On the other hand, geochemical data require an influx of material with Galapagos plume signature, with a “slab gap” of some configuration necessary to deliver it. This scenario requires mantle flow through the CAVG.
We use records of core-refracted shear waves (SKS, PKS, SKKS) from permanent broadband seismic stations in southern Costa Rica. Sets of observations from different source regions are inverted jointly for parameters of seismic anisotropy at depth. West of Cordillera Talamanca we find fast directions with NE azimuths, nearly orthogonal to the Central American subduction zone. These observations clearly favor a scenario where mantle flows through the CAVG, consistent with the idea of a slab gap. We will discuss the details of the upper mantle anisotropy distribution beneath the CAVG, with an emphasis on lateral and vertical changes in its parameters that can be used to characterize the upper mantle flow in this complex region.

ABSTRACTS

O189 Present-day Shortening in Southern Haiti from GPS Measurements and Implications for Seismic Hazard

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The ~3 M inhabitant capital region of Haiti, severely affected by the devastating M7.0, 2010 earthquake, continues to expand at a fast rate. Accurate characterization of regional earthquake sources is key to inform urban development and construction practices through improved regional seismic hazard estimates. Here we use an improved Global Positioning System (GPS) data set and show that seismogenic strain accumulation in southern Haiti involves an overlooked component of shortening on a south-dipping reverse fault along the southern edge of the Cul-de-Sac basin in addition to the well-known component of left-lateral strike-slip motion. This tectonic model implies that ground shaking may be twice that expected if the major fault was purely strike-slip, as assumed in the current seismic hazard map for the region.

O190 Present-day GPS velocity field of South America

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We discuss the present-day velocity field of South American plate based on all available stations installed by several institutions, namely stations part of IGS (International GNSS Service), national mapping networks (Brazil and Argentina), GeoRed (Colombia), and others. In total, we use more than 100 sites to determine a very robust estimation of the velocity field of stable South America. The velocity field is computed with respect to the ITRF2008 global reference frame. We attempt to separate the secular motions from other geophysical signals, like seasonal amplitudes due to loading and other effects and post-seismic deformations, in order to try to quantify the magnitude of intra-plate deformation in the stable part of the South American plate.

O194 Rupture-Length x Magnitude for Intraplate Earthquakes in Brazil using Cross-Correlation of Regional LG Waves

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Earthquake source properties in intraplate areas, such as Brazil in the middle of the South American plate, are often poorly known due to occurrence of few well-recorded events and sparse station coverage. Here we used relative locations to estimate source size of small to moderate events and compare with empirical relations of other regions.
The rupture lengths of several crustal intraplate earthquakes were studied with relative relocation of foreshocks and aftershocks using accurate arrival times picked by cross-correlation of regional P-, S- and Lg waves. The Master event technique was used to relocate other events of the series with respect to the mainshock. This was also followed by HYPODD relocations. In many cases the fault plane orientation was determined and found to be consistent with the fault plane solution. The rupture length of the mainshock was measured by the distribution of the immediate aftershocks. In several cases (such as Mara Rosa 2010, GO, 4.4Mw; Montes Claros 2012, MG, 3.5Mw; Rio Peti 2014, PA, 3.9Mw; and Miranda 2015, MS, 3.8Mw) the rupture evolution could be seen with the mainshock occurring very close to the foreshock, the immediate aftershocks defining the rupture size of the main event, and a trend of later aftershocks to occur further away from the main epicenter.
Our data, together with other published results of Brazilian earthquakes (using aftershock studies or source duration by waveform modeling), indicate that the relation between magnitude and rupture length is more consistent with an extrapolation of the empirical Wells & Coppersmith (1994) relation for global data, rather than the proposed relation of Nuttli (1983) for Central and Eastern US. Our data indicate shorter rupture length than predicted by the Nuttli (1983) relation. The implications of our results in terms of possible average stress-drop values will be discussed.

O195 An automatic approach for sifting through large amounts of data for triggered phenomena

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With the explosion of openly available seismic data, automatic approaches must be developed to systematically process and analyze data. To identify potentially triggered events in the coda of a large earthquake requires processing single station data, and we develop an automated approach to identify small, local events within these large continuous seismic data records. Specifically, we develop and apply time domain short-term average (STA) to long-term-average (LTA) ratio algorithms to three-component data to create a catalog of detections, using the following STA/LTA ratios: 1s/10s; 4s/40s; 8s/80s; 16s/160s. Our preferred detection algorithm for local earthquakes, 4/40, identified three regional earthquakes concurrent with the passage of the S- and surface-waves of the Chile mainshock at USArray station R11A that locate in the Coso region of California, as well as events in Texas near a region identified as having induced seismic events from waste-water injection following the Japan earthquake. We explore the results of using this approach using USArray data for 154 M>7 earthquakes, and use all of the detectors to identify other phenomena, such as tremor.

O196 The impact of stress orientation on remote dynamic triggering in the Coso Geothermal Field

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Over a ten-year period (2004-2013), we search for remotely triggered seismicity in the Coso Geothermal Field (CGF) utilizing data from EarthScope's USArray Transportable Array (TA) and the Southern California seismic network. In particular, we apply an STA/LTA approach for 154 M ≥ 7 earthquakes and use local earthquake catalogs to investigate triggered seismicity in the CGF. Of 154 remote mainshocks, we find 34 mainshocks (22%) show triggered seismicity based on the increase in the magnitude and frequency (rate) from pre-mainshock to post-mainshock auto-detection rates and cataloged seismicity. We observe both instantaneous (16) and delayed (18) triggering within ± 5 hours of the mainshock. We also find that remote triggering in the CGF region is enhanced by the orientation (back-azimuth) of the passing seismic (mostly surface) waves in relation to the local stress field (NNE-SSW trending faults), and there appears to be little correlation between the peak dynamic stress and event triggering. Our results suggest that instantaneous remote dynamic triggering strongly depends on the regional stress orientation, and for the CGF instantaneous and delayed triggered events exhibit different stress thresholds important for dynamic triggering for small earthquakes.

ABSTRACTS

O197 Stress field in Costa Rica. From Focal Mechanisms and Wellbore Breakouts: Implications for Fault Reactivation

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We have compiled and analyzed a database of 1735 earthquake focal mechanisms and 26 breakouts from eight oil drillings as input for determination and modelling of the modern stress field of Costa Rica, southern Nicaragua and northern Panamá. Three stress orders of magnitude are identified, the main one trending sub-parallel to the N 22° E convergence trend of the Cocos plate on the Caribbean plate. The second is recognized where the previous approaches the Cordilleras backbones and mayor tectonic accidents where it is reflected towards North while the third one is locally represented by northwest oriented abrupt and sharp contortions. These properties along with local and regional permutations of the stress ellipsoid explain unexpected fault regimes and important neotectonic complications. The breakout interpretation was very useful to constrain the seismic limitations and sampled the upper lithosphere up to 6 km depth and the focal solutions down to 190 km. A realistic 3D scenario was generated depicting more objective seismotectonic limits by jointly applying the World Stress Map regime categories criteria along with the R' tectonic relation (Delvaux,1995) and the slip sense of every selected nodal plane. In general, the mainland is oveying transtensive-transpresive deformation with isolated small volumes of pure extension and the outer arc, along the strike of the Middle America Trench, depicts pure compression and transpression with outer rise distension. The Back-arc displays a similar stress-strain style. Only top quality stress tensors, assumed or inferred friction, cohesion and pore pressure were used as input for slip-dilation tendency and fracture stability analysis. The theoretical fault reactivation potential of several well studied active structures responsible for recent destructive earthquakes is herewith presented.

O198 Transferencia de Esfuerzos de Coulomb y escenarios de reactivación de fallas asociados al terremoto de Sámara-Nicoya, 05-09- 2012. Mw 7.6, Costa Rica

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Presentamos los resultados del análisis de la transferencia de esfuerzos tectónicos en términos de esfuerzos de Coulomb (CFS), del gran terremoto de subducción Mw 7.6 del 05 de setiembre del 2012, en Sámara frente a la península de Nicoya en el noroeste de Costa Rica. Exploramos las implicaciones para la amenaza sísmica y el potencial de reactivación de fallas ejercido por estos esfuerzos y expresados cuantitativamente como la Tendencia al Deslizamiento (TS= T/σn), calculado tanto con el estado de esfuerzos previo y con el posterior al evento. Hemos usado la solución focal de Yue et al (2012) con plano nodal 307, 21, 93, e hipocentro a 13.1 km, junto con los resultados del análisis integrado de Liu et al (2015) en el cual dicho plano está constituido por 366 sub-fallas con su correspondiente deslizamiento individual. Las propiedades del CFS y las simulaciones para las fallas óptimas normales, de rumbo e inversas se aplicaron a varios escenarios con configuraciones variables de fricciones y profundidades. Los resultados obtenidos son muy coherentes y así los datos GPS reportados por Protti et al (2014) coinciden con los desplazamientos teóricos verticales sugeridos por el método CFS. Hemos encontrado que varias secuencias sísmicas posteriores asociadas dentro de la placa Caribe en Costa Rica pueden ser explicadas en términos de la transferencia de esfuerzos tectónicos al coincidir espacial y temporalmente con los bulbos de incremento de CFS generados por el evento y sus réplicas. Aportamos los valores respectivos para mostrar la buena correlación existente entre los hipocentros de la población total hasta dos años después del terremoto y las fallas regionales que tienen una TS media a alta. Esta interpretación conjunta es una herramienta original que merece ser sometida a más pruebas en diferentes ambientes sismotectónicos.

O199 Analysis of a small magnitude earthquake sequence and its possible relation to the recent collapse of a tailings dam in south-east Brazil

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Following the recent collapse of an iron-mine tailings dam and subsequent mud flood in southeast Brazil, we located and characterized a seismic sequence occurring within the mine area and preceding the dam failure. Both the earthquakes and flood signals were recorded by the Brazilian Seismographic Network. The largest event, mR=2.6 (~2.0 Mw), occurred ~1.5 hours before the accident, and two other smaller events occurred around the time of the collapse. The signal from the mud flowing downstream from the dam starts around 4 p.m. (local time), lasts ~25 minutes, and has largest amplitudes at frequencies 1-4 Hz. A polarization analysis of the mud-flow noise recorded at two of the nearest stations indicates back-azimuth signals consistent with the location and time of the accident.
The tight spatio-temporal association between earthquakes and accident makes it highly unlikely ($p<0.001\%$) that the small earthquakes had no relation to the rupture. Empirical curves of ground shaking due to small magnitude earthquakes at short epicentral distances, as in our case, show that maximum peak accelerations could potentially reach up to 3% of g. Furthermore, the collapsed dam was built following the upstream method, which despite of being one of the most commonly employed methods in the world, it is particularly prone to earthquake liquefaction and failure due to ground shaking. Thus we propose as possible contributing factor for the dam collapse either ground shaking and/or soil liquefaction triggered by the earthquakes. In order to prove these hypotheses, a complete multidisciplinary study of the dam structure and soil conditions is necessary.
Consequently, we emphasize that the hazard from small, nearby earthquakes, however unlikely, should be taken into account as an additional factor in the risk evaluation during projects of tailings dams. A revision of dam construction policies and related legislation is therefore recommended to avoid future accidents.

ABSTRACTS

O200 Detailed Spatio-Temporal Evolution of Aftershocks and Repeating ¬¬Earthquakes Following the 2012 Mw7.6 Nicoya Earthquake

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We apply a recently developed waveform matching technique to obtain a more complete earthquake catalog around the 2012 Mw 7.6 Nicoya earthquake. Starting with a preliminary catalog from SimulPS that incorporates a regionally-defined 3D seismic velocity model, we relocate ~7800 events with new phase picks in tomoDD to better quantify their spatial behavior. Relocated aftershocks are mostly clustered in two regions. The first is immediately updip of the major mainshock slip patch, overlapping with a zone of shallow afterslip. The second one is 50 km SE from the mainshock rupture, which exhibited modest coseismic rupture, and little afterslip. Using these relocated events as templates, we scan the continuous recording from 07/01/2012 to the end of 2012. 20 times more events have been detected using 12 times the median absolute deviation (MAD) as thresholds for the mean cross-correlation values. The early aftershocks appear to expand along both trench parallel and normal directions for both clusters with logarithmic times following the mainshock. In addition, we search for repeating earthquakes with CC values larger than 0.9, followed by additional relocation to ensure that their source patches have significant overlaps. We have identified approximately 50 repeating clusters with at least 4 events per cluster. Most repeating clusters occurred immediately updip of the mainshock slip region with significant afterslip, suggesting that they were driven by afterslip on the plate interface. In contrast, very few repeating clusters were found in the southern edge of the peninsula, a zone with little afterslip. The amount of post-seismic slip estimated from

O201 Aspectos Científicos y Filosóficos Para el Diseño Sismo-Resistente Considerado

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Se presenta en este trabajo los aspectos científicos de la amenaza sísmica considerada para el cálculo estructural de edificaciones en Costa Rica. Se muestran las diferentes zonas sísmicas del territorio costarricense y el valor máximo de la aceleración pico efectiva para sismos con diferente período de retorno.

Se establece la demanda sísmica para obras normales según el sismo de diseño que es determinado como aquel que tiene un 10% de probabilidad de excedencia en un período de 50 años, es decir un sismo con un período de retorno de 475 años.

Se consideran las características del suelo donde se reemplaza la edificación y su efecto en la demanda. Se tienen clasificados 4 tipos de suelo y se ofrecen los espectros de diseño para cada tipo de suelo.

Las edificaciones se clasifican en 4 grupos, y según el grado de detalle estructural de refuerzo se les asigna un valor de ductilidad. La ductilidad es la capacidad de la estructura de deformarse más allá de su límite elástico.

Posteriormente según el valor de ductilidad que la obra demanda durante el sismo, y que es garantizada en la estructura vía el detallado estructural, se calculan las fuerzas sísmicas y con ellas se calculan las resistencias requeridas de la obra debida a la acción sísmica.

Se calculan también los desplazamientos laterales que experimentan los pisos de las edificaciones de manera que no superen los valores que causan daño no estructural y que podrían generar inestabilidad lateral.

El Código brinda una serie de requisitos y lineamientos para el detallado y armado de las secciones de los elementos que permitan el desarrollo de las ductilidades consideradas en el diseño.

O203 Interseismic velocity field and coupling along the Ecuador Subduction interface in relation with the 2016 Pedernales Earthquake

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On April 16 2016, a magnitude 7.8 earthquake occurred along the Nazca-South America plate interface near the city of Pedernales in Ecuador. GPS measurements in the years prior to the earthquake had indeed shown a partial and spatially heterogeneous pattern of interseismic coupling in central-northern Ecuador (Nocquet et al., 2014, Chlieh et al., 2014). Here, we revisit these models using an updated velocity field including mostly continuous GPS. We find a family of models allowed by the data and discuss their correlation with the slip distribution found for the 2016 Mw 7.8 Pedernales earthquake. Additionally, we investigate if precursory signals were recorded in the GPS time-series prior to the 2016 event. Finally, we present a slip budget for the Ecuadorian subduction since the Mw 8.8 1906 earthquake and discuss its implication for the segmentation and seismic hazard along the north Ecuadorian subduction

O204 Rupture process of the Mw 7.8 2016 April 16 Pedernales earthquake from near field data

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Thanks to a coastline located always less that 85 km from the trench and a shallow dipping subduction interface, we could precisely observe the Mw 7.8 2016 Pedernales earthquake using a dense array of GPS, high-rate GPS and accelerometers in the near field of the rupture and record the dynamic motion right above or very close to the rupture. We find maximum static displacements of the order of a 1 m at the coastline and a few centimeters in the Cordillera. Rapid decrease of co-seismic displacement north of latitude 0.1°N and 0.4°S constrain of the rupture extend to be less than 120 km long. Kinematic inversion reveals that the rupture propagated southward and had a maximum slip area near the Pedernales city where damages were the most severe. We find a moment of 5.3E20 Nm equivalent to Mw 7.8. Since the earthquake occurs in the same area as the 1942 Mw 7.8 earthquake, the seismic slip budget seems to exceed the slip deficit budget since the Mw 1906 great Ecuador-Colombia earthquake.

O205 Focal Mechanisms and Spatio-temporal Distribution of the 16 April 2016 M7.8 Pedernales Ecuador Aftershock Sequence

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On 16 April 2016, a magnitude 7.8 earthquake occurred along the Nazca-South America plate interface near Pedernales, Ecuador. Occurring at a depth near 17 km, this event caused extensive damage and claimed the lives of over 600 people in spite of no significant tsunami being generated. Within three weeks of this event, a robust aftershock sequence triggered over 390 events of magnitude greater than or equal to M3.5. These events were initially restrained to the along-strike extent of the mainshock rupture. Within days, however, the aftershocks began to show a distinct migration towards the south near Manta, and slightly northwards near the Atacama Promontory. The Manta aftershocks are especially intriguing since their spatial imprint has expanded and the event rate has stayed steady over the past several weeks. This contrasts with the event rate of the aftershocks near the Atacames Promontory which at the time of this writing have effectively ceased. For the several events large enough to facilitate a moment tensor analysis, we find that their solutions are void of any extensional mechanisms indicating residual stresses are constrained to the main plate interface or thrust-type geometry in the overriding plate. An effort to relocate and potentially recover faulting geometry for event less than M5 is under way. Finally, an initial b-value analysis of the seismicity before the mainshock was performed. Preliminary results indicate a subtle but consistent decrease in the b-value beginning 1.5 years prior to April 2016. The significance of this trend is still being determined, but if confirmed would echo similar studies showing a gradual increase in the state of stress prior to large megathrust events such as the Tohoku-Oki (2011) and Sumatra (2004) events.

O206 InSAR analysis of Ecuador Earthquake using Sentinel 1A imagery

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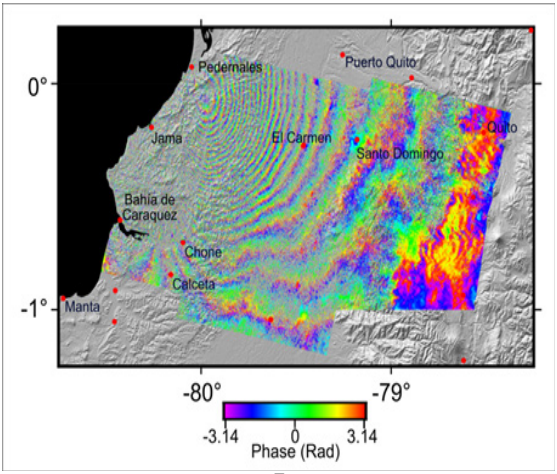
On April 16 2016 Ecuador was shaken by the most powerful earthquake of the last 40 years at a depth of 19km, and the fatality count has reached 660 based on United Nations reports (OCHA). The epicenter was centered approximately 27km from the towns of Muisne and Pedernales and 170km from the capital Quito. The mainshock registered magnitude of 7.8Mw and was followed by subsequent aftershocks that reached 6.1-6.2 magnitude ~25km west of Muisne around 3:30am local time.



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ig. 1: Sentinel-1A interferogram of the ground deformation due to the April 16th earthquake, Pedernales, Ecuador

During earthquakes the earth's surface is deformed; synthetic aperture radar interferograms (InSAR) technology can measure this vertical movement of the crust using two images of the same area taken at different dates, one before the earthquake and the other one after the shock. We used radar images from the ESA Sentinel 1A satellite to compute coseismic interferograms of the very April 16 Ecuador earthquake. In Fig. 1 the first image was taken on 29 March 2016 before the earthquake and the second one on 24 April after the earthquake had occurred, both in descending orbit wide swath mode. This mode images in three sub-swaths using the Terrain Observation with Progressive Scans SAR or TOPSSAR. On the interferogram shown the rainbow-colored fringes, can be similarly interpreted as the elevation contours;the topography is deducted in either image in order to only reveal the elevations changes that were caused by the earthquake. The focal parameters of the earthquake determined by GCMT are consistent with rupture along the plate interfaceof the convergent plate boundary, where the Nazca Plate is subducting beneath the South American Plate. The megathrust earthquake ruptured approximately the same area as major earthquake that occurred in 1942. In this study we present the preliminary results of the deformation maps and modeling to estimate the slip distribution of the mainshock. The data include InSAR ascending and descending orbits.

ABSTRACTS

O207 Detailed Spatio-Temporal Evolution of Aftershocks and Repeating Earthquakes Following the 2012 Mw7.6 Nicoya Earthquake

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We apply a recently developed waveform matching technique to obtain a more complete earthquake catalog around the 2012 Mw 7.6 Nicoya earthquake. Starting with a preliminary catalog from SimulPS that incorporates a regionally-defined 3D seismic velocity model, we relocate ~7800 events with new phase picks in tomoDD to better quantify their spatial behavior. Relocated aftershocks are mostly clustered in two regions. The first is immediately updip of the major mainshock slip patch, overlapping with a zone of shallow afterslip. The second one is 50 km SE from the mainshock rupture, which exhibited modest coseismic rupture, and little afterslip. Using these relocated events as templates, we scan the continuous recording from 07/01/2012 to the end of 2012. 20 times more events have been detected using 12 times the median absolute deviation (MAD) as thresholds for the mean cross-correlation values. The early aftershocks appear to expand along both trench parallel and normal directions for both clusters with logarithmic times following the mainshock. In addition, we search for repeating earthquakes with CC values larger than 0.9, followed by additional relocation to ensure that their source patches have significant overlaps. We have identified approximately 50 repeating clusters with at least 4 events per cluster. Most repeating clusters occurred immediately updip of the mainshock slip region with significant afterslip, suggesting that they were driven by afterslip on the plate interface. In contrast, very few repeating clusters were found in the southern edge of the peninsula, a zone with little afterslip. The amount of post-seismic slip estimated from repeating cluster is consistent with those from geodetic inversion. Our observations suggest that both mainshock slip and afterslip play significant roles in controlling spatio-temporal evolutions of aftershocks in this region.

O208 Seismic Risk Prevention in Costa Rica: A Successful 39 Year Experience

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Successful seismic risk prevention in a particular country or region is the result of a multitask social and economic endeavor with coordinated participation of engineers from academia, consulting and construction
sectors, as well as other professional groups, together with law enforcers and administrators from both private and public sectors. This paper summarizes the author's experience during 39 years of continuous participation as a founding member of the Costa Rican Permanent Seismic Code Committee, the country's professional group legally responsible for the drafting and dissemination of its Seismic Code, which also advices in technical decisions related with matters of public policy regarding earthquake damage prevention.
The paper reviews the most important activities of the Committee along 39 years, that have materialized in four Codes, published in 1974, 1986, 2002 and 2010, as well as the related professional, technical, educational and legal changes that the country has been able to implement.
Keywords: Seismic Codes, Social Organization

MO_P001 Observations of Remotely Triggered Seismicity in Salton Sea and Coso Regions, Southern California, After Big (Mw>7.8) Recent Earthquakes

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We used the Hauksson-Shearer Alternative catalog of Southern California to search for changes in seismicity rate in the Salton Sea and the Coso regions, southern California, during and after large (Mw>7.8) and remote earthquakes. We analyzed the seismicity in these two regions within 30-day windows before and after the occurrence of five major earthquakes: the 2002 Denali fault, Alaska (Mw7.9); the 2004 Banda Ache, Sumatra (Mw9.1); the 2010 Central Chile (Mw8.8); the 2011 Tohoku-Oki, Japan (Mw9.1); and the 2012 northern Sumatra (Mw8.6) earthquakes. The Denali (Mw7.9) earthquake generated a clear increase of seismicity in the Salton Sea region the day when this remote event occurred, indicating that instantaneous triggered seismicity was likely related with the pass of the surface waves. However, in the Coso region the seismicity rate remained approximately constant during the 30-day observation period. The seismicity after the 2004 Sumatra (Mw9.1) earthquake increased in the Salton Sea region 10 days after this major event but in the Coso region the seismicity rate was approximately constant during the 30-day period after the earthquake. The seismicity after the 2010 Chile (Mw8.8) earthquake increased in Salton Sea 12 days after the event but remain invariant in the Coso region. The seismicity in Salton Sea and Coso regions increased two weeks after the 2011 Japan (Mw9.1) earthquake, suggesting that delayed triggered seismicity was induced after the pass of the surface waves in both regions. Similarly, five and 20 days after the 2012 northern Sumatra (Mw8.6) earthquake the seismicity also increased in Salton Sea and Coso regions, respectively. These observations can be interpreted as evidence of instantaneous and delayed dynamic triggering induced by large and remote earthquakes.

MO_P002 Coulomb Failure Stress modeling of past destructive earthquakes in El Salvador, forecasting the next one

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The earthquakes in January and February 2001 in El Salvador are a clear example of the influence of stress transfer in seismic hazard. The Mw 7.7 January earthquake was an intraslab normal faulting event. This earthquake increased the Coulomb Failure Stress in the volcanic arc, triggering the Mw 6.6 February event. This relationship between subduction and volcanic arc events, could also have been the cause of the seismic series of 1982 and 1986 earthquakes, where the first event increased stresses in the area where the second event took place. In order to make a forecast of future scenarios, we analyze the variation of static stresses in recent decades. The events of 1986 and 2001 appear to have increased the Coulomb Failure Stress in the Guaycume fault. This fault is located to the north of San Salvador, and is likely the responsible for the destructive earthquake of 1917. We present an assessment of the Coulomb Failure Stress variation, the advancement of the seismic cycle implied by the variation of stresses, and a scenario of peak ground accelerations considering the occurrence of an event that involved the rupture of the Guaycume fault.

MO_P003 Dynamic earthquake triggering of long period events in the San Miguel Volcano

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Do earthquakes and volcanoes interact? Energy propagating from earthquakes can change the stress in an area and trigger earthquakes remotely (more than 2 faults lengths away from an epicenter). The internal state and activity of an active volcano may be disturbed by changes caused by the passage of seismic energy. The San Miguel Volcano, located in El Salvador, is a highly active stratovolcano that last erupted in December 2013. San Miguel has not been extensively studied and presents a significant hazard to the region actively releasing volcanic gases, historic flank eruptions, and fissure activity. To investigate the internal processes of the volcano, we used data collected from a network of six UTEP seismic sensors recording ground movement from 2007-2008 located around the volcano. Manually analyzing the seismic data, we found 9 regional earthquakes that appear to have triggered a long period response from the volcano mostly during the passage of the surface waves. We compared 5 earthquakes of similar magnitude and distance that did not trigger a long period signal. These earthquakes lacked a strong surface wave signal based on the (LG/P) ratio. We calculated the peak dynamic stresses (PDS) of the triggering earthquakes and found that they had a PDS of at least 0.01 mPa. We conclude that the long period response of the volcano was triggered by the interaction of the volcano and the abrupt surface waves from the regional earthquakes, and we are currently investigating mechanisms for this long period response

MO_P004 Near Surface shear wave velocity increase trend estimation from dispersion curve and its utilization for H/V curve technique at a sediment filled crater site, Sao Paulo Brazil

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The parameters shear wave velocity and soft sediment thickness are very important for the site investigation such as engineering application or microzonation. Shear wave velocity has an average velocity increase trend up to the bedrock,This velocity increasing trend can been obtained from the knowledge of two known variable (shear wave velocity at one meter depth β_0 and the velocity increase dependence on depth x). The velocity at one meter depth β_0 and depth dependence of velocity increase x both these values are obtained from the borehole data which is hardly amiable at each site .We have tried here to utilized MASW data to obtained these two variable (β_0,x) from best fitting the shear wave apparent velocity values versus depth plot. Later we have utilized the newly suggested H/V based average thickness formula to find out the composite thickness which comprised of arbitrary numbers of sub layers thicknesses of Functionally Graded Material (FGM) over bedrock. We have checked this approach for two theoretical model to test its validity, latter this is applied to seismic ambient noise data recorded at meteorite impact based crater, which is filled by very recent soft sediment. Thickness measurement estimated via this procedure are consistent with the results of other geophysical technique performed at same location.

MO_P005 Intraplate seismicity in mid-plate South America: Correlations with geophysical lithospheric parameters

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Mid-plate South America remains one of the least studied regions of intraplate seismicity. Little is known about the origin and controlling factors that make this area the least seismically active intraplate region in the world. We analyzed the distribution of intraplate seismicity and its correlation with several geophysical and geological lithospheric parameters in an attempt to establish which factors might promote or inhibit the occurrence of intraplate earthquakes. We found that above average seismicity occurs mostly in Neoproterozoic fold belts, associated with areas having a positive gravity anomaly, lower elastic thickness, higher heat flow, thinned crust and a negative S-wave anomaly at 100 km depth (associated with non-cratonic crust). Cratonic areas with a higher elastic thickness and lower heat flow are associated with low rates of seismicity. Our study suggests that the most important controlling factors are elastic thickness and heat flow. We propose that earthquake-prone areas with these favorable conditions correspond to regions of weakened lithosphere, where most of the regional lithospheric stresses are supported by the overlying brittle upper crust. These areas act as local concentrators of the regional compressional stress field, with the stress build-up then leading to the occurrence of intraplate seismicity.

MO_P006 Electromagnetic signals and seismicity on the central region of Colombia

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The tectonic convergence process, which takes place in the north-west part of South America, due to Nazca, Cocos, South American and Caribbean Plates interaction has been aim of study with different methods; however, most of them have been applied one after another, not simultaneously, resulting on an extended in time set of data, which includes contributions from different methods applied in different time periods.

Such methods have been applied in the central region of Colombia, particularly in the Bogotá's Savannah. This region is of great interest because of the significant race of the number of seismic events of different magnitudes in recent times. This phenomenon requires additional studies in order to clarify, which is the influence of the particular natural tectonic processes, and, which the intense petroleum exploitation activity developed nowadays.

A number of multiparametric stations are being deployed in the central region of Colombia. The measurements are already providing electric, magnetic and seismic signals. Some of the stations also include radon gas sensor and GNSS data. Here we will show the records and results of instrumental deployment and we will discuss the hypothesis of the electromagnetic perturbation as precursor of seismic events.

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MO_P007 Análisis de la deformación actual del Valle Central a partir de mecanismos focales y mediciones GPS entre el 2010 – 2015, Costa Rica

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En este estudio, se presenta la distribución espacial de la sismicidad desde el año 2010, junto con los mecanismos focales obtenidos a partir de las primeras polaridades en el programa FOCMEC para sismos pequeños y moderados localizados con al menos 20 asociaciones a en los bordes de los Cerros de Escazú-Alajuelita y en las faldas del arco volcánico actual. Las propiedades estadísticas de los mecanismos focales proporcionan información cuantitativa sobre la dirección de esfuerzos en los ejes ortogonales de compresión y tensión.

Se incluyen los resultados de 6 estaciones continuas de GPS cuyos datos proporcionan un nuevo conocimiento sobre la dirección de esfuerzos corticales en términos del campo de desplazamientos y las propiedades mecánicas de las zonas de cizalla que imperan a gran escala sobre el valle Central.

El objetivo de este trabajo es proporcionar un análisis exhaustivo del campo de esfuerzos que afecta al valle central de Costa Rica. Proponemos un modelo de deformación para dicha morfoestructura con el fin de comprender mejor la dinámica de la región interior del país.

La dilatación calculada a partir de los vectores de velocidad GPS sugiere que los Montes del Aguacate presentan una dilatación positiva moderada, mientras que los cerros de Escazú presentan una dilatación negativa fuerte. La distribución espacial de los sismos muestran 7 sectores donde se concentra la sismicidad. La suma de eventos sísmicos significativos han permitido estimar las tasas de deformación locales y regionales en el valle central.

La dilatación Positiva es coherente con los mecanismos focales que muestran un régimen de tensión en los Montes del Aguacate. Mientras que el sector donde ocurre la dilatación negativa no ocurre actividad sísmica. Esto sugiere la que el esfuerzo se puede estar liberando de forma asísmica y generando la exhumación del frente montañoso.

MO_P008 Integrated Static and Dynamic Stress Modeling for Investigating Tremor Source Regions in the San Andreas Fault

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The frictional and stress conditions at aseismic depths in tectonic boundaries are difficult to estimate, these are important parameters in computing stress transfer from plate motion to the seismogenetic zones of the plate boundaries, and thus, in creating seismic hazard models. Ambient and triggered tectonic tremor can be useful in the estimation of friction and stress parameters at large crustal depths. Seismic waves can trigger tremor in tectonic environments, specifically in the San Andreas Fault. A large number of ambient and triggered tremors have been reported near the creeping to locking transition zone along the Parkfield-Cholame section of the San Andreas Fault as well as in the San Jacinto and Calaveras Faults, both triggered by the 2002 Denali Fault earthquake. Ambient and triggered tremor along California is well located and documents well due to the large number of seismic stations in the region. We use recorded seismic signal from magnitude > 7.5 earthquakes to calculate the dynamic stresses capable to trigger tremor in these regions; this is integrated with local tectonic stress models with the objective to estimate the spatial variability of frictional and stress parameters along the areas where tremor are triggered. Integrating static and dynamic stress for San Andreas Fault will allow us to better understand the stress and frictional conditions necessary for tremor occurrence.

MO_P009 Automatic Earthquake Solutions - Quality Assessment and Dissemination

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Rapid Automatic Earthquake detection, location, magnitude assessment and notification are key tasks that a seismological center achieves by making use of its real-time availability and processing of seismic data. This information, which is generally immediately available, needs to be disseminated to stakeholders and the general public through various media. However, prior to this notification process, it is necessary to ensure the quality of both location and magnitude given their intrinsic uncertainties caused by systematic and random errors. To assess the quality of our automatic solutions, we select a dataset, covering approximately one year, from the automatic and reviewed earthquake catalog, to determine which parameters control the quality of an automatic solution. These key parameters become the filters that an autosolution must pass to be reported to decision makers, the media and the general public. In addition, we evaluate the previous outcomes to determine whether or not those parameters are applicable throughout Costa Rica or need to be regionalized. Autosolutions are disseminated using different media such as social networks, email, mobile text messages and an application developed for this purpose. Once users access the information, or they are notified through the mobile application, they can also provide feedback. This is achieved through posts on social networks or the mobile application. The latter is currently being tested and it aims to simplify the collection and classification of observed MM intensities, which will be stored in a database for further processing, such as the generation of shakemaps.

MO_P010 Differences in the lithosphere seismic structure along the Brazilian continental margin from travel time seismic tomography

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Results of the P-wave travel-time seismic tomography method allowed observing differences in the seismic behavior of the lithosphere along the Brazilian continental margin. High velocity anomalies have predominance in the northern portion, which extends from the state of Rio de Janeiro to Alagoas States (between latitudes -22.5 and -8.5), and low velocity anomalies in the southern portion, which extends from Rio de Janeiro to Rio Grande do Sul States (between latitudes -22.5 and -30). Low velocities coincide spatially with the offshore high seismicity areas, as indicated by Assumpção (1998), and the north (high velocities) with low seismicity regions. The high velocity anomalies at northern portion are related to the cratonic and low-stretched lithosphere of San Francisco block that was connected to the Congo block before the opening of the Atlantic Ocean. Low velocities can be assigned to more stretched and weakened lithosphere, where it started the South Atlantic Ocean opening process. The oldest lithosphere in the South Atlantic, indicated by the magnetic anomalies of the oceanic floor, is higher in the southern part than in the northern part, suggesting that the continents in this region were separating, while the northern region was still connected to Africa, which could explain the lithospheric stretching process.

ABSTRACTS

MO_P011 Actividad sísmica en Sandra Ridge – Cuenca de Panamá

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Han sido estimadas soluciones hipocentrales de 209 eventos registrados por cuatro (4) OBS desplegados en la Cuenca de Panamá, alrededor de rift oceánico "Sandra Ridge". Las observaciones de arribos fueron complementadas con datos de varias redes sismológicas permanentes continentales (Colombia, Ecuador, Costa Rica y Nicaragua). Fue utilizado un modelo de velocidad derivado de las observaciones del pozo 504-B del ODP mediante búsqueda iterativa con el código Velest (Kissling et al., 1994). Adicionalmente, fueron estimados valores de atenuación de ondas coda mediante dos aproximaciones metodológicas (modelo de retro-dispersión simple y el modelo de dispersión isótropa simple) con el fin de establecer anomalías de propagación que pudiesen estar relacionados con actividad magmática en Sandra Ridge. Finalmente, fueron estimados mecanismos focales para establecer aspectos cinemáticos de las fuentes.
Además de evidenciar actividad tectónica en esta estructura, muchos de los eventos localizados resaltan actividad a lo largo de la Zona de Fractura de Panamá. Para la misma zona, se aprecia como las anomalías de atenuación coinciden con la distribución de anomalías de flujo de calor reportadas por otros estudios. En este trabajo se hipotetiza sobre la naturaleza de estas anomalías y la actividad sísmica en la zona.

MO_P012 Seismic Anisotropy in the Paraguay-Araguaia Fold Belt, Brazil

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Modern and ancient tectonic processes can be deduced by studying the seismic anisotropy present in the Earth's lithosphere and asthenosphere. With the number of seismograph stations in the Paraguay-Araguaia Fold Belt, the region located in southeastern Amazonian Craton that has very complex tectonic, has been allowed investigating the deep anisotropic effects and, if possible in the crust. For that, we use the analysis of shear wave splitting from teleseismic SKS and SKKS phases through the methods of rotation-correlation (Bowman & Ando, 1987), eigenvalue and minimum energy (Silver & Chan, 1991). Data measurement was made from stations ARAG, AQDB, PP1B, PTLB, and SALV, added to data obtained previously by other authors, covering most of the study region. The average of the results adjusted to one single layer obtained in these stations for the fast polarization direction (anisotropy direction) and the delay time (anisotropy thickness) was 78° and 1.5 sec, respectively (except for PTLB station), which showed the direction of anisotropy, being similar to the previous results by others authors. The consistency of these results in reference to prediction of mantle flow model (Conrad et al, 2007) and the absolute plate motion described by the hot-spot reference model HS3-NUVEL-1A (Gripp & Gordon, 2002) suggest that the fast polarization directions can be related to the direction of deformation between the asthenosphere and lithosphere due to plate motion. Also we been performing the adjustment of anisotropy to two layers, but the non-oneness of adjustment resulted in different estimates which prevented a satisfactory preliminary conclusion. As a next stage, we intend to improve these estimates and, from fast polarization directions for the upper layer, check if there are influences of local geological structures, or even, regional as the Tansbrasiliano Lineament.

MO_P013 Getting Ground Truth events from quarry blasts knowing location, but not the origin time

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In Brazil mining blasts are systematically made at different locations with sufficient energy to be detected at distances up to 1000 km. For these events the locations are known properly with a precision from zero to 2 km. However, the origin time is not accurately measured by the mining staff. In the Carajas mine, located in the State of Para, northern Brazil, at least one big blast is made by month, which could be converted in a GT0 event if origin time was accurately controlled. In the construction of the hydroelectric power plant of Belo Monte, also in Para State, many detonations along a 20 km extension channel were made. Around the reservoir of this plant there is a local network with three stations that recorded very well most of the detonations. Six of them were selected for studies, which were registered by all the stations of local network and some regional stations of the Brazilian Seismographic Network. This work aims to bring these explosions to attend GT0 or GT2 events requirements by measuring the origin time accurately.
Controlled experiments were made very close to the quarry blasting in order to obtain stations corrections and subsequently, the origin times. To validate the method we use these stations corrections to locate the reference events. The result was very close to the true epicenter.
This work will contribute with the development of a three dimensional velocity model for South America as it increases the number of Ground-Truth events in Brazil.

MO_P014 Mantle discontinuities images across stable South American continent

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We stacked receiver functions traces from all Brazilian Seismographic Network (RSBR) stations to obtain cross sections images of major mantle discontinuities in the stable South American territories.
Processing consisted in selecting events with magnitudes ≥ M5 in the distance ranges from 30° to 95° degrees, visually inspecting traces, estimation of the P-wave energy azimuth, rotation into the LQT system (using the estimated azimuth and theoretical incidence angle) deconvolution to obtain the Q-component receiver functions traces and stacking along profiles. Deconvolution used a high pass 0.02 Hz filter. Before stacking all traces were move-out corrected by a ray-parameter of 6.4 s/° in the IASP91 model allowing for stacking traces from different events in different stations that suffered conversion at the same piercing-point defined area. Stacking process was done by considering piercing points locations at depth of 520 km computed using a IASP91 model. Interpretation and results are presented along sections constructed to image know important tectonic provinces.
Most of the studied regions presented normal expected depths for both discontinuities. Variations observed are mostly related to the craton high speed roots that shifts-up time images of the discontinuities under it. This effect could be mapped under the San Francisco craton and under the Amazon craton. A new, not yet documented observation is the interference of the Nazca Slab to the 660 km discontinuity just under the Pantanal/Chaco basin that could potentially, when understood, help to interpret its formation and evolution during the recent history.

MO_P015 The South – Eastern Brazilian Seismological Network and the Brazilian Seismological Portal

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Brazil has recently implemented its seismological network (RSBR) and this paper presents the RSIS sub-network run by Observatório Nacional (ON) in Rio de Janeiro (www.rsis.on.br) comprising 18 broadband seismological stations of high performance and continuous operation covering most of the south eastern coast of Brazil, two of them located in Trindade and Abrolhos islands.
The total RSBR network comprises about 80 stations divided into 4 sub-networks run by University of São Paulo (USP), University of Brasilia (UnB) and University of Rio Grande do Norte (UFRN). It has solved an old problem of the Brazilian Seismology and now all the data is acquired, evaluated, stored and shared to all interested researchers and community in general. IRIS keeps a back-up copy of all data acquired by the Brazilian network.
All stations within the RSIS network transmit data in real-time via cell-phone links and data is real-time shared using SeedLink - SeisComP3. Archived data is distributed via ArcLink service.
Each seismological station within RSIS possesses STS 2 or STS 2.5 seismometer and Q330 Quanterra acquisition systems, operating with solar panels. The acquired data is used to help solve the most common daily problems: local magnitude into the real-time earthquake processor, website plugins, regional earthquake catalog, etc.
ON is also responsible for running the RSBR Portal where all stored data is made public. In this Portal, it is provided information about stations, including photos from locality, dataless files, mini seed data completeness, PQLX spectra for quick assessment of data quality and news regarding seismic events in Brazil. All the seismological data are kept on a secure database server at ON premises and are available for downloading.
The RSBR network was implemented using funds from Petrobras. Its maintenance is now assured for the next 2 years through funding from the Brazilian Geological Survey – CPRM.

MO_P016 Waveform cross correlation to discriminate natural and artificial events

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Discriminating seismic signals generated by artificial events (explosions) and natural events (earthquakes) is sometimes a challenging task for manual seismic analysts, especially when the two sources have similar location. Here we propose a method for automatic seismic event discrimination between natural earthquakes and mining blasts based on cross correlation. In this work, the essence of cross correlation as a monitoring tool consists in a continuous comparison of waveforms in order to identify similarities between them. We highlight the case that has been occurring near the Funil reservoir, located in the southern part of the Minas Gerais State, Brazil, where several mining industries carry out explosions in a region with natural seismicity. Therefore, the seismic events are composed of explosions and natural earthquakes with similar location and magnitudes.
The waveform database was obtained from a local seismograph network composed of six stations installed by the Seismological Observatory of the University of Brasília (SIS) in the Funil reservoir area jointly with the Funil consorcium.

MO_P018 Determination of magnitude and epicenter of historical earthquakes in Brazil by inversion techniques using intensity attenuation curves: application to the 1861 and 1950 events

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This study aims to determine the epicenter and magnitude of historical earthquakes of 1861 (mb=5) and 1950 (mb=3.9), through the implementation of an inversion algorithm and compare the results with the Boxer program (Gasperini et. al., 1999).
An inversion algorithm was implemented with the Nelder-Mead technique (Nelder and Mead, 1965), using the Intensity Attenuation Law applicable to Brazilian earthquakes with magnitudes between 3.5 to 5.5 and intensities III to VI (MM) (Assumpção and Burton, 1985). The earthquakes of 1955 (mb=6.2) and 1998 (mb=5.2), with known instrumental measurements, were used for testing. The inverse problem searches for the magnitude and epicenter of the earthquake that minimizes the objective function (rms deviation of the intensities) by the Nelder-Mead algorithm. The results were satisfactory and provided subsidy to evaluate the applicability of the proposed methodology for the historical earthquakes of 1861 and 1950.
The Boxer method was also tested to determine the parameters of the 1955 and 1998 earthquakes. For this, we used the attenuation coefficients derived for Italy, and also those for the Continental Stable Region in Europe (Gomez-Capera et. al., 2014). The same procedures were applied to the historical earthquakes of 1861 and 1950.
When the distribution of macroseismic data points (MDP) show a clear trend of higher and lower intensities, such as the 1998 and 1955 earthquakes, the Nelder-Mead inversion gives a better epicenter (closer to the instrumental) than the Boxer method (which assumes the epicenter is within the area enclosed by the MDPs). When the intensity distribution is more scattered or subject to larger uncertainties, such as the 1861 event, the Boxer method gives more reasonable results. For the 3.9 mb earthquake of 1950, with good MDP distribution in a small area, the two methods give similar results.
Keywords: Historic Earthquakes, Inversion Intensities, Boxer.

MO_P020 Upper mantle transition zone underneath Southern Peru

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Receiver functions (RFs) from 226 temporary stations and one permanent station in southern Peru were used to characterize the upper-mantle transition zone in that region. Discontinuity at 410 km depth is similar to iasp91, while the discontinuity at 660 km depth is slightly deeper, on average, compared to iasp91, which reflects a slow velocity anomaly in the upper mantle. A low velocity layer on top of the 410 is identified. In general, the RFs show a complex behavior, similar to Central and Southern Mexico (Pérez-Campos and Clayton, 2014), where the mantle has been disturbed by the subducted slab.

MO_P021 Subsurface boundaries of the San Francisco and Amazonian cratons from travel time seismic tomography

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Deep structures of the Earth it has been the object of study researchers. Among the geophysical methods applied in this sense, the seismic tomography method allows to obtain large scale structures images great depths. In South America, seismic tomography studies have been performed obtaining three-dimensional images of cratons in addition to other tectonic structures (e.g. Bastow et al., 2008; Rocha et al., 2011; Scire et al., 2014; Azevedo et al., 2015). Among the studied structures, beneath the San Francisco craton the emphasis is in the extension of this craton beyond its surface boundaries, as was initially proposed in geology and gravimetry studies by Alkmim et al. (1993) e Ussami, (1993). More recent studies (Assumpção et al., 2004; Rocha et al., 2011; Azevedo et al., 2015) reinforce the hypothesis that this craton is part of a larger block in the subsurface. The Amazonian Craton was observed as a large high velocity anomaly in the studies by Heintz et al. (2005) and Feng et al. (2007), using surface wave tomography. In this study, recent results of travel time seismic tomography have improved the resolution of tomography images already used in Rocha et al. (2011) e Azevedo et al. (2015) allowing propose a delimitation in the subsurface of the San Francisco and Amazonian cratons, where high velocities anomalies were observed along these cratons. This characteristic is generally observed in cratonic regions because they are stable regions (old). Another important factor is that these anomalies extends beyond of the geological boundaries of the surface, especially in San Francisco craton agreeing with previous studies. A model of the subsurface boundaries these cratons was proposed in this study.

MO_P022 Studying Active Faults in Colombia using High Precision Geodetic Tecniques: A new challenge

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High precision geodetic measurements of surface deformation constitute the fundamental tools for the study of the behaviour of active faults. These measurements, taken during post-seismic and interseismic intervals, are essential for estimating the accumulated deformation and the rheologic properties of faults. With this in mind, the GeoRED Project of the Colombian Geological Survey has embarked on a program of geodetic analysis of some of the most important faults that mark the Northwestern corner of South America a region known for its extremely complex tectonics. The geodetic arrays of space and/or terrestrial geodetic data acquisition have been projected in specific segments of some of the major fault systems of Colombia, such as the Algeciras, Ibagué and Bucaramanga Faults, and the Colombian sector of the geological feature known as Bocono Fault of the Merida Andes in Venezuela. Site selection of geodetic field stations are based on the results of prior neotectonic surveys complemented, if possible, by detailed paleoseismological studies. This will permit the identification of the most suitable sites likely to have sufficient sensibility for the detection of subtle changes in position that permit the registration of elastic deformation of the crust conform a model with locked faults that, on reaching the elasticity limit of the crust, will be subject to sudden elastic rebound with the concomittant liberation of accumulated energy during a seismic event. The crustal elastic deformation will be monitored by means of the registration of changes in the georeferenced positions of the GNSS stations. Against the background of this promising panorama, we present the state of progress that the GeoRED Project is making in the application of both space and terrestrial high precision techniques in the study of the active faults mentioned above.

MO_P023 Morphology tectonic and seismotectonic of Agua Caliente and Navarro faults

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Costa Rica is located in a region affected by the interaction of three tectonic plates, which has directly in the formation of different fault systems along the whole nation. Often this faults can be found near or even near the Great Metropolitan Area (Gran Area Metropolitana, GAM), where most of the population lives. An example of this are the Agua Caliente and Navarro faults systems, located near Cartago City; where residences, important industrial free taxes zones and mayor agrobusiness can be found. This systems have been characterized as part of the limit between the Caribbean Plate and Panama Microplate, in a diffuse fault zone named Central Costa Rica Deformed Belt (CCRDB). The earthquake of May 4th 1910, which had a magnitude of 6,4 Ms, was associated to the Agua Caliente fault system, and it`s been considered as the deadliest earthquake in the history of Costa Rica. Also caused the seismic swarms of June 5 to 10, October 25 and November 2 1994. In the case of the Navarro fault system it is believed that it caused The August 9 1951 Paraiso-Orosi earthquake (5,0M). This study is developed due the importance that this faults represents, and it`s focus in the tectonic geomorphology and the seismicity associated to each system. It is intend to create digital models in 3D, obtain by RTK type GPS to trace the main fault where presence has been inferred. In a complementary way, using a compilation of seismic data from the area, using the SEISAN program, is attempted to develop focus mechanism from the mayor events, in order to determinate the type of movement all along the trace. Finally, a detailed anWalysis of the results, with interpretation of the faults studied will be done.

MO_P024 Relación entre estructuras-esfuerzo y sismicidad en los sectores de Puriscal-La Guácima, Costa Rica

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En las zonas de Puriscal y la Guacima al suroeste del Valle Central, Costa Rica, han ocurrido varios sismos moderados, desde la década de los 90´s hasta el más reciente en Julio de 2014 con un evento de magnitud de ML 4.7 en la Guacima. Con base en el perfil geológico estructural, relacionamos los sismos de Puriscal con la Falla Candelaria y los sismos de la Guácima con la Falla Jaris.
Nuestro enfoque se basa en el análisis de la orientación de los ejes P y T para cada solución focal basados en la teoría de Wallace-Bott donde el deslizamiento sísmico ocurre en la dirección de tracción de cizalla. En este estudio se utiliza un conjunto de 40 soluciones focales para los enjambres de Puriscal y la Guacima desde el 2010 al 2015.
Estos datos graficados en un círculo de Mohr muestran: 1) En Puriscal, 7 de 15 sismos están situados en el semicírculo superior, lo que implica que la ruptura se da, al menos en la mitad de veces, cerca de uno de los planos de falla y orientado de manera óptima al esfuerzo máximo. 2) En la Guacima solo 6 de 25 sismos tocan la envolvente externa, lo cual indica que el plano de falla está mal orientado con respecto al esfuerzo principal.
La relación de forma o radio de esfuerzos, R, es para Puriscal de 0.23 y para La Guacima de 0.34. A partir de esto y de la ubicación del sigma vertical (□V), se calcula el Régimen de esfuerzos local de la zona, R', con ase en Delvaux, et al (1997), arrojando para Puriscal y La Guacima, valores de 2,23 (Transición Transpresión-Compresión Pura) y de 1,79 (Transición Strike Slip-Transpresión), respectivamente.

MO_P025 Morphotectonic signatures of active faulting and linked seismicity in Central Costa Rica

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As part of a regional research aiming to better understand and characterize the Quaternary to present seismotectonic scenarios, we have detected contrasting values in several morphotectonic indices extracted from a SRTM 1 (30m resolution) DEM covering the western part of the Central Valley in Costa Rica. Our results highlight the effects of active tectonics on the first order rivers. The longitudinal profiles of the Tárcoles river and its tributaries display a major convex zone which differs from the typical concave up shape of stead-state river profiles. Normalized steepness index (ksn) and Chi-plots allows us to map the anomalies in the drainage network. The convex zone extends between Orotina and Alajuela, and is associated to both high ksn values (>200) and high gradient in Chi-plot. This anomaly is possibly related to a regional uplift related to the interaction between the NE- trending La Garita sinistral fault system and the dextral SE-trending Jaris and Picagres faults. Indeed, this area is characterized by well known seismic swarms and destructive earthquakes, and the emplacement of Neogene volcanic flows which correlate pretty well with the anomalies. In the northern part of the Tárcoles catchment, we observe a series of knickpoints aligned with the trace of the E-trending Alajuela thrust, which limits the southern edge of the Central Volcanic Cordillera. These findings contribute to a better understanding of the seismic hazard and ongoing deformation processes in this region where the Caribbean Plate interacts with the Panamá microplate.

MO_P026 Morphotectonic analysis of seismic sources in El Salvador

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We have used hypsometric analysis to improve our understanding of the current tectonic deformation and structure of El Salvador Fault Zone (ESFZ); a ~N90°E oriented strike-slip fault zone that extends 150 km through El Salvador, Central America. Our results indicate an important amount of transtensive strain along this fault zone, providing new data to understand the tectonic evolution of the Salvadoran volcanic arc. We have defined kilometric scale tectonic blocks and its relative vertical movements, length of segments with homogeneous vertical motions and lateral relay of active structures.
This study quantify strike-slip and dip-slip movements in some faults of ESFZ, and lateral changes of the dip-slip and the strike-slip components. We have identified slip-rate variations along-strike of the El Triunfo fault within El Salvador Fault Zone, ranging from 4.6 mm/year in its central parts to 1 mm/year towards the tips of the fault. There could be an important interaction between different faults of the ESFZ. This is evident in the Lempa and El Triunfo Faults detailed study, where there are deformation relays and an accommodation zone between them, interpreted from the results of the topography analysis. This study supports that there is accommodation of the current deformation through the reactivation of pre-existing structures inherited from a previous tectonic regime. The Lempa inter-segment zone is the area where distributed deformation dominates, making this region an interesting zone for future seismic hazard studies because it may be an area acting as a seismic barrier or asperity in large earthquakes along the ESFZ.

MO_P027 Neotectónica de la Falla Cipreses y sus implicaciones en la zonificación del uso del suelo, cantones de Montes de Oca, Curridabat y La Unión

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Ante el crecimiento urbano de la Gran Área Metropolitana, crece la necesidad de conocer las condiciones geológicas del entorno. El Valle Central se caracteriza por tener una alta densidad de fallas geológicas activas, muchas de ellas representan un peligro para los asentamientos humanos que se desarrollan en el centro del país. Históricamente en nuestro país han ocurrido muchos terremotos, algunos de los cuales han sido particularmente destructivos en la zona central del país.
La falla Cipreses atraviesa un sector de los cantones de Montes de Oca, Curridabat y La Unión, a sólo 5 km del centro de San José, zonas de una alta densidad y de crecimiento urbano en la actualidad. En los últimos 15 años la zona circundante a esta falla ha mostrado actividad sísmica por lo que es considerada como una falla activa. En esta investigación se identifica y describe la falla Cipreses a partir de aspectos morfotectónicos y sismológicos con el fin de estimar el tamaño de un evento sísmico en esta área vulnerable ante la ocurrencia de un sismo. Se presentan además localizaciones de los sismos más relevantes registrados por la Red Sismológica Nacional (RSN) y se calculan sus mecanismos focales.
Adicionalmente, este estudio cuantifica la población que está dentro del área de influencia de la falla y analiza la legislación vigente relacionada con la zonas de protección de fallas activas en Costa Rica para comprender la objetividad con la cual se maneja el tema a nivel nacional. Además, se indaga sobre la legislación entorno a la temática de fallas activas a un nivel internacional para establecer un marco de comparación y así hacer críticas y establecer propuestas de zonificación más adecuadas para la parte Central de Costa Rica.

-MO_P028_A Environmental effects triggered by January and February 2001 El Salvador earthquakes: Analysis for hazard assessment

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This paper deals with the analysis of the numerous primary and secondary environmental effects caused by the two destructive earthquakes that hit El Salvador (Central America) on January 13 and February 13, 2001. This dataset has been the basis to evaluate earthquake sizes through the ESI intensity fields, and compare them with the traditional damage-based macroseismic scales.
The January 13 earthquake (Mw 7.7) was located off El Salvador within the subducting Cocos plate. Severe damage and great loss of life was mainly due to the earthquake-induced landslides. More than 5,000 landslides and extensive cracks were recorded over an area of 25,000 km2 in El Salvador. Especially the Las Colinas landslide (about 200,000 m3) had devastating consequences, killing over 500 people. On February 13, a strike-slip earthquake (Mw 6.6) struck the central part of El Salvador causing again many casualties and extensive damage. Associated with the reactivation of the San Vicente segment of the El Salvador Fault Zone, a major regional seismotectonic structure, it triggered additional thousands of landslides over an area of ca. 2500 km2. The earthquake generated two very large landslides: the Rio El Desague (1.5 million m3) and the Rio Jiboa (12 million m3), creating landslide-dammed lakes. Both earthquakes triggered also a number of soil liquefactions as well as lateral spreads, especially along alluvial plains and coastal flats.
The coseismic effects induced by the 2001 earthquakes have been evaluated by means of the ESI-2007 Scale, allowing (1) a detailed picture of the macroseismic fields (200 points), (2) the chance to test the ESI-2007 with the MM intensities, (3) an estimate of the Epicentral Intensity (I0), and (4) useful data for seismic zonation. Our results have confirmed once more the essential role played by coseismic effects in seismic hazard assessment, never to be overlooked in risk reduction programs.

MO_P028_B Archaeological evidence of tsunami deposits in the Lesser Antilles related with the 1755 Lisbon earthquake

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In order to accurately assess tsunami hazard in the oceanic islands, one needs to find more evidence of past events to enlarge the observation time scale window, which is generally related to recent historical records. To that end, evidence of allochthonous sedimentary deposit is a key to go back farther into the past, providing estimates of tsunami maximum inundation, recurrence time and magnitude. However, our field investigation in the Lesser Antilles islands indicates that tsunami deposits in tropical islands are nearly impossible to identify. One noticeable exception concerns deposits that would have been sealed by subsequent human construction. In this paper, we present evidence of an anomalously thick two-layer tsunami deposit in an excavation in Fort-de-France, Martinique, Lesser Antilles. We relate with certainty these deposits to a unique event, the 1755 Lisbon tsunami. The thickness of the deposits can be explained by 2 successive floodings, the first one, producing 1-2 cm layer came straight from the sea, is related to the direct tsunami front waves, and the second one, producing 6-8 cm layer, was due to a tsunami-induced bore. Our interpretation highlights the importance of river catchments in tsunami hazard assessment and also indicates that the tsunami deposit thickness used in tsunami modeling is a parameter that must be carefully checked not to overestimate paleo-tsunamis and to correctly assess the tsunami hazard. Finally, while it was a fortuitous chance for us to find undisturbed tsunami deposits, we can also hypothesize that collaborative geological and archaeological studies of pre-Colombian sites could also reveal paleo-tsunami deposits and enable us to enlarge our observation window and improve our tsunami catalogues in the Americas.

MO_P029 Intensity Attenuation Relationship in Costa Rica

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Seismic intensity is a parameter that describes the degree of ground shaking for an earthquake. It is represented by isoseismal maps, which allow for the direct visualization of earthquake effects. Isoseismals drawn within a few minutes of the earthquake occurrence are particularly valuable for emergency response purposes. In Costa Rica one of the centers in charge of earthquake monitoring is the National Seismological Network of Costa Rica (RSN) located at the University of Costa Rica. In this study we compiled seismic intensity data to develop a new intensity attenuation relationship for Costa Rica. We utilized a dataset of 1575 intensity values ranging between I and IX according to Modified Mercalli Intensity (MMI) scale from earthquakes with magnitudes (Mw) ranging from 5.8 to 7.6 in order to develop an intensity attenuation of the form: $I = a + bM + cR + d\log_{10}(R)$, where a, b, c, d are the coefficients to be determined, R is the hypocentral distance (in km), and M is the moment magnitude (Mw). We aimed to use this relationship with a script already developed to create an automatic intensity map after each earthquake is located by the RSN. The preliminary coefficients obtained are a = 1.006906; b = 1.828731; c = 0.004416; and d = -4.504745. The preliminary results are very consistent with previously published intensity maps for specific earthquakes in the region. The differences found between the automatic and real intensity maps are due to site effects, which are not considered into the regression analysis. Given the history of destructive earthquakes in Costa Rica, studies leading to rapid earthquake products are very important for earthquake emergency response and the assessment of seismic hazards.

MO_P030 Ambient Seismic Noise Levels of OVSICORI-UNA Broadband Seismic Stations

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To characterize and obtain the background noise levels and the geospatial distribution at different frequencies throughout Costa Rica, we are processing all traces of OVISICORI-UNA`s broadband seismic network stations, since 2010 using Power Spectral Density (PSD) and Probability Density Functions (PDFs) (D. McNamara and R. Buland, 2004). Furthermore, we are obtaining the minimum ambient seismic noise level for OVSICORI-UNA´s network. The result will be used as a further reference for new station deployments. In this process we are also comparing the noise levels of seismic stations with the same instrumentation but deployed in different sites and study possible cultural and natural seismic noise contributions

MO_P031 Application of the double difference earthquake location algorithm with HypoDD to four seismic sequences at Central Costa Rica

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In Central Costa Rica several seismic sequences occur each year. A seismic sequence is when earthquakes occur in a short period of time (days to few months) and with little or none hypocentral distance between them. These events can have different magnitudes and can have a recognizable main event.

When seismic sequences are registered at the National Seismological Network of Costa Rica each earthquake is manually located for the national catalog. The analysis and characterization of the sequence clusters and sources is done several months after the sequence presents no further activity.

This study includes four sequences post-processed with manual relocation, cross-correlation, and relocation with a double difference algorithm. The purpose is to give a more accurate location of the source.

The sequences took place in Central Costa Rica at the Caribbean Plate at the Central Costa Rican Deformed Belt; in intervals of 3 to 90 days, with 21 to 64 earthquakes per sequence, and with a moment magnitud range of 2 to 5.1. The minimum number of stations used was 27, with at least 105 degrees of station coverage, and a maximum of 11 km of distance between events.

Several open source programs were used, such as “SeisAn” with “eev” for the manual localization, “corr” for the cross-correlation, “xclust” to separate the events into families, and “HypoDD” for the double difference algorithm analysis, to relocate by reducing travel time errors between earthquake pairs.

After the manual relocation the quality of the earthquake locations fulfilled the requirements for the cross-correlation analysis. After the cross-correlation analysis and several double difference processing the outlier events were eliminated. The results show that it was possible to reduce the hypocentral distance between events on three dimensions and to delimit the source for each sequence.

MO_P032 Detection Threshold OVSICORI-UNA Seismic Network

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We aim to obtain the detection threshold of the OVSICORI-UNA seismic network using ambient seismic noise levels. Ambient noise will be used as an estimate for site response and detection levels at each station, also, we will include a Brune source model for earthquake amplitude and a regional attenuation law. This indirect approach will enable us to generate a geospatial distribution of earthquakes for the lowest magnitude that can be detected and located using the current seismic network. Furthermore, we use noise-level variations at day and night time to see the impact of daily noise on detection threshold. Considering that some stations are located near population centers, with high contribution of cultural seismic noise, understanding which ones have a stronger effect could help redesign the network.

In addition to learn about the geospatial detection threshold, we will use the results to find out where new seismic stations should be installed in order to help reduce the detection threshold for certain regions, and consequently improve the monitoring and location of the seismic activity in Costa Rica and surrounding areas. Current earthquake catalog will be use to test the results.

MO_P033 Depth-dependent periodic change in the interplate coupling at NE Japan inferred from spatial gradient of velocity field

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Uchida et al. [2016, Science] revealed that the interplate coupling between the subducting Pacific and overriding continental plates at the northeast Japan subduction zone periodically changes based on the analyses of the small repeating earthquakes and of surface velocity field. They applied a geodetic data processing for monitoring the spatio-temporal variation of interplate coupling with calculating the spatial gradient of the surface horizontal velocity field within belt-like zones that are taken along the direction perpendicular to the trench axis. Temporal change in the interplate coupling is detected with shifting the time window, and spatial variation along the trench-parallel direction is deduced with shifting the latitude of the belt-like zone. They suggested that the gradient of the horizontal surface velocity depends mainly on the strength of the interplate coupling in shallow portion of the offshore plate interface. The results of Uchida et al. [2016] with respect to the small repeating earthquakes implies that the spatial variation of repeating period of the slow slip depends on the depth along each profile perpendicular to the trench. In this study, I examined the depth dependency of the repeating period of the slow slip on the plate interface by comparing the predominant periods of the temporal changes in the horizontal surface velocity gradients with that of the vertical velocity gradients whose sign correspond to the presence or absence of interplate coupling at the plate interface beneath the land. The result of the examination shows that the predominant period of the temporal change in the vertical velocity gradient is shorter than that in the horizontal component at the most profiles. I will show the potential to detect the depth dependency of the cyclic change in the interplate coupling by using ocean bottom pressure gauges that are included the seafloor networks such as DONET and S-net.

MO_P034 Crustal Kinematics Driven by Aseismic Ridge Collision: Cocos Ridge

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The expansion of regional Global Positioning System [GPS] networks is allowing for improved investigation of modern plate kinematics, and plate boundary zone deformation. Recent GPS observations in the southwestern Caribbean, along the Central American and northwestern South America margins, highlighted the northwestward escape of the Central American Fore Arc and northeast motion of the Panama Region. The motion of these regions is driven by collision of the Cocos Ridge with the western Caribbean plate. Modeling of the GPS derived horizontal velocity field indicated that the Panama Region acts as a rigid tectonic block. Alternative models for the kinematics of the Panama Region have been tested; however, the low spatial density of GPS networks did not allow for adequate testing. Here, we present a new velocity field from an expanded GPS network in Panama that includes new continuous (23) and episodic (2) GPS sites and new kinematic models of the Panama Region testing the hypothesis that Panama Region is not rigid, but cut by isthmus crossing faults. On the other hand, this expanded GPS network captured the coseismic offsets on southwestern Panama due the Mw 6.6 Burica peninsula earthquake on December 08, 2014. Thus, our observations also could be addressed to seismic hazards assessment.

MO_P035 Present day kinematics of El Salvador Fault Zone

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The El Salvador Fault Zone (ESFZ) (Martínez-Díaz et al., 2004) is the main structure seismically active in El Salvador. This structure plays an important role in the tectonics of the Chortis block, since its motion is directly related to the drift of the Caribbean plate to the east and not with the partitioning of the deformation of the Cocos subduction. The geometry and the degree of activity of the ESFZ have been studied from geodetic (Staller et al., 2016), geological and paleoseismological studies (Canora et al., 2012; 2014b; Alonso-Henar et al., 2014).
In this work we use horizontal GPS velocities (Staller et al., 2016), geological and seismological data to investigate the rate and nature of interseismic strain accumulation on major faults along the ESFZ. This allows us to estimate the distribution of interseismic coupling on the subduction zone interface beneath El Salvador and the kinematics of the tectonic block rotations.
Our best model estimates a long-term movement of the Salvadoran forearc of 13.5 ± 1 mm/yr ~NO with respect to the Caribbean plate. The kinematics of the ESFZ confirms an increase in east to west velocity within the forearc block, which is coherent with the regional kinematics of the Chortis Block, as extension is greater in the western part of this block, which combined with the pinning of the forearc block in Guatemala (Álvarez-Gómez et al., 2008), favors east to west strike-slip movement in El Salvador.
We find that the data are best fit with a model that includes two intermediate blocks between the main Caribbean and forearc blocks. Our results confirm that the degree of coupling at the interface of the subduction zone off the Salvadoran coastline is practically zero, however the faults of the Salvadoran volcanic arc are almost completely locked.

MO_P036 The 1976 Guatemala earthquake case study: A contribution to the seismic hazard evaluation

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Guatemala has been repeatedly rocked by violent earthquakes in the last century. February 4th, 2016 recur forty years by the disastrous earthquake of the 1976, the most destructive seismic event associated with the Motagua fault (M=7.5), that caused 23,000 deaths, 77,200 injuries and produced severe damage over a wide area of the country. The coseismic geological effects were a 230 km long strike-slip fault with remarkable displacement and also 50.000 induced landslides, numerous liquefaction phenomena, ground cracks, ground deformation over an area of about 18.000 km2. In spite of this, the estimated intensity was relatively low (Imax= IX MM, in few localities). The aim of this study is to analyse the primary and secondary earthquake ground effects, in order to assess the local intensities according to the ESI scale 2007 (Michetti et al., 2007) thus drawing the new macroseismic field. The analysis of environmental earthquake effects has permitted the evaluation of the ESI intensity in some localities, and to establish a new epicentral Intensity, characterized by Io=XI ESI. The new macroseismic field shows a direct correlation with the fault zone at the surface, infact the general pattern of ESI isoseismal lines is compatible with the rupture mechanism of the Motagua fault and its propagation from ENE to WSW. The recalculated seismic intensity is hence two degrees higher than previous estimates and definitely more consistent with the scenario of the damage caused by the 1976 Guatemala earthquake allowing in the future, a better and more realistic definition and evaluation of seismic hazard of the Guatemala.

Michetti A.M., et al.,(2007). Intensity Scale ESI 2007. Mem. Descr. Carta Geol. d'Italia. 74
Porfido S., et al. (2015) Impact of ground effects for an appropriate mitigation strategy in seismic area: the example of Guatemala 1976 earthquake. Springer -DOI: 10.1007/978-3-319-09057-3_117

MO_P037 Volcanic tremor associated to the eruptive activity between 2014 and 2016 at the Turrialba volcano (Costa Rica)

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The Turrialba volcano is located on the southwest end of the Central Volcanic Range of Costa Rica and is one of the five active volcanoes of the country. During the last 35 years it has been showing a slow awakening that became conspicuous between the decade of 2000 and 2010, at the end of which, a first phreatic explosion opened a new vent at the inner southwest crater wall. Since then, Turrialba volcano has been showing an "in crescendo" activity that reached a new climax at the end of October 2014 and continued, with ups and downs, until the present moment. This work focuses on time-frequency analysis of volcanic tremor episodes (harmonic and non-harmonic) recorded during 2014-2016 in order to characterize it and obtain new insights about the underground dynamics of the volcano, as this is the first time in history of Costa Rica that it is possible to document a volcano awakening by modern seismic means. Close inspection of seismic records using time-frequency analysis have been applied in order to analyze the features of tremor episodes. Non-harmonic tremor is characterized by a wide spectrum with most of the energy between 1 and 15 Hz. In contrast, harmonic tremor presents typical, regularly spaced peaks, at integer multiples of a fundamental frequency, that is usually in the range of 0.6 – 2.0 Hz. Variations of the fundamental frequency on two time scales have been observed; the first in the order of seconds to tens of minutes and the second in the order of months. Further analysis of these variations is carried out in order to establish if tremor signals are a suitable choice in revealing precursory patterns of eruptive activity or if they are more likely associated with changes in the volcanic system along the eruptive stages of the Turrialba.

MO_P038 Análisis de la sismicidad ocurrida en el volcán de San Miguel en los años 2013 y 2014

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El volcán de San Miguel es un estratovolcán de 2130 m.s.n.m., se encuentra al oriente del arco volcánico salvadoreño, a 11 kilómetros de la ciudad de San Miguel, que es el tercer núcleo urbano más poblado del país. Una de sus erupciones más reciente ocurrió el 29 de diciembre del año 2013.Esta investigación analiza la sismicidad ocurrida en el volcán de San Miguel en los años 2013 y 2014, con el objetivo de identificar posibles indicadores sísmicos de aumentos de su actividad. La mayoría de sismos ocurridos en este periodo se localizan en los flancos norte y noroeste del volcán a una profundidad menor a 7 km. La ubicación de éstos coincide con escarpes de coladas de lavas antiguas y fallas con dirección noroeste-sureste que atraviesan el volcán, indicando que la sismicidad está probablemente relacionada con el sistema de fallas locales. Mediante el análisis del contenido espectral y forma de onda de una muestra de sismos, se encontraron cuatro tipos principales de eventos: vulcano tectónicos (VT), híbridos, largo periodo (LP) y explosiones, cuyos enjambres marcaron tanto las etapas pre eruptivas como post eruptivas. Este tipo de eventos están relacionados con rompimiento de rocas, inyección de fluidos y ascenso de magma gaseoso a través de los conductos del edificio volcánico. Mediante el método de mínimos cuadrados, se calculó el valor de b de la relación de Gutenberg - Richter con los sismos localizados, encontrando valores de b mayores a 1.0 lo cual es típico para zonas volcánicas. Los valores más altos corresponden al año 2014, lo cual podría ser indicativo de un mayor flujo de calor, que se evidenció con una mayor actividad fumarólica posterior a la erupción.

MO_P039 Actividad sísmica durante crisis eruptiva del 01 al 09 de mayo del 2015. Volcan Telica, Nicaragua.

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El día 7 de mayo del 2015, a las 04:09 p.m. y 04:15 p.m. el volcán Telica rompió su "estado de calma relativa", que mantenía desde el 26 de septiembre del año 2013, al producir 2 explosiones de gases y ceniza, las que se elevaron unos 200 metros sobre el borde del cráter del volcán. Esto fue el inicio de una actividad que se extendió hasta finales del mes de Mayo en la que se contabilizaron más de novecientas explosiones, de cenizas y gases en su gran mayoría, donde también hubo expulsión de fragmentos de rocas grandes a altas temperatura.
La amplitud sísmica que registró la estación más cercana al volcán Telica se incrementó de 18 a 45 unidades durante las explosiones iniciales, y lo cual fue característico de esta fase eruptiva, en la que el RSAM solamente se incrementó durante las explosiones para luego retornar a su valor de fondo rápidamente. Desde la tarde del 07 de mayo, hasta la noche del día 28 hubo expulsión de ceniza volcánica, pero la gran mayoría de las explosiones fueron de gases y se extendieron hasta el 2 de junio.
El conteo llevado a cabo con los registros sísmicos indica que hubo en total 902 explosiones, de estas 104 fueron acompañadas con ceniza volcánica.
En este mes de mayo, la actividad sísmica fue más alta que los meses anteriores debido a la actividad eruptiva que mantuvo todo el mes. La mayor cantidad de eventos fue entre 1 al 9 de mayo. Las frecuencias de los sismos oscilaban entre 4, 6 y 9Hz.
El tremor volcánico llego a superar las 50 unidades RSAM. Sin embargo las explosiones que ocurrieron llegaron a subir hasta las 1000 unidades RSAM.

MO_P040 Seismicity of Ijaci, southern of Minas Gerais State, Brazil is caused by mining extraction, water extraction or reservoir impoundment?

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Ijaci is a small town located at the southern portion of Minas Gerais State, Brazil, on the southern extension of São Francisco Craton, was shaken on August 14 of 2011 by an earthquake of magnitude 3.2 and intensity (MM) IV-V. On October 5th, November 13th and 23rd, 2011, Ijaci residents were again shaken by earthquakes of magnitudes greater than 2.6.
Surrounding Ijaci, the Funil Reservoir, with a lake of 35 km2 and maximum height of 40m, was formed in December of 2002. At the same time, on its margins, two big quarries started to operate with blast and water table extraction (~340m3/h during 24h/day). The seismic monitoring started on December 21st, 2010. Local events began to be recorded as soon the station started its operation.
After the main event, on August of 2011, a local six stations network was deployed to study the aftershock seismicity. During the six months of continuing monitoring this network detected 1027 events, 608 located, 257 were classified as blasts (artificial) and 284 were classified as natural events.
All the events (natural and artificial) were located very close to each other in the west part of Funil reservoir, surrounding and inside the quarries associated with the metalimestones.
This paper aims to discuss the factors that could be triggering the seismicity in this region, among which stand out.

- The release of gravitational energy, when the limestone of mine is removed. The mines are mainly in a graben structure,
- Fault reactivation as result of mining blasting
- Lowering of water table at limestone mines
- Sudden collapse related to dissolution of carbonate rocks
- The hydroelectric reservoir of Funil, located ~ 2 kilometers from the epicenter

POSTERS TUESDAY SESSION

TU_P001 The Seismic Strong Motion Array Project (SSMAP) and September 5, 2012 (Mw=7.6) Nicoya, Costa Rica Earthquake Investigation

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Seismic gaps along subduction zones are locations where large earthquakes have not occurred in a long time. The Nicoya Peninsula in northwestern Costa Rica was considered a zone with this type of seismic gap. The previous major earthquakes in Nicoya occurred on 1853, 1900 and 1950, which indicates about a 50-year recurrence interval for the characteristic earthquake cycle. With the goals to: 1) record and locate strong subduction zone mainshocks [and foreshocks, "early aftershocks", and preshocks] in Nicoya Peninsula, at the entrance of the Nicoya Gulf, and in the Papagayo Gulf regions of Costa Rica, and 2) record and locate any moderate to strong upper plate earthquakes triggered by a large subduction zone earthquake in the above regions, a seismic strong motion array (SSMAP project) was installed in the Nicoya Peninsula, composed of 10 sites as part of our collaborative research. On September 5, 2012, a Mw=7.6 earthquake occurred in the seismic gap and appears to be the expected event based on the 50 years recurrence interval, but was instead 62 years later. The main shock focal mechanism was thrust faulting of the Cocos plate in the Middle America trench with strike N54W and dip 20 degrees NE. We relocated the mainshock and then 15 moderate aftershocks using the SSMAP, OVSICORI and UCSC networks. Our final location of the mainshock is 9.671 N and 85.878 W. The maximum accelerations from two A900 stations perpendicular to the trench, Fortuna (distance 112km) and Pedernal (distance 128 km) are: 13.8% and 8.9 % g, respectively. The October 10 (Mw 5.3) and 24 (Mw 6.6) aftershocks recorded at Tamarindo (distances 40 km and 70 km, respectively) show accelerations of 2.4% and 8.2% g; respectively. We also relocated 28 events from 2006 to 2012 for moderate magnitudes (4 < Mw< 6.5).

TU_P002 ShakeMap Implementation in Costa Rica

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This work will show the Modified Mercalli Intsensity (MMI) maps of moderate to strong earthquakes recorded by the Observatorio Vulcanólogico y Sismológico de Costa Rica, Universidad Nacional (OVSICORI-UNA) from 2010 to the present. In 2010, the OVSICORI-UNA start using Antelope/SEISCOMP and ShakeMap softwares to record, store, locate earthquakes and make the instrumental intensity map for moderate to large earthquakes, respectively. The aim of the ShakeMap output is to provide a rapid and reliable intensity report to scientists, decision makers and general public.
Recently, we had implemented a mobile application to obtain earthquake perception and damage information from general public, which give us a quick Modified Mercalli values; those values combined with the obtained intrumental intensity map give the final MMI map.

TU_P003 Quality factor Q to model attenuation of seismic waves in Western Venezuela and further calibration of local magnitude MC with updated Mw magnitude values

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[1]Universidad Simón Bolívar, Caracas, Bolivarian Republic Of Venezuela, [2]FUNVISIS, Caracas, Bolivarian Republic Of Venezuela

To advance in the homologation of the Venezuelan Seismic Catalogue, it was established as a goal the characterization of the mean properties of seismic waves attenuation in western Venezuela. It is known that to properly assess the magnitude value of occurring earthquakes, it is necessary to correct for the effects caused by the scattering and intrinsic attenuation. In this regard, the frequency dependent Q value, Q=QOfα, is the customary model to achieve the necessary correction; where the model parameters, QO and α, are influenced by the tectonic environment. In this regard, the CODAQ method as described in SEISAN (Havskov et al, 2010), where it is assumed a simple backscattering model, is used to determine the Q value from the observed decay in filtered coda waves. A total of 500 events were collected from the records produced by the National Seismic Network, operated by FUNVISIS, within the time window 2010-2014, and for a magnitude range 0.6-5.4 Mw. The data set was divided in two subsets, given as: surficial events (≤ 30km) and deeper events (>30km). The obtained result for the sought average model is Q=(61±23)f(1.11±0.18) for surficial events, and Q=(74±26) f(1.05±0.17) for deeper events. This new model gave us the opportunity to improve on the former Mw values, since the Q model now conforms to a media characterized with an active seismic region with widespread fracturing and strong lateral in-homogeneities.
Further, using the same data set of events, it was determined its magnitude MC value, according to Fiedler (1978) from the NOAA report for earthquakes procedures in The Americas.
Finally, a regression analysis was conducted between both set of values (MC and updated Mw) for the collected data set of events, where we found the following exponential expressions: Mw = (1.17±0.06)*exp(0.33±0.01) for surficial events and Mw = (1.47±0.16)*exp(0.25±0.02) for deeper events.

TU_P004 Seismic hazard assessment aimed at improving the building code in Haiti

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Haiti is a country with high seismic risk located on the Hispaniola island, on the northern margin of the Caribbean plate. Its seismicity is mainly associated with two major faults that cross the island, with high slip rates located north and south respectively Septentrional fault (20 mm / y) and Enriquillo fault (7 mm / y).
Before the devastating earthquake on January 12, 2010, there was no building code in the country, neither seismic hazard studies had been developed. Some months after the earthquake, a first preliminary map of PGA was proposed by Frankel et al (2010) and two years later new maps as a result of developed detailed studies were presented within the project SISMO-HAITI, funded by the UPM.These new maps were developed in terms of PGA and various spectral, SA (T), in order to make easier the direct construction of the uniform hazard spectra UHS for different return periods. In addition, some recommendations were also submitted to the government institutions aimed to propose an own building code for the country, after the analysis of other building codes of the region as well as the Eurocode 8.
This paper makes a comparative analysis of: 1) the quoted maps with the hazard map of Dominican Republic, 2) the response spectra obtained by applying the current code of Haiti, with the UHS derived in the frame of the SISMO_HAITI project, 3) The design spectra resulting of the application of the Haiti and Dominican Republic in border towns. As a result a number of recommendations are proposed to improve the seismic code of Haiti, if the institutions responsible consider it appropriate. The ultimate goal of this work is to help decrease the physical and social impact they may have future earthquakes in the country.

ABSTRACTS

TU_P005 Simulación de escenarios sísmicos desfavorables en El Salvador

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El análisis de diferentes fuentes sísmicas en El Salvador ha permitido estimar los parámetros cinemáticos necesarios para su consideración en el cálculo de amenaza sísmica. En esta comunicación presentamos los resultados de la simulación de escenarios sísmicos asociados a diferentes rupturas de fallas que componen la Zona de Falla de El Salvador (ZFES).
Hemos utilizado como modelo de contraste el escenario del movimiento del sismo del 13 de Febrero de 2001 (Mw 6.6), hemos reproducido dicho evento empleando el modelo de atenuación local junto adatos de tipo de suelo y sus factores amplificación. La coherencia entre las aceleraciones registradas y las simuladas, tanto en distribución como en orden de magnitudes, pone de manifiesto que tanto el modelo de atenuación empleado como los factores de amplificación local son los adecuados para esta región. Hemos usado los mismos criterios para simular escenarios sísmicos desfavorables que pueden producirse en relación con la ZFES.
Las aceleraciones calculadas usando los escenarios desfavorables dejan patente que las fallas intraplaca del Arco Volcánico de El Salvador resultan ser fuentes sísmicas con una elevada peligrosidad. Terremotos con magnitudes mayores de Mw ≥ 7.0 son plausibles en el arco volcánico, además, los periodos de recurrencia calculados para terremotos de este estilo (150-270 años) indican que nos encontramos en un intervalo temporal cercano al límite de este periodo de recurrencia, asumiendo que el último terremoto de este estilo pudo ser el terremoto de 1719 (Ms 7.2). Un terremoto de estas características podría generar aceleraciones PGA de 1g en la superficie de ruptura y alcanzar a poblaciones como San Vicente y San Miguel con valores de PGA ? 0.4g. El código sísmico de El Salvador prevé aceleraciones del orden de 0.4g por lo que la vulnerabilidad de la edificación reciente deberá ser baja, adaptada a una aceleración de diseño de 0.4g.

TU_P007 Estimation of the earthquake ground motion features in Tapachula (Mexico) from ambient noise and seismic data

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The high seismic hazard level of Tapachula city (Chiapas, Mexico), due to the occurrence of nearby relevant earthquakes (Mw > 7.0), led us to estimate the empirical characteristics of earthquake ground motion in different parts of the urban area. Firstly, the shallow Vs structure was determined at 6 sites applying an association of the SPAC method and the horizontal-to-vertical spectral ratio (HVSR) method for ambient noise. Secondly, a ground predominant period map was estimated applying Nakamura technique. This map shows differences in local seismic response: a largest zone (in the downtown) with 0.2-0.4s, two small zones (concentric to the previous one) of 0.4-0.7s and 0.7-0.9s, respectively, and the smallest zone (on the edge of the city) with the higher values 0.9-1.1s. Thirdly, we analyze also 220 events recorded at 6 sites by a temporal seismic network (installed by the UNAM) and a set of key engineering ground-motion parameters (such as PGA, PGV, SA, SV, AI, etc.), and their attenuation laws as function of the magnitude and distance, were estimated after selecting the accelerograms with the best signal/noise ratio. The attenuation laws of each parameter are a first approximation of ground-motion prediction equations (GMPE) for the city. The parameters here obtained show different shake levels and frequency content at each site.

TU_P008 New seismic hazard assessment in El Salvador

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In this work, we present a new seismic hazard assessment in El Salvador taking into account the major structures in the zone. We model faults as independent seismogenic sources. This makes it possible to apply a hybrid methodology, in combination seismogenic area-sources and faults with known data, thus obtaining a more reliable and accurate map of seismic hazard for El Salvador.
El Salvador Fault Zone (ESFZ) (Martínez-Díaz et al., 2004; Corti et al., 2005) is the main structure seismically active in El Salvador. It is capable of producing earthquakes such as the February 13, 2001 with Mw 6.6 (Benito et al., 2004), that seriously affected the population, leaving many casualties. The geometry and the degree of activity of the ESFZ have been studied from geodetic (Staller et al., 2016), geological and paleoseismological studies (Canora et al., 2012; 2014b; Alonso-Henar et al., 2014). In this work, we use the seismic catalogue and the geological and geodetic slip rates associated with the main fault segments and faults of the ESFZ to improve the previous seismic hazard studies in the zone (Benito et al., 2010; Benito et al., 2012). As we expected, the accelerations increase close and around fault segments with higher slip rates, and the probability of exceedance decreases in areas where fault recurrence intervals approaches the elapsed time.
For the first time in El Salvador we include modeled faults as independently estimated seismogenic sources. This work provides a significant improvement in the seismic hazard assessment in the region.

TU_P009 Cálculo de parámetros físicos del terremoto de Cúcuta de 1875 a partir de intensidades macrosísmicas actualizadas

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La región Nororiental de los Andes (Cordillera Oriental en Colombia y Andes de Mérida en Venezuela) tiene una amplia historia sísmica donde diversos eventos han impactado a la región, ocasionando desastres y grandes pérdidas.
En particular, el terremoto de Cúcuta de 1875 ocurrió en la etapa pre-instrumental (antes de 1900); y fue un evento que comprometió en gran medida el desarrollo de la capital del departamento de Norte de Santander, Colombia. Este terremoto ha sido objeto de diferentes estudios, donde se han modelado sus parámetros físicos (Magnitud, Localización, e Incertidumbres) a partir de datos macrosísmicos. El último de estos estudios, propuesto por Rodríguez et al (2015) asigna 68 puntos de intensidad en la escala EMS-98.
Este trabajo hace uso de estos datos macrosísmicos, implementando el algoritmo de Bakun and Wentworth (1997) (BW97) y la relación de atenuación de intensidad macrosísmica calibrada en Mw propuesta por Gómez-Capera et al (2016), para calcular los parámetros físicos del terremoto de San José de Cúcuta de 1875. Finalmente se hace una comparación de resultados con cálculos para el mismo terremoto, hechos con otros modelos calibrados para la región.

TU_P010 Receiver Function as a new methodology to model the Continental Crust - Tegucigalpa, Honduras

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On this work it's presented the study of all the recorded events for the seismological station TGUH located at Tegucigalpa, Honduras since September, 2006 to July of 2014. Those events were selected under certain criteria and specific characteristics that should be fulfilled for their use on the model that determines the Continental Crust thickness under the station that recorded them, as the ration that exist between the propagation velocities Vp/Vs, based on the analysis of the Receiver Function method with the Stacking Method (H - k) the results from that are the estimated Bulk parameters were a thickness of 34.8 kilometers and a ration between the propagation velocities of 1.75 were determined, these results characterize the Continental Crust, making an estimation of how the converted waves due the mohorovičić discontinuity that arrive and interact between each other, to collect the pertinent information of the medium under study. Applying a model that is based on different values and weight factors for each wave that arrived considering geological and statistical factors.

TU_P011Seismic characterization of the Sierra de Valle Fértil above the Pampean flat slab subduction in Argentina

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The Western Sierras Pampeanas region is characterized by basement cored uplifts with approximately N-S trending ranges of average 2500-m heights, thick-skinned deformation and a high frequency occurrence of seismic activity. They correlate with the flat slab segment of the Nazca plate subducting at about 100-km depth beneath South America. Lying immediately to the east of the Argentine thin-skinned fold-and-thrust belt Precordillera, mafic and ultramafic lithologies seem to have a record of Paleozoic accretion of terranes as well as extensional processes. This might have caused fracturation and a fault system that remains active.
In this study we analyze the Sierra de Valle Fértil using seismic stations from INPRES (Argentina) and the CHARGE and INPRES broadband experiments. This range of approximately 180 km length separates the Cuyania terrane in the west from the Pampia terrane in the east. We observe a high seismic activity with focal depths < 25 km, mainly reverse focal mechanisms and other solutions including a strike-slip component, a crustal model of high P-wave /S-wave velocity ratio in the first 3 km depth, which is different from the lower crust between 36 and 47-km showing a low P-wave/S-wave velocity ratio. These results are consistent with a more fractured basement and/or the presence of more sediments in the upper crustal level on top of a partially eclogitized lower crust. To the east of the Sierra de Valle Fertil the crust is thinner exhibiting about 40 km-km thickness. In addition, the results are consistent whit 2D reflection cross section analyses at 30° of latitude east of the Western Sierras Pampeanas. Our seismic results agree also with Apatite (U-Th)/He results (AHe) and neotectonic observations across the northern part of the Sierra de Valle Fértil which suggest recent exhumation likely related to uplift since Pleistocene.

TU_P012 RomUkrSeis 2014

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RomUkrSeis 2014 was a controlled source wide-angle reflection and refraction (WARR) profile acquired in August 2014. It is 675 km long, running from the East European Craton in central Ukraine southwestwards into Romania where it crosses the Carpathian Mountains, the Transylvania Basin and terminates in the Apuseni Mountains. Some 350 single component seismic recorders were used in a single deployment (1.75-2 km spacing in Romania and 2-2.25 in Ukraine) to record seismic waves from eleven shotpoints along the profile, eight in Romania and three in Ukraine. The objectives of RomUkrSeis 2014 included mapping the two-dimensional regional architecture of the Carpathian Orogen, and its foreland basin, and the intramontane Transylvania Basin. A particular interest in this regard is crystalline basement affinity and Moho disposition along the profile, which crosses the boundary zone between the Archaean-Palaeoproterozoic cratonic lithosphere of the core of the European plate and lithospheric domains accreted to it during later Phanerozoic tectonic episodes (the Palaeozoic German-Polish Caledonian and Variscan orogenies overprinted by the Mesozoic Alpine Carpathian orogeny). Processed shot gathers will be displayed along with a preliminary velocity model and its first-order interpretation. RomUkrSeis 2014 was acquired by a consortium of organisations led by the University of Bucharest. Financial support came from Prospectiuni, Hunt Oil of Romania, Repsol (all of whom made grants to RomUkrSeis via the Romanian Geoscience Foundation, and "in kind" during fieldwork), the Institute of Geophysics of the National Academy of Sciences of Ukraine (Kiev), the Institute of Geophysics of the Polish Academy of Sciences (Warsaw) and the University of Aberdeen. The numerous individuals who helped in the field, mainly students and others from the University of Bucharest, but also from Prospectiuni as well as from the Kyiv and Warszawa institutes, are gratefully acknowledged. Some instrumentation was provided by the Helmholz Centre of GFZ Potsdam, Germany.

TU_P013 Estructura de la corteza del Brasil central: Una aproximación por refracción sísmica y función receptora

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Datos de la línea sísmica de refracción Porangatu-Cavalcante (1988) sumado a datos de la literatura y nuevas determinaciones de espesor de la corteza obtenidas por función receptora, fueron utilizados para generar mapa de la profundidad de la Moho para Brasil central (8°S-16°S/45°–51°W) y caracterizar el comportamiento de la corteza continental en los diferentes dominios tectónicos. El Brasil central es un extenso orogen Neoproterozoico resultado de la aproximación y posterior colisión de paleoplacas Amazônica, São Francisco y fragmentos continentales más pequeños, representatos por Arco Magmático de Goiás, Maciço de Goiás, Complexo Rio dos Manguês y otros bloques actualmente ocultos por los sedimentos de las cuencas de Parnaíba y Paraná. El espesor de la corteza varía entre 33 y 53 km, con valores típicos para los distintos dominios tectónicos. La cuenca del Parnaíba tiene corteza de 44 km y Vp/Vs 1.71, em contraste con la corteza de la parte norte de la Zona Exterior de la Faixa Brasília, con espessor de 40 km y Vp/Vs 1.70. La parte sur de la zona exterior de la Faixa Brasília, dominada por cubiertas metasedimentarias, presenta espesor de 42-44 km y Vp/Vs 1.70. La corteza del Arco Magmático de Goiás cambia entre 35 km al sur y 42 al norte, con Vp/Vs 1.72. El paleocontinente Amazônico tiene espesor de la corteza con valores maiores de 42 km y Vp/Vs 1.70-1.79. En el contacto del Craton Amazônico con Arco Magmático y la cuenca del Parnaíba, la corteza parece presentarse duplicada con espesor de 50 km. La variación del espesor de la corteza no refleja la variación de la respuesta gravimétrica observada, lo que sugiere que el equilibrio isostático regional se logra principalmente por los cambios en las propriedades físicas del manto de la litosfera, con una menor contribución de la corteza.

TU_P014 Crustal structure across the northwestern region of Venezuela, Northern Andes profile, from wide-angle seismic data.

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Due to the lack of regional deep structural information in western Venezuela, within GIAME Project (Integrated Geosciences of Merida Andes) lithospheric research is done in the west of the country, to generate a geotectonic model underneath Merida Andes. In 2014, seismic data were acquired along a 565 km profile in northern Andes, which extends from Northwestern Falcon to southwestern Guarico, Venezuela. This transect crossed three main structural features that were generated as result of the South American and Caribbean plate interaction, Falcon inverted basin, Merida Andes and El Baul massif. In this presentation, only the first seven shots of the profile, between the Falcón coast and the Andes mountain range, are considered to generate a 2D P-wave velocity model for this 390 km long profile. Approaching to the Andes, the sedimentary width decreases to a thickness of 0.4 km in the vicinity of the cities of Barquisimeto and Cabudare. The lateral variations of low velocities on the top of the upper crust shows the presence of structures perpendicular to the profile: Lara nappes, Boconó fault system and Guárico frontal thrust. The model also indicates the presence crustal thinning to about 30 km located beneath the Falcon Basin. In addition, we identified an interface below the Moho discontinuity corresponding to a high velocity structure in the mantle, that might be related to the downgoing slab of the Caribbean plate.

TU_P015 Velocity model across the southern part of the Mérida Andes, Venezuela. From wide angle seismic profiles

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Within the goals of the Integral Geoscience of the Merida Andes project (GIAME), various geophysical and geological investigations were performed along three main profiles named Northern Andes, Central and Southern Andes, crossing perpendicular to the axis of the mountain chain. Through the acquisition, processing and analysis of wide angle seismic data, crustal P and S wave models were developed. This study is based on one of the main seismic profiles of the GIAME project, called South Andes profile. Data processing include the preparation of seismic sections corresponding to each shot, by incorporating the geometry of the traces, performing a bandpass filter, trace normalization, application of reduction velocities and the identification of the main crustal phases. Among the structures identified during the ray tracing modeling using the RAYINVR code are: unconsolidated sediments, consolidated sediments, upper crust, lower crust and upper mantle. The seismic velocities obtained for the different structures were: unconsolidated sediments, 2.8 km/s (thickness: max. 1.8 km for the Barinas basin and 5 km for the Maracaibo basin); consolidated sediments, from 3.2 to 5.3 km/s (thickness: up to 5 km); upper crust, from 5.8 to 6.3 km/s (down to 20 km depth); lower crust, from 6.7 to 7.2 km/s; upper mantle, 8.1 km/s. In the crustal model we can identify the geometry of the shallow (up to 6 km thickness) Barinas basin to the south, and the deep (up to 10 km thickness) Maracaibo basin to the north. The Andes mountain chain in the center exhibits an asymmetric configuration with a maximum Moho depth of 52 km, shifted about 50 to the northwest compared to the topographic profile of the Andes chain.
KEY WORDS: GIAME, Venezuela, wide angle seismic, Mérida Andes, Moho

TU_P016 BB-ASAP: BroadBand seismic experiment in the Area of Sergipe-Alagoas-Pernambuco, Brazil

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Mountains building and their erosion and peneplanation, sediment and nutriment transfers trough river into continental plate-form and deep ocean, are deeply connected with the growth cycle of the earth, the birth and the evolution of the ocean, the palaeo-climate and the palaoe-oceanography variations, which are all linked with deep earth processes. Probing the strong correlation between deep and surface processes in order to understand the Earth's growing and to model forecasts, needs the multidisciplinary approach proposed in the holistic project "From Mountain to Deep Sea" of the White Paper « an holistic approach of international collaboration in Marine Sciences » (http://marinebrazil.sciencesconf.org/). Considering the complex history of the assemblage of the Brazilian Lithosphere, the understanding of the evolution of the topography and the role of inherited structures from past orogenic episodes need a 3D model of the crust and upper mantle. Recent wide-angle experiment (SALSA cruise) allows high resolution but discrete 2D images of the crust of the NE Brazil margin, but cannot offer a lateral coverage of the lithosphere. We propose a seismic BroadBand (BB) array of stations, deployed both on land and at sea along the coast. The joint analysis of the BB data together with the previous seismic results will allow, by coupling active and passive seismic methods, the construction of a 3D seismic model of the Lithosphere with unsurpassable detail and the detailed and integrated study of the interaction between onshore-offshore (Source to Sink) and surface/deep processes (Mud to Mantle).

TU_P017 Ejercicio de respuesta ante tsunami local, dirigido a los escolares de nivel básico en la comunidad de Zipolite, Oaxaca, México

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Dentro del marco de la Semana Nacional de Protección Civil de México, el 18 de septiembre del año 2015 se realizó un ejercicio de acciones inmediatas de respuesta ante la hipótesis de impacto de un tsunami de origen local, en la comunidad costera de Zipolite, del municipio de San Pedro Pochutla en el Estado de Oaxaca. Para ello se eligió a los escolares de nivel básico, mismos que representan una población cautiva de menores de edad que son vulnerables ante la presencia de una repentina invasión marina. Las regularidades establecidas durante el ejercicio, tomaron en consideración los índices de recurrencia contemplados por la Coordinación Estatal de Protección Civil de Oaxaca (CEPCO), así la como información difundida por el Centro de Alerta de Tsunamis (CAT) de México. Para establecer los planes de ayuda comunitaria e involucrar a las autoridades competentes, fueron integrados a este proyecto representantes a nivel local de: la CEPCO en la Delegación Regional Costa Centro, la Coordinación Municipal de Protección Civil de San Pedro Pochutla, la Agencia Municipal de Zipolite, la capitanía de Puerto Ángel, el capitán de Salvavidas Voluntarios "Delfines de Zipolite" y el personal que labora en los cuatro centros educativos de la comunidad. El trabajo se inició con una plática previa donde se dio a conocer la población vulnerable, las condiciones geológicas que prevalecen en la zona, la posibilidad de ocurrencia de un sismo altamente sensible que detona al tsunami, las acciones inmediatas de respuesta al sismo y la evacuación preventiva a zonas de seguridad (señalizadas con anterioridad por parte de la autoridad). También se incluyeron: simulacros de gabinete, propuestas preliminares para la activación del sistema de alertamiento y se procuró minimizar un intervalo de tiempo hacia un sitio elevado y seguro (cota de 30 metros), logrando un tiempo de respuesta de hasta 7 minutos.

TU_P018Modeling the CaribeWave2015 Tsunami Exercise Scenario: An initiative of a Caribbean-based Collaborative Modeling Group

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For the past seven years, the Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG/CARIBE-EWS) coordinate, supervises and executes an annual Caribbean-wide tsunami exercise known as CaribeWave. The primary objective of the exercise is to test communications for better tsunami preparedness among Tsunami Service Providers, inter-Caribbean emergency management, Tsunami Warning Focal Points, National Tsunami Warning Centers and local government agencies. In 2015, a selected group of tsunami modelers within the Hazard Assessment Working Group of the ICG/CARIBE-EWS joined efforts and developed an initiative to model the effects of the CaribeWave2015 tsunami scenario source (located north of Panamá) along the coasts of Costa Rica, Panama and Colombia. The objective of the modeling is two-fold; first to compare estimates of computed tsunami wave arrival times, and second, provide inundation values for selected vulnerable locations. With regards to the latter, the official CaribeWave2015 manual provided by the ICG/CARIBE-EWS lacks such detailed information. Therefore, for interested member states to help emergency management agencies make well-informed decisions, a-priori knowledge of effects at coastal locations is an essential piece of information to use. In this study, we present modeling results of the Northern Panamá Deformed Belt tsunami source chosen for CaribeWave2015 and report on the effects at selected coastal locations in Costa Rica, Panamá and Colombia. The goal of the modeling group is to perform simulations for the annual CaribeWave scenario by employing the tsunami numerical model NeoWave with a refined Caribbean plate bathymetry of 1 arc-minute, with nested higher resolution grids for specific coastal areas. Part of the long-term goals of the modeling group is to incorporate more tsunami modeling experts within the region to provide their countries with valuable estimates of tsunami effects for better decision-making.

TU_P019 Sensitivity of the tsunami hazard values to input parameters and assumptions: A case study in Central America

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Tsunami hazard assessment carries numerous aleatoric and epistemic uncertainties due to the natural randomness involved in tsunamigenic sources as well as to our limited knowledge about e.g. ruptures characteristics, earthquake rates, near-shore bathymetry and, not the least, to our model assumptions and approximations. The purpose of this study is to assess selected sources of uncertainty and to quantify their relative and absolute effect on the tsunami hazard results for the Central American region. In particular, we test the effects of the zonation models, selected earthquake frequency-magnitude distribution models, maximum magnitudes or upper bounds, different scaling laws and two crustal rigidity models to estimate the effects on the tsunami amplitudes. We provide a systematic sensitivity study by varying each of the above parameters and applying the Monte Carlo technique to generate a “biased” synthetic seismic catalog used on input to tsunami modelling. Thus, perturbation of each parameter to generate alternative synthetic earthquake catalog allows comparing at which extent these parameters are influencing the tsunami hazard curves. Present study was limited to the subduction interface sources only. It is concluded that the different zonation models (different seismicity rates and seismic b-values) greatly affect the hazard estimates to up 48%. Following, the crustal rigidity, which is used to convert seismic moment into the slip, has one of the major effects on tsunami hazard estimates. The maximum magnitude considered in each model also significantly affect the tsunami hazard mainly for the mid-to-longer return periods. Conducting a sensitivity analysis could contribute to generating logic trees by allocating weights to the each node, not always an easy and objective process to perform probabilistic tsunami hazard assessment considering the associated spectrum of uncertainties.

TU_P020 The relation between slip distribution and run-up: Comparison of recent Chilean tsunamis

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The Chilean margin is known to be one of the most tsunamigenic regions in the world. The recent 2014 Mw 8.1 Pisagua and the 2015 Mw 8.2 Illapel earthquakes have shed light on the different potential of earthquakes for triggering tsunamis. This difference may arise mostly from the source characterization. In this study it is aimed to compare the variations in tsunami heights and run-up distributions using various source models and two tsunami codes to account for local effects. Different fault models that resulted from inversions have been used to numerically simulate tsunami propagation and inundation. For these simulations tsunami codes that solve the shallow water equations (SWE) are used. On one side, the linear approximation is used as reference of several early warning systems due to the low computational demands and reliability to quickly simulate propagation. In turn, the non-linear non-hydrostatic tsunami code is used to generate propagation and inundation. Modeling scheme is based on nested grids in a spherical coordinates system with a 120", 30", 6" and 1" of resolution. The time coverage of numerical model is six hours with a one minute time interval. The resulted numerical simulations are compared with DART, tide gauges and with run-up measurements taken during post-tsunami field campaigns. This study provides an overview of the tsunamigenic characteristics based on fault model slip distribution and the effects of using different numerical approximations for the tsunami modeling. These results are essential for early warning systems, and also provide the groundwork for future tsunami hazard assessments in the region.

TU_P021 Percepción del riesgo ante tsunami y otros peligros de origen telúrico-meteorológico, por parte de los profesores de la Escuela Primaria Rural en Zipolite, Oaxaca, México

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Zipolite es una playa de bolsillo del Municipio de San Pedro Pochutla, con longitud cercana a 1,700 metros y se sitúa al extremo sur del estado de Oaxaca, una región costera del Pacífico Mexicano continuamente azotada por diversos fenómenos marinos derivados de eventos sísmicos e hidrometeorológicos. En enero de 2016, se planteó un estudio piloto para conocer la percepción ante el riesgo por tsunami y otros peligros en Zipolite. El turismo que visita la zona es llamado "alternativo-ecológico" pues la derrama económica, no es suficiente para ofrecer trabajo a toda la población. Así, la gente se autoemplea en la pesca, la construcción y las artesanías, utilizando los recursos tanto de la playa como de las lagunas y manglares del estero. Con este antecedente y ante la falta de un sistema de prevención de riesgo de desastre, se decidió comenzar a indagar qué sector de la población podría apoyar a las autoridades municipales y de protección civil para la activación de un sistema de alerta temprano ante invasiones marinas. Una vez establecido el contacto con la comunidad, observamos que la Escuela Primaria Rural Estatal "Lázaro Cárdenas" cuenta con profesores comprometidos con su profesión, por lo que se decidió comenzar con este sector. Por ello, se aplicó un cuestionario piloto a los docentes y al director de dicho centro de estudios, con el objeto de saber cuánto conocen sobre el entorno natural de Zipolite y cuál es su percepción de riesgo ambiental. Debido a la historia reciente de huracanes como Pauline en Octubre 1997, la alerta internacional de tsunami asociada al macrosismo de Tohoku, Japón en marzo del 2011; y el evento de mar de leva de mayo 2015; los profesores refieren la inquietud de su vulnerabilidad cada vez mayor ante la ocurrencia de eventos que impacten de forma importante la comunidad.

TU_P022 Seismic Interferometry applied to fracture seismicity recorded at Planchón-Peteroa Volcanic Complex, Argentina-Chile

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Seismic interferometry (SI) studies the interference phenomenon between pairs of signals in order to obtain information from the differences between them. SI is now regularly used in exploration and global seismology with active and/or passive sources, i.e., artificial sources (dynamite, vibroseis, sledge hammer, etc.) or natural sources (earthquakes, anthropogenic noise, ocean microseisms, etc.). SI allows one to extract subsurface information from complicated or random wavefields.
This research aims to contribute to the knowledge of the subsurface structure at Planchón-Peteroa Volcano Complex (PPVC) by using SI technique. Inspired by the theory and applications in Wapenaar (2003) and Ruigrok and Wapenaar (2012), this work applies SI to fracture seismicity originated at PPVC or in active geologic faults located nearby this volcanic complex. Applying autocorrelation to a selected time window at each event, zero-offset reflection responses were obtained for each station. This response can be used to determine the location of shallow subsurface reflectors underneath each station.
This application uses seismic data recorded by stations deployed in Argentina and Chile. The Argentine data was recorded by an array of six 2-Hz 3-component stations on the eastern flank of the volcano, deployed during the MalARRgue project in 2012. The Chile data is provided by OVDAS-SERNAGEOMIN (South Andes Volcanic Observatory, Chile). OVDAS has six 3-component 30-seconds stations located on the western flank of the volcano; these stations overlap in the same time period as the Argentine data.
Events had been identified and located independently by the arrays deployed in each of the flanks (Casas, 2014; RAV SERNAGEOMIN, 2012). In order to obtain accurate locations of the detected events, the two datasets were used together to relocate them. This result constitutes a necessity for enhancing the resolution of subsurface images obtained by application of SI at PPVC. Preliminary results of this research will be presented.

TU_P023 Shear – wave velocity structure beneath northern South America from ambient noise rayleigh wave tomography

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This study presents shear – wave velocity maps beneath northern South America from ambient noise tomography. Several profiles are extracted in the study area from the tomographic model obtained after the inversion of group and phase velocity dispersion curves. The ambient noise data used were recorded at 72 broadband seismic stations in northern South America and the Caribbean from 10 seismic networks. The Green functions were obtained from cross-correlations and temporal stacking of long time-series between station pairs separated up to 2000 km revealing Rayleigh wave signals. These time series correspond to records up to 1 year of coincidence of the different station pairs. Rayleigh wave group and phase dispersion measurements are carried out using a frequency time analysis method (FTAN). Tomographic dispersion maps of group and phase velocity are shown from 11 to 45 s period. The path density in periods out of this range is lower which increases the uncertainty in dispersion measurements. Average resolution estimated is 1.5 x 1.5° from checkerboard test method allowing the analysis of structures such as sedimentary basins, cratonic shields and mountain ranges. Resolution kernels indicate that could be analyzed shear – wave velocity results in a range of 10 to 50 km depth. It is shown that is possible to recover information coherent with known geological features from ambient noise tomography as demonstrated in previous studies around the world.

TU_P024 Crustal Structure of North Peru from analysis of teleseismic Receiver Function.

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In this study we present results from a teleseismic receiver function study, in order to investigate the crustal thickness and Vp/Vs ratio variation beneath the northern Peru. A total number of 1457 receiver-function data were analyzed, recorded by 28 broadband seismic stations from the permanent seismic network of Peru, combined with local temporary SisNort network and one CTBTO station. Estimation of Moho depth and average crustal Vp/Vs ratio were measured at each station using H-k stacking technique to identify the primary arrival times of P to S conversion and crustal reverberations (PpPms, PpSs+PsPms). The results show that Moho depth correlates well with the surface topography, and increases significantly from West to East, showing shallow depth around 25 km near the coast and has a maximum depth of 55-60 km beneath the Andean Cordillera and 35-40 km further to the east in the Amazonian basin. The bulk crustal Vp/Vs ratio range between 1.6 to 1.88 with mean of 1.75, showing higher values between 1.75 to 1.88 beneath the Easter and Western cordillera, consistent with the mafic composition to the lower crust. While values vary of 1.6 to 1.7 in the extreme flanks of the Easter and Western Cordillera related a felsic composition. We find positive relationship between crustal thickness, Vp/Vs ratio, Bouguer anomaly and Topography. These results are consistent with previous studies applied around of our study region.

TU_P025 Moho depth and Vp/Vs estimates in the North and Central-West Brazil

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Moho depth determination can provide valuable information about processes related to the formation and tectonic evolution of the South American plate. This study is aimed at full crustal information gaps in the North and Central-West Brazil, a huge area composed by six different tectonic provinces and not well studied yet. For this reason, it is being applied the receiver function (Ligorría and Ammon, 1999) and

H-k stacking methods (Zhu and Kanamori, 2000) to estimate crustal thickness and Vp/Vs ratio using data recorded mainly by Brazilian Seismic Network, a project funded by Petrobras and administered by four institutions: Seismological Observatory (University of Brasília), National Observatory, University of São Paulo and Federal University of Rio Grande do Norte, each one responsible for part of the network. The preliminary results indicate that the cratonic region is thick (~40km). The cratonic basins are thinner, with values which achieve 25,4km. This thinner crust is associated with rifting process that formed the Parecis basin and the flexure of caused by Andes in the plate that formed the Acre basin. Because of the great variability in Moho depth results, it is not possible to correlate a typical crustal thickness with a tectonic province in Brazil. The same happens to the Vp/Vs ratios, which are not yet reliable and it is not possible to correlate them to a mean crustal composition. These results are being revised and a velocity crustal model will be made using the joint inversion of receiver function and surface wave dispersion.

TU_P026 Group and Phase velocities of the Falcón Basin from Ambient Noise Correlation

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We study the upper crust of the Falcón Basin (Northwestern Venezuela) with correlation of ambient noise data. In this study, we use 7 seismographs deployed in a linear pattern perpendicular to the direction of the main structures in the region. The Green functions were obtained from phase matched cross-correlations and stacking all the available time-series and for all possible stations pairs. Despite low Noise to Signal ration in some stations we were able to measure Rayleigh wave group and phase from 10 s up to 40 s. Within this periods, group velocity values range from 2.6 km/s to 3.5 km/s, while phase velocity values range from 3.0 km/s to 4.1 km/s. These values are in agreement with observations made in other continental basins and reflect the granitic character of the upper crust of the studied region. Further work is needed in order to establish a way to used the linear pattern of the stations to fully reconstruct the crustal structure of the region.

TU_P027 MSNoise: A framework for Continuous Seismic Noise Analysis

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MSNoise is an Open and Free Python package known to be the only complete integrated workflow designed to analyse ambient seismic noise and study relative velocity changes (dv/v) in the crust. It is based on state of the art and well maintained Python modules, among which ObsPy plays an important role. To our knowledge, it is officially used for continuous monitoring at least in three notable places: the Observatory of the Piton de la Fournaise volcano (OVPF, France), the Auckland Volcanic Field (New Zealand) and on the South Napa earthquake (Berkeley, USA). It is also used by many researchers to process archive data to focus e.g. on fault zones, intraplate Europe, geothermal exploitations or Antarctica.
We first present the general working of MSNoise, originally written in 2010 to automatically scan data archives and process seismic data in order to produce dv/v time series. We demonstrate that its modularity provides a new potential to easily test new algorithms for each processing step. For example, one could experiment new methods of cross-correlation (done by default in the frequency domain), stacking (default is linear stacking, averaging), or dv/v estimation (default is moving window cross-spectrum “MWCS”, so-called “doublet”), etc.
We present the last major evolution of MSNoise from a “single workflow: data archive to dv/v” to a framework system that allows plugins and modules to be developed and integrated into the MSNoise ecosystem. Small-scale plugins will be shown as examples, such as “continuous PPSD” (à la McNamarra & Buland) or “Seismic Amplitude Ratio Analysis” (Taisne, Caudron).
We will also present the new MSNoise-TOMO package, using MSNoise as a “cross-correlation” toolbox and demystifying surface wave tomography !
Finally, the poster will be a meeting point for all those using or willing to use MSNoise, to meet the developer, exchange ideas and wishes !

TU_P028 Improved Seismic Travel Times in Central and Northern Costa Rica for Accurate Earthquake Location

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Reducing the prediction error of seismic-phase travel times leads directly to improvement in earthquake location accuracy. One-dimensional (1D) velocity models are most commonly used to calculate seismic phase travel times because computer codes are readily available and the computations can be done on inexpensive hardware. Travel time predictions based on 1D models are accurate to within 1 to 2 seconds at teleseismic distance, but complex crust and upper mantle structure can triple prediction errors at regional distance. Increased travel time prediction error at regional distance is particularly prevalent in regions like Central America, where subduction tectonics results in large lateral variations in seismic velocity and crustal thickness. The Regional Seismic Travel Time (RSTT) method (Myers et al., 2010) was specifically developed to improve travel time prediction accuracy by accounting for 3D seismic velocity structure. The RSTT model is inherently global in extent, but the accuracy of travel time prediction is dependent on the accuracy of structure along each ray path. Many studies make use of the well-instrumented Nicoya Peninsula in Northern Costa Rica and the underlying seismogenic zone to image the structure of the region. In this study we update the RSTT 3D velocity model in northern and Central Costa Rica using published studies of velocity structure (DeShon et al., 2006 and Arroyo et al., 2009). Travel times for the updated model are compared to observed travel times for well-constrained earthquakes. We relocate the earthquakes using only regional data to measure the improvement in location that can be achieved with the updated model. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-682665.

TU_P031 Numerical modeling of initial slip and poroelastic effects of the 2012 Costa Rica earthquake using GPS data

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Remote sensing and geodetic measurements are providing a new wealth of spatially distributed, time-series data that have the ability to improve our understanding of co-seismic rupture and post-seismic processes in subduction zones. We formulate a Bayesian inverse problem to infer the slip distribution on the plate interface using an elastic finite element model and GPS surface deformation measurements. We present an application to the co-seismic displacement during the 2012 earthquake on the Nicoya Peninsula in Costa Rica, which is uniquely positioned close to the Middle America Trench and directly over the seismogenic zone of the plate interface. The results of our inversion are then used as an initial condition in a coupled poroelastic forward model to investigate the role of poroelastic effects on post-seismic deformation and stress transfer. From this study we identify a horseshoe-shaped rupture area with a maximum slip of approximately 2.5 meters surrounding a locked patch that is likely to release stress in the future. We model the co-seismic pore pressure change as well as the pressure evolution and resulting deformation in the months after the earthquake. The results of the forward model indicate that earthquake-induced pore pressure changes dissipate quickly near the surface, resulting in relaxation of the surface in the seven to ten days following the earthquake. Near the subducting slab interface, pore pressure changes are an order of magnitude larger and may persist for many months after the earthquake.

TU_P032 Co- and Post- seismic ground deformation on the volcanoes of Costa Rica after the 5th September 2012 Mega Earthquake

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Co-seismic ground deformation at volcanoes, generated by mega-thrust earthquake, often differs from the surroundings ground deformation. InSAR observations show that after large earthquakes ground response around volcanoes is more important than the background deformation. This difference is mainly detected on the vertical component with, for example, a subsidence up to 15 cm on some Chilean volcanoes after the Mw 8.8 Maule EQ. The 5th September 2012 Costa Rica has been hit by a Mw 7.6 Mega-thrust Earthquake generating a sub metric co-seismic ground deformation above the zone of the rupture. Based on GPS and tacheometric (i.e. combination of Electronic Distance Measurement and triangulation) data, we provide the combined co- and post- seismic ground deformation of Arenal, Irazú and Turrialba volcanoes, distant of 110 km, 195 km and 205 km from the zone of rupture, respectively. We assess whether the co and post-earthquake deformation differs from the background deformation. Our preliminary results do not show decimeter subsidence around the volcanoes however, at Arenal volcano the subsidence may be slightly superior than the surrounding subsidence.

TU_P034 Atenuación sísmica a partir de datos de redes temporales en el segmento de subducción horizontal de los Andes Centrales

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En la República Argentina la actividad sísmica se distribuye principalmente hacia el oeste y es originada por la convergencia de las placas de Nazca y Sudamericana. Los terremotos de mayor intensidad se concentran entre los 27°S y 33°S, sobre el segmento de subducción horizontal pampeano.
Se han realizado numerosos esfuerzos para tratar de entender este entorno desde diversos puntos de vista. En particular, los estudios de atenuación sísmica en regiones tectónicamente activas, brindan un mejor conocimiento de su geodinámica y son útiles para obtener modelos de litósfera así como para la determinación de los parámetros de fuente, además de proveer coeficientes que permiten evaluar la peligrosidad sísmica. El efecto de la atenuación puede determinarse mediante el análisis de las pérdidas y redistribuciones de energía en los sismogramas registrados a diferentes distancias y suele representarse por la función disipativa o su inversa, el factor de calidad del medio; Q. Este factor está inversamente relacionado con el grado de heterogeneidad del medio y es muy sensible a sus condiciones viscoelásticas, temperatura, rigidez y presencia de fluidos.
En esta oportunidad se propone analizar registros de más de 60 estaciones de banda ancha instaladas por los proyectos CHARGE (2000-2002) y SIEMBRA (2007-2009). La localización conjunta de hipocentros sumada al uso de un modelo de velocidades local (Scarfi et al., 2012) definirá con mayor detalle la geometría de la subducción. Se determinarán los factores de atenuación de ondas directas P y S mediante el método de las razones espectrales (Tsujiura, 1966, Rojas Arce, 2013) y de ondas coda empleando modelos de scattering simple (Aki y Chouet, 1975, Sato, 1977). Con estos resultados se podrán observar detalles de los efectos de la atenuación sísmica, identificar los efectos de la anelasticidad y de las heterogeneidades e interpretarlos en relación a los procesos asociados a la subducción.

TU_P035 Crustal structure and rheological performance beneath Eastern Cordillera, Colombia

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We carried out an analysis of the seismicity in the northern sector of the Eastern Cordillera of Colombia, between 3°-7° N, and 71.5-75° W, in order to determine its depth distribution and its link to the subduction of Nazca and Caribbean oceanic slabs beneath northwestern South America. To do this, we analyzed the seismicity recorded by the Colombian National Seismological Network between 1993 and 2015 in several regions along two regional profiles transverse to the regional trend of the Cordillera, one located north and another located south of Caldas tear. This tear represents the boundary between the Caribbean (to the north) and Nazca (to the south) subduction segments. The results show that, along the regions analyzed, the seismicity is mainly restricted to the upper part of the continental crust, exhibiting a marked decrease in the occurrence of earthquakes in the middle crust. This behavior fits the rheological profile set for the lithosphere, where the transition between brittle and plastic regimes usually occurs at this depth. Additionally, the MOHO and Curie isotherm depth values reported by other authors are very similar along the study zone, and seem to be controlling the seismicity distribution in the crust. Finally, a concentration of seismicity is observed at intermediate depths along the two profiles, which is related to the Wadati-Benioff zone of the Caribbean and Nazca subduction segments.

TU_P037 Shape of subducting Nazca Plate and lithospheric structure in the Pampean Flat Slab Region of Argentina

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We obtain earthquake locations and a detailed three-dimensional model of the subduction zone velocity structure in west-central Argentina by applying a regional-scale double-difference tomography algorithm to earthquake data recorded by the SIEMBRA (2007-2009) and ESP (2008-2010) broadband seismic networks. In this region, the flat subduction of the Nazca Plate including the Juan Fernandez Ridge is spatially correlated in the overriding South America Plate with a gap in the arc volcanism and the thick-skinned, basement-cored uplifts of the Sierras Pampeanas. Our model shows the subducting Nazca Plate as a mostly continuous band of increased (2-6%) P- and S- wave velocities (Vp and Vs). The lithospheric mantle of the South America Plate appears to be heterogeneous but mostly characterized by Vp of 8.0-8.2 km/s, Vs of 4.5-4.7 km/s, and Vp/Vs ratio of 1.75-1.78, which is consistent with either a depleted lherzolite or harzburgite. We observe a region of higher Vp/Vs ratio (1.78-1.80) that we correlated with up to 10% hydration of mantle peridotites above the flat slab. In addition, we observe localized regions of lower Vp/Vs ratio (1.71-1.73) in the mantle above the westernmost part of the flat slab, suggesting orthopyroxene enrichment. Additionally, we present new contours for the Wadati-Benioff Zone (WBZ). The top of the WBZ of the Nazca Plate is nearly flat at ~100 km depth. We determined that WBZ is a single layer of seismicity with thickness of 10-15 km. We found that the flat slab region is wider (~240 km) than the Juan Fernandez Ridge offshore (~100 km), and together with the shape of the slab contours may reflect the response of the geometry of the slab to the southward migration of the buoyant ridge. The non-uniform spatial distribution of the slab seismicity may reflect the variability in the hydration state of the subducting Nazca Plate.

TU_P038 Samarray – proposal for a seismological backbone of a South American subduction zone observatory

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Coverage of seismological stations in South America (SA) is widely limited to the western margin, with increasing station coverage along this margin, in the Caribbean Region, and in Brazil during the last decades. Nevertheless, spatial distribution of stations is still very irregular, which complicates the comparison of lithospheric structures of the downgoing plates, as well as on the overriding SA continent. In the northern part, Caribbean (CA) plate is migrating east with respect to SA, and the Atlantic plate, connected to SA further south, is subducting to the west beneath CA. At its southwestern edge, CA is subducting as flat slab beneath SA towards east, whereas to the west, subduction beneath Panama (PA) microplate is inferred. Dynamics in the region is controlled by subduction of Cocos and Nazca plates beneath PA and SA. Along the Nazca – SA plate margin, changing subduction angles of Nazca plate are responsible for alternating volcanic and non-volcanic behavior of the Andes chain in time and space. At the southern tip, triple junction at Chile ridge creates a complex pattern towards Scotia plate. Study of the seismicity and lithospheric structure of cratons interacting with the subduction zones, Andes chain and subduction zones are among the main objectives. If possible, seismological stations from USARRAY, which is in its final stage, might cover the continent in coordination with national seismological networks which could act as reference, and take advantage of the experience of USARRAY. South American Array – SAMARRAY could be a standing array of stations at 300+ km distance, as well as a mobile array, that should benefit from existing local networks and research capacities. Tropical rainforest and high mountain chains address only some of the logistical challenges for a project that requires coordination of multinational partners for potential impact for a SA subduction zone observatory.

ABSTRACTS

TU_P039 Nanoseismic Monitoring an Attractive Choice for Civil Engineers

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Land sliding (LS) has been posing a serious threat to human population and economics of mountainous areas throughout the globe. Complex integration, multiplicity and non-linearity of factors involved make LS related investigations difficult. We propose a new monitoring approach for a field scale artificial experiment in District Federal of Brazil by using Nanoseismic Monitoring (NM).
Nanoseismic Monitoring (NM) is a method dedicated to the detection and location of very low seismic energies (ML < 1) in short distances (< 10 km). Data are acquired by small-aperture (max 200m) easy to install seismic-arrays that consist of one central 3-C sensor surrounded by three vertical sensors in a tri-partite layout and which are suited for beam processing. Detection and location of weak events (ML < 1) is done by a dedicated software: the NanoseismicSuite (developed at Stuttgart University-Germany). Seismograms are processed in the form of sonograms (i.e. spectrograms with a frequency-dependent noise adaptation). Sonograms enhance the display of weak signal energy down to the noise threshold and allow for a supervised pattern recognition of weak target events in the frequency domain. Location of weak events is supported by a graphical-jackknifing approach. Case studies on active creeping LS in Europe show that NM successfully detects various weak fracture signals induced by the LS dynamic. Thus, NM provides an insight to the mechanisms driving the slope movement. Since seismic monitoring resolves events with the most precise timing, the method present a potential for further Early Warning Systems tools.

TU_P040 Caracterización del subsuelo utilizando el método geofisico de refracción por microtremores ReMi para segmento de la Avenida Circunvalar y Parque Central Simón Bolivar

Jessica Paola Pulido Vasquez[1,2], **Maria Daniela Rodriguez Gutierrez**[1]
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Este trabajo de investigación, tuvo como propósito identificar las características del subsuelo en dos lugares de la ciudad de Bogotá, un tramo de la Avenida Circunvalar y una zona del Parque Central Simón Bolívar, con el método de refracción por microtremores ReMi.
En el desarrollo se utilizó la metodología descrita por Louie en el 2001, la cual consiste en capturar ruido ambiental e interpretar las ondas superficiales para los dos lugares de estudio, con el equipo de sísmica SEISMEX S/N 0002012003 elaborado por la empresa Subsuelos3D en colaboración de Colciencias y el Doctor en Geociencias Germán Yuri Ojeda Bueno. Para comparar la utilidad y la eficiencia de esta metodología se hicieron modificaciones en la distancia entre los geófonos, un aporte que se realizó en este proyecto y corresponde con un valor agregado con respecto a otros estudios realizados por la compañía. Además, en este proyecto se realizaron perfiles 1D, modelos 2D y un modelo 3D en un sector del Parque Central Simón Bolívar, utilizando una geometría de líneas ortogonales en la zona de adquisición. Dada las condiciones en la zona de estudio, se realiza una comparación del método de refracción sísmica convencional y el método ReMi en la Avenida Circunvalar con el fin de revisar la utilidad y observar las diferencias entre los métodos. El procesamiento y análisis de la información se realizó con los software SeisOpt ReMi (Modulos ReMiVspect y ReMiDisper), SeisImager (Modulos Pickwin y Plotrefa) y Voxler.
Con los resultados y la información geológica y litológica previa de cada uno de los lugares de estudio, se concluye que el método de refracción por microtremores es adecuado a las necesidades de investigación en ambientes urbanos como Bogotá y además presenta una facilidad en la adquisición de los datos, lo cual es óptimo para realizar estudios a gran escala.

TU_P041 Using GNSS data to monitor the National Geodetic Reference after the ocurrence of natural phenomena

José Francisco Valverde[1], **Jorge Moya**[1], Sara Bastos[1], Ana Lucía Garita[1], Daniela Ovares[1]
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Costa Rica is a country with high level seismic-volcanic activity. These events cause changes in the coordinates of the national geodetic reference frame. Nowadays, the GNSS continuously networks are one of the most powerful tools to study the crustal deformation due these phenomena. However, the recollected data by GNSS receivers must be processed using special software and it is necessary to refer the results into a modern and dynamic system. Taking advantage of SIRGAS continuously operating network, it exposes the principal results of two projects developed as part of Centro Nacional de Procesamiento de Datos GNSS (CNPDG) activities. First the MARVEL project, which main objective is to do a weekly processing of a Costarican GNSS network. Using Bernese software and SIRGAS international standards, the MARVEL project will quantify coordinates' differences as result of national kinematic. The second project it's related with the determination and analyze of the post seismic deformation associated with the Nicoya´s 2012 earthquake and it´s repercussion on the geodetic reference. One of the main goals of this project is propose a set of activities related with the estimation of co-seismic deformation and how a "correction model" for the coordinates of the reference frame can be computed to be used in practical activities, as cadastre and others.

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