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Sesión especial

Alert G-Gap: Assessment of large earthquakes and tsunamis in the Guerrero Gap for disaster prevention

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SE01-1

NEW COLLABORATION WITH JAPAN ON DISASTER MITIGATION OF LARGE EARTHQUAKE AND TSUNAMI HAZARDS IN THE GUERRERO GAP: SATREPS

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The Pacific coast of Mexico faces a high risk of natural disasters owing to the frequent occurrence of megathrust earthquakes and tsunamis. The Guerrero seismic gap, specifically, is one of the largest hazard-prone areas in central Mexico and requires urgent attention to mitigate the associated risk. Our five-year collaborative project with Japan (to begin next year) will investigate earthquake/tsunami scenarios based on onshore seismogeodetic observations and on new data observed with offshore seismometers and bottom pressure gauges. We will develop earthquake/tsunami hazard maps and tsunami evacuation guidelines to mitigate damage caused by megathrust earthquakes on the Pacific coast of Mexico. A relevant educational program will also be conducted. This project has been made possible with the financial support of “SATREPS”, a Japanese government program that promotes international collaborative research. The program aims to address global issues, such as disaster mitigation of megathrust earthquakes and the associated tsunamis, and to produce research outcomes with practical benefits to both Mexico and Japan. The project will also investigate factors that determine similarities and differences between the subduction zones of Japan and Mexico. In particular, slow earthquakes are one of the key focal points of this project because they have been observed around megathrust faults in Mexico and Japan. We will try to achieve a fundamental understanding of the physical mechanisms underlying slow earthquakes as well as megathrust earthquakes and tsunamis. The project will attempt to integrate seismology of subduction zones and disaster science as a part of the global challenge to support both the Mexican and Japanese governments’ long-term strategies to bring about sustainable social development.

SE01-2

GUERRERO SEISMIC GAP: THE TARGET OF THE SATREPS PROJECT

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The Japanese-Mexican “SATREPS” project proposed to advance the study of the Guerrero Seismic Gap (G-GAP) is close to being a reality. The famous G-GAP has been expected to rupture as a large seismic event on the Costa Grande de Guerrero at least during the last 30 years, after the 1985 Mw8.0 catastrophic Michoacán earthquake. Considering an average recurrence time of Mw>7.5 earthquakes along the Pacific coast of Mexico to be of 30-60 years, and a long time passed since the last 1911, Mw~7.5 subduction thrust earthquake in the G-GAP area, the gap is obviously overdue. Important efforts have been done by the Instituto de Geofisica and Instituto de Ingenieria, UNAM to deploy a number of seismic and GPS stations in the gap and around it to understand the seismotectonic processes in the subduction zone, which should lead finally to the main rupture. Analysis of continuous GPS data obtained for the last 10-17 years in Guerrero permitted to discover a new type of slow tectonic event: Slow Slip Events (SSE), which apparently perturb the “classical” seismic cycle by releasing some part of the elastic strain on the deep area of the seismogenic zone. These SSE are occurring approximately every four years downdip from the shallower seismogenic zone on the plate interface. Another important observation is an existence of so called non-volcanic tremors, low frequency, and very low frequency earthquakes in the subduction zone, which accompany the SSEs in Guerrero. All GPS and seismological stations are located inland and do not provide reliable data for the offshore area of the G-GAP, which still may represent a potentially important seismogenic segment with a possible rupture of Mw~7.8 in the future. The main goal of the SATREPS project is to complement the inland networks with autonomous ocean bottom seismometers (OBS) and pressure gauges (OBP) installed close to the trench to monitor seismicity and relative vertical displacements in the presumably coupled offshore zone of the G-GAP. The SATREPS plan includes also a densification of the inland networks. In this presentation we will discuss main scientific perspectives and expectations of the project.

SE01-3

VARIABILITY IN REPEATING EARTHQUAKES ACTIVITY AFTER THE 2012 OMETEPEC EARTHQUAKE

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The 2012 Ometepec earthquake is one of largest earthquakes recorded since the devastating 1985 Michoacan earthquake along the Middle America subduction zone. This event was followed by a usually large amount of aftershocks that resulted in a significant increase in the number of characteristic repeating sequences in the rupture area. Here, we examine the possible implications and the mechanisms of the characteristic repeating sequences in an attempt to better understand the post seismic relaxation and the healing of the rupture zone that occurred after the event.

SE01-4

TECTONIC TREMOR MODULATION BY INTRASLAB FLUID DIFFUSION DURING SILENT EARTHQUAKES

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Observations in different subduction zones have suggested that overpressured fluids surrounding the plate interface may be related to the origin of sustained tectonic tremors (TT) and low frequency earthquakes (LFE). One condition for a causal relationship to exist between fluids and such seismicity is their spatial collocation. Fluids at nearly lithostatic pressures within the top few kilometers of the oceanic crust have been inferred in several subduction zones, including the province of Guerrero, Mexico. In this work, we report tens of thousands of TT locations and mechanisms using the TREP method (Cruz-Atienza et al., JGR, 2015) from a large catalog that includes the TTs occurred during the two long-term Slow Slip Events (SSE) of 2006 and 2009-2010 in Guerrero (i.e., data from the MASE and G-Gap seismic arrays). Unlike earlier investigations, most TT hypocenters lie at 43 km depth and have subparallel rake angles to the Cocos-North America plate convergence direction. These results are in agreement with independent locations and mechanisms of LFEs in the region. Poroelastic modeling of fluid diffusion during the SSEs with an experimentally-based permeability function of the effective pressure and a sealed plate interface show that the evolution of Coulomb Failure Stresses within the top 4 km of the slab (i.e., below the plate interface) are consistent with the time-dependent occurrence-rate of LFEs. Furthermore, solutions of the non-linear diffusion equation constrained by the SSEs strain fields reveal the existence of solitary pressure waves (i.e., solitons) propagating at speeds of the observed tremor source migration (i.e., 20–100 km/h). This suggests that a moderate horizontal gradient of pore pressure (i.e., ~0.05 bar/km) should exist in the oceanic crust of the subducting plate. A pressure gradient that may be due to dehydration processes and temperature changes in the slab with distance from the trench. We conclude that (1) TTs and LFEs are generated few kilometers below the plate interface in the crust of the subducted slab, and that (2) the fluid diffusion in the uppermost layer of the subducted slab is responsible of both, the slow evolution of the LFEs occurrence rate and the rapid migration of tremor sources (i.e., streaking).

SE01-5

LONG-TERM AND SHORT-TERM VERTICAL DEFORMATION ACROSS THE FOREARC OF THE MEXICAN SUBDUCTION ZONE, GUERRERO SEISMIC GAP

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Spatial scales of the earthquake cycle, from rapid deformation associated with earthquake rupture to slow deformation associated with interseismic and transient slow-slip behavior, span from fractions of a meter to thousands of kilometers (plate boundaries). Similarly, temporal scales range from seconds during an earthquake rupture to thousands of years of strain accumulation between earthquakes. The complexity of the multiple physical processes operating over this vast range of scales and the limited coverage of observations leads most scientists to focus on a narrow space-time window to isolate just one or a few process. We discuss here preliminary results on the vertical crustal deformation associated with both slow and rapid crustal deformation along a profile across the forearc region of the central Mexican subduction zone on the Guerrero seismic gap, where the Cocos plate underthrusts the North American plate.

SE01-6

TSUNAMI MODELING OF THE JALISCO 1995 EARTHQUAKE, BASED ON FINITE FAULT SEISMIC SOURCE MODELS

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Tsunamis are a real threat to the Mexican coast, with 20 tsunamis documented in the last century (Devora and Farreras, 1993) and a mega tsunami documented in 1787, with an estimated run up of 6 km (García Acosta and Suárez, 1996). In the last years there have been important advances in tsunami modeling, with new algorithms being able to simulate the wave propagation while simultaneously accounting for bottom friction as well as wet and dry elements. In this study we simulate the tsunami generated by the Jalisco 1995 earthquake in Mexico using the freely available tsunami modeling tool Geoclaw (George and LeVeque, 2006). Geoclaw solves the complete nonlinear shallow water equations using high-resolution finite volume methods using an adaptive mesh refinement (AMR) discretization. We model the tsunami for several different earthquake source models, that were constrained to fit observed teleseismic body- and surface waves as well as regional static offsets, in order to discriminate between them. The models have variable amount of slip allowed on the seismic interface closest to the oceanic trench, with one model having a fully locked trench while another has most of the slip close to the trench. We qualitatively compare the computed tsunami runup to the one observed on the coast of Jalisco and Colima.

SE01-7

LA BRECHA SÍSMICA DE GUERRERO: “UN RETO PARA LA PREVENCIÓN DE DESASTRES”

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La zona de la Brecha Sísmica de Guerrero (BSG), es considerada un sitio maduro sísmicamente. Han pasado mas de 104 años, sin que en esta región haya ocurrido un sismo con magnitud igual o mayor que 7.6. Los últimos sismos cercanos a esta zona: San Marcos en 1957, Petatlán en 1943, 1979 y 1985 (Replica), con magnitudes de 7.5 a 7.6, han producido daños importantes en la región epicentral y en la Cd. De México. Desde la ocurrencia de estos sismos, tanto Acapulco como la Cd. De México han crecido de manera muy importante. Un sismo en la BSG, similar a los mencionados, o de mayor magnitud, podría generar un tsunami de 3 a 9 metros de altura, dependiendo de la magnitud del evento. En la zona de Acapulco, Punta Diamante y Laguna de Coyuca, existen aproximadamente: 73,000 personas, 49,000 viviendas, 4 hospitales, 82 escuelas, 85 mercados, 2 aeropuertos, 162 hoteles 51 bancos y 12 estaciones de gasolina, todos ellos ubicados en elevaciones menores de 10 mts sobre el nivel medio del mar. En el caso de la Cd. De México, para las Delegaciones Benito Juárez, Cuauhtémoc, Gustavo A. Madero y Venustiano Carranza, en donde hay aproximadamente: 2.3 Millones de personas, 800 Mil viviendas, 184 hospitales, 3,200 escuelas, 1,240 mercados, 1 aeropuerto, 613 hoteles, 714 bancos y 138 gasolineras, todos ellos expuestos a intensidades importantes ante un sismo proveniente de la BSG. Los datos antes mencionados fueron obtenidos del Atlas Nacional de Riesgos. Es posible obtener mucho mas información que la expresada. Por ejemplo se tienen el número de cruces de calles en Acapulco, en la zona inundable, con la finalidad de conocer el número de letreros necesarios para indicar el nivel de peligro ante tsunami, en cada esquina y así establecer las rutas de evacuación y las zonas seguras. En el caso de la Cd. De México, los datos permiten aproximar el número de edificios vulnerables, por su altura y fecha de construcción. Actualmente se cuenta con sistemas de alerta temprana ante un sismo y tsunamis generados en la BSG. Pero dichos sistemas son el último eslabón de una serie de acciones prioritarias como son: el conocimiento del fenómeno, el entendimiento de la vulnerabilidad de los bienes y las personas, así como el potencial riesgo al que está expuesta la población. Es importante llevar a cabo medidas preventivas en los tres niveles de gobierno, priorizando aquellas que involucren la participación ciudadana , tales como difusión constante sobre los fenómenos, promoción de planes de Protección Civil y la realización de simulacros frecuentes. No sabemos cuando ocurrirá un sismo en la Brecha de Guerrero, pero si estamos preparados, evitaremos que este fenómeno se convierta en un desastre. Prevenir es Vivir.

SE01-8 CARTEL

TSUNAMI DISASTER MITIGATION IN JAPAN AND LESSONS FROM RECENT DISASTER EVENTS TO ENHANCE TSUNAMI RISK REDUCTION

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More than 2.7 billion people were affected by disasters in the world within the first decade of the twenty first century. Some of these disasters are related to tsunami events, in some cases considered as mega-disasters based on their magnitude, extent of impact and number of victims. As examples remaining in the memory of current generations are the 2004 Indian Ocean tsunami in Sumatra, the 2010 Maule Earthquake in Chile and the 2011 Great East Japan Earthquake and Tsunami (GEJET). For years, Japan was seen as the country with the highest technology and infrastructure on tsunami mitigation and preparation, including tsunami warning and monitoring systems. Unfortunately, the 2011 GEJET event was larger than the expected tsunamis and the impact resulted on extensive damage and exceeding many aspects of local evacuation plans. Several structures collapsed or were heavily damaged, thousands of people were killed by the tsunami and significant losses were registered in the Tohoku economy. What we have learned and still need to learn form these events? What lessons can be shared with western pacific countries? These and other questions are discussed here.

SE01-9 CARTEL

COSEISMIC STRESS TRANSFER FROM RECENT LARGE SUBDUCTION EARTHQUAKES ALONG THE MEXICAN SUBDUCTION ZONE: INVERTED AND THEORETICAL SLIP DISTRIBUTIONS

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We analyze the coseismic stress transfer produced by recent large subduction earthquakes (M?6.9), occurred between 1973 and 2014, along the Mexican Subduction zone. Two of the analyzed earthquakes occurred along the tectonic interface between the Rivera and North American plates, and the rest of them along the Cocos - North American plate interface. Stress changes are computed assuming the Coulomb Failure criterion, based on the slip distribution obtained by two different ways. On one hand, assuming theoretical slip distributions along the fault plane, and on the other hand, using inverted slip distributions on the fault plane, obtained from kinematic waveform inversion. One of the theoretical distributions yield an approximately constant stress drop inside the rupture area (?CFST1), while the other one is set to produce low edge stress effects (?CFST2). For the same earthquakes previously analyzed, the Coulomb stress changes are then computed using slip distributions obtained from waveform inversions (?CFSI). In this case, stress computations inside rupture areas show highly heterogeneous stress distribution; however, outside the main ruptured areas stress distributions show in various cases, similar behaviour and spatial extent as the ones computed assuming theoretical slip settings. Stress changes are calculated along the extended fault plane, coincident with the tectonic interface between the subducting slab and the continental plate. Results obtained from these methodologies are compared in terms of their spatio-temporal evolution and their spatial extent along the fault interface. Our results show that under certain circumstances, stress triggering analysis by large subduction earthquakes in the Mexican subdution zone, might be suitably done assuming different theoretical distributions of slips.

SE01-10 CARTEL

ANÁLISIS DE ZONAS DE INUNDACIÓN EN IXTAPA-ZIHUATANEJO, GUERRERO DEBIDO A UN TSUNAMI SIMULADO EN LA PLACA DE COCOS

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Es de suma importancia para el desarrollo de la sociedad el conocer las zonas potenciales de inundación ante un posible Tsunami, tanto para crear posibles rutas de evacuación como para delimitar las zonas de seguridad ante este fenómeno. En este trabajo se utilizó un modelo hidrodinámico para simular un tsunami en la Placa de Cocos frente a la costa de Ixtapa-Zihuatanejo con un desplazamiento inicial de 10 metros de altura de la columna de agua. Para los datos de terreno se utilizaron cartas batimétricas de la SMN y de Lidar medidos por INEGI. Los resultados comparan las zonas de inundación entre la zona de Ixtapa y la bahía de Zihuatanejo.