Sesión especial

ESTUDIO DE GRANDES TERREMOTOS Y TSUNAMIS PARA LA PREVENCIÓN DE DESASTRES

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SE12-1

UNVEILING THE MYSTERY OF THE GUERRERO SEISMIC GAP

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The Guerrero seismic gap, G-GAP, has not ruptured as a large subduction thrust earthquake on the Costa Grande de Guerrero since 1911, when the last Mw~7.5 subduction thrust earthquake happened in this area. The average recurrence period of Mw>7.5 earthquakes along the Mexican Pacific coast estimated from the historical catalog is about 30 to 60 years. It means that the G-GAP is overdue almost twice the recurrence period. After catastrophic consequences of the 1985 Mw8.0 Michoacán earthquake, the G-GAP has become one of the main targets of geophysical studies in Mexico. Seismic and geodetic investigations in Guerrero during the last twenty years revealed new seismotectonic phenomena such as long- and short-term slow slip events (SSE), nonvolcanic tremor, low frequency earthquakes, and very low frequency earthquakes. Similar observations were done in other subduction zones and tectonic plate boundaries. Inversions of GPS position time series for the slow slip show that large SSEs, which are happening in Guerrero approximately every 4 years, can propagate into the shallow, seismogenic zone of the plate interface within the seismic gap, reducing the effective strain accumulation by about 75%. Besides, the last 2014 SSE has likely triggered the Mw7.2 Papanoa thrust event, leaving unbroken the main area of the G-GAP that extends between Acapulco and Papanoa. This anomalous behavior of the gap is difficult to explain considering that its accumulated elastic strain energy since the last rupture were sufficient to produce a Mw>7.5 earthquake. While the SSEs are releasing some part of the elastic strain in the downdip portion of the seismogenic zone, the offshore segment of the plate interface can still have high seismic potential. One offshore thrust earthquake of Mw 7.5-8.0 in the gap may produce potentially devastating tsunami. New Japan-Mexico SATREPS project should help to resolve several crucial problems of the G-GAP: Why the gap has been silent for such a long time? Is the offshore coupling across the gap strong enough to accumulate sufficient elastic strain to produce a catastrophic seismic even? How large and harmful could be the tsunami due to this earthquake? What are the main physical processes and parameters that govern the behavior of the G-GAP? How important are SSEs in the seismic cycle of the gap?

SE12-2

HOW TO USE SLOW EARTHQUAKES: MONITORING AND EXPLOITING SLOW EARTHQUAKES TO MEGATHRUST EVENT

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Slow earthquakes as a transient acceleration of plate motion are now being identified as ubiquitous phenomena in subduction zones. They distribute around the strong interplate coupling area or near the asperity of megathrust earthquakes in several subduction margins, such as the Middle American, Casicadia, Alaska, Hikurangi and Nankai subduction margins. Recent seismic and geodetic facilities have successfully captured some slow-earthquake activity leading up to large earthquakes, especially megathrust events in subduction zones. For instance, they observed slow earthquakes by the trench near the foci of the 2011 Tohoku-Oki earthquake before the mainshock occurred. They also observed similar slow earthquakes prior to the magnitude-6 class earthquake in 2008 at the same region as that of the 2011 slow earthquakes. These slow earthquakes on the plate interface increase stress on the foci of the large earthquakes, ultimately triggering the largest interplate earthquakes. The difference between the 2008 and 2011 earthquakes is whether they ceased or continued before they triggered the large interplate earthquakes. Consequently, the faults of the slow earthquakes were included in extremely the huge coseismic-slip region exceeding 30 m slip during the megathrust event. This suggests that slow earthquakes facilitate huge coseismic slips on its own fault if coseismic ruptures reach the ongoing slow-earthquake's fault. A recent laboratory rock experiment on the frictional properties of slow earthquakes shows that a rise in sliding velocity on the slow-earthquake's fault could induce frictional weakening behavior, specifically of slip-weakening. This suggests that a fault experiencing slow earthquakes may be induced more easily to slip coseismically if a dynamic rupture from a large earthquake propagates onto the fault. Slow earthquakes both trigger ruptures at asperities of large earthquakes and facilitate coseismic slips on ongoing slow-earthquake faults. The latter eventually causes the large coseismic slip near the trench and the extremely huge tsunami height on the 2011 Tohoku-Oki earthquake. Recent progress in ocean bottom seismic and geodetic networks hopefully contribute to real-time monitoring of earthquake activity and early warning to the public. Evaluating slow earthquake activity will be useful for forecasting large earthquake/tsunami disasters and for issuing early warning if we can monitor them in real time.

SE12-3

THE GEOLOGICAL CHARACTERISTICS THAT ALLOW FOR TRANSIENT SLIP WITHIN THE SEISMOGENIC ZONE IN THE GUERRERO GAP

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Slow Slip Events (SSE's) are typically found in the transiently slipping regime between the brittle seismogenic zone and the freely slipping ductile regime. However, a few examples of SSE's have been found in seismogenic zones. Most notably the largest SSE's in the world invade the Guerrero Seismic Gap in southern Mexico. Previous studies have suggested that the SSE's there reduce the seismic slip deficit by about four times. Here we examine the mechanism that allows for the large SSE's to invade the Guerrero Gap. Southern Mexico is the only active margin in the world where 1000 km of coastline are within 100 km of the trench with a seismic gap in the middle. The large earthquakes (> M7) rupture at least partially beneath the coast so that characteristics of the seismogenic zone can be measured from land based studies. We take advantage of this unique tectonic geometry to look for changes throughout the seismogenic zone that coincide with the gap. Combining evidence from magnetotelluric (MT) profiles with the geologic evolution and seismotectonics of southern Mexico we observed significant structural and compositional changes across the Guerrero seismic Gap. Four MT profiles were performed. One was within the Gap and the rest were outside. The profiles outside the Gap revealed that fluids, corresponding to high conductivity zones, once they leave the slab are free to infiltrate the continental crust. By contrast inside the gap the fluids are trapped below a very highly resistive body observed in the lower crust. An analysis of the Late Cretaceous-Cenozoic igneous activity of southern Mexico showed that magmatism lasted for less than 10 m.y. along most of the coast but was continuous for ~45 m.y. in the Gap area. We suggest that the highly resistive body found in the MT profile within the Gap is related to this long lasting magmatic activity, which likely produced the formation of an impermeable gabbroic layer in the lower crust. This lower crustal body has acted as a seal to trap fluids and over-pressurize the plate interface, thereby allowing for SSE's to invade the seismogenic zone. Additionally, recent seismotectonic activity outlines the SSE region as is commonly observed throughout the world further adding evidence to its existence. It seems that transient slip can occur in typically seismogenic regions, but requires very special conditions. This peculiar geologic-tectonic setting suggests that the coupling and therefore the seismic hazard are permanently reduced in the Guerrero seismic Gap.

SE12-4

NUMERICAL SIMULATIONS OF TEMPERATURE, DEHYDRATION, AND FLOW FIELDS ASSOCIATED WITH SUBDUCTION OF THE COCOS PLATE, AND ITS RELATION TO THE OCCURRENCE OF INTERPLATE SEISMIC EVENTS IN SOUTHERN MEXICO

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In southern Mexico, tectonic tremors mainly occur in the "flat slab region, and the last three SSEs in southern Mexico occurred in the shallower region. Besides, there are two seismic gaps of megathrust earthquakes in Guerrero and Oaxaca. To investigate generation mechanisms of megathrust earthquakes, tectonic tremors, and slow slip events (SSEs) in southern Mexico, we performed three-dimensional numerical simulations of temperature and mantle flow associated with subduction of the Cocos plate, and estimated dehydrated water content from the subducting plate. Here we considered retreat of the Middle American trench initiating about 16 Ma as one of the generation mechanisms of the slab flattening. In our model, we introduced the trench retreat effect during only a certain period between 16 Ma and present in order to best fit the observed heat flow data (from Global Heat Flow Database) as well as Curie point depths defined by the 580 ? isotherm. Our preliminary results show that trench rollback has a strong influence on temperature distribution. Models with trench rollback induce a weaker mantle wedge convection cell compared with models with stationary trench. Other parameter that is currently investigated in this study is the rate of trench retreat.

SE12-5

DETECTION OF VERY LOW FREQUENCY EARTHQUAKES IN THE MEXICAN SUBDUCTION ZONE

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Tremors have already been detected in three different areas (Jalisco, Guerrero and Oaxaca) of the Mexican subduction zone but their moment tensor is difficult to estimate. However, Very Low Frequency (VLF) earthquakes have been shown to occur at the subduction interface in Guerrero, Mexico at the same time as tremors and their focal mechanisms have been calculated. We try to detect VLF events using the same method in Jalisco and in Oaxaca. With this aim we detect tremors using an envelope correlation method in Oaxaca and use a previously determined tremor catalog in Jalisco [Idehara et al., 2014]. Using the method of Ide and Yabe [2014], we stack waveforms, in the VLF band, at the time of occurrence of tremors. Finally, the stacked waveforms are inverted to better estimate the depth of these events and their moment tensor. This analysis is carried out for different time periods between 2005 and 2015, depending on the deployment of temporary network along the Mexican coast. In addition, permanent broadband stations of the Servicio Sismológico Nacional (Mexico) are used. The tremors detected in Oaxaca area are located farther west than previously known probably because of the more eastern location of stations. Our results show the spatial distribution of moment tensor along the Mexican subduction zone. The VLF sources are located at or close to the plate interface in Oaxaca and Jalisco as is observed in Guerrero. These events have magnitudes of about 3 and very low-angle to low-angle thrust mechanisms in agreement with the varying geometry of the subduction interface. The slip directions of VLF earthquakes are also consistent with the plates convergence vectors. This indicate these signals are probably radiated by shear slip on the plate interface.

SE12-6

MOMENT TENSOR INVERSION OF TECTONIC TREMORS IN THE GUERRERO SUBDUCTION ZONE

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Recent studies in different subduction zones suggest that tectonic tremors (TT) are caused by point dislocations at depth. The systematic study of focal mechanisms of tremor sources turns out to be important to understand the processes that originate this phenomenon and the implications they have in the occurrence of slow slip events. Cruz-Atienza et al. (2015) introduced the “Tremor Energy and Polarization” (TREP) method to locate tectonic tremors assuming horizontal point dislocations, which is a reasonable hypothesis for deep tremors in the state of Guerrero. However, this assumption could be a limitation in other cases where the fault dip is different (i.e., San Andreas Fault). The simultaneous determination of tremor locations and focal mechanisms would allow studying this phenomenon in any tectonic environment. In this work, the TREP method is generalized employing a global inversion technique (i.e., simulated annealing) to determine simultaneously the tremor source location and the associated moment tensor from the energy spatial distribution and the azimuth of the particle motion polarization. Preliminary results employing synthetic tremor sources are encouraging and show that this new methodology could be used to analyze real tectonic tremors and the associated processes.

SE12-7

PORE PRESSURE EVOLUTION DUE TO SLOW EARTHQUAKES: IMPLICATIONS FOR TECTONIC TREMOR GENERATION IN GUERRERO, MEXICO

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Since the discovery of the tectonic tremors (TT) and the slow slip events (SSE), many studies claim that their origin is related to the presence of overpressure fluids. However, in order to determine the role of fluids in the generation of slow slip phenomena, physical models should explain quantitatively the observations. In Guerrero, TTs occur in two regions within the flat slab section called the transient zone, between 150 and 175 km from the trench, and the sweet spot downdip between 200 and 240 km. Recent seismological observations in these regions suggest that the upper oceanic crust is under near-lithostatic pore pressure. In this work we compute the poroelastic fields induced by the long-term 2006 and 2009-2010 SSEs in Guerrero and compare their evolution with the spatial-temporal activity of TTs and LFEs. Our modeling results show that: (1) the stress transfer by the SSEs does not correlate with the occurrence-rate of TTs and LFEs; (2) in the Transient zone, the slip velocity is consistent with the activity rate of TTs and LFEs; and (3) in the Sweet spot, the evolution of the pore pressure is well correlated with the occurrence rate of the TT and LFEs during both, long-term and short-term SSEs. The later result strongly suggests that changes in the effective normal stress due to the evolution of pore pressure close to the plate interface is the dominant mechanism modulating the occurrence-rate of the TTs and LFEs in the sweet spot.

SE12-8

TECTONIC TREMOR MIGRATION INDUCED BY PORE PRESSURE SOLITONS IN GUERRERO, MEXICO

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Observations in different subduction zones suggest that overpressured fluids close to the plate interface may be linked to the origin of tectonic tremors (TT) and low frequency earthquakes (LFE). Fluids at nearly lithostatic pressures within the top few kilometers of the oceanic crust have been inferred in several subduction zones, including the state of Guerrero, Mexico. The actual effect of fluid diffusion on fault zones may strongly affect the seismicity rate by inducing transient changes in the effective fault-normal stresses. In the upper crust during fluid-injection tests, these changes propagate slowly (i.e., ~50 meters per day or 0.002 km/h). However, when fluids are subject to nearly lithostatic levels at depth (i.e., ~40 km), pore pressure gradients may induce large transient variations of the permeability that, under some conditions, produce solitary pressure waves (i.e., solitons) propagating much faster across the fault zone. Recent TT epicentral locations in Guerrero using the Tremor Energy and Polarization (TREP) method (Cruz-Atienza et al., JGR, 2015) show that sources of these events cluster in separated patches during slow slip events (SSE). Besides, rapid tremor migrations with speeds ranging between 10 and 80 km/h also occur primarily within these patches. Migration directions change with time, so that they are parallel to the slow slip front first, as observed in other subduction zones. However, latter migration directions are different and consistent with the pore pressure gradient, as predicted by our poroelastic modeling of SSEs in Guerrero. A parametric study of the governing non-linear diffusion equation further shows that soliton-like solutions propagate, under realistic conditions (as settled by experimental rock tests), with the same speeds as those observed for the TT migrations. This result along with the clustered distribution of TT suggest that physical conditions surrounding the plate interface in Guerrero (such as pore pressure and/or fault geometry) are likely to produce solitary pressure waves, and that these waves may be responsible for the migration of tectonic tremor sources.

SE12-9

DID THE LONG DURATION, APRIL 18, 2002 (MW 6.7), MEXICO EARTHQUAKE BREAK THE GUERRERO GAP?

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The April 18, 2002 (Mw 6.7) earthquake was located about 55 km off the coast of Guerrero, near to the Mesoamerican Trench. The hypocenter location (Pacheco & Singh, 2010) is inside what is known as the Guerrero Gap, a segment of the Mexican subduction zone that has not had a large (M>7) earthquake in at least 100 years (Singh et al 1981). The 2002 earthquake is anomalous in the sense that it produced very small accelerations for its size (Iglesias et al 2003) and it is one of the earthquakes with longest duration relative to its magnitude recorded globally in the last 40 years (Duputel et al, 2013). A small tsunami (less than 10 cm) was detected at nearby sites. Furthermore, it is notable that this event occurred at the end of the 2002 slow slip event, that occurred on the down dip portion of the same segment from jan-april the same year(Kostoglodov 2003). The location and extent of the rupture area of this event, is key to understanding the seismogenic potential of the Guerrero Gap. Often the rupture area of an earthquake is estimated by the extent of the aftershock area. However, locating earthquakes near the trench is difficult, due to their emerging P-waves and as they occur outside of the network of observation. In this study we calculate the duration of the 2002 earthquake by observations of both near- and far-field records. We then relocate the aftershocks to estimate the rupture area, and finally discuss the implications of our results for the seismogenic potential of the zone.

SE12-10

FAST IDENTIFICATION OF NEAR-TRENCH EARTHQUAKES ALONG THE MEXICAN SUBDUCTION ZONE BASED ON CHARACTERISTICS OF GROUND MOTION IN MEXICO CITY

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We explore the versatility of three parameters computed from recordings at station CU, located in Mexico City, ~ 300 to 600 km from the trench, for quick detection (= 7 min after the origin time) of near-trench earthquakes for potential use in tsunami warning. The parameters are: (1) ER, the ratio of total to high-frequency energy, (2) Sa*(6), the pseudo-acceleration response spectrum with 5% damping at 6 s normalized by peak ground acceleration (PGA), and (3) RESN, the PGA residual with respect to a newly-derived ground motion prediction equation at CU. Since near-trench earthquakes are relatively deficient in high-frequency radiation, we expect ER and Sa*(6) to be relatively large and RESN to be negative for such events. Tests on CU recordings of 65 interface earthquakes occurring along the Mexican subduction zone (4.8 = Mw = 8.0; 270 = R = 615 km) show that if ER = 100, Sa*(6) = 0.70, and RESN = 0 then the earthquake is near trench. Such an event has greater tsunami potential and produces low acceleration. Few misidentifications and missed events are probably a consequence of poor location, although unusual depth and source characteristics may also be responsible in some cases.

SE12-11

SLIP DISTRIBUTION OF TWO RECENT LARGE EARTHQUAKES IN THE GUERRERO SEGMENT OF THE MEXICAN SUBDUCTION ZONE AND THEIR RELATION TO PREVIOUS EARTHQUAKES, SILENT SLIP EVENTS AND SEISMIC GAPS

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In 2012 and 2014 large subduction earthquakes (M>7) occurred approximately 300 km apart, in the state of Guerrero, Mexico. The westernmost half of the segment between them is known as the Guerrero seismic gap and has not had a large earthquake in at least 100 years while most of the easternmost half last broke in 1957. Silent slip events have been reported down dip of both 2012 and 2014 earthquakes as well as in the gap between them (Kostoglodov et al 2003, Graham 2014). There are indications that the westernmost half has different frictional properties than the areas surrounding it. However, the two events at the edges of the zone also seem to behave in different manner, indicating a broad range of frictional properties in this area, with changes occurring over short distances. The 2012/03/20, M7.5 earthquake occurred near the Guerrero-Oaxaca border. This earthquake is noteworthy for breaking the same asperities as the previous events of 1937 M7.2 and1982(a) M6.9, in what appears to be very large “repeating earthquakes”. Furthermore, the density of smaller repeating events is greater in this segment than in other parts of the subduction zone (Dominguez et al, submitted) and this earthquake generated an anomalously large number of aftershocks for its size (UNAM Seis. Group, 2013). The 2012 event may have broken two asperities (UNAM Seis. Group, 2013). How the two asperities relate to the previous smaller “large events”, the repeating earthquakes, the high number of aftershocks and the slow slip events is not clear. The 2014/04/18 M 7.2 earthquake broke a patch just beyond the western edge of the Guerrero gap, a region that previously broke in the 1979 M7.4 earthquake and in the 1943 M 7.4 earthquake. This earthquake, despite being smaller, had a much larger duration, few aftershocks and clearly ruptured two separate patches (UNAM Seis. Group, 2015), that seem not to coincide with the main asperities of previous events. In this work we estimate the slip distributions for the 2012 and 2014 earthquakes, by combining the data used separately in previous studies; farfield body- and surface-wave data, GPS displacement vectors and near field and regional strong motion records. We focus on estimating the rupture areas as well as how well constrained their limits and separations are. Finally, we discuss the implications for the friction on the fault plane and the persistency in time of the asperities.

SE12-12

RADIATED SEISMIC ENERGY FROM THE SEISMOGENIC ZONE OF GUERRERO, MEXICO

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During earthquakes, potential energy stored in the Earth is released as fracture energy, thermal energy and radiated energy. Although this energy partitioning is difficult to quantify, radiated seismic energy can be estimated by seismological observations, and can be used as a parameter to determine physical properties and the potential threat that an earthquake presents. In an attempt to clarify the mechanisms that control the distribution and dissipation of seismic energy along the Guerrero segment of the Mesoamerican trench, we estimated radiated seismic energy, stress drop and radiation efficiency of two recent large earthquakes, the 2012 Ometepec (Mw7.5) earthquake and the Papanoa 2014 (Mw7.2) earthquake, and many of their aftershocks. Estimations of radiated energy scaled with seismic moment (Es/M0), for the two earthquakes and their aftershocks, show similar results as other seismic energy studies for earthquakes in Guerrero. Furthermore, we found find no clear dependence of Es/M0 on distance from the trench or depth, suggesting an irregular spatial distribution of seismic energy release in the area. Additional analysis shows lateral heterogeneities in stress drop and efficiency along the trench. For example low radiated energy release is observed during those aftershocks of the 2012 earthquake which occurred over the area that had ruptured in the 1996 Ometepec earthquake (Mw7.0). The 1996 earthquake is a slow event which produced anomalously low Es.

SE12-13

OVERVIEW OF THE SATREPS TSUNAMI MODELING GROUP: COMPREHENSIVE TSUNAMI HAZARD ASSESSMENT OF THE MEXICAN PACIFIC COAST

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The potential for large earthquakes around the subduction zone near the Mexican Pacific is not negligible and the tsunami associated with this event signifies high risk for several coastal cities along the Mexican coastline. The main objective of the SATREPS tsunami modeling group includes numerical simulations of tsunami wave height and inundation for different scenarios for earthquake in de Guerrero Gap. To achieve this goal, we first validate the numerical models used in this project (TUNAMI and GeoCLAW) within the study area. Thus, we have carried out numerical simulations for the historical tsunami events ocurring along the Mexican Pacific Coasts during the past 40 years and validated these using field observations reported in the literature. The tsunami source models for these events have been obtained from the Finite-Source Rupture Model Database (SRCMOD). In addition, we proposed several stochastic scenarios that will be studied in detail for at least two target coastal cities. Throughout the following five years of the project, the different scenarios will be then updated based on the dynamic source scenarios provided by the SATREPS Earthquake modeling subgroup (B-1) and the results will be delivered to the C-1 and C-2 members for risk evaluation, and education and outreach, respectively. Here, we present the framework, progress and future work of the SATREPS tsunami group.

SE12-14

PHYSICAL AND NUMERICAL MODELLING OF TSUNAMI INUNDATION IN URBAN AREA

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The 2011 off the Pacific coast of Tohoku Earthquake Tsunami caused catastrophic disaster to coastal areas. This and similar coastal hazards emphasize the need for engineers to understand the fundamental processes causing damage and the potential of maximum damage in order to design coastal communities with increased resilience to tsunami events. Common methods used to evaluate local conditions caused by tsunamis include post-disaster reconnaissance field surveys, numerical modelling, and laboratory experiments. Behaviour of land side tsunami inundation is not well known as well as the fluid forcing and accuracy of tsunami hazard mapping.

This study aims to understand tsunami behaviour in a building scale and to improve modelling of tsunami inundation in an urban area. Laboratory experiments are an essential starting point in the investigation of urban roughness effects on wave propagation and maximum pressures in coastal communities. Physical modelling usually uses solitary wave, N-wave, or sinusoidal wave as a tsunami wave. However, the observed tsunami trace during the Tohoku event showed a complex wave profile, consisting of a steep water level rise following a slow water level rise. DPRI, Kyoto University made a new wave flume (HyTOFU: Hybrid Tsunami Open Flume in Ujigawa laboratory) to reproduce realistic complex tsunami profiles by three wave generation mechanisms: a flow pump, a mechanical piston, and a vertical discharge of a constant volume of water from a set elevation above the free surface (falling head). Experiments were conducted at HyTOFU with the combined use of flow pump and mechanical piston wavemaker. Quadratic prism models assuming coastal houses with 1:20 scale and a urban city model (Onagawa City, Japan) with 1:250 were used for the experiment. We measured water levels by wave gauges, pressures acting on buildings by sensors, flow velocities by ADVs, and inundation areas by video image visualization. Experimental results are compared with existing empirical formulas, e.g. Asakura et al. (2000), ASCE 7 (2016). Numerical modelling of tsunami inundation in urban areas is under development, e.g., Park et al. (2014), Koshimura (2016). Macro-roughness obstructions significantly affect wave propagation especially in urban areas. To better understand these effects, we conducted numerical simulation comparisons to physical model experiments of Seaside City, Oregon, US by Park et al. (2013) and of Onagawa City by our group. We are planning to organize a benchmark test and a blind test by providing the Onagawa model experiment results.

SE12-15

UNCERTAINTY ANALYSIS OF NANKAI TROUGH EARTHQUAKE TSUNAMI USING STOCHASTIC SOURCE MODEL

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In 2012, the Central Disaster Management Council (CDMC) of the Cabinet Office proposed 11 slip distributions (scenarios) of the future Nankai Trough Earthquake. However, since only one critical scenario is defined for each region, it is difficult to evaluate the uncertainty of tsunamis. In this study, we develop stochastic slip distributions to explore a wide range of possible tsunami scenarios for the Nankai Earthquake. A series of procedure, i.e. stochastic slip generation, initial tsunami profile determination, and numerical simulation of tsunami propagation, is defined as stochastic tsunami model. The simulated tsunamis are basis to assess uncertainty and variability of tsunami wave profiles and characteristics. As a case study, two regions (Kochi and Wakayama) are focused upon for tsunami hazard assessment. Stochastic slip distribution is generated based on spatial correlation of inverse slip distribution. The value of spatial correlation, which is defined as three parameters (H, Ax, Az) is founded by spectral analysis of inverse slip distribution. H is the Hurst number, which determines the slope of the power spectral decay in the high wave-number range. Ax and Az are correlation length for the along-strike and down-dip directions, respectively. Estimated H usually fall between 0 and 1 in agreement with physical theories. Anisotropic features of slip distribution in the down-dip and along-strike directions are captured by Az and Ax. Based on these parameters, stochastic slip distribution can be generated adjusting maximum value, standard deviation, and so on. We generated 50 stochastic slip distributions and simulated tsunami propagations based on each stochastic slip distribution. Uncertainty analysis was conducted comparing with the CDMC model. The results indicate that the maximum tsunami height at a specific location is sensitive to the details of the tsunami sources and the dispersion of the maximum tsunami height is significant. The earthquake slip distribution also affects the time of tsunami arrival greatly. It is important to take into account tsunami source uncertainty in making tsunami hazard maps for coastal areas in Wakayama and Kochi. Furthermore, the appearance probability of maximum tsunami heights in 50 cases is fitted to inverse Gaussian distribution and the exceedance probability of CDMC projection value in each point is calculated. The results can point out that the possibility of tsunami exceeds the assumption value is not negligible.

SE12-16

A STUDY ON INTER-LOCAL ADAPTATION OF DISASTER EDUCATION MATERIAL

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Disaster Risk Reduction (DRR) education transfers the knowledge on appropriate actions taken before, during and after disasters. Different types of DRR education materials have been developed by various organizations based on the local needs. However, it is common to most of the projects that continuous monitoring is not implemented after projects end and results in the discontinuation of the use of developed educational materials. On the other hand, one DRR education material named “BOSAI Duck” developed in Japan was adapted into El Salvadorian context in 2010 and follow-up monitoring held in 2016 revealed its continuous use. Hence, this study aims to analyze the process of adaptation and discuss factors of continuous use. The BOSAI Duck is a card game to teach “first move” against natural hazards. It consists of 16 cards in Japanese version, and one side of card shows the pictures of natural and man-made disasters such as earthquake and kidnapping, and the other side shows the animal figures taking corresponding reactions. Hence, children can learn following the actions taken by the animal on the card. The author together with two other Japanese started to work from July 2010 to adapt the contents of BOSAI Duck for El Salvadorian context. First of all, disaster management personnel from five city halls, personnel from Civil Protection, teachers and medical staffs (in total 21 people) gathered and discussed to adapt it into the El Salvadorian context. In the discussion, two types of adaptation were raised, one was the modifications of contents in order to adapt to the El Salvadorian culture (=cultural tuning) and the other was the modifications of contents in order to adapt to the El Salvadorian natural and social needs (=customization). Thus, cultural tuning and customization were held and BOSAI Duck El Salvador version completed in May 2011. In order to disseminate the material, the series of workshops to teach how to use BOSAI Duck were implemented to the personnel of city hall, Civil Protection and teachers. In addition, in June 2011, the ceremony of delivery to the national level Civil Protection were realized, thus the BOSAI Duck became authorized material by the national government of El Salvador. With these background, BOSAI Duck was utilized by local people and applied for more than 2,000 students between May 2011 and June 2012. Follow-up study was held in August 2016 and it revealed that the material has been continuously implemented in various places of El Salvador. This simple data can be a strong evidence of continuity of BOSAI Duck. Cultural tuning and modifications, authorization by national government and series of workshop may be factors which lead to the continuous use, however, the crucial factor can be related deeply with the culturally-deprived personality of El Salvadorians. Non-verbal and physical movement-based teaching method may fit to them as even users stated the word of excitement and joyfulness before and after implementing BOSAI Duck.

SE12-17 CARTEL

STRESS TRANSFER ALONG THE TECTONIC INTERFACE OF THE MEXICAN SUBDUCTION ZONE USING A 3D SLAB MODEL

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We investigate the seismic stress transfer along the subduction interface of the Mexican Subduction Zone, using a 3D slab model. The geometry of the slab used in this work was estimated using the depth profiles along the subduction zone previously obtained by different authors. In a first approach we computed the coseismic stress transfer due to large subduction earthquakes with Magnitudes M=6.5 using theoretical slip distributions along the interface. The interface surface was discretized by means of a 2.0 km x 2.0 km segments, with observing points located over the interface in a staggered-type grid to avoid edge singularities. Stress tensor changes were computed for a 3D half-space, and stress transfer were analyzed assuming the Coulomb Failure Stress criterion. For computations, the stress change due to a given subfault of an earthquake was computed on each grid segment of the subduction interface, resolved along its normal and dip-slip directions. This computation method implies that for each earthquake of a given magnitude, the stress changes along the subduction interface will vary with respect to the spatial location. As the dip angle of the subducting slab changes along the subduction zone, results are presented for different segments of the tectonic interface.

SE12-18 CARTEL

LA RELACIÓN ENTRE LOS EVENTOS EXTREMOS Y EL CAOS ESPACIO TEMPORAL EN UN MAR ÓPTICO

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Cada año se reportan olas gigantes destructivas que aparecen, aparentemente sin causa física, y desaparecen sin dejar rastro alguno, estas olas son conocidas en la literatura como rogue waves y pertenecen al régimen de eventos extremos, es decir, eventos cuya probabilidad de manifestación es aparentemente despreciable. La principal diferencia entre este tipo de olas destructoras y los tsunamis es que no necesitan un precursor físico externo, como un gran terremoto, sino que son inherentes al sistema, en otras palabras, son eventos que por naturaleza misma del medio aparecen sin necesidad de estímulos externos. Esta característica las vuelve muy peligrosas, ya que su predicción acertada es un tema aún no resuelto. Los eventos extremos, como las ondas gigantes, están normalmente asociadas con la fusión de estructuras coherentes, solitones que 'suman' su intensidad al momento de encontrarse, sin embargo, este enfoque no resulta del todo convincente ya que no es muy común observar estructuras coherentes en un medio aparentemente desordenado como el océano. En este trabajo se reportan resultados experimentales en la física de la emergencia de eventos extremos, i.e. rogue waves, en un mar óptico y se establece la relación de este fenómeno con la aparición de caos espacio

temporal. El mar óptico es generado con una válvula de cristal líquido sujeta a retro inyección óptica. Este sistema, bajo condiciones muy particulares, puede exhibir patrones de rollo que pueden desestabilizarse en texturas cuasi periódicas y caóticas modificando apropiadamente sus parámetros dando lugar a una dinámica cualitativamente similar a la de la superficie oceánica. Se identificaron las regiones paramétricas donde las fluctuaciones extremas de intensidad pueden ocurrir y se estableció su origen a través de una relación directa con los exponentes máximos de Lyapunov experimentales, la proporcionalidad de los eventos extremos encontrados y la kurtosis normada.

SE12-19 CARTEL

ELABORATION OF CATALOGUES FOR TECTONIC TREMOR DETECTION ASSOCIATED TO SUBDUCTION ZONES IN MEXICO

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Since the discovery of the Non Volcanic Tremor (NVT) in Japan, the interest of the scientists on this phenomena started to grow in many parts of the world. Due to the difficulty on NVT's location the origin of these is still a problem because it has been observed that guards relationship with other recently discovered phenomena, like the slow slip events (SSE), low frequency events (LFE) and very low frequency events (VLF). Their detection has been posible since the installation of more sensible seismometers with the ability of register in a wide range of frequencies and the new tendencies in data storage capacity that made available continuous measurements. The reason of the importance of studying these phenomena has its basis on the dynamics, knowledge of the manner in how does the interplate stresses change and the energy liberation ratios due to slow events and tremors. Due that the variation of tremors bursts are linked to small SSE, in this work we will elaborate an uniform catalogue in order to generate a comparison of the periodicity of slow SSE to large SSE. In our case, the identification and analysis of tremors will be focused mainly in the states of Guerrero, Jalisco and Oaxaca; the data will be obtained from the stations installed by the Servicio Sismologico Nacional (SSN) that are inside the area of interest. For each station an standard spectra will be determined from the average spectra of TT using many TT's detected visually in spectrograms; then the standard spectra will be compared with the spectra of the time series. Additionally we will elaborate histograms of each one of the stations to monitoring the tremor activity and finally make a comparison of the obtained results with previous work. The elaboration of the TT catalogues used in this work will be useful since in other studies it has been found that TT's have happened in intervals of approximately 90 days and 4 years, both in the same interest zone (Guerrero). For that motive, the intention is to have a catalogue with a great number of data (since the date when the station was installed until today) in order to do a possible interpretation of why does this periodicity variations are present regarding other works.

SE12-20 CARTEL

LOW FREQUENCY EARTHQUAKES STUDY IN THE JALISCO STATE, MEXICO

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Studying and detecting LFEs alongside tectonic tremors (TTs) is part of the observational tools which trace repeating low frequency events carried out at the most downdip part of the seismogenic zone, through the transition zone and almost up to the mantle wedge. Using the "Mapping the Rivera Subduction Zone" (MARS) seismic array, which is a large and dense array of 51 stations located in Jalisco, Colima and part of Michoacán, it allowed for TT detection and location. LFEs are thought to make up TTs and have been successfully used in Guerrero, Mexico to make more detailed analysis of the TTs. The advantage of LFEs is that they act as a point process and therefore has an almost 'digital' signature in time and space that allows for mapping migrations of the TT as has now been seen in multiple subduction zones. From their nature, LFE and TT activity helps to set the limits downdip the seismogenic zone, constraining perpendicular to the trench the size of a fault a large earthquake can rupture. Here we present early advances finding and locating LFE's. We will use a large-scale beam-form search for LFE templates, followed by a match filter search (Frank et al., 2014). We begin with visual determination of LFE templates as a proof of concept before launching the beam-form search. We identify various templates throughout different sections of the TT activity zone by searching in previously identified TT's. We then run a match filter search to be sure that the templates are real repeating events. We identify LFEs events by setting a threshold to the summed cross correlation coefficients, which is at least fivefold the rms. Our analysis shows that repeating LFE's do exist, and we will be able to begin the large scale search for LFE's.