Sesión Especial

Slip on subduction interfaces

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SE10-1

CHARACTERISTIC REPEATING SEQUENCES ALONG THE SUBDUCTION OF THE COCOS PLATE. EVALUATION OF THE SLIP BUDGET ALONG THE SEISMOGENIC ZONE

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Evaluation of the spatial and temporal variation using repeating earthquake activities provide a unique tool to estimate the aseismic fault slip and seismic coupling at frequently inaccessible seismogenic depths. Repeating earthquakes are sequences of events that are thought to rupture the same asperity and thus provides nearly identical waveforms. The number of times the earthquake repeated puts constraints on the relative aseismic slip rate surrounding the repeating event asperities. We systematically examine 14 years of seismic data (from 2001 through 2014) to identify repeating earthquakes along the subduction of the Cocos plate. Our study evaluates the slip budget at the interface, and the contribution of transient phenomena such as slow slip events to the earthquake cycle. We find ~50 clusters of repeating earthquake sequences (magnitude ranges from 3.5 to 4.2) located near the edges of the rupture zones for the past M~7 earthquakes (1995, 2012) in which Mw~7.0 slow slip events occur. We discuss the possible implications and needs for future deployments along the Middle America trench both inland and offshore. Understanding the different components of the aseismic slip budget is a key factor to pinpoint areas where large megathurst earthquakes nucleate and consequently better assess the seismic hazard.

SE10-2

SLIP DISTRIBUTION OF THE APRIL 18TH, 2014, MW 7.2, PAPANOA EARTHQUAKE AND IT'S RELATION TO THOSE OF PREVIOUS EVENTS IN THE REGION

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The April 18th, 2014, Mw 7.2, Papanoa earthquake broke the Middle America Subduction Zone, along a section between Zihuatanejo in the west and Papanoa in the east, a total of ~50 km. Substantial damage was observed in the towns of Papanoa, Petatlan and Tecpan. ?We map the distribution of slip on the fault plane produced by the earthquake using teleseismic seismograms recorded on global networks as well as near-field accelerograms from the networks of the National Seismological Service and the Engineering Institute of UNAM. Rupture initiated about 6 km north of Papanoa and during the first few seconds it propagated towards the north, with around 2 m of maximum slip over an area of 25 by 20 km. After about 10 s, a second patch to the west, between Petatlán and Zihuatanejo, started breaking with 1.6 m of maximum slip over a slightly smaller area. Although the rupture clearly propagated from east to west through two main slip patches, whether the patches are connected with an area of small or no slip, cannot be resolved by the inversion. The absolute location of the two patches depends almost entirely on the hypocenter location. Using the hypocenter determined by first motion directions at near-field stations, the center of the first slip patch is all under land to the north of the town of Papanoa. The second patch is all off-shore, with it's westernmost end almost reaching the town of Zihuatanejo. The first slip patch partly falls within the aftershock area of the 1979, M7.6, Petatlán earthquake, and the second patch similarly has a partial overlap with the Sept 20th 1985, Mw 7.5 event (aftershock of the great 1985 Michoacán earthquake). As the two areas of large slip seen in this event only partly overlap with the rupture area inferred from aftershocks for the previous events in this region, we infer that the slip did not occur on asperities that are consistent over time.

SE10-3

TSUNAMI MODELING OF RECENT EARTHQUAKES IN MEXICO

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Tsunamis are a real threat to the Mexican coast, with 20 tsunamis documented in the last century (Devora & 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 tsunamis in Mexico using the freely available tsunami modeling tool Geoclaw. Geoclaw solves the nonlinear shallow water equations using finite volume methods and adaptive mesh refinement. To accurately account for the earthquake source we use finite slip models estimated from local and teleseismic waveforms when available. We are in the process of modeling the tsunami propagation and run-up for two recent earthquakes in Mexico, the 2012 Ometepec and the 2014 Papanoa earthquakes, as well as hypothetical much larger events. We will present our most recent advances during the meeting.

SE10-4

AN OCEAN-BOTTOM GEODETIC AND SEISMIC NETWORK FOR ASSESSING THE MEGAEARTHQUAKE AND TSUNAMI HAZARD POTENTIALS ALONG THE MEXICAN SUBDUCTION ZONE

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Most of subduction zones involve a tsunami hazard potential. Although large tsunami records, such as sedimentary deposits along the coast and ancient documents, are seldom available and constrained to limited regions worldwide, the tsunamigenic earthquakes potential cannot be underestimated. Tsunamigenic earthquakes occur as a result of slow stress accumulation due to long-term plate motion, which can be monitored by geodetic and seismic observations. In other words, geodetic and seismic data recorded in the interseimic period is useful to estimate the tsunami hazard potential in a given region. Toward the evaluation of such hazard potential and the mitigation of the associated risk across the Guerrero seismic gap, in the present proposal we focus on several questions regarding the seismic coupling in the region during the occurrence of Slow Slip Earthquakes (SSE) and the inter-SSE period: What the seismic coupling is in the plate interface near the trench during a SSE? (i.e. is it locked or creeping?) What the slip rates are near the trench? Does slow slip penetrate offshore regions close to the trench? What are the implications in the Guerrero seismic gap? What is the probability of occurrence of a megaearthquake all across the gap? To answer these questions, we propose to develop an ocean bottom network of ocean-bottom seismometers (OBS) and pressure recorders (OBP) above the Guerrero gap and across the Middle American trench. Recently, many ocean bottom seismic and geodetic instruments, such as OBS, OBP, GPS/Acoustics positioning system had been deployed around Japan. Specifically, in the Japan Trench, both SSE and tectonic tremor were observed using OBSs and OBPs before the occurrence of the large 2011 Tohoku-Oki earthquake. They were observed at the shallowest portion of the plate interface near the trench, where the slip of the mainshock exceeded 50 m. In particular, OBP played a key role in the study because OBP recorded preseismic crustal deformations such as uplift/subsidence produced by the SSE. These results encourage us to deploy the network in Guerrero and suggest that OBP and OBS instruments will provide important information to better understand the seismic coupling and tsunamigenic potential in that segment of the Mexican subduction zone.

SE10-5

MYSTERIOUS SSE OF THE GUERRERO LAND

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Aseismic slow slip events (SSE) are happening periodically in the Guerrero segment of Mexican subduction zone with an interval of about four years. Since the first SSE recorded by permanent GPS station in 1998 there were four more large slow slip events with equivalent magnitudes Mw > 7.0. The last 2014 SSE has started in January and should cease in October of this year if the SSE in Guerrero obeys the slip predictable model. The 2014 SSE is unusually fast comparing with all previous events, and a series of large subduction thrust earthquakes (Mw 7.2, 6.4, 6.1) in April-May in the NW part of the Guerrero subduction zone could be triggered by this slow slip. SSEs perturb the records of all GPS stations in Guerrero, nevertheless a number of GPS have more than 10 years of continuous data that makes it possible to estimate a log-term trend of the displacement at each such GPS site. The secular GPS velocity vectors are oblique to the Meso-American trench and the along-trench (lateral) velocity components are abruptly diminished to the north by 4-5 mm/year across the area of Chacalapa fault zone (CFZ). This velocity drop can be interpreted as a partitioning of the relative convergence between the Cocos and North America plates with a sinistral motion of a forearc sliver. While the origin and physical mechanism of the subduction slow slip events (SSSE) are still not well known, the SSSE in Guerrero could be accompanied by the strike-slip SSE on the Chacalapa Fault, akin to the SSE on the San Andreas Fault. An analysis of the long GPS displacement records in Guerrero shows that during the inter-SSSE periods the Chacalapa Fault is probably locked, and the shear rate across it is about of 2.0-2.5 mm/year but during the SSSE episodes in 2002 and 2006 there are sudden reverse changes of the motion on the fault, which may be understood as the SSEs on the CFZ. The subduction zone in Guerrero is probably a unique region where two different types of SSE are occurring together, and this fact makes the mystery of the SSE in Mexico even more challenging. This study was supported by PAPIIT IN110514 grant.

SE10-6

AN OVERVIEW OF NON-VOLCANIC TREMOR AND NEW FINDINGS FROM LOW FREQUENCY EARTHQUAKES IN GUERRERO, MEXICO

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Non-volcanic tremor (NVT) in Mexico has a complicated behavior. All tremors occur close to the plate interface at 40 km depth. The area of tremor activity has been divided into 3 zones. The transient zone located at the corner of the slab when it first bends up at 40 km depth (~130 km – 165 km from the trench). The buffer zone, which has very little NVT and is located ~165 km – 190 km from the trench. Then downdip the Sweet Spot follows that has the overwhelming majority of NVT and is located ~190 km – 245 km from the trench. Previous studies have shown near continuous NVT within the Sweet Spot with large bursts of activity about 3 - 5 times a year called NVT episodes. During the NVT episodes the tremors also occur closer to the trench. Low frequency earthquakes' (LFE) studies show that during an NVT episode LFE streaks are seen in the Sweet Spot that travel trench perpendicular at speeds of 10's km/hr. They move both towards and away from the trench. They also invade the buffer zone each time the streak moves in towards the trench and returns, however the number of LFE's is far fewer than when they are in the Sweet Spot. After several days LFE's are found within the transient zone, however they do not appear to streak or be related to the streaks in the other zones. These episodes have been found to correlate with small slip seen on the GPS record and are considered small, short-term slow slip events (small SSE). The Sweet Spot also has a near continuous amount of smaller bursts that do not cross into the buffer zone or provoke LFE's in the transient zone. The large, long-term slow slip events (SSE) that occur approximately every 4 years in Guerrero provoke a very large number of NVT episodes within these same zones. The LFE's, however, farthest from the trench show no difference in their rate during the majority of the SSE. The closer the LFE's are to the trench the more they are found to occur in separate bursts or episodes. This observation has suggested that the NVT closer to the trench follows a more stick-slip type model; while further from the trench it is more continuous. In the last stage of the SSE, the number of LFE's declines dramatically with the greater the decline the further the distance from the trench. Assuming a hypothesis that the origin of SSE, NVT, and LFE is related with reduced pore pressure on or in the vicinity of the plate interface, the activity, location and migration of these seismic phenomena may provide important information on the fluid migration.

SE10-7

NONVOLCANIC TREMORS AND INTRASLAB FLUID MIGRATION IN GUERRERO, MEXICO, DURING SLOW SLIP TRANSIENTS

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Observations in different subduction zones have suggested that overpressured fluids close to the plate interface may be related to the origin of nonvolcanic tremors (NVT) 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. However, NVT hypocentral depths in this region have been poorly resolved so that casualty could not even be tested as a hypothesis. In this work, we report NVT relocations from a 3-year-catalog in Guerrero that includes the period of the Slow Slip Earthquake (SSE) of 2006. We used a new location technique called the "Tremor Energy and Polarization" (TREP) method (Cruz-Atienza et al., JGR, 2014), which jointly determines the source location and focal mechanism of sustained tremor signals by simultaneously inverting (1) the energy spatial distribution, (2) the energy spatial derivatives, and (3) the azimuthal direction of the particle motion polarization ellipsoid. In agreement with previous works, NVT epicentral locations concentrate between 200 and 230 km from the trench and then migrate ~40 km trenchward during the occurrence of the SSE. However, unlike earlier investigations, most NVT hypocenters lie at 43 km depth near the plate interface and have subparallel rake angles to the Cocos plate convergence direction. These results are consistent with independent locations and mechanisms of LFE in the region and allow us to examine the casualty hypothesis mentioned above. Poroelastic modeling of fluid transport during two SSEs in Guerrero (Villafuerte and Cruz-Atienza, AGU, 2014) show that fluids migrate towards the spots where this seismicity occurs with maximum velocities ranging between 10-3 and 10-9 km/day, which are more than 3 orders of magnitude smaller than the LFE migration speeds. We conclude that fluid diffusive transport is not responsible of the NVT and LFE migration during the SSEs but instead that slip transients act as a long-term pumping process decreasing the effective pressure where the seismicity takes place as a consequence of small stress perturbations associated to the propagation of the aseismic slip.

SE10-8 CARTEL

ESTUDIO DE LA DEFORMACIÓN EN EL MARGEN CONTINENTAL MARINO FRENTE A LA BAHÍA DE PETACALCO, IMPLICACIONES GEOLOGICAS EN LA ZONA DE GRANDES SÍSMOS EN MICHOACÁN Y GUERRERO

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Con la finalidad de aumentar el conocimiento sobre la deformación sismotectónica en el margen continental marino entre los estados de Guerrero y Michoacán se realizó un estudio de geofísica marina frente a la Bahía de Petacalco. En esta región, la ruptura de tres sismos mayores: Petatlán (Mw=7.6) de 1979, Michoacán (Mw=8.1) de 1985 y su réplica sísmica (Mw=7.9), cubrieron gran parte del margen marino. Mediante un levantamiento batimétrico sistemático se obtuvieron datos e imágenes acústicas del lecho marino y su subsuelo, por medio de adquisición de valores batimétricos multihaz y perfiles sísmicos de reflexión de alta resolución, realizados en dos campañas de Geofísica Marina: MAMRIV12 en 2012 y BAPET13 en 2013, que cubrieron un polígono de una superficie de alrededor de 10,000 km2 (entre 17°N a 18°N y de 101°W a 103°W). Como parte del estudio, una base de datos del relieve batimétrico de cruceros anteriores en la región de la Bahía de Petacalco se integro utilizando el software y servidor de datos GeoMapApp de Lamont-Doherty Earth Observatory. El procesamiento de los datos de batimetría colectados ha proveído, por primera vez, una imagen detallada del relieve del talud en este margen continental, mostrando la transformación del relieve en la parte superior del talud una intensa erosión causada por numerosos cañones submarinos, y con una mayor aporte por el cañón submarino del Río Balsas que descarga gran cantidad de sedimentos en la cuenca de la trinchera Meso Americana. Las secciones de reflexión sísmica han revelado la existencia de fallas superficiales anastomosadas, relacionadas con la cambiante estabilidad del talud conforme a la alta depositación de sedimentos y al movimiento vertical sismotectónico del área. Además este estudio integro un análisis de pendientes para identificar taludes con un mayor riesgo de movimiento de masas en el talud. Al integrar todos los resultados, el relieve submarino frente a la bahía de Petacalco es afectado principalmente en la parte superior del talud por procesos de erosión fluvial submarina y en la parte inferior por procesos tectónicos. La profundidad de disección en los cañones depende del balance entre las fuerzas del levantamiento y erosión, el drenaje encajado en el relieve del talud indica que posiblemente algunas áreas de esta región se han elevado. Este marcó estructural-tectónico muestra grandes posibilidades de un mayor riesgo geológico tsunamigénico que pudiese afectar a la población costera. Este estudio recibió apoyo financiero del programa UNAM-DGAPA-PAPIIT No. IN115613

SE10-9 CARTEL

S-WAVE RECEIVER FUNCTIONS TO STUDY THE TRANSITION ON THE GEOMETRY OF THE COCOS PLATE IN CENTRAL-SOUTHERN MEXICO.

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The tectonic setting, between the Cocos and North American plates, follows complex geometries over the west and south coasts of Mexico. Previous studies in central Mexico showed that the slab dips nearly horizontally before steeply subducting into the continental mantle; in contrast, in southern Mexico, the slab dips, at a constant angle, under the continental plate. Yet, the geometry of the Cocos plate and the transition angle, in central-southern Mexico, remains unclear. S-wave receiver functions from earthquakes recorded at epicentral distances between 65° and 115° are used to image the subducting plate underneath four seismic networks: GECO (Geometry of Cocos), SSN (Servicio Sismológico Nacional), OxNet (Oaxaca Network) and UV (Universidad Veracruzana). We developed an algorithm that automatically selects S and SKS theoretical arrival times for each event. The equalization of a receiver function includes: a rotation to the longitudinal-radial-transversal (LQT) system and the time domain deconvolution of the L and Q components. We present receiver functions sorted by back azimuth and epicentral distance. We analyze the azimuthal dependence of the slab's depth solving the inverse problem with simulated annealing. This procedure gives insight of the geometry of the Cocos plate and the transition angle within the study area.

SE10-10 CARTEL

ANÁLISIS DE ENERGÍA SÍSMICA IRRADIADA DE RÉPLICAS DEL SISMO DEL 20 DE MARZO DEL 2012 (MW7.5) EN OMETEPEC-PINOTEPA NACIONAL, MÉXICO

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Una de las alternativas para poder describir el tamaño de un sismo y su fuente, es la estimación de su energía irradiada. El objetivo de este trabajo es describir la distribución de la energía sísmica (Es) escalada con el momento sísmico (Mo), Es/Mo, en la zona de subducción del Pacífico mexicano. Para ello, se estudió el sismo ocurrido el 20 de marzo del 2012 (Mw7.5), en Ometepec-Pinotepa Nacional, junto con sus réplicas, estimando para cada evento su energía sísmica irradiada con registros locales y regionales de velocidad y aceleración. Para los sismos de mayores magnitudes, se obtuvieron también sus estimaciones de Es con datos telesísmicos. Resultados preliminares muestran que la distribución de Es/Mo para estos eventos, presenta una razón menor en zonas cercanas la trinchera. Por lo contrario, para los eventos lejanos a la trinchera y cercanos al epicentro del evento principal, la razón Es/Mo es mayor.

SE10-11 CARTEL

CRUST AND MANTLE ANISOTROPY VARIATIONS ALONG THE MASE PROFILE USING RECEIVER FUNCTIONS

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Receiver functions (RFs) are widely used in seismic structure studies. We use radial and tangential RFs obtained along the Meso America Subduction Experiment (MASE) as our primary tool to analyze the dynamic processes that take place in the Mexican subduction zone and its relation with the Trans-Mexican Volcanic Belt (TMVB) complexity. RFs show waveform variations in amplitude, timing and polarity, both in the Moho and the slab Ps phases in function of its backazimuth; that is a diagnostic of a non-homogeneous horizontal layer medium. Using a particle motion analysis and a cross-correlation procedure, we are able to quantify the shear wave splitting in the continental crust, the subducted oceanic crust and the mantle below each station of the array in terms of a time delay, and a fast azimuth direction. From these observations, we are also able to determine if either dipping interfaces or the anisotropic properties of the medium explain the tangential energy. These results allow us to distinguish between three major regions: 1) dipping subducted slab, 2) horizontal subducted slab, and 3) absence of subducted slab. Results for region 1 are consistent with the geometry of the Cocos plate previously determined by other studies, showing negligible shear wave splitting of the Ps phases and a minimum energy content in the tangential RFs for events arriving along the dip direction. In region 2, we identify a strong azimuthal dependence with a variable periodicity of 180° and 360° as well as the existence of “split” Ps phases in our data, possibly related to the presence of fluids and the ultra low velocity layer (ULVL) localized between the continental and oceanic crust. We compare these results with previous silent earthquakes and non-volcanic tremors studies in the area.

SE10-12 CARTEL

SEISMIC NOISE TOMOGRAPHY IN THE GUERRERO SEISMIC GAP

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We use the records of Seismic Mini Arrays (SMA) which is part of the G-GAP project and stations from the National Seismologic Service network (SSN). This work is a preview of a seismic noise tomography in the Sweet Spot in Guerrero (Mexico). The Sweet Spot is the zone where tectonic tremor (TT) are continuously located and have the largest episodes (in quantity and length). For these reasons, it appears that this site has the best physical conditions for TT to occur (Husker et al., 2012 and Jödicke et al., 2006). In this site Kim and Clayton (2010) found a high pore pressure (high Vp/Vs) in the lower plate and Huesca and Husker (2013) in the crust inside the Sweet Spot. This study looks for variations of Vs within the Sweet Spot.

SE10-13 CARTEL

SPECTRAL CROSS-CORRELATION METHOD FOR DETECTING AND CLASSIFICATION OF THE NON-VOLCANIC TREMOR

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Non-volcanic tremor (NVT), or tectonic tremor is still one of the most curious and attractive subjects in seismology. The physical mechanism of the NVT is uncertain and its precise localization is problematic because of a transient type of the tremor records. There were a lot of observations and studies of the NVT in different subduction zones and in the San Andreas Fault since this phenomenon had been discovered some twelve years ago (Obara, 2002). Tremor activity is closely related to the slow slip events (SSE) while there are ample evidences that the NVT episodes are also triggered by tele- and regional seismic events, earth tides and even by large atmospheric instabilities. In many cases the NVTs are accompanied by the swarms of small low frequency earthquakes (LFE), which occur on the plate interface at the depth around of ~40 km. LFE hypocenters are easier to estimate then those of the NVT because the LFE events have a simple source mechanism. There is a hypothesis that the NVT is simply an assemble effect of the LFE swarms (Shelly, 2006, 2007), nevertheless to explore this perception we need at least to confirm that the NVT are occurring at the same limited area as the LFE. Tremor location methods generally use some time windowed part of the seismic records ignoring the fact that different NVT bursts may be closely sequential or even overlapping. If the analyzed time window contains mixed signals from different tremor sources the localization of this NVT episode could be a priory wrong. To avoid this kind of mistakes and recognize different types of tremor we applied the spectral cross-correlation technique (SCCT), which permits effectively detect tremor duration and recognize its spectral variation. The SCCT helps to generate routinely the catalogs of different NVT types and also estimates frequency lags for similar spectral types of NVT. The main objective of the SCCT application for the NVT studies is to improve localization of these events to a degree comparable with the accuracy achieved for the LFE.