

Numerical models of repeating events also yield a non-linear moment release rate that is most rapid immediately following the occurrence of the repeat. This behavior is consistent with our hypothesis that repeating earthquakes partially reload themselves.

Tsunami Warning System in Latin America and the Caribbean: COVID-19 Challenges

Oral Session · Wednesday · 21 April · 2:00 PM Pacific
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Geophysical and Sea Level Monitoring in Puerto Rico, A Resilience Experience

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The Puerto Rico Seismic Network and the Puerto Rico Strong Motion Program conform the PR network which is the regional authority for monitoring ground shaking and tsunamis in Puerto Rico and Virgin Islands. The mission of the PR is to monitor and rapidly determine the parameters of all earthquakes and support the Tsunami Service Provider to determine the Tsunami alert level in the Area of Responsibility, and to immediately disseminate this information to concerned agencies and stakeholders. The PR compiles the microseismic catalogue, continuous waveforms, and earthquake effects which serve as a foundation for basic and applied earth science & oceanography research in Puerto Rico and the Caribbean. The PR net also promote the education and preparedness of our population to mitigate the effects of a significant earthquake or tsunami.

In September 2017, two severe hurricanes (Irma and Maria) devastated the Virgin islands and Puerto Rico causing a major emergency. Both, originally powerful Category 5, were the strongest storms to impact the islands of the northeastern Caribbean in nearly 90 years. In the case of Maria, it made landfall in Puerto Rico on September 20 as a category 4+, causing large storm surge, heavy rains, and destructive winds of more than 160 mph gusts. In the aftermath, the US Federal government through the USGS provided the assistance and help to repair the damaged seismic monitoring infrastructure.

Fortunately, these improvements were almost complete in the main island of Puerto Rico, when at the end of 2019 and early 2020, a severe seismic activity hit the island. The SW seismic sequence that struck the Island of Puerto Rico, causing vast destruction and significant damages to the southern municipalities of Puerto Rico. To complete the memories of 2020, in March under the worldwide pandemic, a lockdown was declared in Puerto Rico, and the network was required to continue the operations under that emergency.

The goal of this abstract is to describe the experiences of the PR network, the SOP's and how the response protocol was adjusted to the new reality.

Operational Capabilities During Crisis: The Chilean Seismographic Network

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In Chile, authorities' severe mobility restrictions in response to the pandemic of SARS-CoV-2 have impacted all areas of activities, including seismic network maintenance. Travel limitations began in March 2020 with partial quarantines in the capital city, which later extended to other cities in the country, and it soon transformed into total confinement. We examine the evolution of the pandemic and its consequences on the field and headquarters operations of the National Seismological Center (CSN) as remote stations could not be visited to carry out maintenance work. Several indicators as a function of time, such as station operability percentage, timely reports, ability to deliver requested information, reveal some negative impact on the uptime of stations but not in the capability of the CSN to fulfill its mission, which is to provide

timely seismic information to emergency services. The largest event in the country in 2020 took place on June 3, activating in a timely manner the new tools on finite fault modeling being developed within the center.

Continued efforts on integrating new tools to rapidly characterize large events and efforts on development and implementation of a prototype earthquake early warning system will be presented.

PRSN Annual Communications Exercise Caribe Wave 2020 During the COVID-19 Pandemic, A Comparison With Previous Exercises

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The PRSN monitors and studies the seismicity in Puerto Rico/Virgin Islands Region. At the beginning of 2020 we faced an unprecedented seismic sequence in the South Region of PR that began on December 28, 2019, with a 4.7M event. This event was a precursor to the principal event of 6.4Mw that occurred on January 7, 2020. This sequence produced the most damaging earthquake to hit PR/VI Region since 1918 (7.3M), a reminder to the entire region about the importance of tsunami preparedness. Understanding the high seismicity and the possibility of the occurrence of a tsunami that could affect our region, we have dedicated efforts in preparing earthquake and tsunami communication exercises, as well as leading the emergency management agencies and general public's participation. The Caribe Wave is the annual regional tsunami exercise in which the PRSN conducts communication tests for entire Puerto Rico and the Virgin Islands Region. In the last decade, we have been working tirelessly on tsunami exercises and supporting related educational initiatives. We never imagined that in 2020 during the response to a seismic sequence, we would be facing a pandemic emergency. During the preparations for the Caribe Wave 2020 we were impacted by the COVID19 pandemic. The COVID19 pandemic emergency affected what are usually the activities related to the Caribe Wave for PRSN, however, we moved forward with the Communications Exercise through our region. We will discuss our findings during the preparation and development of this exercise, as well as the lessons learned during the Caribe Wave 2020 Communications Exercise in the region as affected by the new regulations implemented during the COVID19 Pandemic. We will discuss the communications between emergency management agencies from the PR/VI Region and the use of social media for public communications. The 2016 (pre-Hurricane Maria PR), and 2018 (post-Hurricane Maria) exercises will be used as a reference point to compare with the 2020 (COVID-19 Pandemic and the seismic sequence) PRSN Caribe Wave communications exercise and its challenges.

Tsunami Exercises on a Remote Basis: Costa Rican Experiences

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As part of the guidelines to obtain the Tsunami Ready recognition from IOC/UNESCO, the Pacific communities of Tamarindo and Uvita were required to perform a tsunami exercise. On the 16 March 2020 started in Costa Rica the lockdown because of the SARS-Cov2 virus. The measures corresponding to the lockdown have alternatively relaxed and tightened since then, but have implied telework for the University staff and the suspension of domestic trips. The National Emergency Commission (CNE), the Costa Rica disaster management office, suspended all gatherings that were not strictly necessary. Therefore, the tsunami exercises planned for both Tamarindo and Uvita were suspended. Despite all these limitations, it was possible to carry out remote table-top tsunami exercises with both communities, with representatives from SINAMOT participating in the video calls. In Tamarindo, the Community Emergency Committee (CCE in Spanish) met at a hotel in separate rooms, in this way the CCE was able to better control the exercise. In Uvita, each participant was in a separate location, from where they participated in a group video call as well as individual telephone calls. Having the table-top exercises on a remote basis had some advantages: 1. it represented a more realistic scenario where the participants were not in the same room and had to make decisions on a remote basis. 2. It generated a better evaluation of the message disseminated within the participants and of the technological capacities of the CCE

in case of emergency. 3. It simplified the evaluation process, as all the messages were recorded. Theoretically, the exercises completed the guidelines for both communities to become Tsunami Ready. However, Costa Rica National Tsunami Ready Board hasn't been able to meet, as authorities from CNE belonging to this board are completely devoted to the sanitary emergency.

Tsunami Generated From Asteroids Impacting Earth's Oceans: Consequences on Coastlines of Latin America and the Caribbean Region for Disaster Response and Management Preparedness

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A hypothetical asteroid-impact scenario (<https://cneos.jpl.nasa.gov/pd/cs/pdc21/>) designed by the International Academy of Astronautics (IAA) is used as the basis for discussion and analyses of the table-top exercise. The asteroid is classified as a potentially hazardous asteroid with a diameter initially estimated between 35-700 meters. The asteroid's position uncertainty region at the time of the potential impact is much larger in both length and breadth than the size of the Earth. Impact could occur anywhere on the forward hemisphere during the hour or so when the Earth crosses the asteroid orbit and sweeps through the uncertainty region. Given the significant water-impact probability, and because most of the potentially affected coastal regions are heavily populated, we focused our simulation efforts on modeling water impacts at several locations along the asteroid risk corridor. We have simulated the problem from asteroid entry, to ocean impact, to wave/tsunami generation, propagation, interaction with the shoreline and the flooding of the coastline major cities. We have simulated four different asteroid diameters (100, 250, 500 and 700m) and we have delimited the zones of inundation for each scenario for risk assessment and disaster management & response around the world. Here we emphasize the coastlines of Latin America and the Caribbean. The interaction of the asteroid with the ocean are simulated using the hydrocode GEODYN, creating a wave source for the Boussinesq-based water-wave-propagation code, WWP. Run-up and flooding were simulated using WAST – water/structure – a CFD code for urban flooding assessment. Results are displayed with high resolution in Google Earth for major coastal cities of interest. We will demonstrate these new capabilities and we illustrate the consequences at the local and global scales.

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The UN Decade of Ocean Science for Sustainable Development and Seismology

Oral Session · Monday · 19 April · 9:45 AM Pacific

Session Chairs: Christa Von Hillebrandt-Andrade, National Oceanic and Atmospheric Administration (christa.vonh@noaa.gov); Monica Kohler, Caltech (kohler@caltech.edu)

Cabling a Tectonic Plate—A Decade of Geophysical Monitoring Enabled Through Ocean Networks Canada's Neptune Observatory

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Ocean Networks Canada (ONC; <http://www.oceannetworks.ca/>) operates the multidisciplinary NEPTUNE and VENUS cabled ocean observatories off the west coast of Canada. All data collected by these observatories are permanently archived and publicly available through ONC's Oceans 2.0 data portal (seismometer data are available from the Incorporated Research Institute for

Seismology (IRIS)). Much of the data are related to marine geohazards, such as earthquakes, submarine landslides, and tsunamis and are delivered in real-time, e.g. to early warning centers.

The NEPTUNE cabled observatory consists of a cable loop deployed off Vancouver Island that is over 800 km long and covers the northern part of the Cascadia subduction zone, Cascadia Basin, and the Endeavour Segment of the Juan de Fuca Ridge. It is uniquely located to study plate scale patterns of seismicity and strain created from the interplay of episodic spreading events at the Juan de Fuca Ridge, transform earthquakes on the Nootka Fault Zone, and slip events on the Cascadia megathrust. Cabled instruments supported by the observatory include a regional network of buried broadband seismometers, a local seismic network at the Endeavour Ridge Segment, seafloor tiltmeters, bottom pressure recorders, and CORK borehole observatories that allow volumetric strain measurements. A network of seven seafloor GPS-Acoustic (GPS-A) sites and an autonomous Deformation Front Laboratory will be operational in 2021. With upgraded onshore geodetic stations (operated by Natural Resources Canada) this will form the Northern Cascadia Subduction Zone Observatory (NCSZO).

Additionally, ONC is building a unique Earthquake Early Warning System that relies on eight subsea strong motion instruments as well as seismogeodetic stations on Vancouver Island.

We will review a decade of geophysical monitoring, instrument development, and research findings across ocean science disciplines and give an outlook for future plans.

Earthscope-Oceans: Closing the Oceanic Coverage Gap for Seismology and Environmental Sensing

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While all of us are sequestered inside, planes are grounded, and ships are berthed, a fleet of forty-seven autonomous earthquake recorders are drifting at 1500 m depth along with the currents in the Pacific, surfacing every 4-7 days to report, via satellite, a good handful of recently recorded seismic records. The targets of the ongoing *South Pacific Plume Imaging and Modeling* project are teleseismic global earthquakes, but MERMAID lends itself equally well to recording local or regional seismicity, and making marine environmental observations. In its current commercially available third-generation incarnation one MERMAID costs about \$40k to acquire, \$100 per month for data recovery, and as little to deploy (and never to recover) as can be had by using ships of opportunity. A fleet of autonomous marine instruments is a vital component of a modern-day seismological and environmental observing strategy. We will report on past successes and future directions, and invite community input.

Science Monitoring and Reliable Telecommunications (SMART) Subsea Cables for Climate Monitoring and Disaster Risk Reduction: A Contribution to the UN Decade for Ocean Science for Sustainable Development

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Science Monitoring And Reliable Telecommunications (SMART) Subsea Cables integrate sensors into commercial submarine telecommunications systems for ocean-climate monitoring and disaster warning, resulting in a planetary scale array monitoring ocean heat and circulation and sea level rise and providing real-time data for earthquake and tsunami early warning and disaster mitigation. This is enabled by the trans-ocean cable infrastructure linking society together: 1.4 million km of cable with 20,000 repeaters every 70 km that can host sensors, constantly being refreshed and expanded over 10-25 years. Initial sensors are ocean bottom temperature, pressure and seismic acceleration. The first major SMART project is funded and underway in the northeast Atlantic off Portugal, motivated in part by the disastrous 1755 earthquake and tsunami (CAM2, 3700 km ring connecting the continent with