The California State University
COUNCIL ON OCEAN AFFAIRS, SCIENCE & TECHNOLOGY (COAST)

Graduate Student Research Awards
AY 2015-2016 Application Form

Application Deadline: Monday, October 26, 2015, 5:00 p.m. PDT
Save this file as *LastName_FirstName.docx* and email it as an attachment to: graduate@share.calstate.edu.

Student Applicant Information

First Name:	Frances-Julianna	Department or Degree Program:	Geological Sciences
Last Name:	Leiva	GPA in Major Courses:	3.97
Student ID#:		Matriculation date (mm/yy):	09/14
CSU Campus:	Pomona	Anticipated graduation date (mm/yy):	09/16
Email:	fmleiva@cpp.edu	Degree Sought (e.g., MS, PhD):	MS
Phone		Thesis-based? (Y/N):	Y

Have you previously received a COAST Research Award? (Y/N)	N
If yes, please provide year of award:	

Faculty Advisor Information

First Name:	Jascha	Position/Title:	Professor
Last Name:	Polet	Email:	jpolet@gmail.com
CSU Campus:	Pomona	Phone:	
Department:	Geological Sciences		

Research Project Title:	A Tsunami Magnitude Scale Based on DART Buoy Data

Project Keywords (5-7 keywords related to your project):	Tsunami, DART buoys, Magnitude, Tsunami earthquakes, Earthquakes

Budget Summary (must add up to $3,000)

Award amount directly to awardee:	3000
Award amount to Department:	

Please refer to the Award Announcement for detailed instructions on the information required for each of the following sections.

Project Description (60 points)-1750 word maximum

Description, Goals and Significance

When a tsunami is initiated, it is difficult to predict how the resultant waves will interact at the coast, making it challenging to produce accurate predictions (Okal, 1987; Shuto, 1990). Once tsunami waves reach a shoreline, there are complexities that arise based on near-shore bathymetry and coastal geometries. Due to a rapid decrease in ocean depth as waves travel up the continental shelf, shoaling effects will take place, where the behavior of these waves changes drastically. These shoaling waves will experience a decrease in velocity and an increase in amplitude, so that while amplitudes at the deep ocean can vary from a few centimeters to a meter, amplitudes at the coast can measure up to several tens to hundreds of meters (Tao, 2011).

The quantification of tsunami energy has evolved through time, with a number of tsunami magnitude and intensity scales utilized in the past century (Murty & Loomis, 1980; Abe, 1981; Papadopoulos & Imamura, 2001). The true nature of the physical behavior remains elusive, and many assumptions are made when creating models on which predictions are based. Moreover, the tsunamigenic potential of earthquakes can be difficult to assess, especially in real-time. In order to further our understanding of tsunamis and the earthquakes that excite them, a new dataset must be implemented. Developing a tsunami magnitude scale based on deep ocean wave heights provides a more direct, accurate and objective method for assessing tsunami energy, independent of the source. Such a scale is imperative in the discussion and interpretation of tsunamis. Most importantly, the development of a tsunami magnitude scale, when implemented in real-time, can ultimately be used to better predict tsunami wave heights upon arrival along coastal regions.

Objectives

Current tsunami predictions rely heavily on earthquake occurrence and magnitude. It is important to note that this is an indirect means of measurement; seismometers measure ground motions, not the consequent behavior of water waves. Furthermore, the specific relationship between tsunamigenic earthquakes and their associated tsunamis is not clearly defined (Polet & Kanamori, 2000). Due to the current reliance of tsunami prediction on seismic data, it is important to either improve current knowledge of the behavior of tsunamis in relation to their seismic source, or to develop a new method for tsunami prediction that does not rely on seismic occurrence. The goal of this project is to attempt to do both.

According to previous work (Abe, 1979; Abe 1981; Abe 1994), correlation between earthquake magnitude and coastal data can be described most simply as a linear relationship, where increased wave and run-up heights are expected for larger earthquake magnitudes. However, this is a highly generalized concept, and is not always accurate. A tsunami earthquake, for example, is a term that describes the occurrence in which an earthquake produces anomalously larger wave amplitudes than predicted (Polet & Kanamori, 2000). Tsunami earthquakes are specifically dangerous in that current prediction methodologies tend to underestimate corresponding tsunami magnitudes and, consequently, little to no warning is given for these events. The current reliance on seismic magnitude as a means for determining tsunami probability is inadequate. By incorporating an alternate source of data – deep ocean wave heights – we can improve the understanding of the relationship between earthquakes and tsunamis, thus improving current prediction methodologies, as well as opening up the possibility of developing a new magnitude scaled based on this dataset.

Methodology

DART Buoy Network and Instrumentation

The Deep-ocean Assessment and Reporting of Tsunamis (DART) Project was developed in the early 2000s through the U.S. National Tsunami Hazard Mitigation Program (NTHMP) in an effort to improve early detection and real-time reporting of tsunamis in the open ocean (Milburn et al., 1996; Gonzalez et al., 1998). The program involved the placement of buoys in the Pacific Ocean, which has been the site of major tsunamis in the past, and displays potential for future tsunamis. The two phases for the DART Project included the initial deployment of six buoy stations (DART I) starting in 2000, followed by an expansion after the 2004 Indian Ocean tsunami. The second generation of DART buoys (DART II) was completed in 2008, and expanded the United States' DART network to 39 stations. Other countries have sought to deploy their own sets of DART buoys to use as part of their own tsunami warning system. Within the United States, the NTHMP has involved a major collaboration of federal and state organizations, where management of the DART buoys is administered by NOAA through the National Data Buoy Center (NDBC).

The DART II system buoy contains GPS antennas and is anchored to the ocean bottom, marking the location of the station. Bottom Pressure Recorders (BPRs) are positioned on the ocean floor, and are used to measure the amount of pressure due to the weight of the water column directly above the recorder. In this way, ocean wave heights from 1 centimeter and up to 6000 meters can be measured (Milburn et al., 1996; Gonzalez et al., 1998). This data is transmitted to the surface buoy, which then relays this information to ground stations through satellite communications.

Available Tsunami Event Data

A major advantage of using DART buoy data is accessibility. Information is recorded and provided through NOAA's National Geophysical Data Center (NGDC) for raw wave height data, computed tidal data, and computed residuals, or signals leftover once the tidal data has been removed from the raw data. The NGDC automatically calculates tidal effects and removes them, so that the computed residuals are available to the public, in a ready-to-use format. The maximum tsunami wave heights found in the computed residual data will be used in solving for a tsunami magnitude scale, which is discussed in the next section.

The DART Project provides approximately ten years' worth of data to use for the 39 DART stations. Potential tsunami events that can be utilized in this project include the following events: 2006 Kuril Islands, 2007 Kuril Islands, 2007 Solomon Islands, 2007 Peru, 2009 Samoa, 2010 Haiti, 2010 Chile, 2011 Tohoku, 2013 Solomon Islands, as well as the Chile event of this year. In total, data for ten tsunami events at up to 39 DART buoy stations are available, which will provide abundant usable tsunami wave height data for the proposed project, with the possibility of adding in data from smaller seismic events in the future.

Proposed Tsunami Magnitude Calculation

The proposed methodology to develop a new tsunami magnitude scale will closely follow a process similar to Charles Richter's methods for developing a scale for local magnitude, M_L (Richter, 1935; Gutenberg & Richter 1942; Gutenberg & Richter 1956). In his development of the local magnitude scale, Richter found that the amplitude of ground displacements decayed with distance away from the source. In the context of tsunami waves rather than seismic waves, we will use data collected from DART stations to find the maximum displacement of tsunami wave heights, in place of ground displacements. The equation traditionally used for solving the amplification factor (a_{0j}), or the value that will be representative of our tsunami magnitude, is as follows:

$$a_{ij} = a_{0j} s_i r_{ij}{}^{-n} \exp(-k r_{ij}) \tag{1}$$

where the indices, i and j, represent the station and the event, respectively. a_{ij} is the observed amplitude, s_i is a correctional term for station effects, r_{ij} is the distance between the source and the receiver, and n and k are attenuation coefficients, which will be constant for all station and event pairings. The observed amplitudes will be measured from residual wave height data, and the distance will be calculated for each seismic event and station pairing. We can fit a curve with equation (1) to the plot of maximum wave height against distance, where the attenuation constants vary depending on each seismic event. Initially, we will attempt the curve fitting process to each seismic event in order to observe the strength of quality for each event. We will then pick and choose which events to use in a combined regression analysis, which will become iterative as we pick and choose which events to include and remove. This portion of the project will be the most time consuming as many permutations of selected datasets are possible.

Following the solution for the attenuation constants, the next step will be in calculating the station corrections for each station. Once this is done, the amplification factor can be determined for each event, which will then be categorized into bins depending on observed patterns and behaviors. During the analysis portion of the project, any relationships with seismic magnitude will be examined.

Current Status of the Project

Currently, the ten major seismic events have been analyzed and the most useful stations have been selected. The M_w 9.0 2011 Tohoku event has proven to have the cleanest data set as a result of having the largest magnitude of all the events, whereas the 2010 Haiti event had the lowest data quality. The Haiti event will likely be ignored for the initial regression analysis, and will be included in the later stages. Preliminary speculation shows that a magnitude of approximately 7.5 – 8.0 is necessary for the level of data quality needed for the regression.

Codes for plotting the data and selecting the maximum wave height has been created, allowing for light processing in the way of clipping of the dataset and removal of linear trends. The interactive nature of the code allows the user to select different time intervals to observe and to request the code to recalculate the maximum wave height if it is outside the tsunami wave train. This code produces an output file with the measured distance (r_{ij}), the observed maximum amplitude (a_{ij}), and the logarithm of the observed maximum amplitude, which will be used for the next portion of the project.

Timeline

The expected timeline for this project will span the next year, with a likely deadline at the end of summer 2016. By the end of this fall, I plan on writing the code to perform the linear regression to solve for the attenuation constants. The code writing will likely extend into the following year, in the hopes that the actual regression process will be started during these months. This portion of the project is expected to take the longest, due to the trial and error aspect of the regression. By the start of spring, I will begin analyzing results and focus on creating a simplified magnitude scale for the selected tsunami events. Throughout spring and summer, I will begin fully interpreting the results, and start the write up of the thesis.

References (10 points)-no limit

Abe, K. (1979). Size of great earthquakes of 1837–1974 inferred from tsunami data. *Journal of Geophysical Research*, 84, p. 1561-1568.

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Murty, T. S., & Loomis, H. G. (1980). A new objective tsunami magnitude scale. *Marine Geodesy*, 4(3), 267-282.

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Okal, E. A. (1988). Seismic Parameters Controlling Far-field Tsunami Amplitudes: A Review. *Natural Hazards*, 1, p. 67-96.

Papadopoulos, G. A., & Imamura, F. (2001, August). A proposal for a new tsunami intensity scale. In *ITS 2001 Proceedings* (No. 5-1, pp. 569-577).

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Relation to COAST (15 points)-250 word maximum

This project aims to use data collected within the open ocean to understand phenomena that occur at major coastlines along the Pacific Ocean, including the coast of California. Tsunamis are a major economic and sociological issue, and recent work has shown a heightened risk for tsunami hazard if a major earthquake event were to occur along the Ventura Fault in southern California, or along the Cascadia Subduction Zone (CSZ) in the Pacific Northwest.

Development of a tsunami magnitude scale using data from DART buoys can provide a new perspective in the discussion and interpretation of tsunamis. If performed in real-time, such a magnitude scale could garner improved predictions of wave heights along the coast prior to the arrival of the tsunami waves. This could help increase the accuracy of tsunami warnings, reduce the cost of human life and other damages, as well as provide an additional dataset to advance current knowledge on tsunami research.

Budget and Justification (15 points)

Item/Description	**Unit Price**	**Quantity**	**Amount to Awardee (via Financial Aid)**	**Amount to Department**
Laptop Computer	~$900	1	$900	-
MATLAB Student Suite	$100	1	$100	-
Living Expenses	~$800/Month	1	$800.00	-
Tuition (Partial)	$300/Unit	4	$1200.00	-
		Subtotals:	*$3000.00*	-
		Grand Total	**$3,000.00**	

Justification (250 word maximum):

I am a full-time student who heavily relies on student loans as a source of income. I have received a small amount of funding from my department, which has unfortunately ceased this year. Additional sources of income come from teaching classes part time and doing small jobs for the department, however, this is nowhere near enough to sustain myself without the aid of student loans.

I am currently covering my own living expenses. Splitting an apartment with roommates and choosing a location with cheaper housing has helped curtail some of the costs. Also, due to the recent demise of my laptop of several years, I have been interested in purchasing a new laptop, but unable to do so. I have been using computers available at my school, and have been borrowing an old laptop from a friend for the past few months, which has been fairly unreliable. This issue has already set my project back several weeks as I am not always able to use the only computer with MATLAB available in our department graduate office. If I were awarded the scholarship, I would be able to purchase a new laptop, as well as the MATLAB software I need for my thesis project, which would free me to work wherever I please, and not be restricted to one location. The award would also be used towards my monthly rent, as well as for part of my tuition, and would go a long way in alleviating my dependence on loan money.

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