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Improving Tsunami Warning with a Rapid Linear Model

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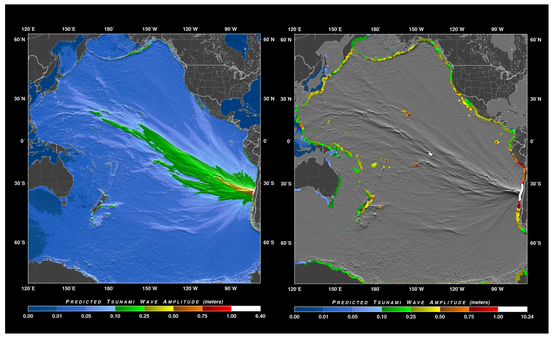
Project Introduction

The Pacific Tsunami Warning Center developed a model that can be used to predict tsunami wave heights in real time (RIFT). Using focal mechanisms from the Global Centroid Moment Tensor Database, we attempt to validate RIFT by comparing model results with historic tsunami coastal wave height data supplied by the National Geophysical Data Center. Data availability restricted our study to 9 of the largest tsunamis over the last 20 years: Nicaragua (1992), Peru (2001), Japan (2003), Aleutian Islands (2003), Sumatra (2004), Kuril Islands (2006 and 2007), Samoa (2009), and Chile (2010). These tsunamis gave us a diverse set of epicentral locations within the Pacific and Indian basins.

Model Background

Tsunami calculation is commonly broken down into three phases: wave generation, wave propagation, and wave inundation. Each portion is governed by a different set of physical equations, and depending on the desired level of sophistication, more or less complex analysis can be substituted in during any phase of the calculation.

In the context of tsunami warning, modelers are forced to balance sophistication with speed of calculation. RIFT emphasizes the wave generation phase of calculation, allowing complete customizability over the source earthquake, while using a linear propagation function and Green's law for coastal wave height estimates. The figure to the right is an example of RIFT output for a hypothetical Chilean earthquake (8.5 M_w), plotting both deep ocean and coastal results.

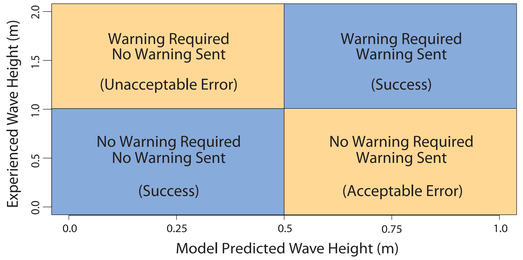


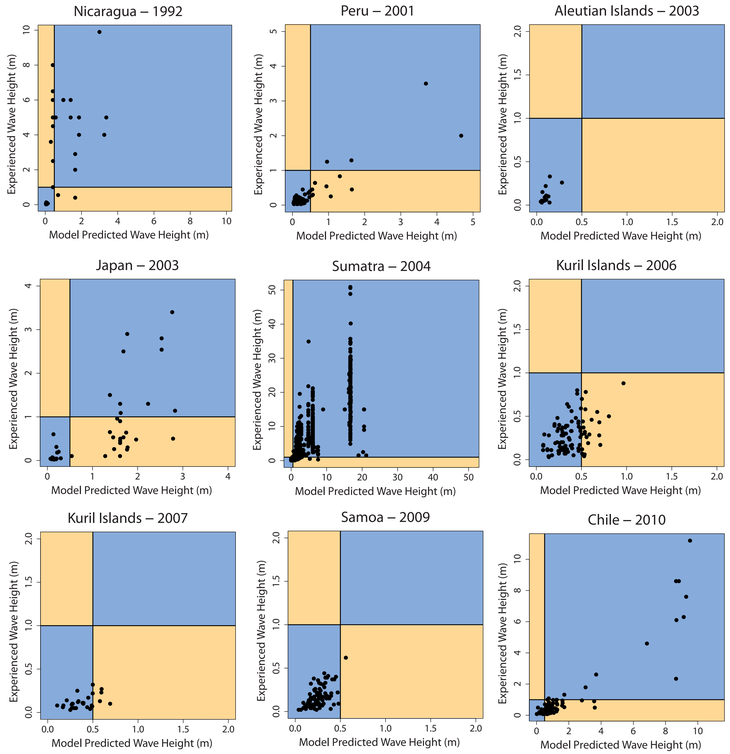
Warning Protocol

A warning is currently issued for locations which are expected to experience wave heights greater than one meter. It is therefore important that any warning method using RIFT is guaranteed to issue a warning for locations that experienced greater than one meter of run-up during the historic events.

We first tested what would happen if the PTWC were to only send warnings to places that, according to RIFT's predictions, will experience wave heights greater than one meter. We found that using this method, as many as 25% of locations that needed a warning would not receive one. We progressively lowered the warning threshold until we were satisfied that all locations that required a warning would receive them.

The result is the method displayed to the right; for every location that RIFT predicts will experience greater than 0.5 meter waves, a warning must be issued. Below is an example of one of these plots, with the implications of each quadrant labeled. Note the only case in which this protocol failed unacceptably was Nicaragua 1992, and using a higher resolution for calculation solves this problem.



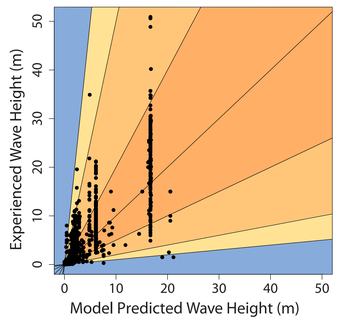


	Results (2 Minute Calculation Resolution)						
	Number of Predictions within a Factor of:			Percentage of Predictions within a Factor of:			Number of Samples
	2	5	10	2	5	10	
Nicaragua	8	21	25	25.8%	67.7%	80.6%	31
Peru	44	74	84	51.8%	87.1%	98.8%	85
Aleutians	13	17	17	72.2%	94.4%	94.4%	18
Japan	20	37	47	40.8%	75.5%	95.9%	49
Sumatra	581	864	885	63.7%	94.7%	97.0%	912
Kuril 06	62	104	109	55.4%	92.9%	97.3%	112
Kuril 07	4	20	29	13.3%	66.7%	96.7%	30
Samoa	71	98	105	66.4%	91.6%	98.1%	107
Chile	71	123	137	51.1%	88.5%	98.6%	139
Overall	874	1358	1438	59%	92%	97%	1483

Historic Data Comparison

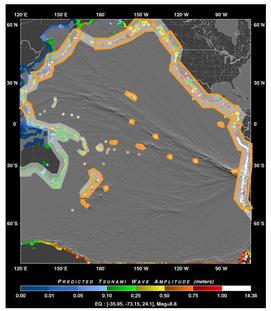
The scatter plot and table display the results of our historic data and model prediction comparisons. The goal of this comparison is to quantify how well the model predicts coastal wave heights, which we do by determining the frequency of model predictions that fall within the ranges of 0.5-2 times, 0.2-5 times, and 0.1-10 times the observed wave heights.

We find from the analysis of these 9 tsunamis that RIFT's wave height predictions are not reliable at a 2 minute calculation resolution. However, with an understanding of the margin of error implicit in the predictions and using a conservative warning threshold, the model can still be valuable in the tsunami warning process.



Performance Improvement

During the 2010 Chile event, the entire Pacific basin receieved a warning (coasts highlighted in white). Using the above protocol, RIFT would have reduced unnecessary warning by 35%, without losing accuracy, to the area highlighted in orange.



Acknowledgements

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