An Analysis of Tsunami Sensitivity to Fault Plane Orientation Using a Rapid Linear Model

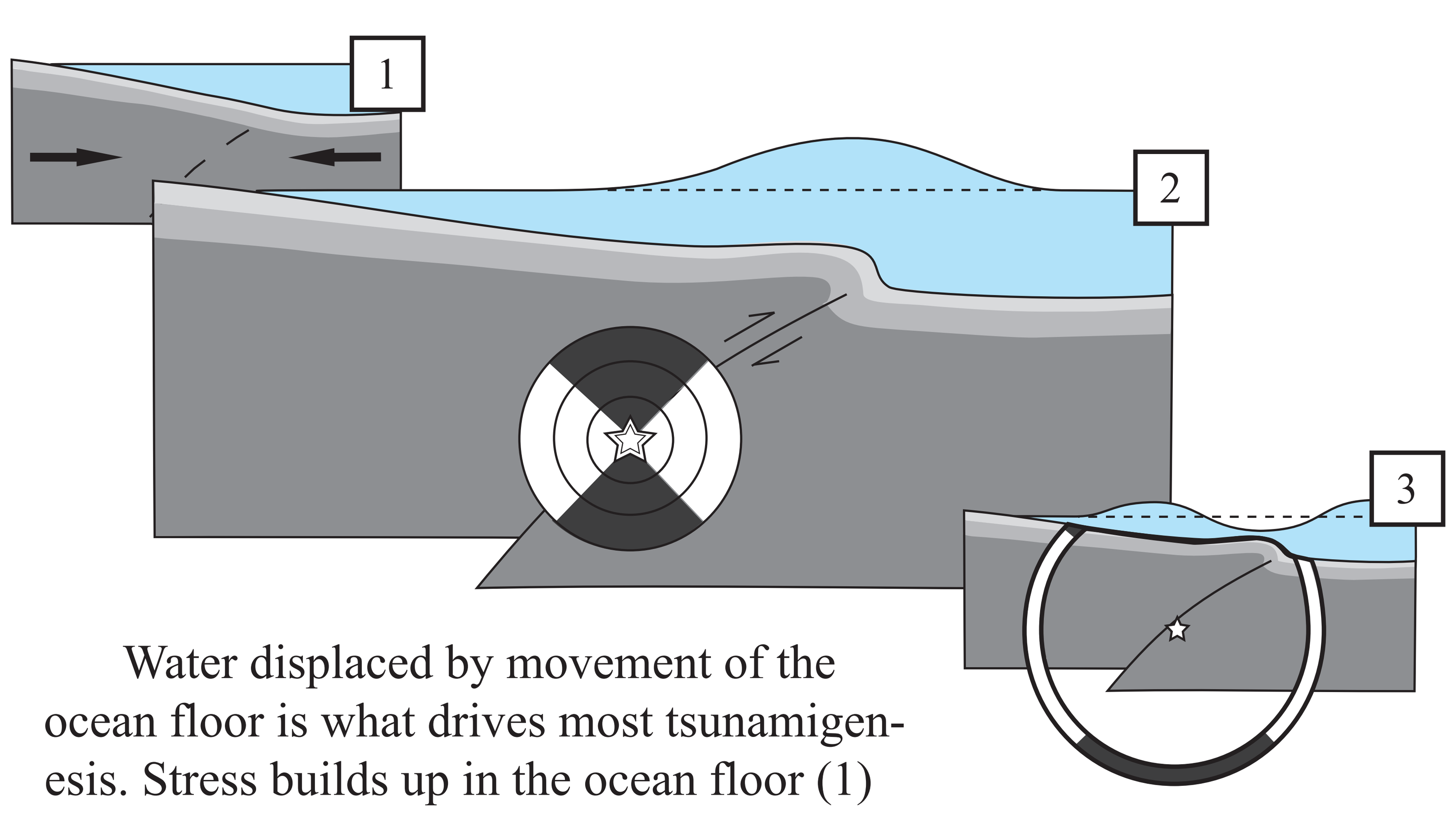
Nick Holschuh - Carleton College, Northfield, MN 55057
Advisors: Sarah Titus (Carleton College), Gerard Fryer (PTWC)

Project Introduction

Tsunamis pose both a societal and economic threat to coastal countries across the globe. As a result, geoscientists collect and analyze tsunami data in an effort to characterize the physical processes which control tsunami formation. The ultimate goal of this analysis is to develop a mathematical framework which can explain tsunami generation, wave propagation, and coastal inundation. With a robust model, it would be possible to forecast tsunami hazard in real time.

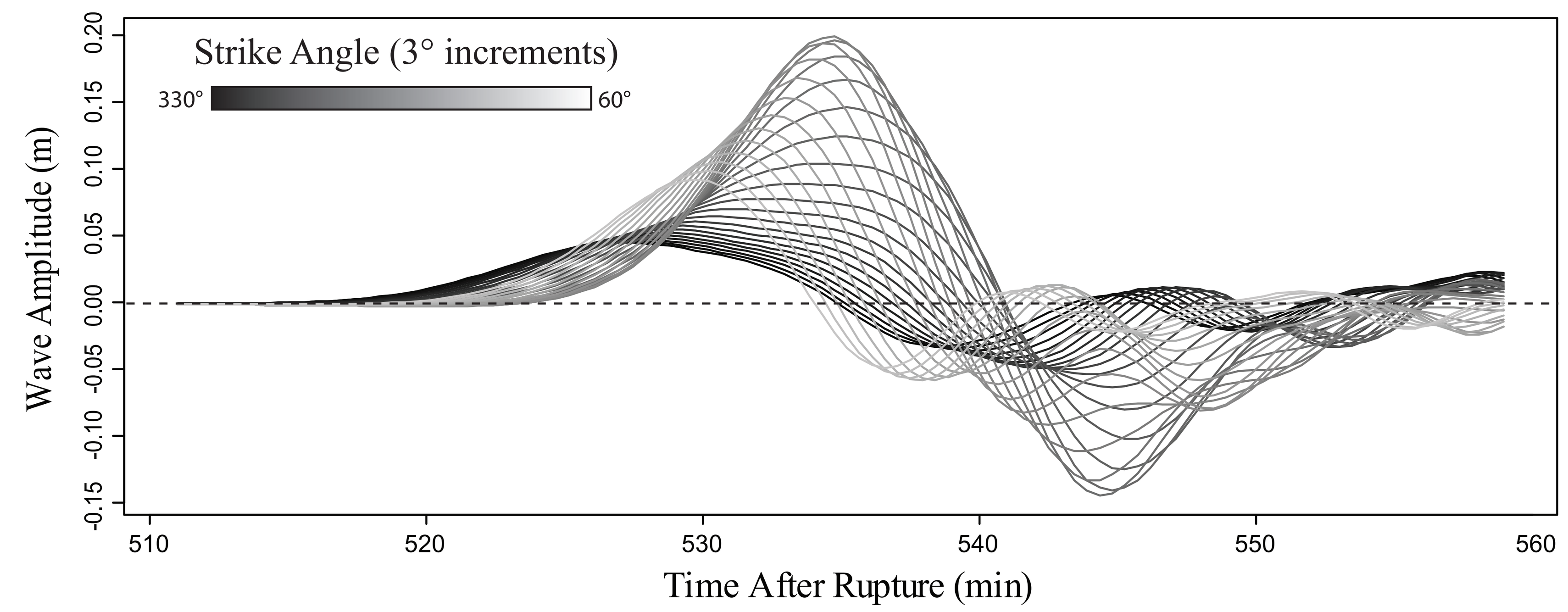
For a model to be useful during a tsunamigenic event, it must be comprehensive enough to accurately predict tsunami hazard based on the available and often incomplete earthquake information. Because it takes time for the seismic data to arrive, fault plane depth and orientation are not well constrained during the period relevant for tsunami hazard management. Using a linear model, this study looks at how fault strike, dip, rake, and depth affect tsunami wave hazard. By analyzing the changes in wave height resulting from an incremental adjustment to the source earthquake, it is possible to quantify the model uncertainty caused by inaccurate fault plane assumptions.

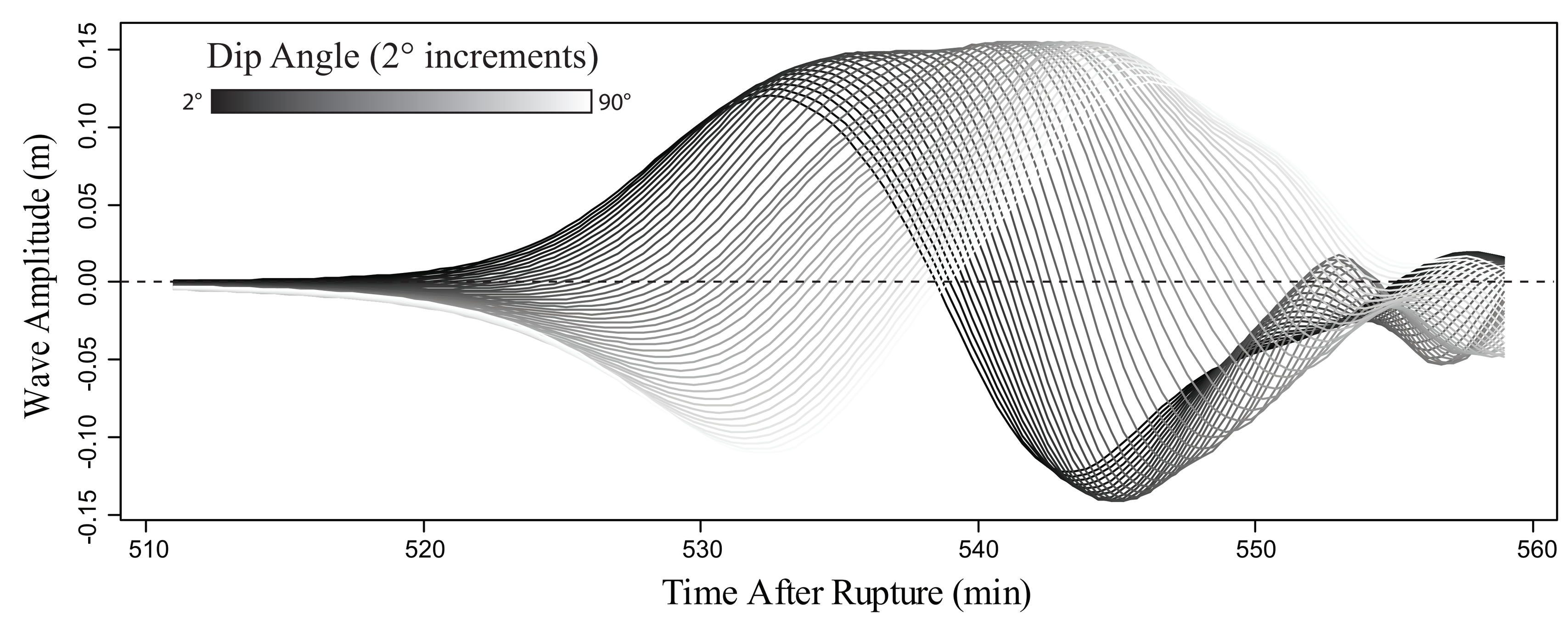
Tsunami Generation

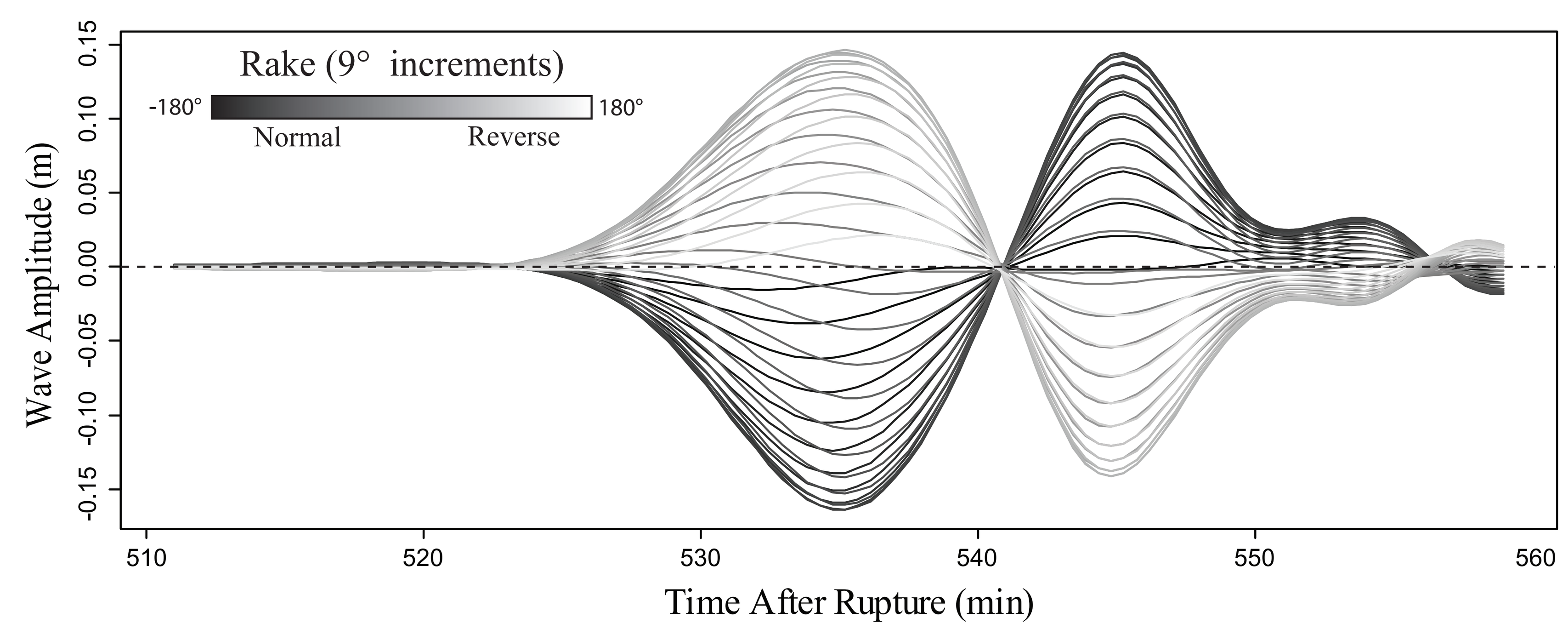


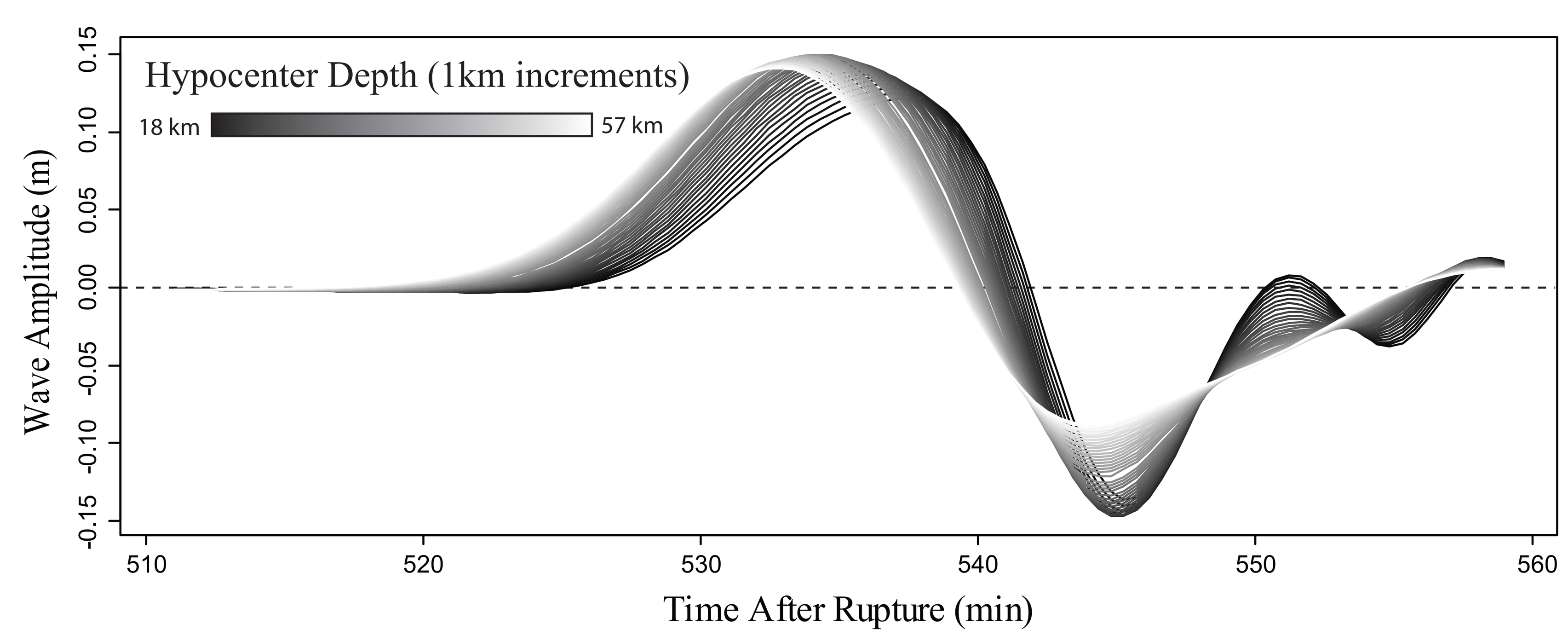
Water displaced by movement of the ocean floor is what drives most tsunamigenesis. Stress builds up in the ocean floor (1) until fault rupture occurs (2). Motion on the fault results in the uplifting or down-dropping of the overlaying water column. As the system equilibrates, tsunami waves and seismic data propagate away from the source (3). It is the time between seismic data reception and tsunami wave arrival that hazard management takes place.

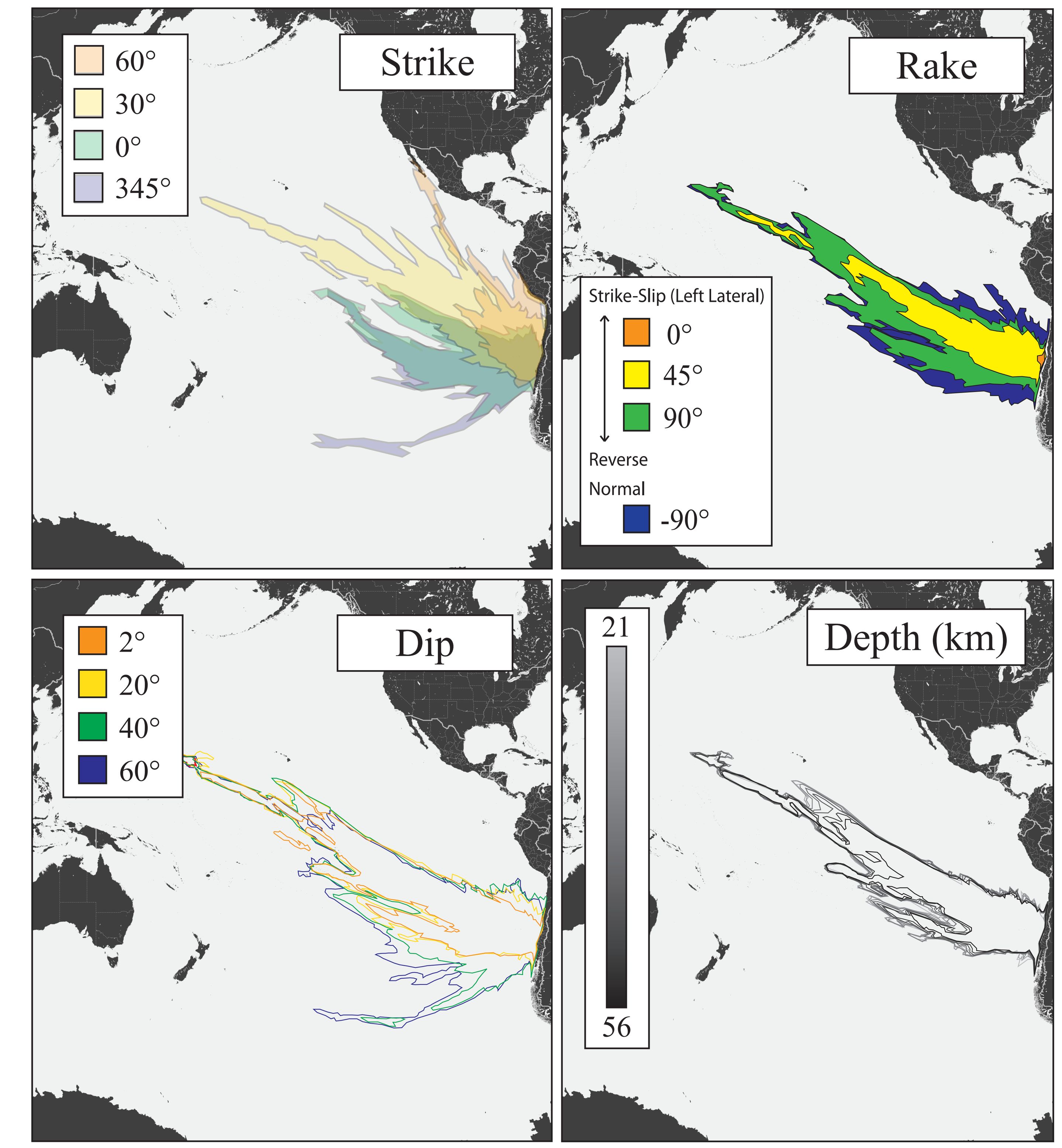
The graphs to the right are overlain time series describing deviations from mean sea surface at a tide gauge ~400 km off of the west coast of Chile. Each line represents the tsunami from a different source earthquake. These model runs are based around incremental adjustments to a decollement earthquake with the source parameters: Longitude = 73°W, Latitude = 36°S, Mw = 8.5, Strike = 15°, Dip = 20°, Rake = 90°, Depth = 30 km.











The above maps overlay the areas subjected to greater than 10 cm waves for a subset of the tsunamis modeled. The goal is to illustrate the effect of earthquake parameters on the size of the effected area and the directionality of the resulting tsunami. By plotting the data spatially, it makes it easy to determine if changes in tsunami severity exhibited by the time series data are global or local.

Results and Conclusions

Of the four parameters studied, three were shown to impact tsunami severity either locally or globally. The primary tsunami beam trended perpendicular to fault strike, causing large but local differences in observed wave heights with slight changes in fault strike. Fault dip and rake cause tsunami severity to change across the entire basin, although the incremental differences in predictued wave height are not as large as those caused by changes in strike.

While hypocentral depth does not significantly affect wave amplitude predictions, this study shows that fault strike, dip, and rake can all bias hazard forecasts if inaccurate values are assumed. This means that models which do not have customizable source parameters introduce a large potential for error by restricting tsunami generating earthquakes to the decollement only.