SEI 03 Microseisms interpreted as coastal reflections of ocean waves generated by storms based on Mexico Array data

SEI 03.1 Overview
We are exploring the correlation of daily microseism travel times, amplitude, and azimuth along the linear MASE seismic array with global wave height and global sources of microseisms. The Meso-American Subduction Experiment (MASE) was a 100 station 500km linear broadband seismic array deployed for 2 years across Mexico. The time series of daily travel times between pairs of stations, determined from noise correlation, fluctuates by up to two seconds, and are correlated with one another across independent pairs of nearly aligned stations. We have successfully modeled the fluctuations between stations by describing the phase change introduced by the biased energy from the off receiver-line sources. The goal of this effort was to enabled the application of Data Driven Time Synchronization (DDTS), which uses underlying characteristics in the data to provide time synchronization, to repair incorrectly time synchronized data. The method was successful.

To further improve the accuracy of seismic DDTS we began searching for an external model to correlate the travel time fluctuations with. Part of this model is determining where precisely the microseism are generated. The search has uncovered new correlations between global ocean effects such as wave height and helped us develop a model based on these correlations which can predict the microseism travel time fluctuations. This model supports the theory that for our array, microseisms are generated near the Mexican coast and not in the southern hemisphere as was generally believed before.

SEI 03.2 Approach
There are two prevailing theories on the sources of microseisms for our network. They do not differ in how the microseisms are created but they differ in where microseisms are created relative to the stations. Both theories describe microseisms generated in interfering ocean surface waves. The first, which we will call the $\Psi_c$ theory, proposes that the microseisms come from storm centers, specifically the Roaring Forties, the storms in the lower southern latitudes. $\Psi_c$ is the microseism source intensity: it is the expected amplitude of the microseisms at the source. The second theory, which we will call the HR theory, proposes that the microseisms are generated by the ocean waves from the storms in the Roaring Forties, but after the waves have traveled to and reflected off of the coast. In other words, the coastal reflection interferes with the incoming ocean surface waves in the correct way to create microseisms. This occurs within 5000Km (about 45°s of latitude) of the stations. In this case, the effects from the storms are essentially delayed by the amount of time it takes for the ocean surface waves to travel from the storm to the coast. Both of these theories can be tested and verified using existing data sets of weather and ocean effects: wind velocity, wave height, and the microseism source intensity ($\Psi_c$).

Using the weather and ocean effects we searched for an external model to correlate our results to and potentially track the microseisms over time. Our search has focused on the global wave height, wave-wave interaction intensity ($\Psi$), and microseism source intensity ($\Psi_c$) and we correlated these with the measured microseism azimuth, microseism amplitude, and microseism travel time.

SEI 03.3 System(s) Description and/or Experiments
We began with two month time series (on a one day scale) of microseisms azimuth, microseism amplitude, and microseism travel time and used various methods for correlation. To test the $\Psi_c$ theory we used the ocean effects from the entire planet over the same two months. We obtained these by running the National Oceanic and Atmospheric Administration (NOAA) / National Centers for Environmental Prediction (NCEP) WAVEWATCH III wave...
action model software. To test the HR theory we followed the same processes except restricted the search regions near the coast of Mexico.

SEI 03.4 Accomplishments
Our search revealed two strong correlations. When restricted to a 5000Km region around our array, we can correlate the ocean wave height with the microseism azimuth and the microseism amplitude. Figure (2) and Figure (3) shows these correlations. With these correlations we have created two models to predict the travel time. The first is an empirical model based on our earlier microseism propagation model. The results can be seen in Figure (4). The second model uses a ray theoretic approach which computes how the phase arrivals for a distribution of sources around two stations combine. It calculates the phase delay from the true straight line travel time that will be obtained when computing the travel time from the seismic data. The result can be seen in Figure (5).

Both of our strong correlations show that the travel time fluctuations are indeed a result of the amplitude and the location of the ocean effects near our seismic array. This is evidence to support our HR theory that the microseisms are generated by the interference of the incoming ocean surface waves and the outgoing coastal reflections.

SEI 03.5 Future Directions
The next step is to implement coast reflections in the WAVEWATCH III wave action model software. Since WAVEWATCH III does not implement coast reflection we used the wave height as an approximation in our work. If successful the implementation will provide stronger correlations and more evident to support the HR theory. Other next steps include performing the same analysis with more of the MASE data, data from our Peru Subduction Experiment, and data from other board band seismic stations around the work.