Tropical cyclones (hurricanes and typhoons) are mostly atmospheric phenomena but they also generate significant ground motions in the solid earth when they become strong. If a dense seismological array existed along the path of a hurricane, we could learn about some processes near the hurricane eye and the change of its intensity through seismic data. Prior to this summer we have reported on our analysis of Hurricane Isaac in 2012, which made landfall in Louisiana and passed through Earthscope’s Transportable Array (TA) (Tanimoto and Lamontagne 2014). Its decay process was recorded in seismic and barometric data, as the TA is equipped with both seismometers and barometers. This is a unique set of stations that have never been used for hurricane studies and gave us an opportunity to monitor the decay of a hurricane in detail for the first time. Our basic approach to study hurricanes is to perform a joint inversion of the seismic and barometric data in order to analyze the seismic amplitude-distance data and pressure-distance data for each 6-hour hurricane location.

The Isaac data shows a sharp peak at about 75 km from the eye in both the seismic and barometer data after landfall. This is interpreted to be the location of the eyewall, where there is a region of strong ascending flow in the hurricane. Overtime, this peak deteriorates, which is related to the decay of the hurricane after landfall. From this, it is evident that the intensity of the hurricane can be tracked over time from the ground motions picked up by the array of seismometers.

This summer one of my goals was to perform this analysis on any other hurricanes that passed through the TA and generated a strong enough signal to use. Hurricane Arthur in 2014 gave us a short window of useable data. Arthur very briefly made landfall in North Carolina, before passing by and continuing out over the ocean. However, in that hour of data where Arthur is in contact with the land and is passing over the TA, we have enough data to perform the same joint inversion of the seismic and barometric data that we did for Isaac. In both the seismic and barometric data we observe a peak from the eyewall similar to that of Isaac. A peak is also evident in the data 6 hours before and after Arthur made landfall, however it is smaller and has more scatter since the hurricane was only close to the coast and not directly over land at those locations. Following this summer, we also have plans to analyze a number of hurricanes in Mexico using the Mexican seismic network, where we hope to also observe the eyewall signal, although the network is not as dense nor does it have barometers like the TA.

Additionally, we are using the data from Hurricane Isaac to constrain the relationship between the pressure exerted by the hurricane and the resulting ground motions. We previously developed a stochastic theory of seismic-wave excitation by surface pressure using data sets interpolated from the original data. There are two parameters involved in this theory; first there is the pressure power spectral density and second is the correlation length in the pressure field. This summer we used this theory to solve for the correlation length, which varies spatially from the center of the hurricane, and found that the correlation length is larger towards the center. We are also currently applying this method to the raw data to get a better model relating the seismic and pressure data.
Further work on this project will involved continuing to create a better model for the seismic data based on the surface pressure exerted by a hurricane on land. Once an on-land model has been developed we can apply it to hurricanes while they are still out over the ocean. One of the long-term goals of this project is to develop a method to track the intensity of hurricanes in real time from the ground more accurately than is possible with satellite data.

We recently submitted a manuscript for publication in the Journal of Geophysical Research on this subject. The stochastic theory of seismic-wave excitation by surface pressure was presented at the 2015 SSA Annual Meeting in May, and the new developments with Hurricane Arthur and our results for the Mexico hurricanes will be presented at the 2015 AGU Fall Meeting in December.

References


Tanimoto, T. and A. Valovcin, Stochastic excitation of seismic waves by a hurricane, submitted to JGR, 2015

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