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Seismic and pressure signals when a hurricane moves over an array

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General structure in a tropical cyclone (hurricane/typhoon) in the atmosphere is reasonably well known; it has a very calm central region surrounded by a circular eyewall at a radius of about 50-100 km from the center. Winds are strongest at the eyewall and outside the eyewall, there exists a fairly strong windy region that extends to about 500-1000 km from the center. The main purpose of this study is to understand how seismic waves in the solid Earth are generated by a tropical cyclone. We focus on a low frequency band (below 0.05 Hz) in this study. The basic mechanism of seismic wave excitation in such a low frequency band is relatively straightforward; changes in wind speed generate surface pressure changes and that in turn excite ground motions in the solid Earth.

In a rare example of a hurricane (Hurricane Isaac in 2012) that moved through the USARRAY (Earthscope), that had co-located seismometers and barometers, we can directly examine how ground motions and surface pressure are influenced by the passage of a hurricane eye. When a hurricane eye passes over a station, pressure and three-component seismic time series show a gap in amplitude (envelope) for filtered time series below 0.05 Hz. Typically, long envelopes in time series appear to be truncated by a gap that is at the arrival time of the hurricane eye (although it is not a real gap in data). Using a few stations on the track of a hurricane, we can show that this gap moves in time. This feature only occurs for stations that are within about 50 km from the hurricane track.

We also point out that pressure and vertical ground motions show very high correlation (the correlation coefficient or CC about 0.8-0.9). On the other hand, horizontal-component seismic data show small correlation with pressure (CC close to zero) even though their amplitudes (envelopes) show gaps that are coincident in time with pressure. What it means is that phase is quite incoherent between pressure and horizontal components whereas phase is almost perfectly coherent between pressure and vertical motions. This high correlation between pressure and vertical motion is seen between 0.01 and 0.05 Hz but becomes weaker toward higher frequencies.

This high coherence between pressure and vertical motion (displacement) at low frequencies implies that, even though this is for non-zero frequency dynamic motions (0.01-0.05 Hz), the solid earth is responding to surface pressure as though it were a static force problem. Propagation of excited seismic waves must be occurring but they seem to be much smaller. To first order, the ground directly responds to the local surface pressure changes in this low frequency band.