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Stochastic excitation of seismic waves by an intense Hurricane: Seismic excitation proportional to the cube of pressure

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Earthscope Transportable Array (TA) has recorded a few hurricanes that propagated through the network. We report our analysis of Hurricane Isaac in 2012 that provided an opportunity to monitor the interactions between the atmosphere and the solid earth in detail as this hurricane passed through the network; this was possible because TA has both seismometers and barometers and allowed us to examine how seismic ground motions were excited with changing surface pressures. We analyzed data in a low frequency band 0.01-0.02 Hz because we had evidence that the signals are generated by processes near the center of a hurricane.

Surface pressure is the excitation source of seismic signals; it has short correlation length (˜1 km or less) whereas excited surface waves (0.01-0.02 Hz) have horizontal wavelengths of 100-300km. The source is also spread over some areas. Under such conditions, we must model the source by a stochastic pressure source that is spread over the surface of the Earth. In terms of parameters, this source is then characterized by two parameters, the pressure power spectral density S_p and its correlation length L but both parameters can vary in space. We derived a relation between the observed power spectral density (PSD) of seismic velocity S_v and the PSD of surface pressure Sp by the normal mode theory.

For a low frequency range 0.01-0.02 Hz, seismic and pressure amplitudes show, at least to first order, axisymmetric variations and also decreasing trends with distance from the center of a hurricane. Taking the center of a hurricane at the origin and assuming axisymmetry, we can write down an integral relation between Sv and Sp as

$S_v (x) = \int K(x, y) L^2 S_p(y)\, dy$

where x and y are distances from the center of a hurricane. K(x,y) is the excitation kernel for a source at y and a seismic observation at x and was computed for an Earth model PREM.

From data, we have Sv and Sp in the integrand. We first noted that a constant L cannot make the two observed quantities compatible. Therefore, we introduced the y dependence in L^2 where the correlation length varied with distance and solved for it . With such spatially varying L(y), the two data can be made compatible. The important point is that we also found a correlation between this L (solution) and surface pressure Sp. In fact there is a good linear relationship that can be expressed as L=c Sp where c is a constant. This is equivalent to saying that $L^2 S_p$ in the integrand is $c^2 S_p^3$.

This relation implies that the excitation of seismic ground motion becomes proportional to the cube of pressure. Near the center of a hurricane, pressure variations generally increase, but seismic-excitation becomes even more efficient near the center because of this nonlinear relation.

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