Deciphering atmosphere-ground coupling in the seismic hum period band from hurricane observations and Large-Eddy Simulation of turbulence

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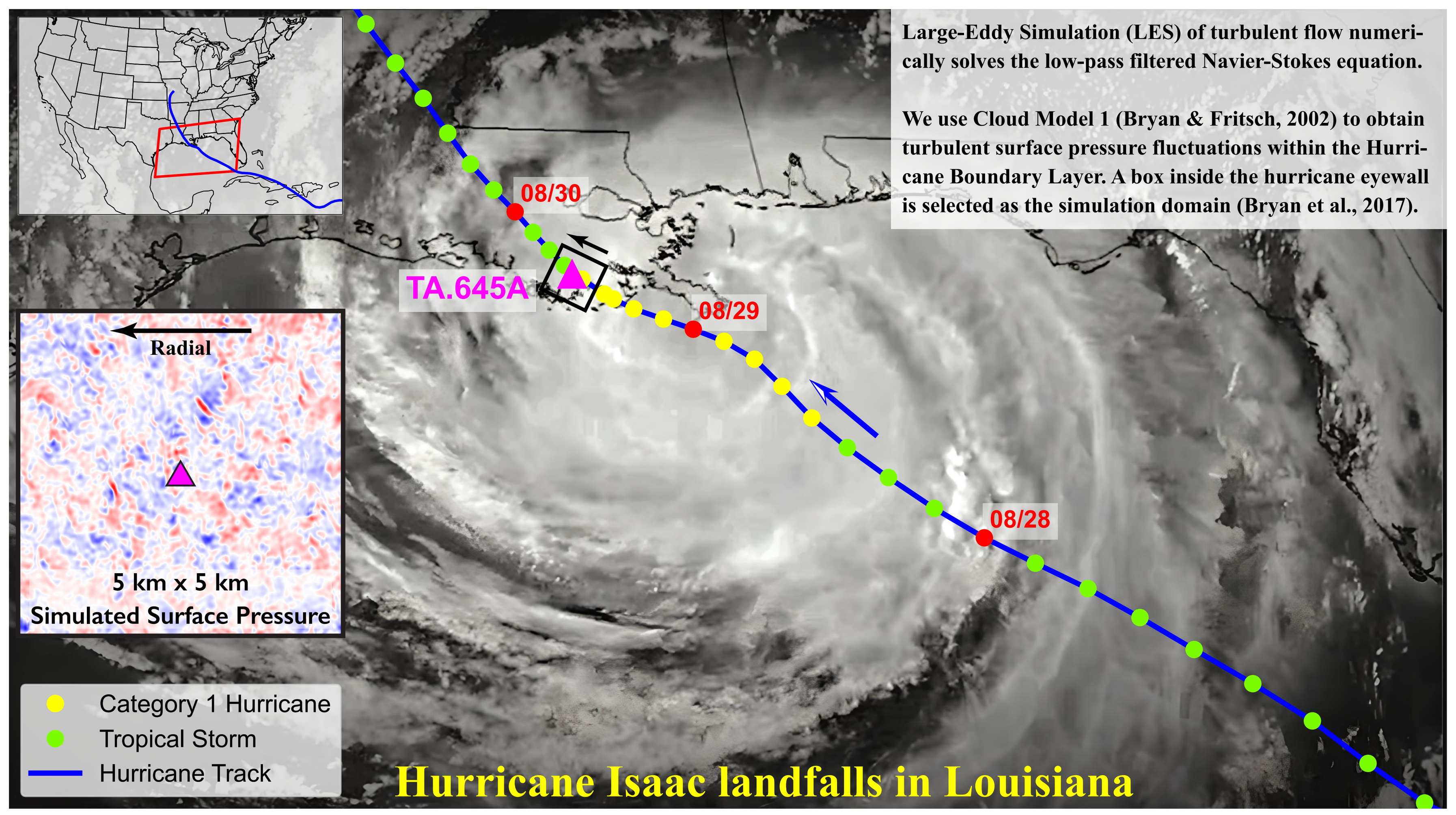
Landfall of Hurricane Isaac in 2012



Key Points

Seismometers and co-located atmospheric pressure sensors record signals from turbulent air flows between 20 s - 100 s period band, as Hurricane Isaac passed through the station during its landfall.

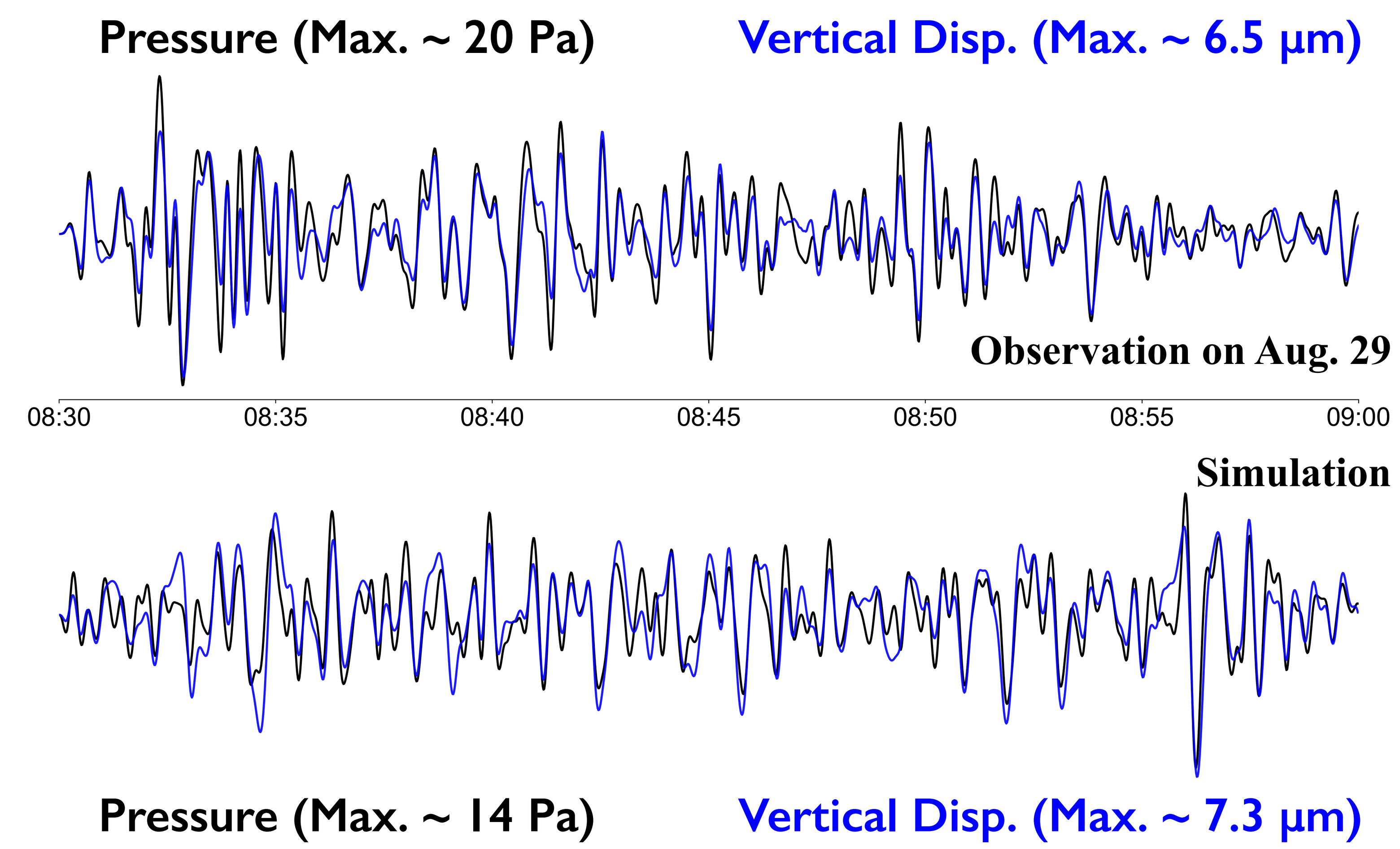
Turbulence simulation such as LES provides a more realistic representation of the surface forcing.

Local quasi-static modeling framework for an elastic half-space can explain the seismic vertical observations pretty well.

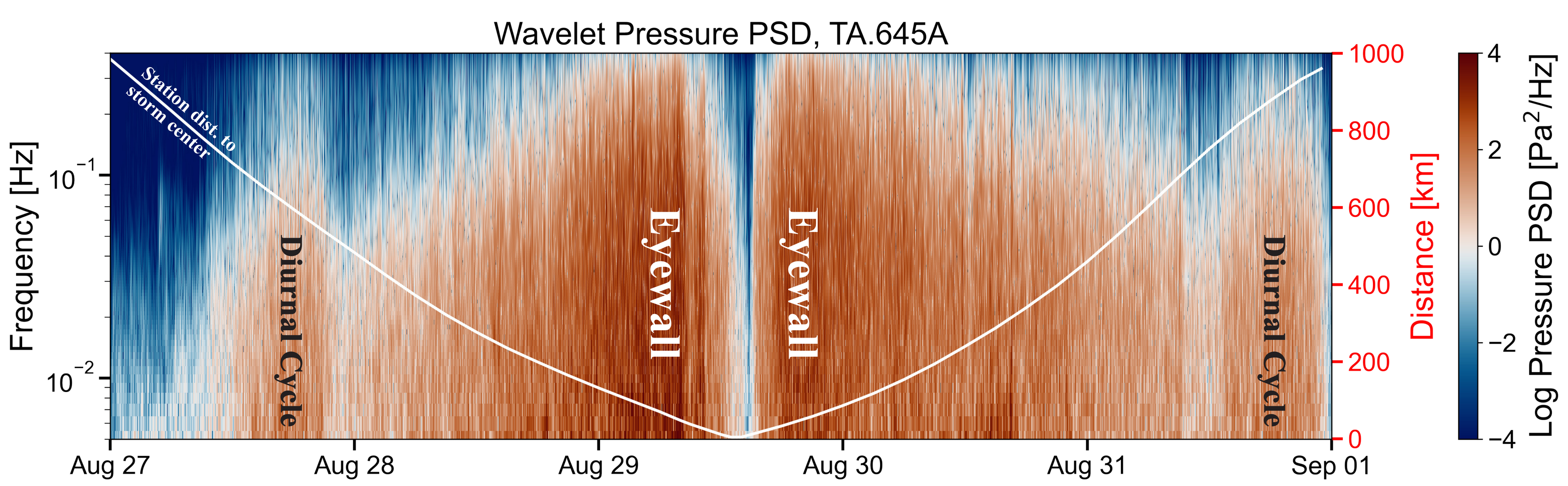
Horizontal tilt signals, however, still requires further investigation

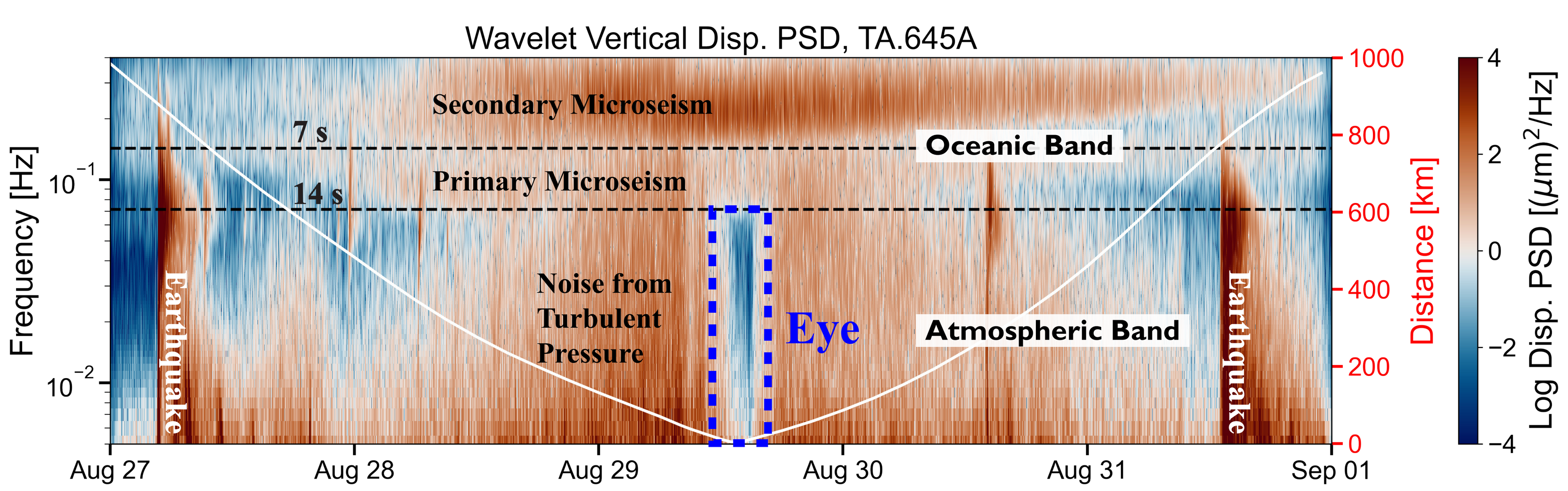
Inter-disciplinary approach can extend the investigation of atmosphere-ground coupling into the area of seismic ambient noise.

Observation VS Simulation in Eyewall

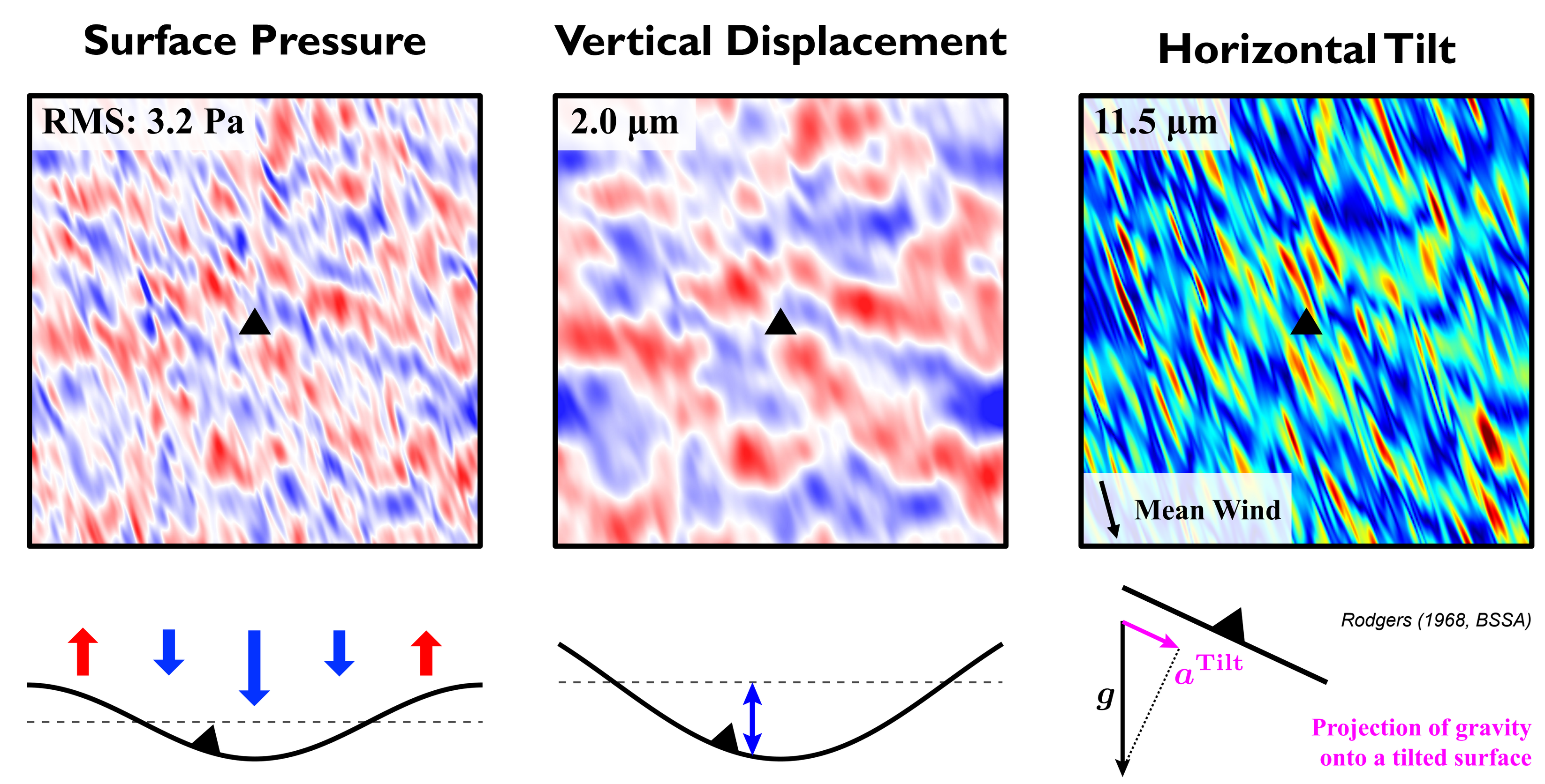


Seismic Imprint of Calm Hurricane Eye





Quasi-Static Model of Seismic Response



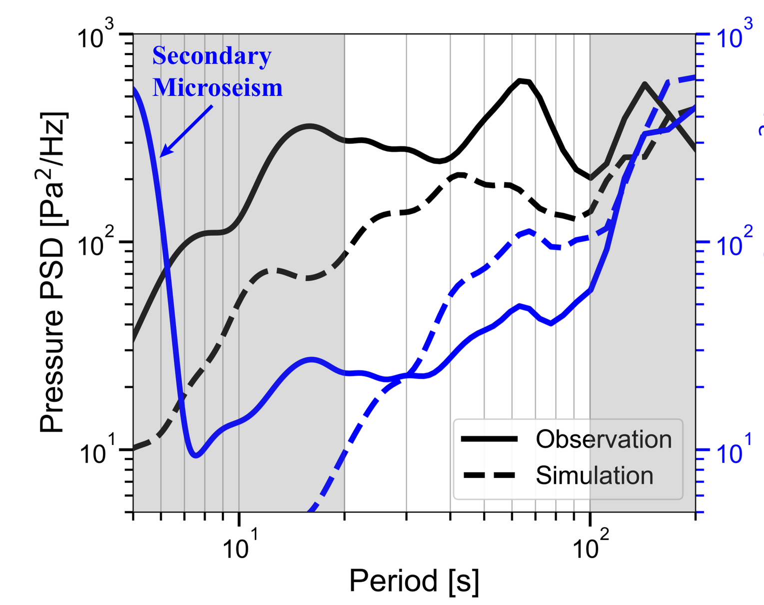
Filter range: Period 20 - 100 s
Grid element size: 20 m

$$\hat{u}_z(\boldsymbol{k},\omega) = \frac{1}{4\pi\mu}\,\frac{\lambda+2\mu}{\lambda+\mu}\,\frac{\hat{p}(\boldsymbol{k},\omega)\Delta S_k}{|\boldsymbol{k}|}$$

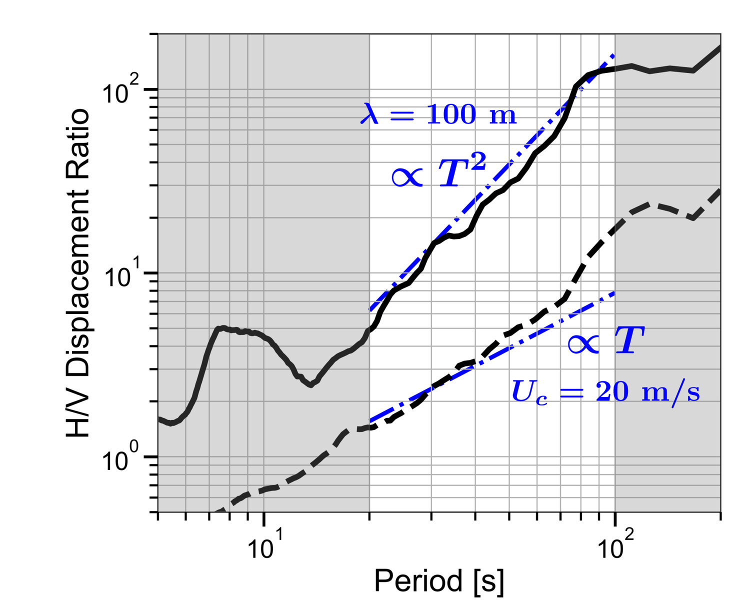
$$\hat{\boldsymbol{u}}^{\mathrm{Tilt}}(\boldsymbol{k},\omega) = \frac{g}{\omega^2}\, i\boldsymbol{k}\,\hat{u}_z(\boldsymbol{k},\omega)$$

We perform local-scale quasi-static modeling of seismic signals, as demosntrated by Ji & Dunham (in revision) that only the forcing within several kilometers of the station is important. We consider an elastic halfspace with its properties estimated from the Vs30 model compiled by USGS.

Pressure & Vertical Displacement Spectra



H/V Ratio for Tilt Analysis



Within the period band of 20 s - 100 s, LES output of turbulent surface pressure and the modelled vertical displacement are comparable to observations. The spectral difference in vertical dispalcement could be due to the seismic ambient noise from the ocean (e.g., long-period seismic hum).

The horizontal-to-vertical (H/V) displacement ratio is indicative of the tilt response:

$$\mathrm{H/V} = \left|\frac{\hat{u}^{\mathrm{Tilt}}}{\hat{u}_z}\right| = \frac{gk}{\omega^2} \propto T \quad \text{if} \quad \omega = U_c k \qquad \textbf{or} \qquad \mathrm{H/V} \propto T^2 \quad \text{if} \quad k = \text{const.}$$

The first case is conceptually similar to the wind-related pressure wave with wind speed U_c (or the convective speed of the turbulence). The latter case indicates a constant characteristic length scale of eddies. The difference suggests further investigation of the tilt signals.

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Satellite image of Hurricane Isaac is from GOES 14, courtesy of NOAA and the University of Wisconsin-Madison Cooperative Institute for Meteorological Satellite Studies

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