Acoustic signature of tropical storm Ernesto and noise cross correlation


Acoustic noise from ocean waves

Ocean wave pressure decrease with depth,

**ocean wave frequency**: Generated by shoaling of ocean waves. Often dominant in strong storms
Can travel long distance (~across US)

**Higher frequency**: Generated by wave interference in deep water

$$\sin(\omega t - kx) + \sin(\omega t + kx) = 2\sin(2\omega t)\cos(kx)$$
Beamforming based on 150 seismic stations

Ocean wave period ~10 s
Microseisms created by Shoaling

Gerstoft and Tanimoto, A year of microseisms in southern California, GRL 2007
• Freq>2Hz: Wind dominated
• 0.2-2 wave interaction
• <0.2Hz Distant ocean waves

• Swami32 some clipping (removed)
• Shark heavy clipping
Ocean noise beamforming

Continuous field

Normal modes

Broadside: 180° vertical beam width
Endfire: cone beam, no higher modes, no continuous field

Continuous field ~ local
Modes ~ regional

Rachel M. Hamson: Array responses to noise in shallow water
Beamforming

- Sum over 15-30 Hz
Noise correlation: 1D example

\[ u(x,t) = R(t - x / c) + L(t + x / c) \]
1D example

\[ u(x, t) = R(t - x / c) + L(t + x / c) \]

Cross-correlation

\[ u(x = 0) \otimes u(x = H) = C_R(t - H / c) + C_L(t + H / c) \]

- sum of causal and acausal response
- uncorrelated left- and rightgoing waves
Right-going wave only

\[ R(t - x/c) \]

\[ x = 0 \quad x = H \]

\[ H / c \]
Noise correlation processing

- Data collected September 2006 during Tropical Storm Ernesto
- 20 element unevenly spaced 256m HLA
SWAMI52

- Cross correlation (dB) with tail hydrophone.
- Dashed lines show arrivals (from oases)
The SWAMI32 experienced channel switching during the deployment.

Using noise cross correlation we find the switching.

The reason for the switch remains unknown.
Clearly, Channel switching occurred!
Time of switching

- Cross correlation based on 6:24 min
- Switch 7:17 Z +/- 3min
- Switch 12:14:45 +/- 5 s
correlation as a function of receiver separation distance
Time of 2nd switching

- 20-s cross correlation 12:14 Z
- Time of switch 12:14:45 Z +/- 5 s
Travel times from cross correlation

Before

One channel switched

Two channel switched
Ernesto: Noise cross correlation

(a) Map of the study area

(b) Scatter plot of North vs. East coordinates
Spectrograms unnormalized

Swami32

swami52

shark