# Extracting Tsunami and Short-Period Motions from HF Doppler Radar Data through Empirical Orthogonal Function Analysis

EC24B 1115

L. R. Benjamin[1], P. Flament[1], K. F. Cheung[2], D. S. Luther[1];

[1]Department of Oceanography, [2]Department of Ocean and Resources Engineering; University of Hawaii at Manoa, Honolulu, HI

## Introduction

Meteotsunamis are waves of tsunami wavelength and period caused by resonance between atmosphere and ocean:
1) Atmospheric disturbance creates displacement on the ocean surface
2) Speed of the atmospheric disturbance matches the shallow water (edge) wave speed, causing Proudman (Greenspan) resonance
3) Waves shoal and amplify, may experience shelf resonance
4) Waves further amplified by harbor resonance

Meteotsunamis occur in the Balearic Islands, Sicily, Malta, Japan, the Baltic Sea, the Yellow Sea, the Adriatic Sea, the Aegean Sea, the English Channel, the Great Lakes, the eastern coast of North America, and New Zealand [Monserrat et al., 2006].

The recorded signals from meteotsunamis are nearly identical to those of seismic tsunamis.

## Methods

Use the response from a seismic tsunami to look for a meteotsunami: Koko Head high-frequency Doppler radio (KOK HFDR) on south Oahu

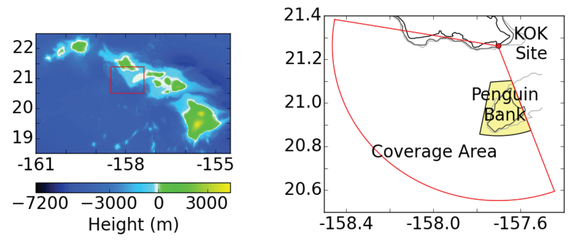


Figure 1. Hawaiian Islands and bathymetry, with KOK HFDR coverage area and local bathymetry in inset at right. The shaded area is the area used for the tsunami and current analysis.

Decompose two years of KOK HFDR data, processed for 4.2 min temporal resolution, using the spatial EOF modes found during the 2011 Tohoku tsunami

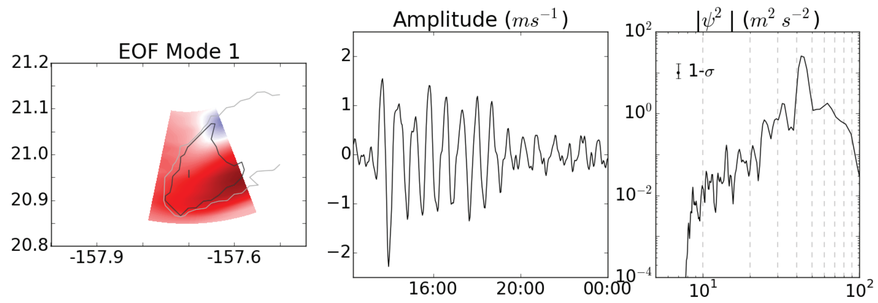


Figure 2. First EOF (left) spatial mode, (center) time series, and (right) spectrum from the 2011 Tohoku tsunami over Penguin Bank from currents from the KOK HFDR on south Oahu. After Benjamin et al. [2016].

## Results

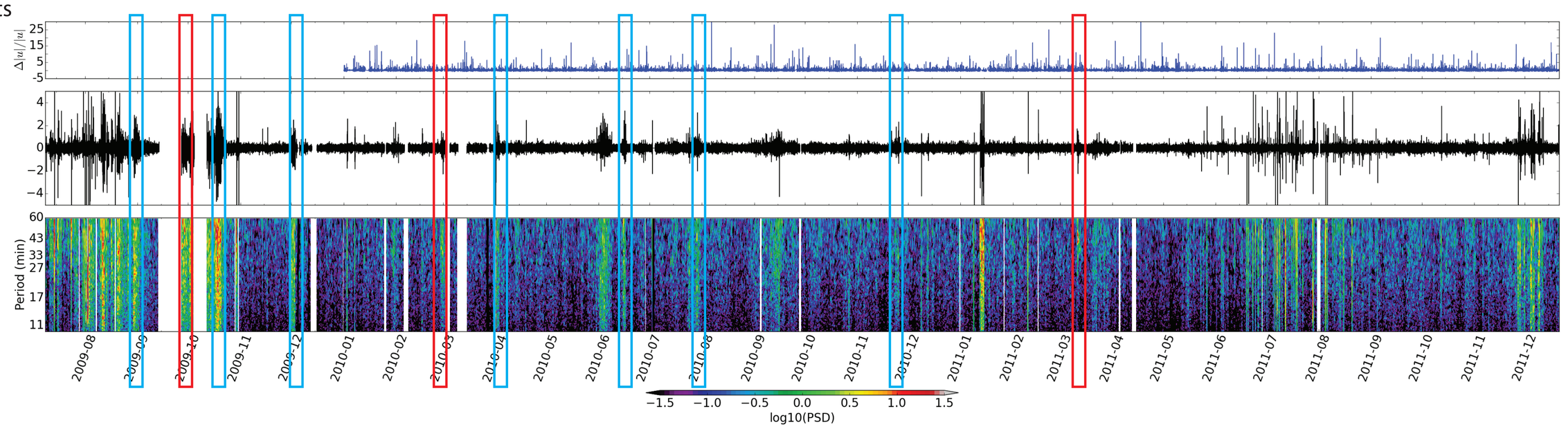


Figure 3. (Top) Fractional change in wind speed from a wind buoy on the south shore of Oahu, and (center) time series and (bottom) spectrogram from decomposition of data with EOF mode 1 from the 2011 Tohoku tsunami. The times bracketed in red are the 2009 Samoan, 2010 Chilean, and 2011 Tohoku tsunamis, while the times bracketed in blue are shown in more detail in Figure 4.

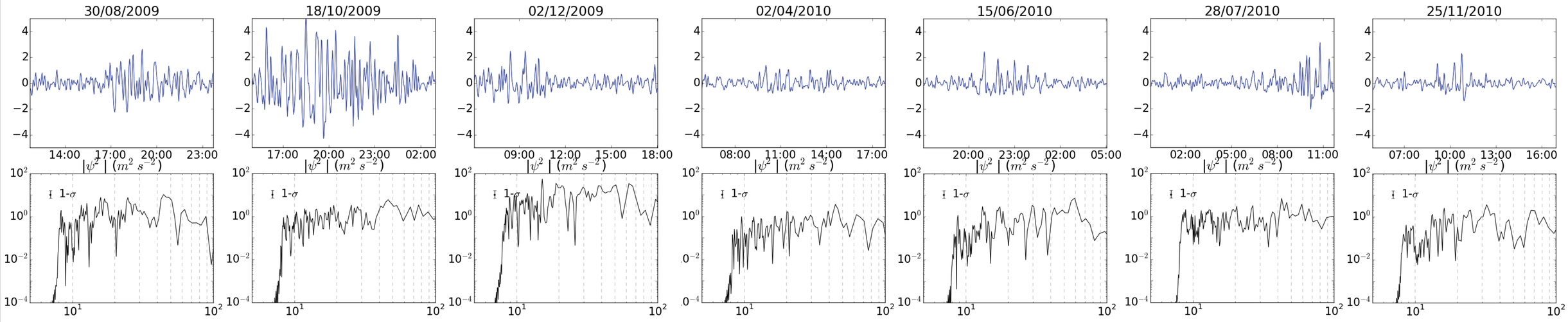


Figure 4. (top) Time series and (bottom) spectra from select time periods, magnified from Figure 4. All time periods cover 12 hours, and all spectra were taken over the time shown.

## Discussion

There are several times when there may be resonant currents consistent with the response to the 2011 Tohoku tsunami.
There were two seismic tsunamis besides the 2011 Tohoku tsunami during this period: plots of the Mode 1 index and associated spectra do not show evidence of those events. The method described here does not show a response to the 2009 Samoan tsunami at all, and the response to the 2010 Chilean tsunami is much weaker and has a shorter period.

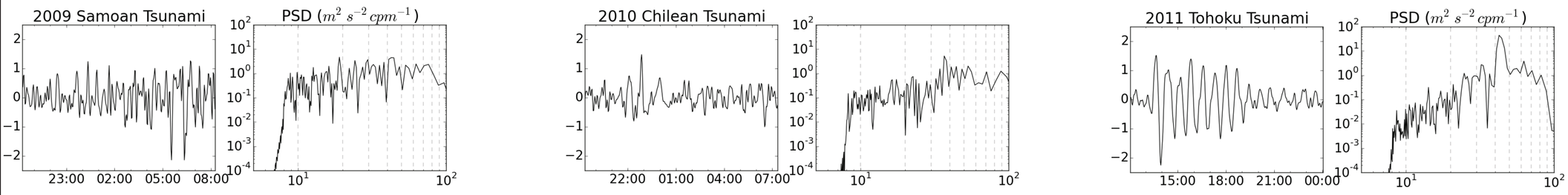


Figure 5. (left panel) Time series and (right panel) spectra for the (from left) 2009 Samoan , 2010 Chilean, and 2011 Tohoku seismic tsunamis that occured during this time. All time series are over 12 hours, and each spectrum was made with the same number of points. Note that the Chilean tsunami does have a peak, but it is at 34 minutes rather than at the same period as the strong 43-minute peak in the 2011 Tohoku tsunami.

## Future Work

Continue examination of mode 1 data

Examine other modes to look for any other possible incidents, or further evidence for an incident already identified

Pressure sensor over Penguin Bank to look for this response in sea level

Look at atmospheric data to try and find possible generating anomalies

References

Benjamin, L. R., P. Flament, K. F. Cheung, D. S. Luther (2016), The 2011 Tohoku tsunami south of Oahu: high-frequency Doppler radio observations and model simulations of currents, Journal of Geophysical Research 121, doi: 10.1002/2015JC011207
Cheung, K. F., Y. Bai, and Y. Yamazaki (2013), Surges around the Hawaiian Islands from the 2011 Tohoku tsunami, Journal of Geophysical Research Oceans, 118, 5703–5719, doi: 10.1002/jgrc.20413
Goring, D. G. (2009), Meteotsunami resulting from the propagation of synoptic-scale weather systems, Physics and Chemistry of the Earth, 34: 1009–1015, doi: 10.1016/j.pce.2009.10.004
Monserrat, S., I Vilibić, and A. B. Rabinovich (2006), Meteotsunamis: atmospherically induced destructive waves in the tsunami frequency band, Natural Hazards and Earth System Science, 6 (6): 1035–1051.
Munger, S. and K. F. Cheung (2008), Resonance in Hawaii waters from the 2006 Kuril Islands tsunami, Geophysical Research Letters, 35, L07605, doi: 10.1029/2007GL032843

Contact

Lindsey R. Benjamin LRB@HAWAII.EDU
Pierre Flament PFLAMENT@HAWAII.EDU
Kwok Fai Cheung CHEUNG@HAWAII.EDU
Douglas S. Luther DLUTHER@HAWAII.EDU

Department of Oceanography
University of Hawaii at Manoa
1000 Pope Road,
Marine Science Building 204
Honolulu, HI 96822

Department of Ocean and Resources Engineering
University of Hawaii at Manoa
2540 Dole Street, Holmes Hall 402
Honolulu, HI 96822