Analysis of 1 Hz, High Precision Pressure Sensor Data to Identify Gravity Waves

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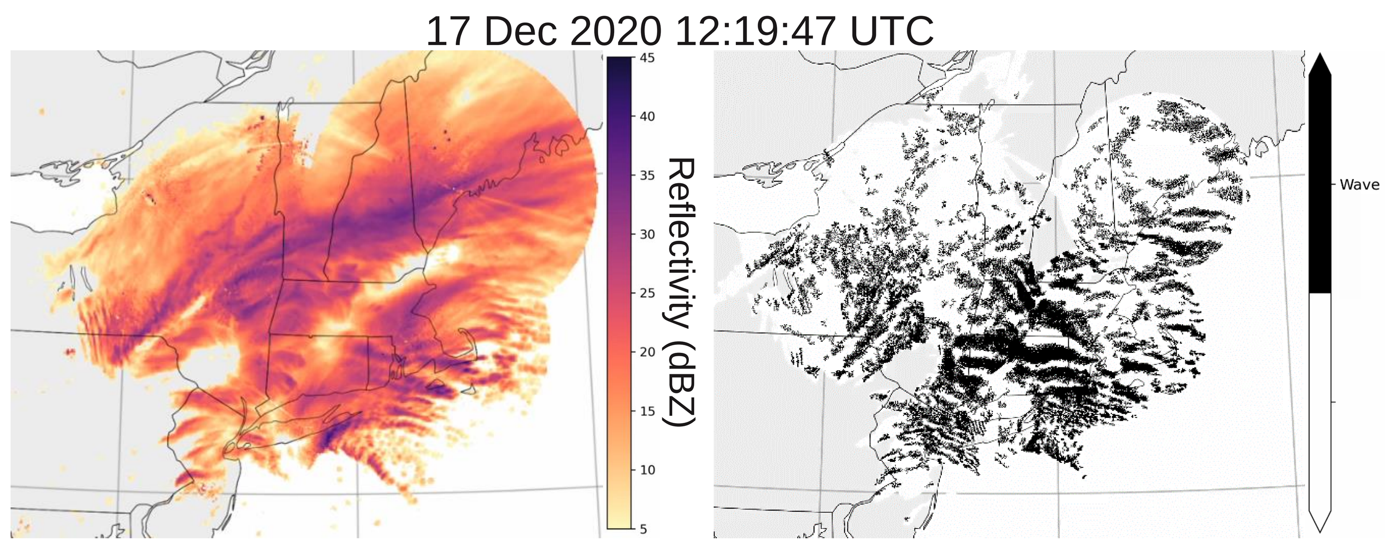
Motivation

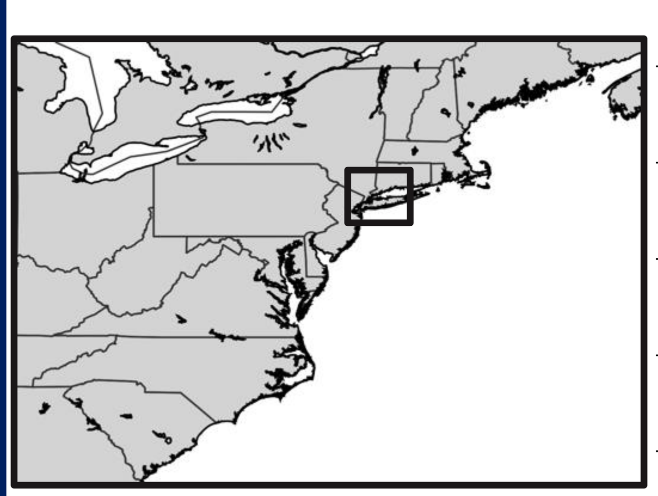
- Winter storms in the Northeast U.S. often exhibit linear sets of Doppler radar velocity waves
- Groups of snow bands often co-occur with Doppler velocity waves[1]
- It is hypothesized that some of the Doppler velocity waves are associated with *gravity waves*
- Gravity waves are oscillations in the atmosphere in which buoyancy acts as the restoring force on parcels perturbed from hydrostatic equilibrium
- Gravity waves should be associated with oscillations in surface pressure



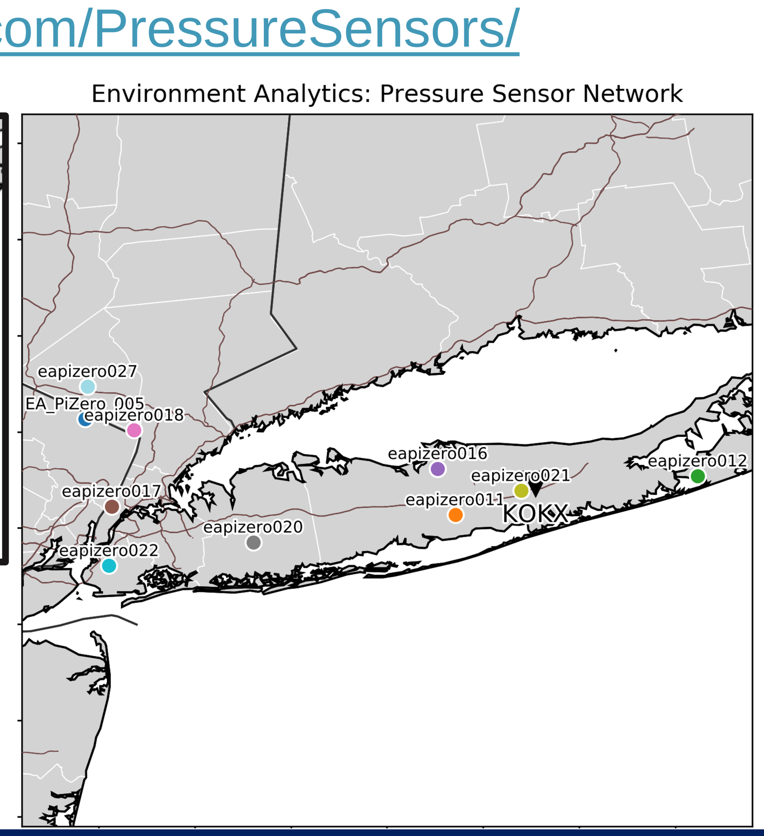
(Left) Radar reflectivity mosaic and (Right) wave detection from Doppler velocity data for 12:19:47 UTC on Dec 17,2020.

Data

- Bosch BME280 and BMP388 pressure sensors (1 Hz measuring frequency, 0.8 Pa precision)
    - Pressure data are smoothed using 10-second averages for analysis
- Networks of pressure sensors have been deployed in Raleigh, NC, New York, NY, and Toronto, ON, metro areas
- Real-time data at environmentanalytics.com/PressureSensors/

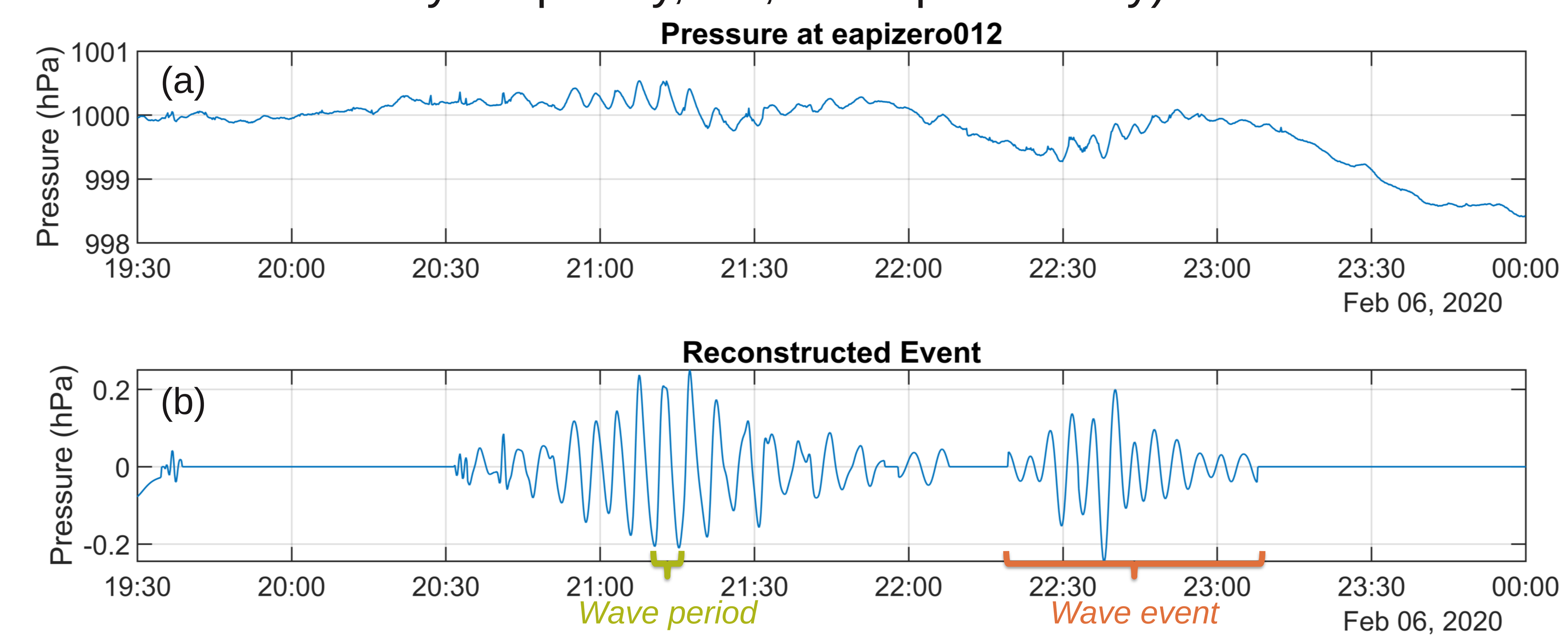


Locations of pressure sensors deployed in the New York, NY, area



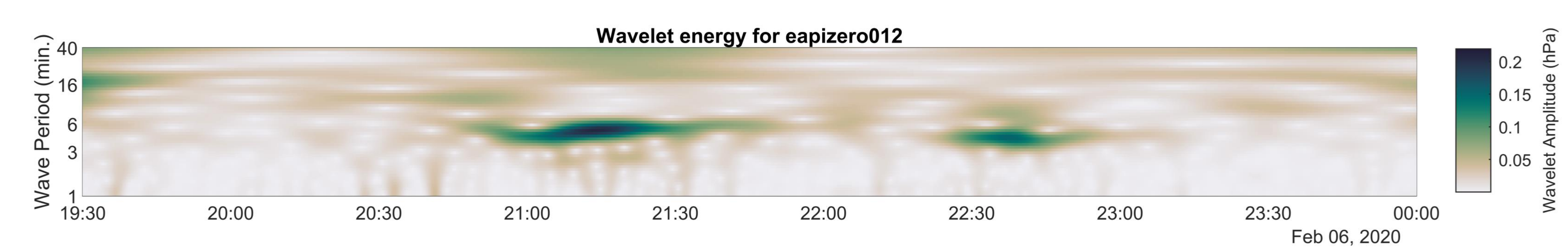
Objective Wave Identification

Wave events are identified using wavelet analysis, which can be used to find localized oscillations in time and wave period (unlike a Fourier transform, which finds localized oscillations by frequency, i.e., wave period only).



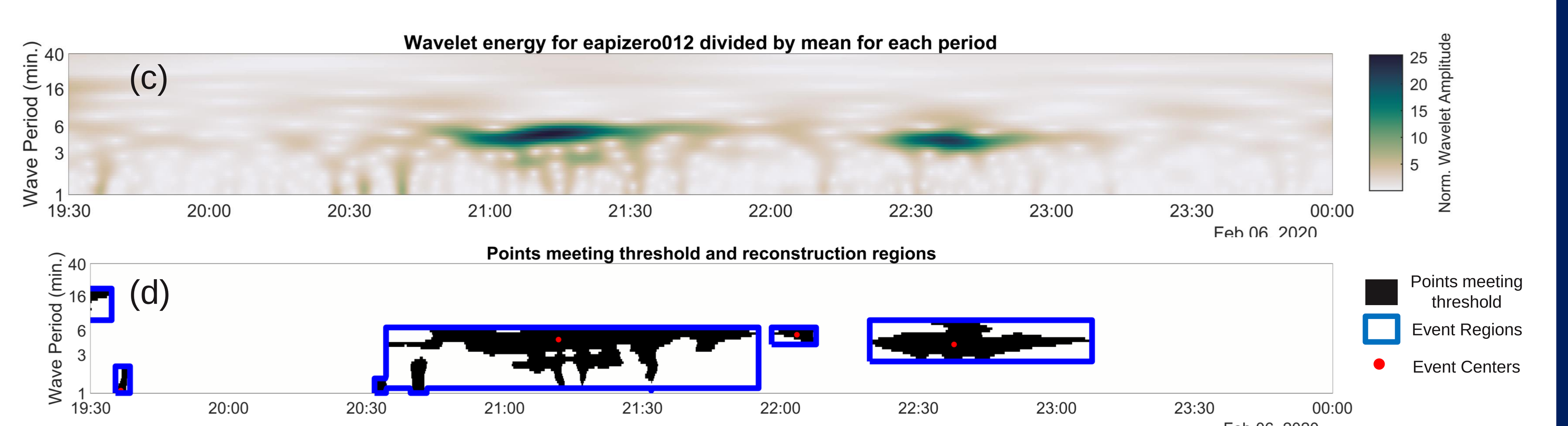
(a) Smoothed (to 0.1 Hz) pressure time series for one sensor for 1930-2359 UTC Feb 06, 2020. (b) Extracted wave events for the same time series. A wave period (time from one trough to the next) and wave event (i.e., wave 'envelope') are annotated).

To extract the wave event above, first the Morlet wavelet transform is used to calculate the wavelet amplitude for the input pressure time series.



Wavelet amplitude for the time series (a) above. Wave period is plotted on a logarithmic scale in this and the following figure.

Regions in (time, wave period) space are identified where the localized wavelet amplitude exceeds 4 times the wave period's mean amplitude for all the data collected since 2018. Then the rectangular bounding boxes of those regions are used to define wave *events* (adapted from [2]).



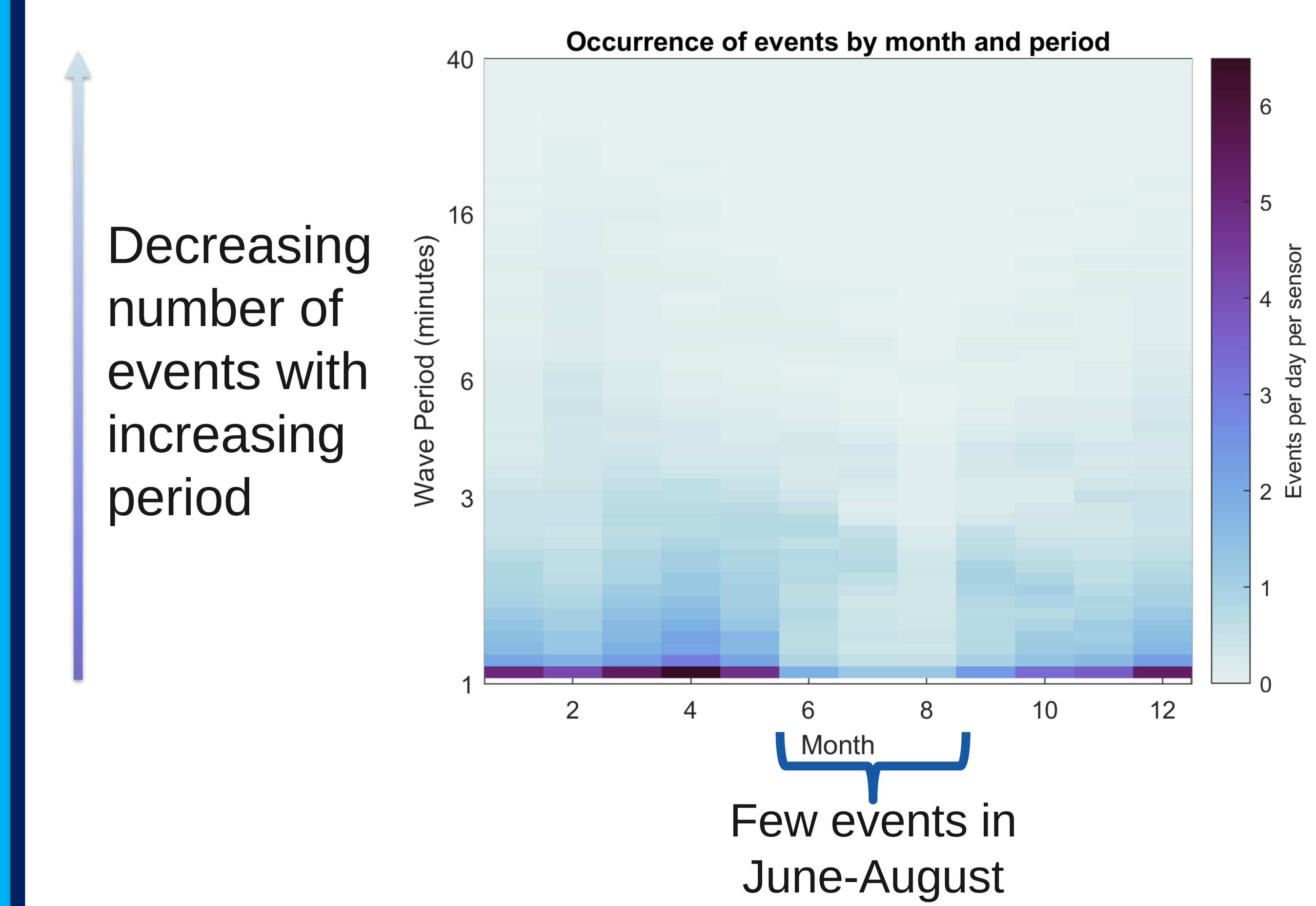
(c) Normalized wavelet amplitude for the time series above. (d) Regions where the normalized wavelet amplitude exceeds 4 (black shading), wave event regions (blue outlines), and event centers (maximum normalized wavelet amplitude within each event; red dots).

The wavelet transform is then inverted only over the event regions (i.e., the wavelet transform is set to 0 outside event regions) to 'reconstruct' the wave events in the output time series (b) above.

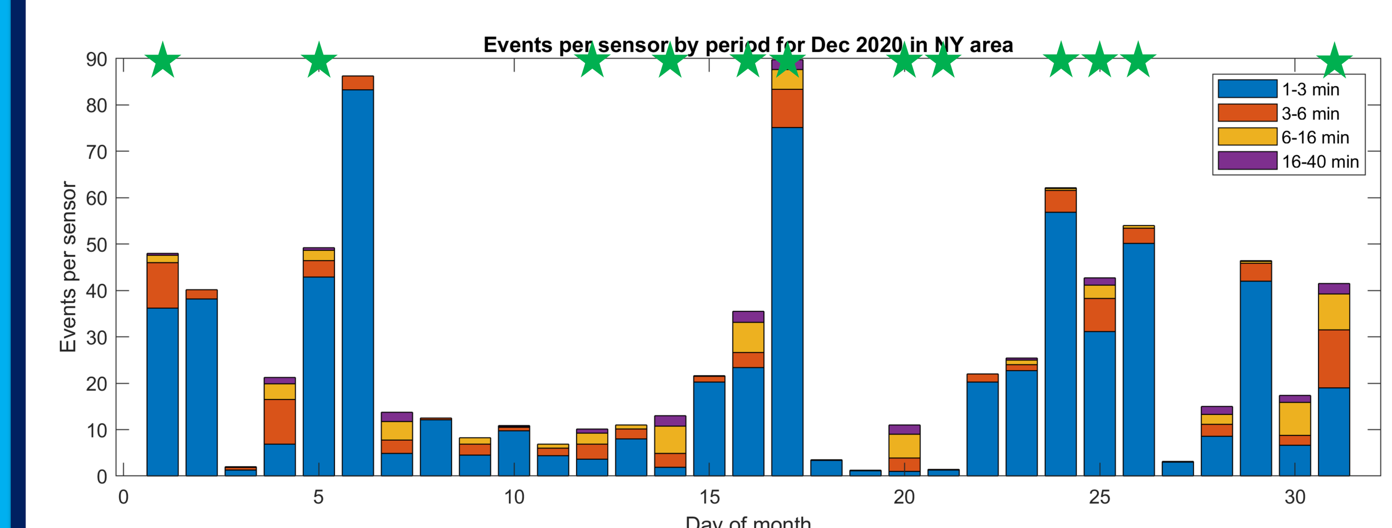
Summary and Future Work

- Wave events were objectively identified for a network of pressure sensors near New York, NY, between 2018 and 2021
- Waves were more often identified during the cool season and with shorter wave periods
- For December 2020, there was not a clear relationship between days with precipitation and days with more wave events
- Future steps include identifying events spanning multiple sensors and characterizing wave propagation speed and direction

Occurrence of Wave Events



Occurrence of wavelet events by month and wave period for the entire network of sensors near New York, NY, between 2018 and 2021.



Occurrence of wavelet events by day and wave period for the entire network of sensors near New York, NY, in December 2020. Green stars indicate days on which GPM IMERG precipitation rates exceeded 1 mm/hr anywhere within 300 km of Stony Brook, NY.

References:
[1]Hoban, N. P. (2016). Observed Characteristics of Mesoscale Banding in Coastal Northeast U.S. Snow Storms (M.S. thesis). North Carolina State University.
[2]Grivet-Talocia, S., and F. Einaudi, 1998: Wavelet Analysis of a Microbarograph Network. *IEEE Transactions on Geoscience and Remote Sensing*, **36**(2), 418-433.

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