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Comparing the Efficiency of a Marsh-Sill and Oyster Reef Balls in Attenuating Waves

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Background

- Flooding and erosion are affecting coastal communities

- From 2016-2018: 3,400 live lost and $30 Billion (USD) in damage per year (EM-DAT, 2019)

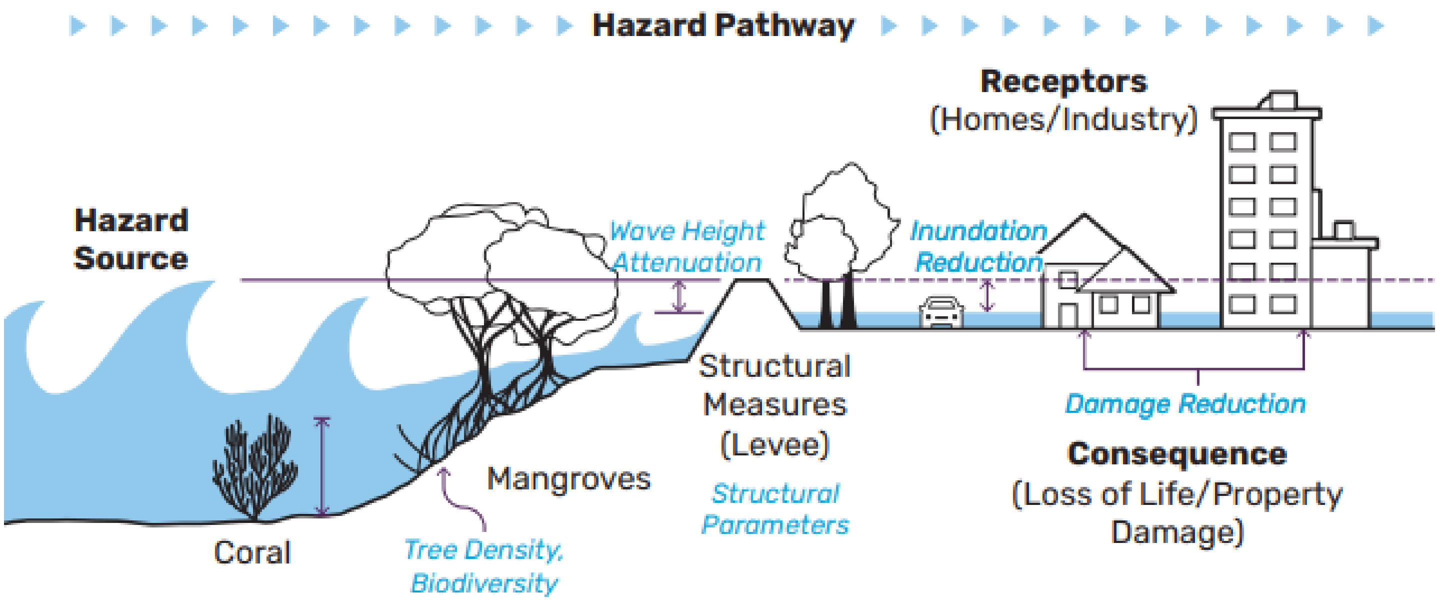
- Estimated median annual global value of coastal wetlands, based on current storm probabilities (Costanza et al., 2021):

  $447 billion/yr (2015$US) and 4,620 lives saved/yr

- Climate change drives the intensity and frequency of storms, and sea level is rising, and thus this prevented damage will increase

Background

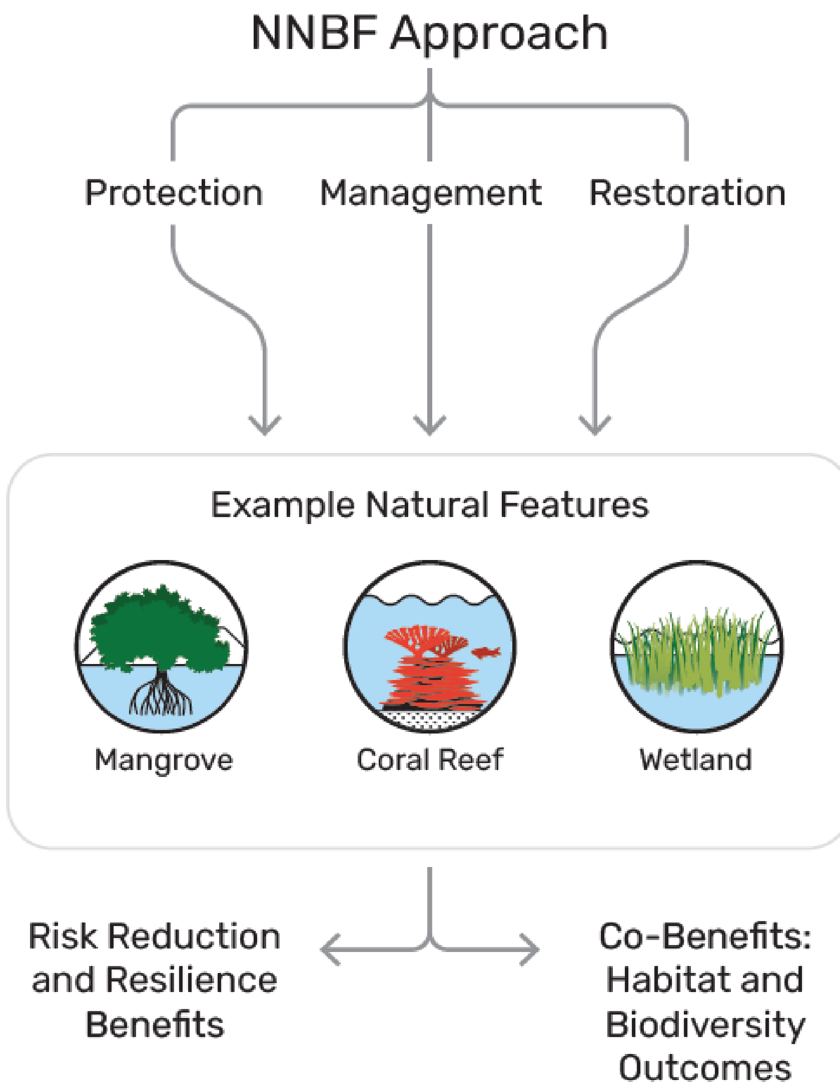
Natural and Nature-Based Features (NNBF) for Coastal Hazard Mitigation



Source-Pathway-Receptor-Consequence Model for NNBF
(*International Guidelines on NNBF for Flood Risk Management*)

Background

Unlike gray infrastructure (bulkhead, breakwaters, levees, etc.), the role of NNBF in mitigating flood risk is less studied, and is an area of active research



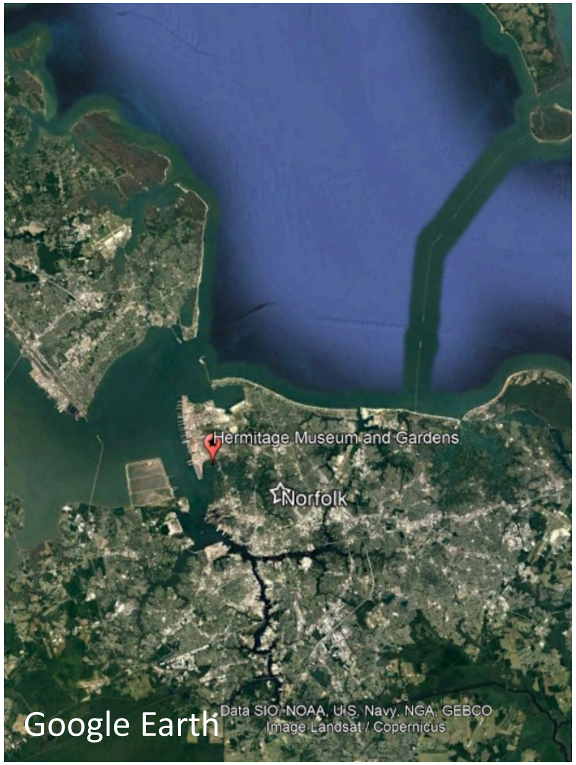
Flood reduction

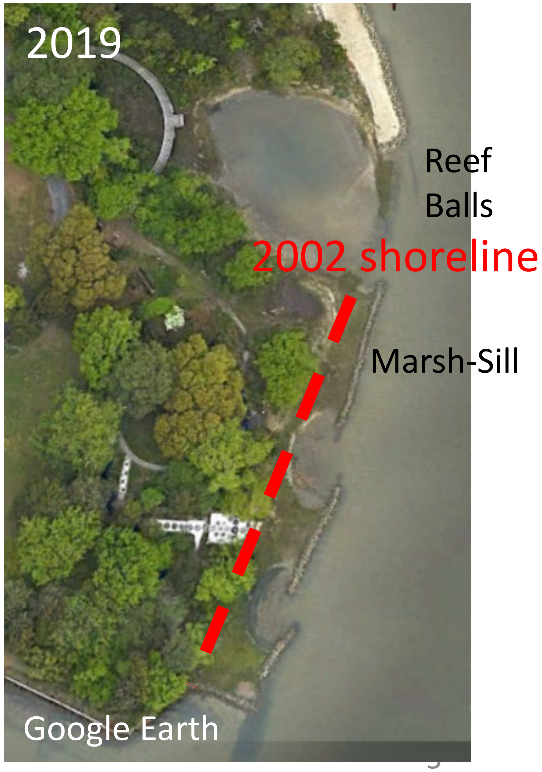
Wave attenuation

(International Guidelines on NNBF for Flood Risk Management)

Study Area

- Hermitage museum and Gardens in Norfolk, VA
- Substantial coastal erosion
- Marsh-Sill (2007) and Oyster Reef Balls (2010)
- Advantage: Two distinct features with to the same environmental conditions (waves, tides, winds, sediments, etc.)

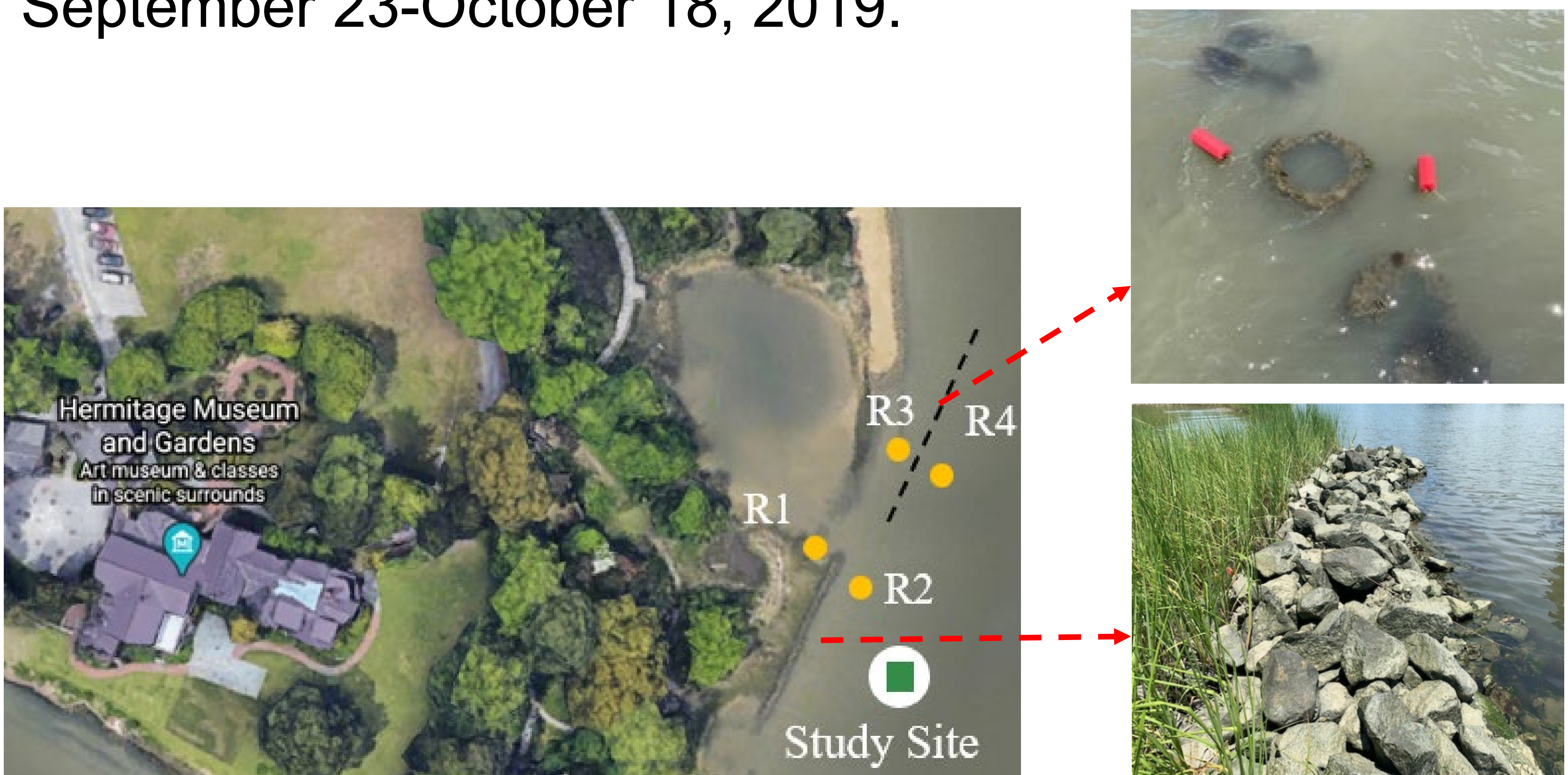




Field Experiments

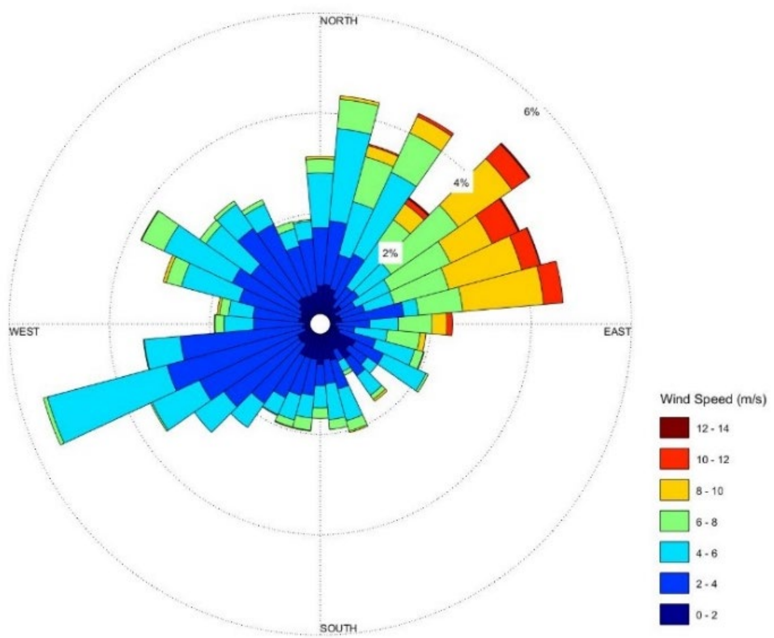
- Pressure sensors: 4 RBR Solo D|Wave, continuous recording at 8 Hz

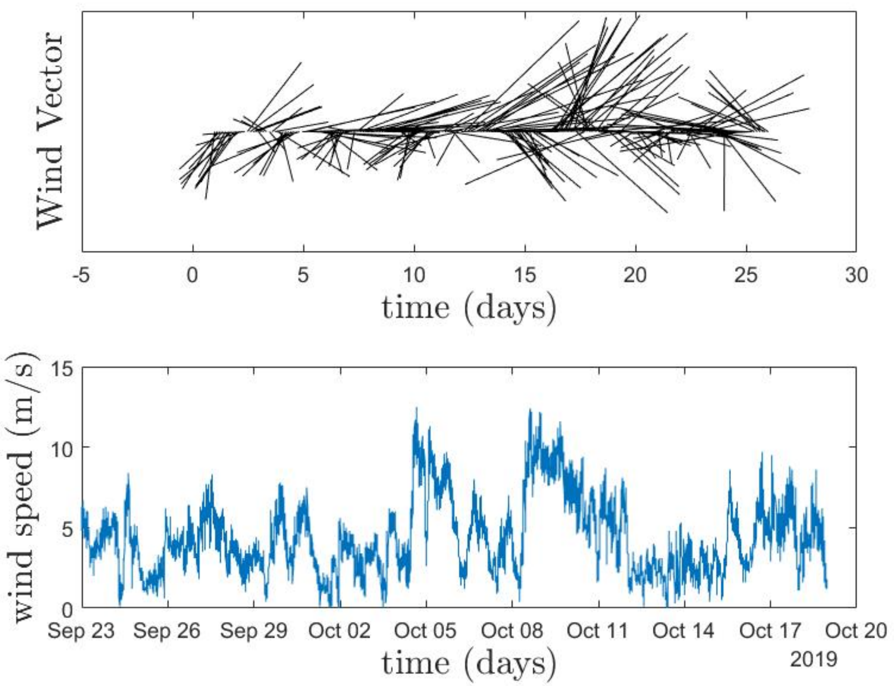
- Deployment time: September 23-October 18, 2019.



Winds

- NOAA meteorological station CRYV2
- Dominant wind speed: 2-4 m/s from southwest (same direction as the largest fetch)
- Secondary winds: from northwest, maximum reaches 14 m/s,

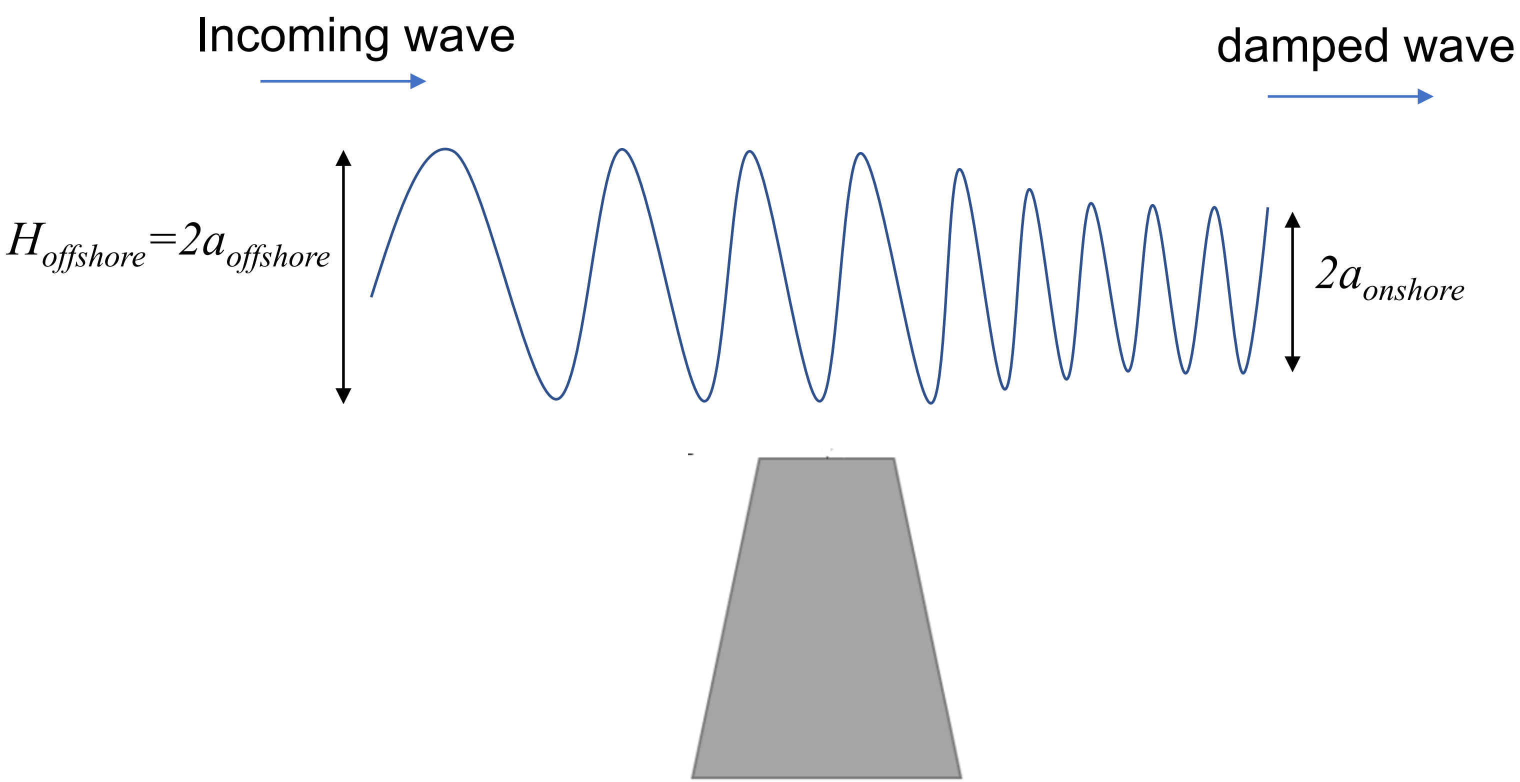




Wave Analysis

$$\varepsilon = \frac{F_{offshore} - F_{onshore}}{\Delta x},$$ Wave attenuation rate

$$F \sim a^2$$ Wave energy flux

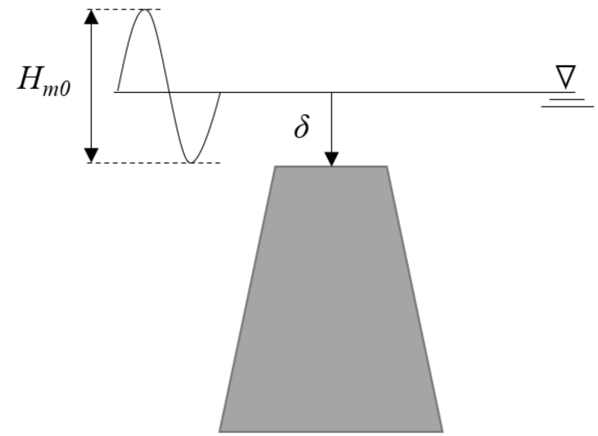


Damper (structure, vegetation, hybrid NNBF, etc.)

Wave Analysis

Criterion for wave transmission over the structure (after Van der Meer et al., 2005):

$$R = \frac{(H_{m0})_{offshore}}{\delta}$$



High wave dissipation: $R > 0.625$

High transmission: $R < 0.625$

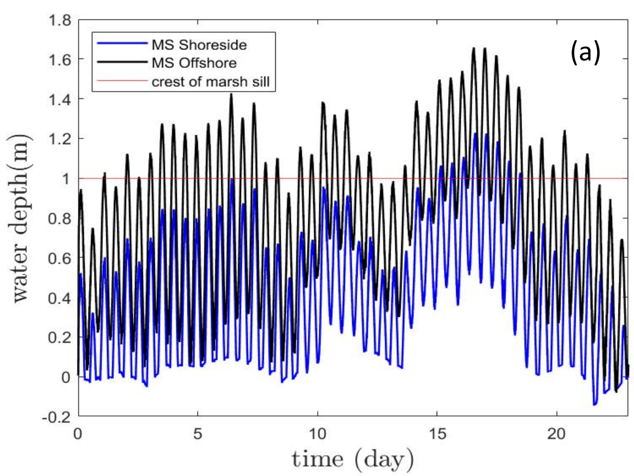
Crest is exposed: $R < 0$, Crest is submerged when $R > 0$.

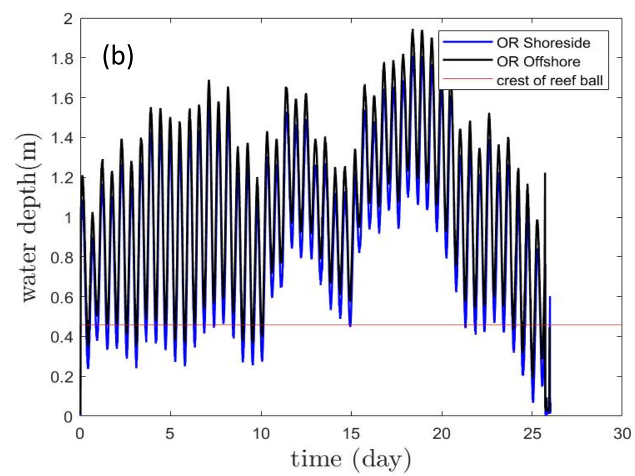
Measured water depth (tide range = 0.8 m)

Submerged:

28% of the

deployment





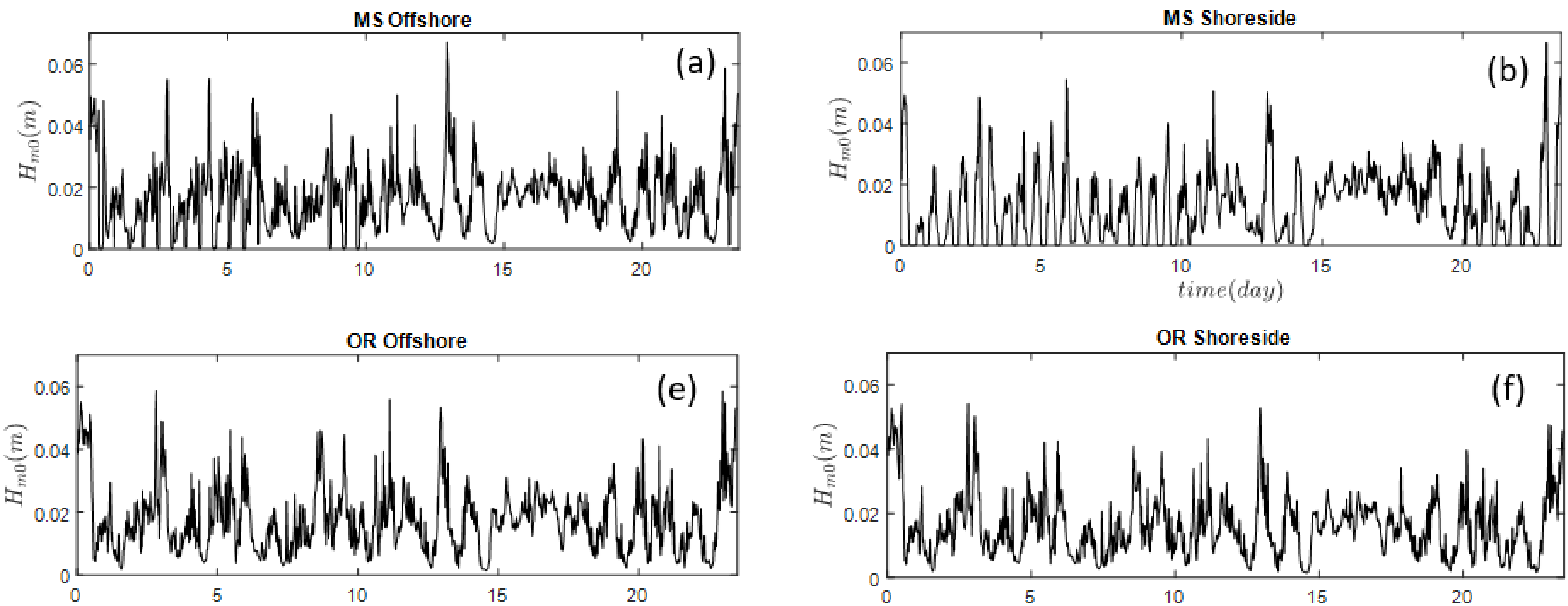
Submerged:

94% of the

deployment

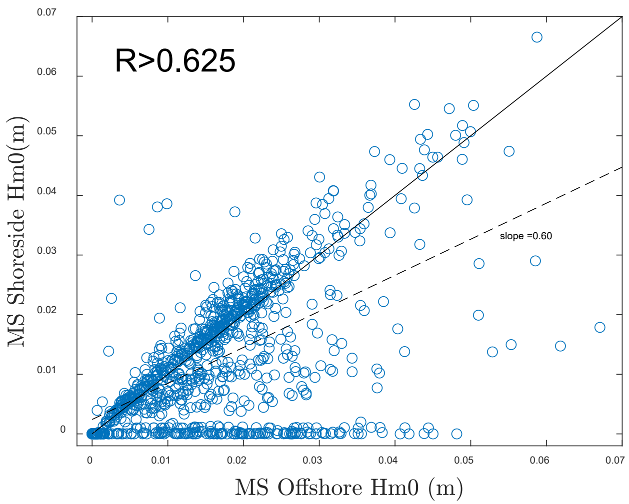
Wave Analysis

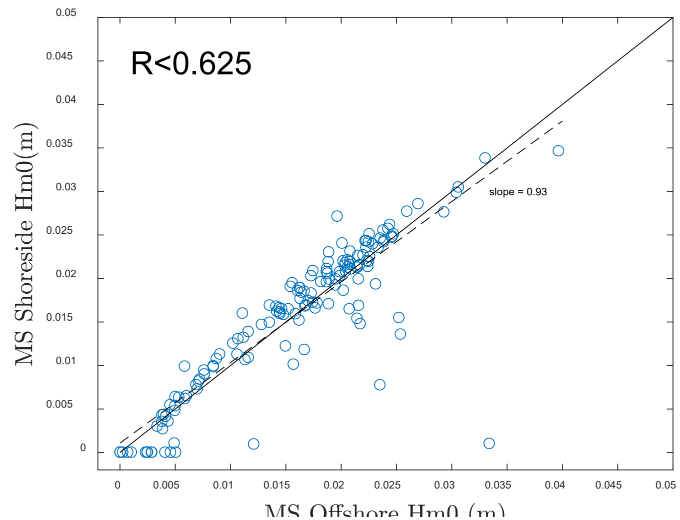
Applying a spectral analysis to water depth time-series (e.g. Karimpour and Chen, 2017) gives wave height, wave period, wave spectrum

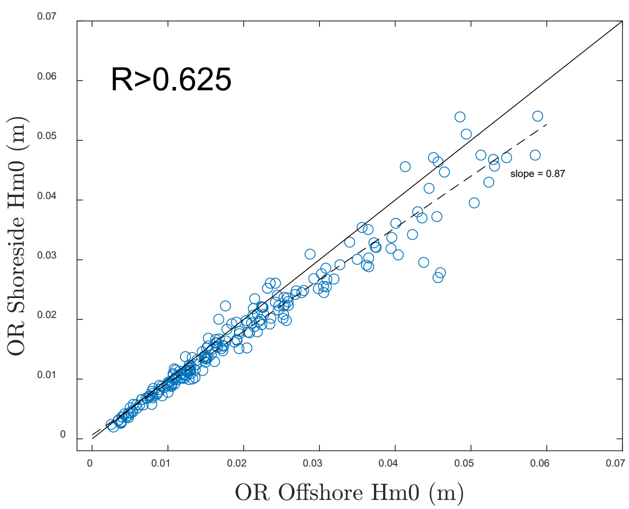


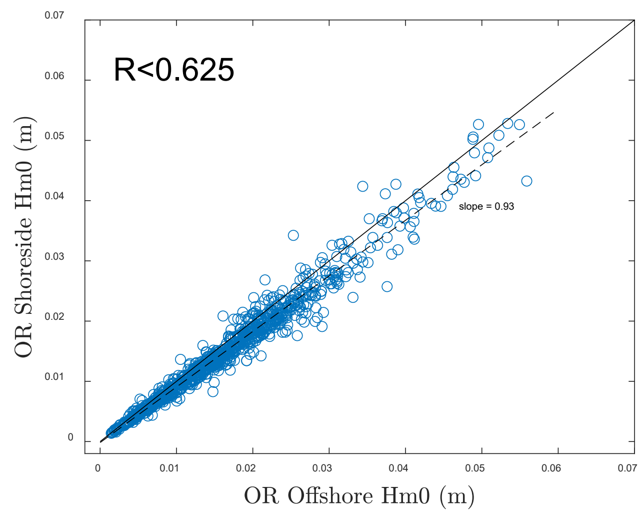
Wave Analysis-Attenuation Rates

Examining wave height for wave attenuation rates based on *R* parameter:



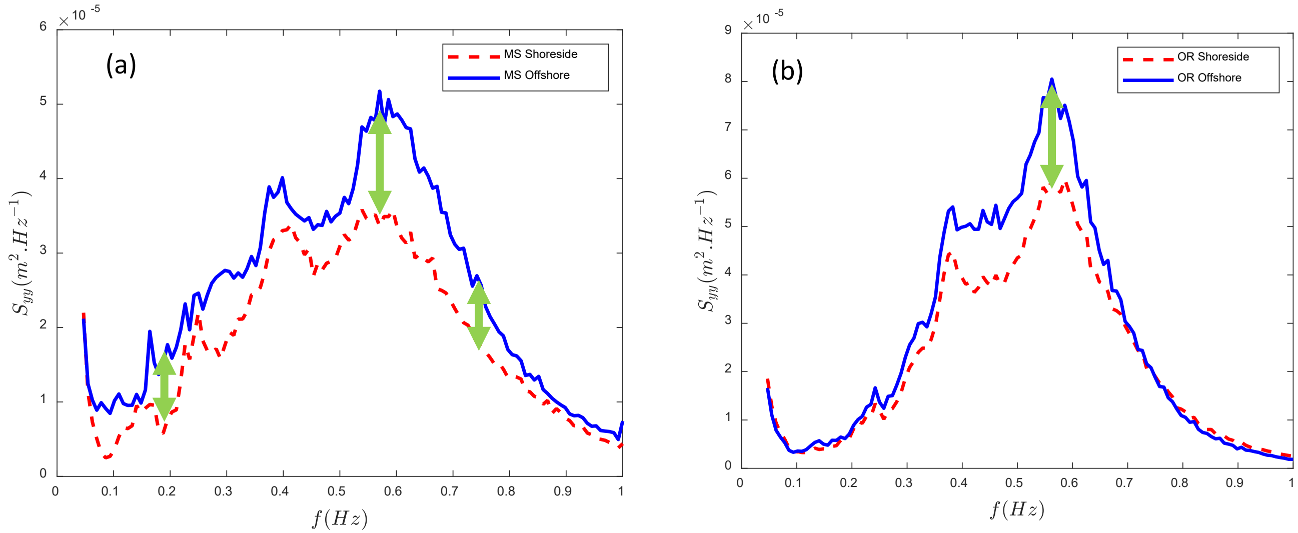




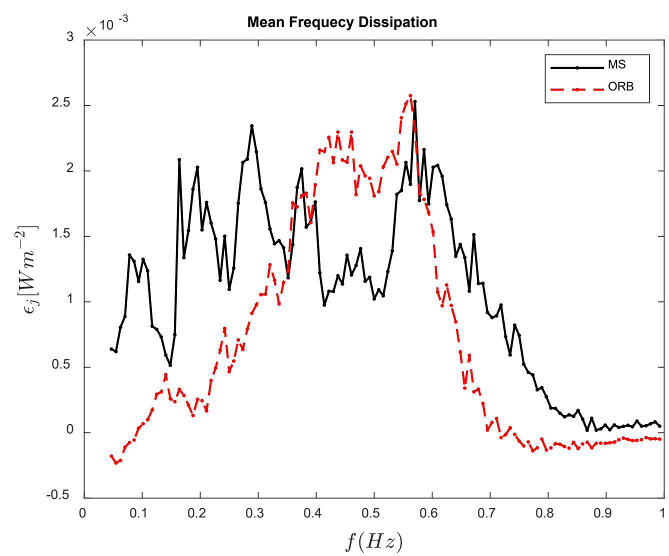


Wave Analysis-Spectra

Comparing the damped spectra from marsh-sill and oyster reef balls:

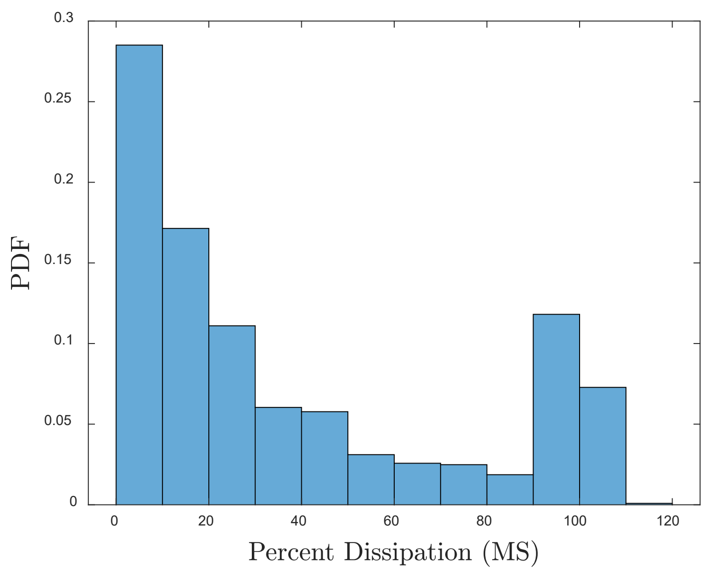


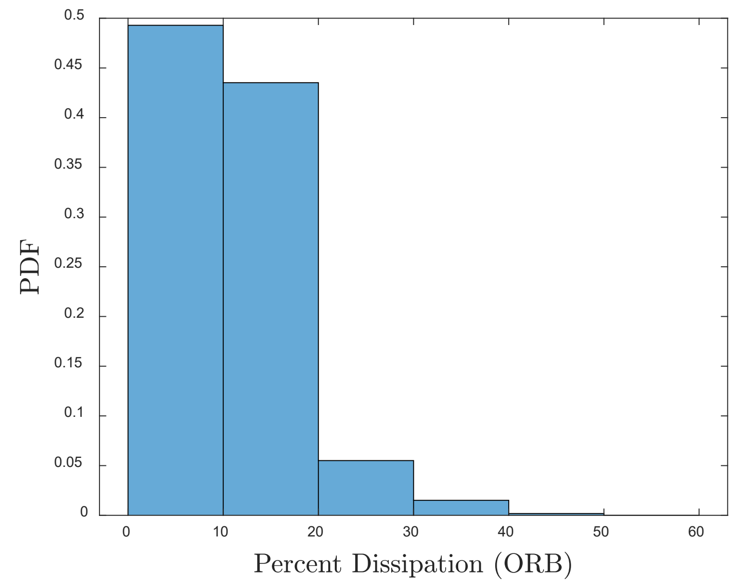
$$\varepsilon = \frac{F_{offshore} - F_{onshore}}{\Delta x}$$



Wave Analysis-Attenuation across Spectra

Probability distribution function of percent dissipation of incoming waves:





Marsh sill shows a variety of wave dissipation rates while oyster reef ball shows mostly small dissipation rates.

Discussion & Conclusion

- Marsh-sill is more dissipative than oyster reef balls. This is due to two factors:

1. The sill has a higher crest than reef balls,
2. The marsh behind the sill is filled with sand, and is thus more elevated than the shoreside of the reef balls

- The marsh-sill is more dissipative than the reef balls when free board is small compared to incoming waves

- When free board is large, both features are not effective in attenuating waves and show comparable wave attenuation rates

Reference and Acknowledgement

Leone, A., Tahvildari, N., “Spectral Wave Dissipation by Oyster Reefs and Marsh Sills in a Sheltered Tidal River”, in review in *Estuaries and Coasts.*

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