The Role of Infragravity Waves in Coastal Processes with Numerical Modeling Results from Southwest France Compared to Potential Applications along Florida's Atlantic Coast

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OUTLINE

1. Simplistic explanation of infragravity (IG) waves and generation mechanisms,
2. Discussion of numerical modeling results from SW France coastline, and
3. Applicability to Florida's Atlantic coastline.

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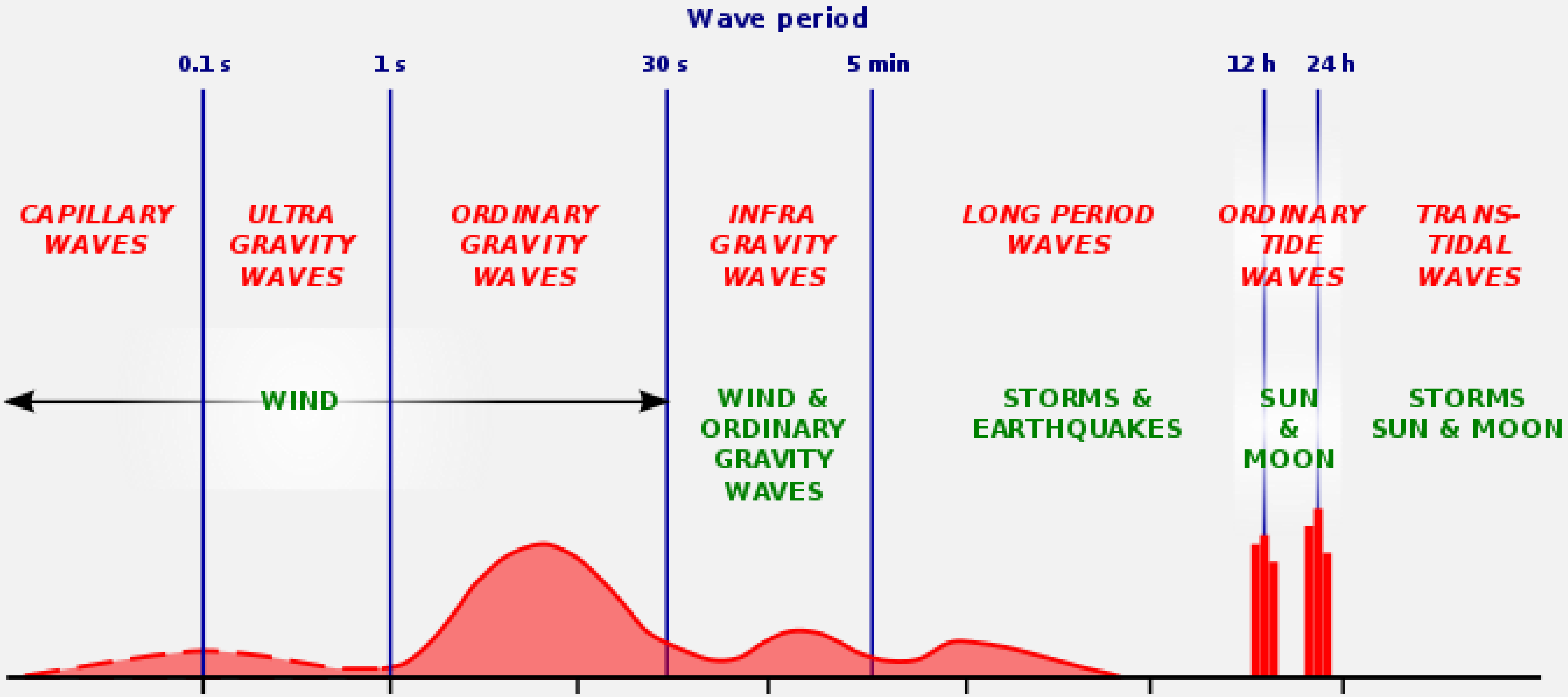
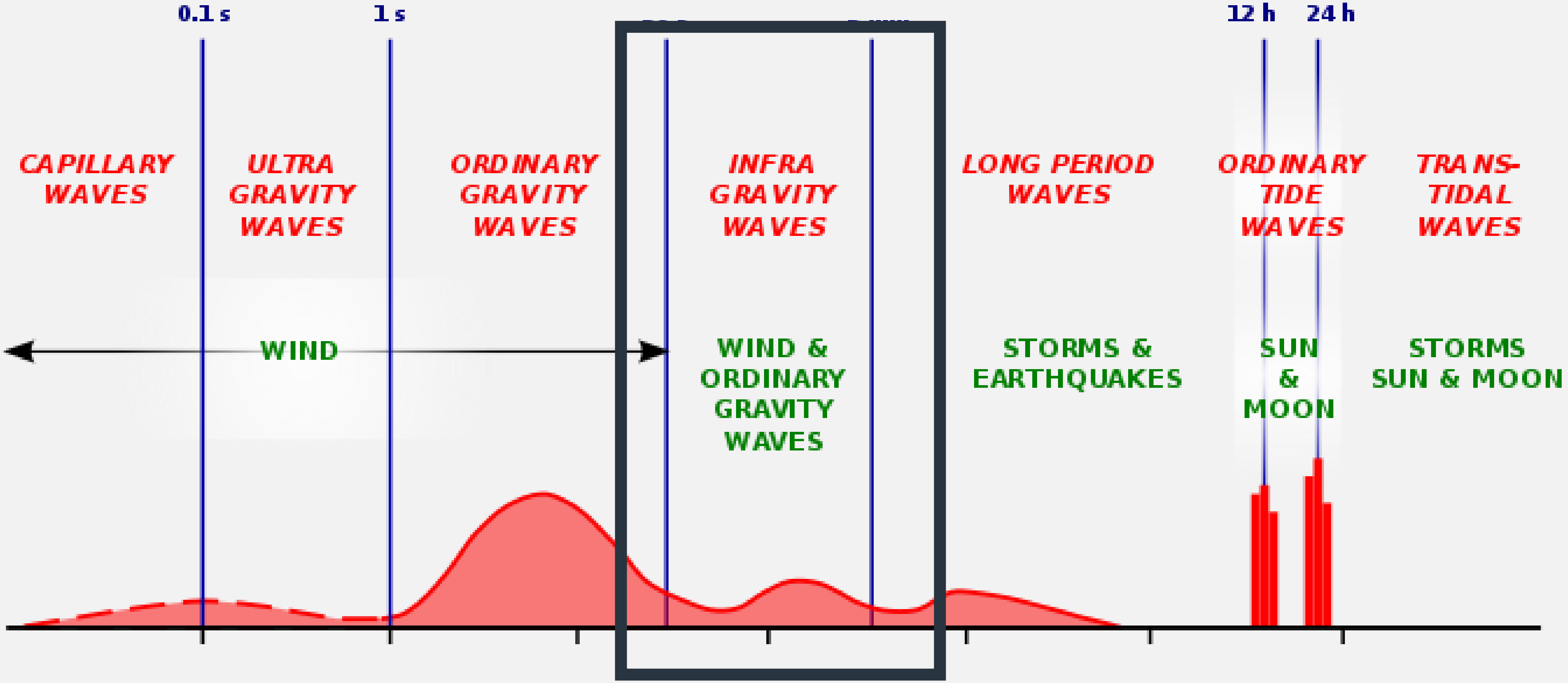
WHAT ARE INFRAGRAVITY (IG) WAVES?



https://en.wikipedia.org/wiki/Infragravity_wave

Infragravity Waves:
~30 seconds to 5 minutes



WHY DO WE CARE ABOUT IG WAVES?

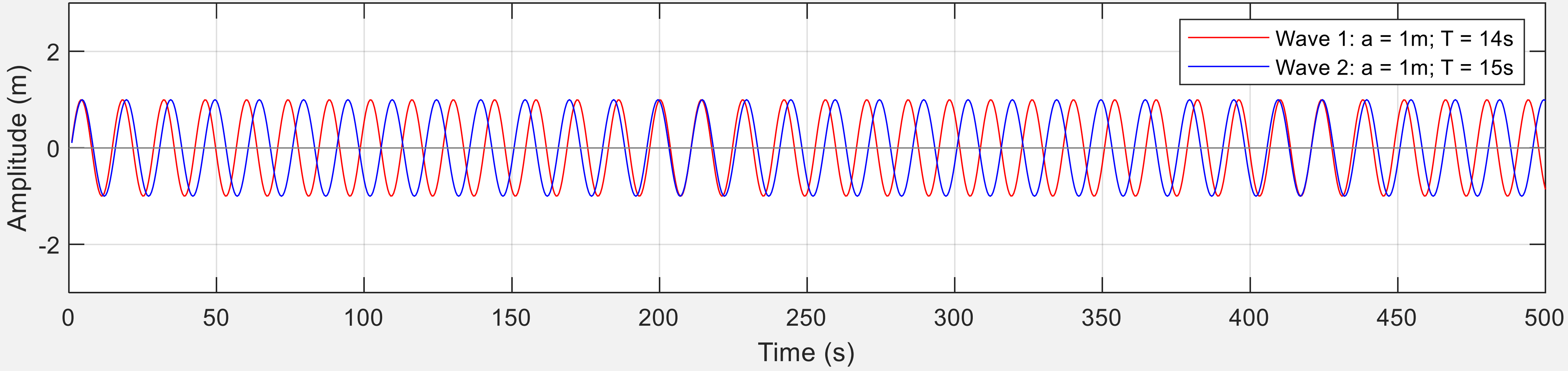
IG WAVE INFLUENCES NEARSHORE HYDRODYNAMICS AND MORPHOLOGY

- Sediment transport
- Runup/overwash
- Rip currents
- Reef hydrodynamics
- Harbor resonance

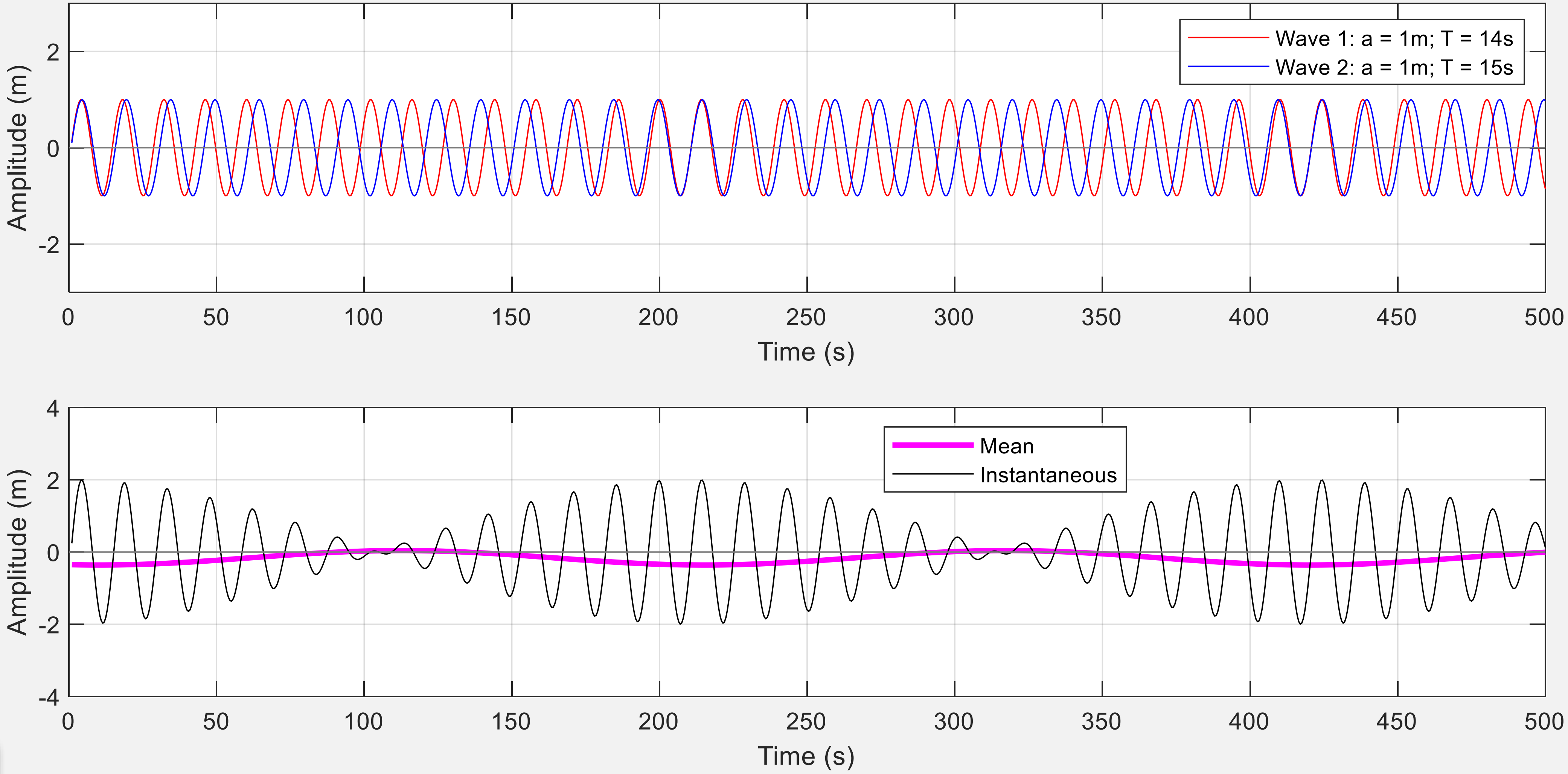
IG WAVE GENERATION MECHANISMS

- Bound wave theory
  - Longuet-Higgins and Stewart – 1962
- Moving breakpoint theory
  - Symonds et al. – 1982
- Bore merging theory
  - Huntley and Bowen – 1974

BOUND IG WAVE THEORY



BOUND IG WAVE THEORY



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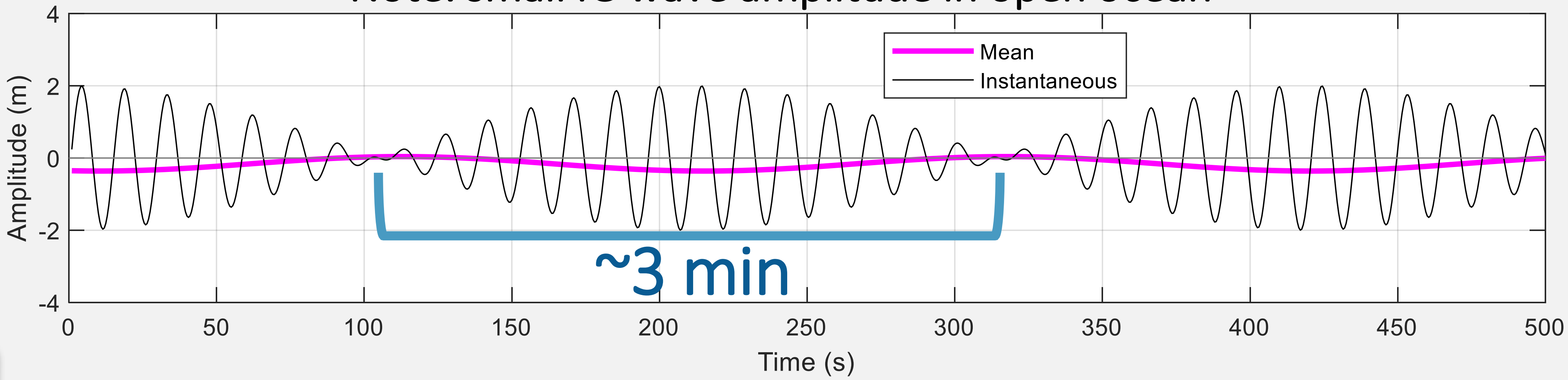
Replicated from: Bertin, X., et al., 2018. Infragravity waves: from driving mechanisms to impacts. Earth. Rev. 177, 774–799.

BOUND IG WAVE THEORY

Waves groups create IG waves!

Bigger group waves produce bigger IG waves at shoreline, up to a limit

Note: small IG wave amplitude in open ocean



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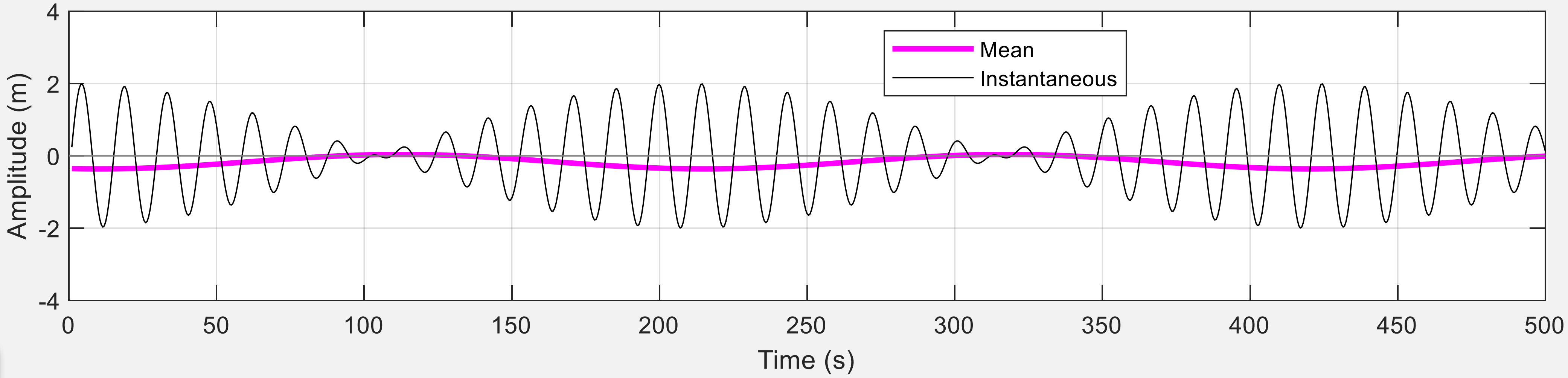
BOUND IG WAVE THEORY

Considered dominant mechanism
on mild-slope beaches, like Florida’s coast



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AS BOUND IG WAVES APPROACH SHORELINE,

- IG waves shoal
- Increase in energy
- They *feel* the bottom before sea/swell waves, resulting in decrease in speed
- The IG waves begin to lag behind the wave groups, eventually becoming FREE (unbound) IG waves

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AT THE SHORELINE, IG WAVES

- Energy is partially dissipated by sea/swell wave breaking
- Are reflected off the shoreline back out to sea
- Become refractively trapped to become edge or standing waves
- Temporarily elevate sea level, increasing runup (and potentially erosion) on shoreline

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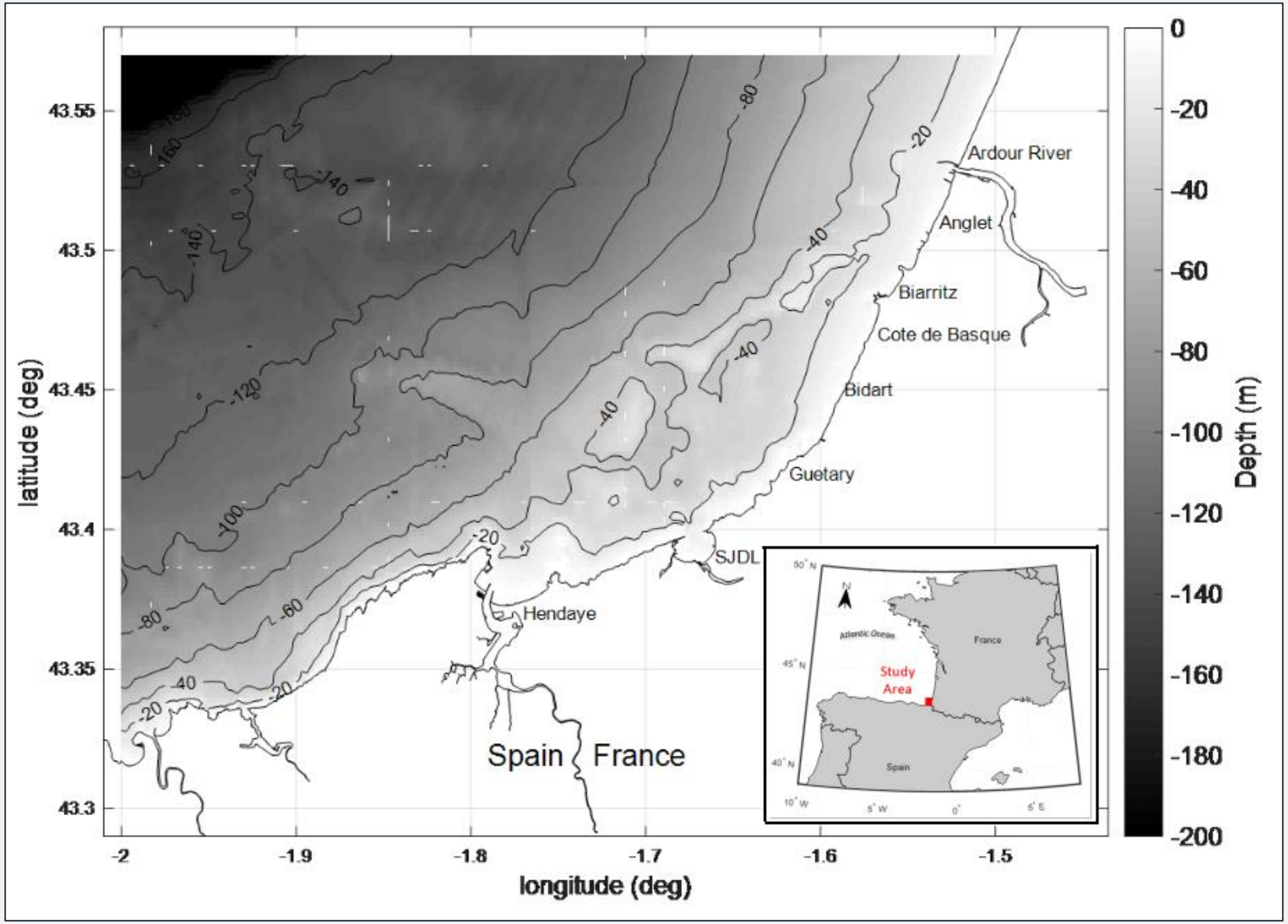
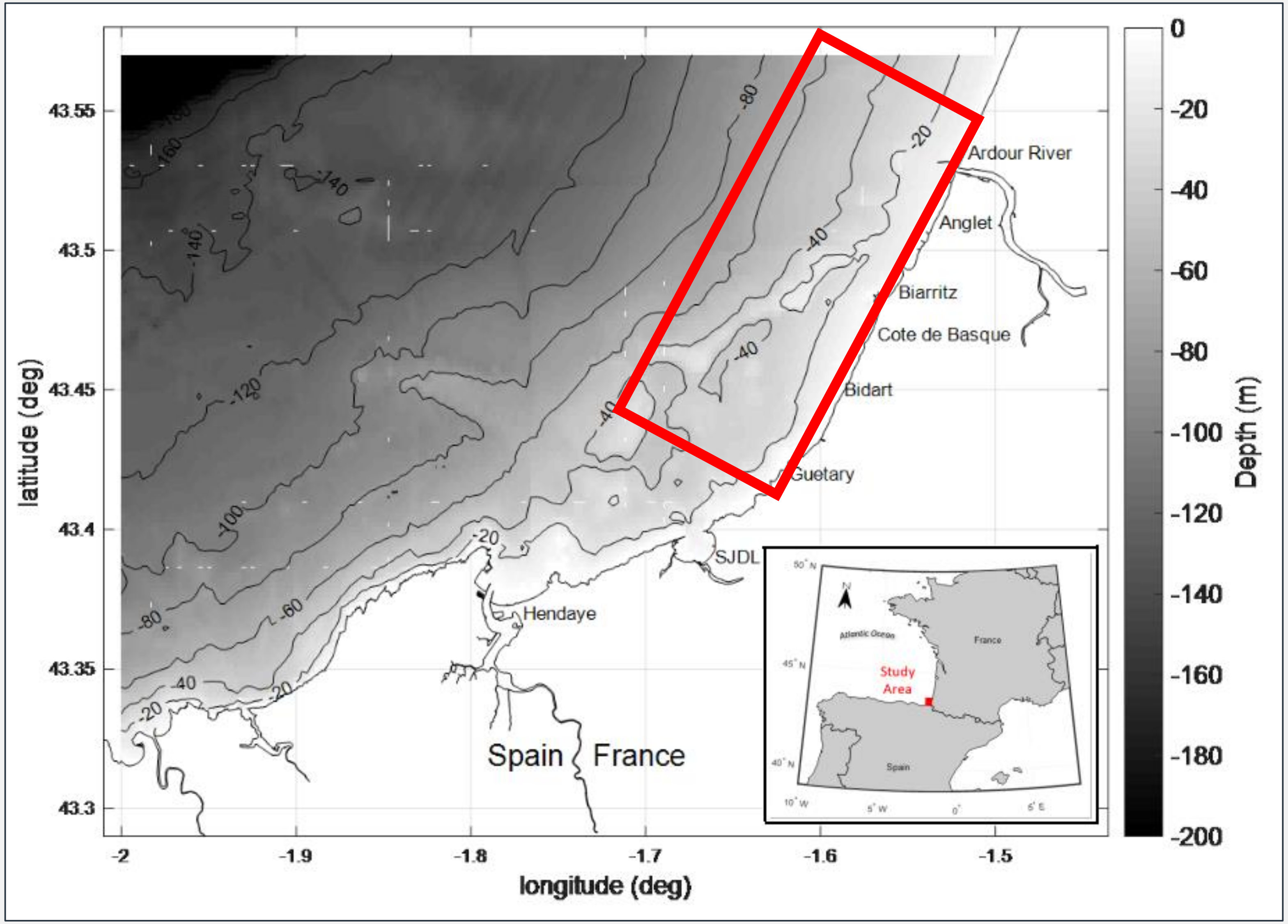
OBJECTIVE

Compare and contrast infragravity wave variability along the French Basque coast using a phase-resolving model.



GRID

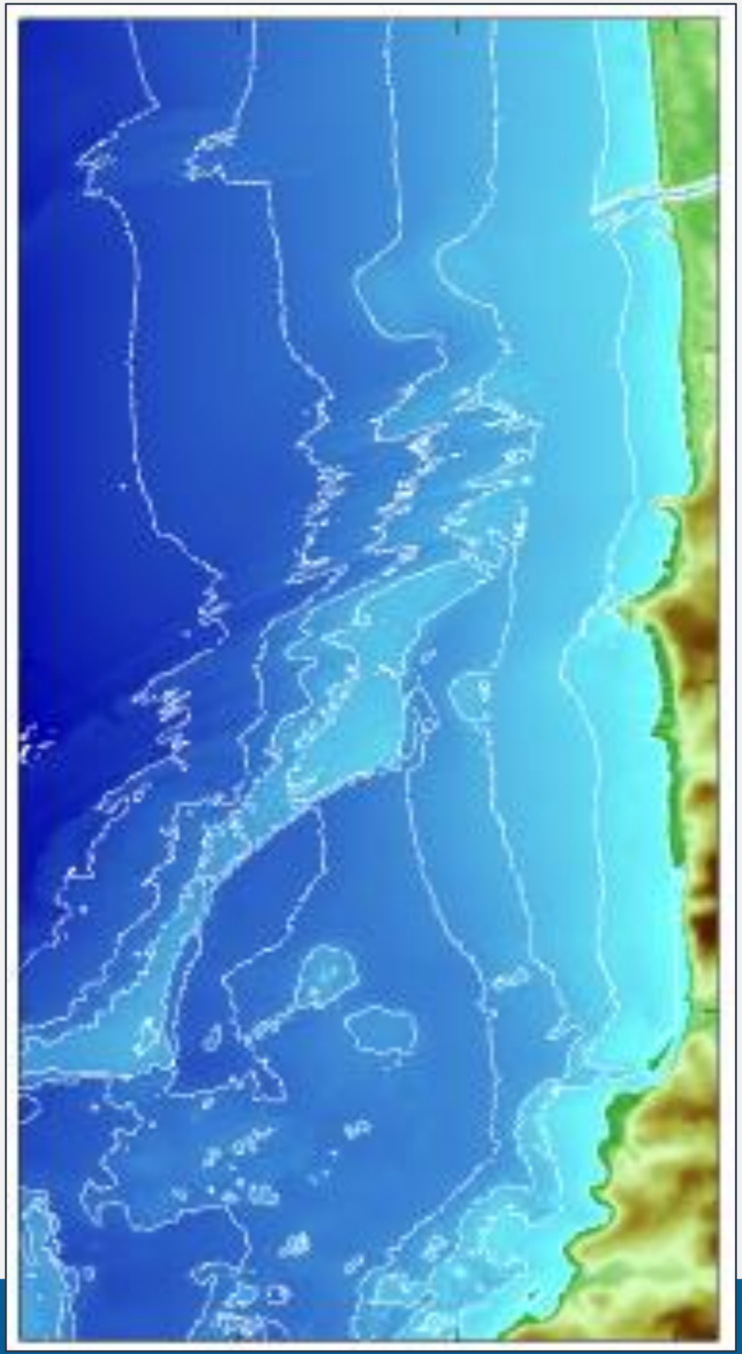
- 20 km x 8 km
- 5 m x 5 m
- 6.4M nodes



GRID BATHYMETRY

Notable bathymetric features

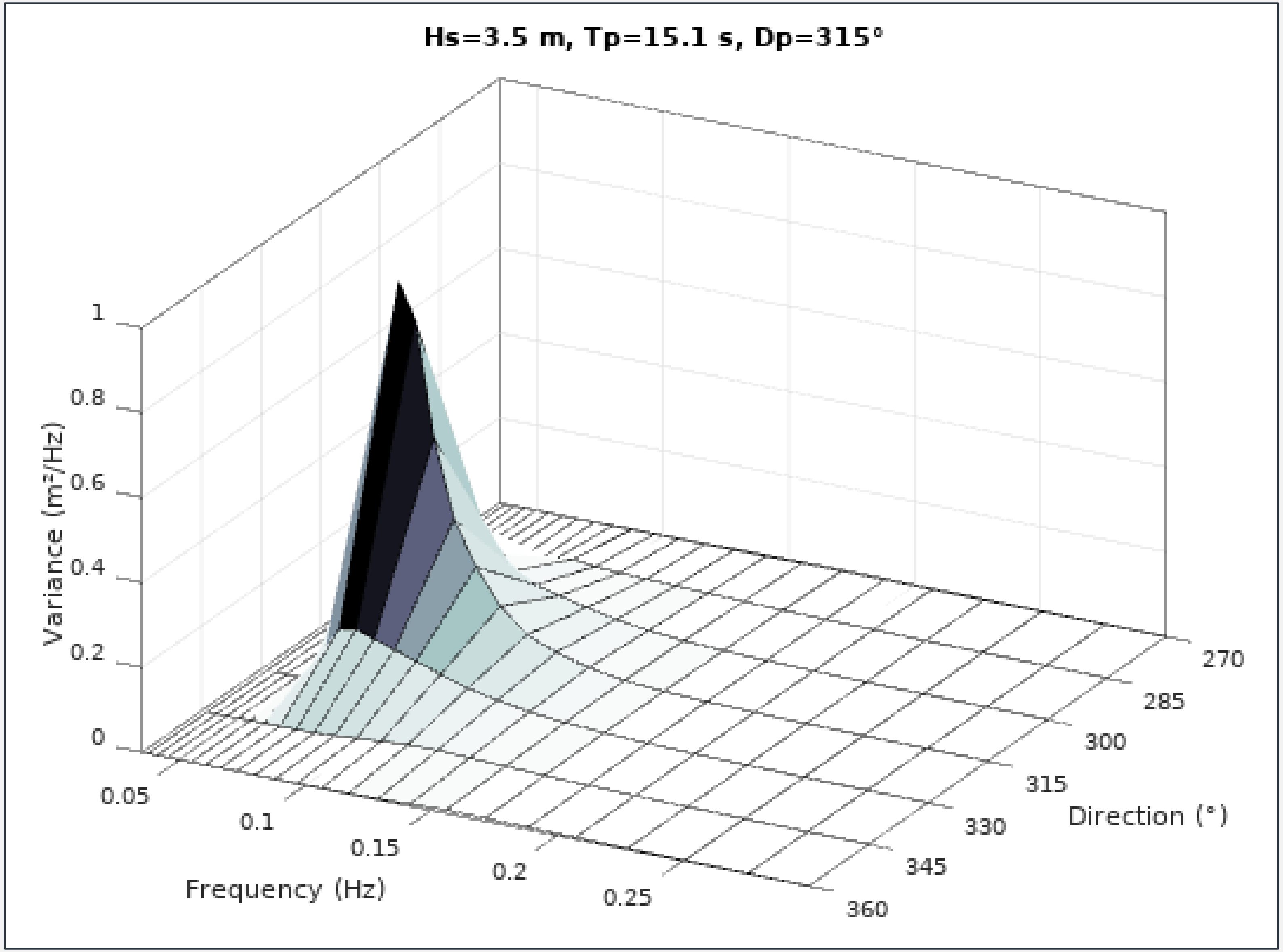
- Relic sand disposal site
- Offshore rock



INPUT SPECTRA

Typical storm conditions

- Hs ~ 11 ft
- T = 15.1 s



BOUSSINESQ OCEAN & SURF ZONE (BOSZ)

- Phase-resolving model designed for the nearshore environment
- Depth-integrated
- Boussinesq equations in conserved form to handle shocks and irregular bathymetry
- Includes nonlinear interaction of wave quadruplets and triads which create IG waves, unlike phase-averaged models
- Refraction, reflection, diffraction, shoaling, wave breaking
- Secondary wave processes like setup and recirculation
- BOSZ well suited for this modeling study

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MODEL RUNS

- Tested influence of **water level**, **wave direction**, and **storm intensity** on IG wave variability along the coastline
- Note: model not validated with field data, outside scope of study
  - More interested in qualitative trends than quantitative results

Run	Hs (m)	Tp (s)	Dp (°)	Water Level (m)
1	3.1	14.5	310	+2.5 (MSL)
2	3.1	14.5	310	+0.5 (MLW)
3	3.1	14.5	310	+4.5 (MHW)

Run	Hs (m)	Tp (s)	Dp (°)	Water Level (m)
4	1.6	14.5	310	+2.5 (MSL)
5	3.1	14.5	295 (south)	+2.5 (MSL)
6	3.1	14.5	325 (north)	+2.5 (MSL)

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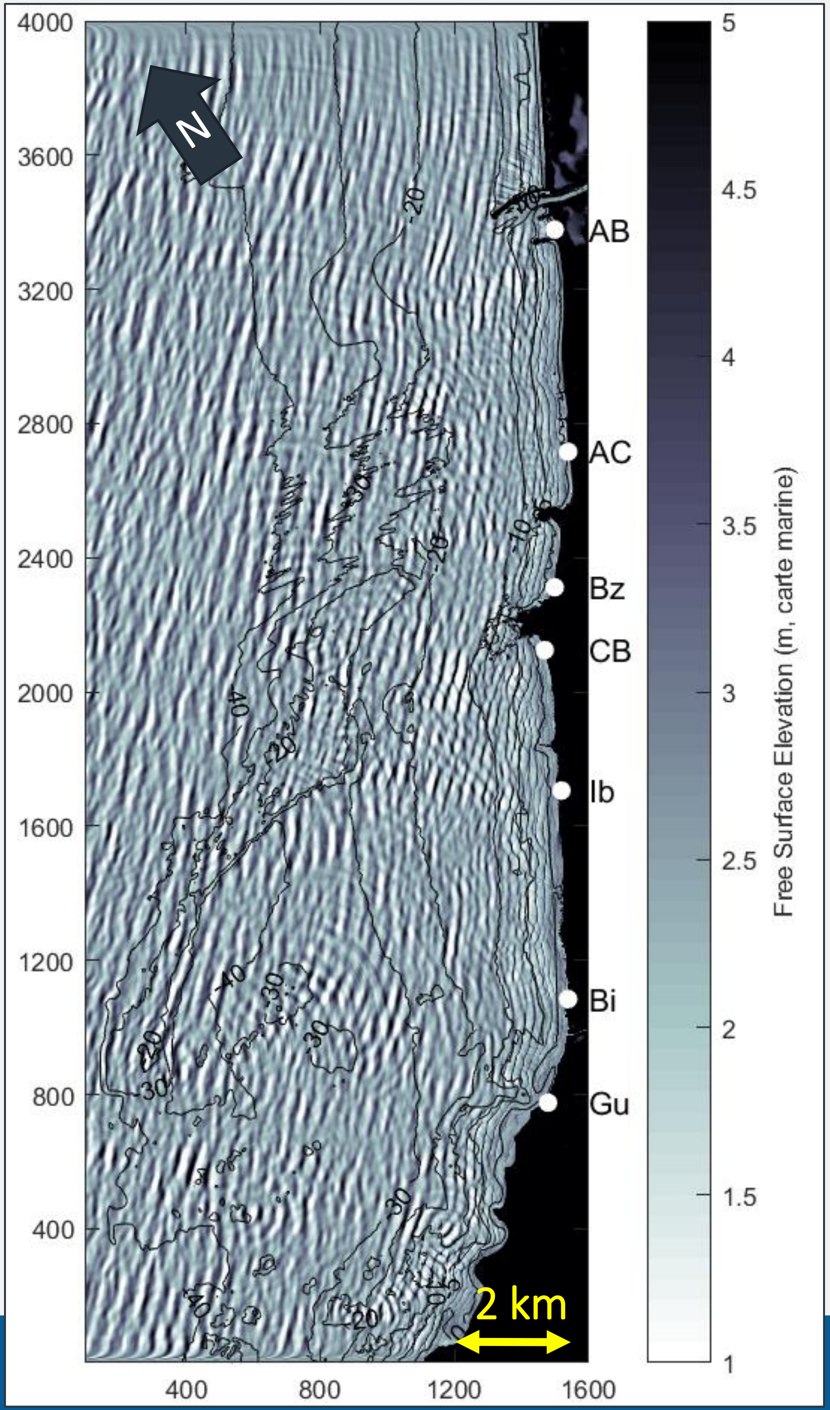
ANALYSES

BOSZ model outputs water surface

- Power Spectral Density analysis
- Swash
- IG energy flux/dissipation
- Cross-correlation between sea-swell wave envelope and IG free surface



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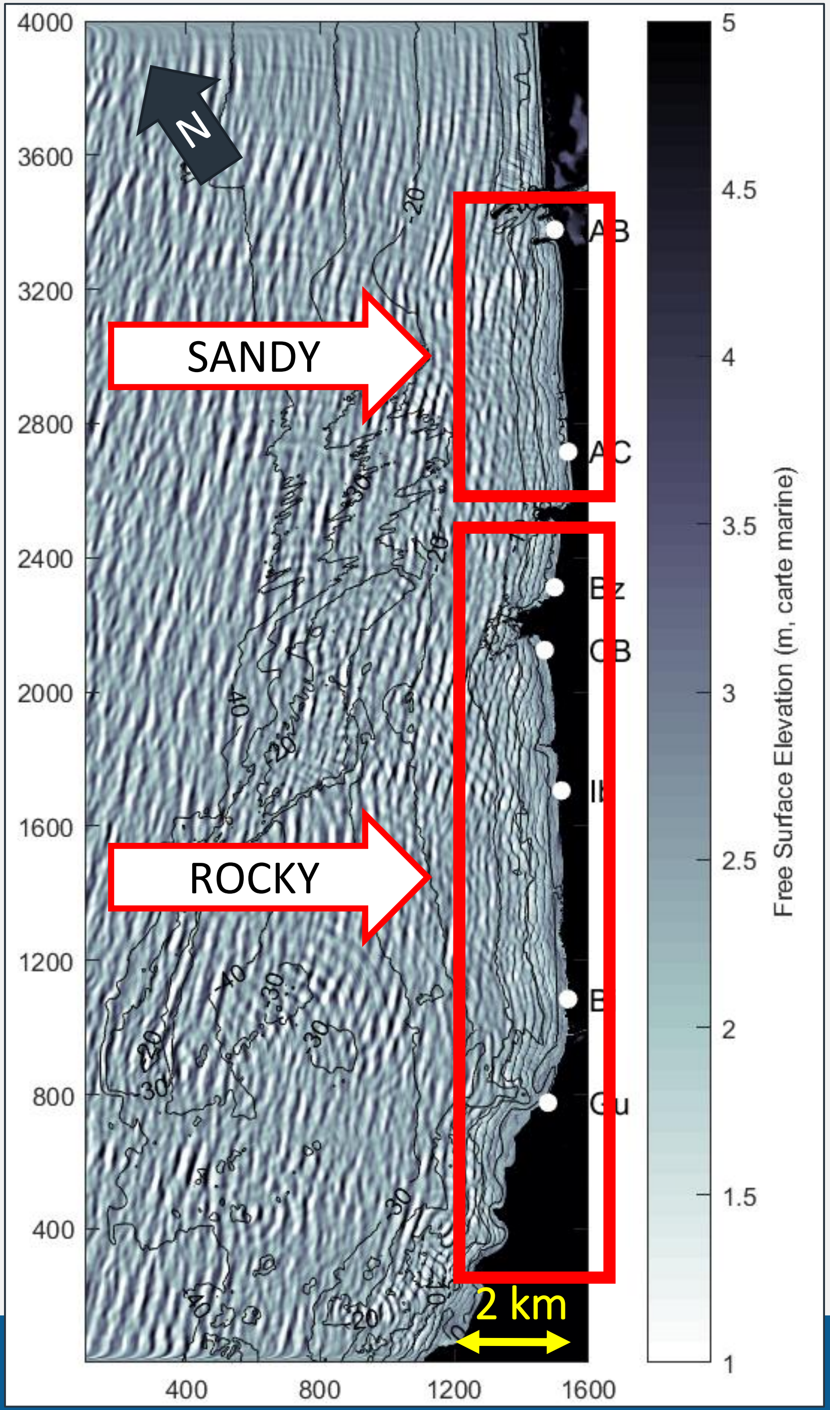
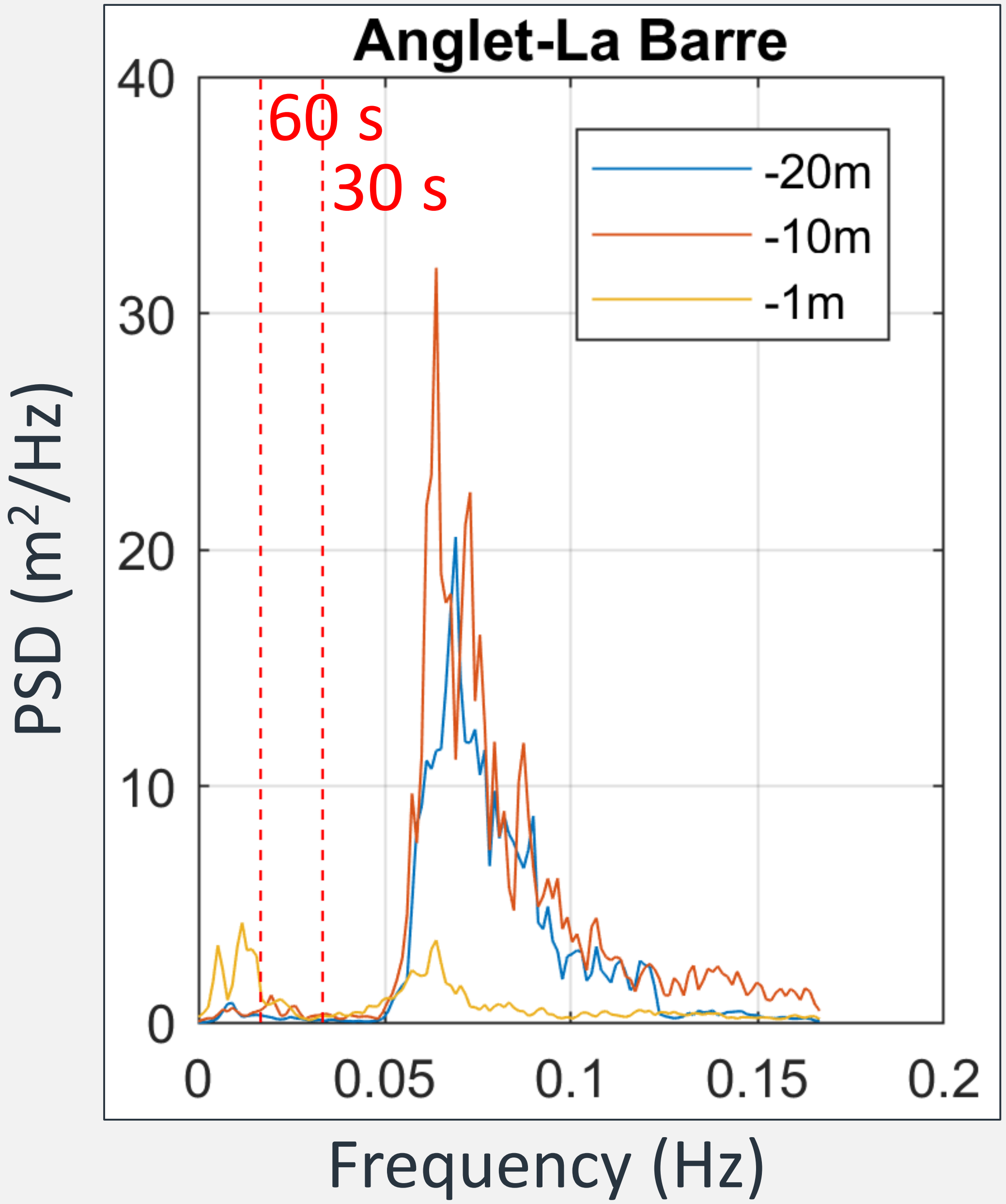


POWER SPECTRAL DENSITY

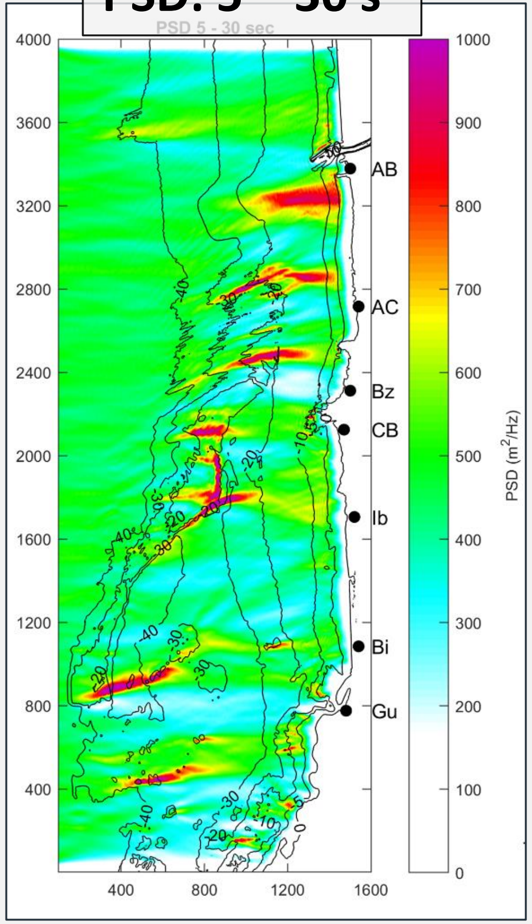
Measure of wave energy vs. frequency

- Welch Method
  - 750 s (12.5 minute) Hanning window (250 points)
  - 50% overlap
  - Averaging 5 segments
  - Equivalent degrees of freedom not computed
- Little change between -20 m and -10 m
- Large decrease between -10 m and -1 m



PSD(f) = $\sum_{f1}^{f2} E(f)$

PSD: 5 – 30 s



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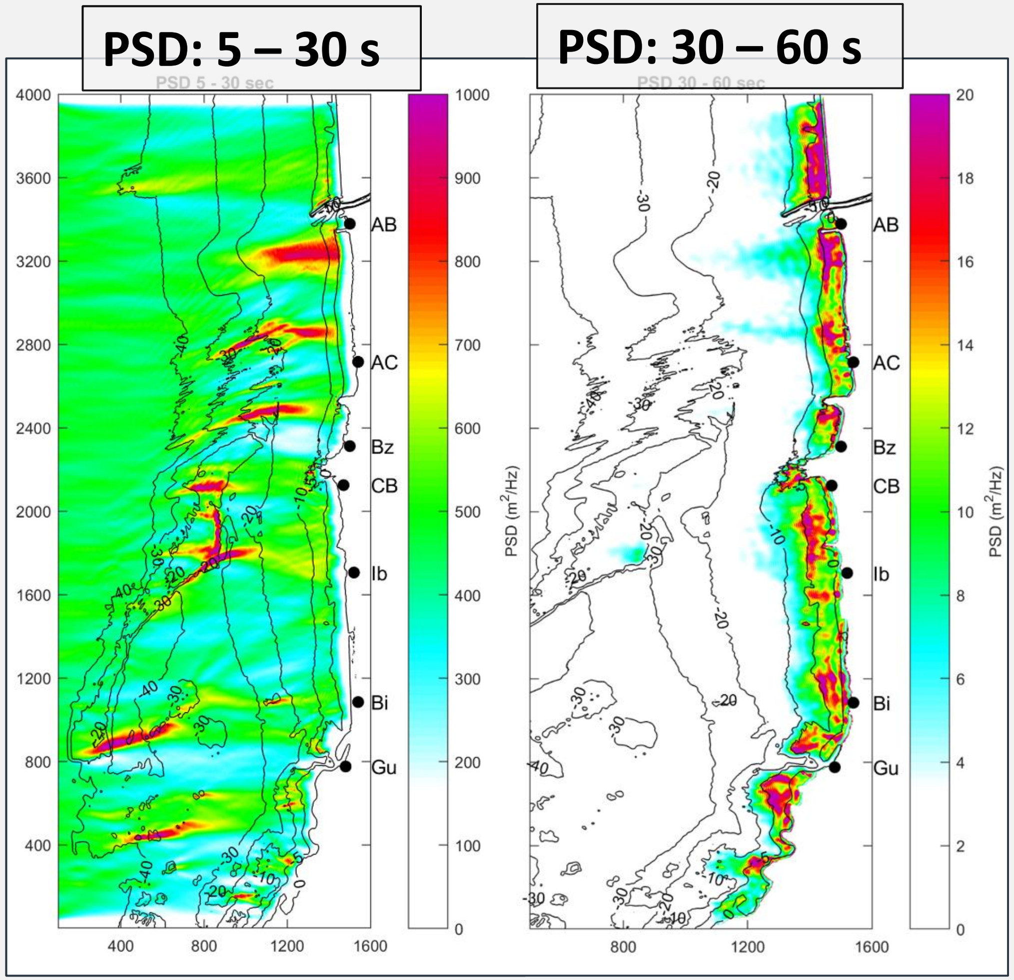

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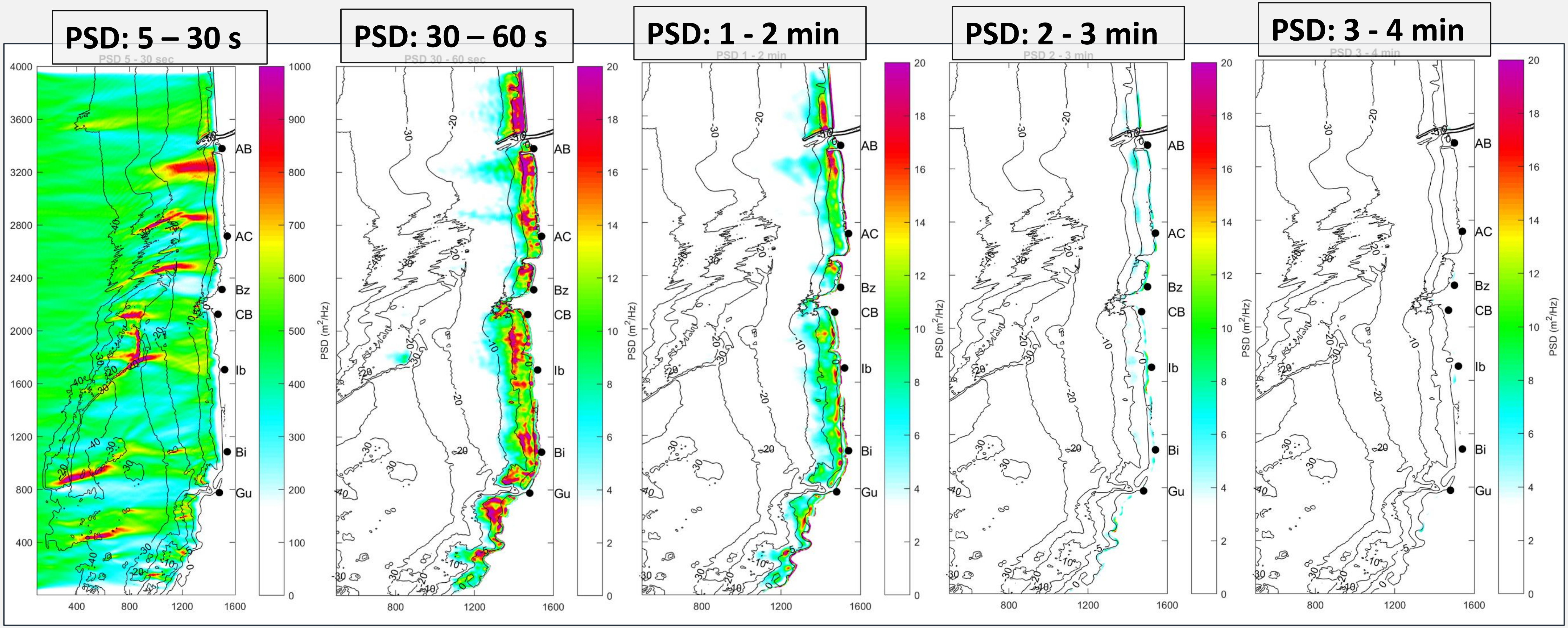
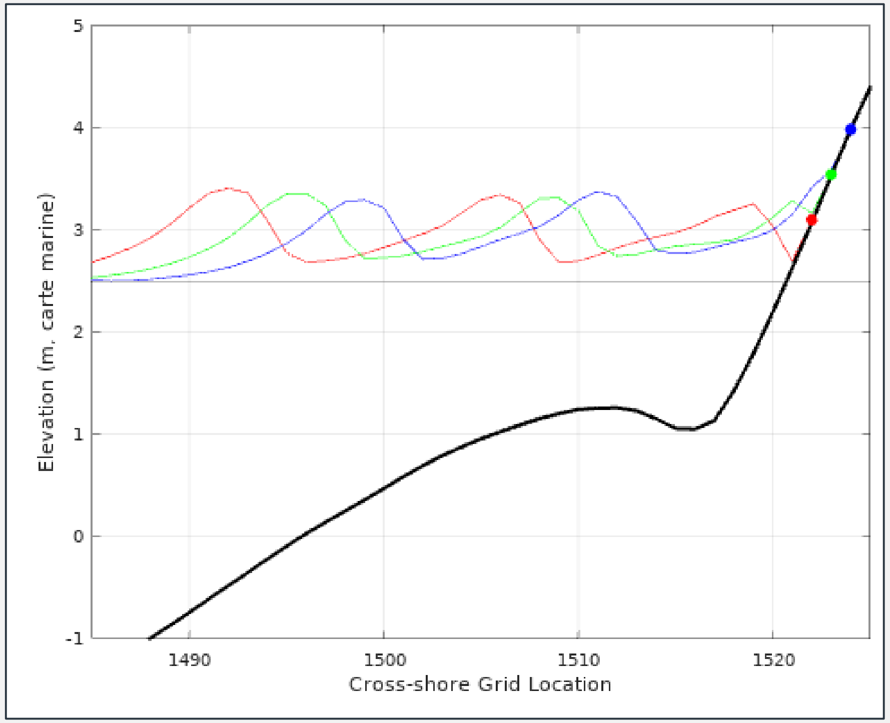
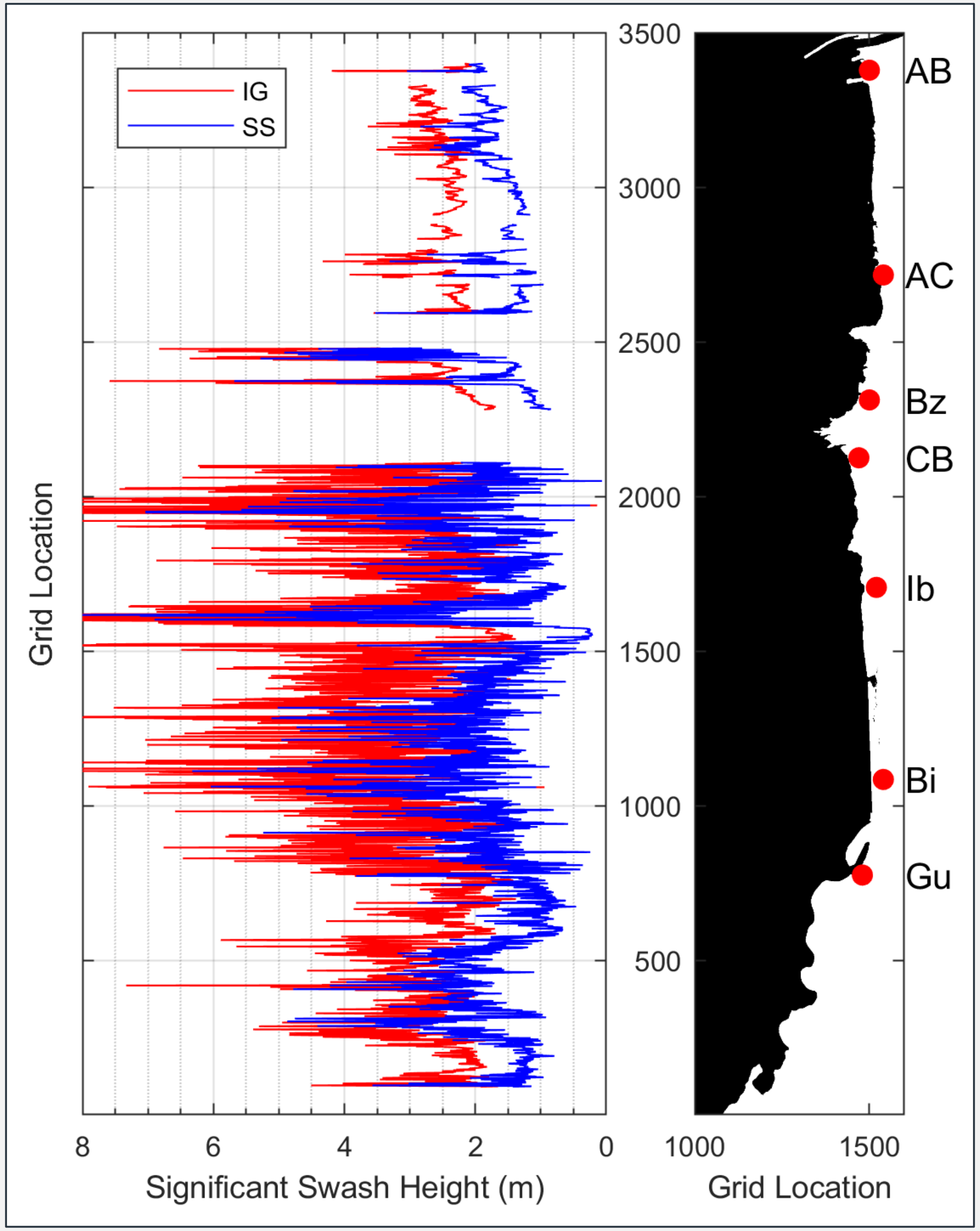


SIGNIFICANT SWASH HEIGHTS (S_S)

- Algorithm considers swash to be runup of 1 mm depth
- $S_S = 4\sqrt{\int_{f1}^{f2} E(f)df}$
- $S_{S,IG} > SS_{,SS}$ in general





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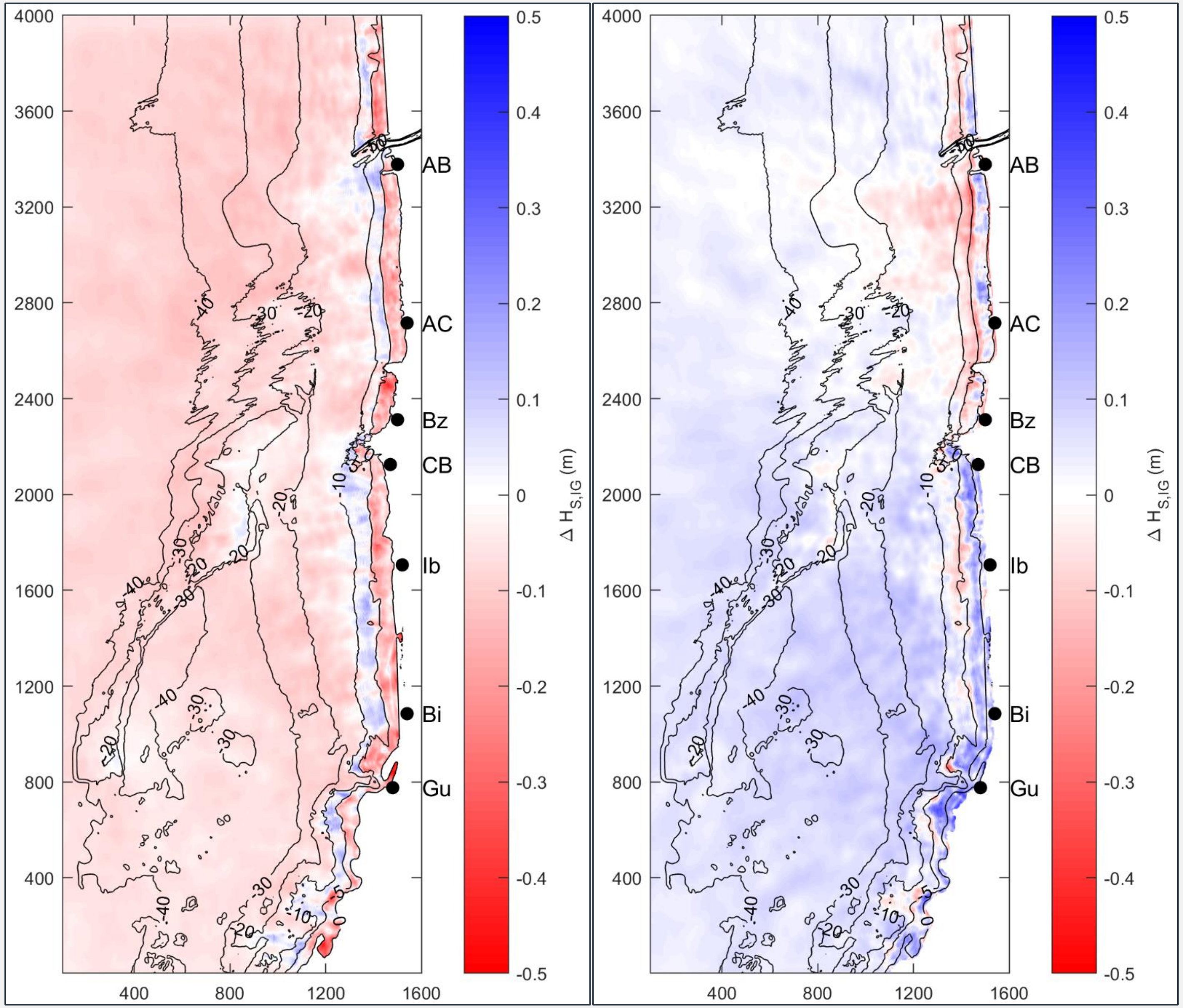
WATER LEVEL VARIATION

- Variations in water level appear to typically change $H_{S,IG}$ by 4 - 8 in
- Low tide decreases $H_{S,IG}$ everywhere except between -30 and -15 ft contours, due to wave breaking further away from shore
- High tide increases $H_{S,IG}$ nearly everywhere at shoreline, $H_{S,IG}$ wave breaking = less dissipation
- Sand disposal site less efficient at wave focusing during high tide



Low tide: 6 ft lower

High tide: 6 ft higher

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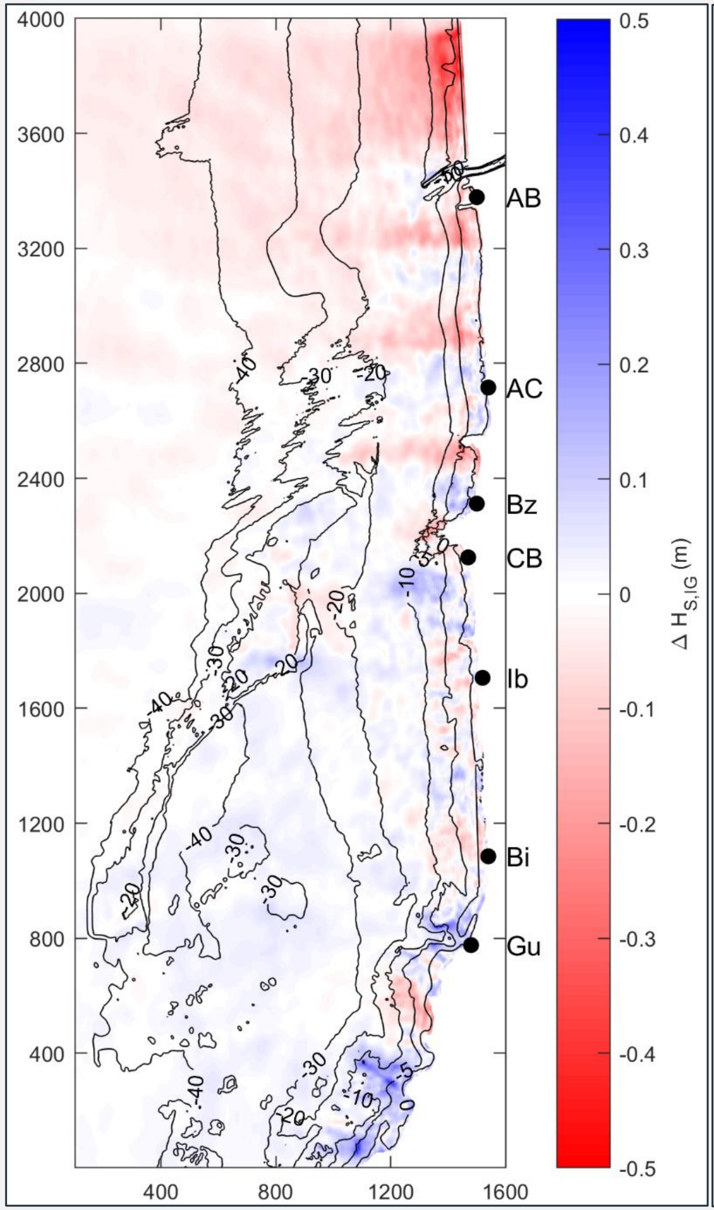
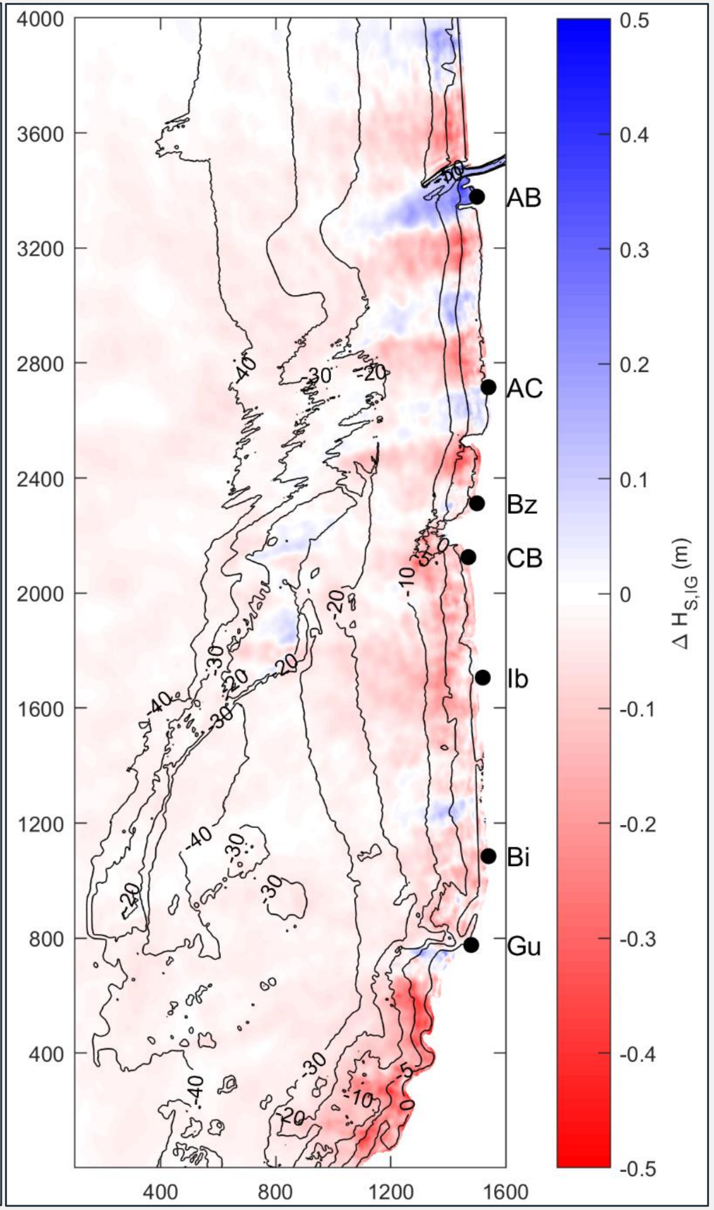
WAVE DIRECTION VARIATION

- Change in direction causes minimal change in offshore $H_{S,IG}$ heights (0 - 4 in)
- Translation in IG hotspots approx. 1 km to the south (left fig.) and north (right fig.)
- Disposal site less (more) effective at wave focusing at more northerly (southerly) direction
- Wave focusing formations offshore Anglet affect, at minimum, shoreline from Adour River inlet to Grand Plage



5° northerly



5° southerly

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STUDY CONCLUSIONS

- Offshore bathymetry highly influences IG energy hotspots
- Water level influence – IG wave heights increase during high tide, decrease during low tide
- Wave direction influence – wave direction changes IG wave heights by typically 0-4 in
- IG waves (and swash heights) more sensitive to changes in water level than wave direction
- Storm intensity influence – decrease in storm intensity decreases IG wave heights everywhere, but disproportionately at wave break zone and wave focusing features

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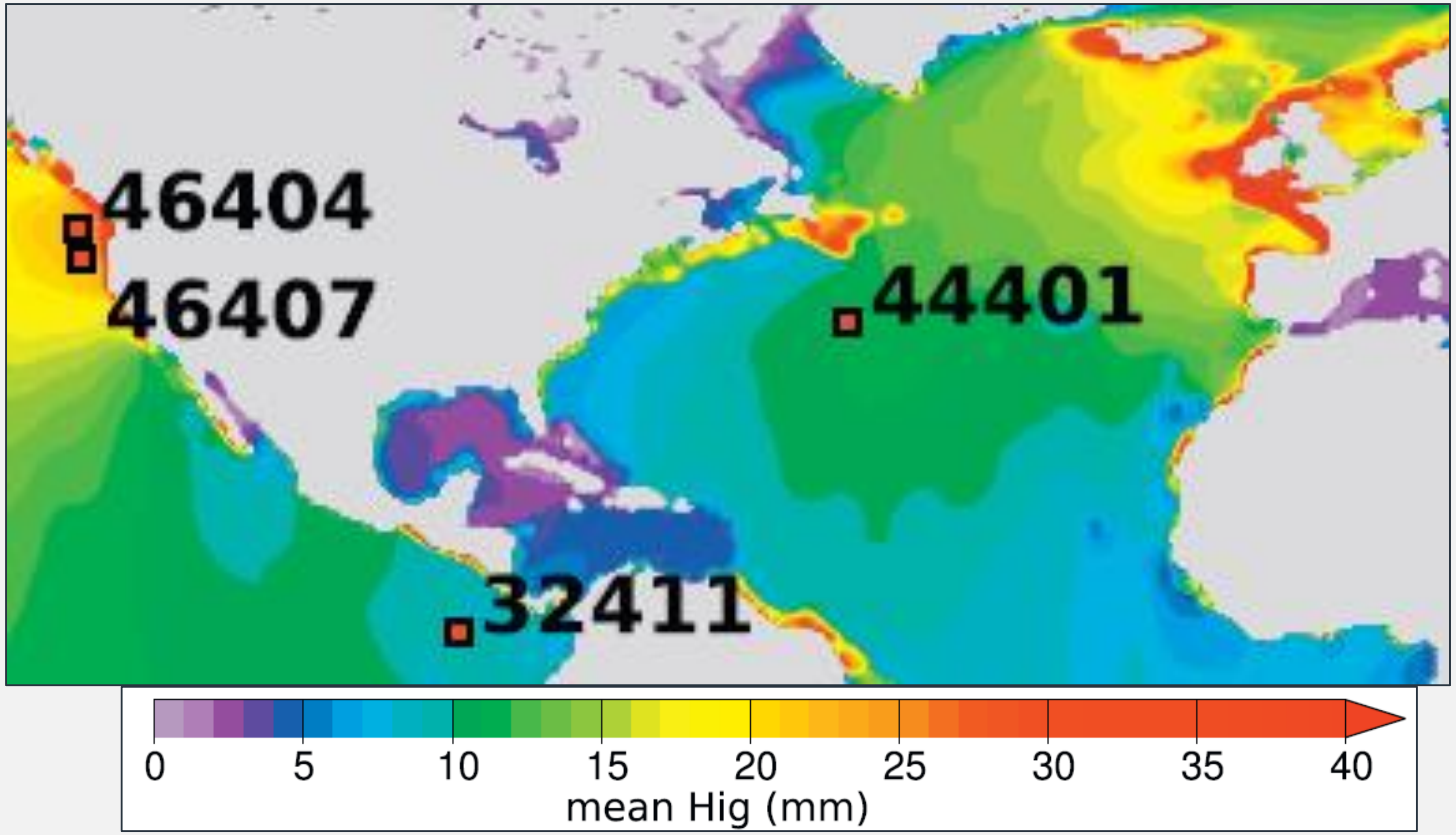
INFRAGRAVITY WAVES IN FLORIDA

- Little IG research in Florida
- Generally low IG wave energy
- Following locations are selected for illustration
  - Mayport
  - Bathtub Beach Park
  - Delray Beach



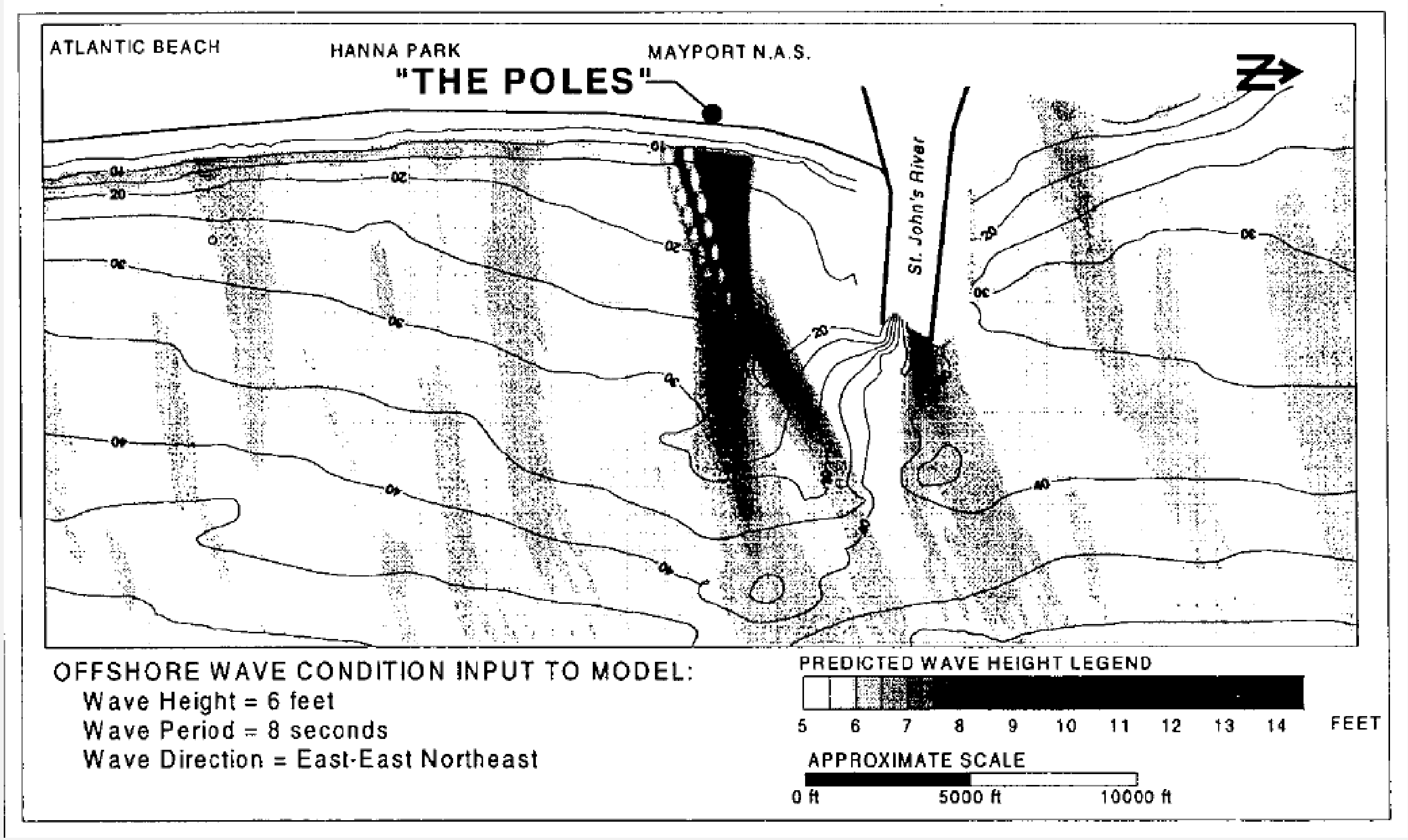
Modeled, mean IG wave heights during winter 2008.

Bertin, X., et al., 2018. Infragravity waves: from driving mechanisms to impacts. Earth. Rev. 177, 774–799.

MAYPORT, DUVAL COUNTY

Offshore wave focusing

- Higher wave heights at shoreline likely cause higher IG wave heights



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RAICHLE, A.W., 1998. Numerical predictions of surfing conditions at Mavericks, California. Shore and Beach, April, 66(2), 26-30.

BATHTUB BEACH PARK, MARTIN COUNTY

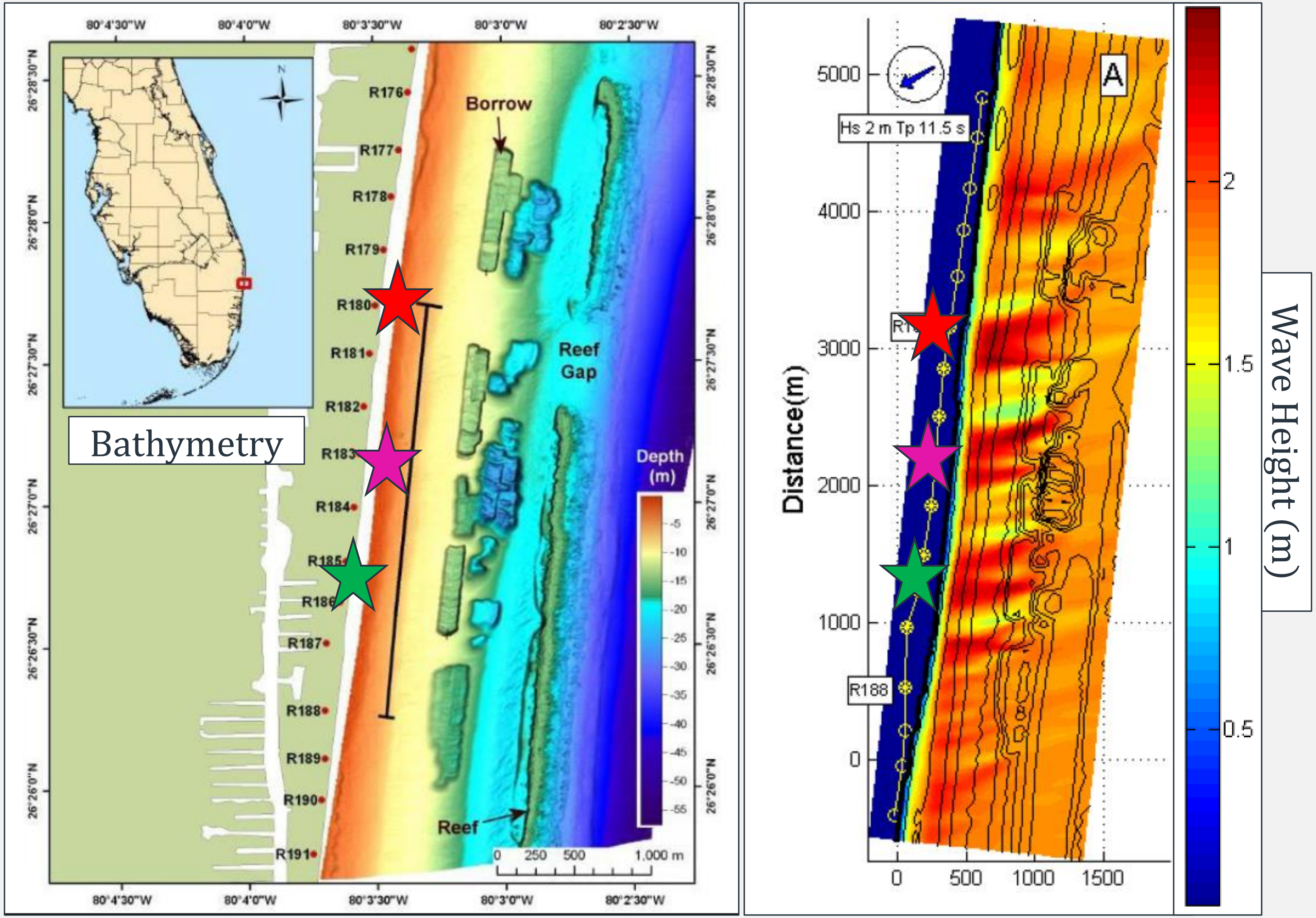
Fringed reef environments

- IG wave component of runup more dominant
- Potential for IG wave resonance/ amplification

DELRAY BEACH, PALM BEACH COUNTY

Wave divergence due to dredge pits

- Higher wave heights at shoreline likely results in higher IG wave heights



Benedet, L. (2016). Process controlling beach nourishment performance at Delray Beach, Florida, USA.

SUMMARY

1. Simplistic explanation of IG waves and generation mechanisms
   - Waves with periods between 30 seconds and 5 minutes
2. Discussion of numerical modeling results from SW France coastline
   - Offshore bathymetry highly influences IG wave hotspots
3. Applicability to Florida's Atlantic coastline
   - IG waves are everywhere

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Questions?

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Albada et al. 2007. https://fsbpa.com/07Proceedings/05Albada2007.pdf