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Georgia Tech

THE EFFECT OF OBLIQUE SHOREFACE-CONNECTED RIDGES ON ALONGSHORE TRANSPORT AND SHORELINE CHANGE

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CREATING THE NEXT®

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INTRODUCTION

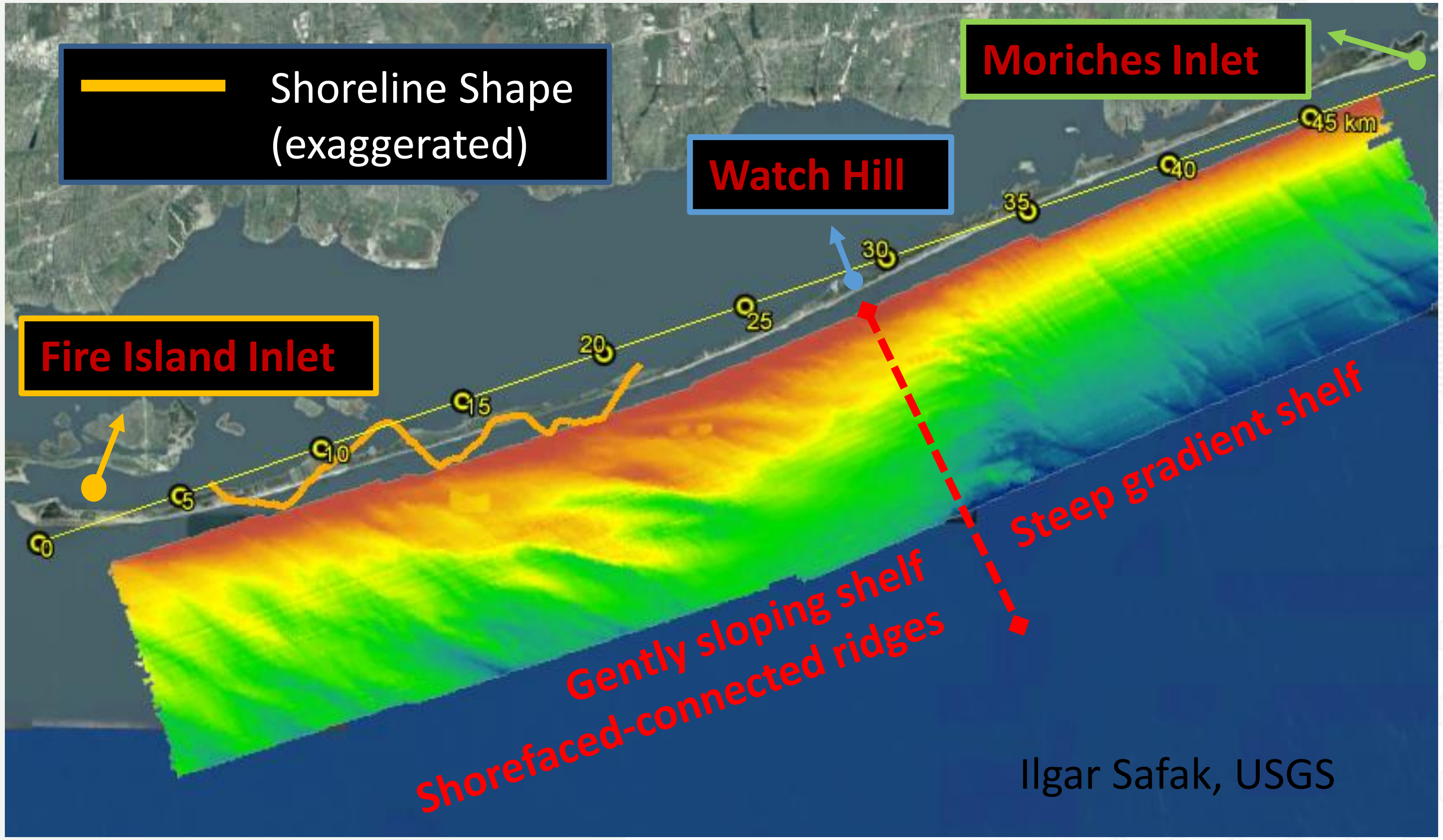
Fire Island, New York

50 km long barrier island on the southeast side of Long Island

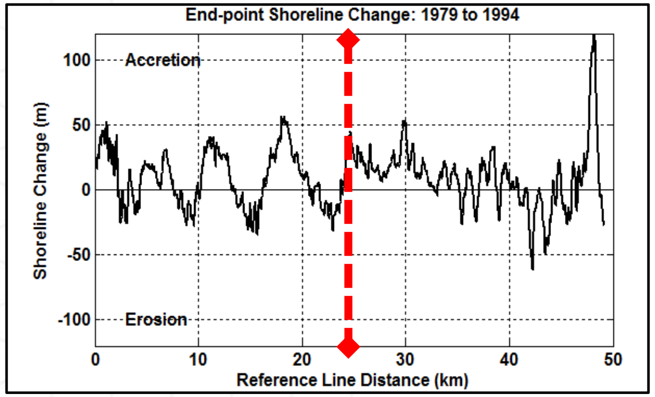
INTRODUCTION

Shore-face Connected Ridges (SFCR)
Ridge Widths: 2 - 3 km; Ridge Amplitudes: 2 – 4m

2011 USGS Bathymetry & Average Shoreline Shape 1933-2011



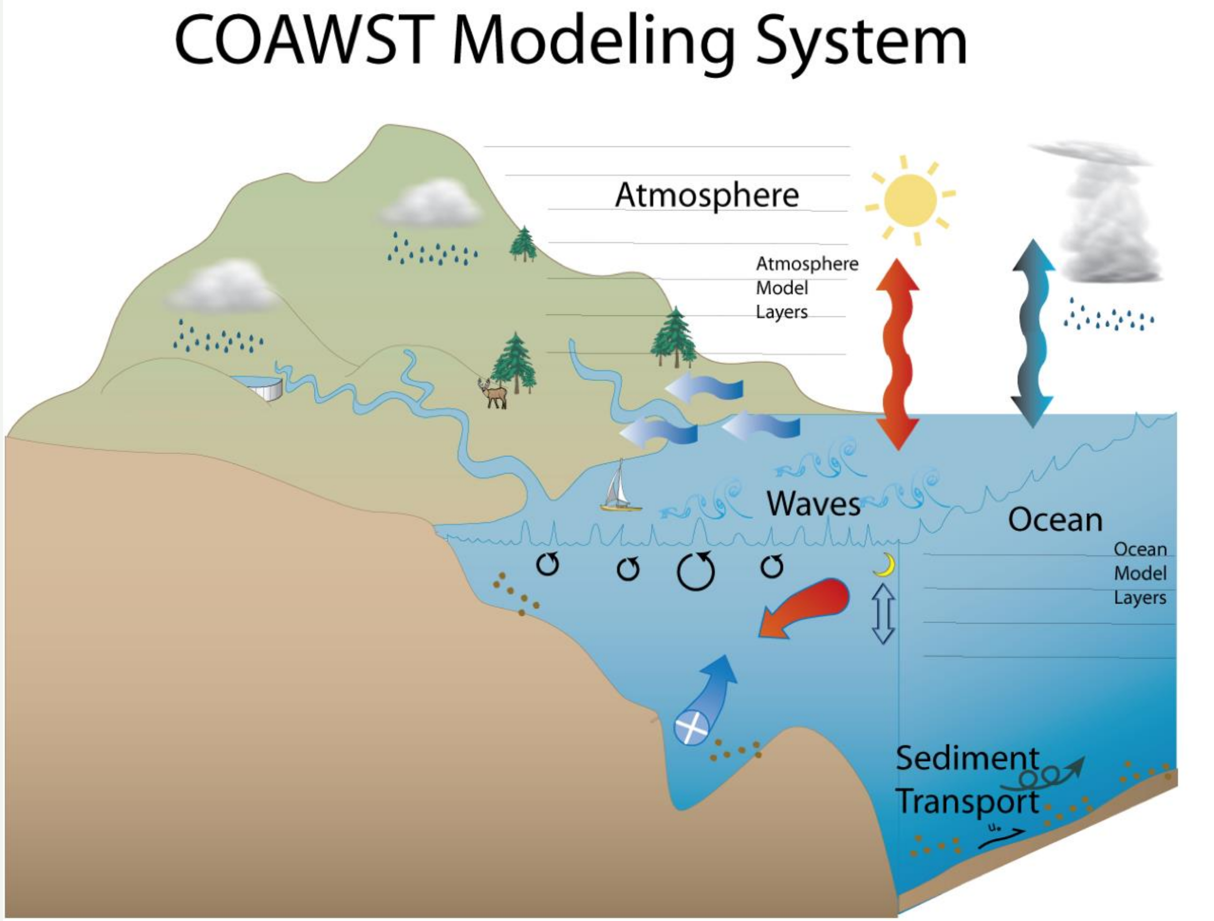
Allen et al., 1997



Objective

Develop a better understanding of the influence of Shoreface-connected Ridges (SFCR) on wave transformation, sediment transport, and the shoreline response.

MODEL SETUP

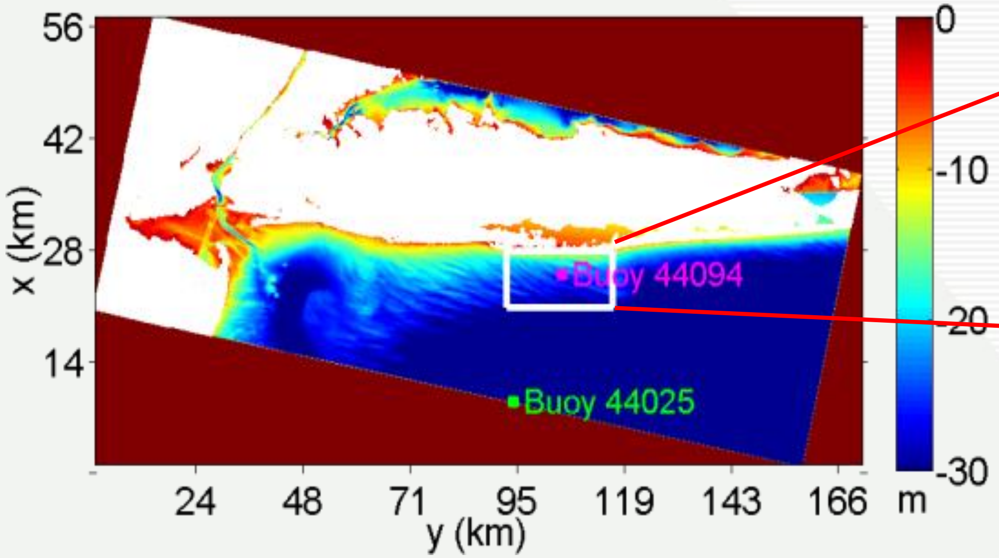


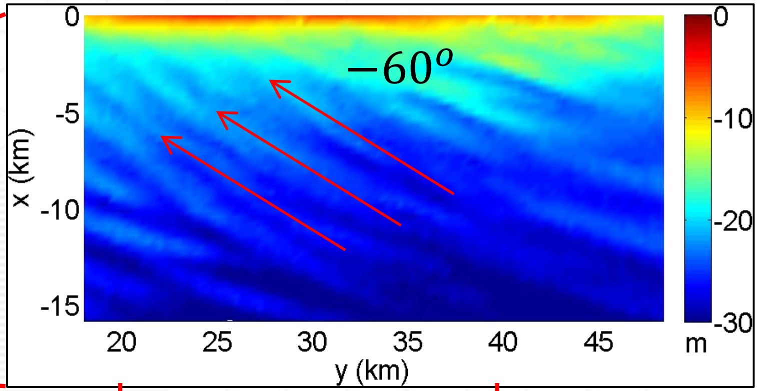
https://woodshole.er.usgs.gov/operations/modeling/COAWST/

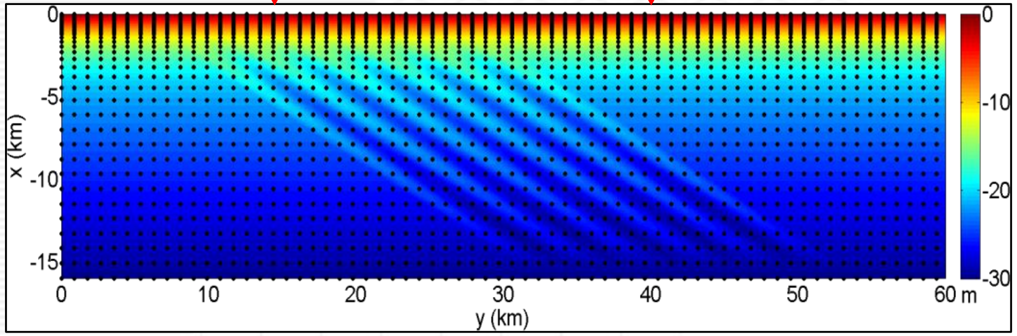
Fully coupled models

ROMS – Circulation
SWAN – Waves
Community Sediment Transport

MODEL SETUP



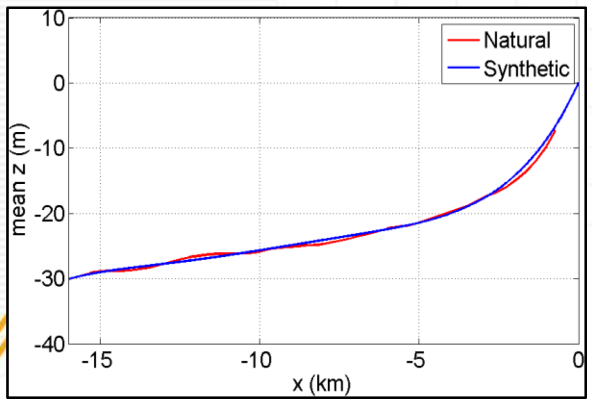


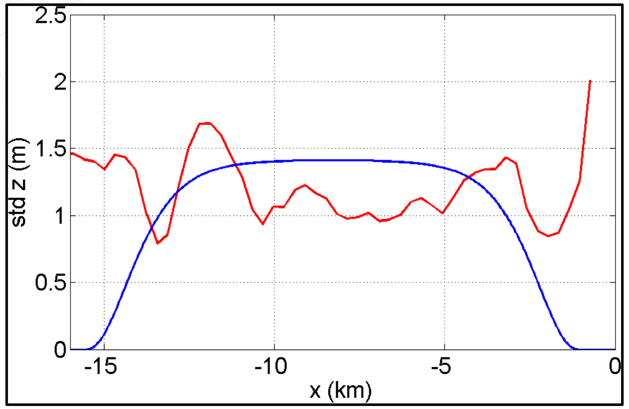


Synthetic Bathymetry

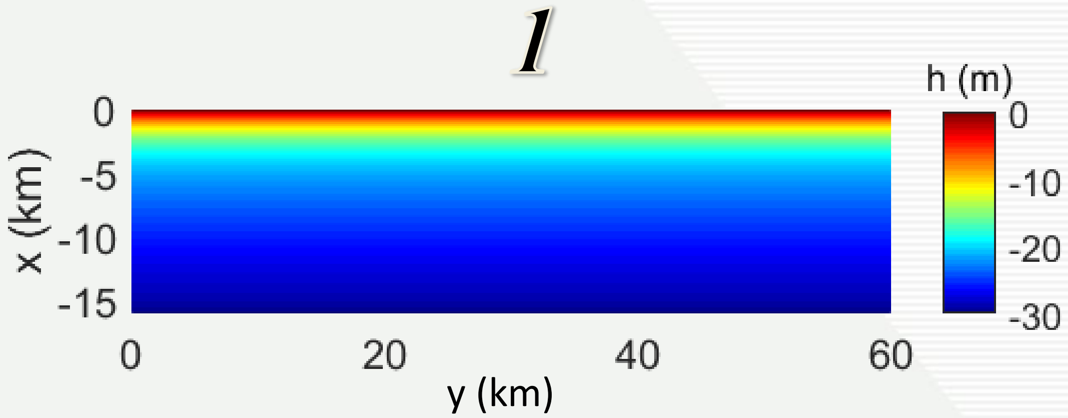
Synthetic Profile:

- 60000m × 16000 m
- Ridge Angle to Shore Normal: -60 degree
- Ridge Width: 2 km
- Ridge Amplitude: 2 m





MODEL SETUP



- ***Regular Grid***

  Spacing 200m×50m; grid points 301×321
- ***Bathymetry***

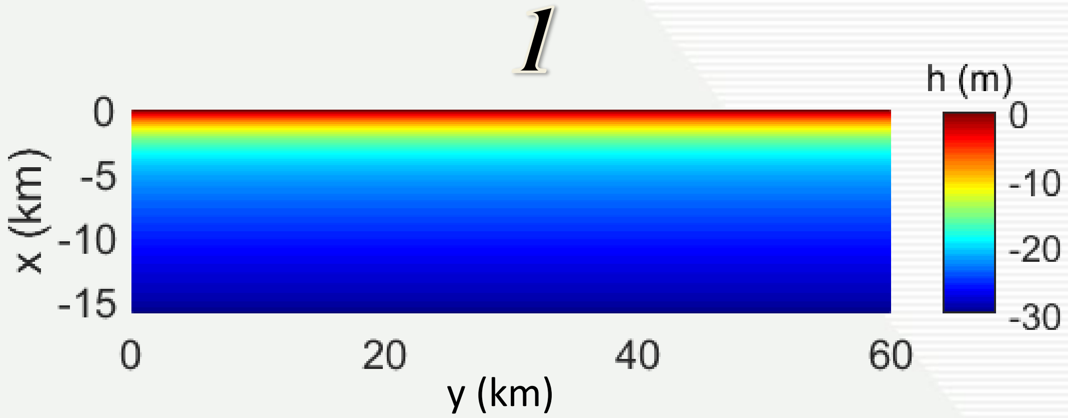
  Slope bottom without ridges & troughs
- ***Boundary***

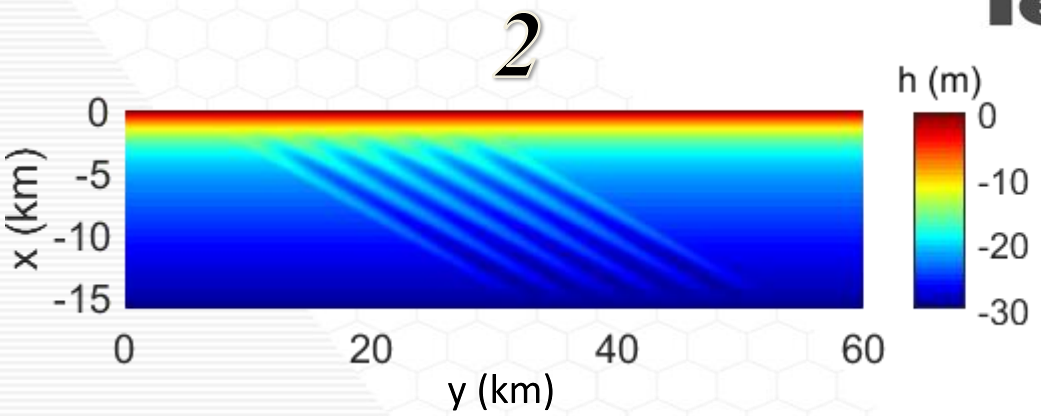
  West & East Periodic Boundary Condition

  South- Wave forcing
- ***SWAN***
- ***Output***

  Energy Spectrum for Boundaries from the 1st SWAN Run

MODEL SETUP

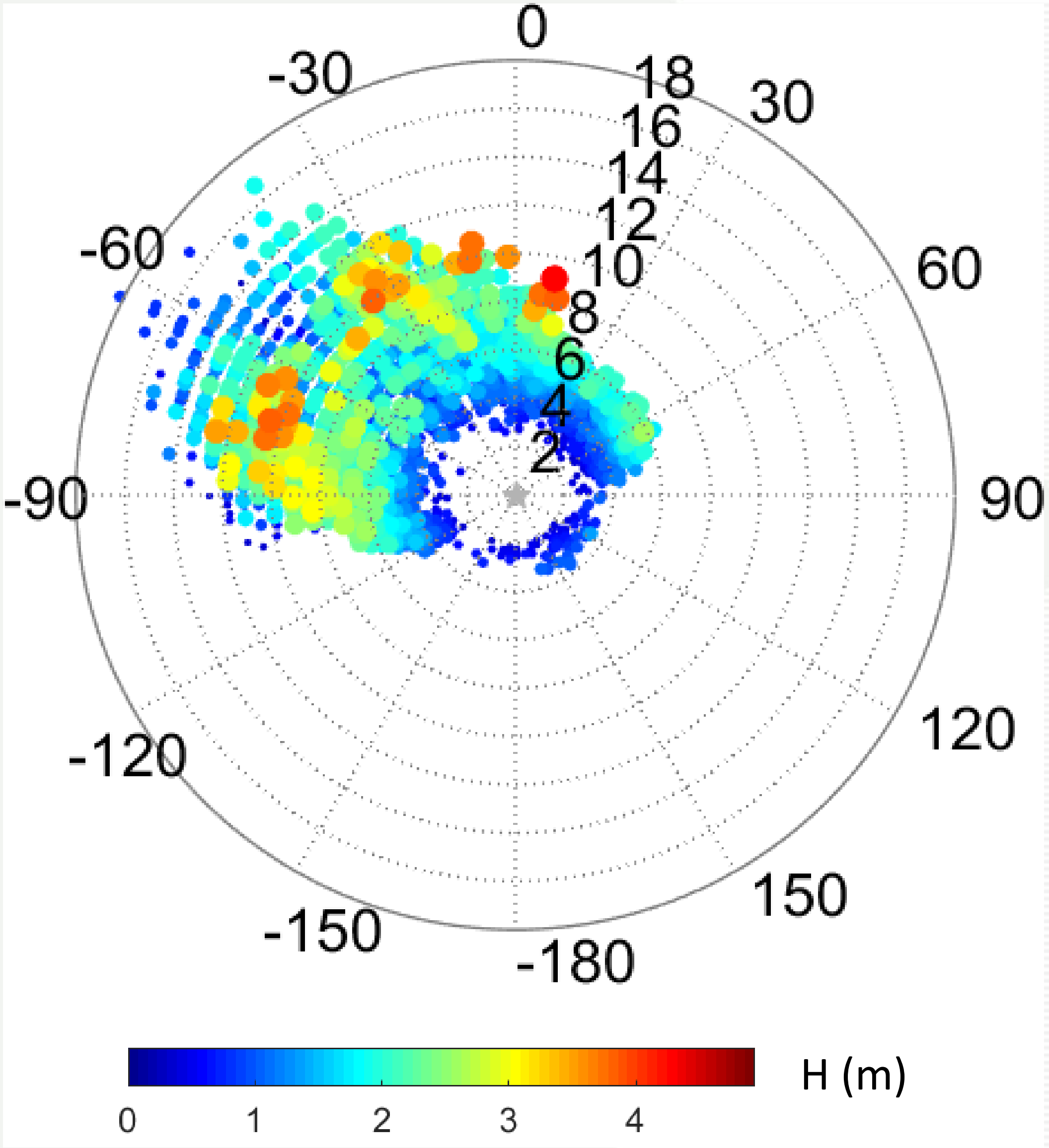




- ***Regular Grid***
  Spacing 200m×50m; grid points 301×321
- ***Bathymetry***
  Slope bottom without ridges & troughs
- ***Boundary***
  West & East Periodic Boundary Condition
  South- Wave forcing
- ***SWAN***
- ***Output***
  Energy Spectrum for Boundaries from the 1st SWAN Run

- ***Irregular Grid***
  Spacing 100m× 10~100m; grid points 601×308
- ***Bathymetry***
  Slope bottom with ridges & troughs
- ***Boundary***
  SWAN: Energy Spectrum from the 1st SWAN Run
  ROMS: West & East Periodic Boundary Condition
- ***SWAN & ROMS***

WAVE CONDITIONS



Hourly Wave Records of NDBC Buoy 44094 (Feb 2014 - July 2015)

Direction relative to shore normal (0 degree)

Baseline Wave Condition:
Hsig = 2.5 m, T = 12 s

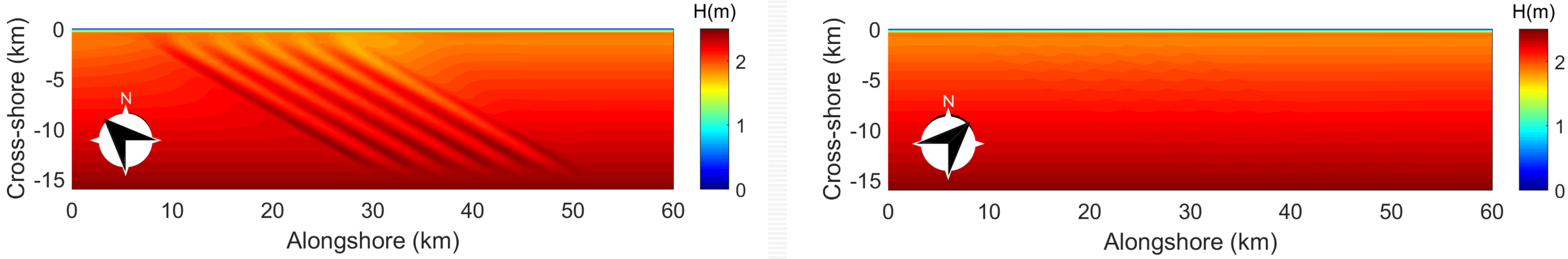
ALONGSHORE VARIABILITY

- Sensitive to the relative angle between incoming wave direction (θ_I) and ridge orientation

Wave Height

a) $\theta_I = -45^o (SE)$

b) $\theta_I = +45^o\ (SW)$



ALONGSHORE VARIABILITY

- Sensitive to the relative angle between incoming wave direction (θ_I) and ridge orientation.

a) $\theta_I = -45^o (SE)$

Wave Height

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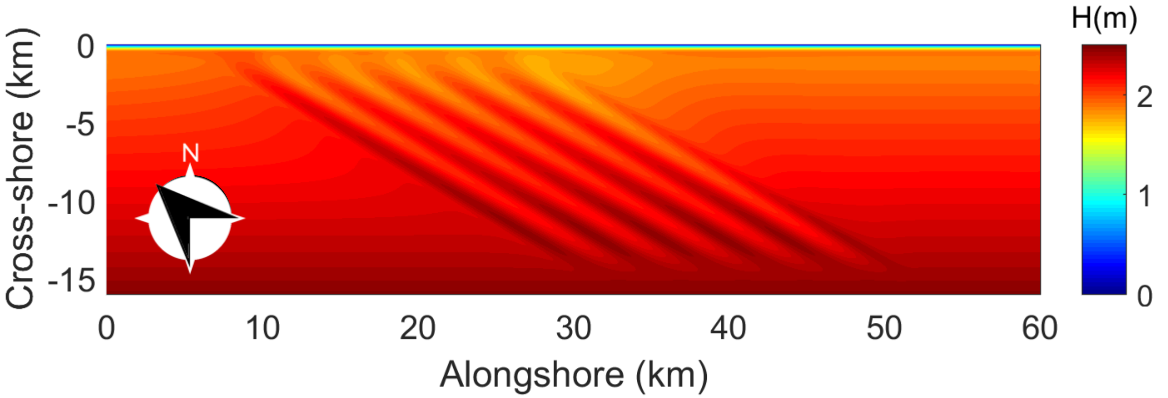
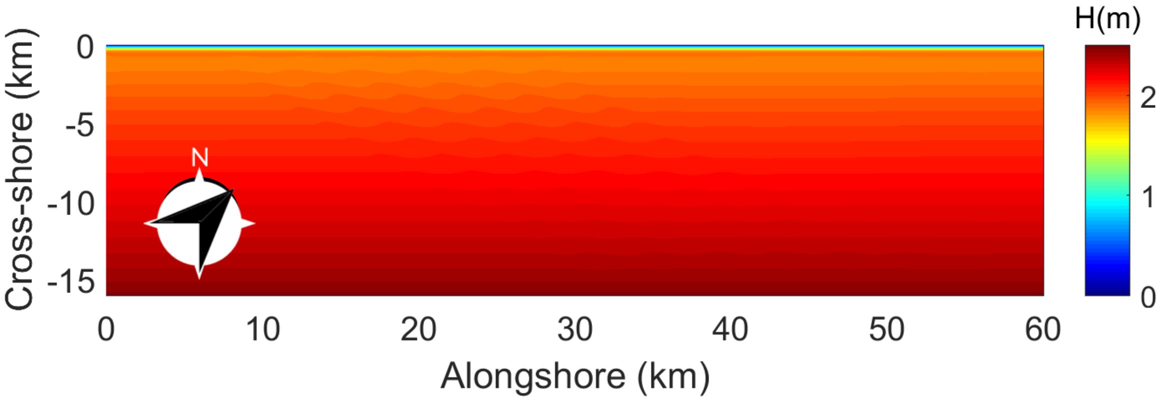
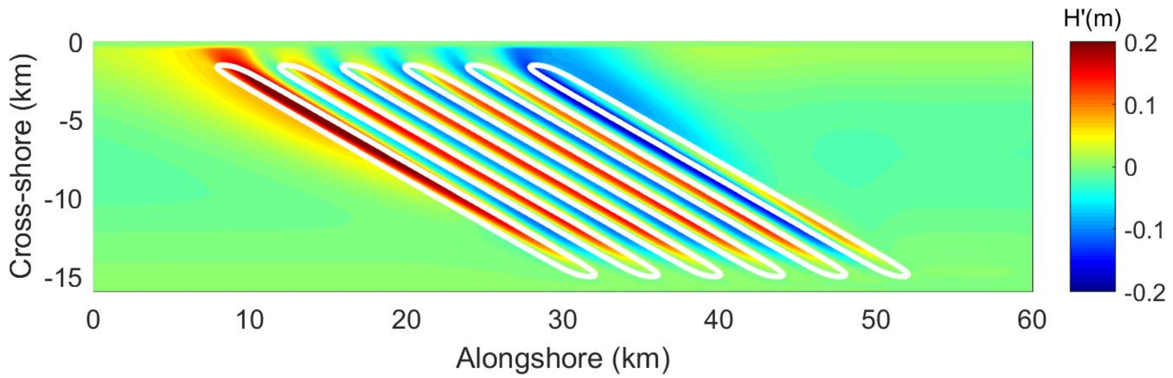
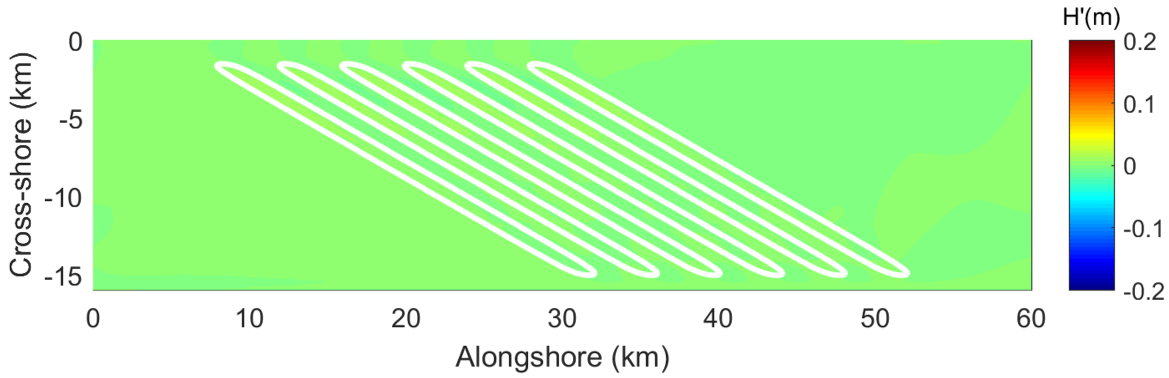




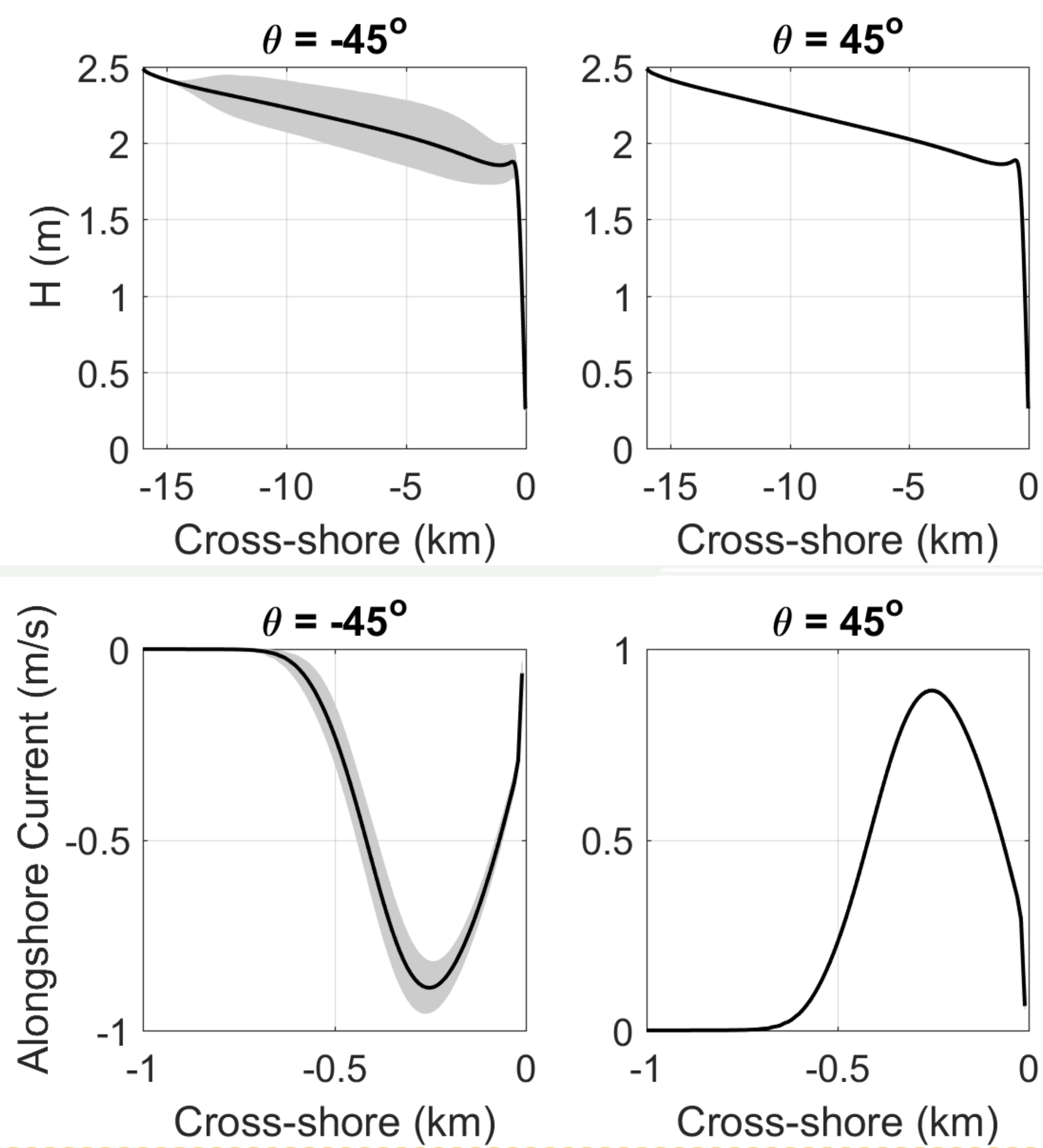
Wave Height Variability (Alongshore mean removed)





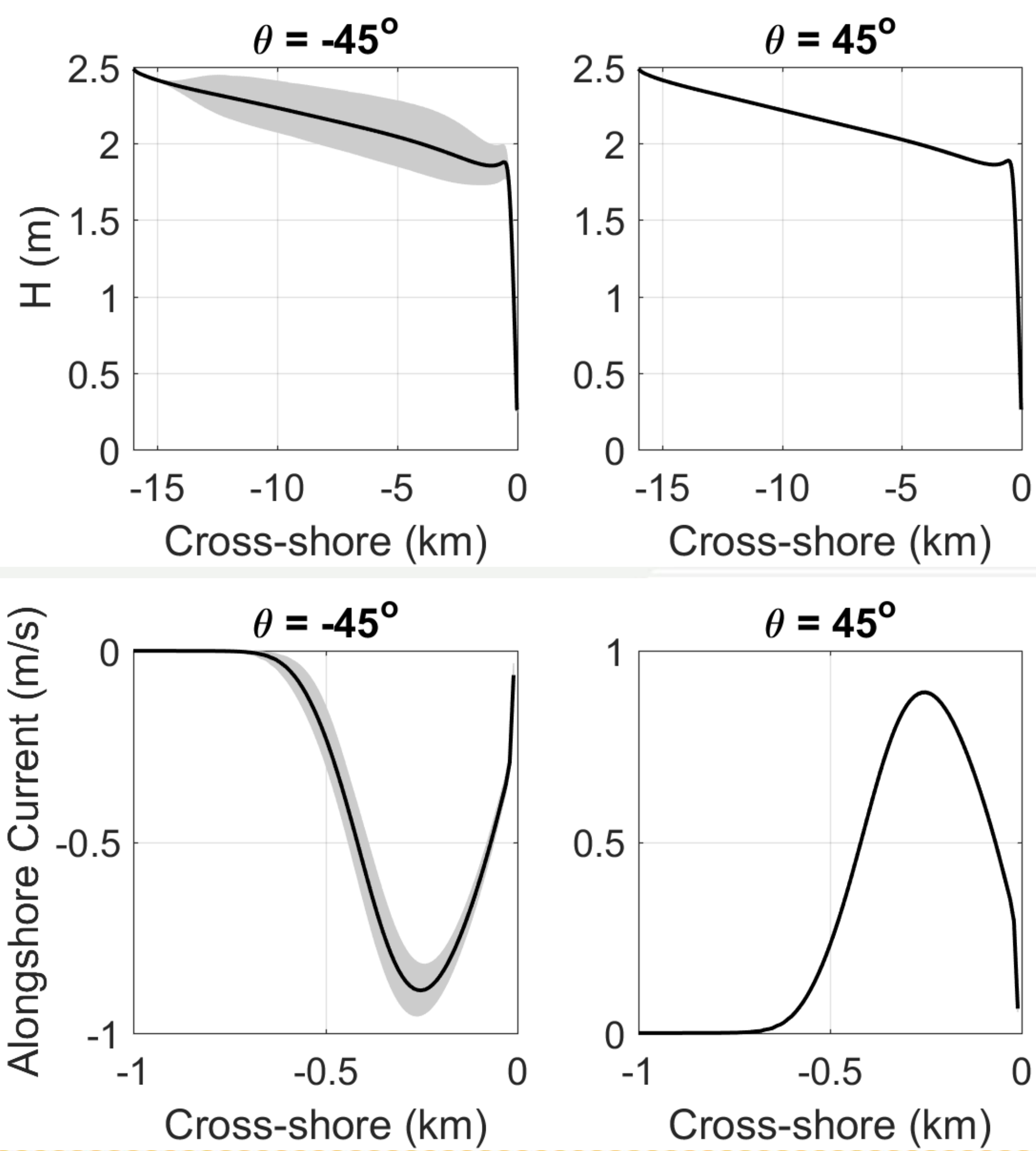
ALONGSHORE VARIABILITY

Alongshore mean and envelope of variability



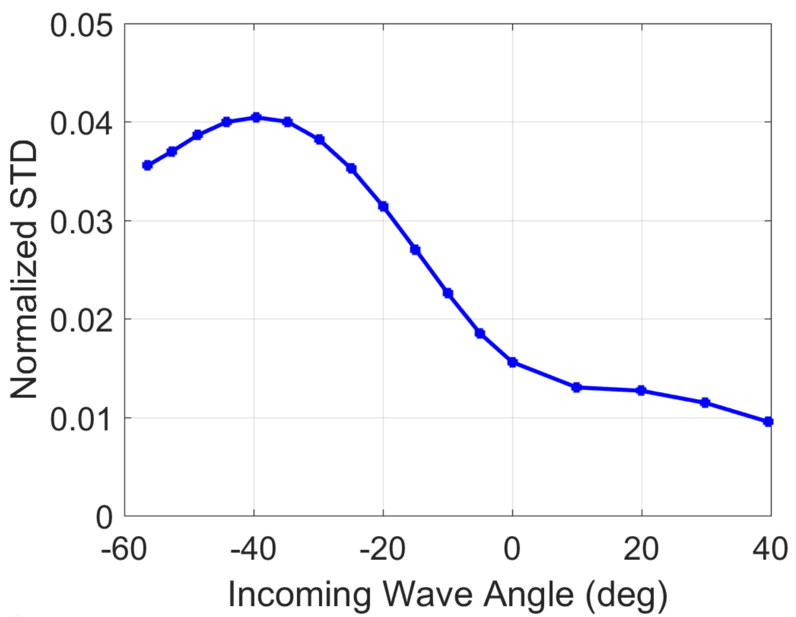
ALONGSHORE VARIABILITY

Alongshore mean and envelope of variability



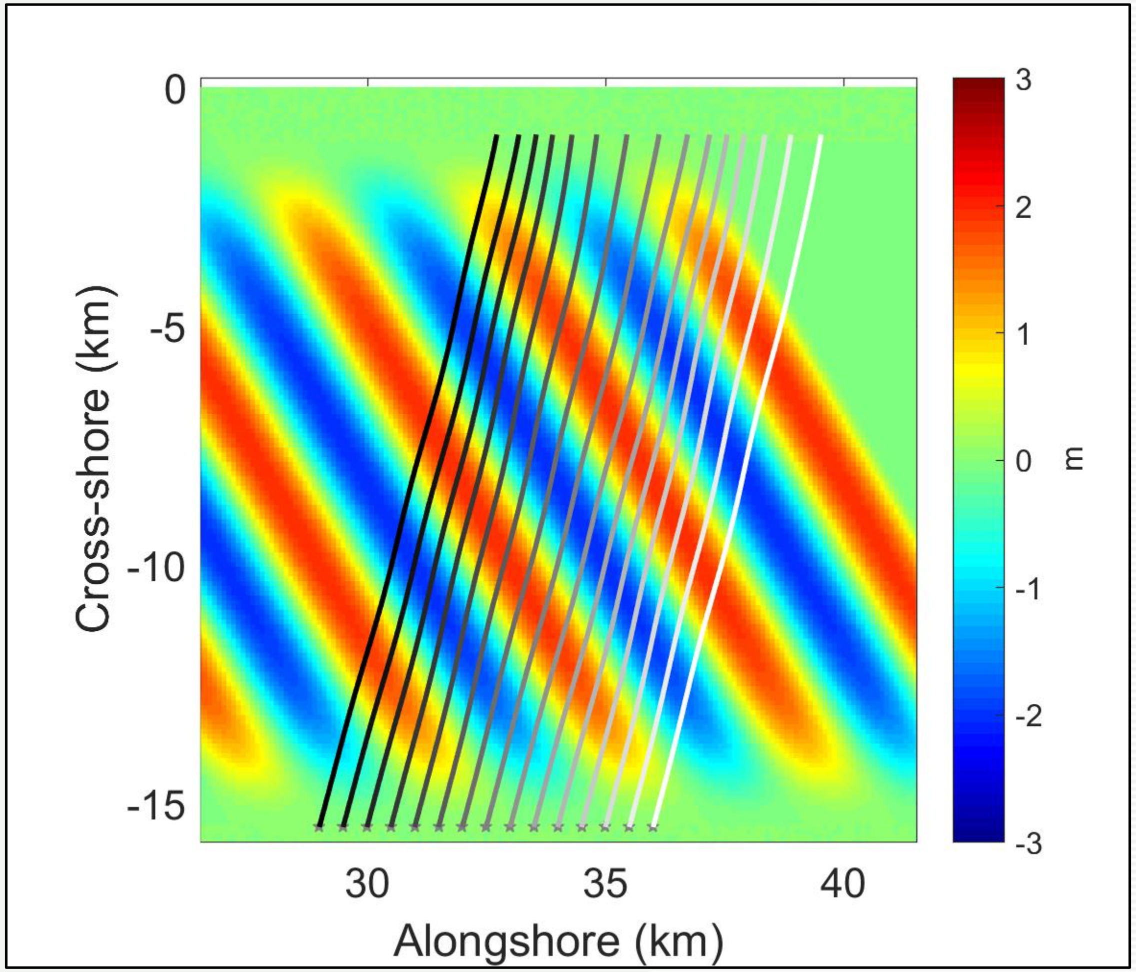
Use ridges with a -30 degree orientation to look at full range of wave directions around ridges

Normalized standard deviation of wave height alongshore variability

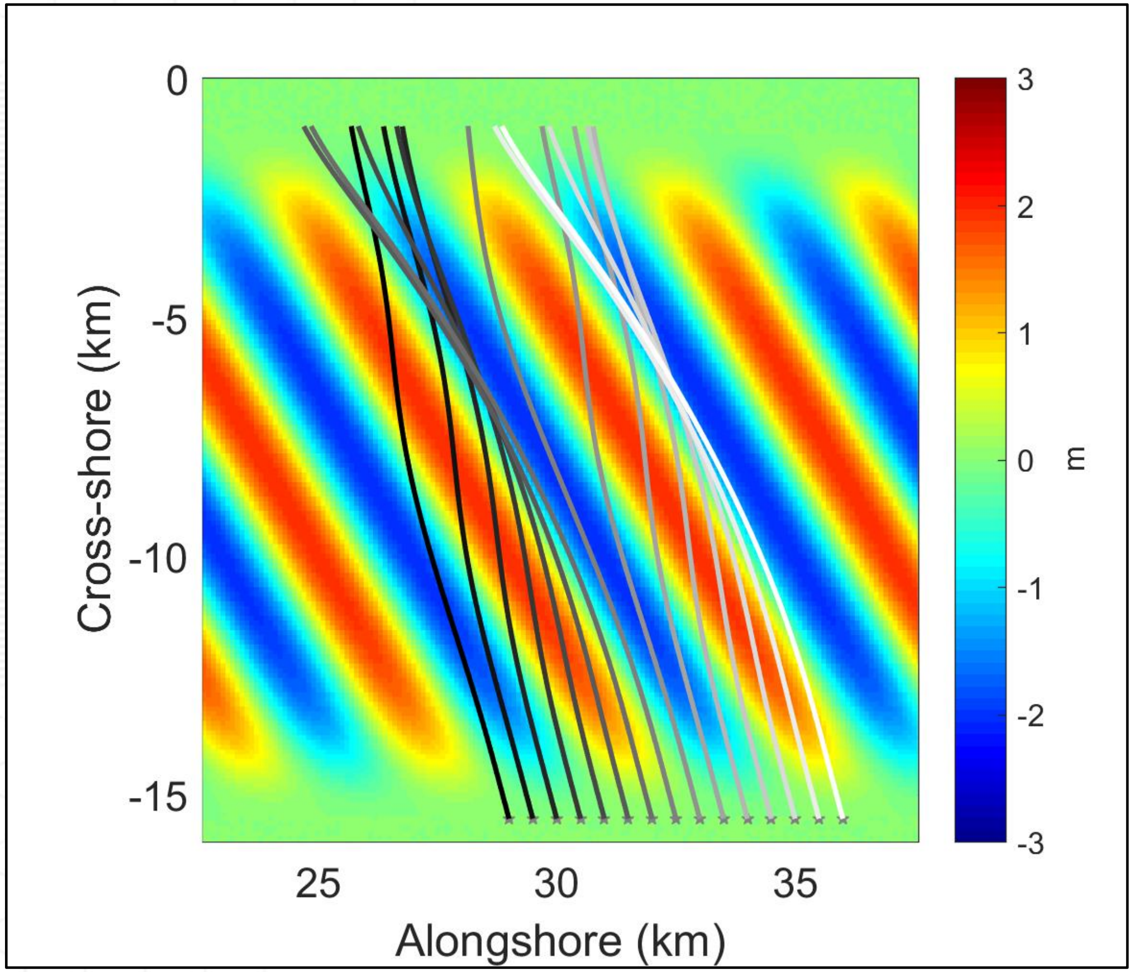


WAVE RAYS

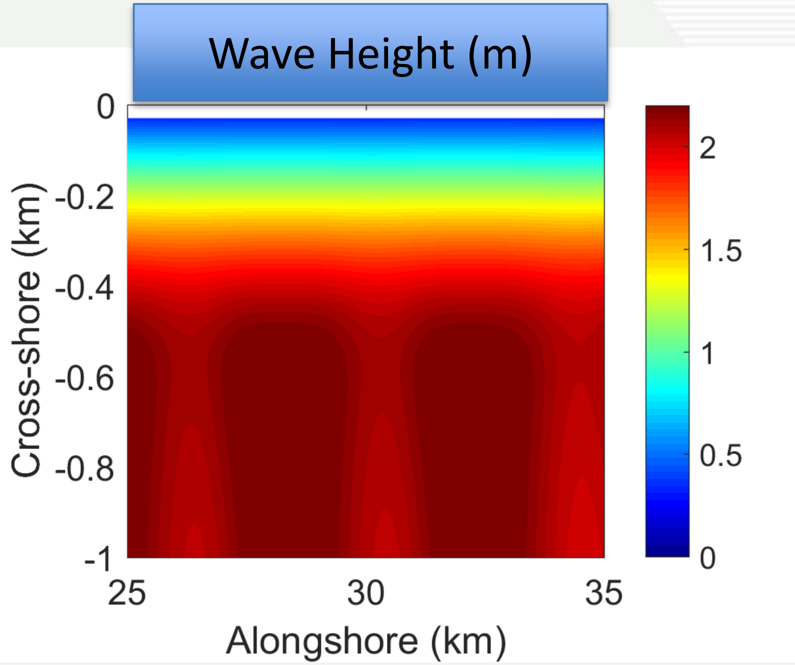
15 degrees

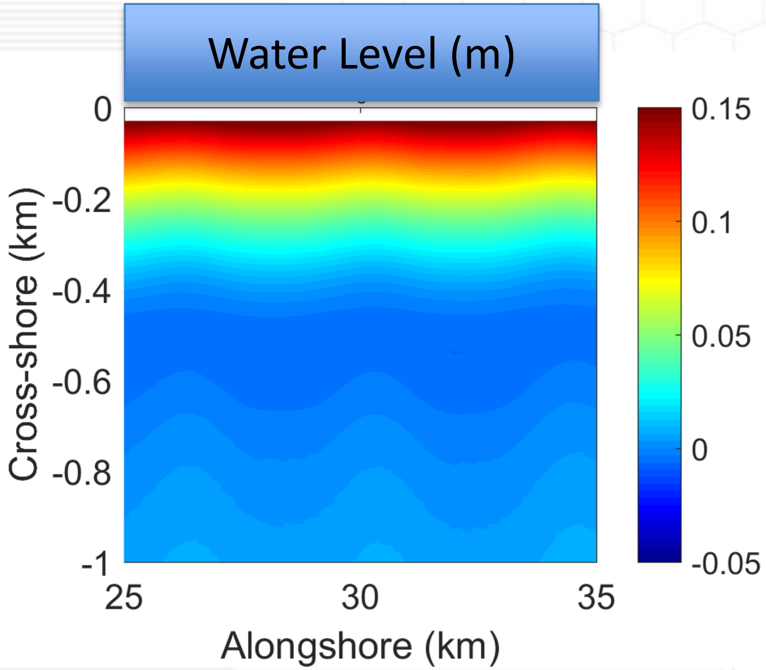


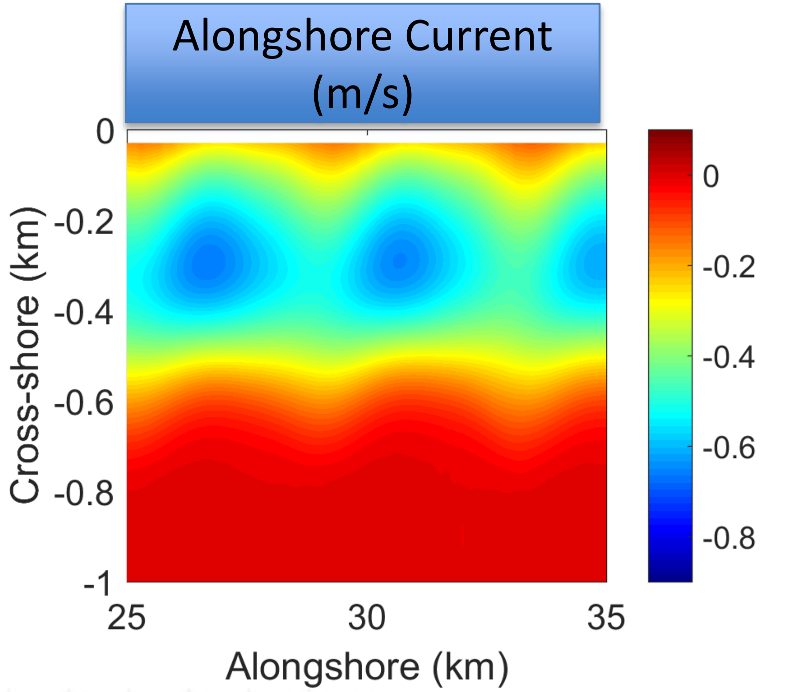
-15 degrees



EFFECT OF RIDGES







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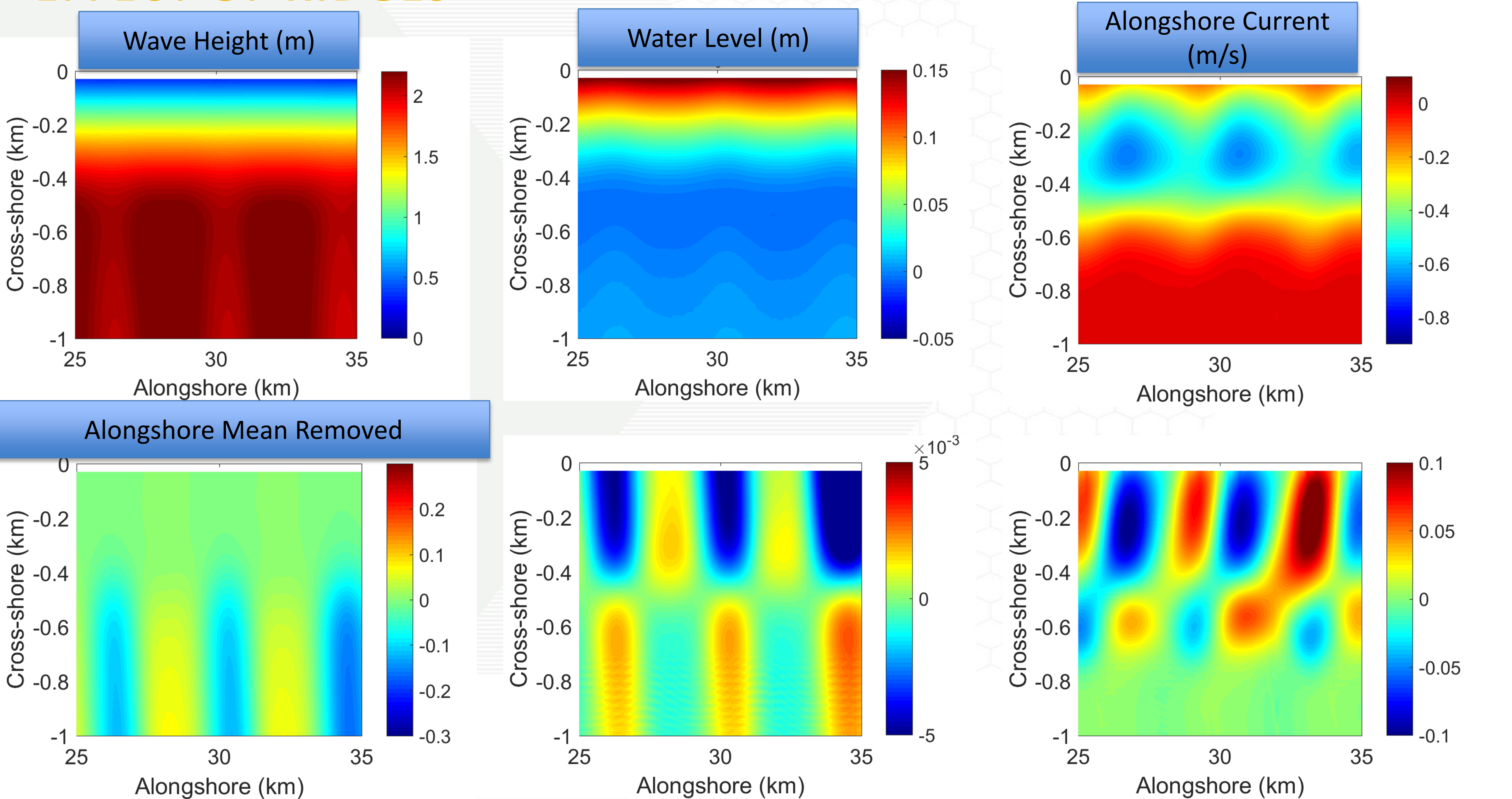

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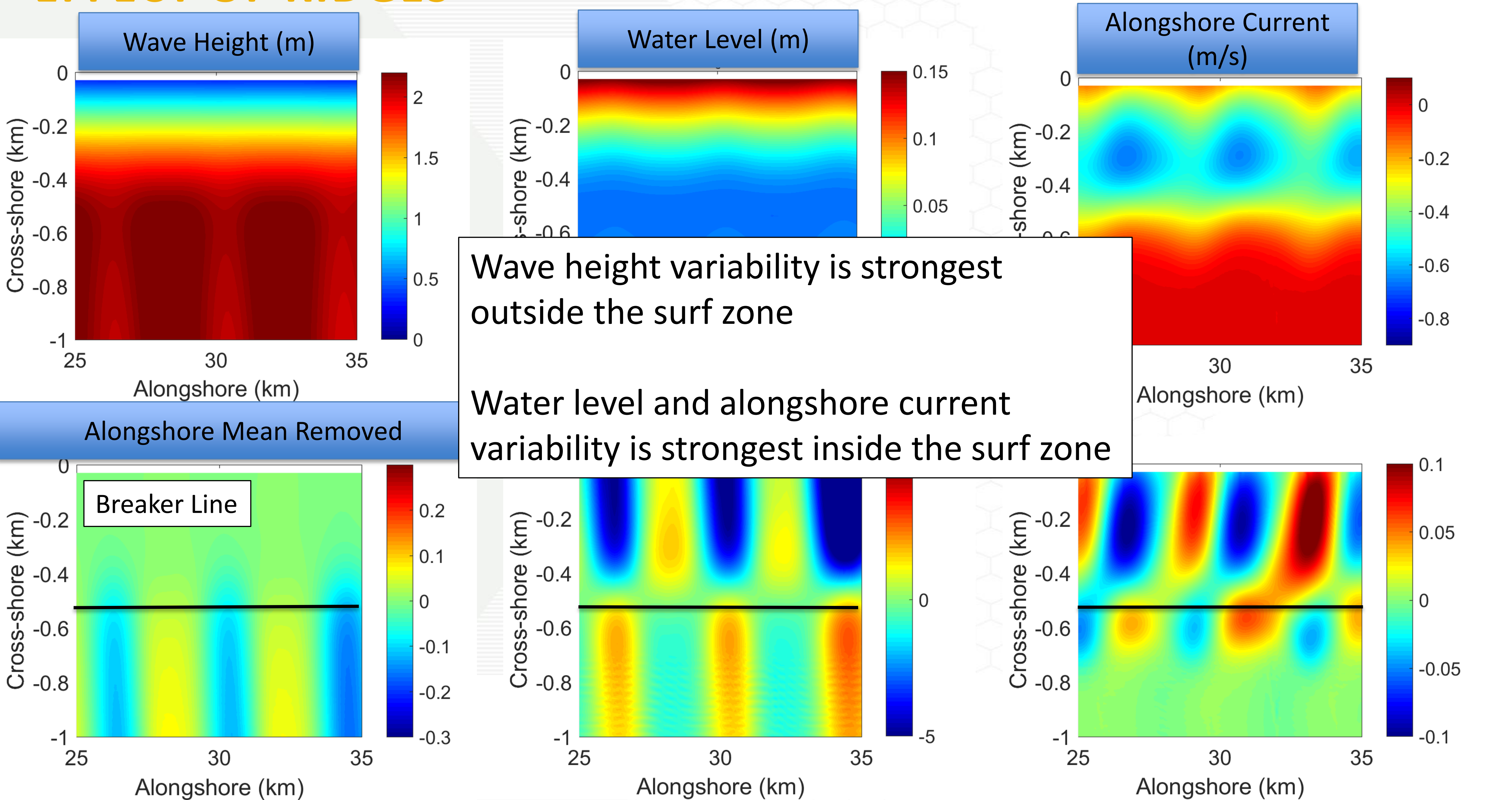
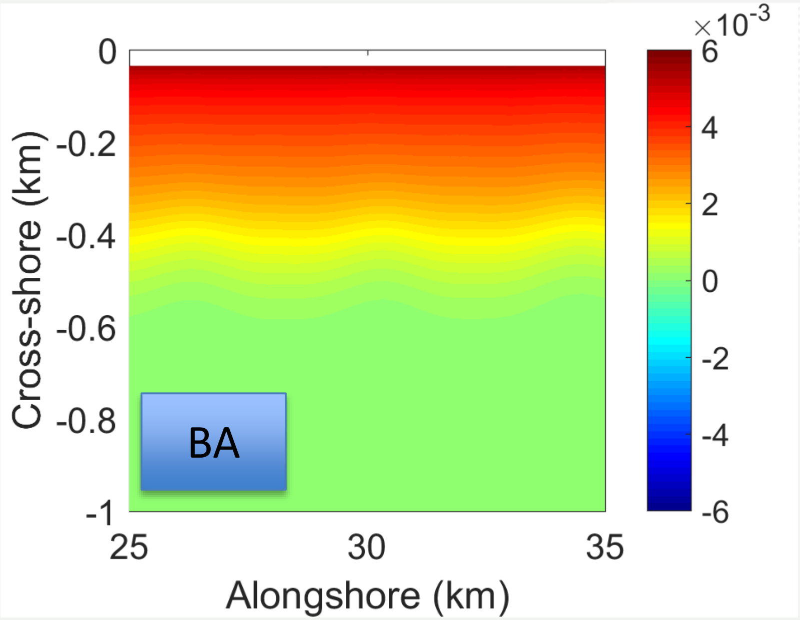
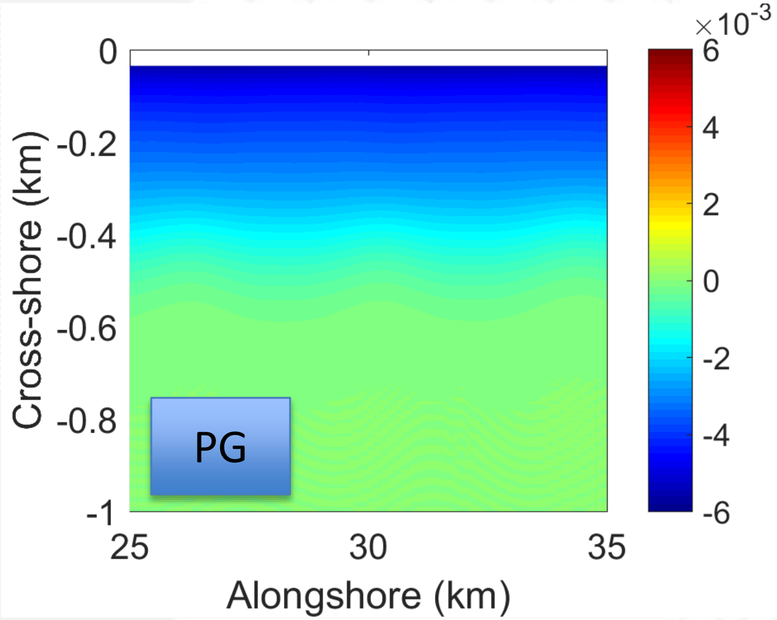


Wave height variability is strongest outside the surf zone

Water level and alongshore current variability is strongest inside the surf zone

CROSS-SHORE MOMENTUM BALANCE





BA – Breaking acceleration
PG – Pressure gradient
HA – Horizontal advection
VF – Vortex force
BS – Bottom stress

Primary cross-shore balance is between the wave forcing (BA) and the pressure gradient (PG)

CROSS-SHORE MOMENTUM BALANCE

BA – Breaking acceleration
PG – Pressure gradient
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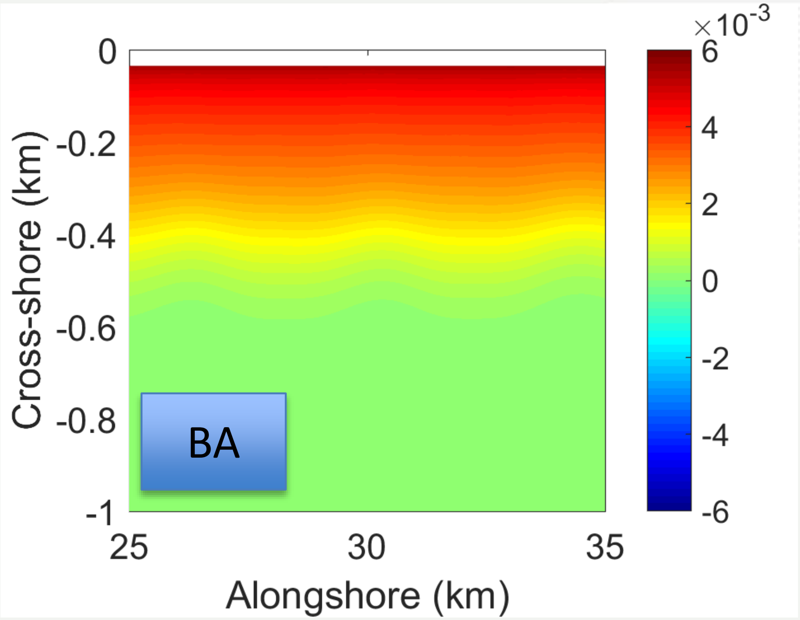
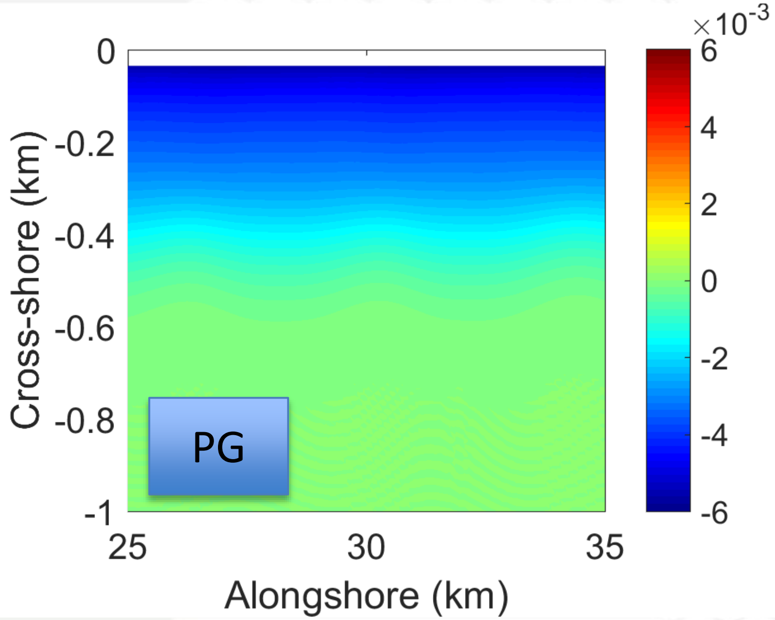
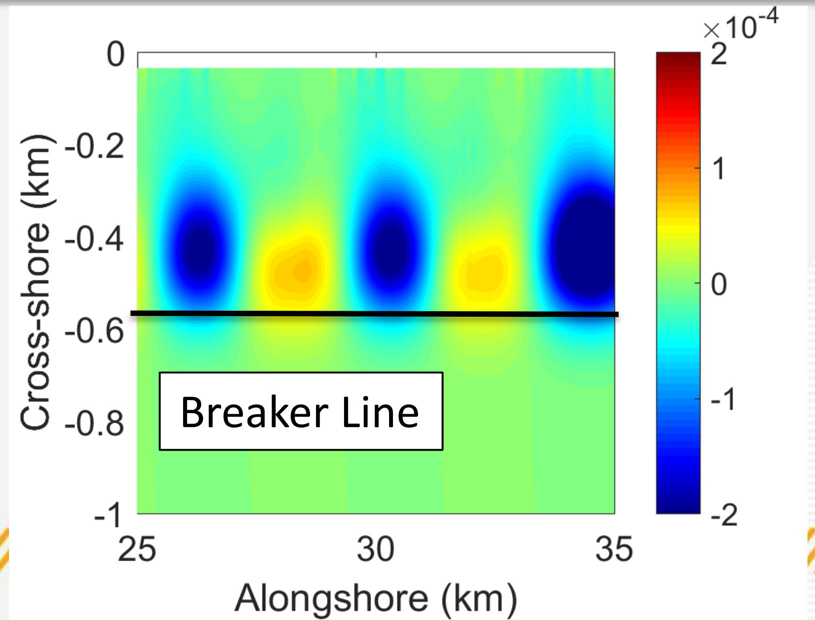


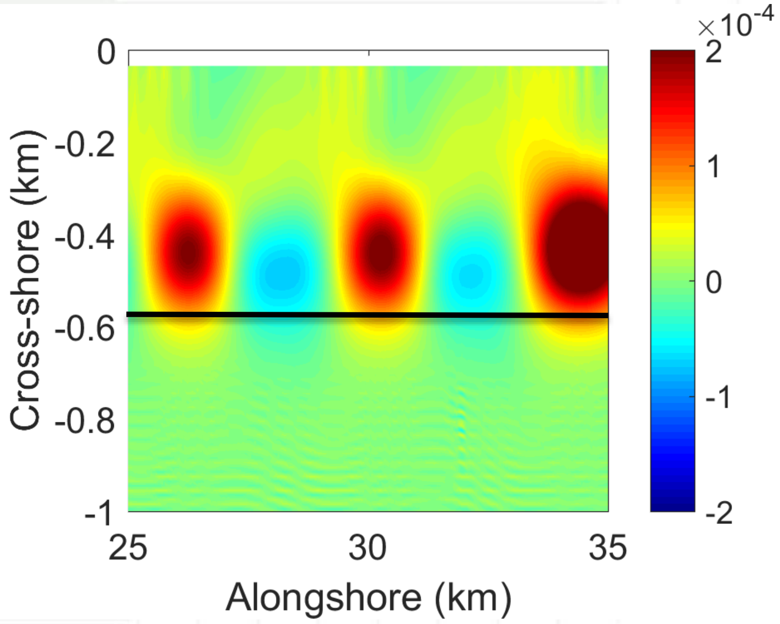


Primary cross-shore balance is between the wave forcing (BA) and the pressure gradient (PG)

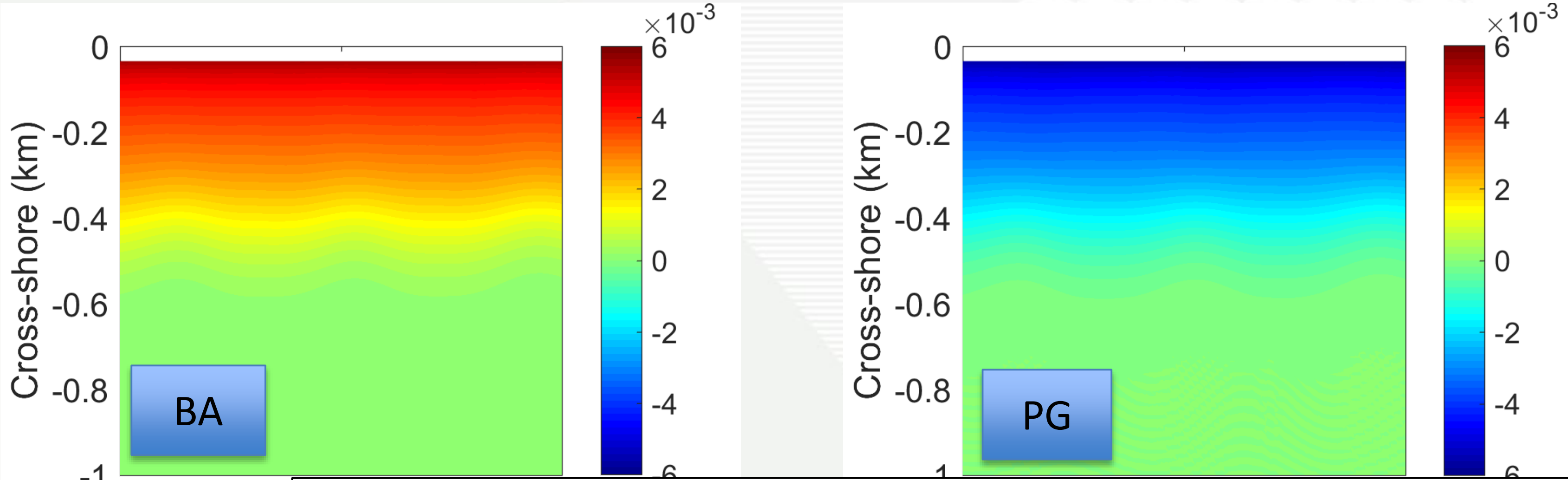
Strongest variability for wave forcing is inside the surf zone

Alongshore Mean Removed





CROSS-SHORE MOMENTUM BALANCE



BA – Breaking acceleration
PG – Pressure gradient
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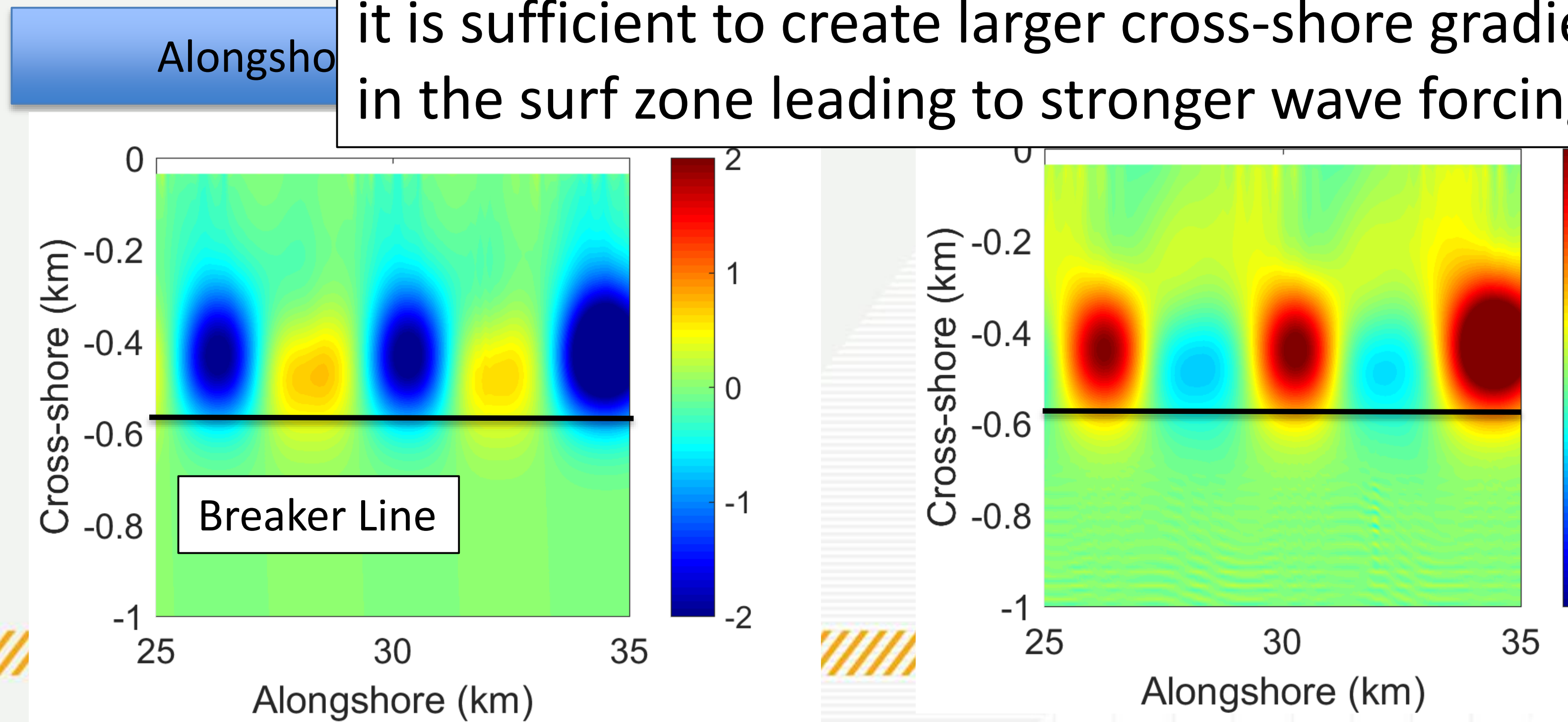
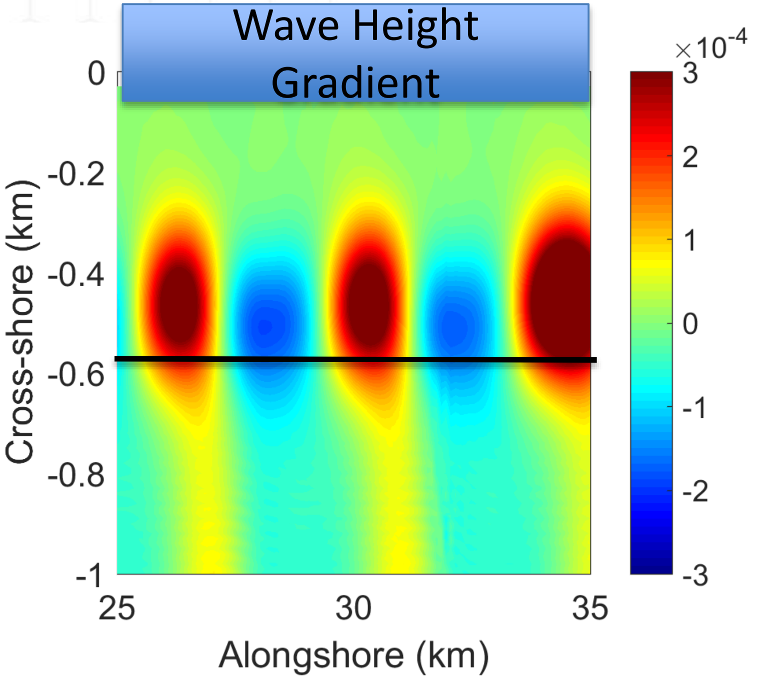
Primary cross-shore balance is between the wave forcing (BA) and the pressure gradient (PG)

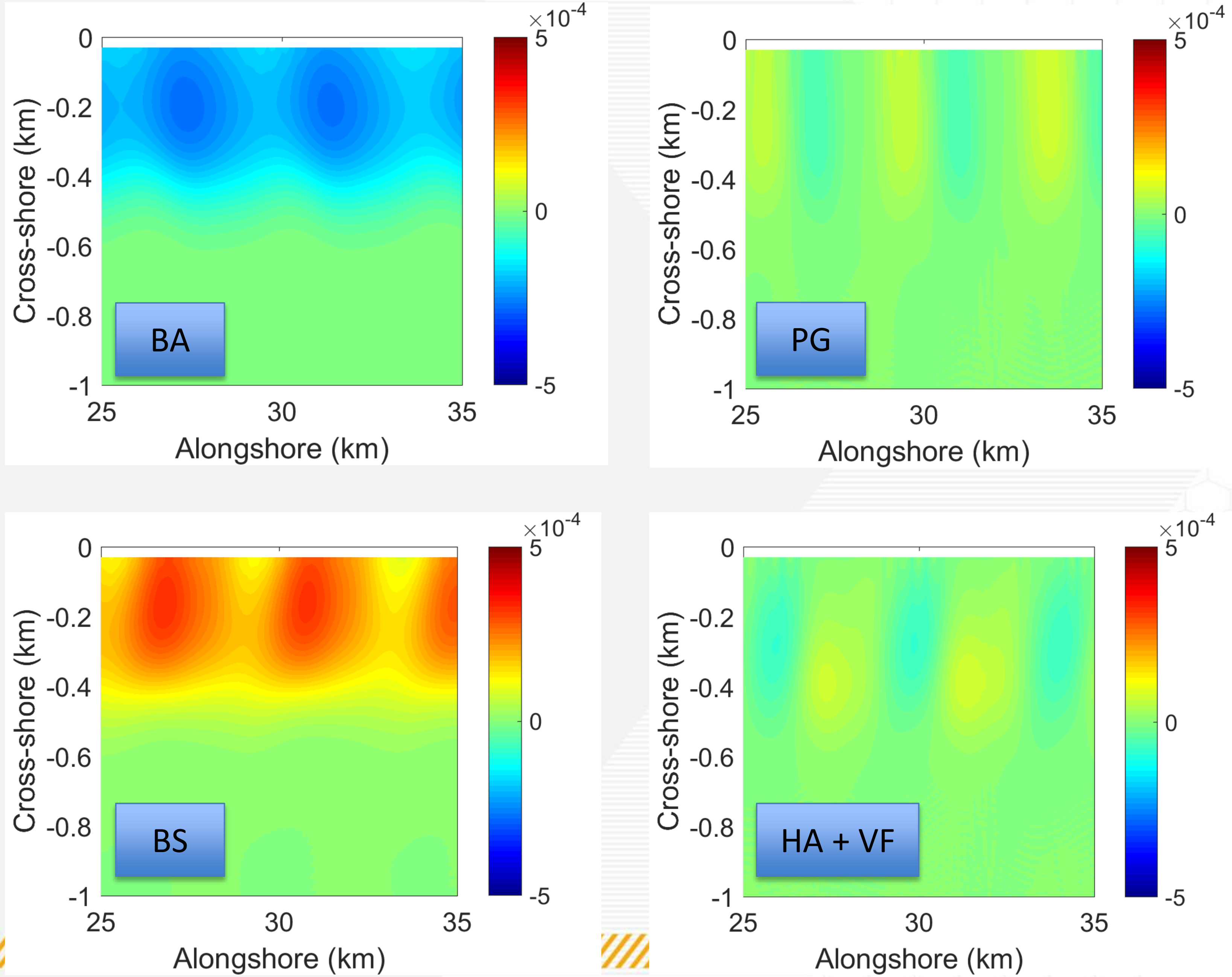
Although the wave height variability seemed small, it is sufficient to create larger cross-shore gradients in the surf zone leading to stronger wave forcing

Strongest variability for wave forcing is inside the surf zone





ALONGSHORE MOMENTUM BALANCE

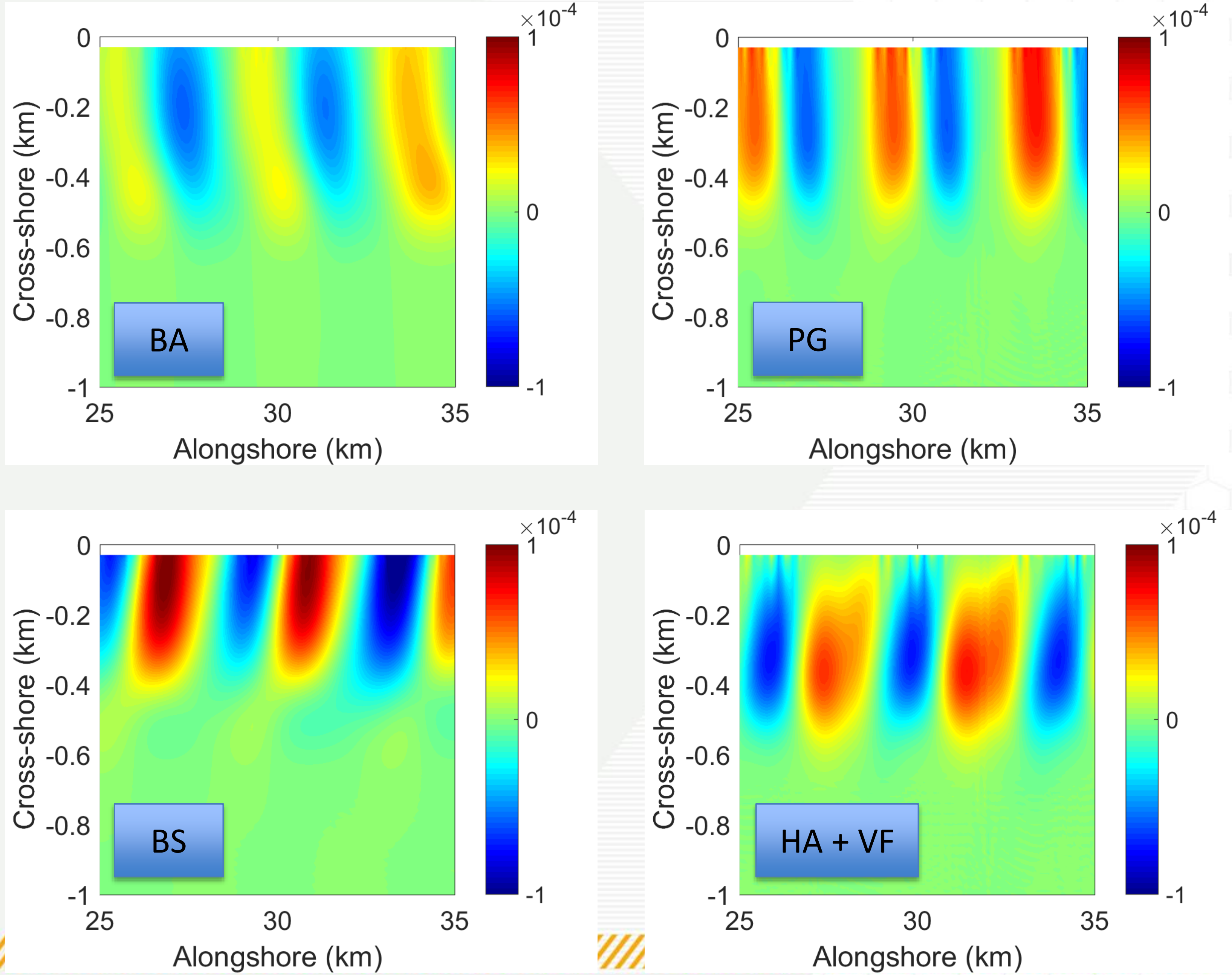


BA – Breaking acceleration
PG – Pressure gradient
HA – Horizontal advection
VF – Vortex force
BS – Bottom stress

The biggest terms in the alongshore balance are the the wave forcing (BA) and the bottom stress (BS)

Other terms are smaller but still important (PG, HA+VF)

ALONGSHORE MOMENTUM BALANCE (alongshore mean removed)



BA – Breaking acceleration
PG – Pressure gradient
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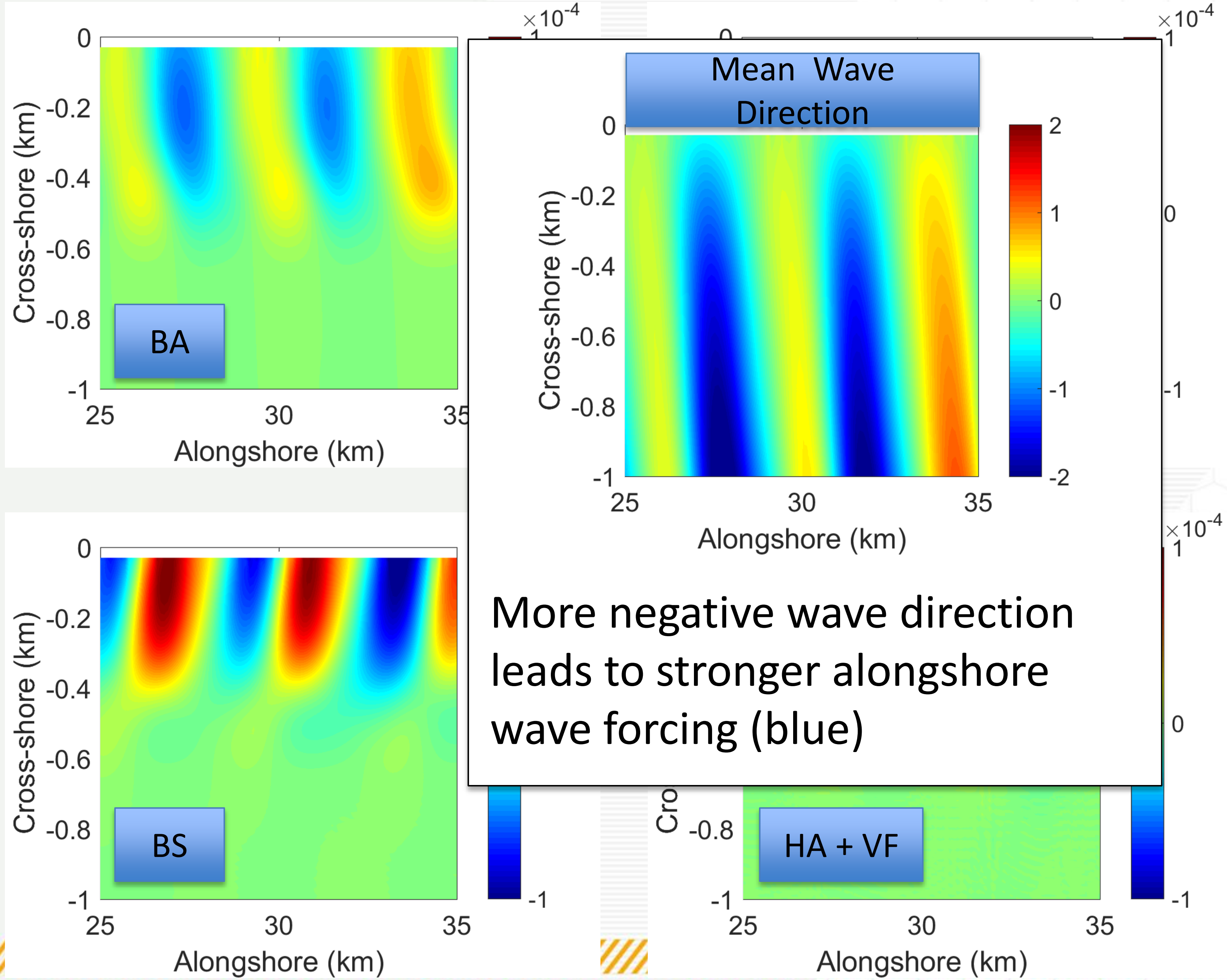
BS – Bottom stress

All terms contribute to the alongshore current variability

ALONGSHORE MOMENTUM BALANCE (alongshore mean removed)

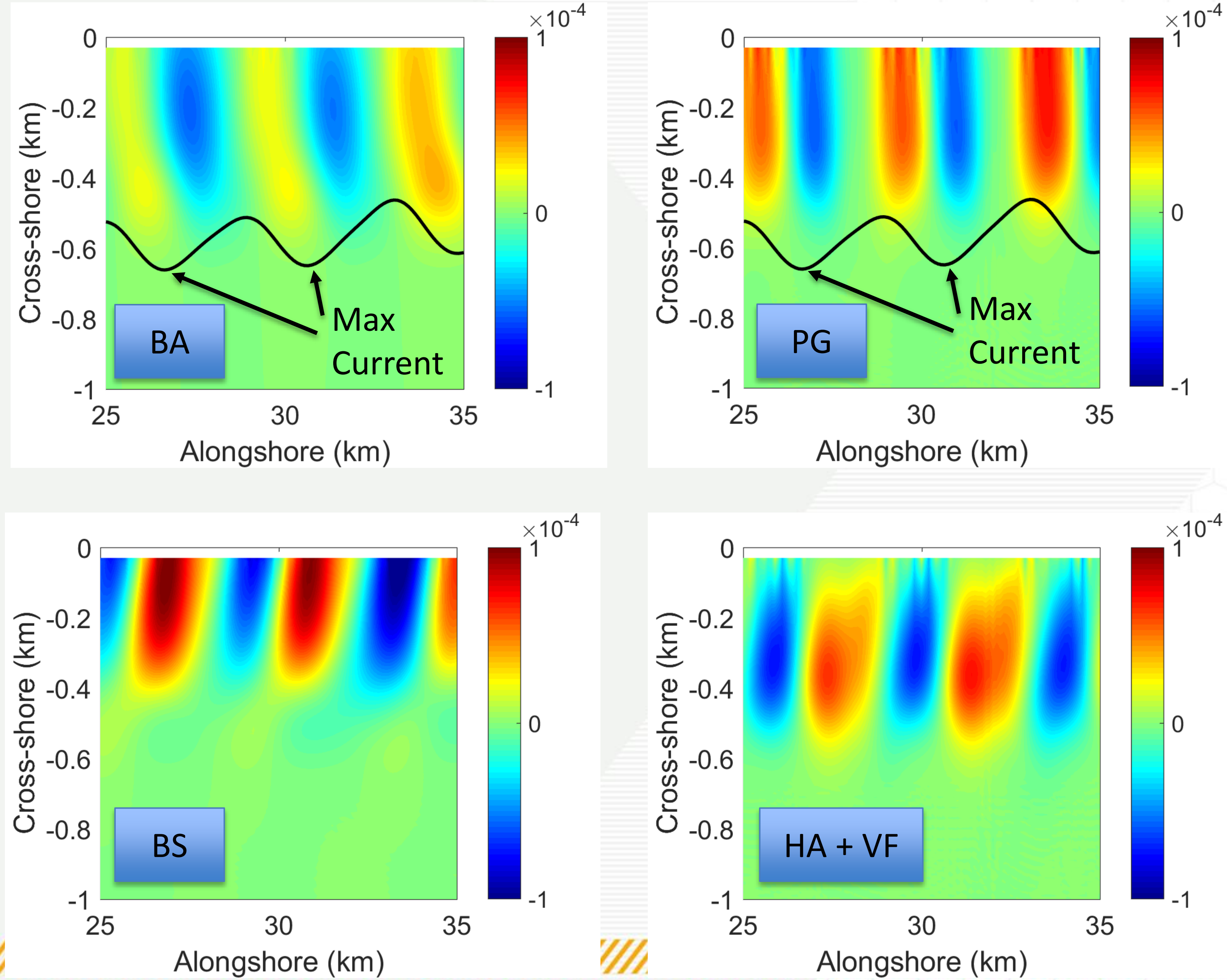


More negative wave direction leads to stronger alongshore wave forcing (blue)

BA – Breaking acceleration
PG – Pressure gradient
HA – Horizontal advection
VF – Vortex force
BS – Bottom stress

All terms contribute to the alongshore current variability

ALONGSHORE MOMENTUM BALANCE (alongshore mean removed)



BA – Breaking acceleration
PG – Pressure gradient
HA – Horizontal advection
VF – Vortex force
BS – Bottom stress

All terms contribute to the alongshore current variability

Both PG and BA contribute to the increase in current (blue) but with a spatial lag created by the horizontal acceleration

ALONGSHORE SEDIMENT TRANSPORT

CERC Formula

$$Q_c = \frac{K(ECn\cos\theta\sin\theta)_b}{\rho(s-1)g(1-p)}$$

$$E = \frac{1}{8}\rho g H_b^2, n = \frac{1}{2}(1 + \frac{2kh}{\sinh 2kh})$$

GENESIS Formula

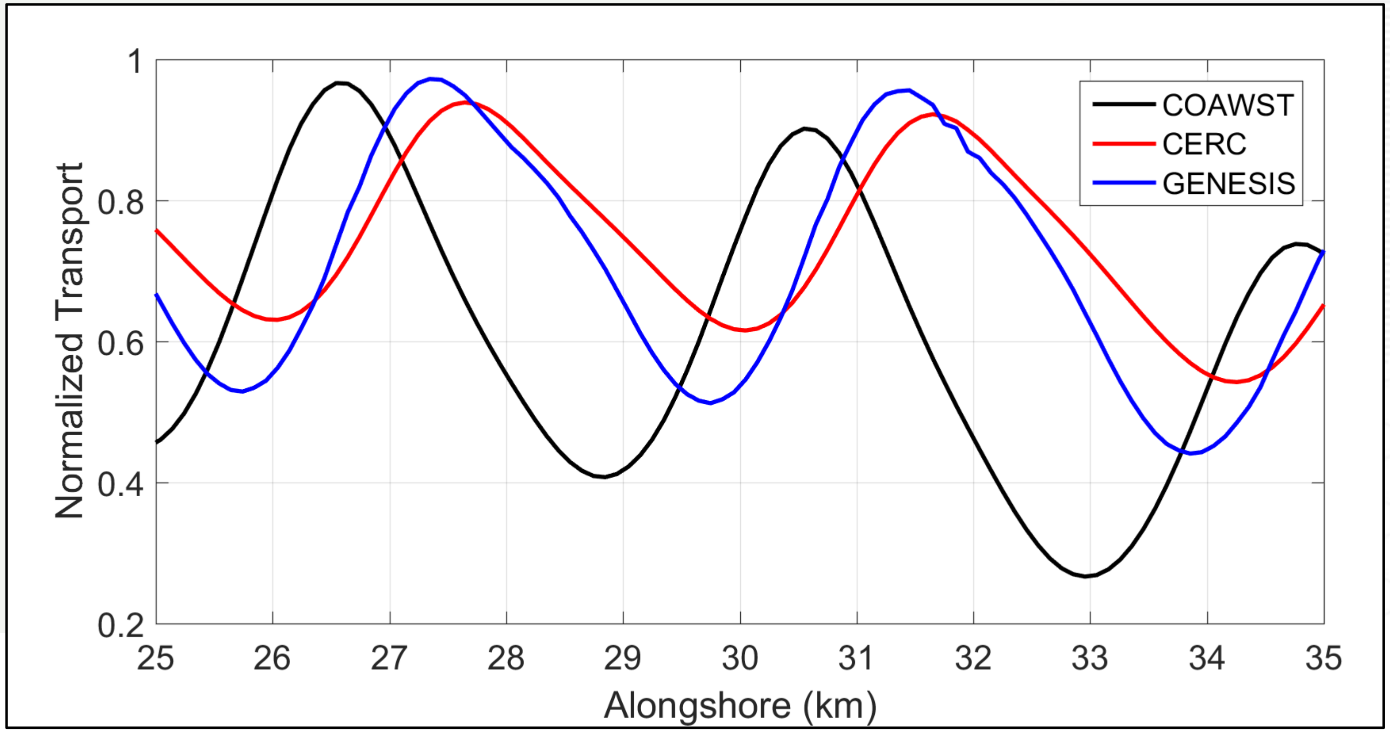
$$Q_c = \left[H^2 Cn\left(a_1 sin2\theta - a_2 cos\,\theta\frac{dH}{dy}\right)\right]_b$$

COAWST

Suspended Load

Bed Load - Meyer-Peter Müeller (1948)

Alongshore transport normalized by the maximum transport



More than 1km difference for locations of peaks in transport

CERC – Peak transport matches maximum wave height/direction

GENESIS – Peak shifted to left based on location of maximum wave height gradient

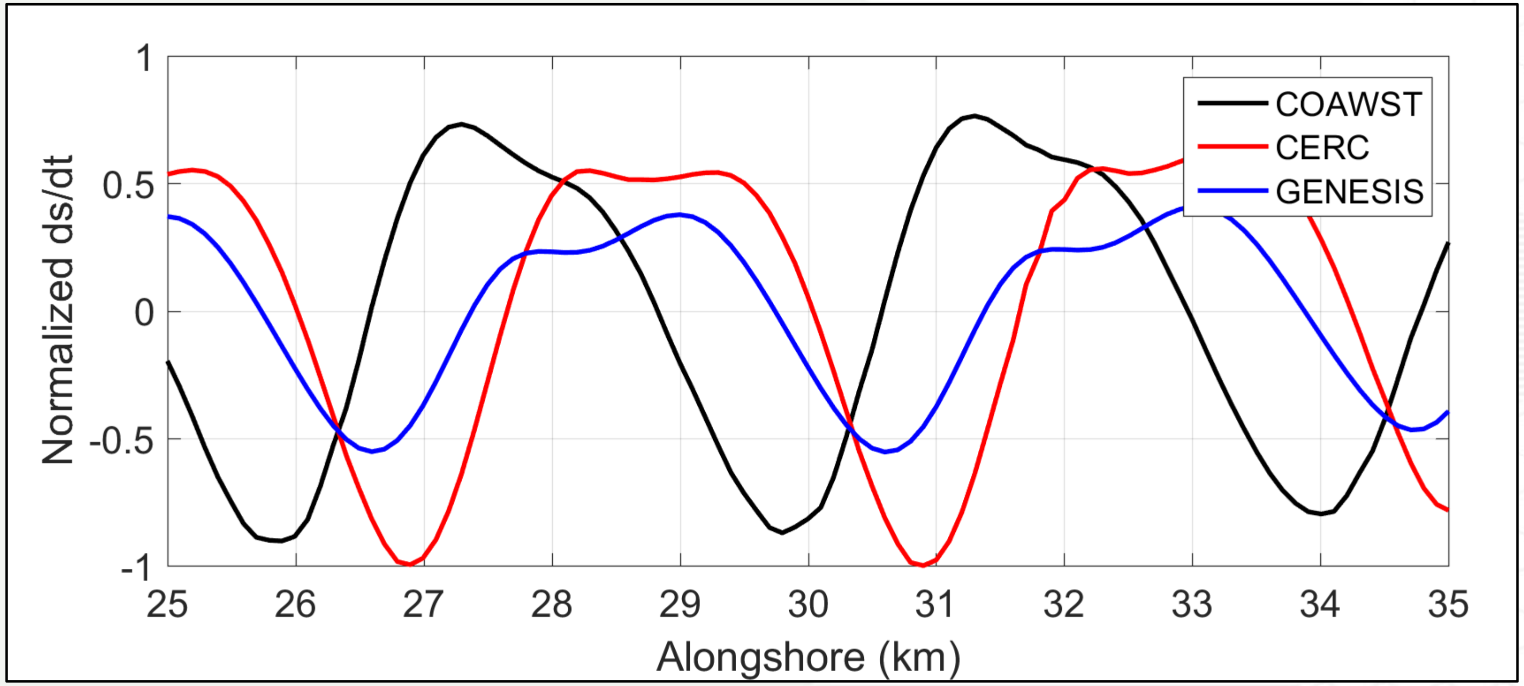
COAWST – Peak shifted further left due to location of maximum alongshore currents

SHORELINE CHANGE

- Standard Shoreline Continuity Equation

$$\frac{\partial s}{\partial t} = -\frac{1}{h_*}\frac{\partial Q_l}{\partial y}$$

Similar shift in maximum erosion

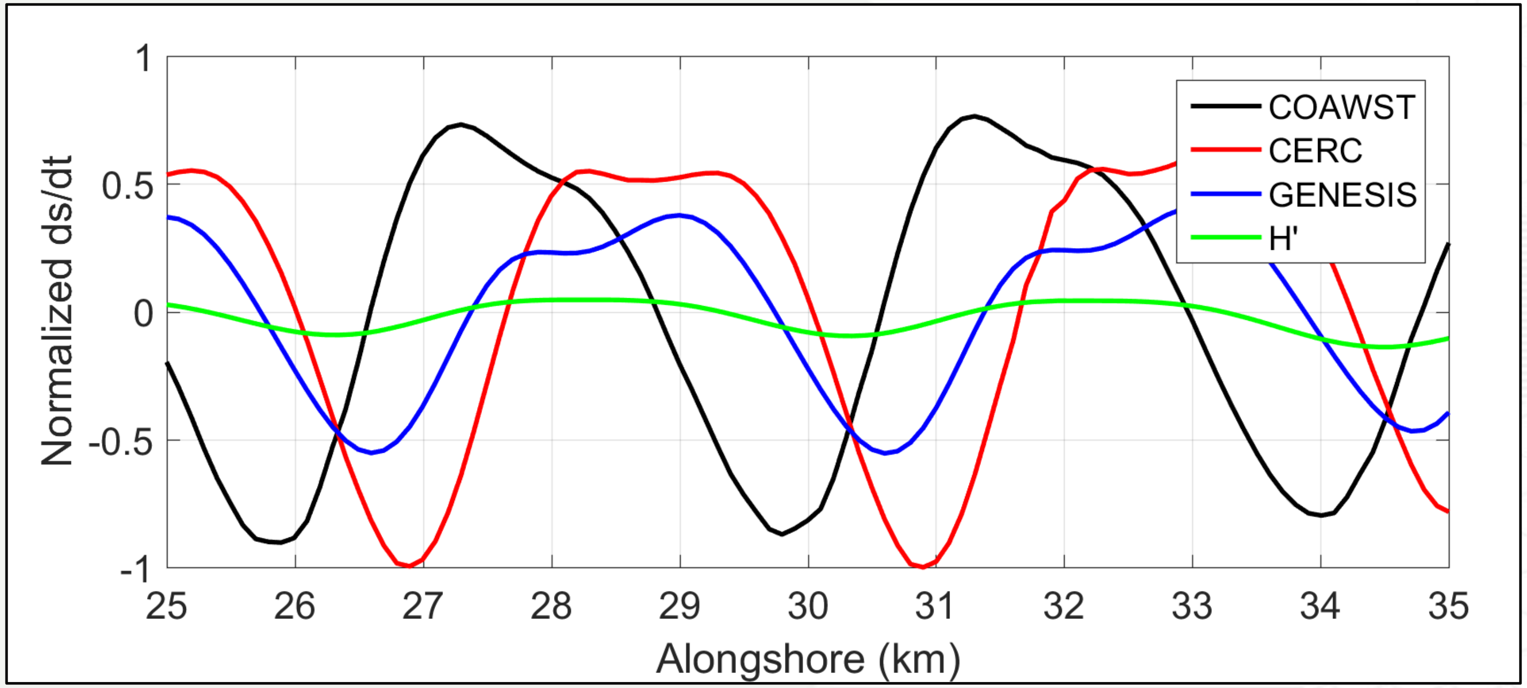


Negative values indicate erosion

ALONGSHORE SEDIMENT TRANSPORT

- Standard Shoreline Continuity Equation

$$\frac{\partial s}{\partial t} = -\frac{1}{h_*}\frac{\partial Q_l}{\partial y}$$



Negative values indicate erosion

Similar shift in maximum erosion

Maximum erosion for CERC and GENESIS occurs upstream of the minimum wave height

Maximum erosion for COAWST occurs downstream of the minimum wave height

CONCLUSIONS

- The ridges serve as a wave guide, leading to wave focusing/defocusing, dependent on the incoming wave direction

- Variability in the wave forcing leads to alongshore variations in the setup

- Resulting pressure gradients together with alongshore wave forcing drive variations in the alongshore currents

- The locations of the peak currents are shifted due to horizontal advection

- The alongshore transport and shoreline change is correspondingly affected

- All formulations for computing the alongshore transport have variations with the same alongshore scale as the ridges; however, the specific locations differ

Thank You