BOSTON UNIVERSITY

The importance of coastal headlands on reducing nearshore hydrodynamic forces under climate change

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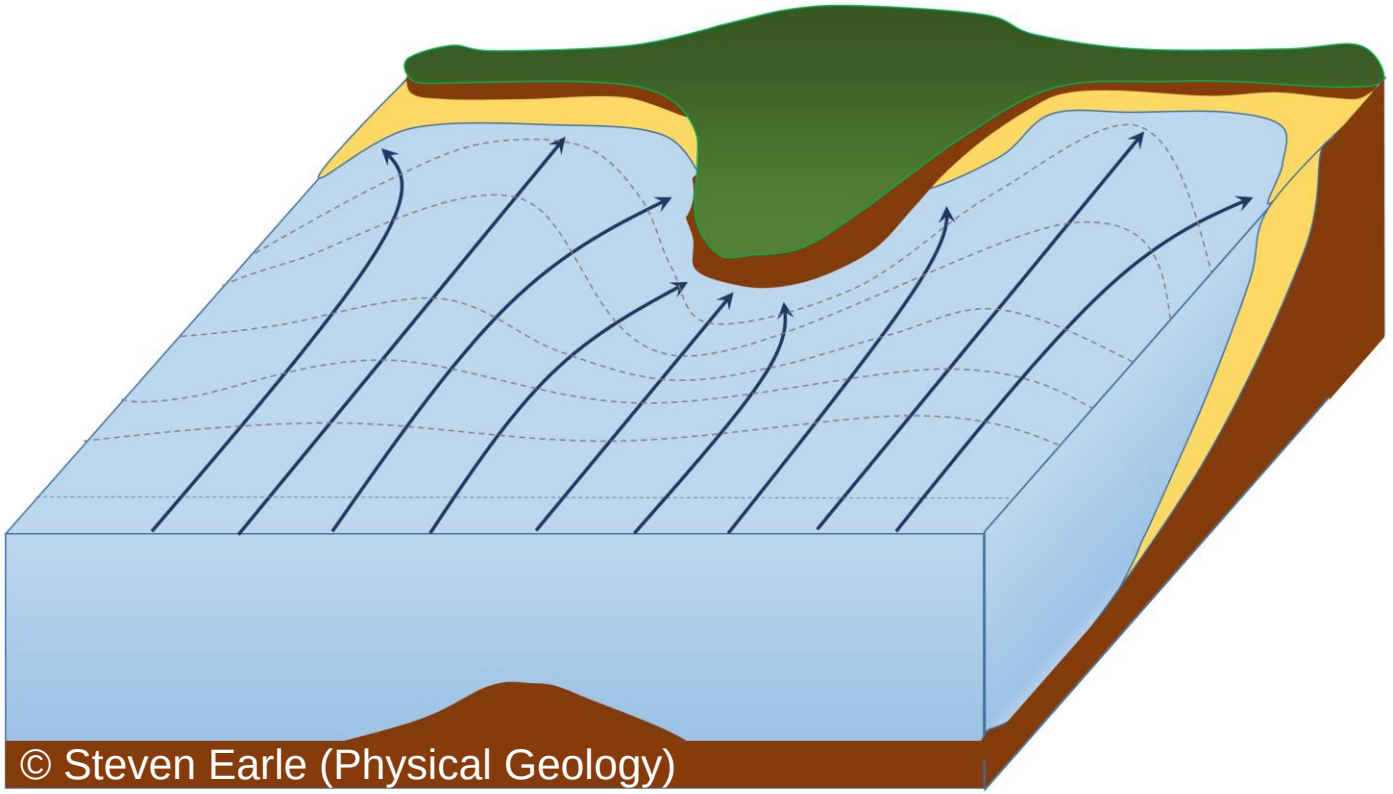
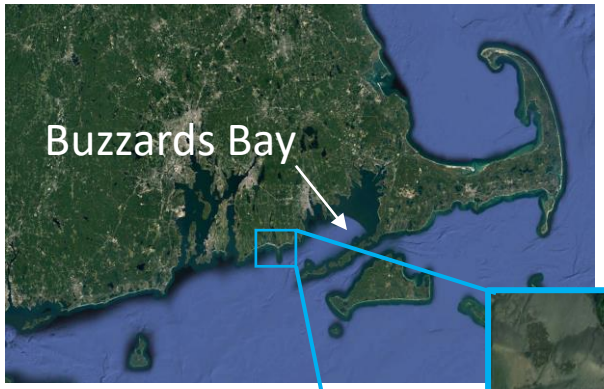
Common… and important!

But how will they disturb nearshore hydrodynamics in future?



Headland at Outer Buzzards Bay



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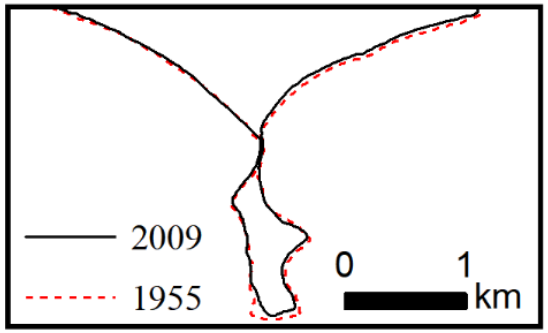
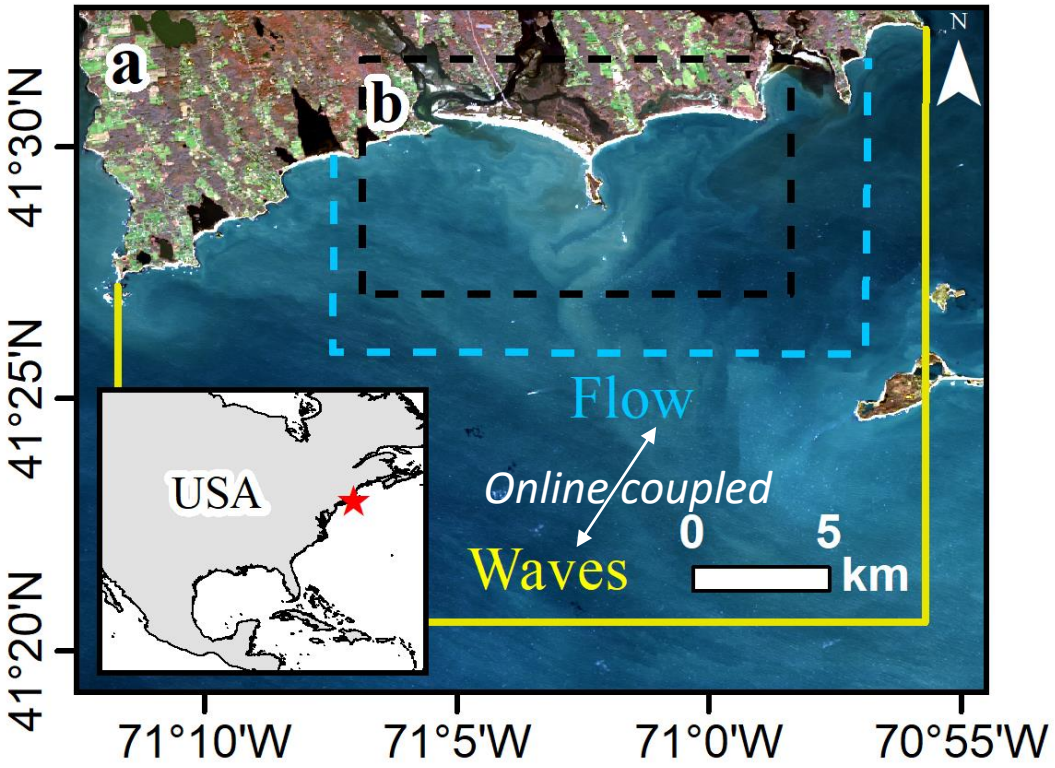
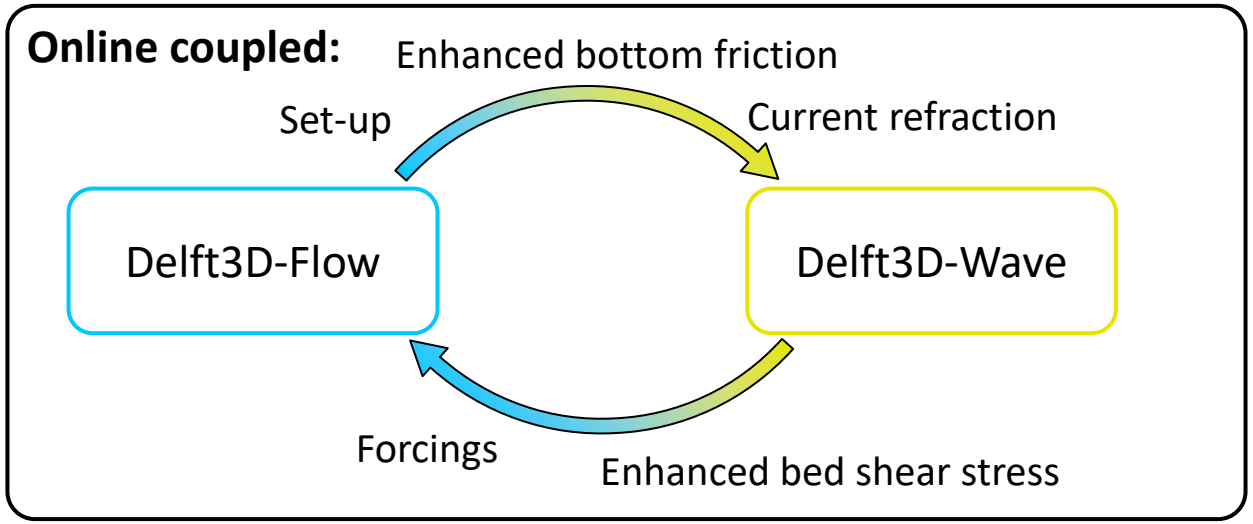


Slightly erosion

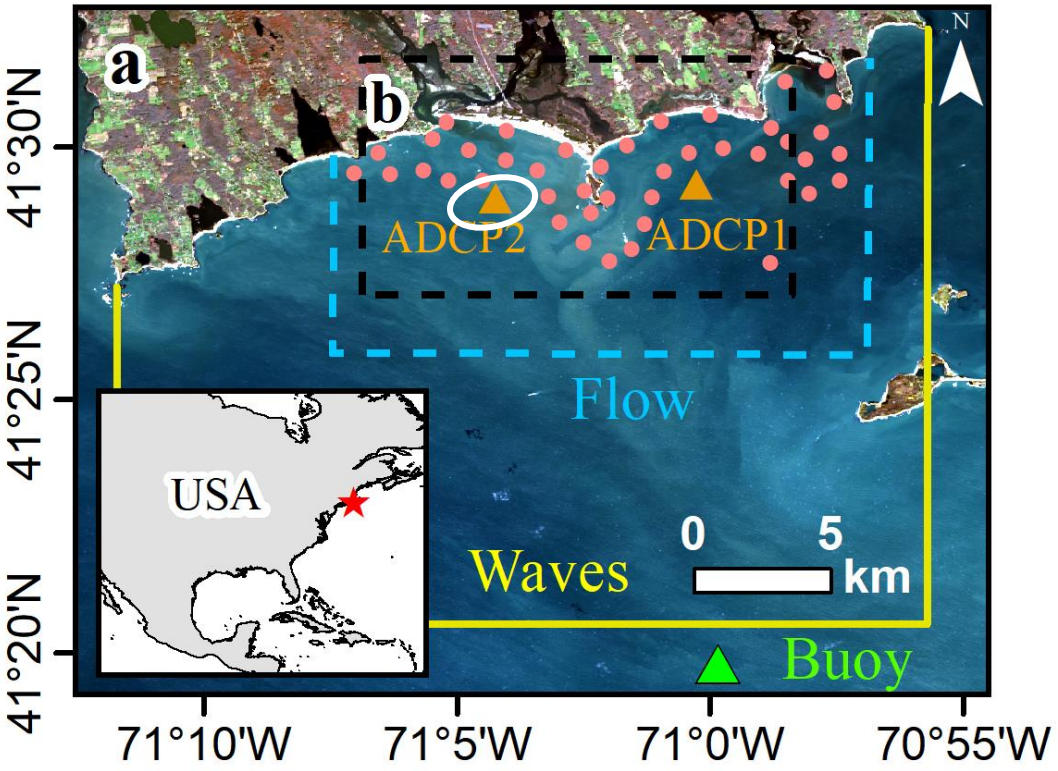
Beach at Outer Buzzards Bay

Development of Delft3D Flow-Wave Model



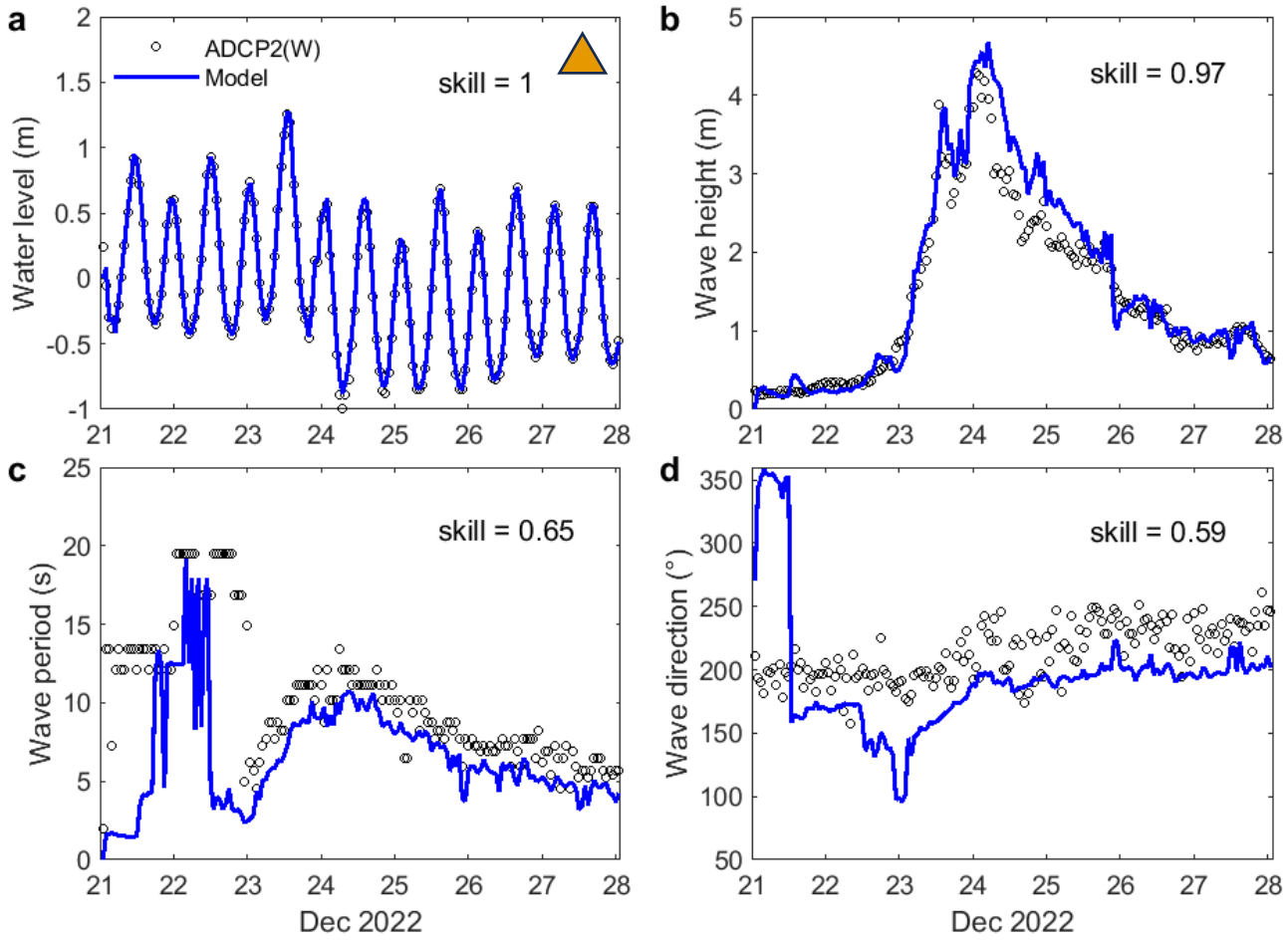


Development of Delft3D Flow-Wave Model

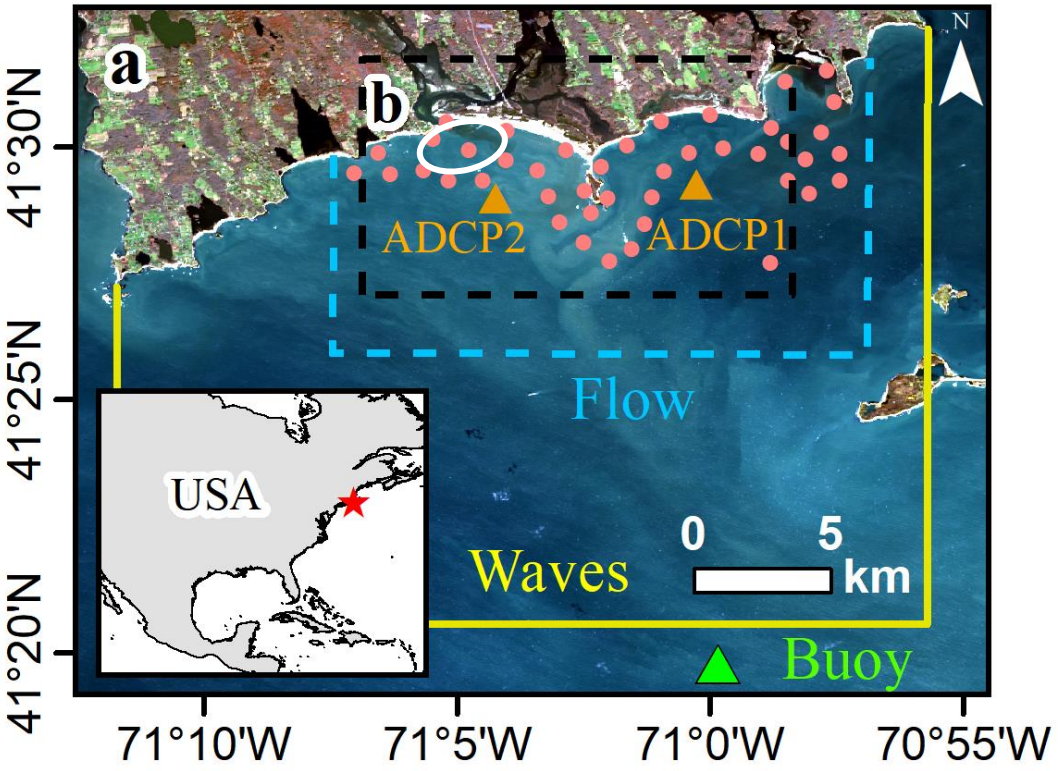


● ▲ : **Validation points**

Winter Storm Elliot 2022

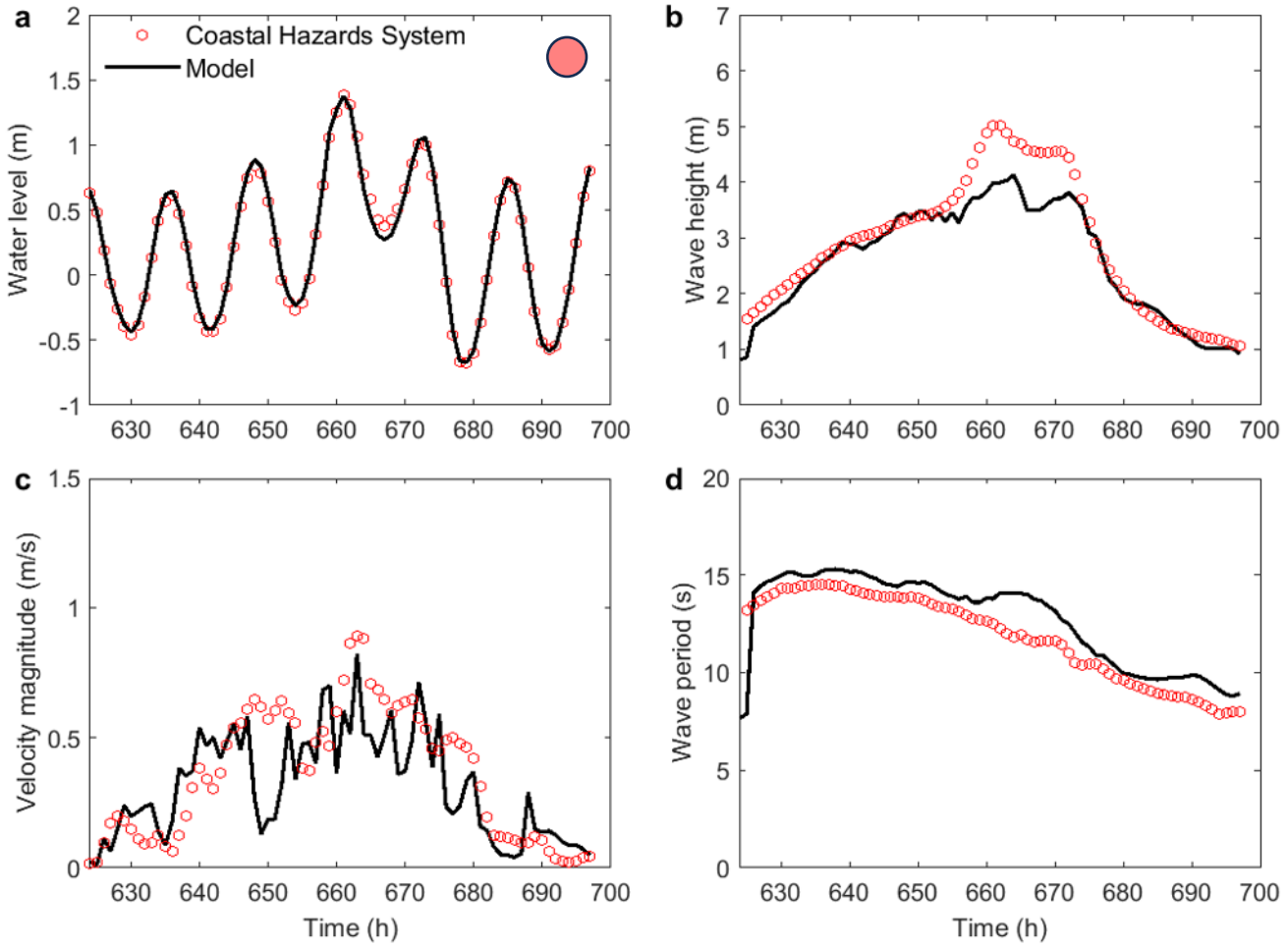


Development of Delft3D Flow-Wave Model

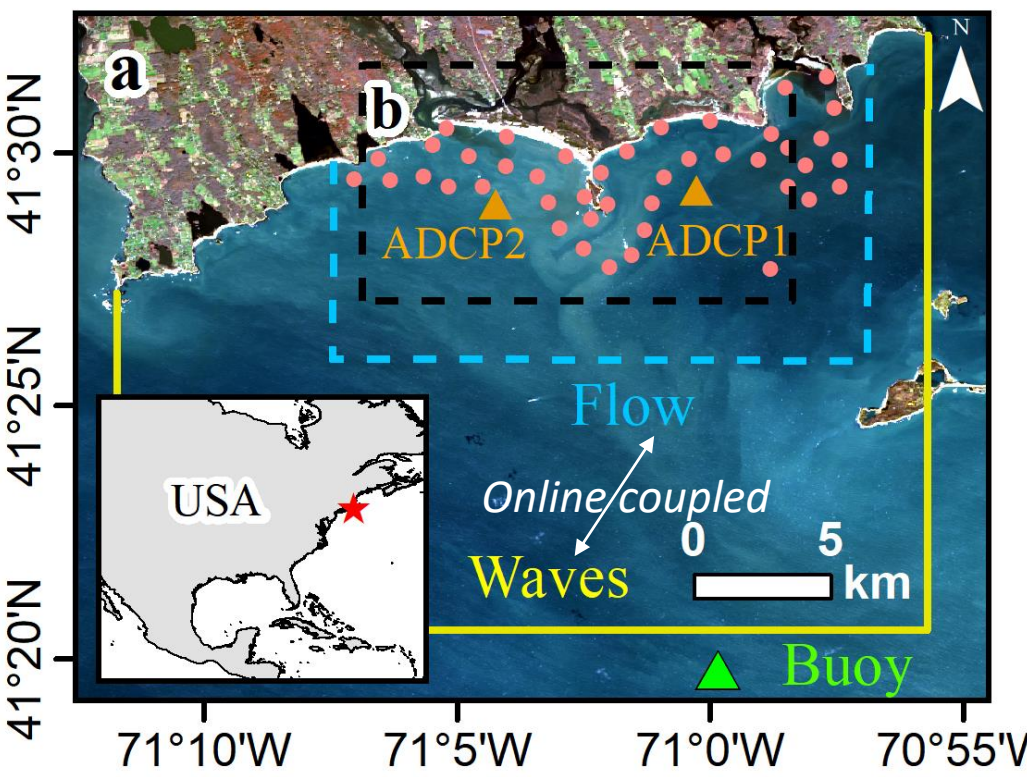


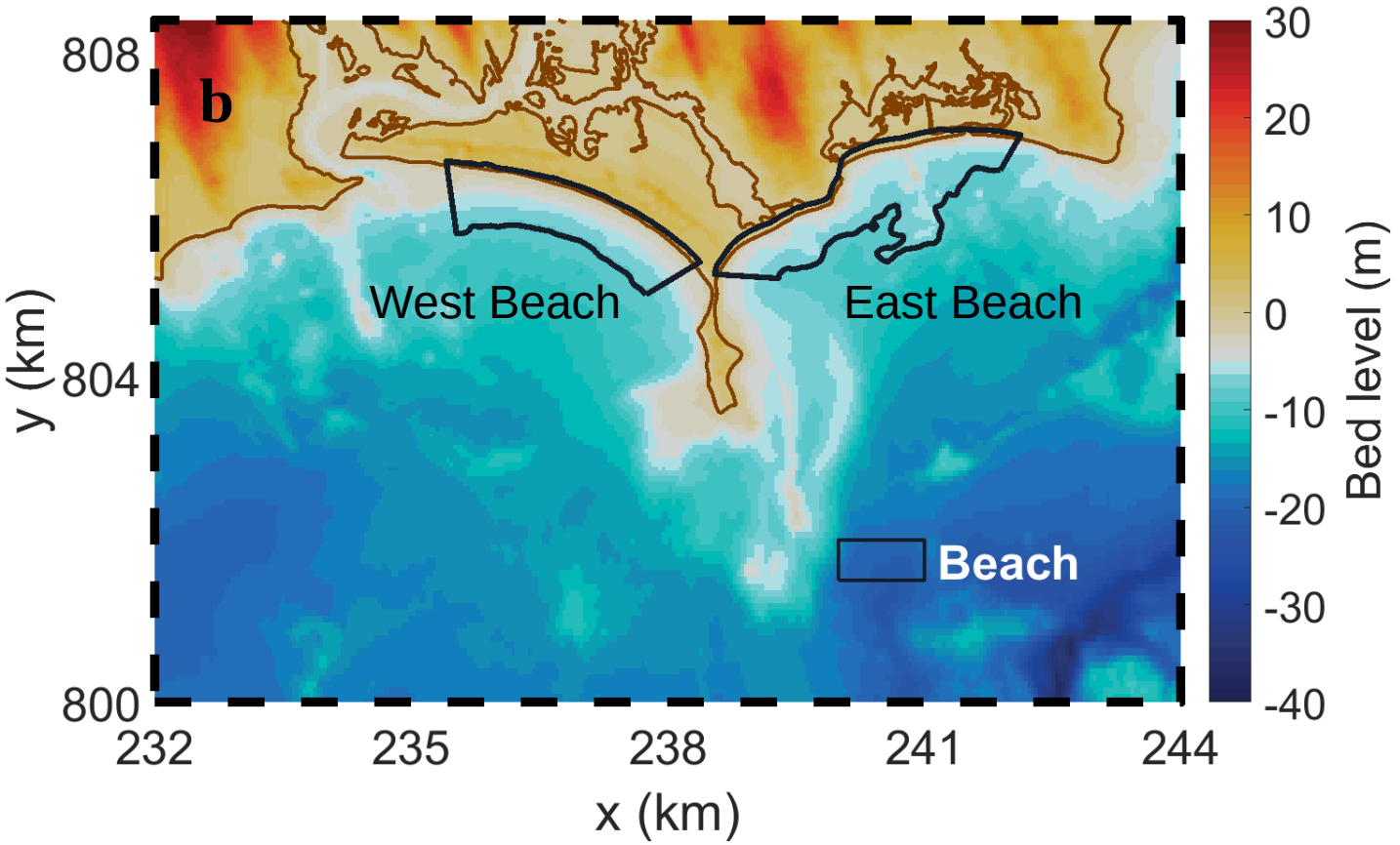
● ▲ : **Validation points**

Tropical cyclone Irene in 2011



West Beach and East Beach

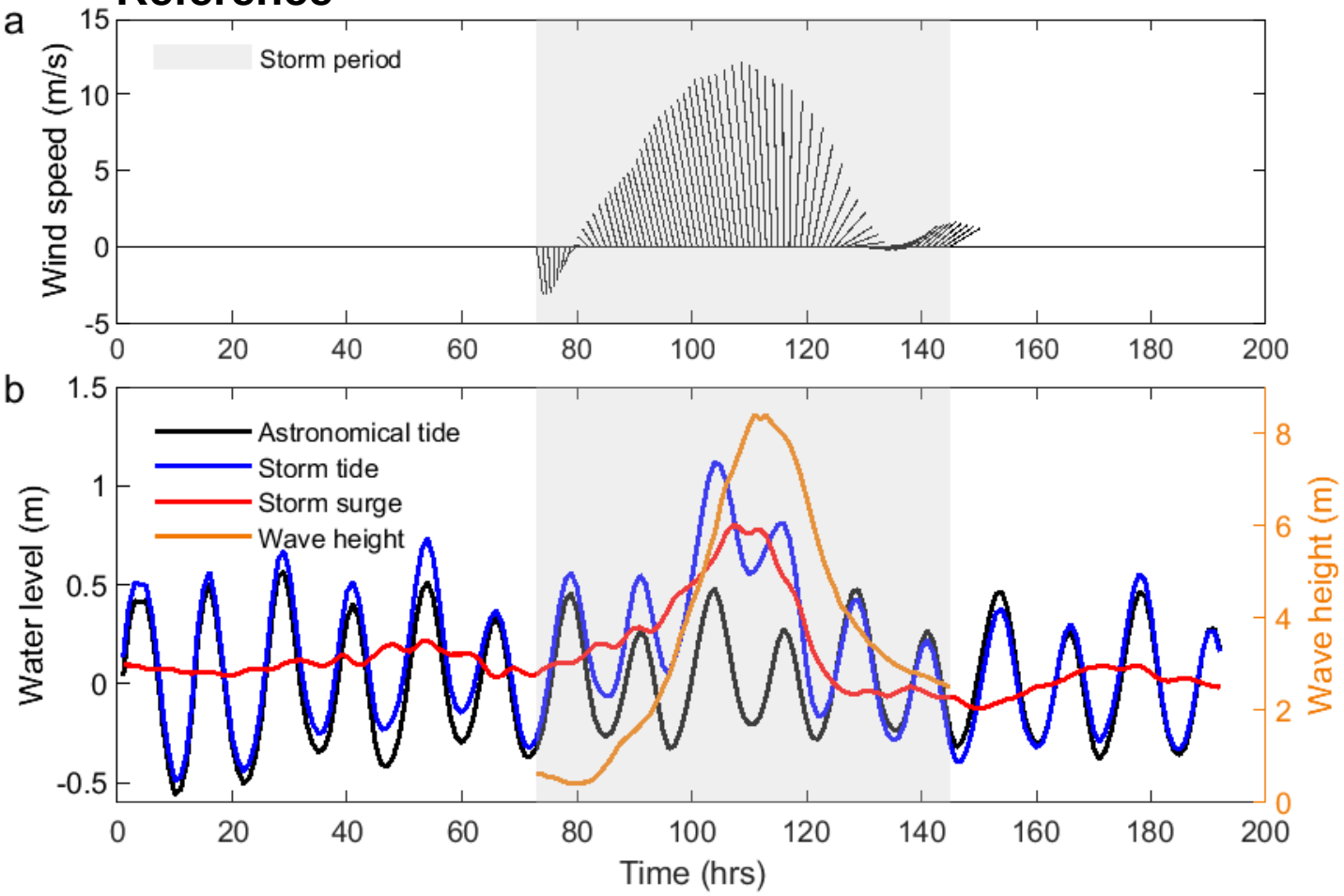




- For hydrodynamic forces comparisons
- Boundary is determined by the depth of closure (beyond which less morphologic changes are expected; 8 m)

Model boundary conditions

Reference



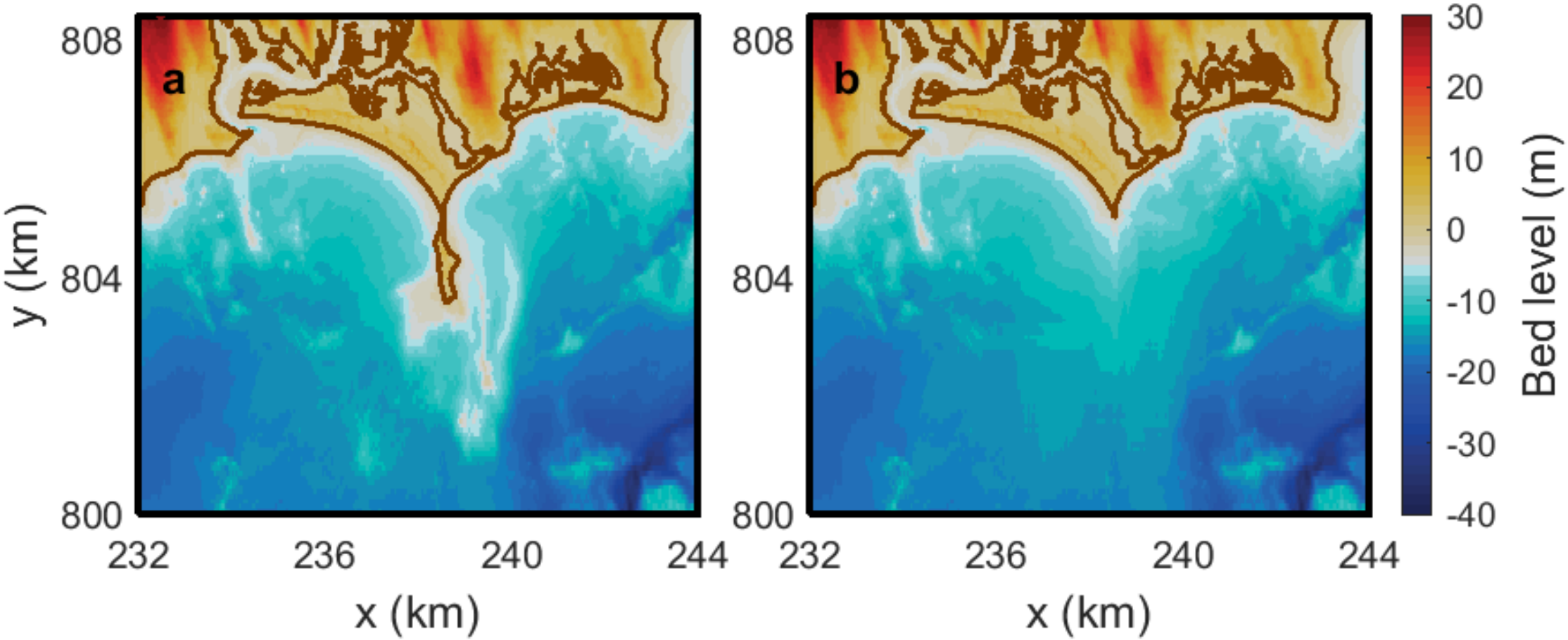
Reference run: 1938 winter storm

- Storm surge: 0.7 m
- Peak wave height: 8 m (every 5 years)

Model scenarios:

No.	Group	Peak storm wave height; m	Sea-level rise (m)	Note
1	Present-day scenario	8	0	Reference
2	Larger storm waves	10	0	SW 10m
3		12		SW 12m
4		14		SW 14m
5	Sea-level rise	8	0.25	SLR 0.25m
6			0.5	SLR 0.5m
7			0.75	SLR 0.75m
8			1	SLR 1m

To quantify the role of the headland, I removed the island and made a new bathymetry



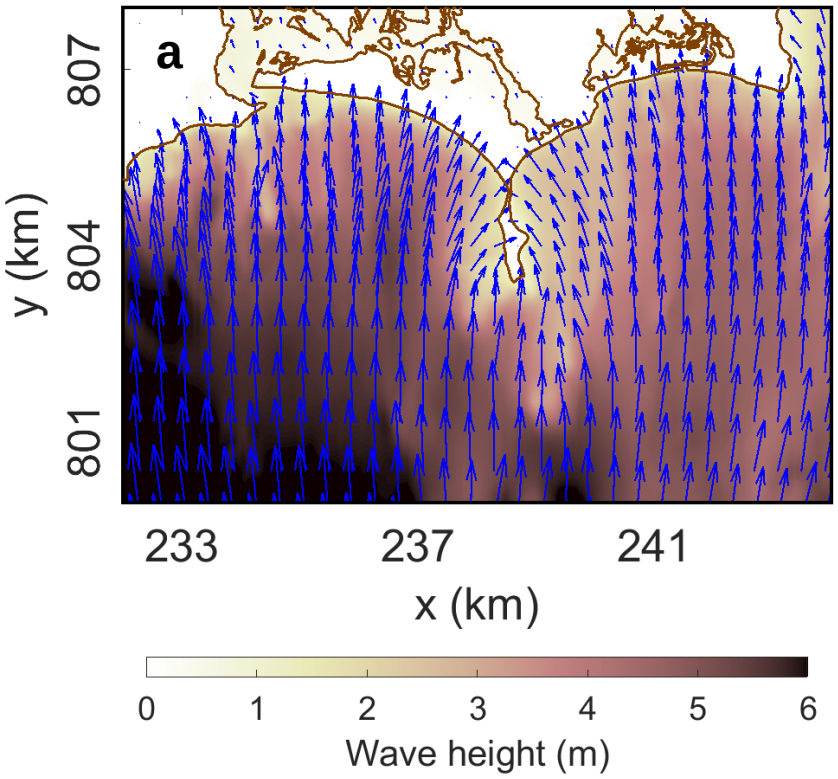
Bathymetry with vs. without headland

Hydrodynamic convergence around headland

Waves **Flow** **Forces**

Hydrodynamic convergence around headland

Waves



Flow

Forces

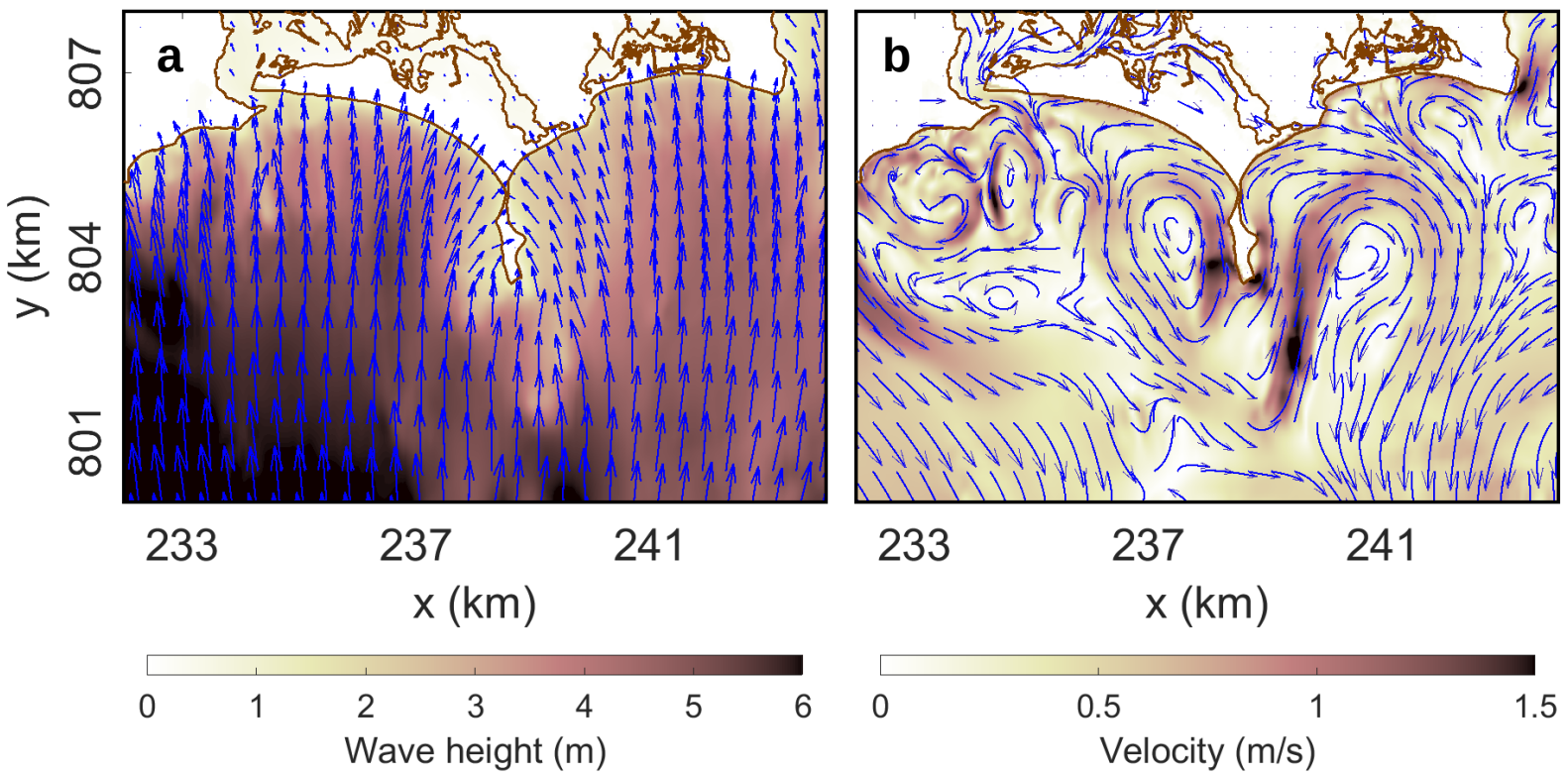
- Wave diffraction
- Wave height is higher on west

Hydrodynamic convergence around headland

Waves

Flow

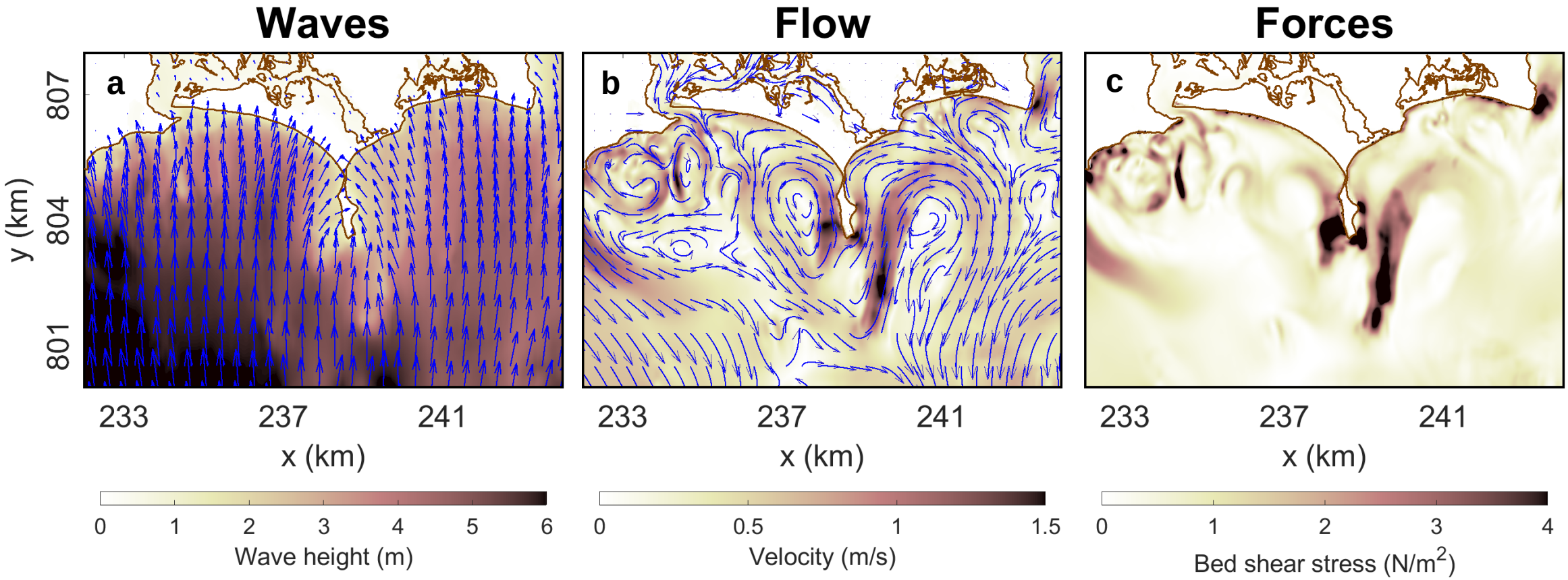
Forces



- Wave diffraction
- Wave height is higher on west

- Two circulation cells formed
- Higher around the headland

Hydrodynamic convergence around headland

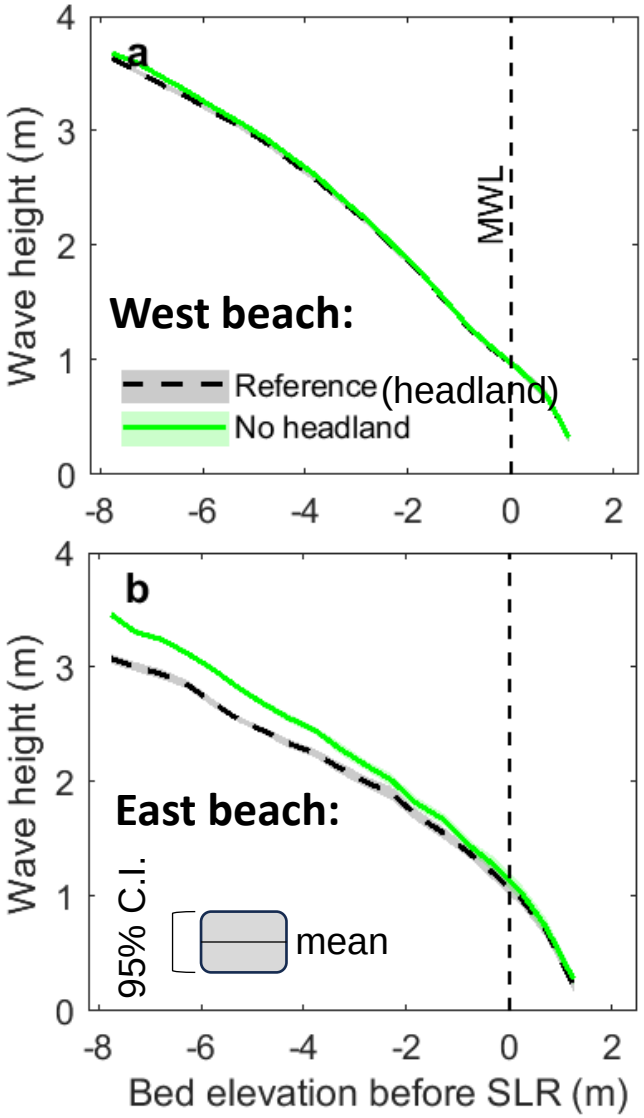


- Wave diffraction
- Wave height is higher on west

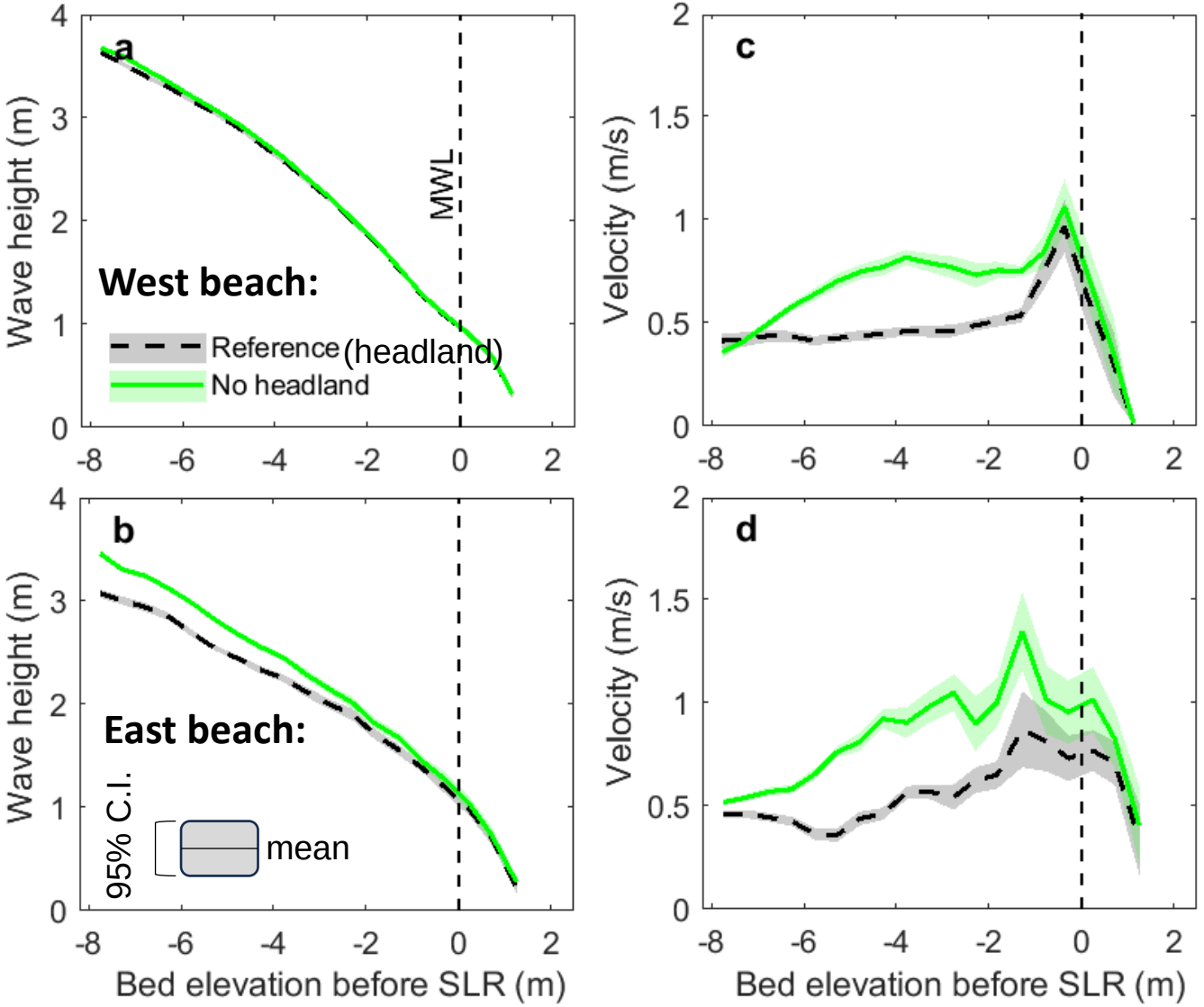
- Two circulation cells formed
- Higher around the headland

- Energy converged around headland
- Less forces along beach

Coastal Headlands Reduce Nearshore Hydrodynamics



Coastal Headlands Reduce Nearshore Hydrodynamics



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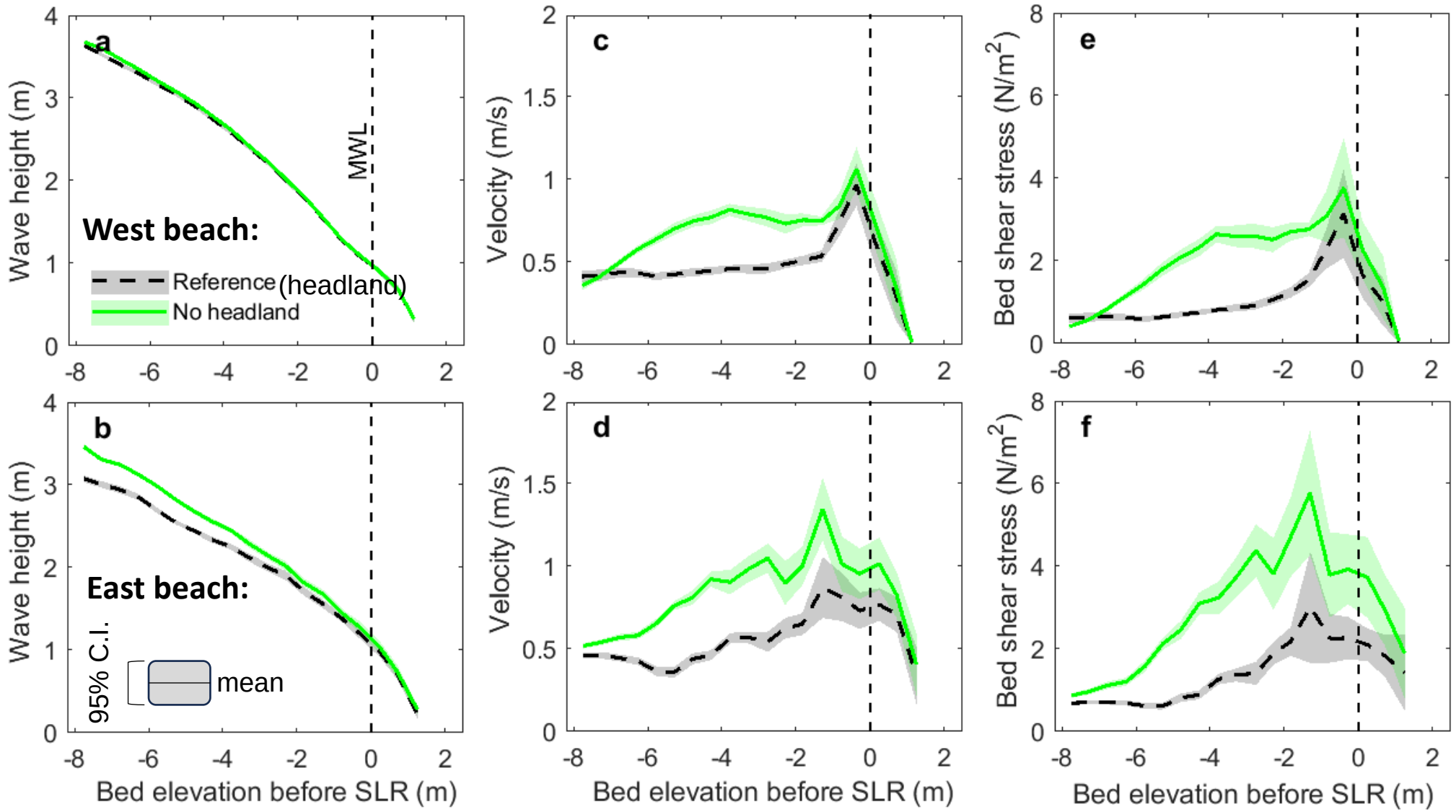
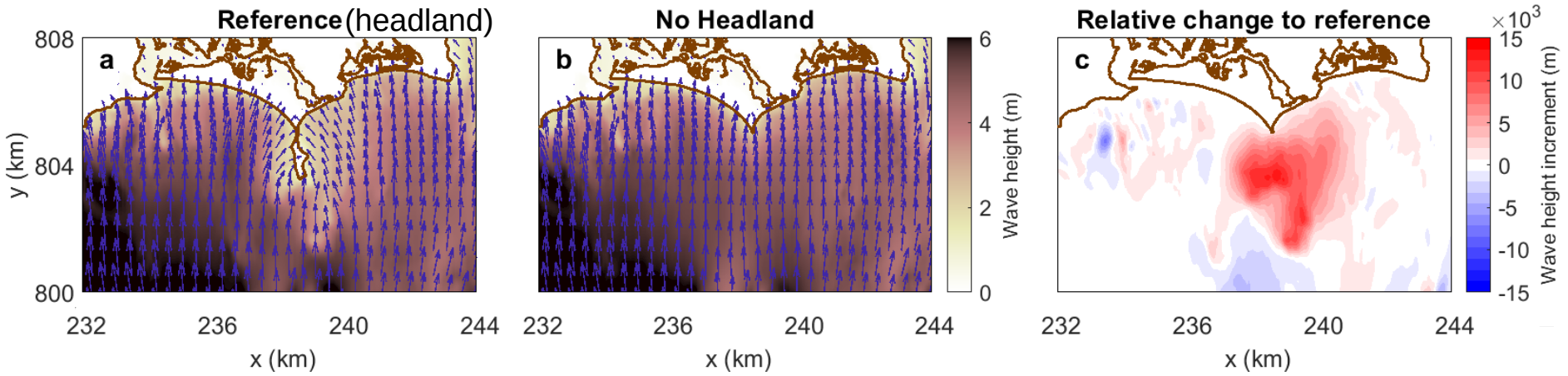


- Without headland, waves, flow and forces near the beach were enhanced, particularly on East Beach

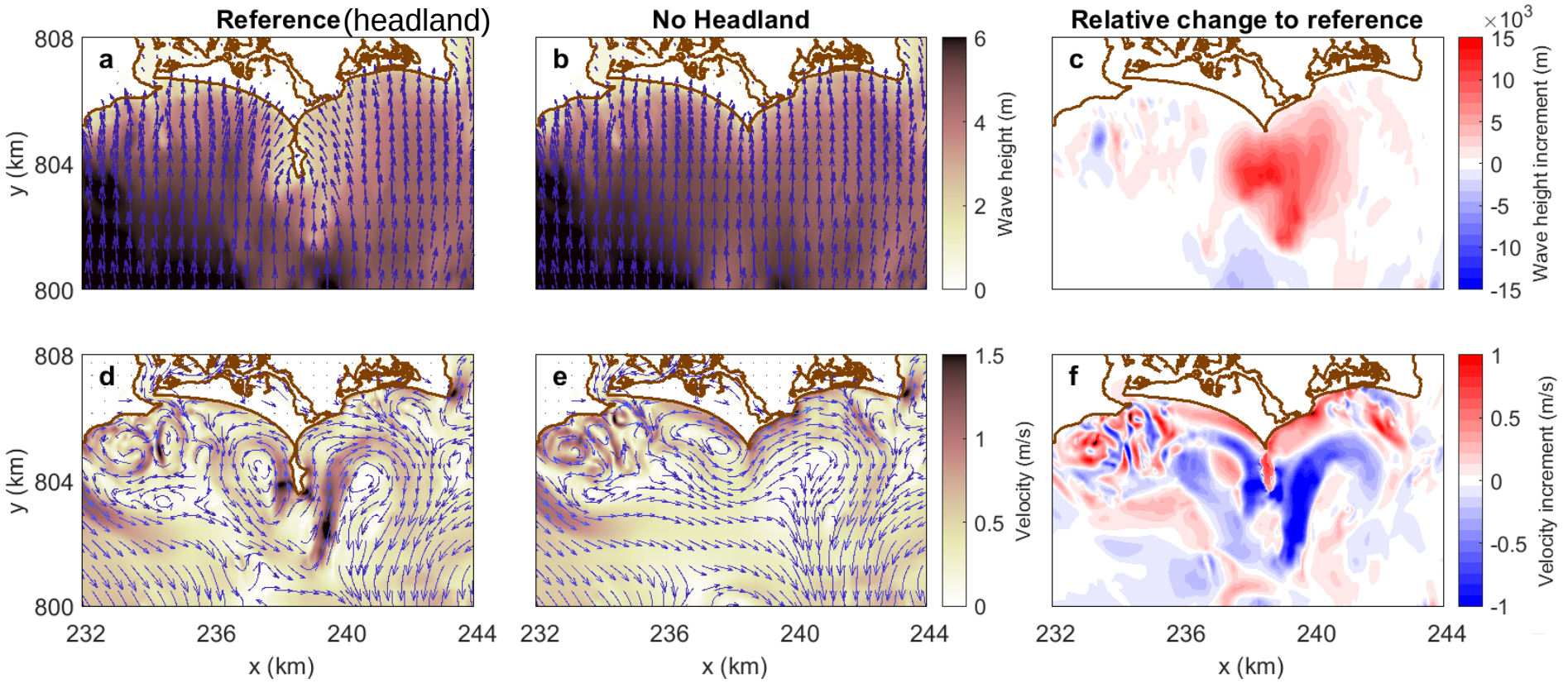
Coastal Headlands Reduce Nearshore Hydrodynamics



Without headland:

- Larger waves due to the lost of sheltering and shoaling effects

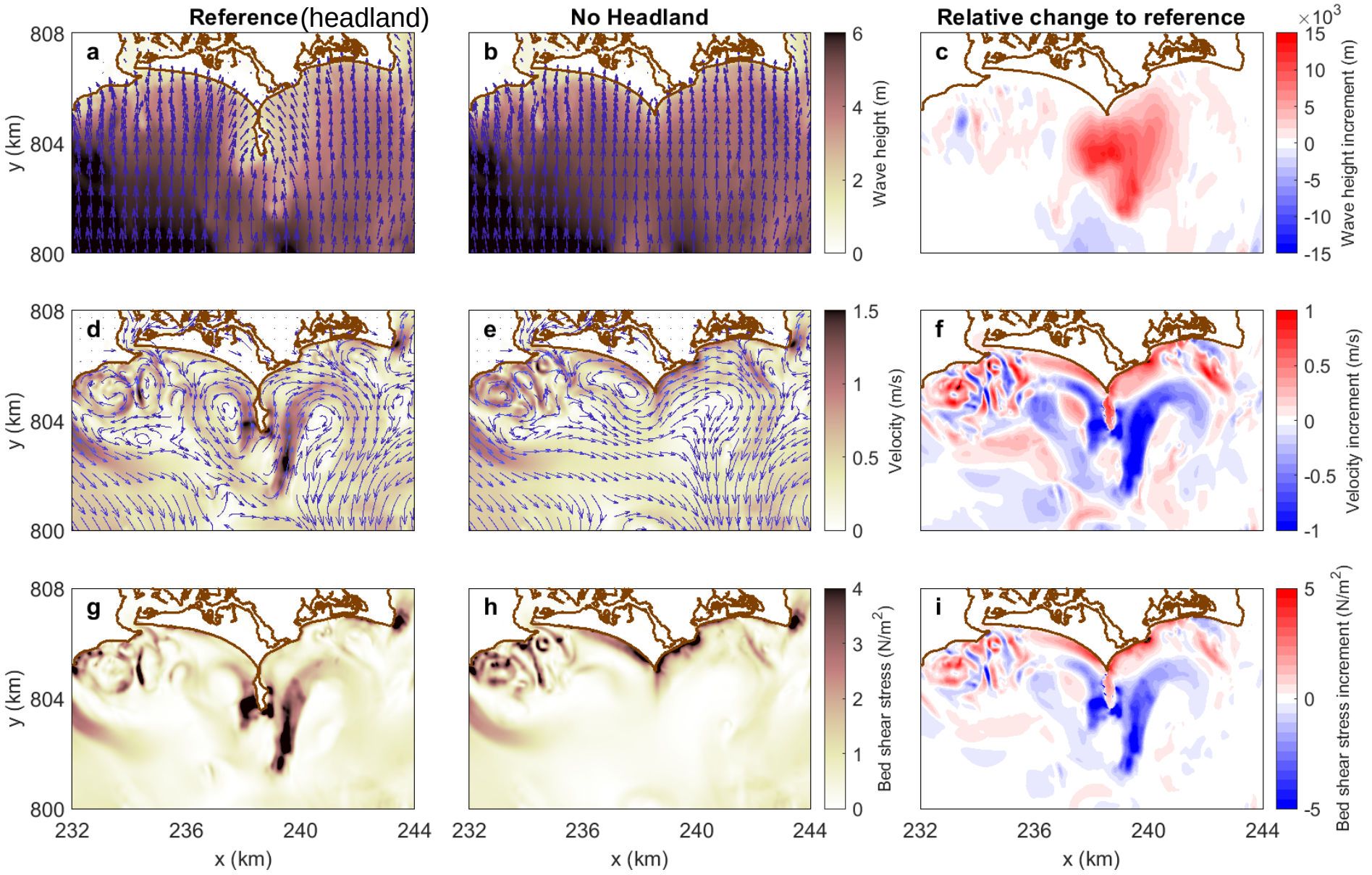
Coastal Headlands Reduce Nearshore Hydrodynamics



Without headland:

- Larger waves due to the lost of sheltering and shoaling effects
- Stronger currents due to flow patterns reconfiguration
- Longshore drift

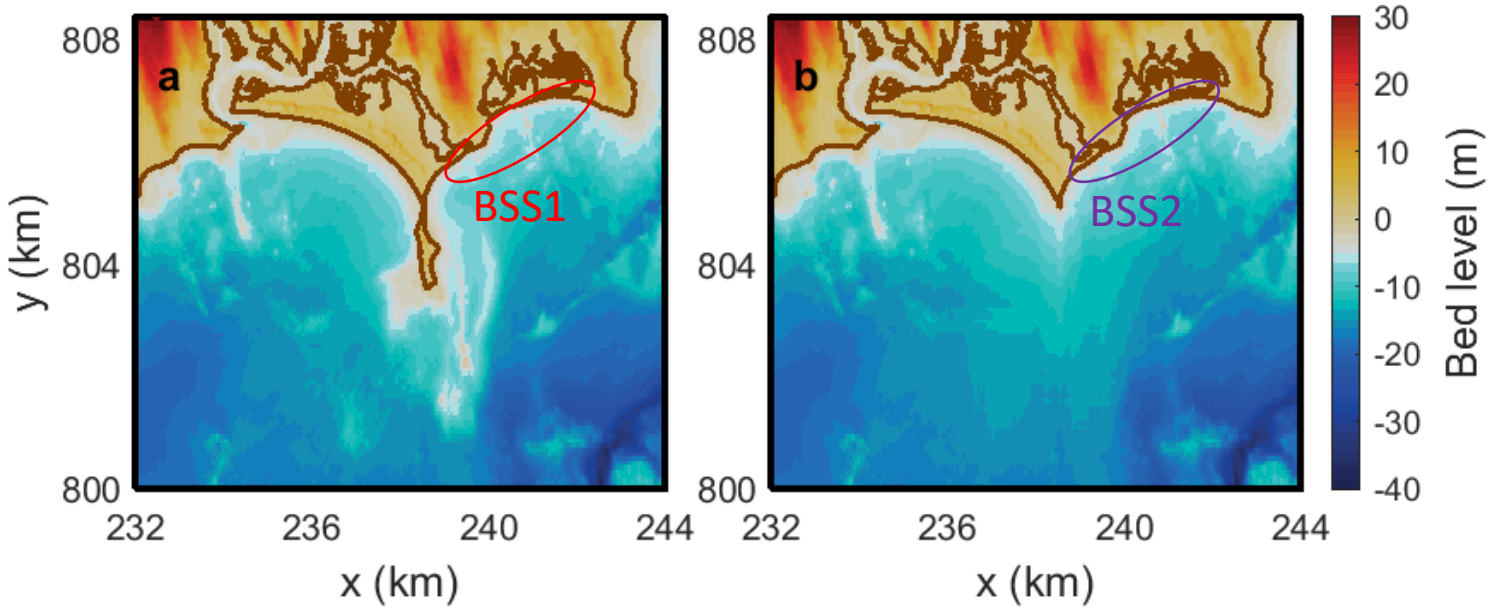
Coastal Headlands Reduce Nearshore Hydrodynamics



Without headland:

- Larger waves due to the lost of sheltering and shoaling effects
- Stronger currents due to flow patterns reconfiguration
- Longshore drift
- Higher hydrodynamic forces

Protection Potential of a Coastal Headland

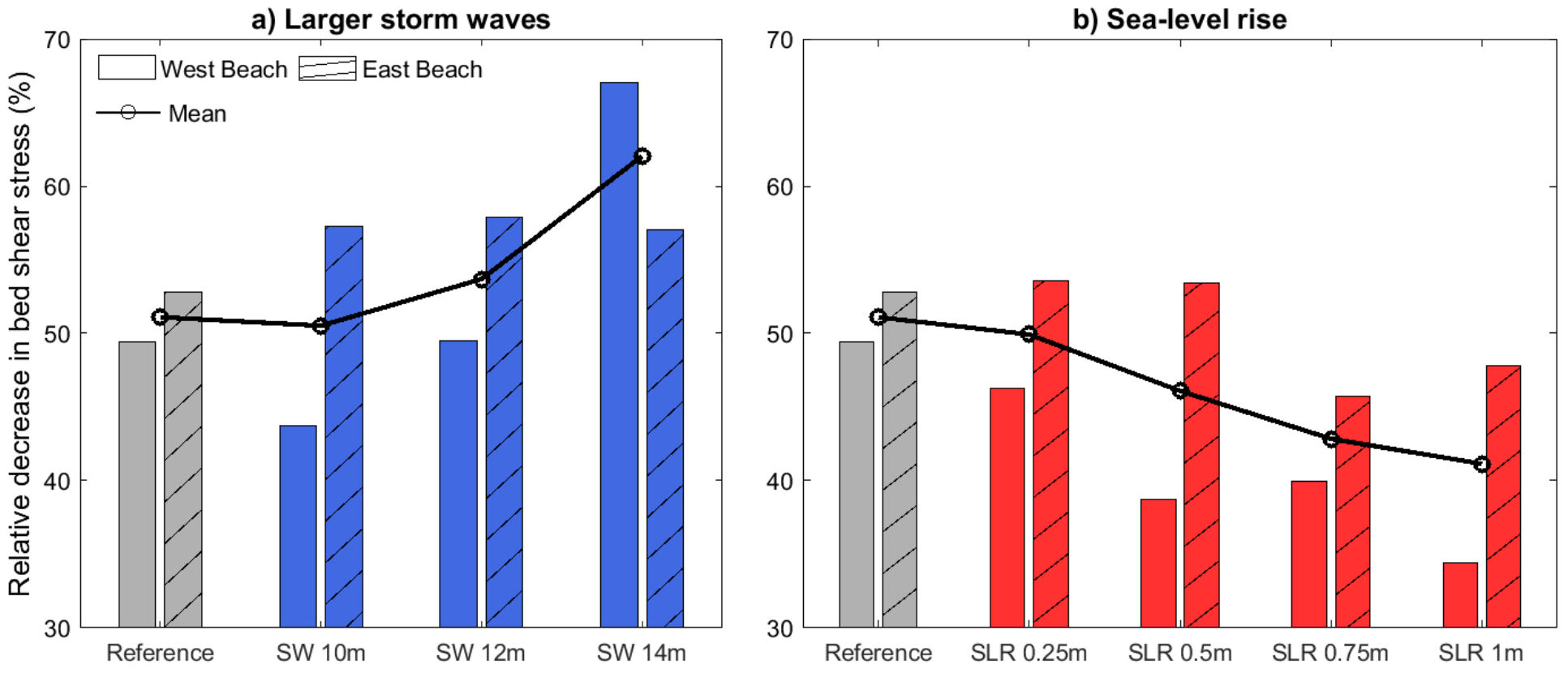


We defined protection potential (pp) as:

$$pp = \frac{BSS2 - BSS1}{BSS2} \times 100\%$$

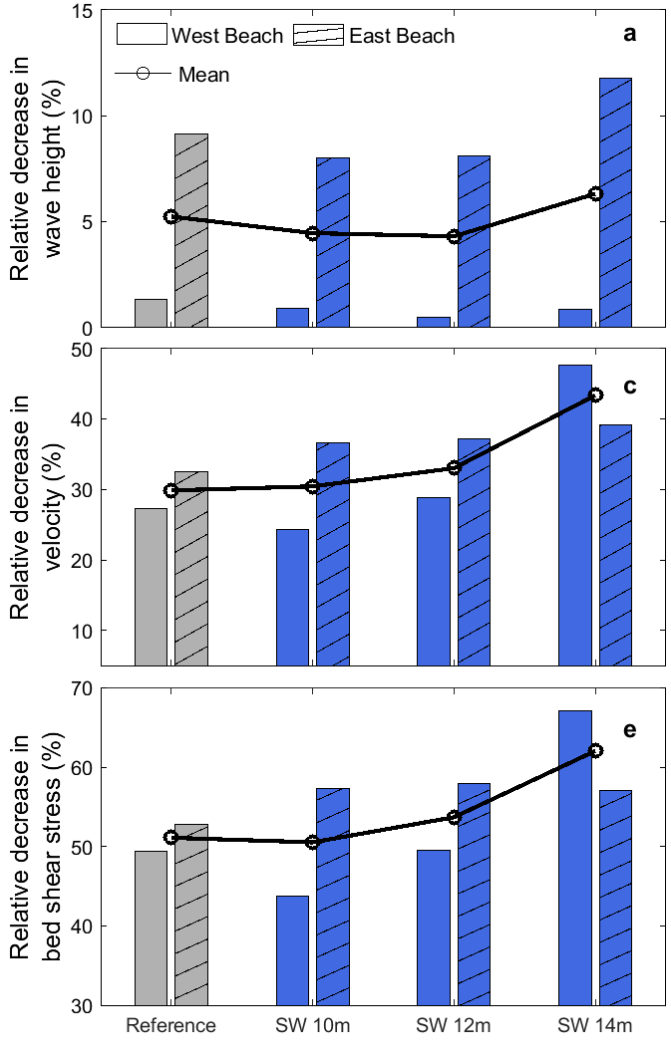
Representing relative decrease of bed shear stress when headland is present

Climate Change Affects the Protection Potential



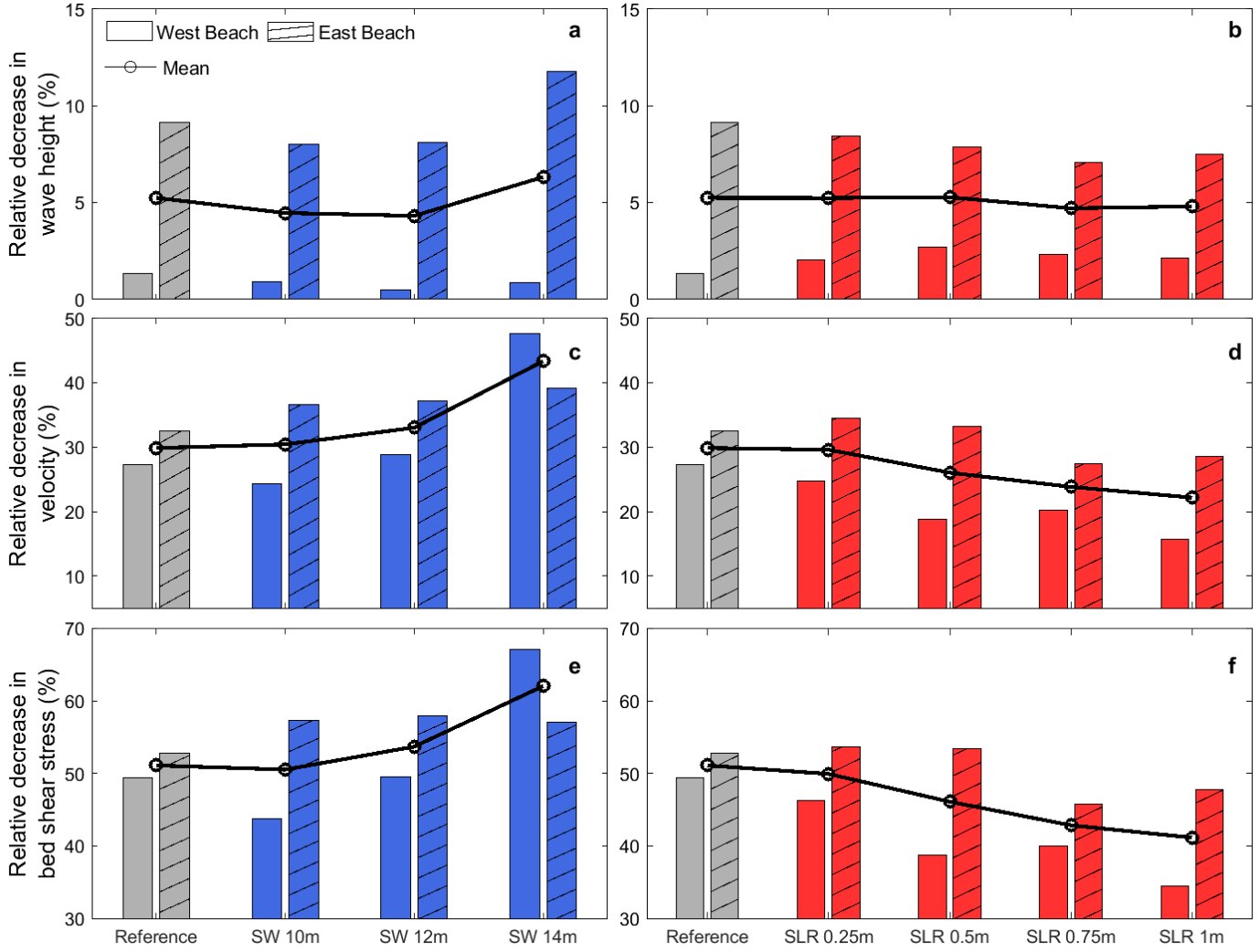
The pp of the headland is higher for larger storm waves; however, the pp reduces when the sea level rises.

Climate Change Affects the Protection Potential



The impact of headland on reducing waves and flow increases with larger storm waves

Climate Change Affects the Protection Potential



The impact of headland on reducing waves and flow increases with larger storm waves

The impact of headland on reducing flow decreases with SLR

Key messages

- **Coastal headland converges wave energy, forming circulation cells on its two sides**
- **Without headland, beach will be exposed to higher hydrodynamic forces due to 1) larger waves and 2) landward movement of circulation cells**
- **The role of a headland on reducing nearshore hydrodynamic forces increases as peak storm wave height increases but reduces as sea level rises.**

Questions?