Time-varying wave effects on flows and dynamics at an unstratified inlet

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Steve Elgar, Julie Chen, Fengyan Shi

Photo by Gordon Farquharson

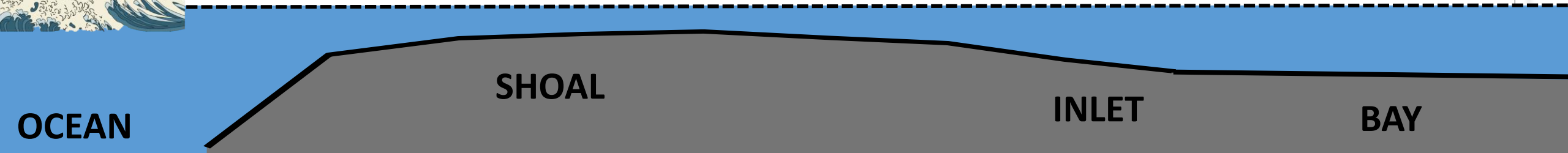
August 2, 2018

International Conference on Coastal Engineering

Funding:

Motivation:

Waves impact circulation in ocean inlets (Bertin et al., 2009)



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Wave radiation stress gradients ("wave forcing") can:

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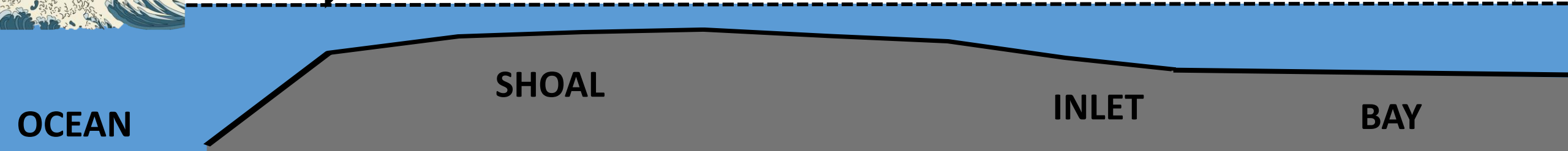
wave forcing



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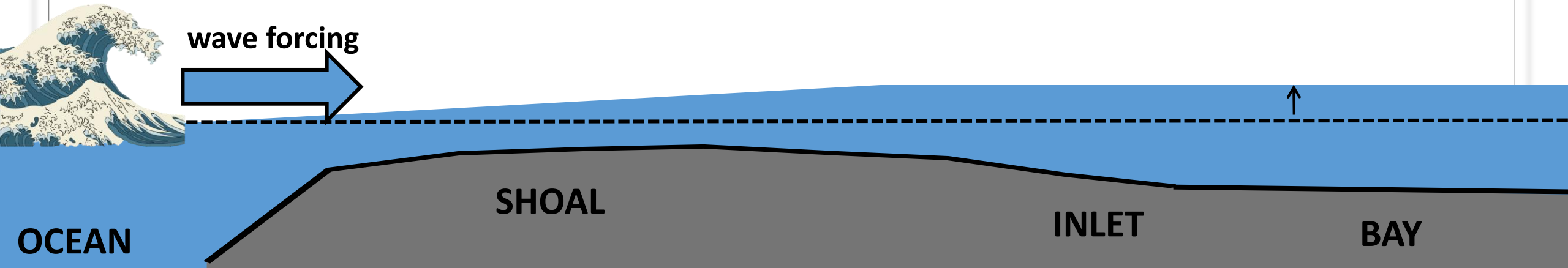

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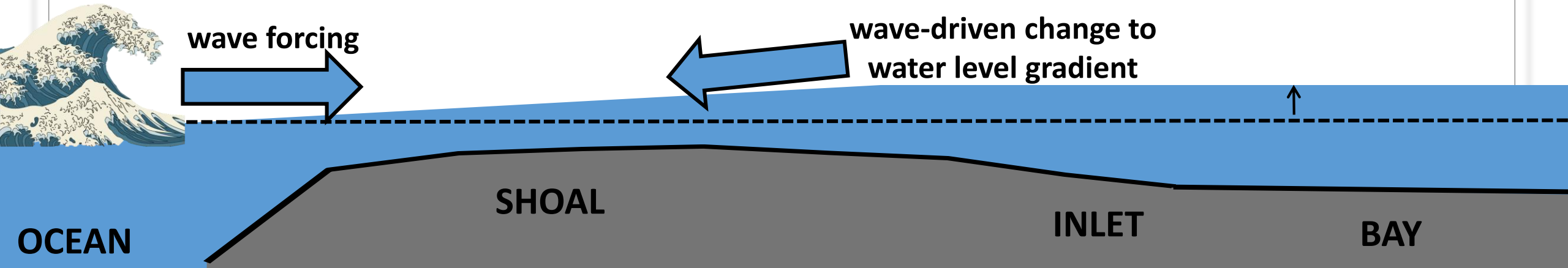

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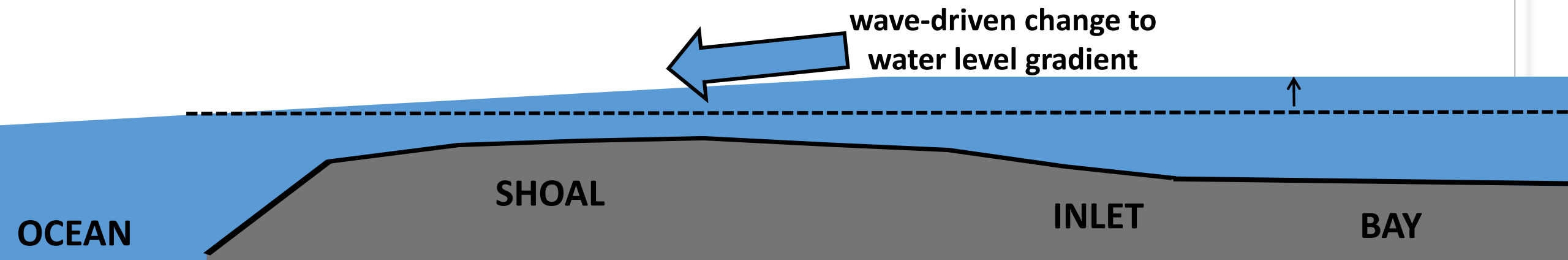

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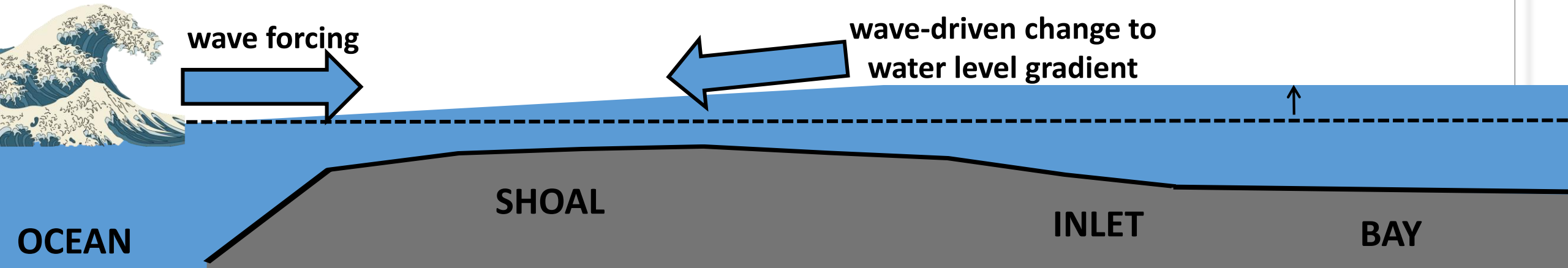
Question: How does the response of flux to waves change **during a storm**?



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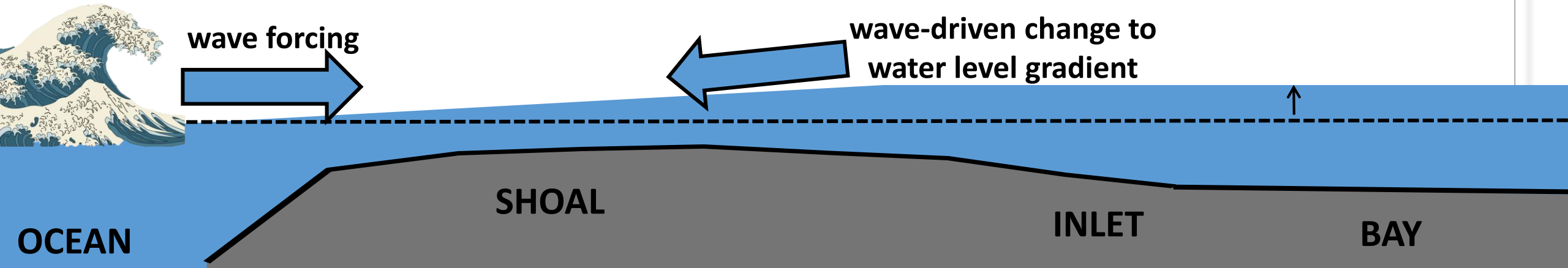
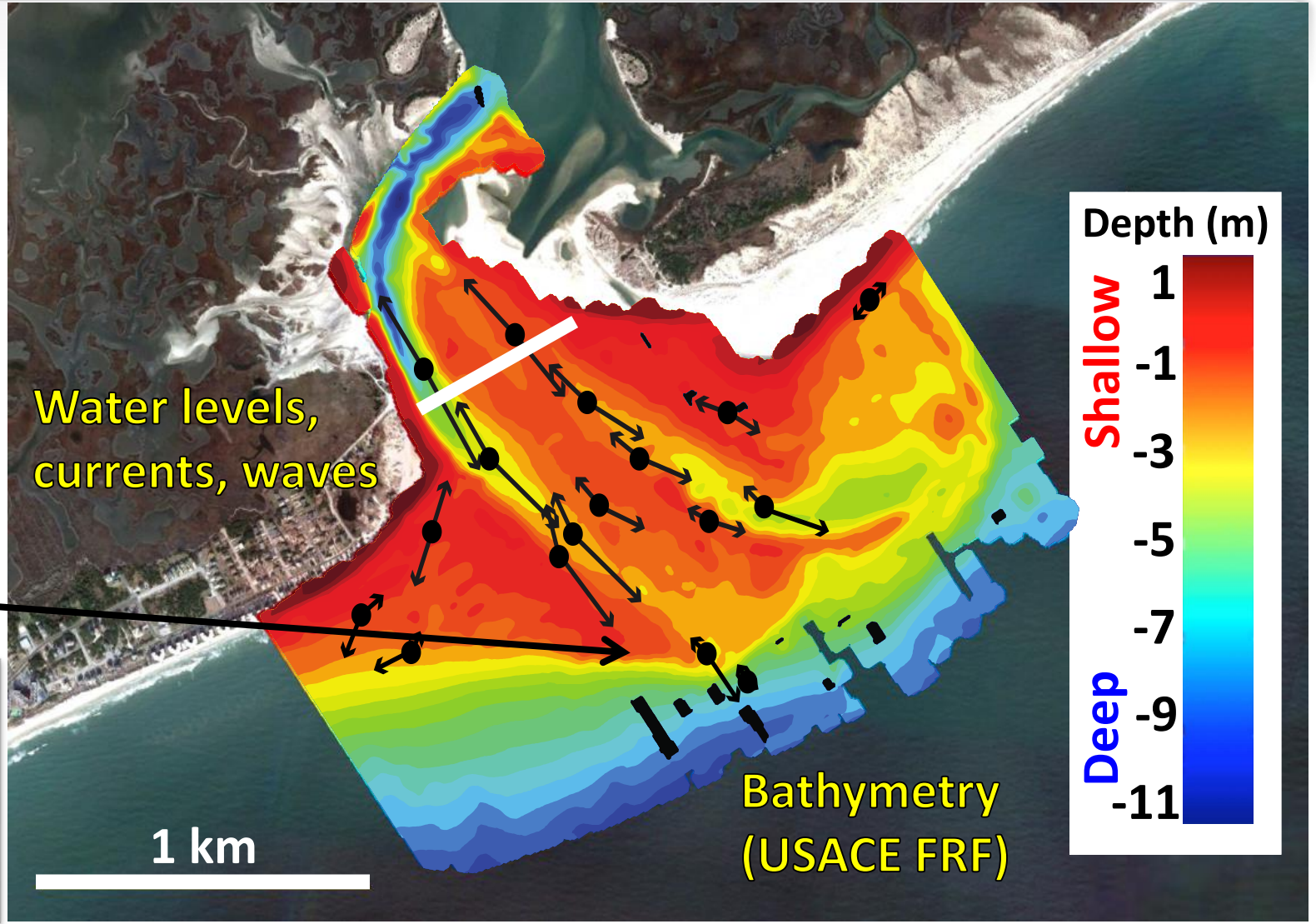
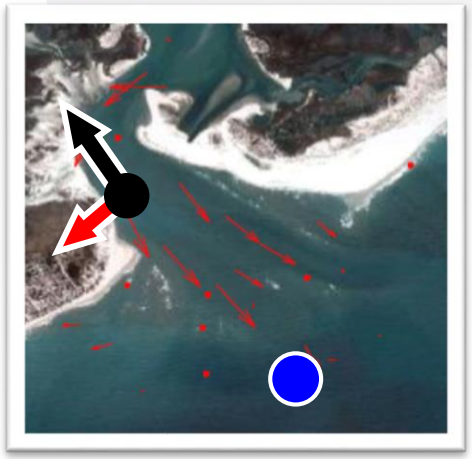
Question: How does the response of **flood** flux to waves change **during a storm**?

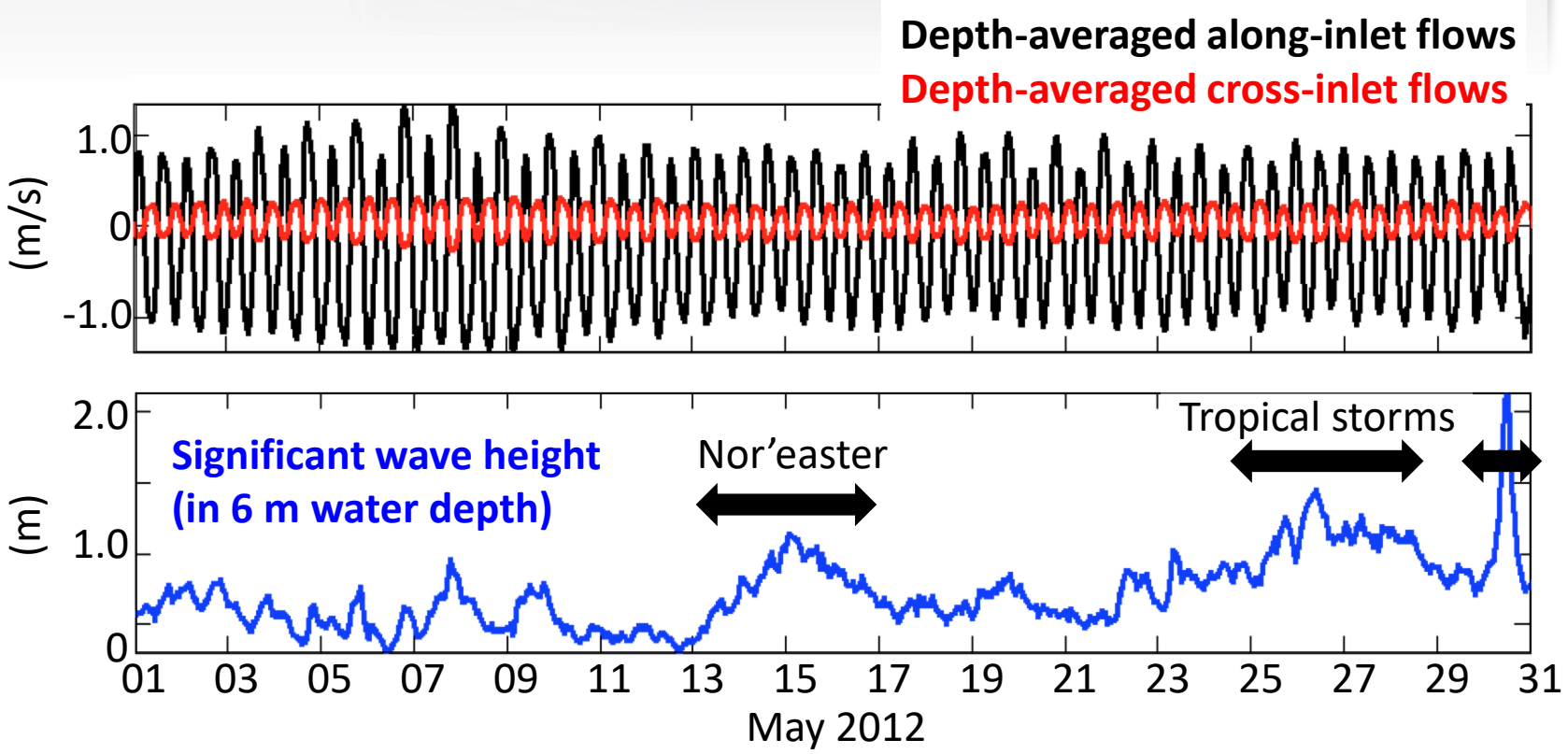


Observations: May 2012



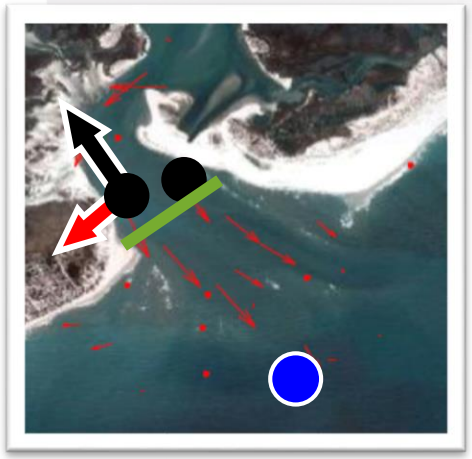
Wave-breaking is depth-limited.





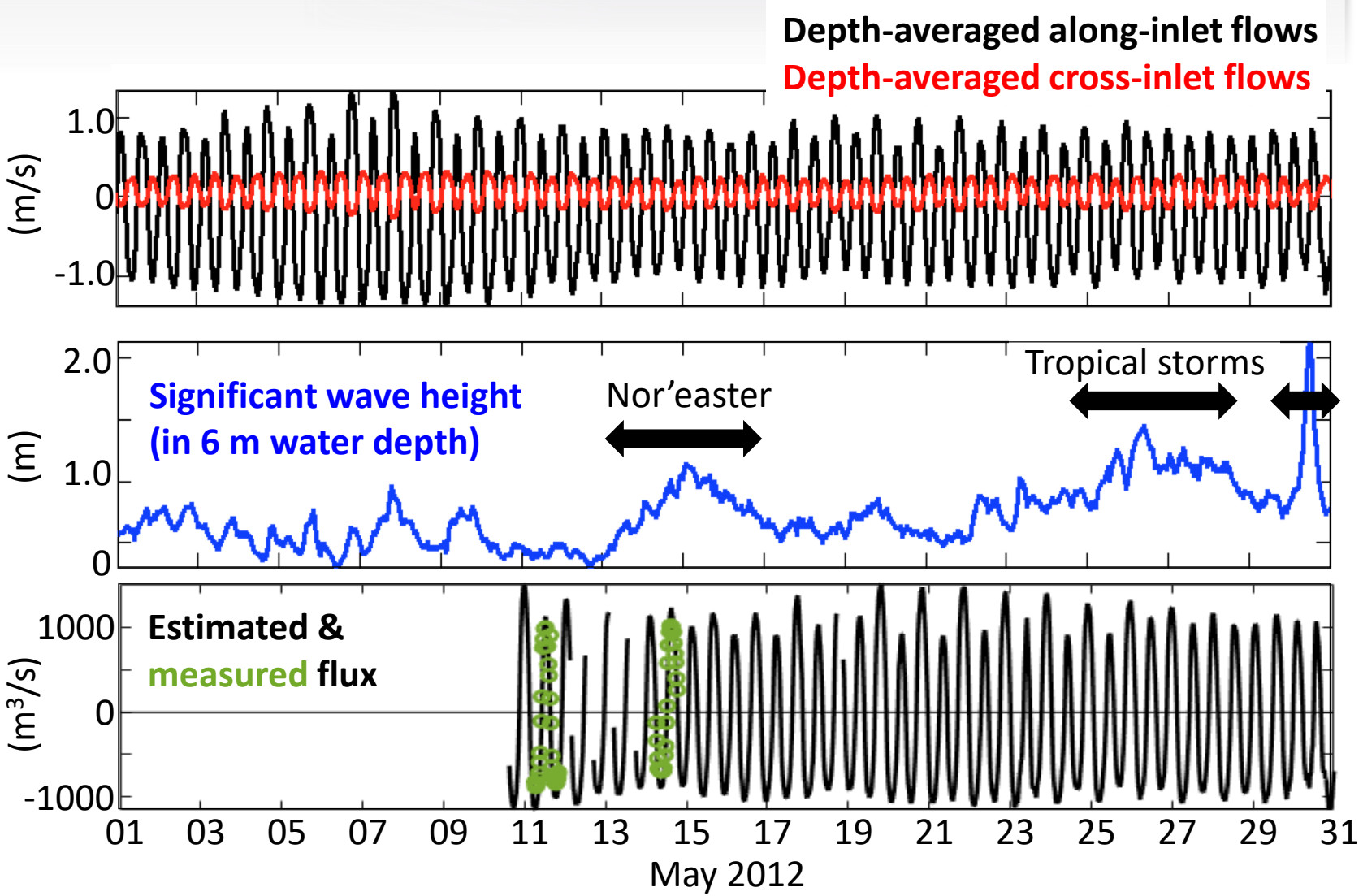
Progressive tide: maximum flood coincides with high tide.

Wave directions were 0 – 20 degrees relative to shore-normal.



Flux estimated from **two sensors** compared to **boat-mounted** measurement.

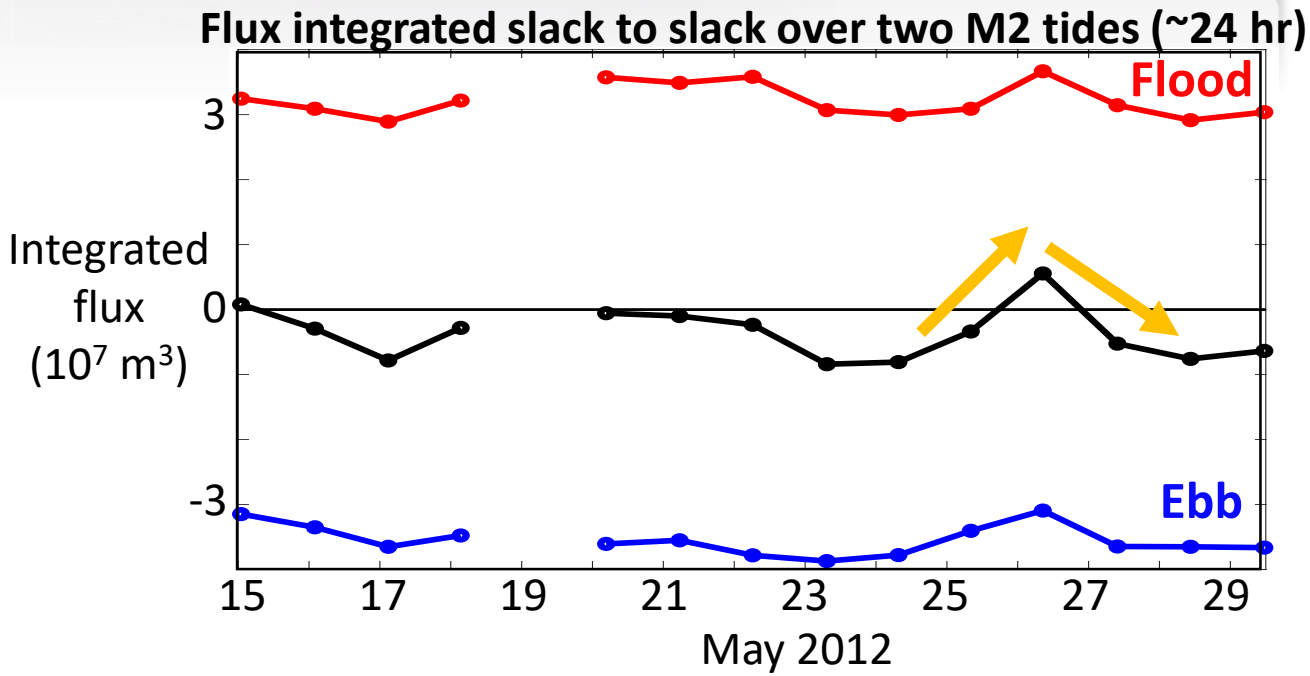
Gaps owing to no data at eastern sensor.



Subtidal variability in ~24 hr integrated flux

Tropical storm (May 26 – 28)

- Integrated flux (**total, flood, ebb**) increases and then decreases during the tropical storm



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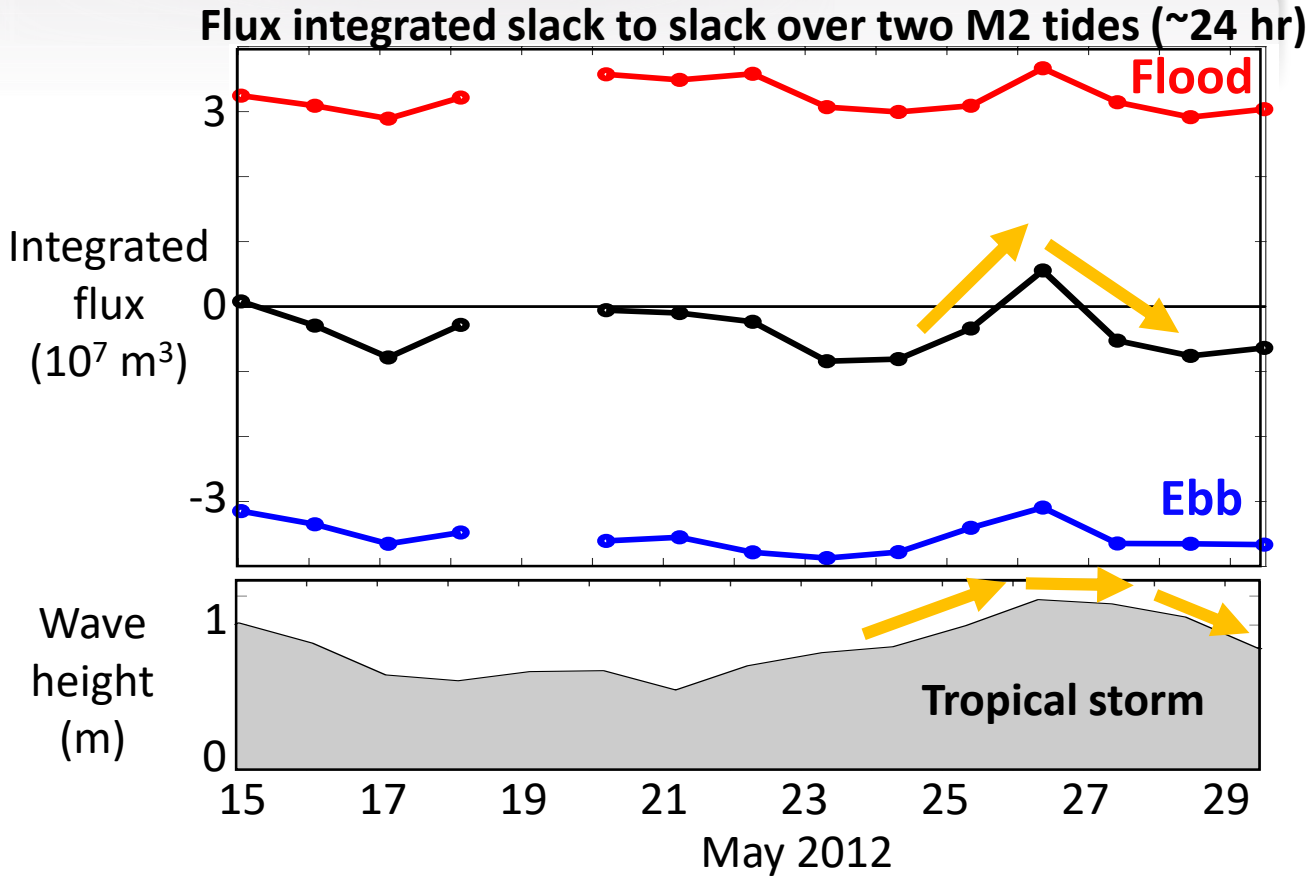

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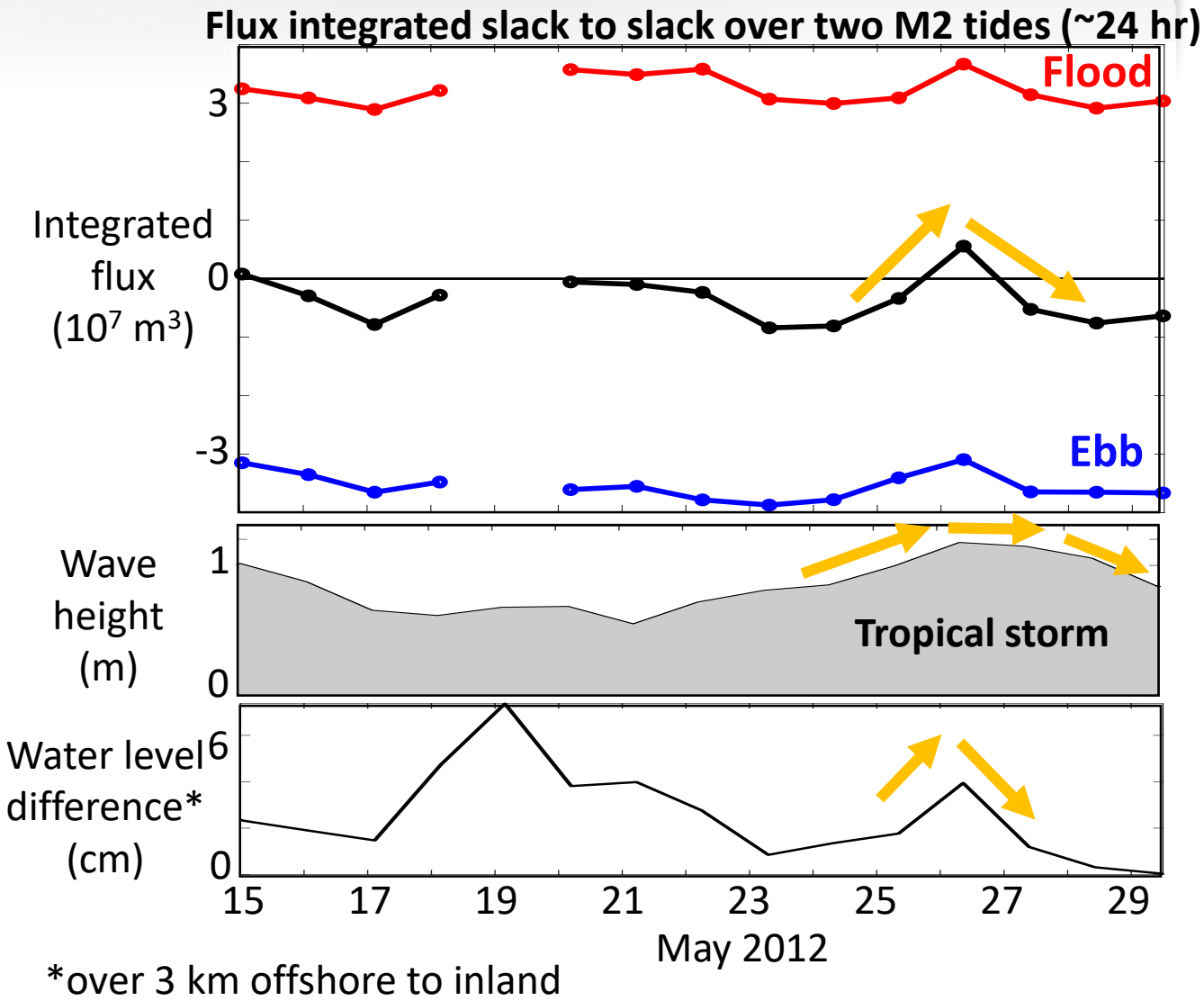

*over 3 km offshore to inland

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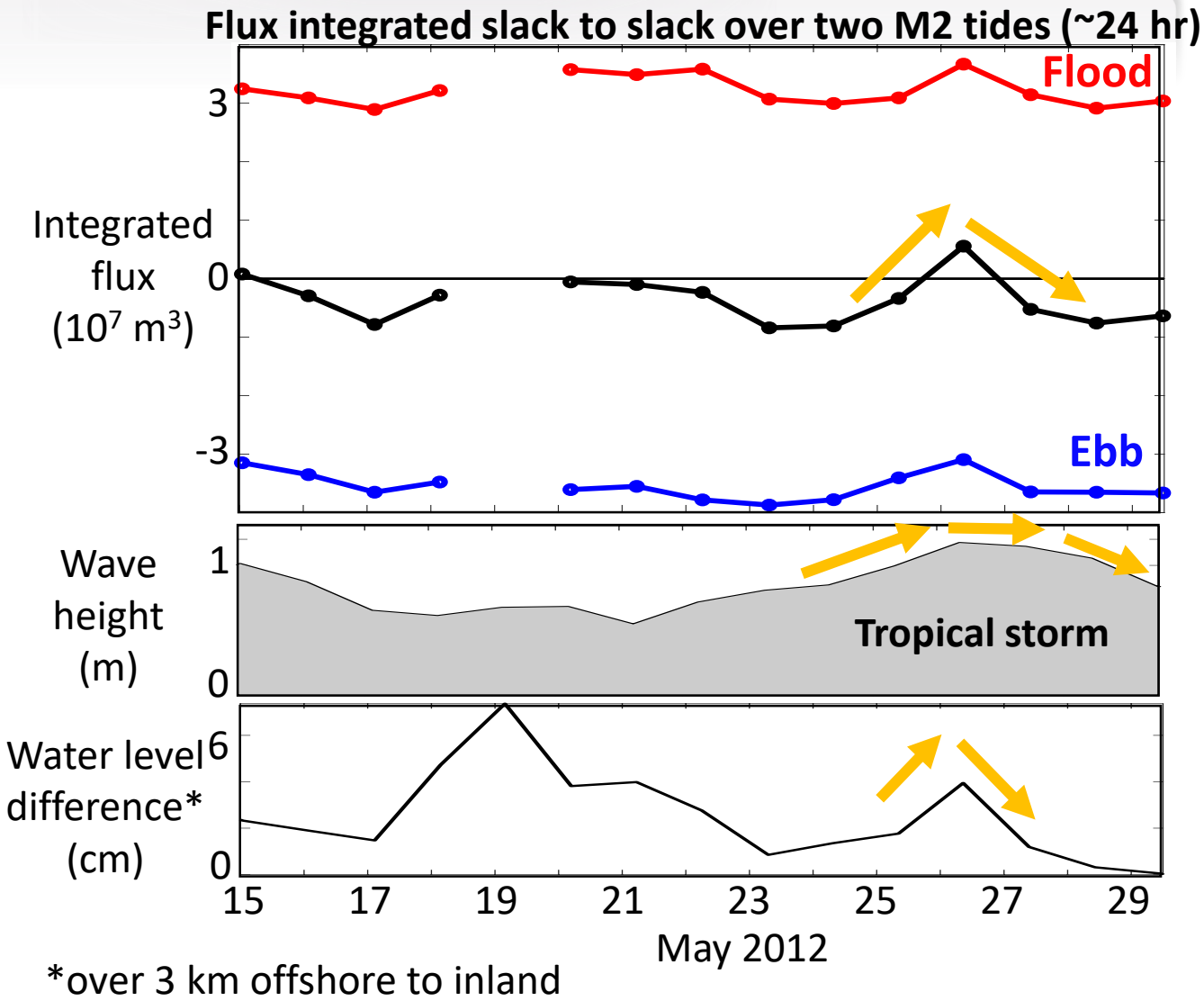
Time-varying response to sustained wave height or unrelated subtidal signal / wind?



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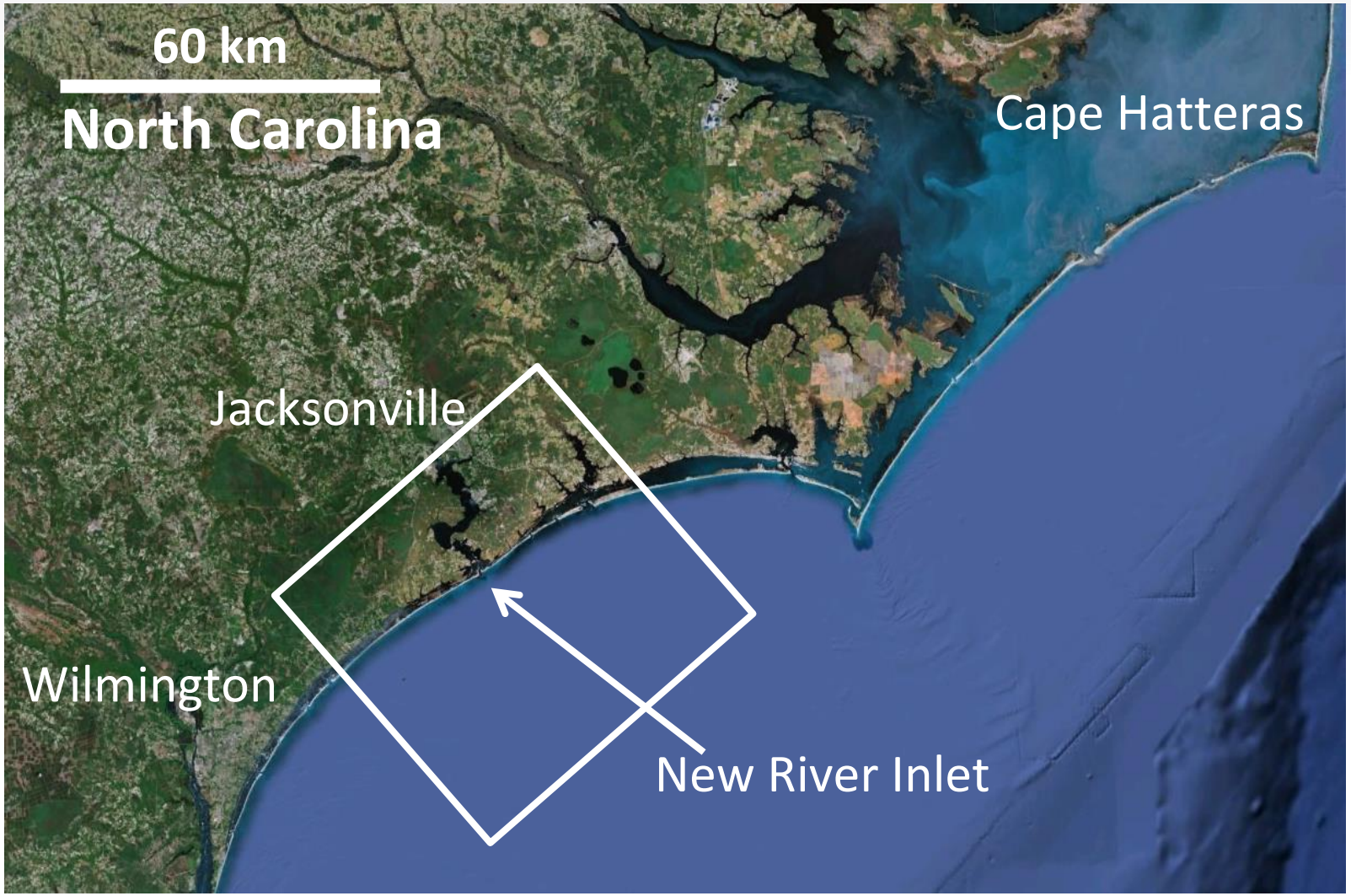
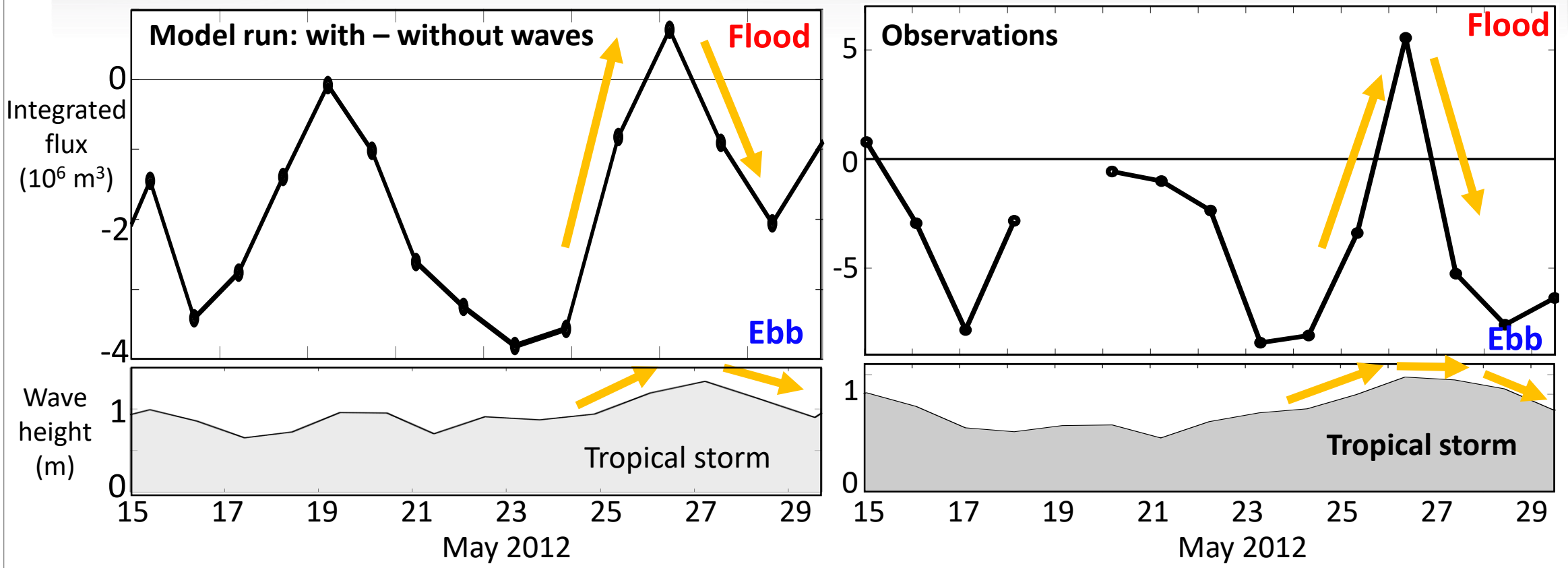
NearCoM-TVD
SHORECIRC + SWAN

Model shows reasonable agreement with field observations of water levels, waves, and currents (Chen et al., 2015)



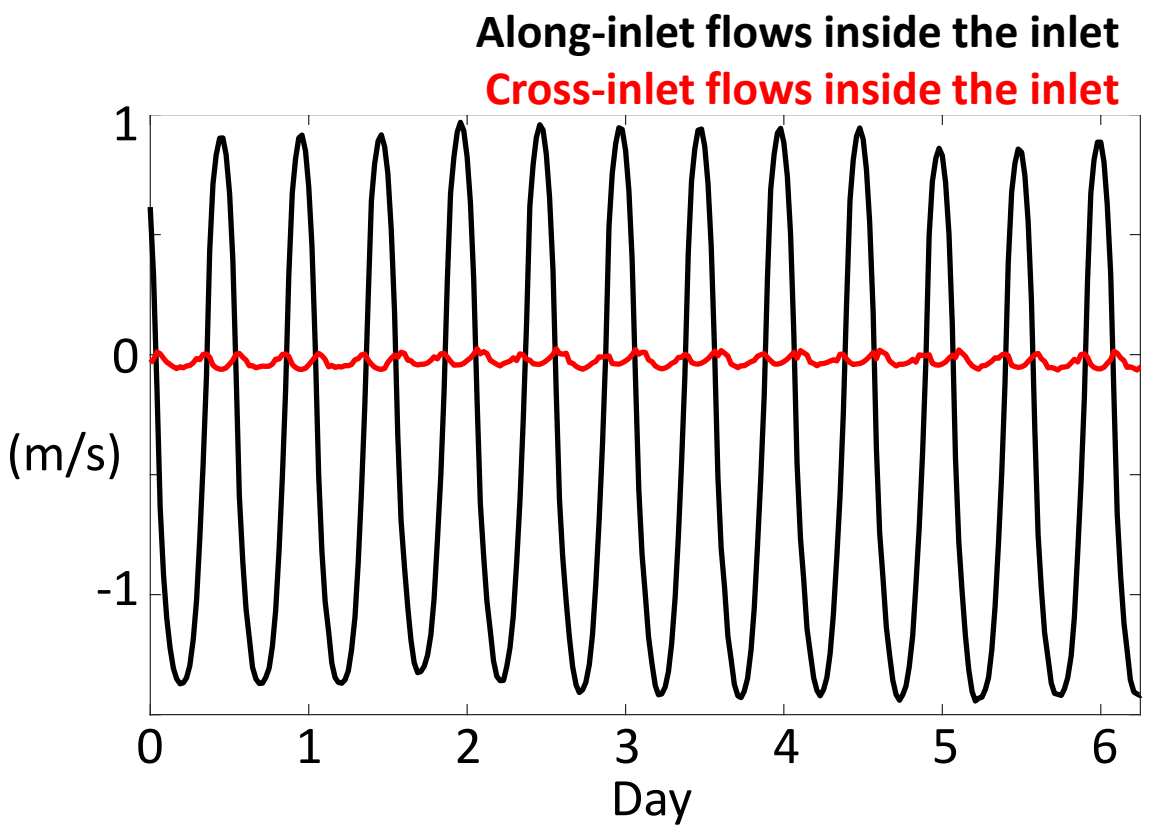
Flux integrated slack to slack over two M2 tides (~24 hr)

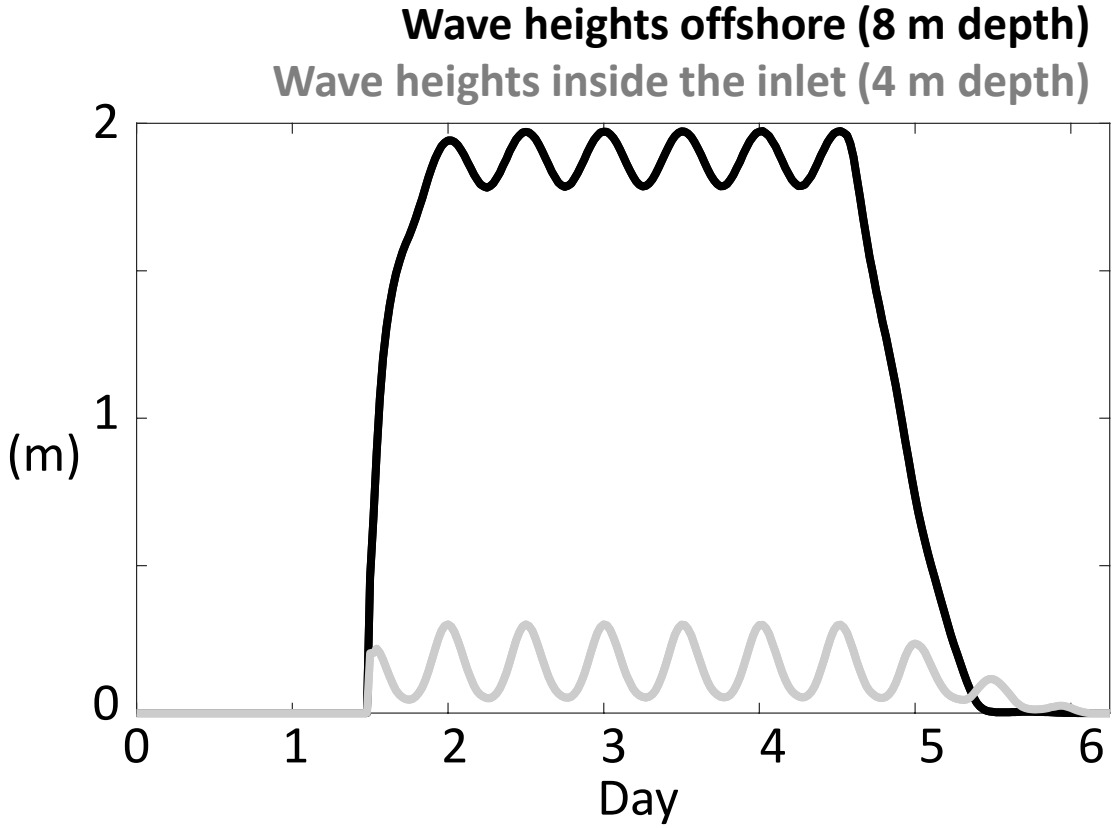


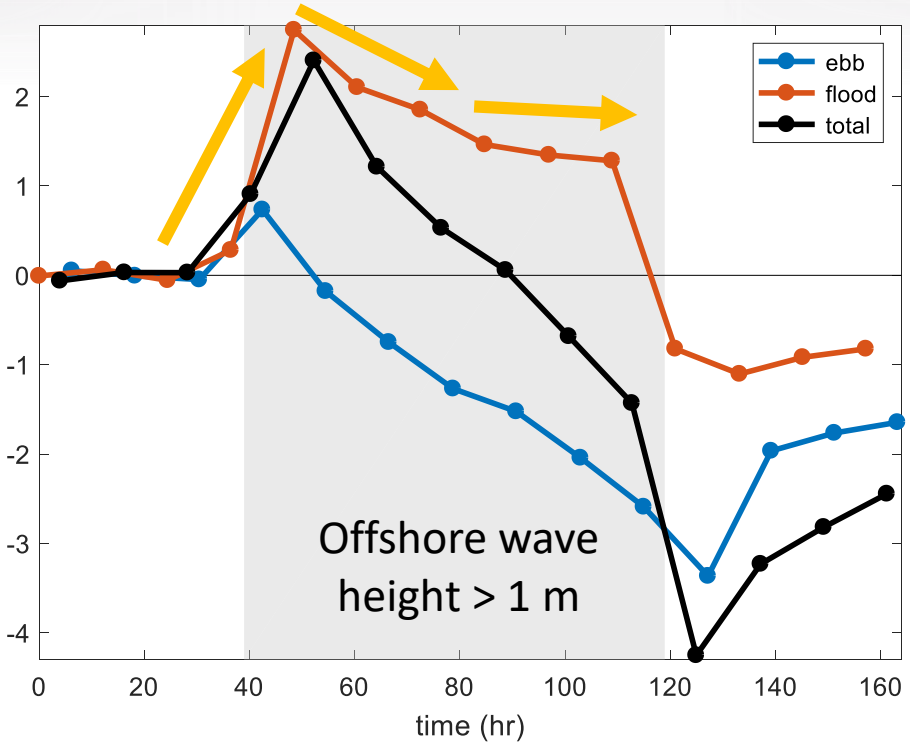
Model suggests that the pattern of temporal variability in flux is owing to waves

Idealized model run:

- M2 tide
- 2-m wave event lasting 6 tidal cycles





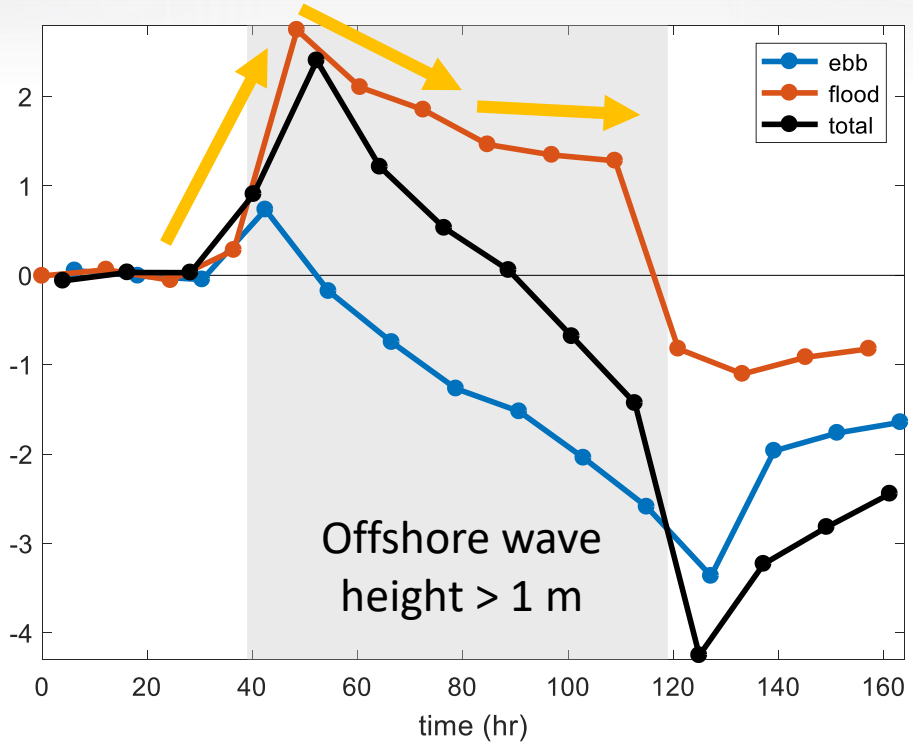


Flood flux increases (ebb flux decreases) during the beginning of the storm.

As storm progresses relative increase in integrated flood flux

1. Decreases (~3 tidal cycles)

1. Levels out (~3 tidal cycles)



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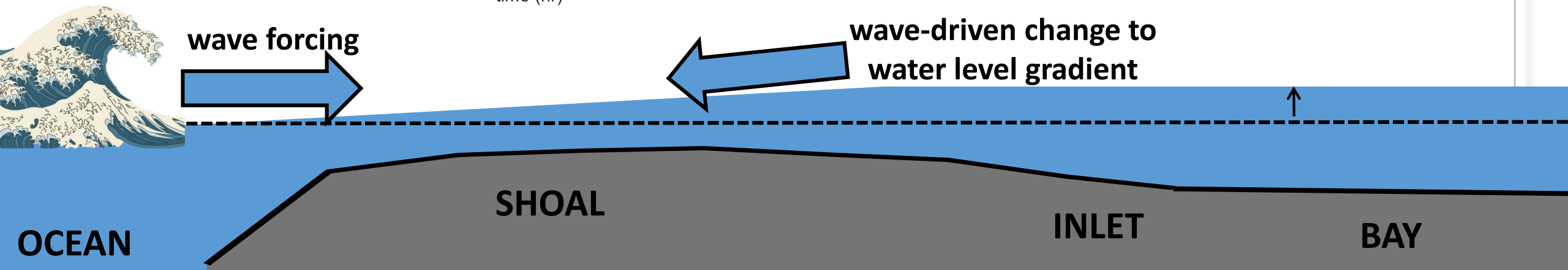
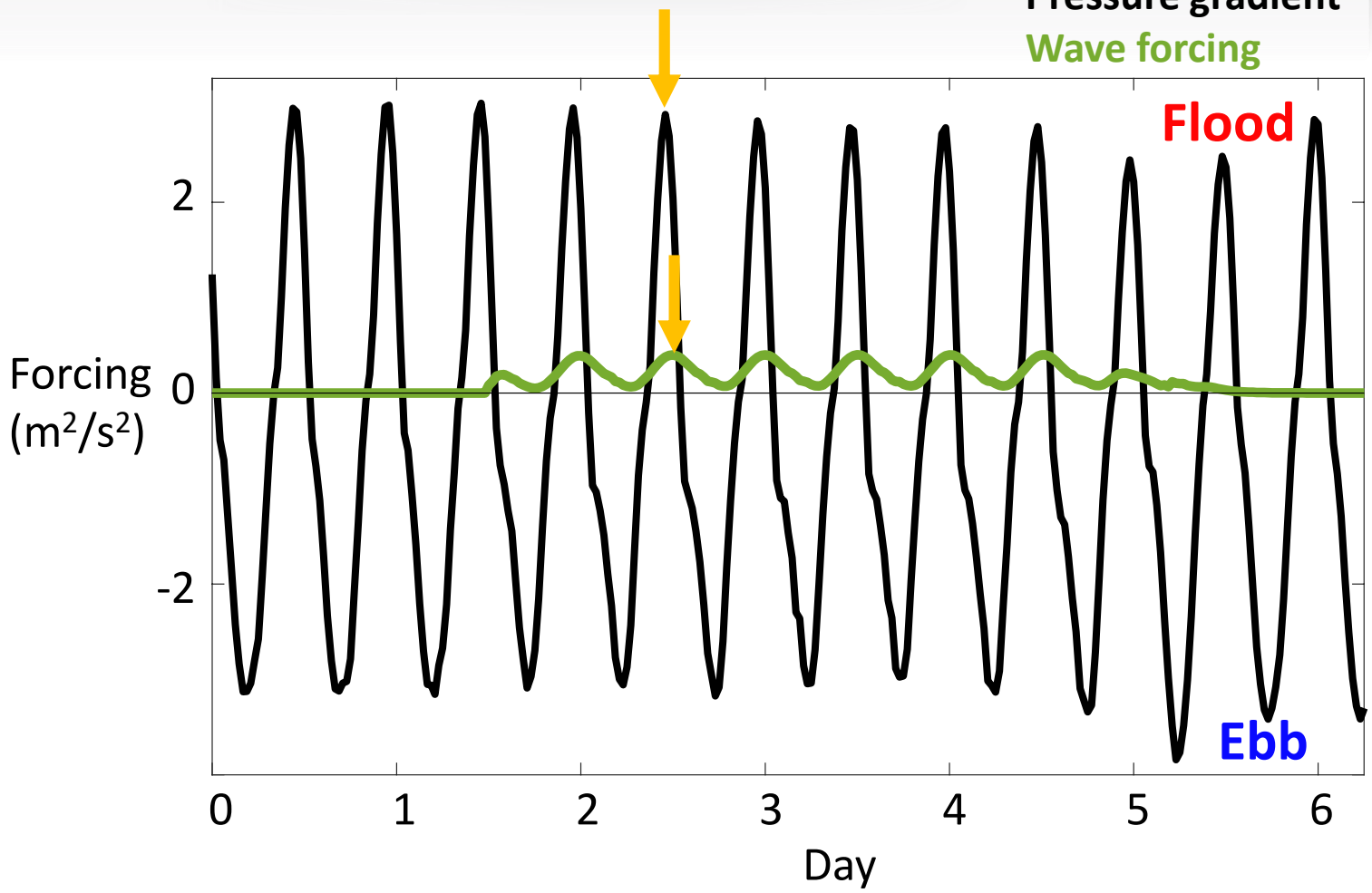


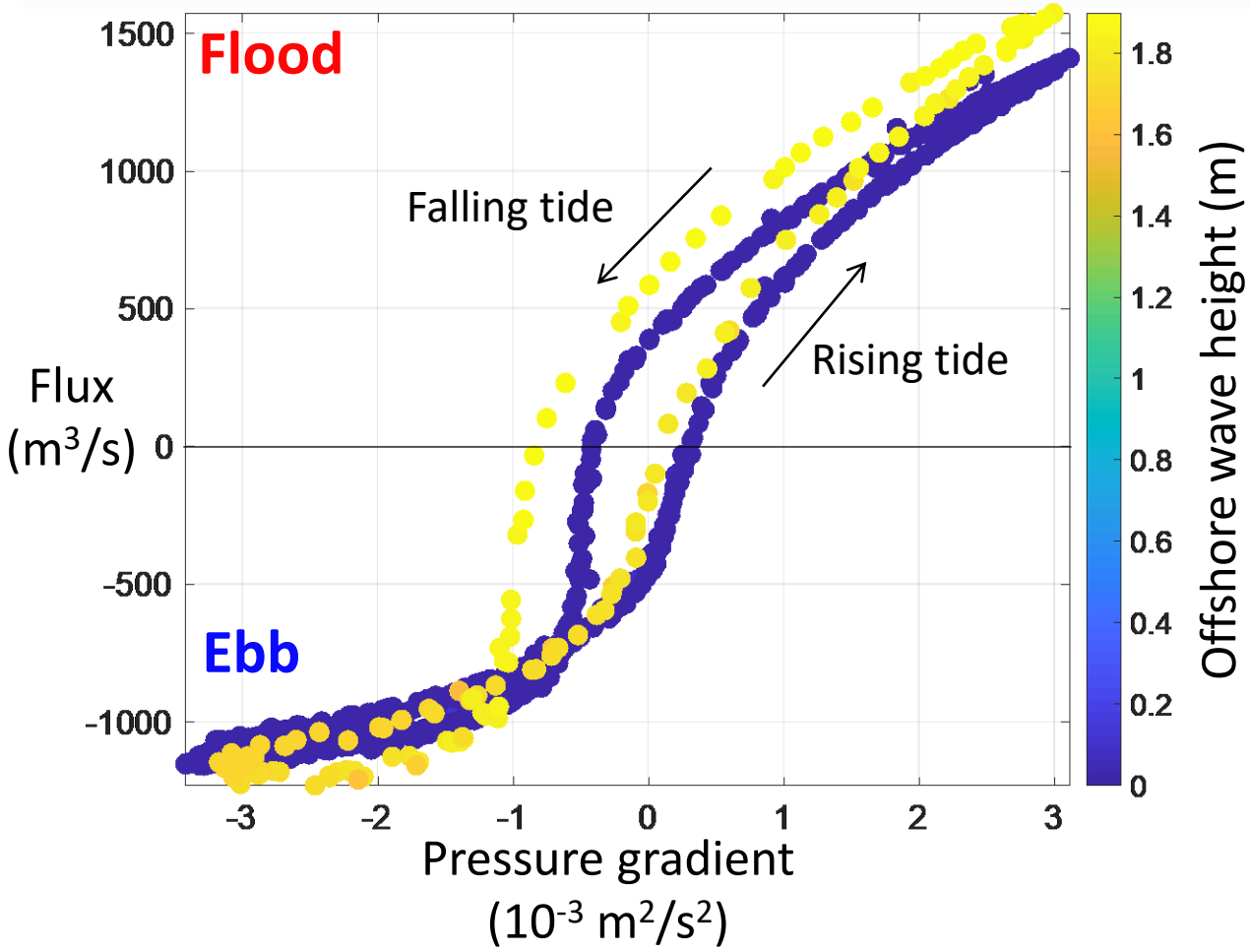
Wave forcing

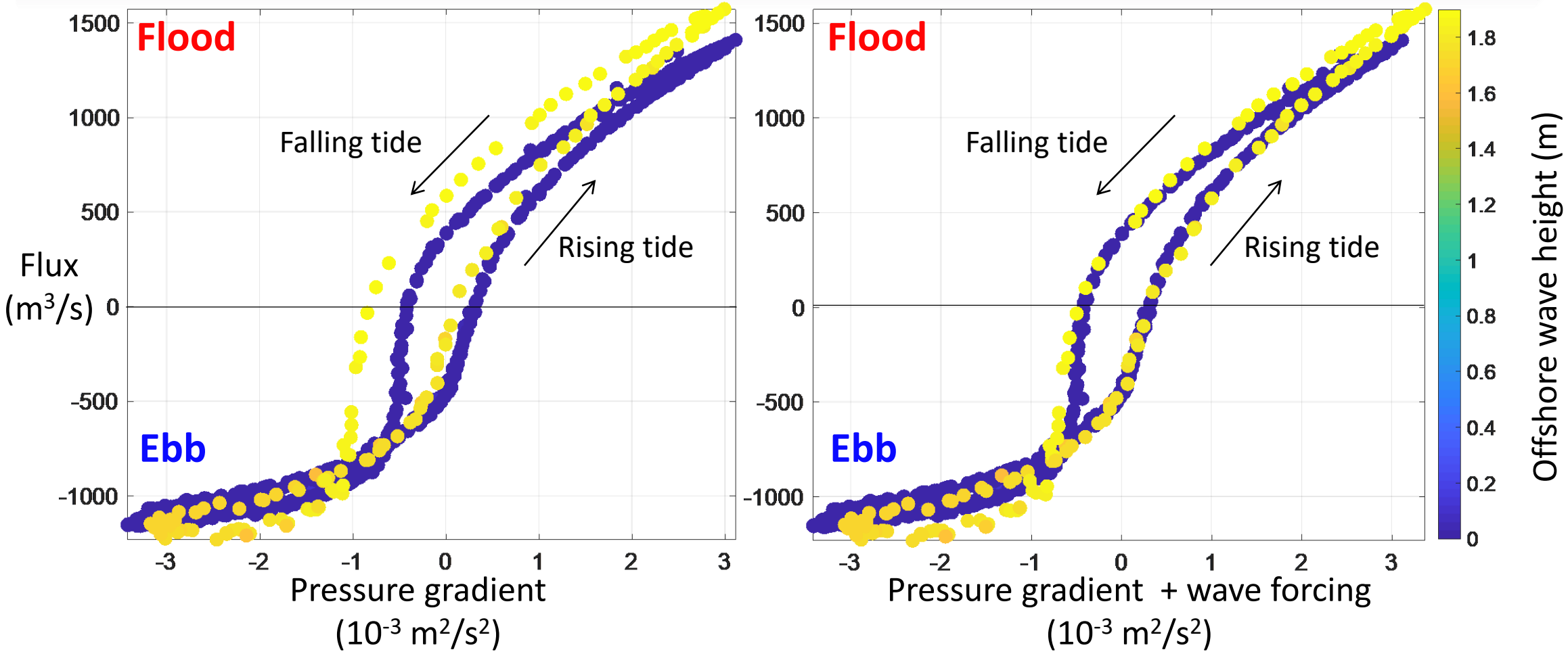
Wave forcing is positive, driving mass flux into the inlet

Maximum wave forcing is offset from maximum pressure gradient

-> more important during falling tide




Flood
Ebb
Falling tide
Rising tide
1500
1000
500
0
-500
-1000
Flux
(m3/s)
-3
-2
-1
0
1
2
3
Pressure gradient
(10-3 m2/s2)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Offshore wave height (m)


Flood
Falling tide
Rising tide
Ebb
Flux
(m³/s)
1500
1000
500
0
-500
-1000
-3
-2
-1
0
1
2
3
Pressure gradient
(10⁻³ m²/s²)
Flood
Falling tide
Rising tide
Ebb
Pressure gradient + wave forcing
(10⁻³ m²/s²)
1.8
1.6
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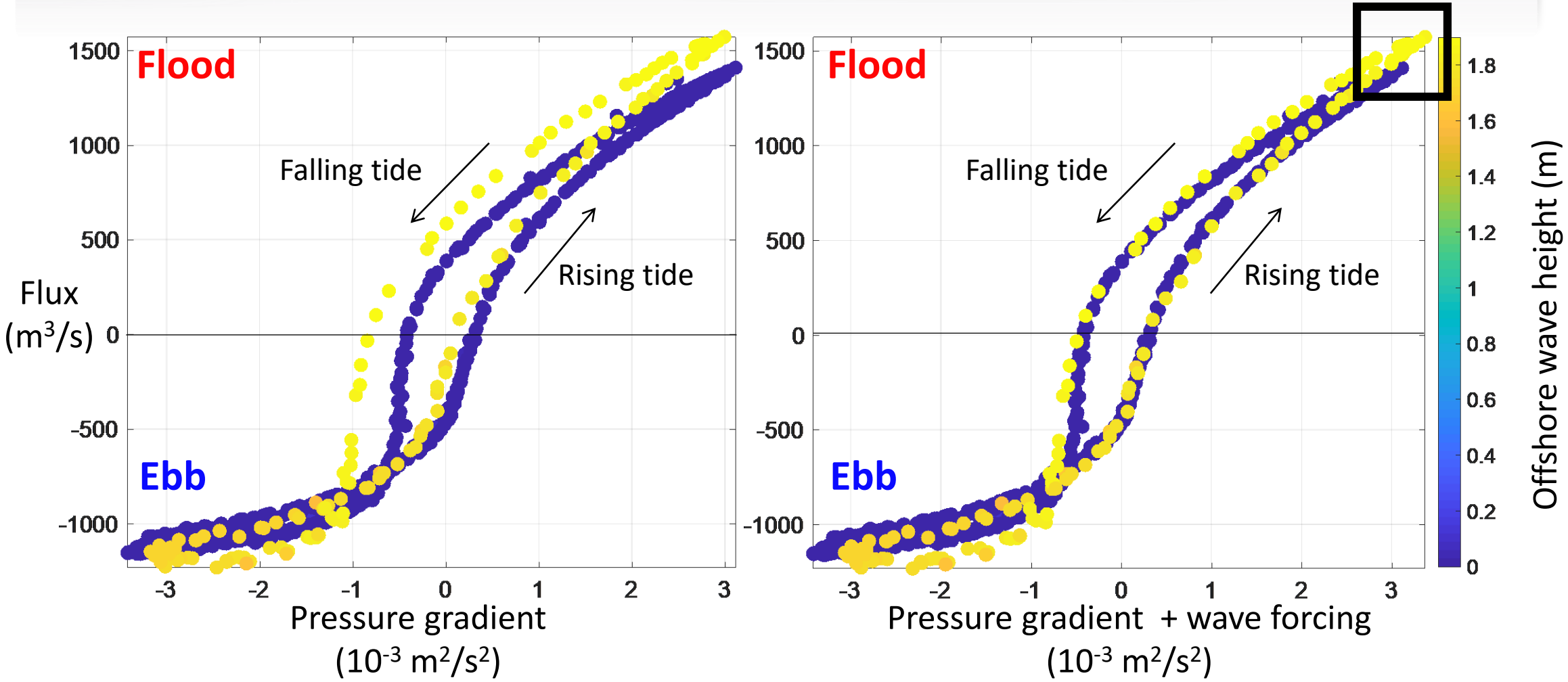
0.2
0
Offshore wave height (m)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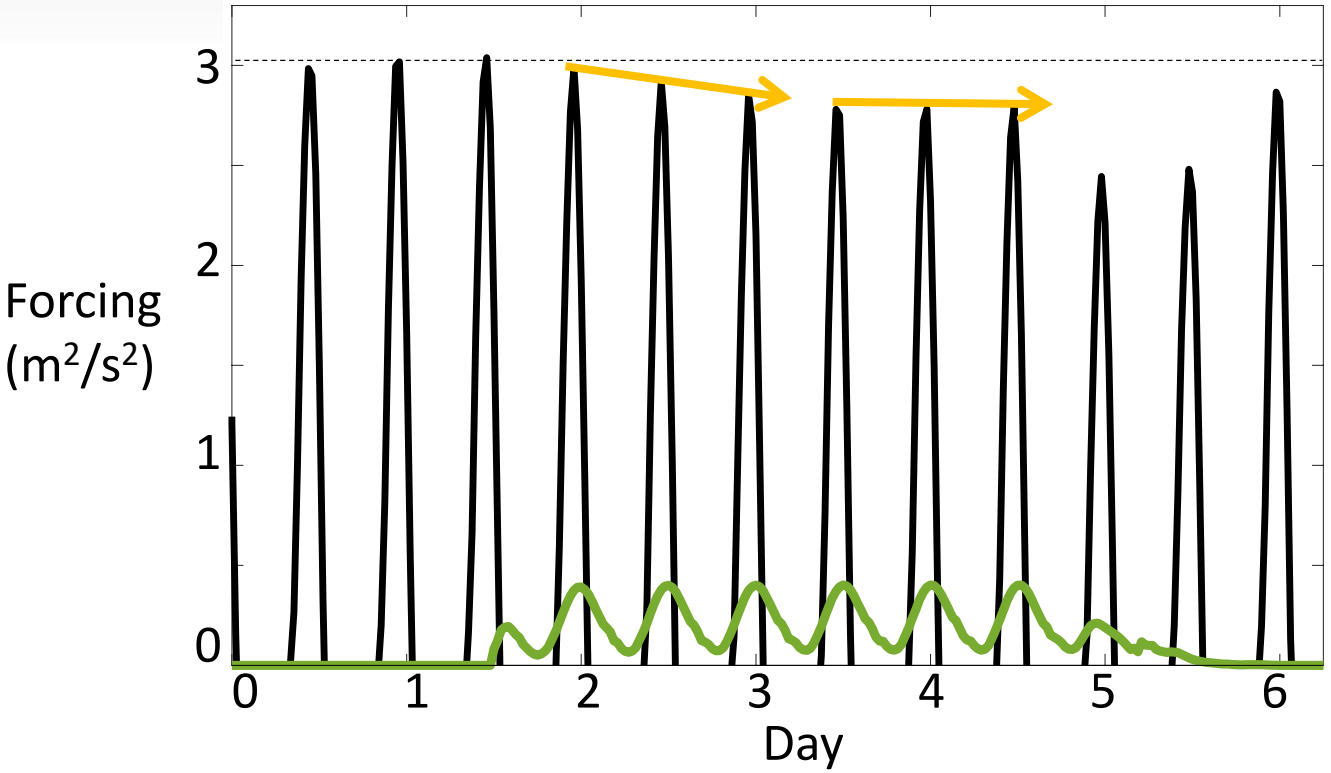
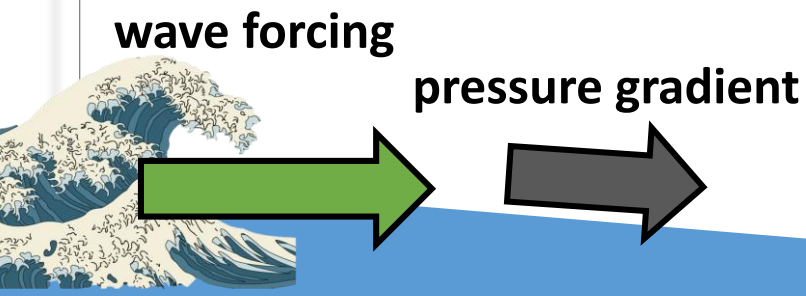
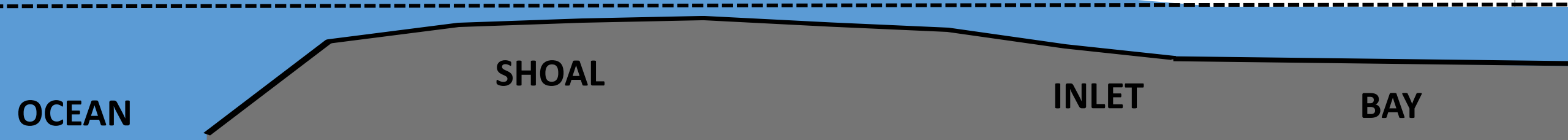
Pressure gradient

Decreases at beginning of storm and then levels off







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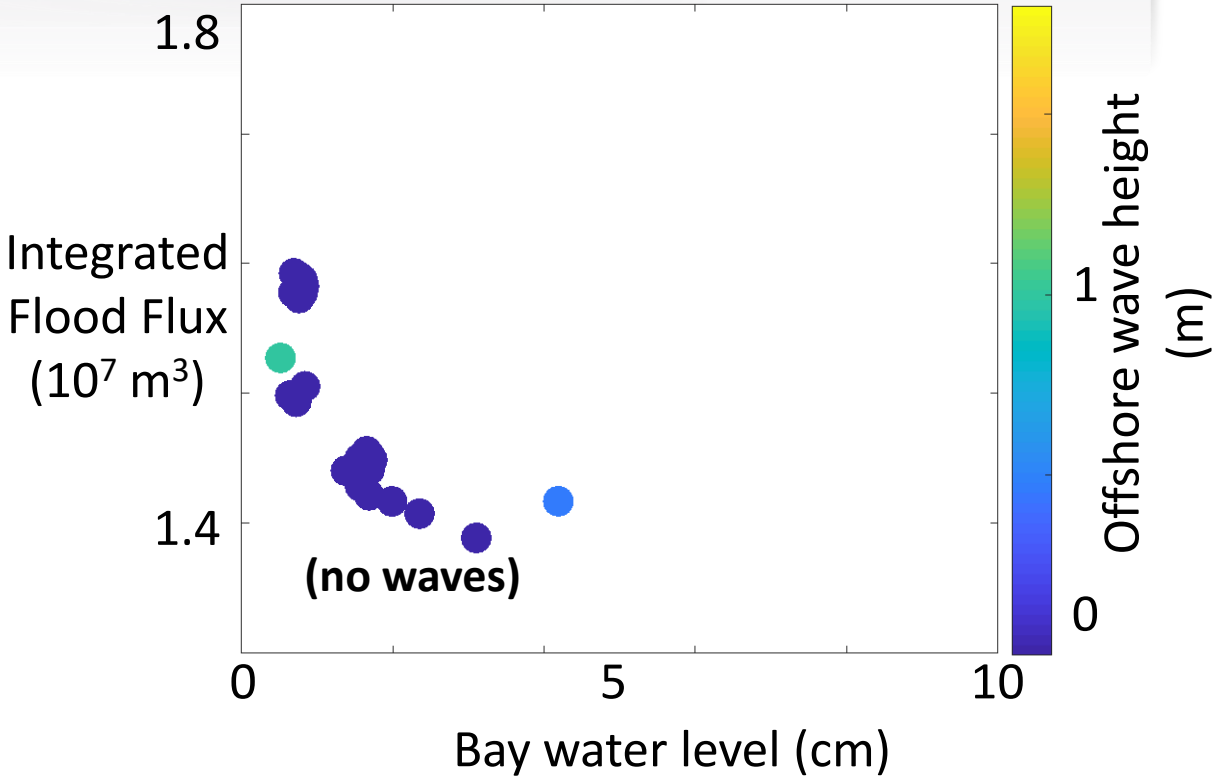
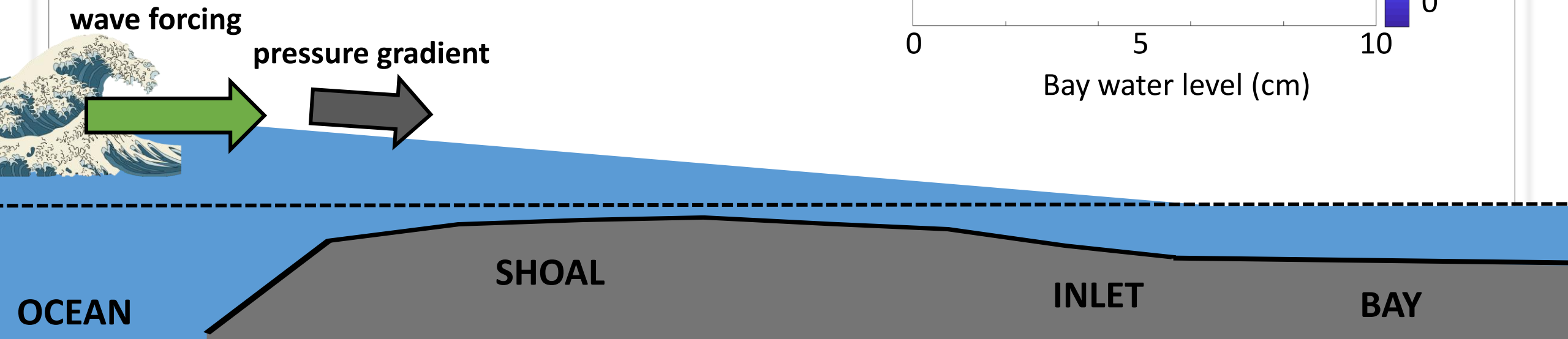
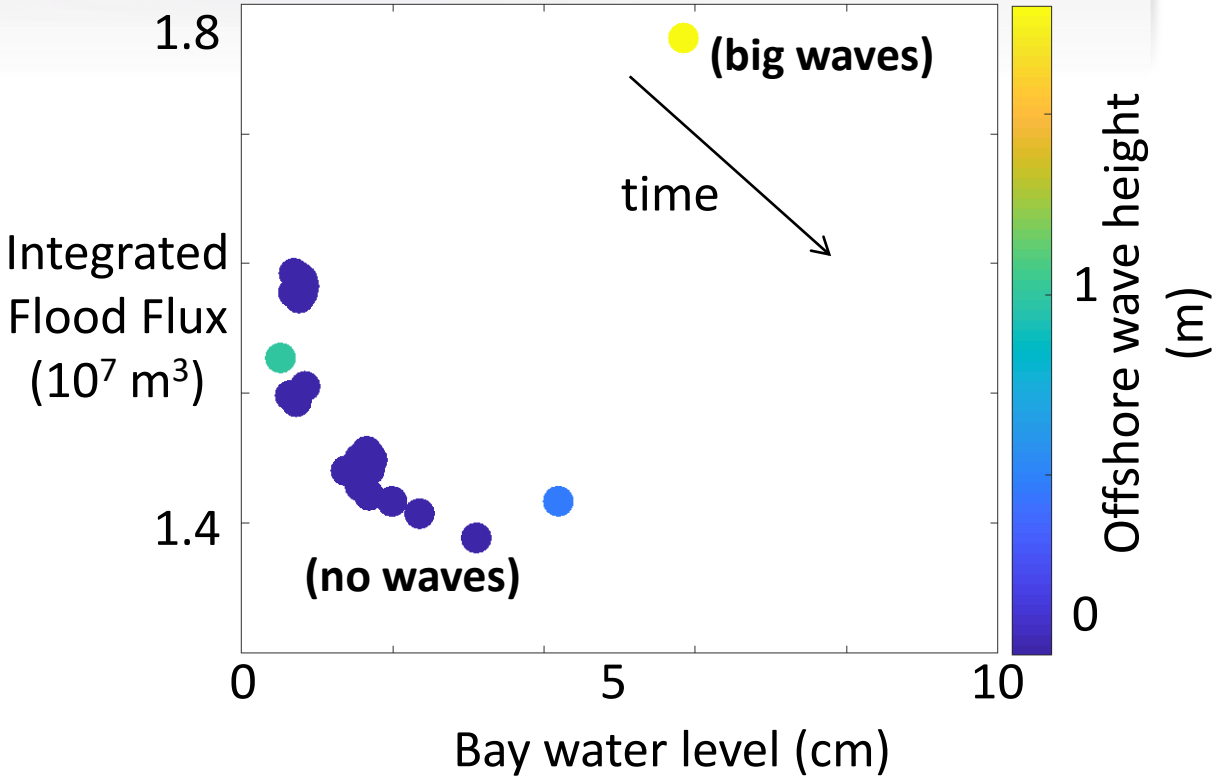


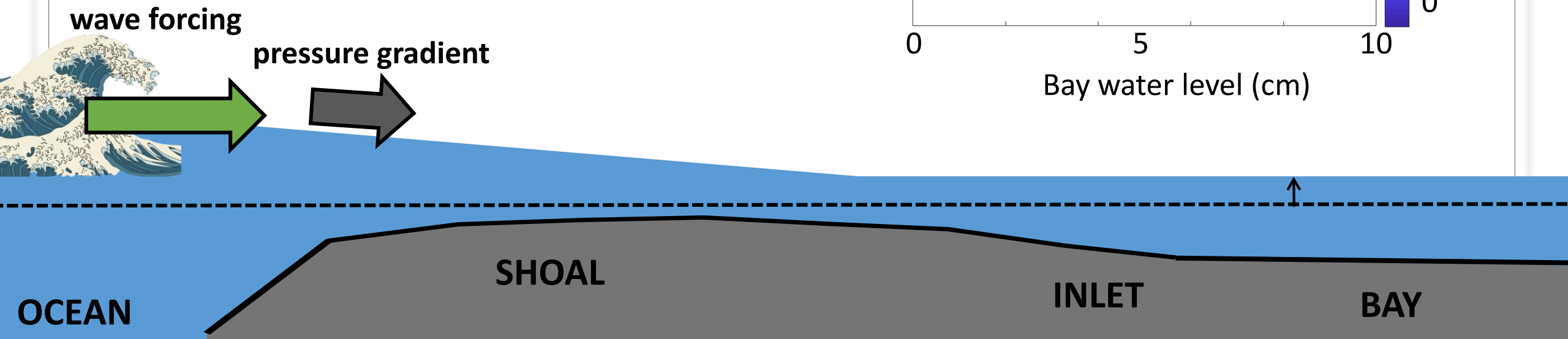


Pressure gradient

Decreases at beginning of storm and then levels off

Pressure gradient decreases as bay water levels increase





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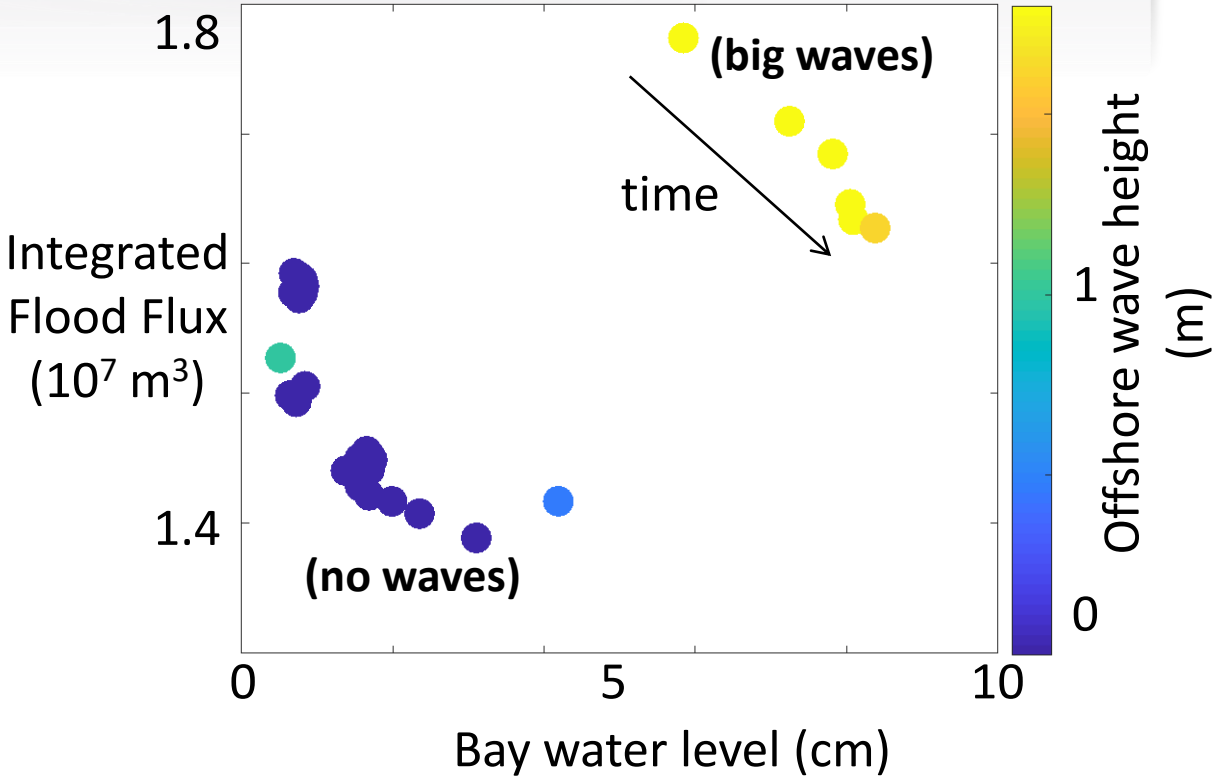

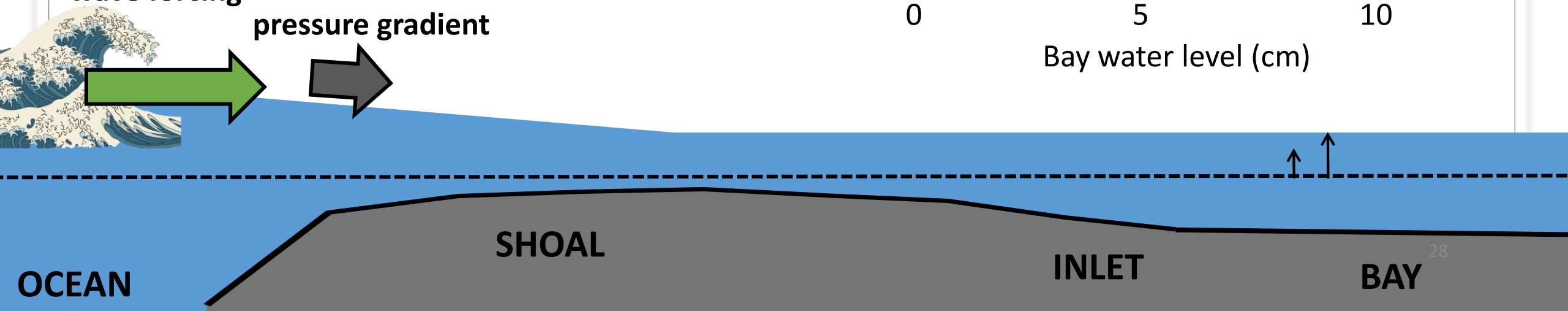

Summary

Flood mass flux is proportional to the pressure gradient and wave forcing

Wave forcing enhances mass flux into the inlet
Bay water levels increase incrementally during the wave event and level off
An increase in bay water levels leads to a decrease in the flood pressure gradient