Can ocean currents prolong coastal floods?

A case study of how the Shelfbreak Jet contributes to coastal flooding in Southern New England

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Sea-level Rise & Coastal Floods

- Coastal floods are mainly caused by sea-level rise (Fig 1), atmospheric pressure, tides and storm surges.
- Yet, other forces also play a role, such as waves, winds, river discharge, among others.
- At least 50% of the floods in Southern New England are related to non-tidal processes[1], yet **the precise nature of these effects has not been established.**

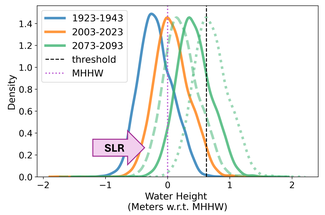

Figure 1. How sea-level rise (SLR) is shifting the baseline in Boston, making floods more frequent. Dashed and dotted green lines represent low and high projection scenarios. MHHW= mean higher-high water.

Can (local) ocean dynamics be a contributing process?

Sea Level & the Shelfbreak Jet

- The Shelfbreak Jet (SBJ) is a cold-water ocean current flowing southward along the shelfbreak.
- Coastal sea level and the SBJ are in geostrophic balance, with a shoreward Coriolis force (green arrow), counterbalanced by a pressure gradient from the shore to offshore (gray arrow).
- Sea level and the SBJ at Southern New England are highly correlated on timescales of 1-15 days[2].

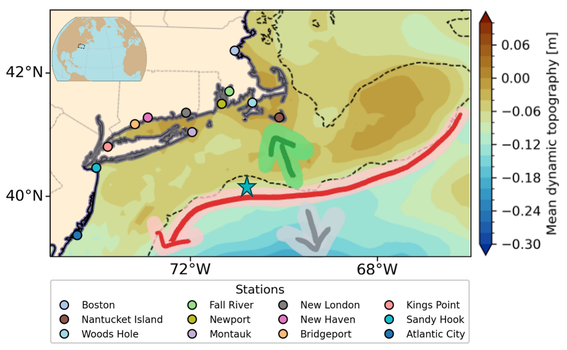

Figure 2. Map of the study region: Southern New England coastline (Northeast U.S.) Circles indicate tide-gauge stations, star the location SBJ of measurements, red arrow the Shelfbreak Jet, green arrow the Coriolis force and gray arrow the pressure gradient.

Drivers of Coastal Flood

- We look at the which mechanisms contribute to coastal floods by:
  1. Determine frequency and process components of still water level at tide gauges
  2. Apply a regression to the storm surge component with ocean dynamics (SBJ transport from the OOI Pioneer[2]) and wind stress (ERA5[3]) as the predictor variables.

1. Still water level components

Total still water level @ tide gauge = Tides + Inverted Barometer (IB) + Storm Surge (SS) (high-frequency) + Mean sea level (MSL) (low-frequency)

2. Regression of Storm Surge Component

Storm Surge (SS) = ocean dynamics + winds

b_{SBJ}*SBJ + b_u* Tu + b_v* Tv + residual

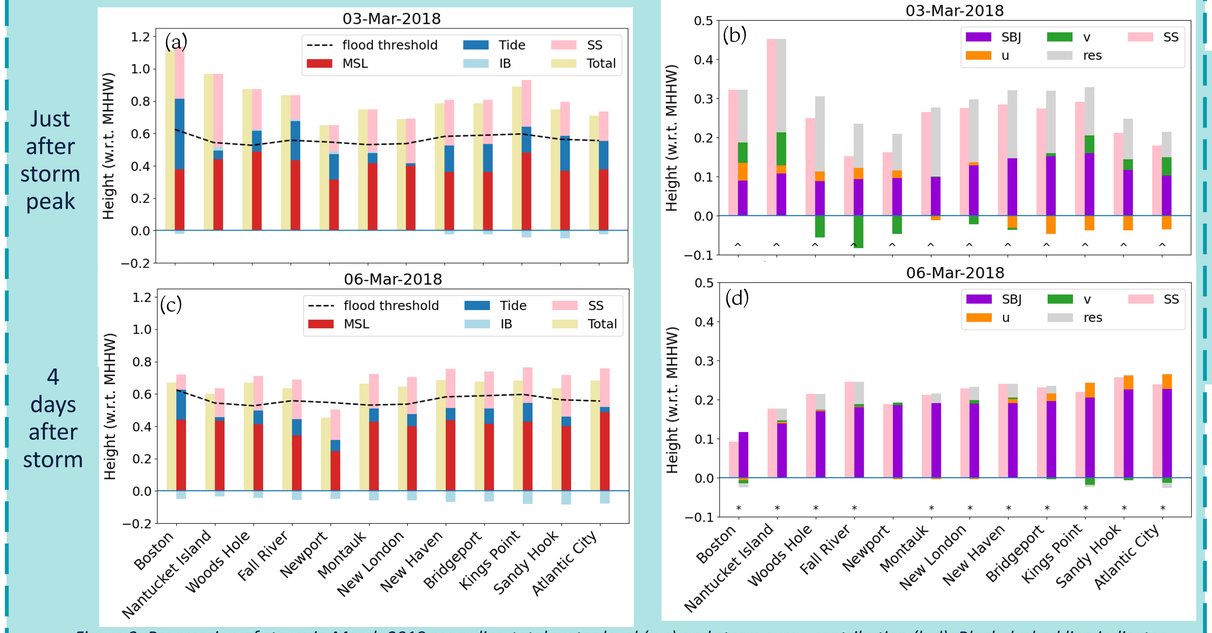

Figure 3. Progression of storm in March 2018 regarding total water level (a,c) and storm surge contribution (b,d). Black dashed line indicates flood threshold for each station, and symbols in the bar plots indicate if a flood was observed (triangle), and if the water level would be below flood threshold without the SBJ contribution (star). In case a flood was not observed, no symbol is added.

What About Other Instances?

- Overall, the SBJ explains about 30% of the daily SS variance from 2014-2022. (Fig. 4)

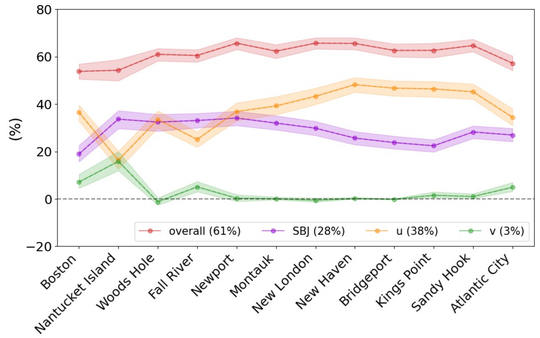

Figure 4. Overall explained variance of storm surge by the regression model (red), and by each predictor (purple for SBJ, orange for zonal wind stress (u) and green for meridional wind stress (v), considering entire time series. Shaded area represents the 95% confidence interval.

The March 2018 Case

- In March 2018, a large Nor'easter hit the region, causing widespread flooding along the coastline (Fig 3a).
- After the storm passed, there was still widespread flooding even 4 days later (Fig 3c).
- SBJ-dynamics was responsible for most of the storm surge of this event, and for about 30% of the water height at the tide gauge.
- **This prolonged flood only happened because of the SBJ-dynamics contribution.**

Take Home Message

- SBJ dynamics contribute to the lingering effect of a flood after a storm has passed
- Ocean dynamics should be considered in flood studies elsewhere

References: 1. Li et al (2022), *JGR: Oceans*; 2. Camargo et al (2024), *GRL*; 3. Hersbach et al (2023), *C3S CDS*

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