Integrated Modeling of Coastal and Riverine Flooding to Estimate Return Levels of Extreme Skew Surge

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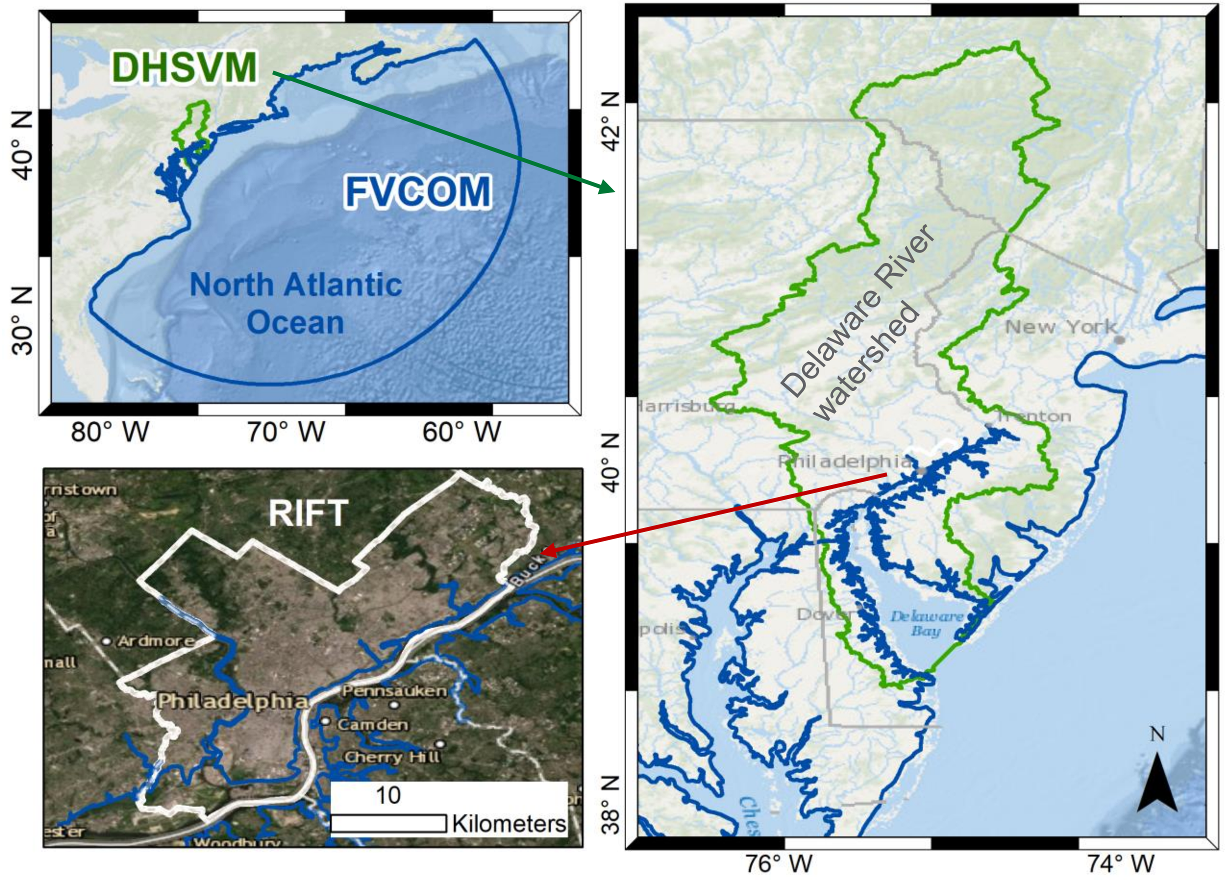
Integrated Coastal Modeling (ICoM) is funded by multiple programs in the Earth and Environmental System Science Division of DOE's Office of Science

Objective: Develop an integrated terrestrial-coastal modeling system to characterize the compounding effect of different flood types

- Coupling of hydrologic (DHSVM) and hydrodynamic (FVCOM and RIFT) models to capture key flooding processes
- Evaluating the sensitivity of compound flooding to changes to watershed and estuarine characteristics in the future climate
- How could the projected changing climate influence the future flooding potential?

DHSVM-FVCOM-RIFT model domain in the Mid-Atlantic

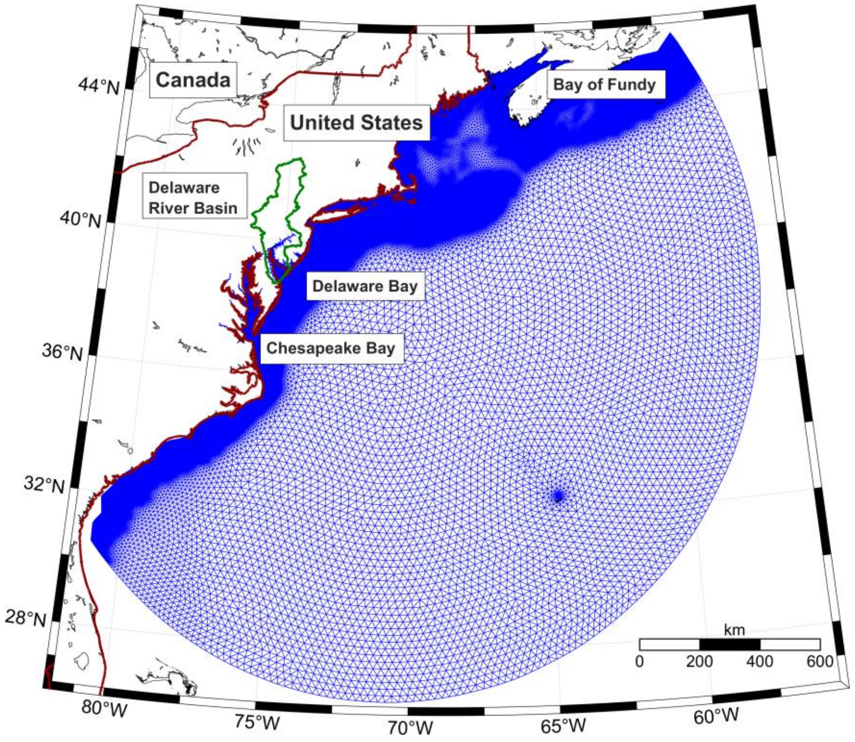


DHSVM-FVCOM implementation in Delaware Bay and River

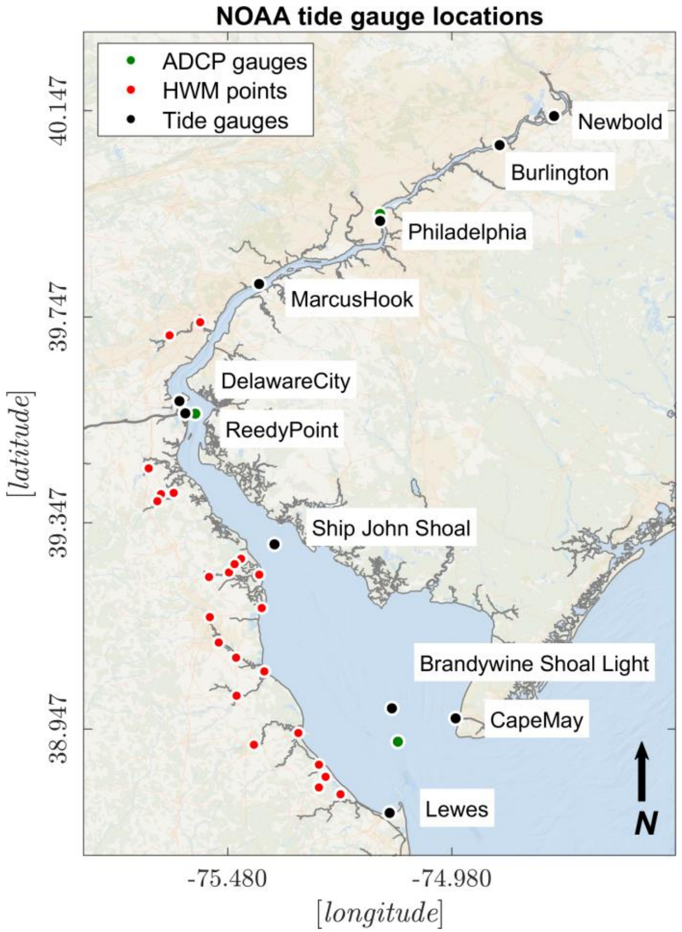
Model Resolution

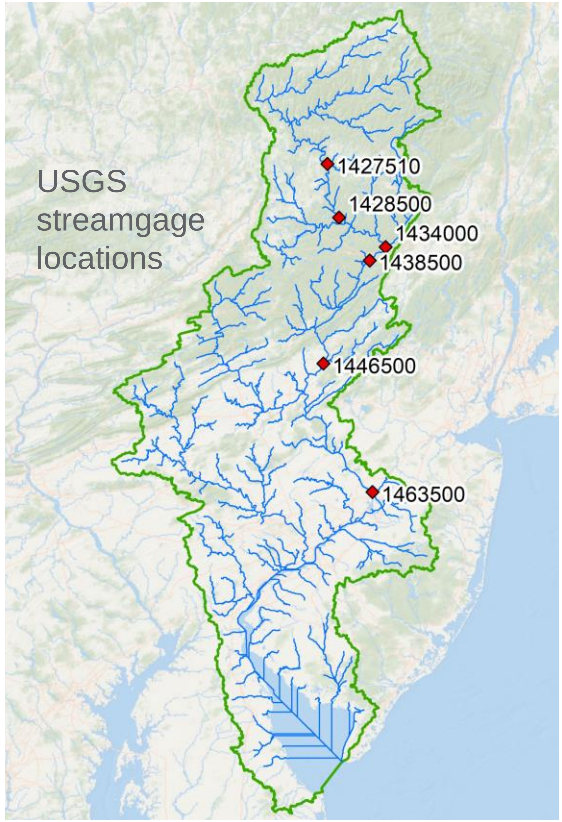
DHSVM: **90** m

FVCOM: **10 m** (creeks) - **30 km** (ocean)

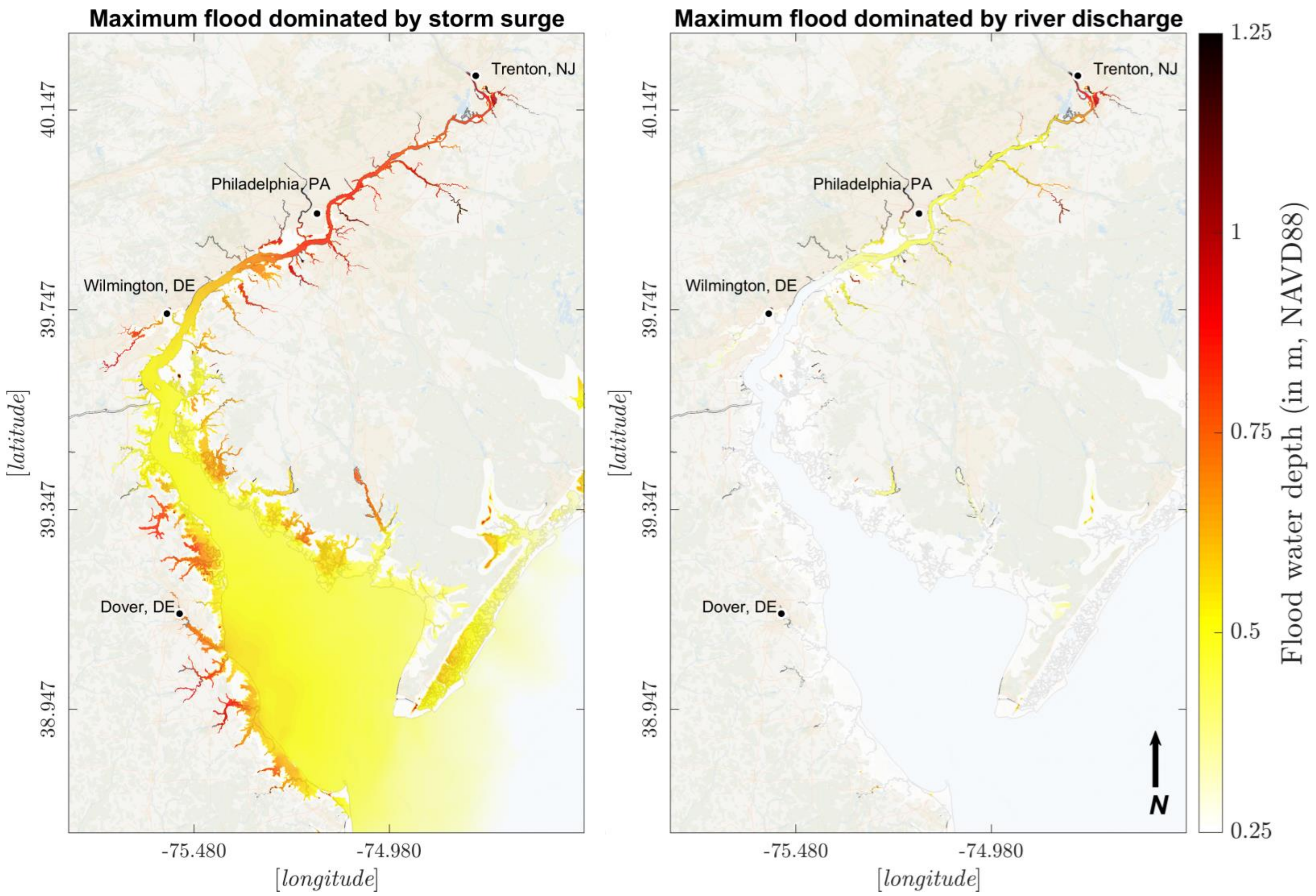


Model validation using USGS streamgages, NOAA tide and ADCP gauges, and high-water marks





DHSVM-FVCOM implementation in Delaware Bay and River



1. *Non-linear interactions between tide, surge, and river flow*

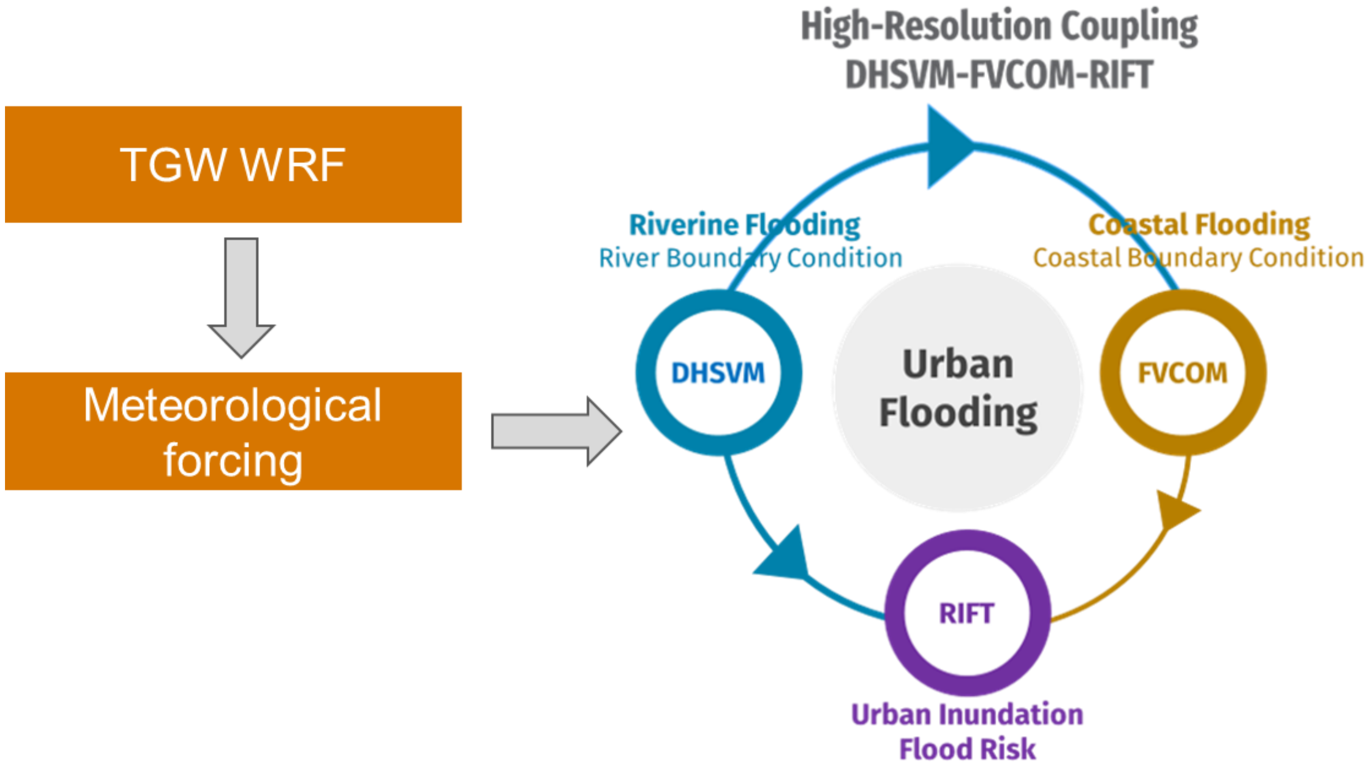
Xiao, Z., Yang, Z., Wang, T., Sun, N., Wigmosta, M., & Judi, D. (2021). ***Characterizing the Non-linear Interactions Between Tide, Storm Surge, and River Flow in the Delaware Bay Estuary, United States***. Frontiers in Marine Science, 8

2. *Interacting effects of watershed and coastal processes on the evolution of compound flooding*

Deb, M., Sun, N., Yang, Z., Wang, T., Judi, D. R., Xiao, Z. and Wigmosta, M. S. (2023). ***Interacting effects of watershed and coastal processes on the evolution of compound flooding during Hurricane Irene***. Earth's Future, 11

Long-term flood simulations using Thermodynamic Global Warming data (TGW WRF)

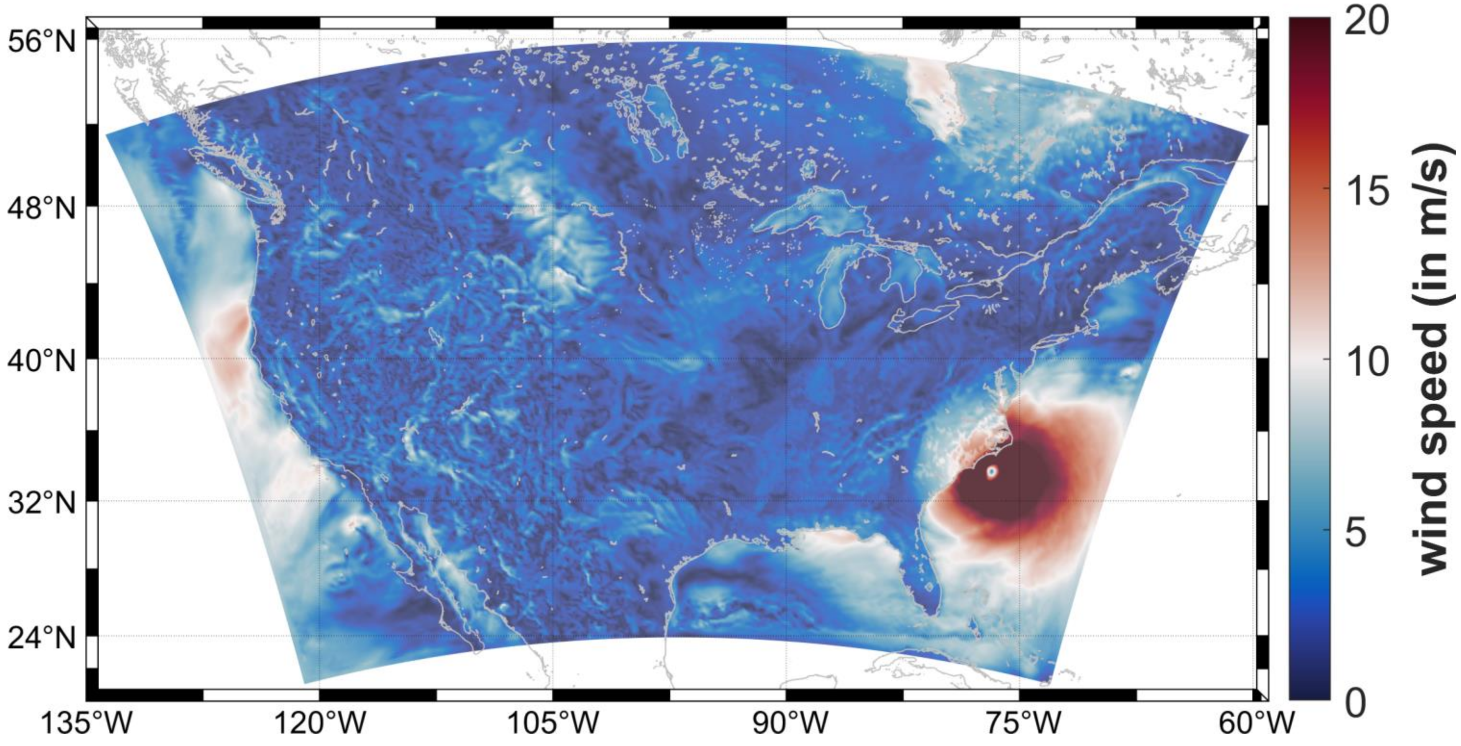
Long-term flood simulations for Philadelphia under historical climate and future climate scenarios using TGW WRF datasets



Thermodynamic Global Warming data (TGW WRF) [https://tgw-data.msdlive.org/]

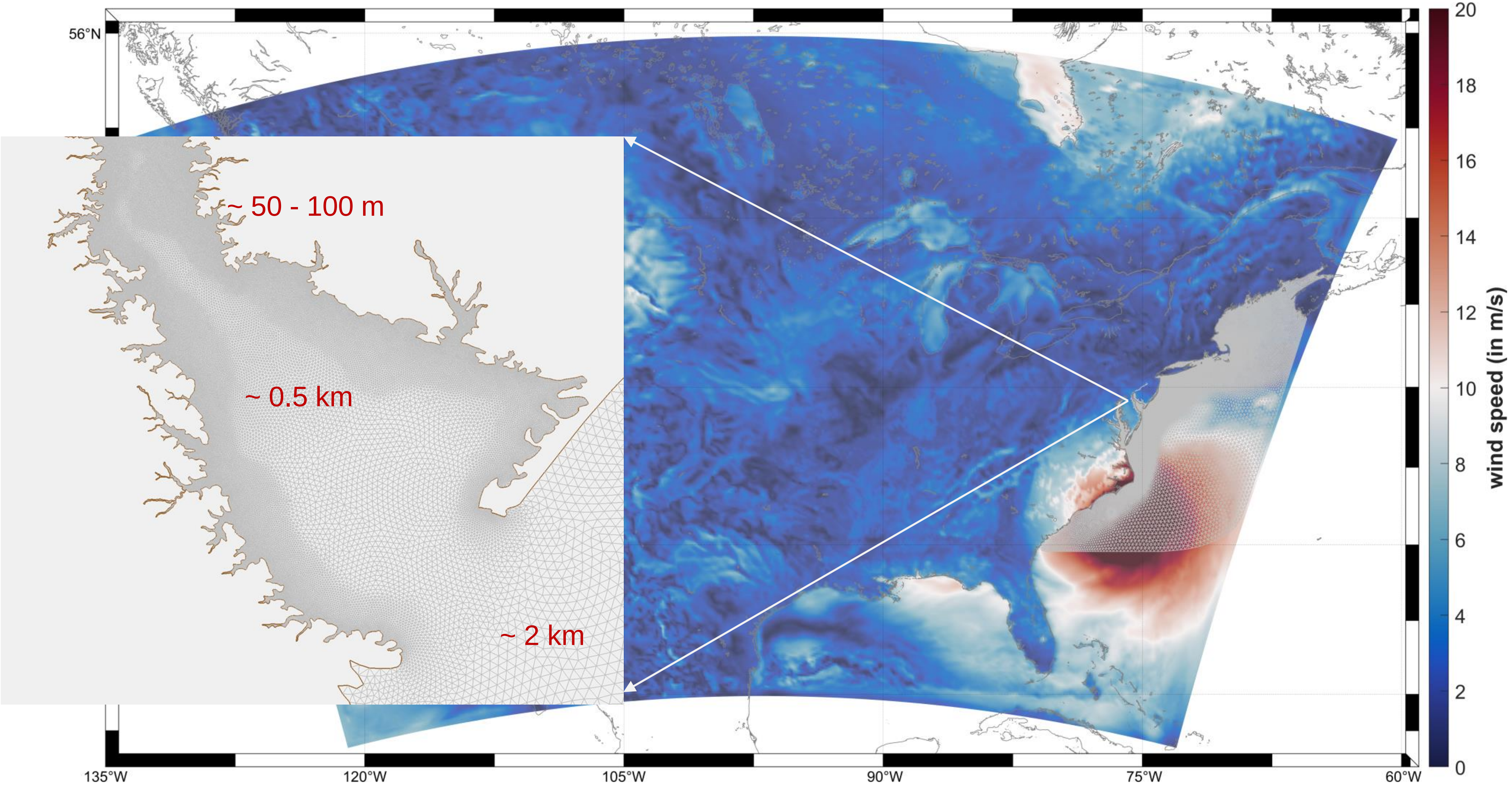
40-year historical (1980-2019)

- Temperature at 2 meters above surface, Precipitation, Downward short-wave and long-wave radiation at ground level
- Wind velocity at 10 meters, Pressure at surface level



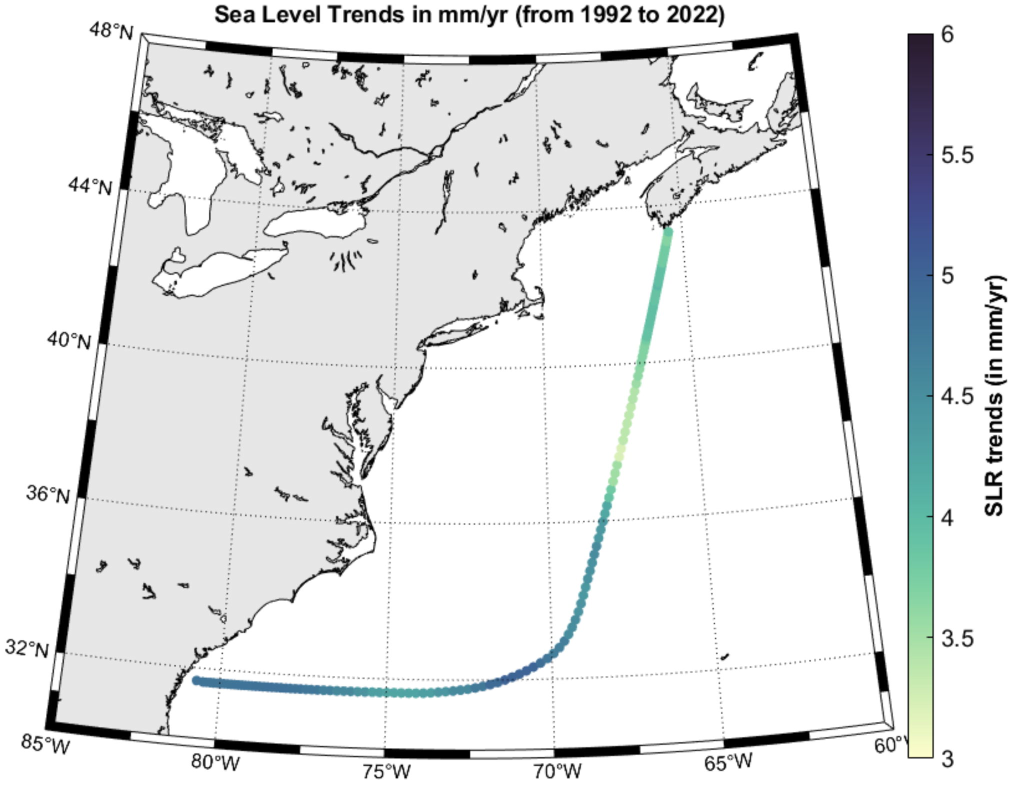
Hurricane Irene (2011) wind field during landfall

Model setup and forcing for long-term simulations (FVCOM model domain)



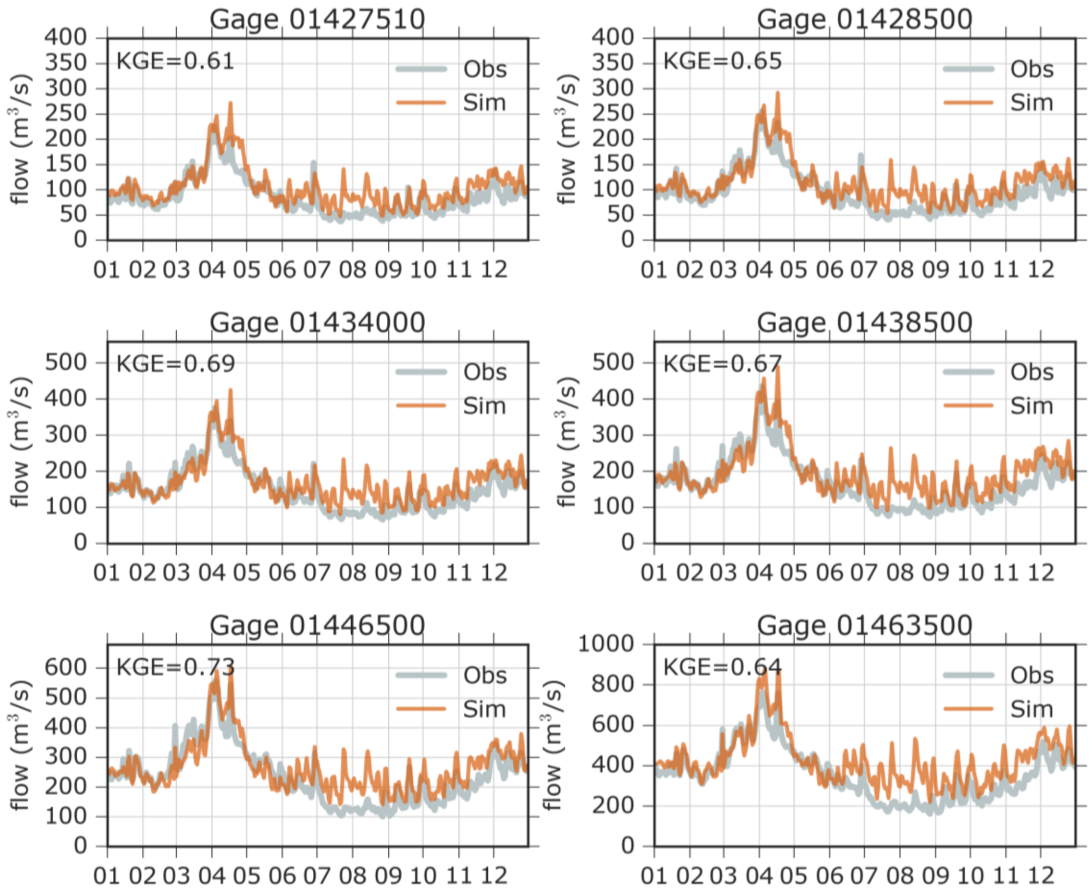
Model forcings: water level at the open boundary and the DHSVM river discharge

Water level time-series is constructed using ADCIRC tidal constituents and SLR trends at the open boundary

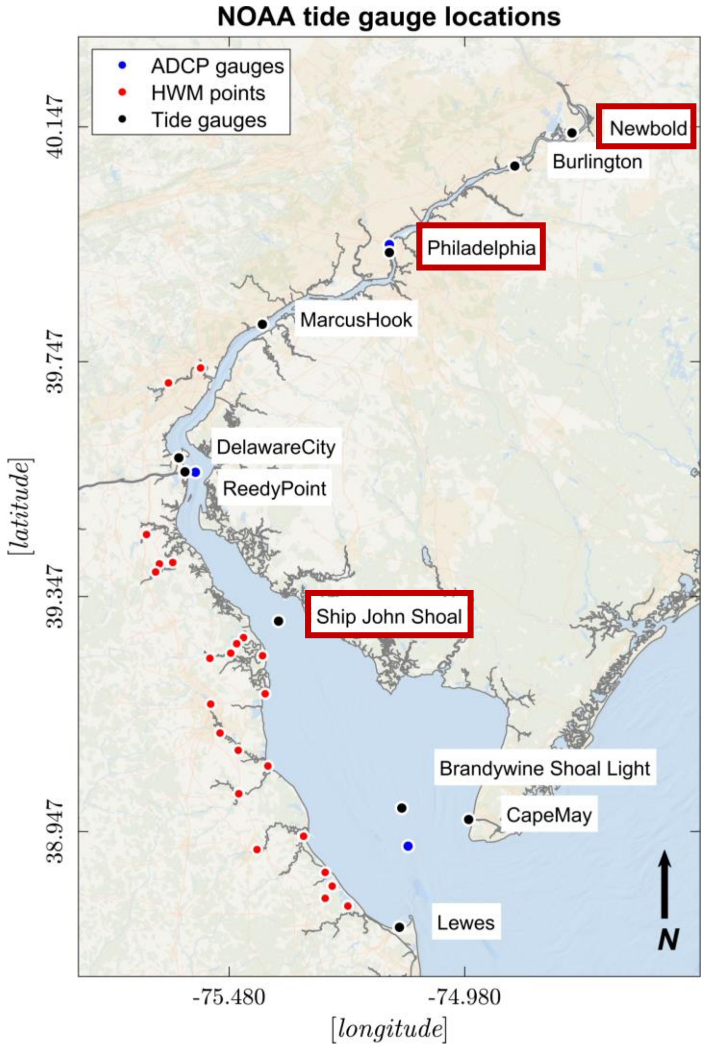


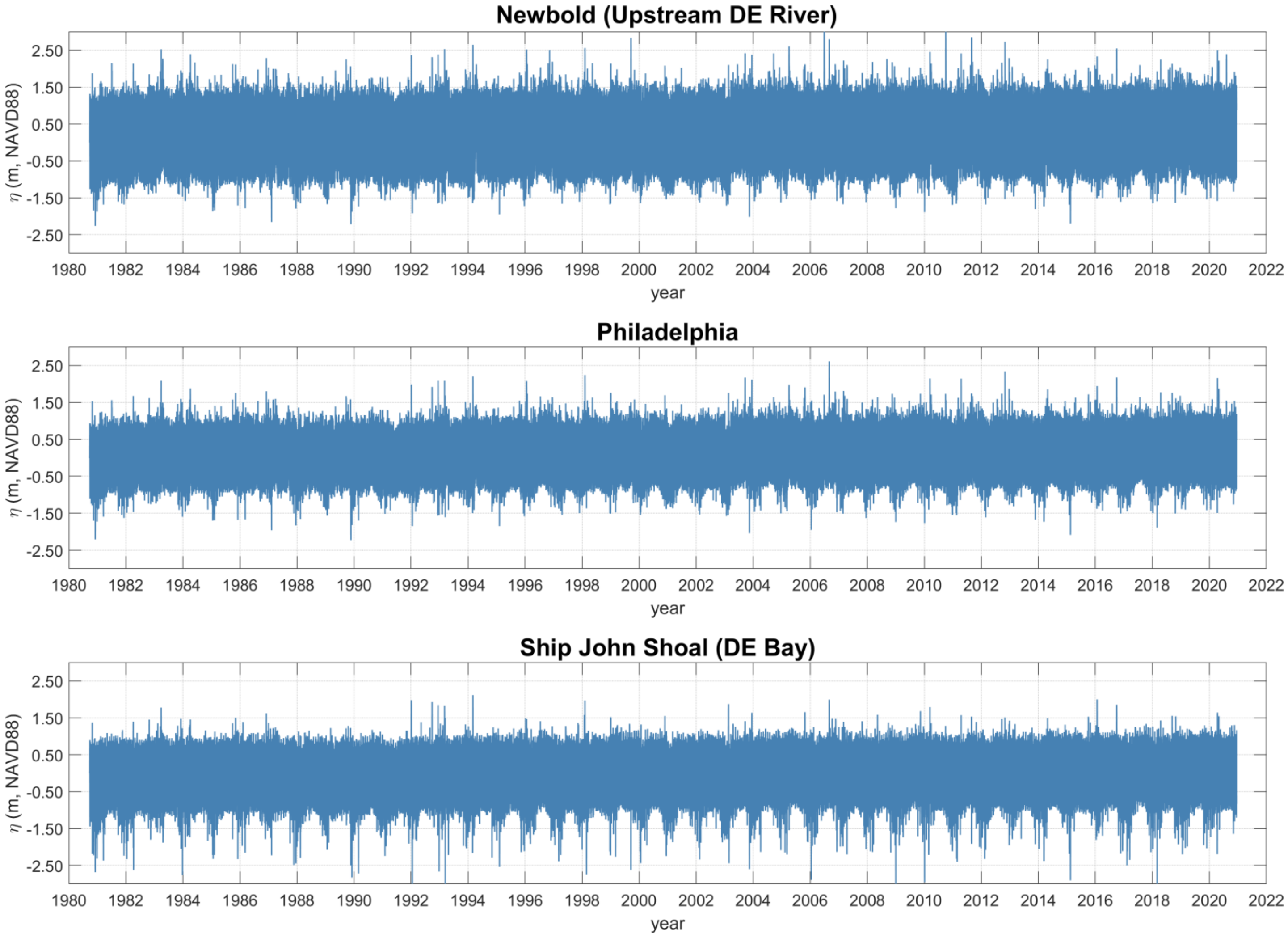
NOAA NESDIS Satellite Altimetry data

DHSVM skill in simulating daily flow along the Delaware River from 1982-2020

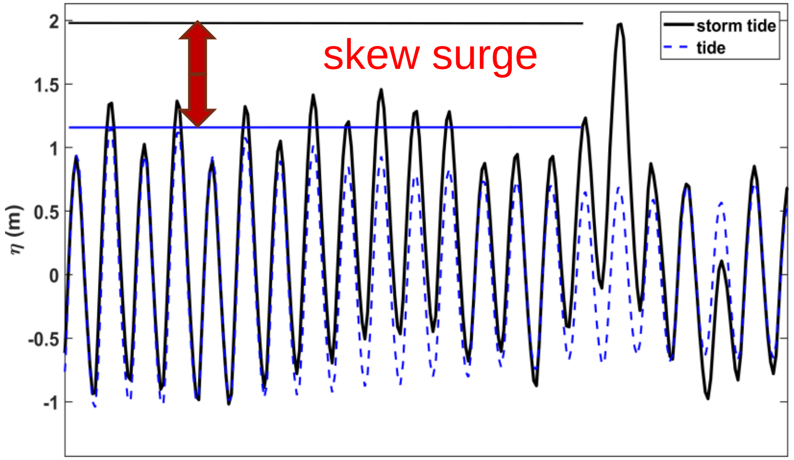


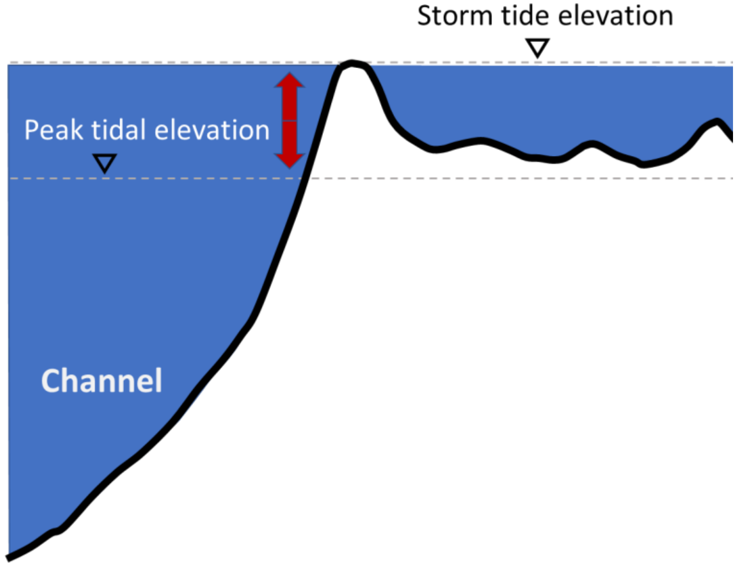
Model results: water surface elevation at different tide gauge locations along DE Bay and River

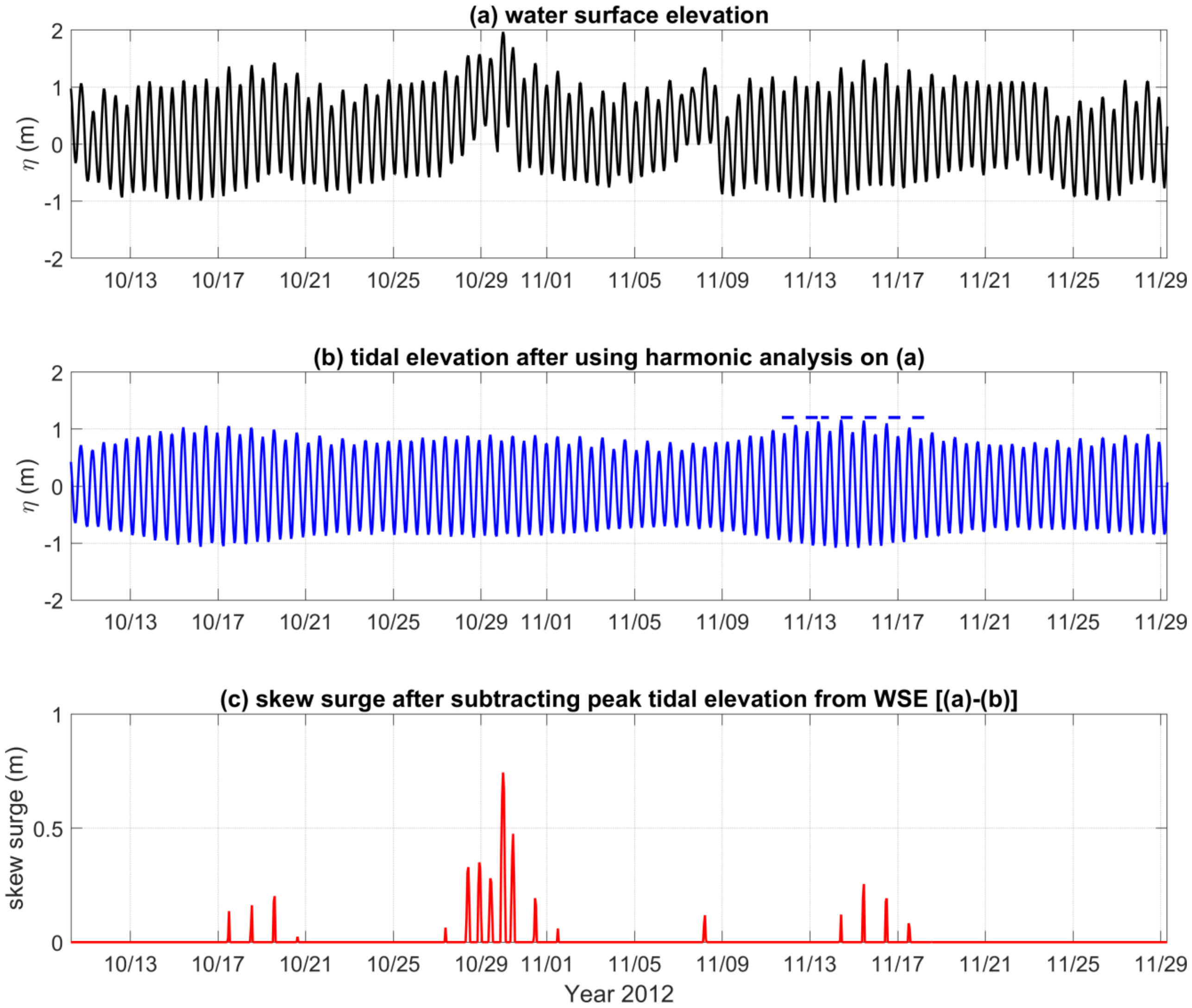




Post-processing of the long-term data set for estimating skew surge / flood water depth







Univariate Extreme Value Analysis (EVA)

- **Estimating the return-level of extreme skew surge using the historical 40-years data**

We used two families of extreme value distributions to model extreme values:

- ***Generalized extreme value (GEV) distribution***

Can be fit to the set of maximum values of discrete, non-overlapping blocks called **Block Maxima (BM)** [e.g., annual maximum values]

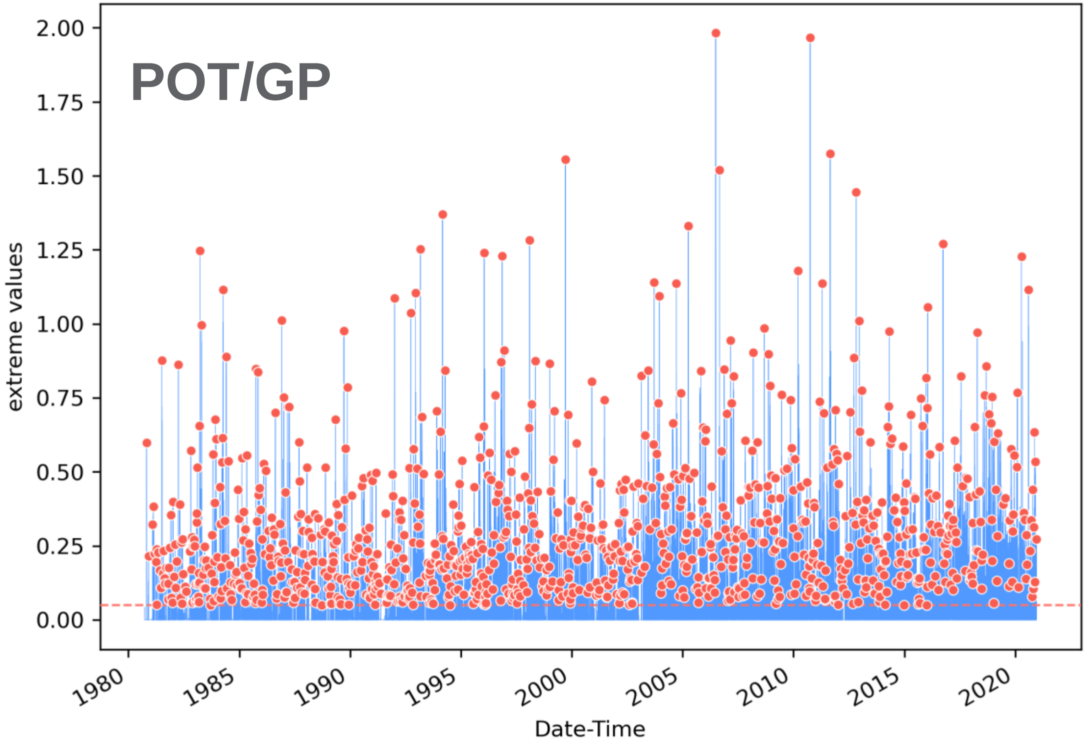
- ***Generalized Pareto (GP) distribution***

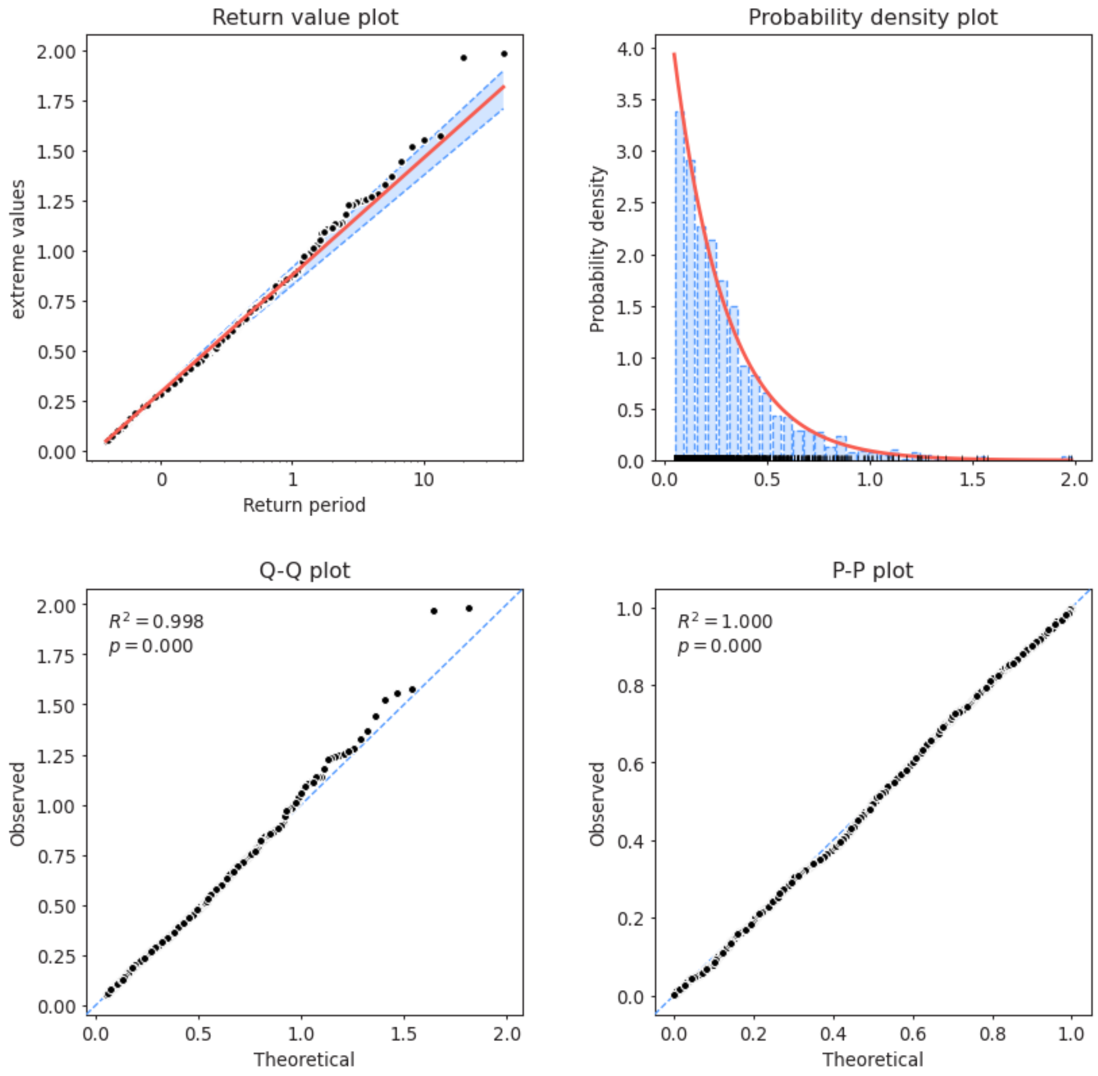
Can be fit to the upper tail of the parent distribution using the **Points-Over-Threshold (POT)** approach

pyextremes, *by George Bocharov*
(https://georgebv.github.io/pyextremes/)

Return levels using BM/GEV and POT/GP in the river discharge-dominated zone

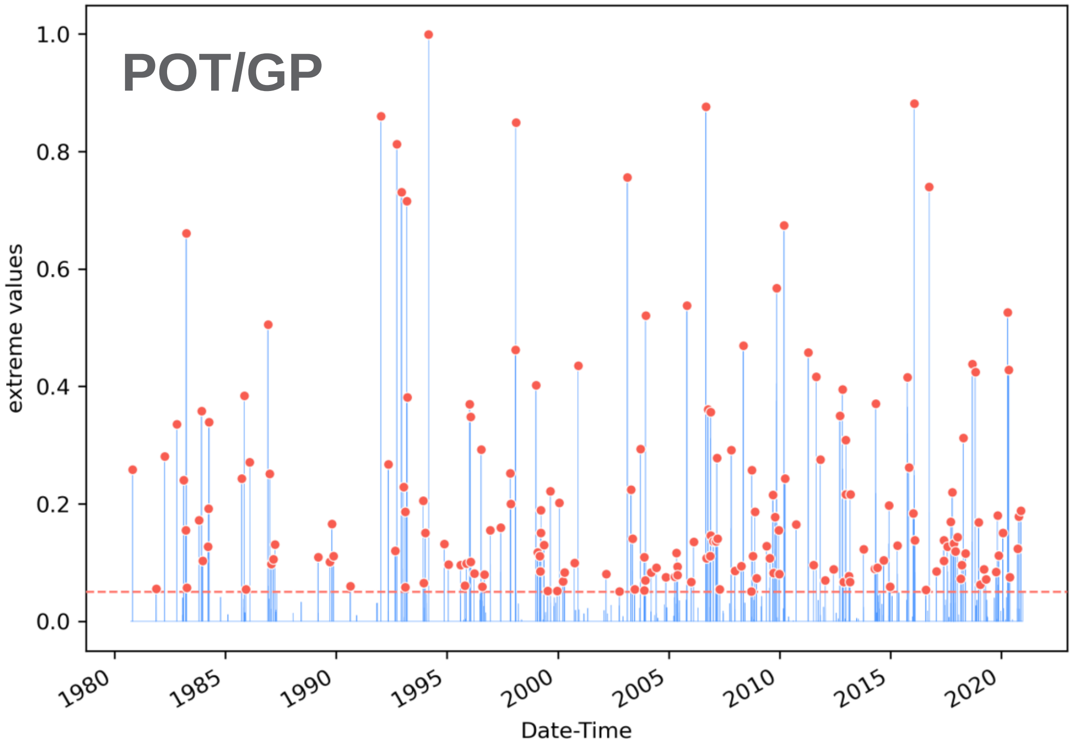
Newbold, NJ

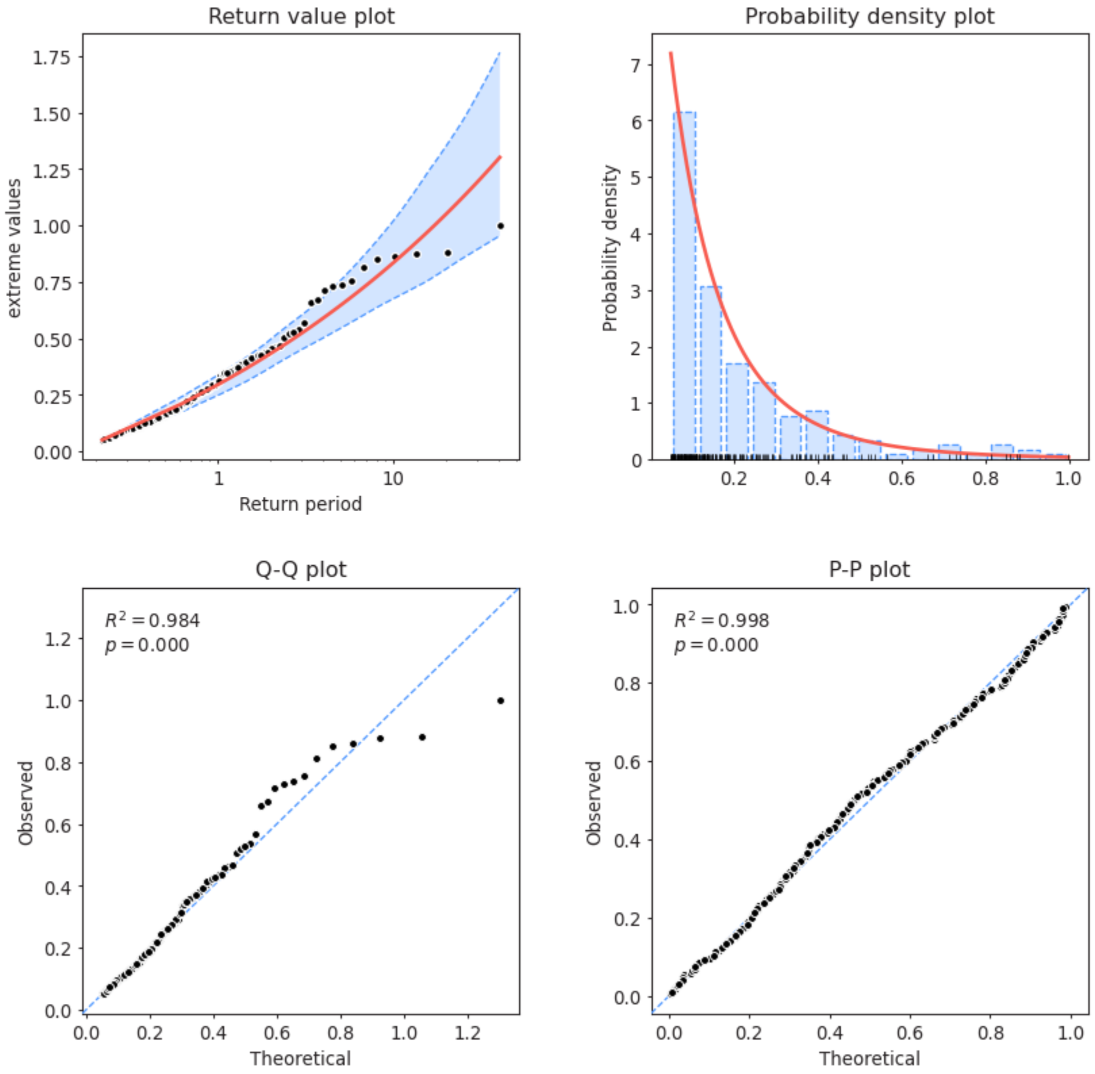




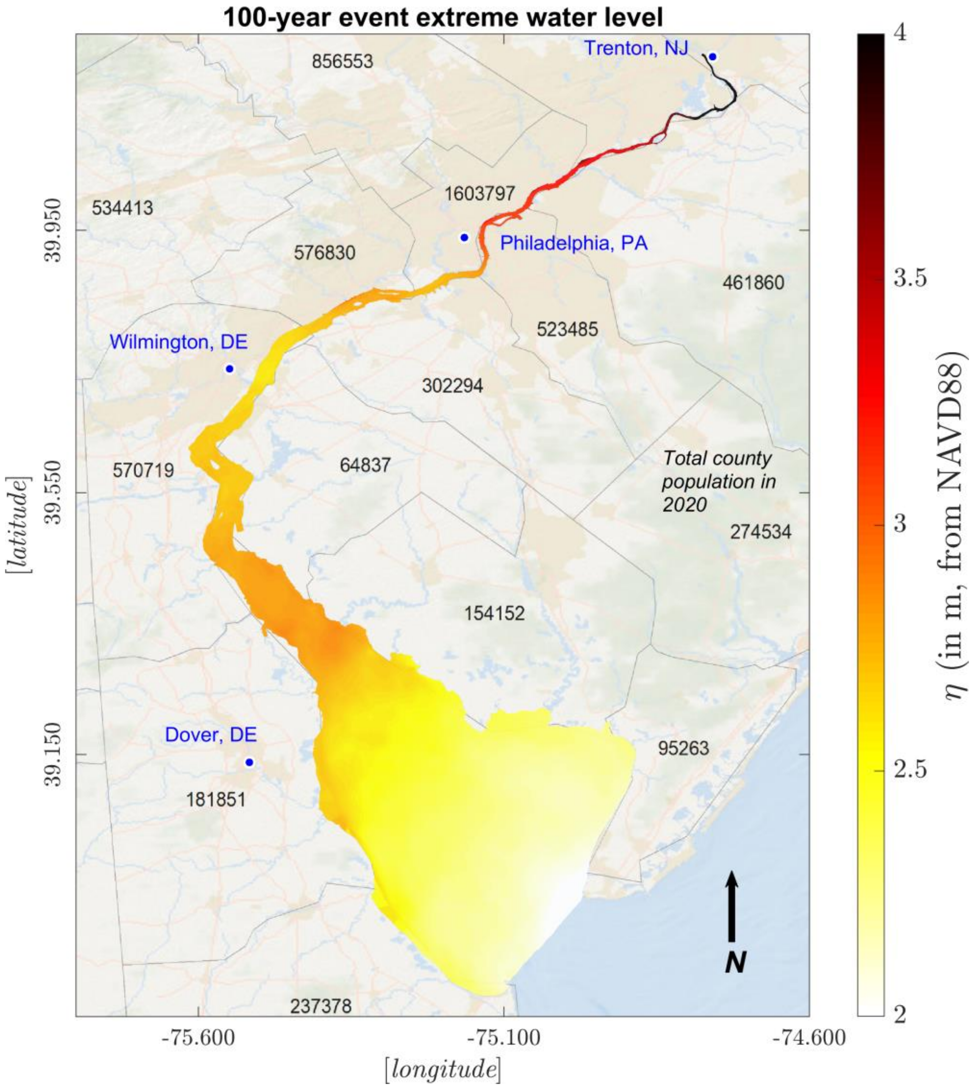
Return levels using BM/GEV and POT/GP in the storm surge-dominated zone

Ship John Shoal, NJ





Spatial distribution of the 100-year extreme water level in the DE Bay and River using POT/GP



Future Works

- Comprehensive model vs in-situ comparison to estimate the bias
- Identify isolated fluvial and coastal flooding events and compound flood events
- Direct simulations of discrete flood events using RIFT to examine urban flooding
- Examine how floods are affected by climate change and sea level rise, including the driving mechanisms for both univariate and compound floods

Thank you!

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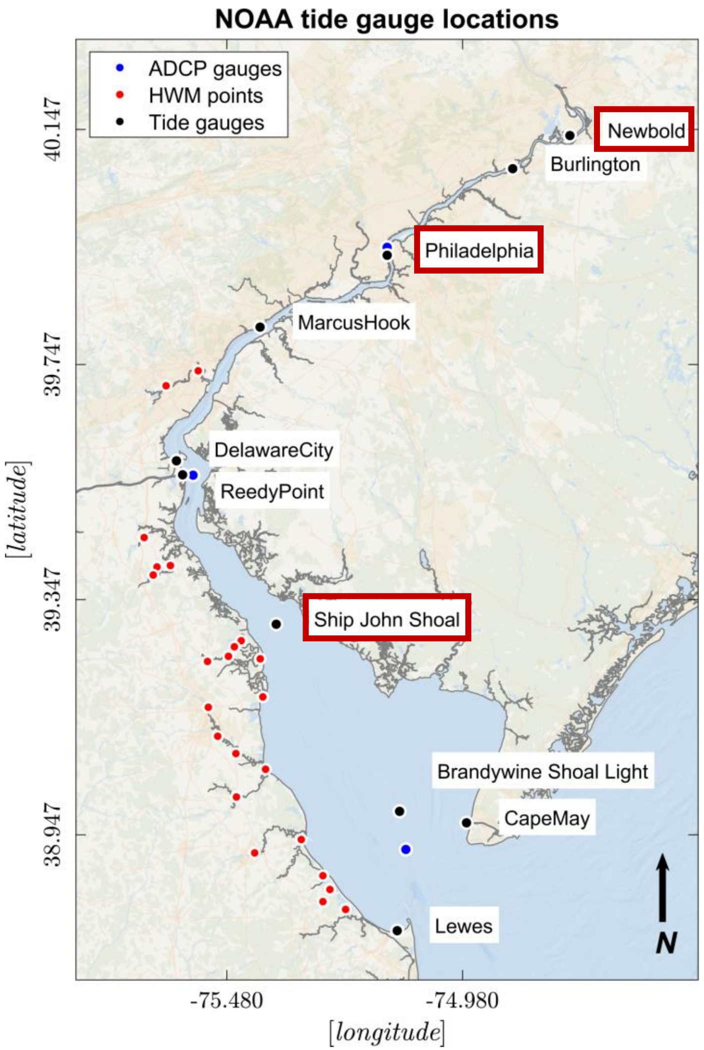
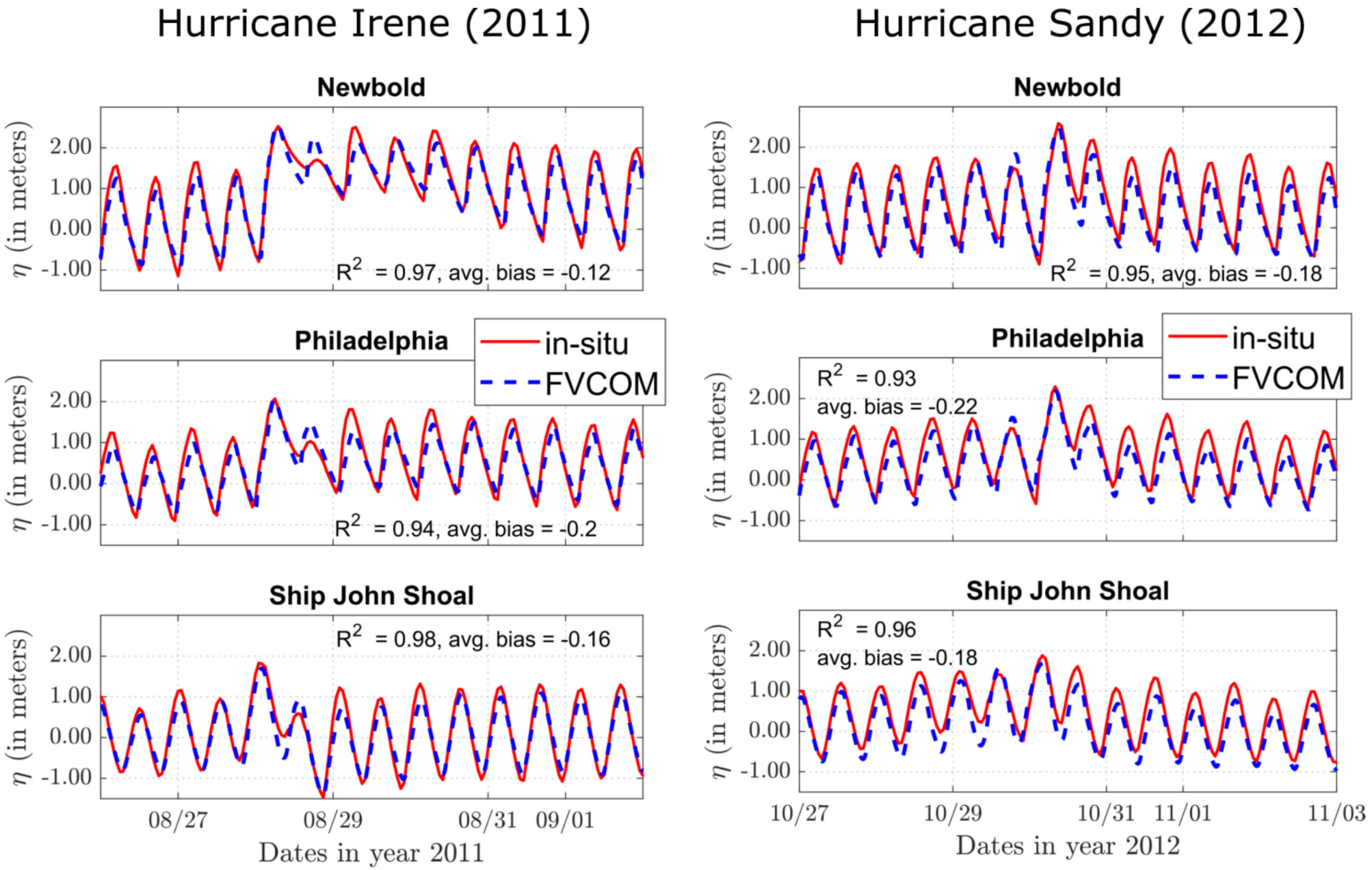
FVCOM model validation using extreme events (water surface elevation)





Model forcings: TGW WRF wind speed comparison