Probabilistic Extra-Tropical Storm Surge Guidance

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Background

The National Weather Service's (NWS) Meteorological Development Laboratory (MDL) developed the Extra-Tropical Storm Surge (ETSS) model in 1995 by modifying the Sea Lake and Overland Surges from Hurricanes (SLOSH) model (Jelesnianski et al. 1992) to use Global Forecast System (GFS) winds as an input to predict the impacts of extra-tropical storms. Over the last two years, MDL, with Hurricane Sandy Supplemental funding, has enhanced the ETSS model to meet the anticipated requirements of a potential extra-tropical storm surge watch (Liu et al. 2015). The latest such enhancement, implemented in October 2015, enabled ETSS to operationally provide deterministic inundation guidance four times a day based on storm surge and tide in all of its model domains (Liu et al. 2016).

Storm surge guidance has various uncertainties associated with it such as (a) atmospheric forcing (wind speed, wind direction and atmospheric pressure), (b) initial water conditions, (c) included physical processes, (d) numerical scheme. While some of these can be reduced by enhancing the storm surge model, others, such as atmospheric forcing, rely on external inputs. Uncertainty in atmospheric forcing is particularly challenging as it is the main source of uncertainty in storm surge based inundation guidance. Ensemble techniques are necessary to produce quantitative estimates of storm surge based inundation risk.

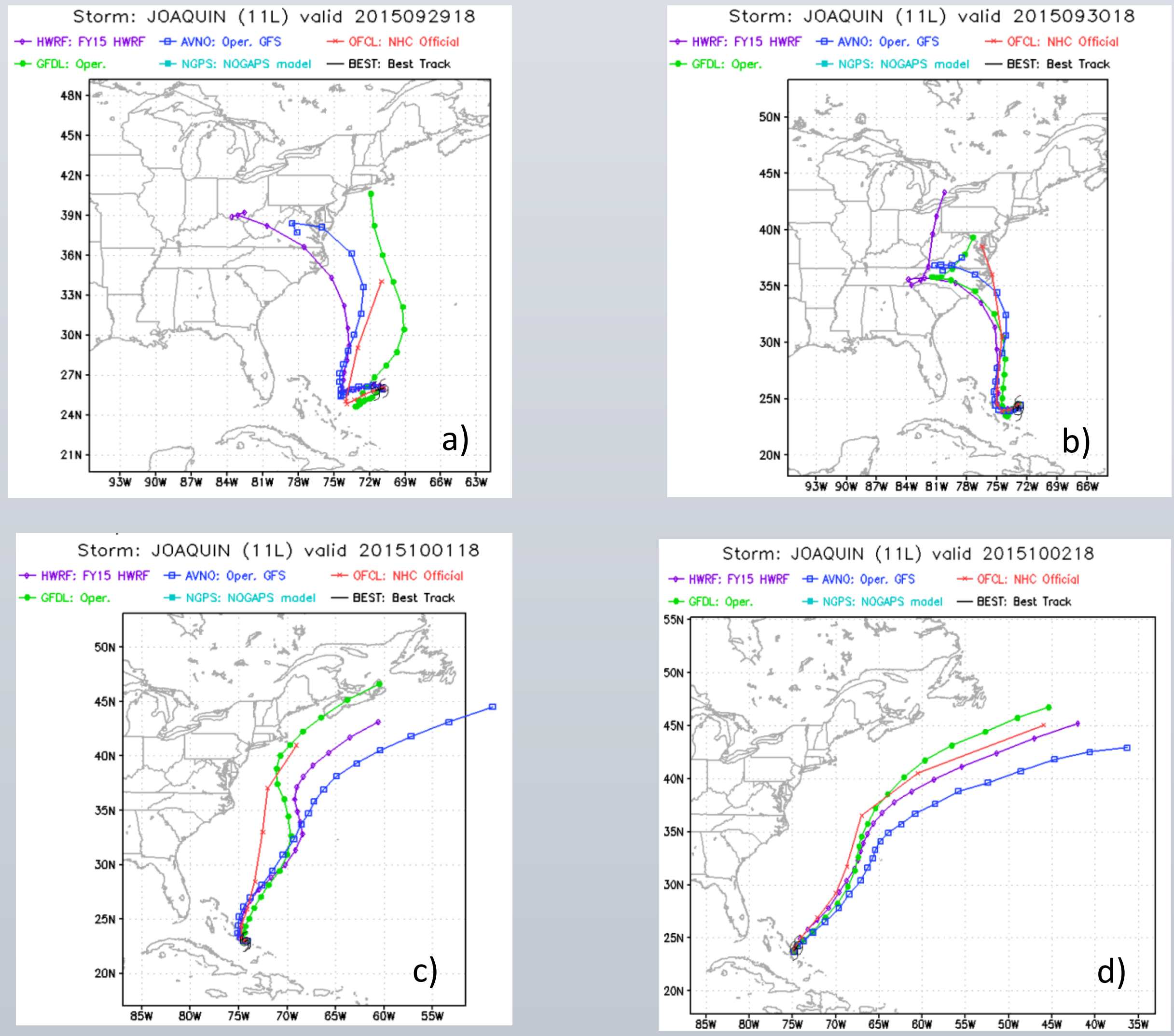


Fig. 1. Hurricane Joaquin track forecast from GFS (blue) and other models at 18z UTC on (a) Sep. 29, (b) Sep. 30, (c) Oct.1, and (d) Oct. 2

(From NCEP Operational HWRF Forecast Guidance for Storm JOAQUIN)

The ETSS model run for Hurricane Joaquin (Fig. 1) is good example of how the uncertainty of the model forecast play into the difficulty of storm surge forecast (e.g. atmospheric forcing from wind model GFS). Slight variation in the atmospheric forcing can result in considerable variations in storm surge model results (Fig. 2).

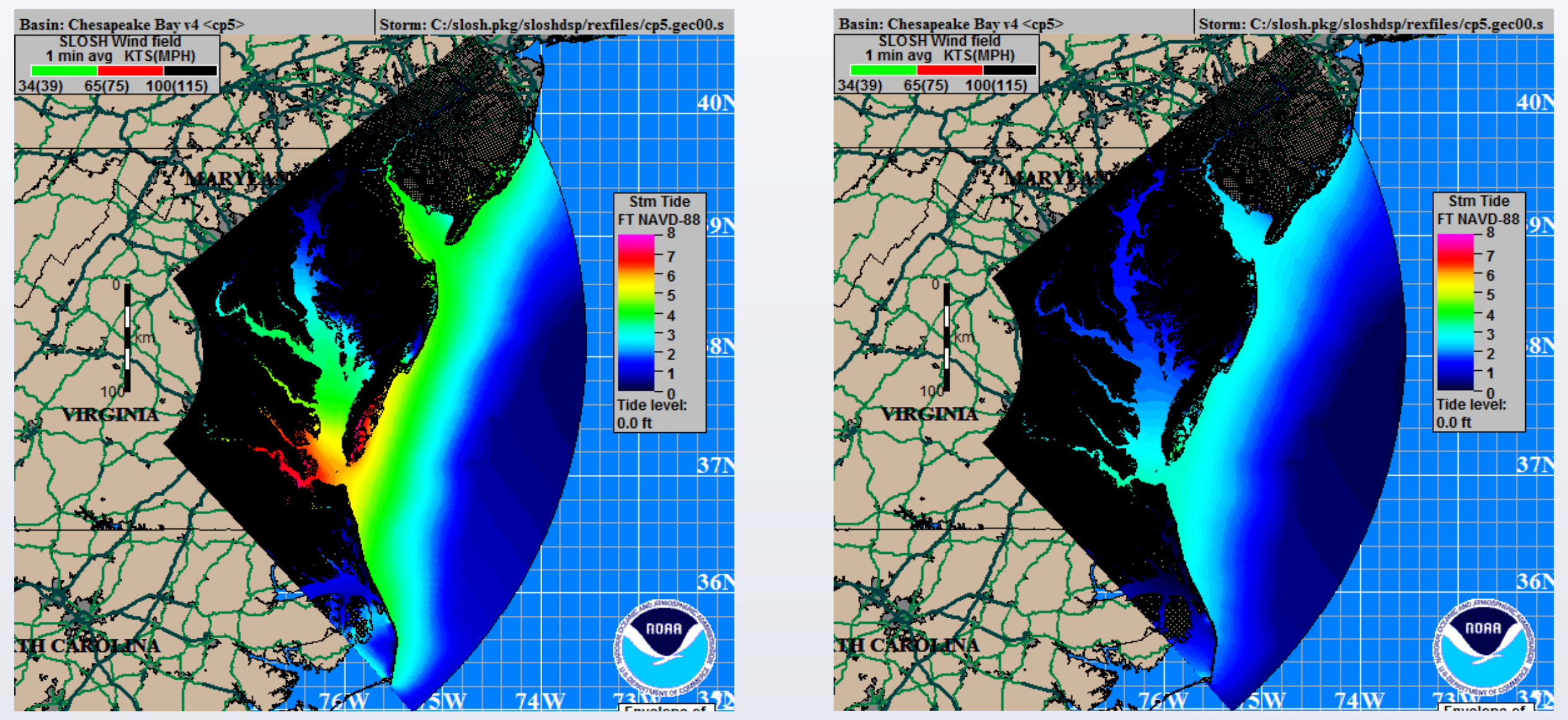
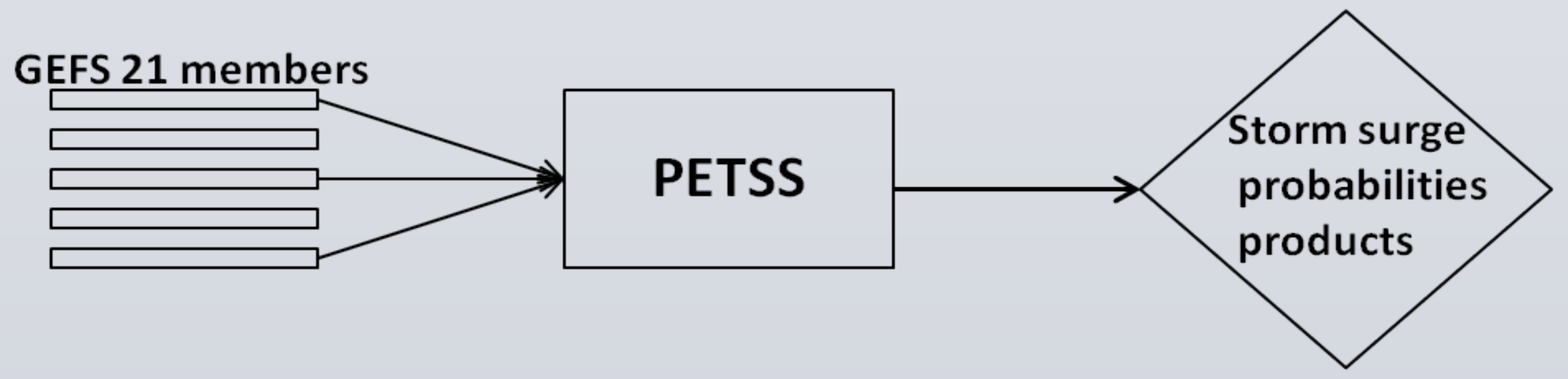


Fig. 2. Maximum storm surge forecast valid through UTC 18z Oct. 3 of 2015 (left) ETSS2.1 forecast results from 18z UTC Sep. 30 of 2015 and (right) ETSS2.1 forecast results from 18z UTC Oct. 1 of 2015.

Due to the such limitations of deterministic ETSS inundation guidance, as with Probabilistic Hurricane Storm Surge (Taylor and Glahn 2008; Taylor et al. 2014), MDL began developing PETSS inundation guidance based on ETSS. The PETSS model is an ensemble of storm surge runs by using 21 GEFS ensemble members.

Methodology and Products



Methodology:

PETSS use equally weighted GEFS ensemble to estimate the probability of storm surge. (1) Sorting surge height in ascending order for ensemble runs; (2) Counting number (m) of ensemble runs greater than 1, 2, 3, 6 and 9 ft.; (3) Calculating the probability (m/21*100).

Products:

1) **Exceedance Height:** The surge value which is exceeded by Y%.

E.g.: Height exceeded by 10% of storms = 9ft (Fig. 3)

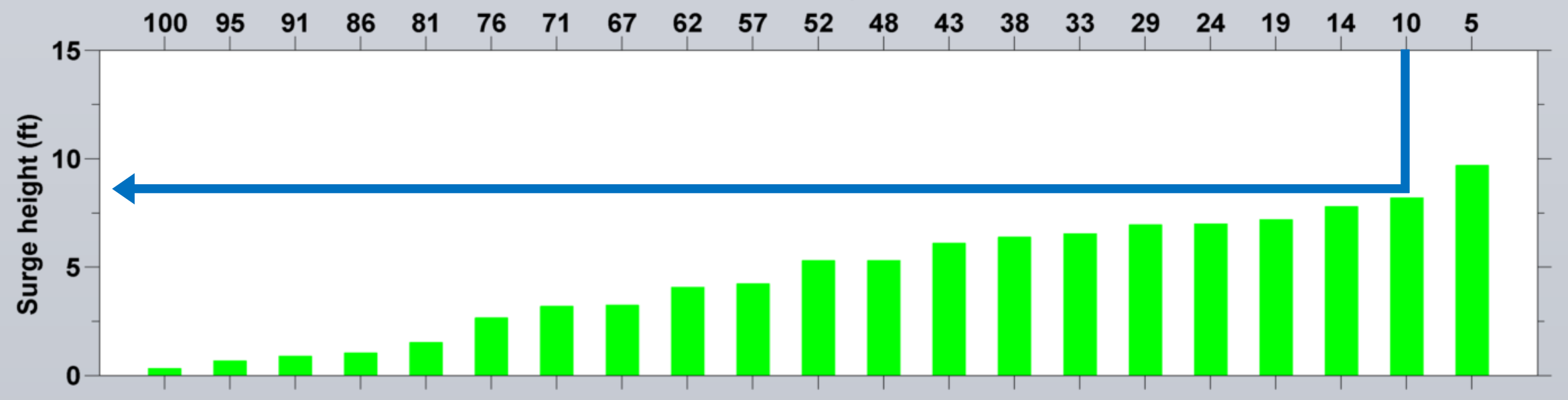


Fig. 3. Example of storm values with surge (ft.) and respective probability

2) **Probability of Surge:** The probability of storm surge greater than X feet.

E.g.: Probability of > 1 ft is 80% (Fig. 4).

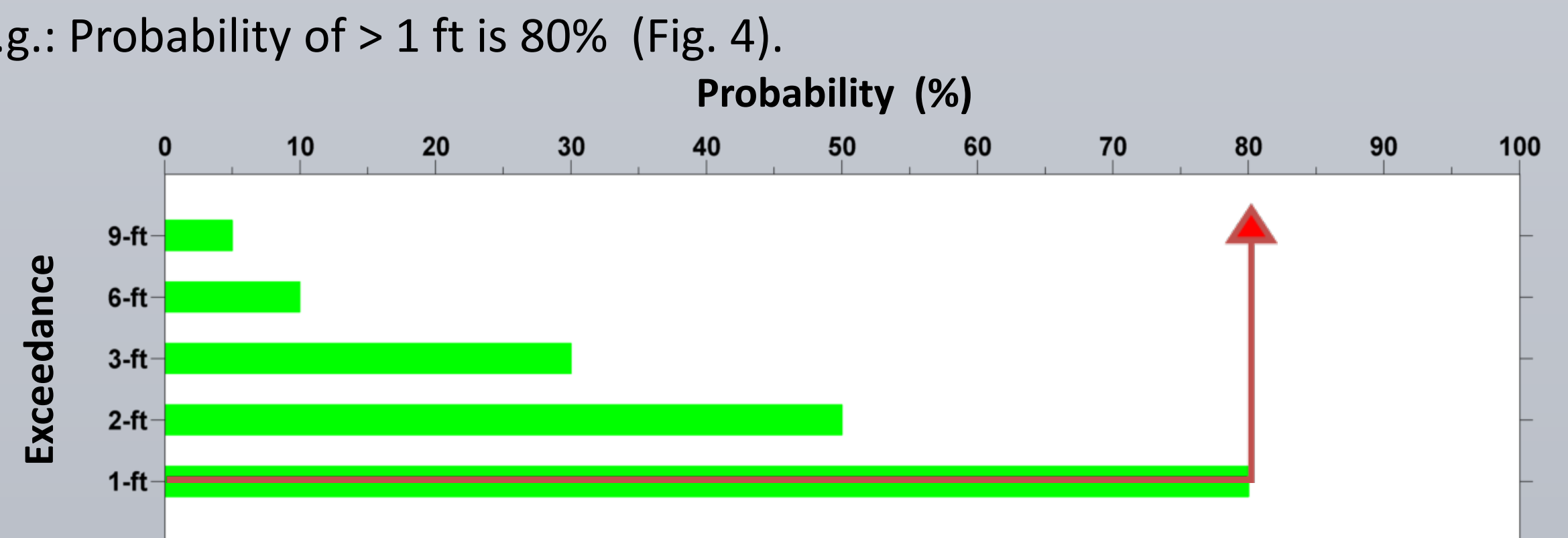


Fig. 4. Example of storm values with surge (ft.) and respective probability

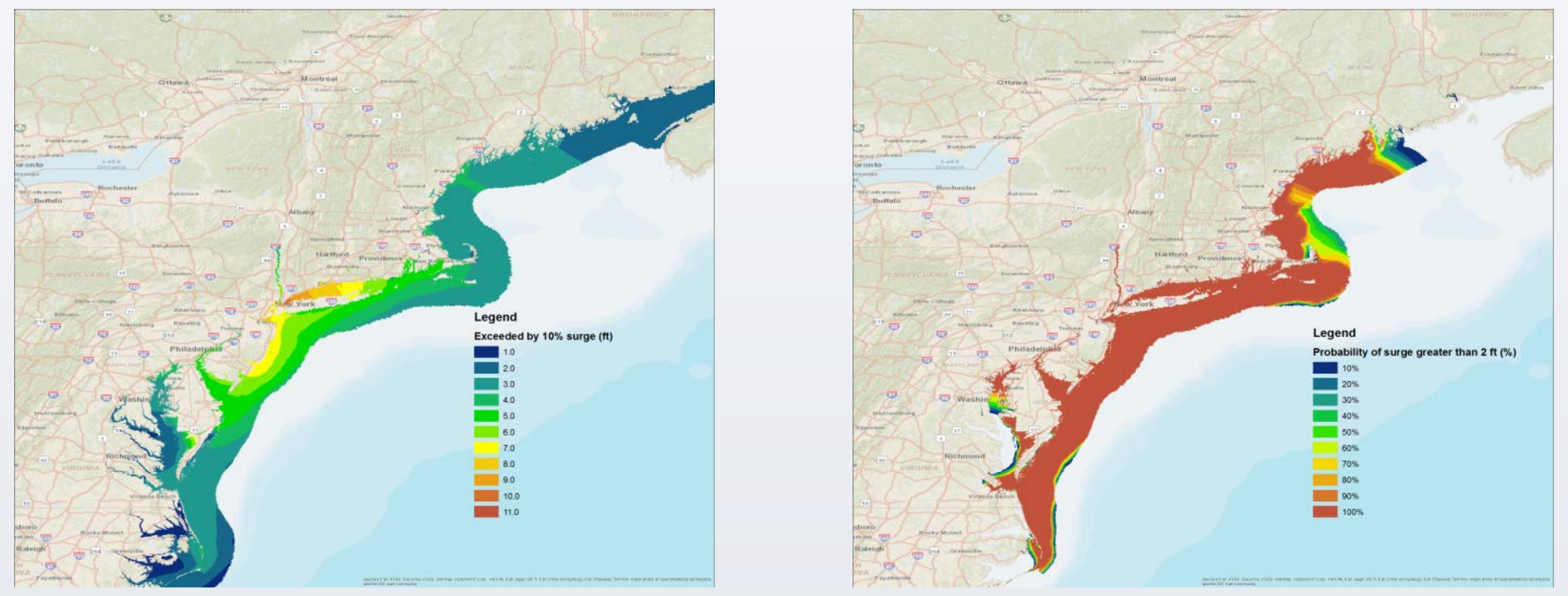


Fig. 5. (left) Exceeded by 10% chance surge height (ft) and (right) Probability of surge greater than 2 ft.

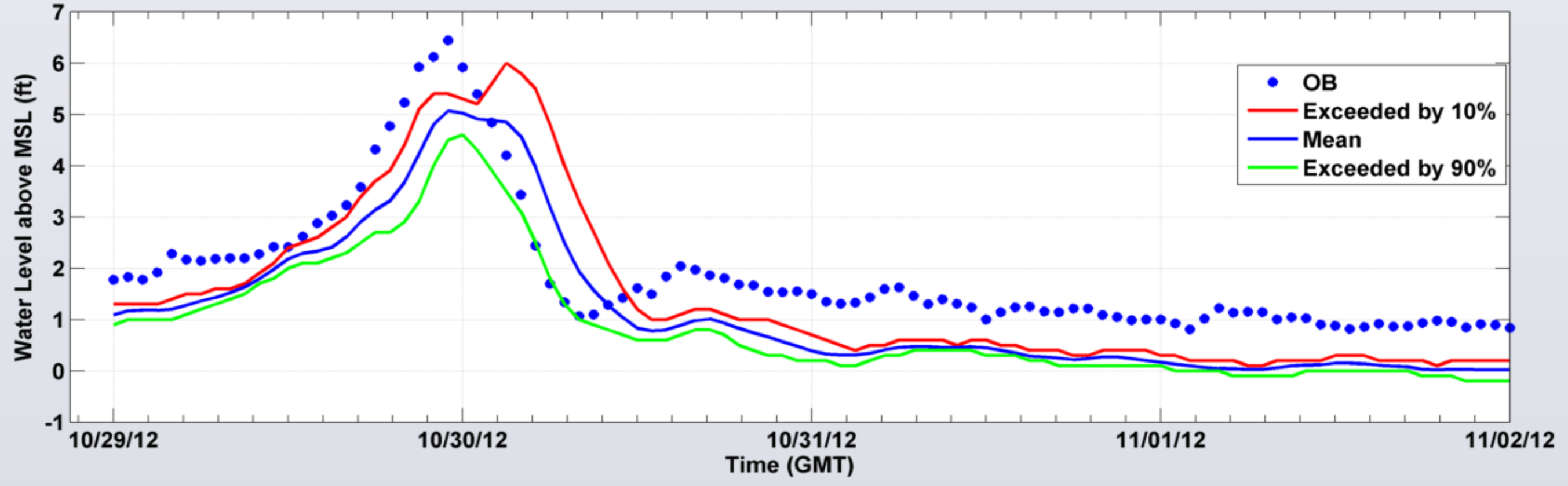


Fig. 6. Surge height at station including exceeded by 10%, 90% and mean of Ensembles.

Case Study Results (Joaquin-2015)

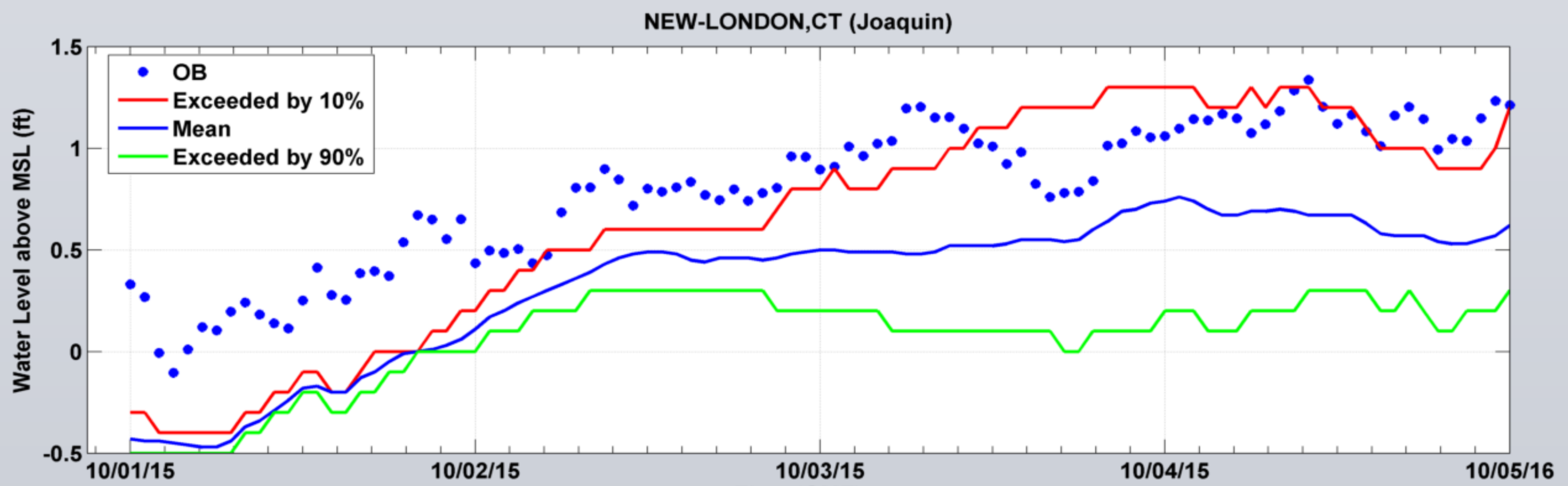


Fig. 7. Surge height at station including exceeded by 10%, 90% and mean of Ensembles from 18Z run of Sep. 30, 2015.

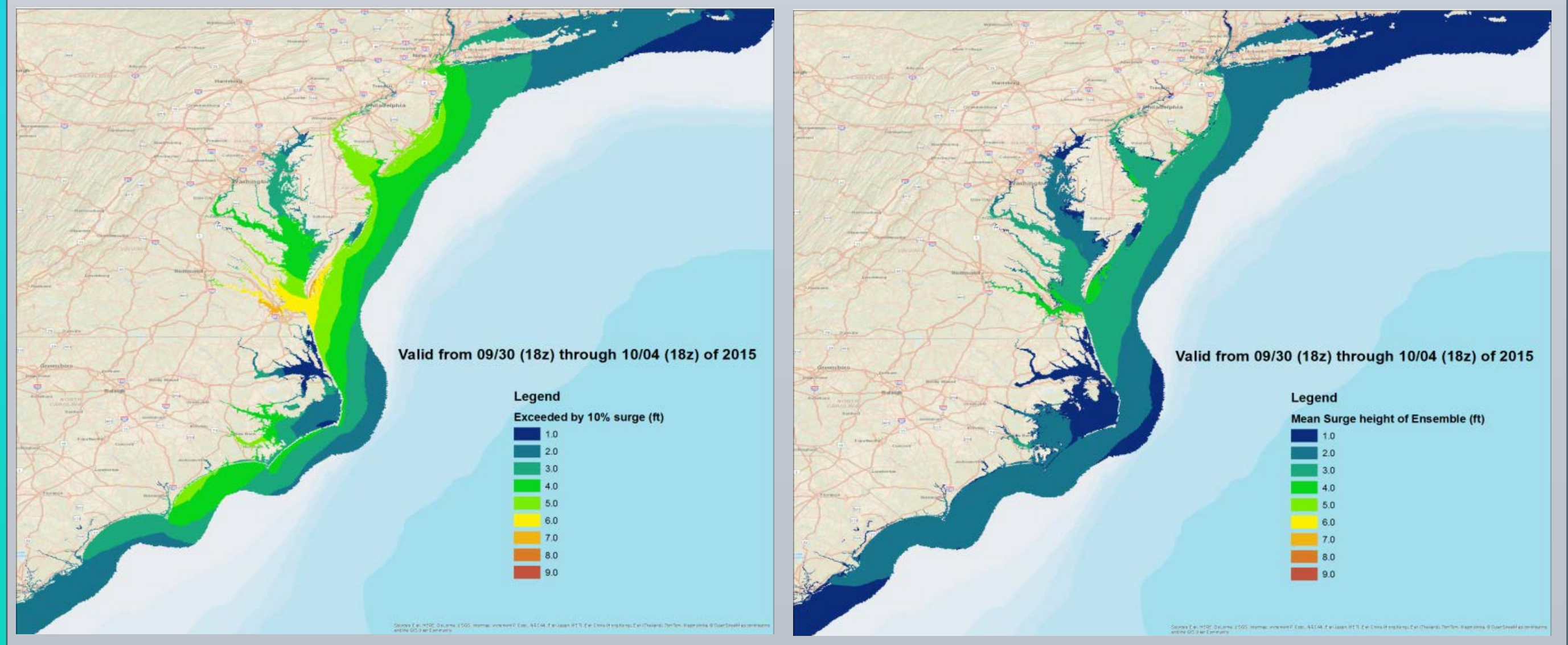


Fig. 8. (left) Exceeded by 10% chance surge height (ft) and (right) Mean surge height (ft) of Ensembles from 18Z run of Sep. 30, 2015.

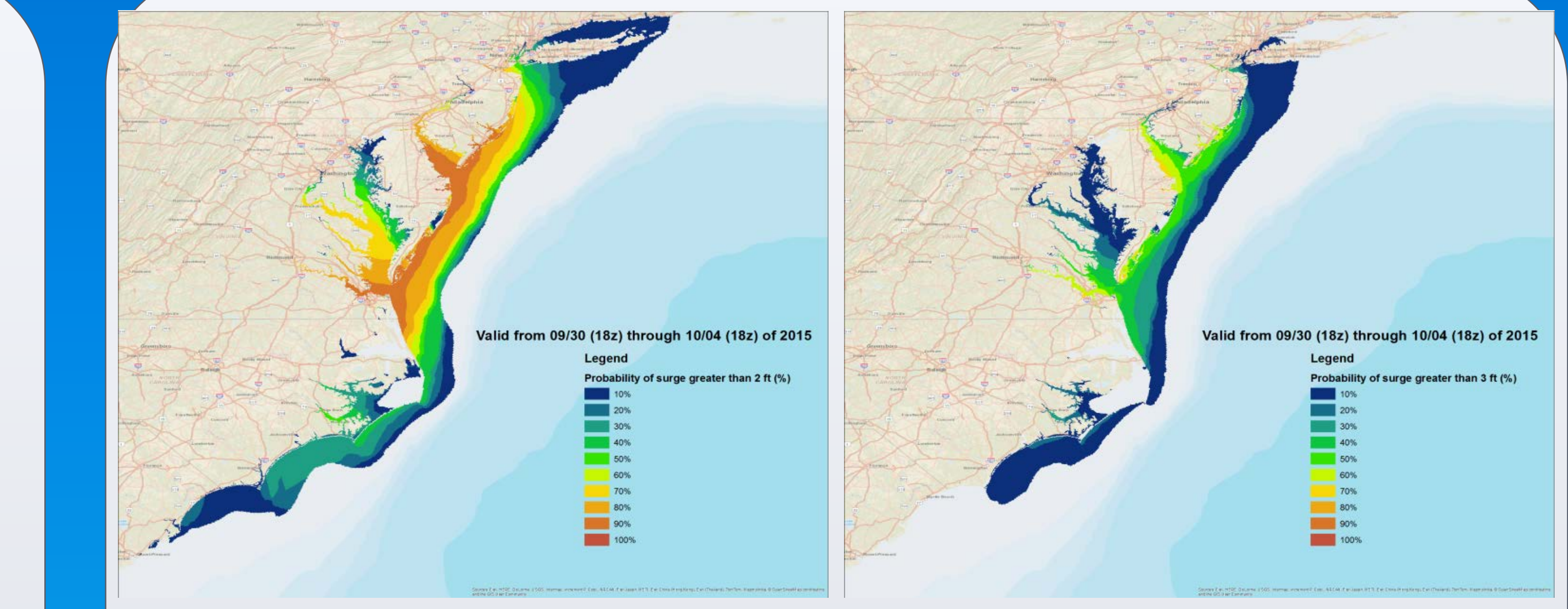
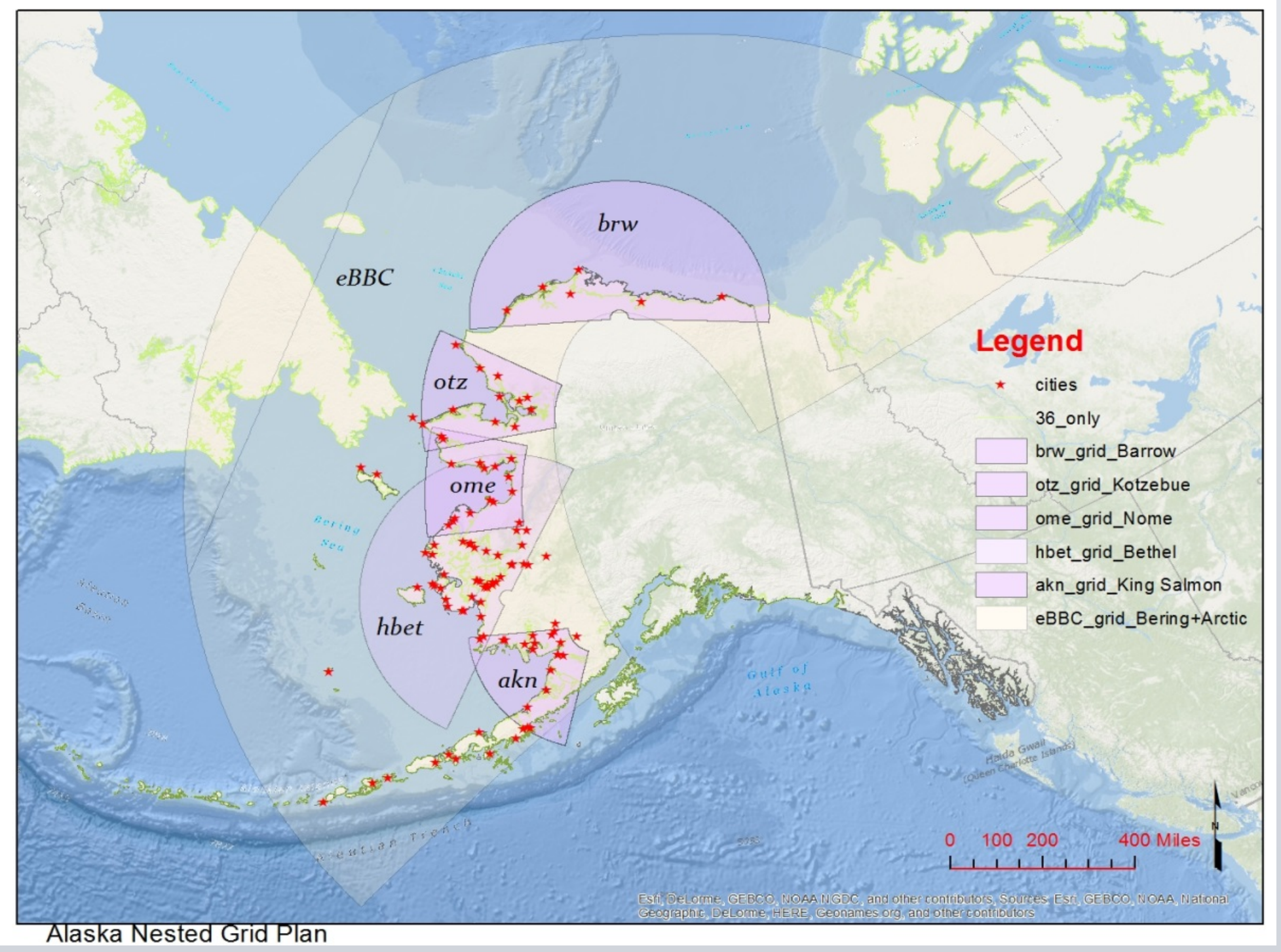


Fig. 9. Probability of surge greater than 2 ft (left) and 3 ft (right)

Future Plan

- Nest higher resolution overland grids to improve storm surge forecast in Alaska region.



- Improve bottom friction scheme in SLOSH codes to allow the use of varying friction in:
  - water cells dependent on water depth
  - land cells dependent on land cover type
- Explore different methodologies to estimate the probability of storm surge.

References

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