Development of the NWS' Probabilistic Tropical Storm Surge Model

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Abstract

The National Weather Service's (NWS) Meteorological Development Lab (MDL), in furtherance of its mission to help protect life and property, developed the Probabilistic tropical storm Surge (P-Surge) model between 2003 and 2008 to provide storm surge inundation guidance for tropical cyclones which takes into account the uncertainty in the forecast. P-Surge utilizes a parametric wind model which uses the National Hurricane Center's (NHC) official forecast along with historic errors in its track, size, and intensity. This allows P-Surge to be consistent with NHC's message and utilize the best available parametric information as NHC's official forecast has historically outperformed other guidance.

MDL overhauled the system in 2014 by introducing gridded tide calculations; providing products above ground level as well as above datum; providing products in 6-hr time ranges; and updating the computational grids to provide more accurate overland inundation guidance. MDL's latest improvements have involved: 1-hourly 10, 20, 30, 40, and 50% exceedance above datum; extending the forecast to 102 hours (from 78) and using a 24-hr (vs 20-hr) hind-cast; replacing the five retired basins in South Florida with three sub-basins of the current operational basin; creating 90% exceedance products; and providing NHC with coarser 2.5 km CONUS grids to assist with the Storm Surge Watch/Warning. This poster will describe the history of P-Surge, its latest enhancements and future plans.

Motivation

MDL developed the Sea Lake and Overland Surges from Hurricanes (SLOSH) model to generate deterministic storm surge guidance, however deterministic guidance is not very useful before landfall as slight errors in the advisory can result in considerable variations in storm surge model results (Figure 1).

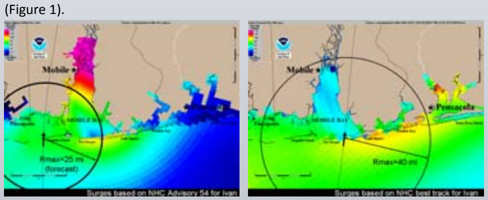


Figure 1. (left) SLOSH model run for Hurricane Ivan (2004) made 12 hours before landfall. (right) SLOSH storm surge hindcast created for Hurricane Ivan (2004).

Methodology and Products

The P-Surge model is an ensemble of SLOSH model runs, that provides real-time probabilistic predictions based on the current NHC hurricane forecast. Each ensemble member's input is derived from the current NHC hurricane forecast along with the associated 5 year average along track, cross track and intensity errors. Additionally P-Surge utilizes error distributions based on the derived size of the storm.

P-surge Error Statistics:

NHC determines the 5 year error statistics by considering the following:

1. Official forecasts initiated and verified within 10-45N and 60-100W.
2. Official forecasts which started with at least hurricane strength.

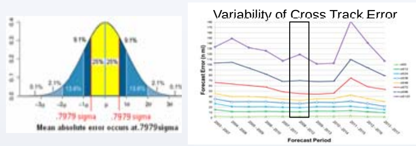


Figure 2. (left) Normal error distribution is assumed and 5 year mean absolute error at 0.7979*sigma. (right) P-Surge 5-yr period cross track error statistics.

Intensity Error Sampling:

- Three samples for Strong (30%), Medium (40%), Weak (30%) Intensity.

Along Track Error Sampling:

- Seven equally weighted samples (14%) for different forward speeds.

Cross Track Error Sampling:

- Cross track samples cover 90% of the area (± 1.64 sigma) under the normal distribution assigning the 5 year mean absolute error to 0.7979 sigma.
- To be dense enough, the storms were chosen to be one radius of maximum winds apart from each other at the 48 hour forecast projection. (Figure 3).

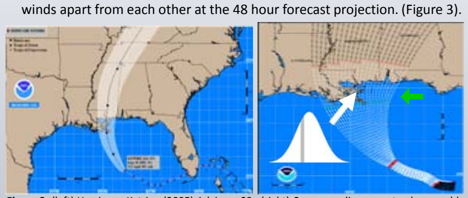
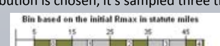


Figure 3. (left) Hurricane Katrina (2005) Advisory 23. (right) Corresponding cross track ensemble spread. The green arrow is the 48-h forecast locations.

Size Error Distribution and Sampling:

- The size error is bounded, invalidating the normal distribution assumption. Instead, five error distributions were derived by grouping storms based on initial size and determining the historic size guidance skill in the Atlantic. Once an appropriate error distribution is chosen, it's sampled three times similarly to the Intensity errors.



The result is the number of ensemble members is 3*7*X*3 where X depends on the density of the cross track sampling. The weight of each member is the product of the weight of each error sample: e.g. 0.3 * 0.14 * 0.1 * 0.4 = 0.00168

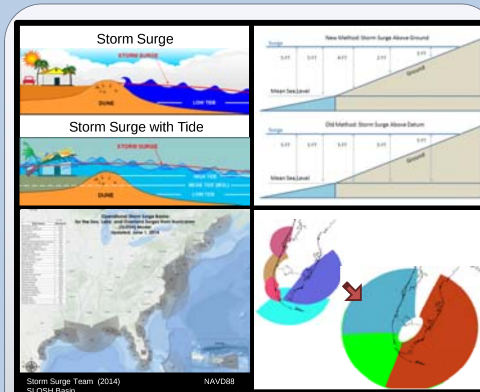
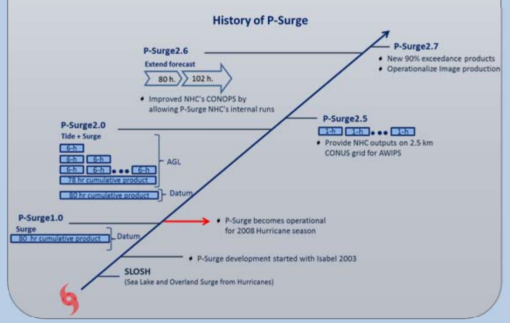


Figure 4. P-Surge enhancements. (top left) Adding Tides, (top right) AGL products, (bottom left) updating basins, (bottom right) the south Florida area was updated by replacing the current five basins with three sub-basins, to enhance the accuracy in the south Florida area.



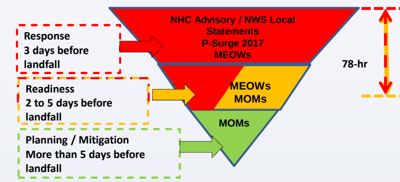


Figure 8. Recommended Surge Guidance in the 5 days before landfall. Maximum Envelope of Water (MEOW) and Maximum of MEOWs (MOM). The 102 hour forecast allows the recommended usage of P-Surge to start 72 (vs 48) hours before the onset of tropical-storm force winds, assuming that 30 hours after the onset, the storm will be inland with diminished storm surge impact.

P-Surge Products

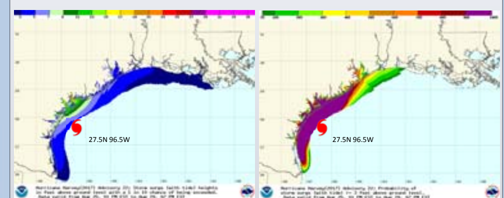


Figure 9. Hurricane Harvey Advisory 22 (Aug. 25, 2017 2100 UTC) with maximum sustained winds of 130 mph (215 km/h), center located near 27.5N 96.5W, position accurate within 10 NM (left) 10% Exceedance AGL. (right) Probability of Surge > 3 ft. AGL. Harvey became category 4 hurricane by August 26, 2017 at 0000 UTC.

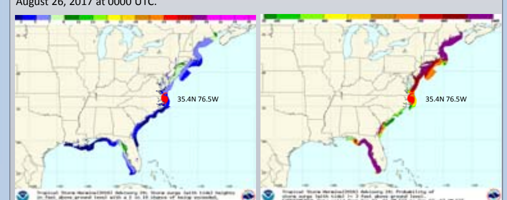


Figure 10. Hurricane Hermine Advisory 24 (Sept. 3, 2016 0900 UTC) center located near 35.4N 76.5W, position accurate within 20 NM (left) 10% Exceedance AGL. (right) Probability of Surge > 3 ft. AGL. Irene reached hurricane intensity by October 1, 2016 at 1800.

Product Generation

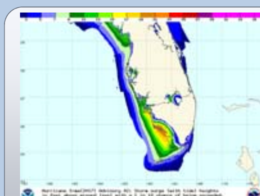


Figure 5. AGL Storm Surge with Tide exceeded by 10% of Ensemble Members for Irma 2017 Advisory 42.

Exceedance Height: The surge value which is exceeded by Y% (Figure 5).
Eg: Height exceeded by 60% of storms = 4 (.6 < .2 + .4 + .1) (Figure 6)

Probability of Surge: The probability of storm surge greater than X feet (Figure 7).
E.g.: Probability of > 4 ft is 60% (.4 + .2) (Figure 6)

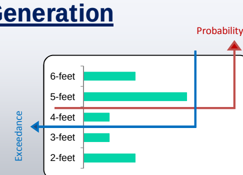


Figure 6. Example of storm values with surge (ft.) and respective weights

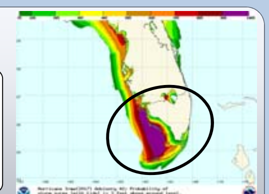


Figure 7. AGL Probability P-Surge product for Irma 2017 based on NHC Advisory 42, shows considerable surge threat to the southwest FL. region

Future Plans

- Adding a 60 hour forecast point
- Adding error statistics per initial intensity
- SLOSH / P-Surge code parallelization
- Adding a 2nd generation wave model for OCONUS support
- Nesting the current narrow fine resolution basins within broader coarser basins.

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