Operational Storm Surge Modeling

HFIP Annual Meeting
November 15\textsuperscript{th}, 2021
NHC Storm Surge Unit

Laura Alaka
\texttt{laura.alaka@noaa.gov}

Andrew Penny
\texttt{andrew.penny@noaa.gov}
Introduction to Probabilistic Storm Surge

• P-Surge is based on an ensemble of Sea, Lake, and Overland Surge from Hurricane (SLOSH) model runs
  • SLOSH: numerical-dynamic tropical storm surge model
  • SLOSH requires bathymetry and is applied to a ‘basin’
  • SLOSH requires meteorological driving forces: “Wind model is just as important– if not more so– as a surge model” (Jelesnianski et al. 1992)

• P-Surge ensemble incorporates uncertainty using a statistical method based on NHC historical errors of:
  • Cross track (landfall location, # members varies) attempts to encompass 90% of cross track uncertainty
  • Along track (forward speed, 7 members)
  • Intensity (3 members)
  • Storm size (RMW, 3 members)

Irma (AL112017) 2017090900 P-Surge tracks
P-Surge RMW forecasts
Hurricane Ida (AL092021) 2021082618

(72 h prior to landfall)
RMW Forecast Verification (2015-2019)

- **P-Surge v2.7**: RMW based on SLOSH parametric wind profile. RMW often inconsistent with observations.

- **P-Surge v2.8**: BEST track RMW used to initialize P-Surge. Led to improvements in storm structure.

- **P-Surge v2.9**: RMW forecasts based on NHC forecast parameters. RMW forecasts have lower MAE and less negative bias.

- Improved RMW forecasts will help efforts to extend the lead time of reliable/skillful P-Surge forecasts.
P-Surge Retrospective Runs

- 13 storms between 2008-2018: Spans the period of USGS pressure sensors
- recently added 12 storms from 2019-2020
- Evaluation Methodology:
  - Determine landfall advisory
  - Determine advisory when the 12-, 24-, 36-, 48-, 60-, 72-hr forecast points first came closest to the landfall point (the 60-hr was approximated)
- Evaluated the >3, >6, >9 ft NAVD88 probability fields from P-Surge

hurricanes.gov/surge
USGS Stormtide Sensors: all available deployed sensors

NOAA tide station data: subjectively chosen relative to hurricane impact area, and must reference NAVD88
Forecast/Observation Pairing
Cumulative Probability > 9ft NAVD88
36 hours prior to Hurricane Sandy’s landfall

Battery NOAA tide station,
Observation: 11.28 ft NAVD88 ~ 9 ft above ground
Forecast: 24%, 53%
Make a contingency table for each threshold (10%, 20%, 30%, ..)
Calculate POD/FAR
Plot each POD/FAR pair as a point on the curve

Higher Area Under Curve (AUC) for v2.9, i.e. increased skillfulness
E50: Bias and Error

*50% exceedance is a proxy for the ‘most likely’ value

- Low bias in ‘most likely’ values at longer leadtimes
- v2.9 60-hr errors are comparable to the 48-hr errors in v2.7
E10: Bias and Error

*10% exceedance is used as ‘near worst case scenario’

Expected high bias eroded at 60/72-hrs
e10 72 hours prior to Sandy landfall

OBSERVED

>9ft
6-9ft
3-6ft
1-3ft
e10 72 hours prior to Cristobal landfall

OBSERVED

- >9ft
- 6-9ft
- 3-6ft
- 1-3ft
- <3ft

hurricanes.gov/surge
e10 72 hours prior to Zeta landfall

OBSERVED

- >9ft
- 6-9ft
- 3-6ft
- 1-3ft
- <3ft

hurricanes.gov/surge
Landfall Adjustment for Intensity/RMW

- Interpolation of intensity/RMW at landfall using post-landfall forecast points leads to a low bias for intensity and a large bias for RMW.

- Keeping the intensity/RMW constant (green) reduces the biases, and improves run-to-run consistency.

[Graph showing intensity changes over time with different adjustment methods.]
Michael: Run-to-Run Consistency
15.55ft NAVD88 storm surge observed at Mexico Beach

Intensity/RMW interpolation causes an oscillating forecast

@NHC_Surge
hurricanes.gov/surge
Michael 2018100912
15.55ft NAVD88 storm surge observed at Mexico Beach

Intensity/RMW Interpolation
Constant Intensity/RMW up to landfall

Intensity/RMW Interpolation:
- >9ft
- 6-9ft
- 3-6ft
- 1-3ft

3 ft higher at Mexico Beach and greater inland flooding

hurricanes.gov/surge
Future Work

• evaluate the impact of adjusting the intensity/RMW forecast values at landfall
• adopt non-uniform Manning-N bottom slip coefficients
• couple wave model with SLOSH for select basins, and integrate into P-Surge (code optimization necessary)
• add the capability to account for storms w/ an asymmetric wind structure
• incorporate dynamic uncertainty information (track, intensity, size, and structure) when generating the P-Surge ensemble