Operational Storm Surge Modeling Update

HFIP Annual Meeting

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NHC Storm Surge Unit

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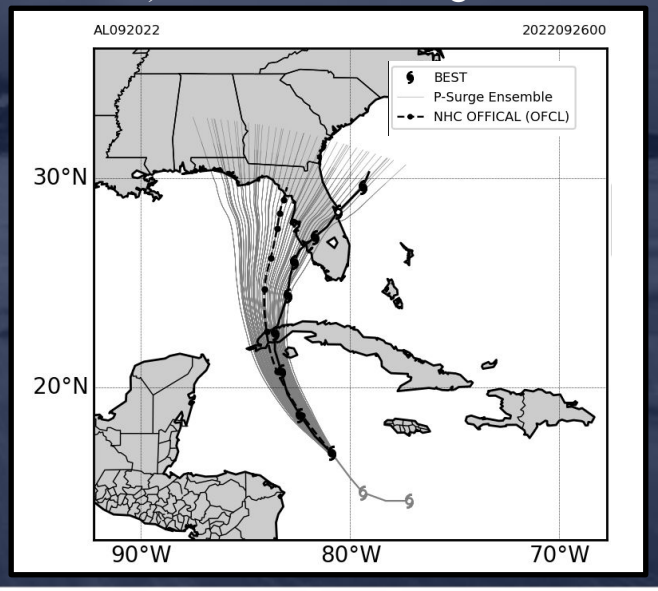
Introduction to Probabilistic Storm Surge

- 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)

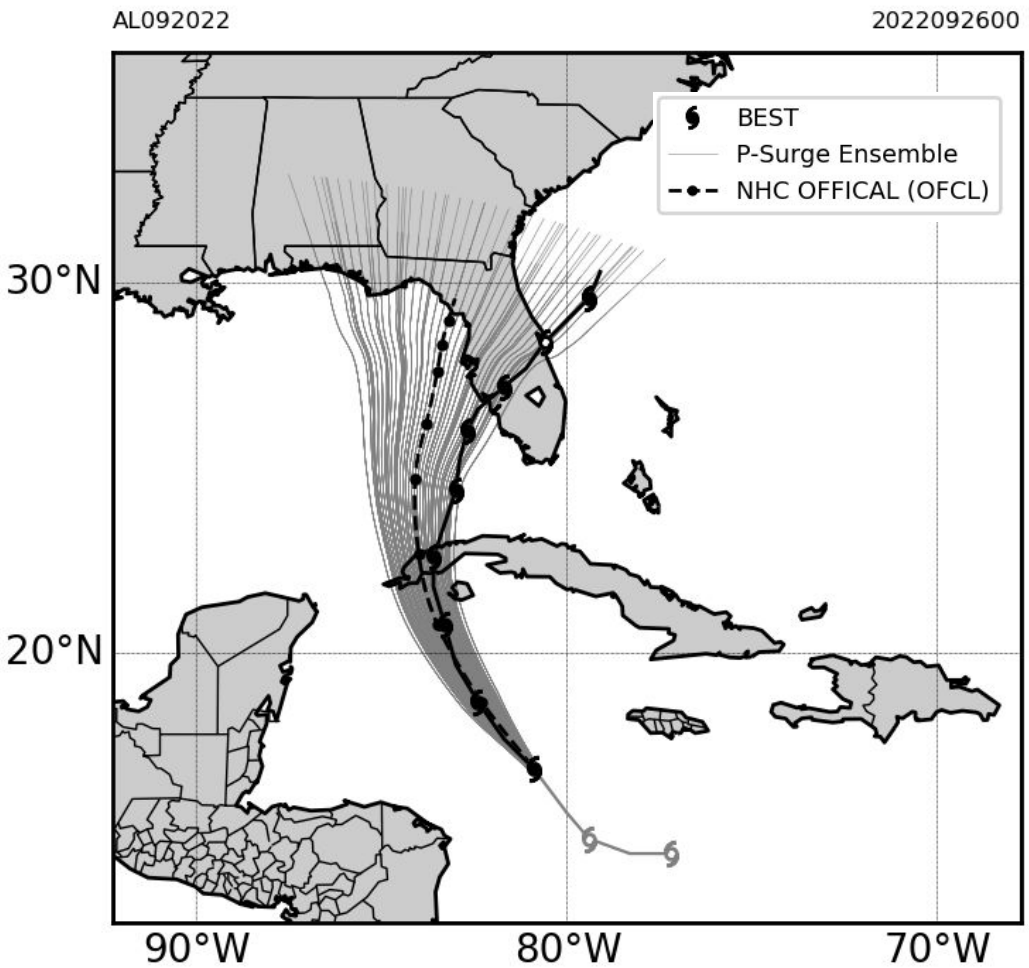
- P-Surge ensemble incorporates uncertainty using a statistical method based on NHC historical errors of:
  - Cross track (landfall location, # members varies) attempts to encompass 90% of cross track uncertainty
  - Along track (forward speed, 7 members)
  - Intensity (3 members)
  - Storm size (RMW,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

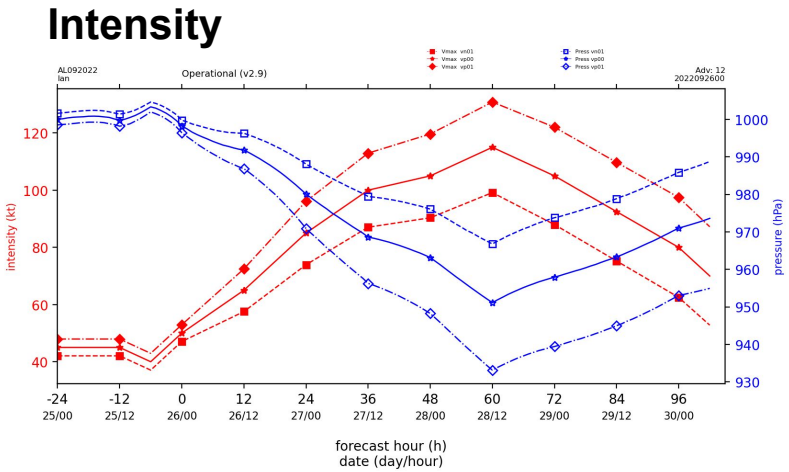
Ian (AL092022) 2022092600 P-Surge ensemble tracks

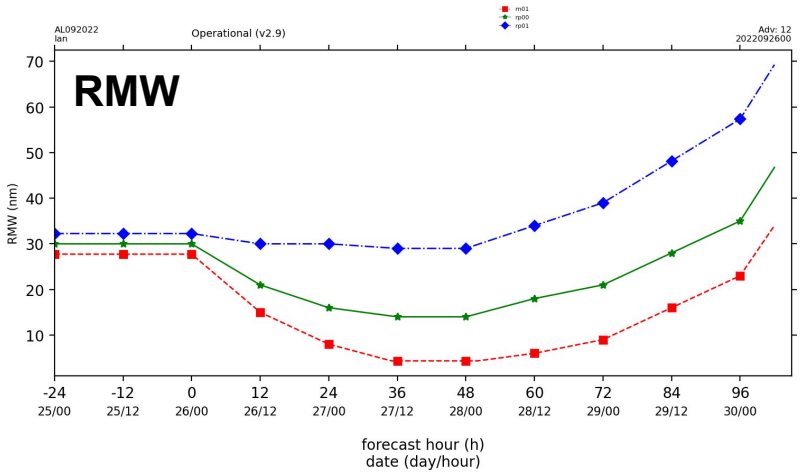


Hurricane Ian – 9/25 11pm, SS Watch issued

2022092600



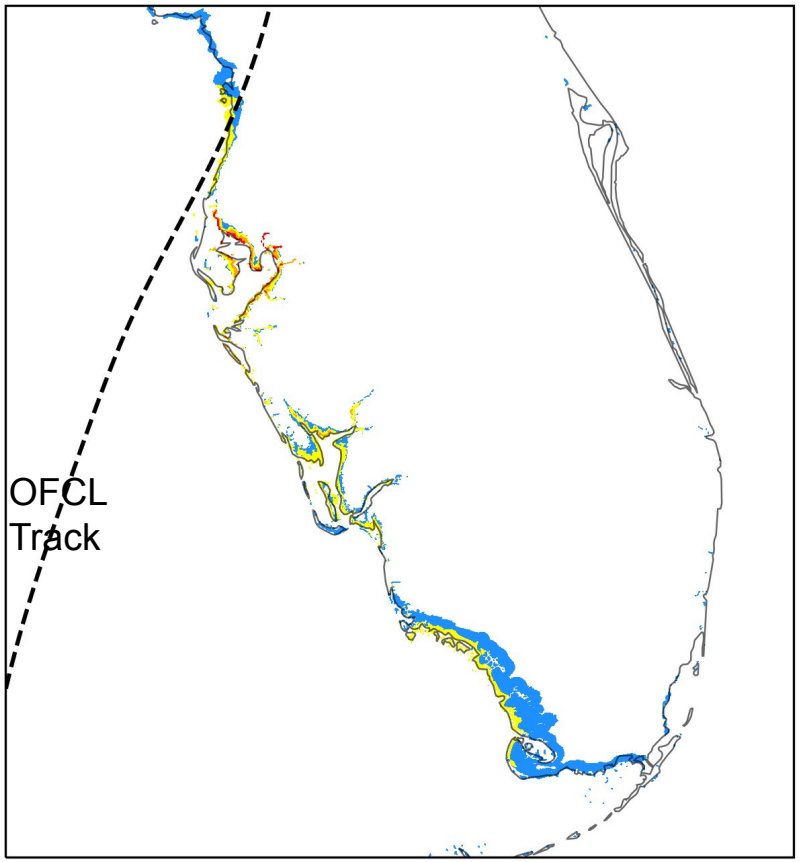




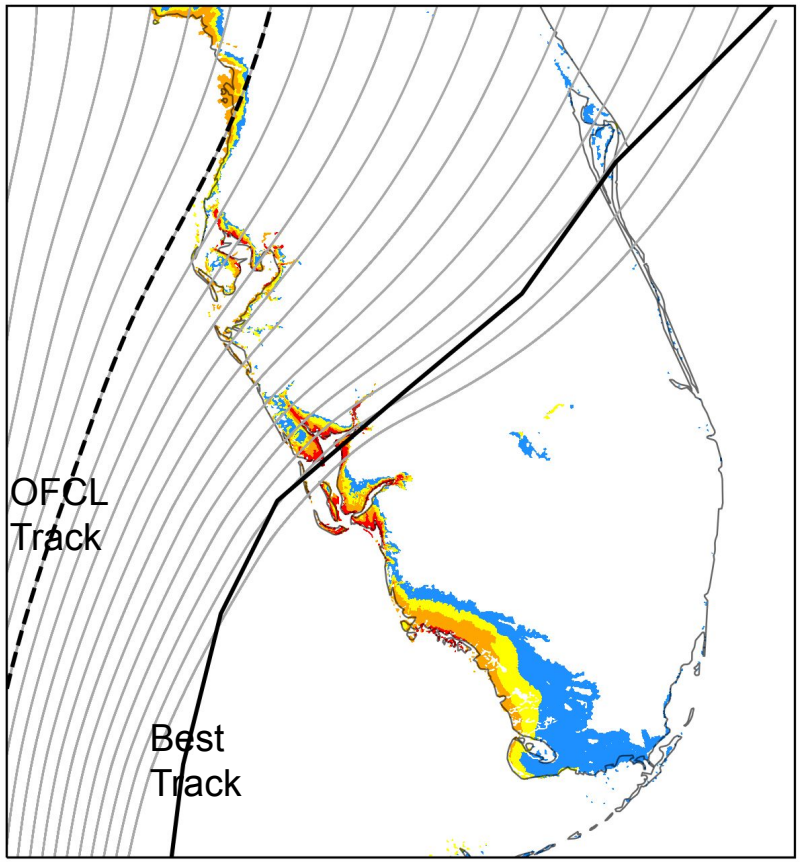
Hurricane Ian – 9/26 5pm, SS Warning issued

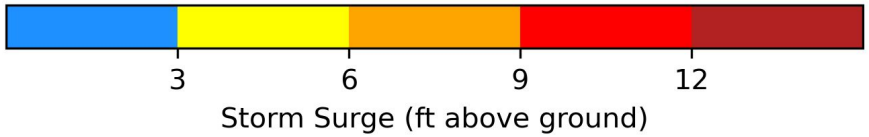
2022092618

Deterministic Storm Surge



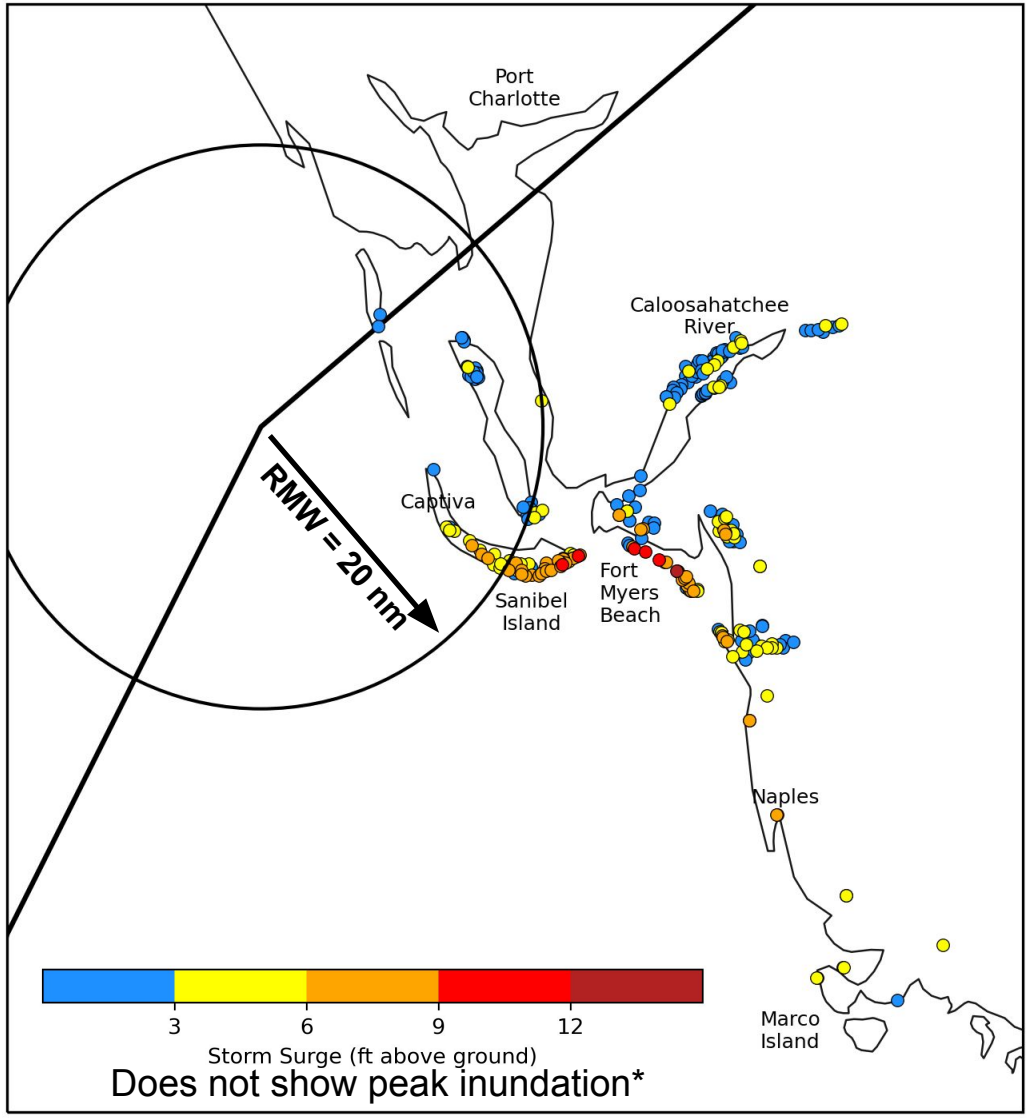
Probabilistic Storm Surge: e10





Hurricane Ian – Preliminary USGS HWMs

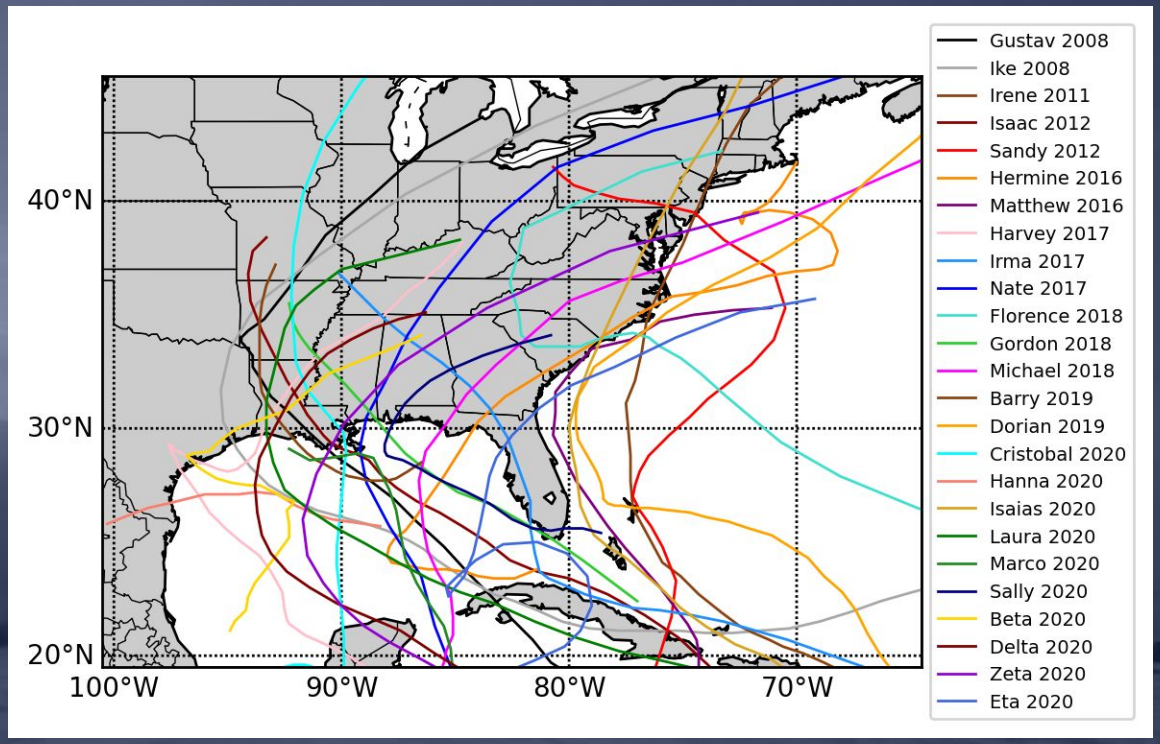
- Highlights sharp storm surge gradient relative to the track and RMW, especially noticeable from Sanibel Island to Captiva

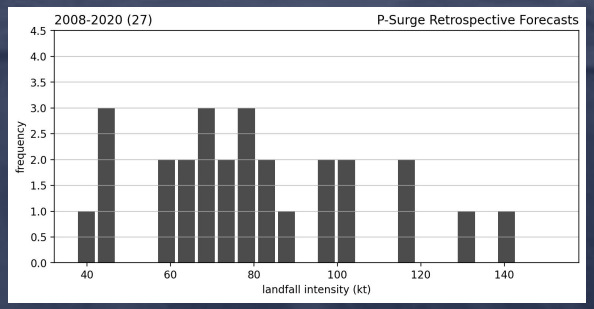


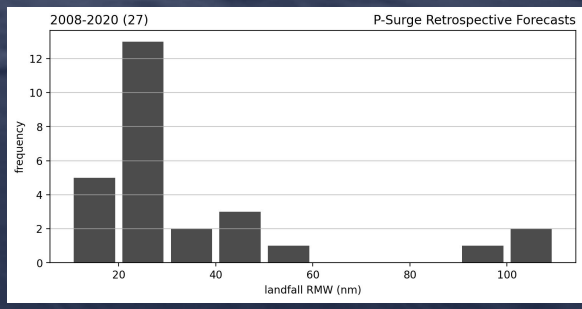
Does not show peak inundation*

P-Surge Retrospective Runs

- 25 storms between 2008-2020: Spans the period of USGS pressure sensors
- 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





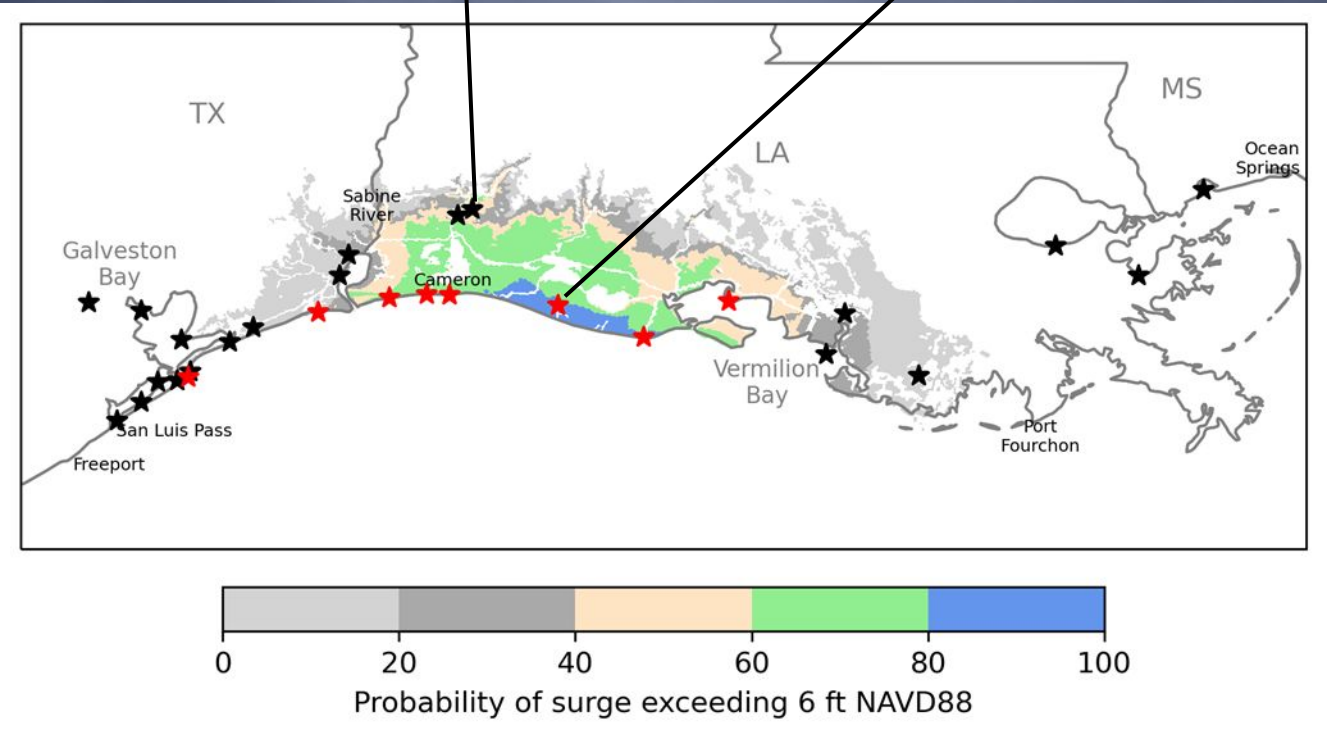


Forecast/Observation Pairing

24 hours prior to Hurricane Laura's landfall

Lake Charles NOAA tide station
Observation: 5.39 ft NAVD88
Forecast: 69%

LACAM27067 USGS pressure sensor
Observation: 10.05 ft NAVD88
Forecast: 92%

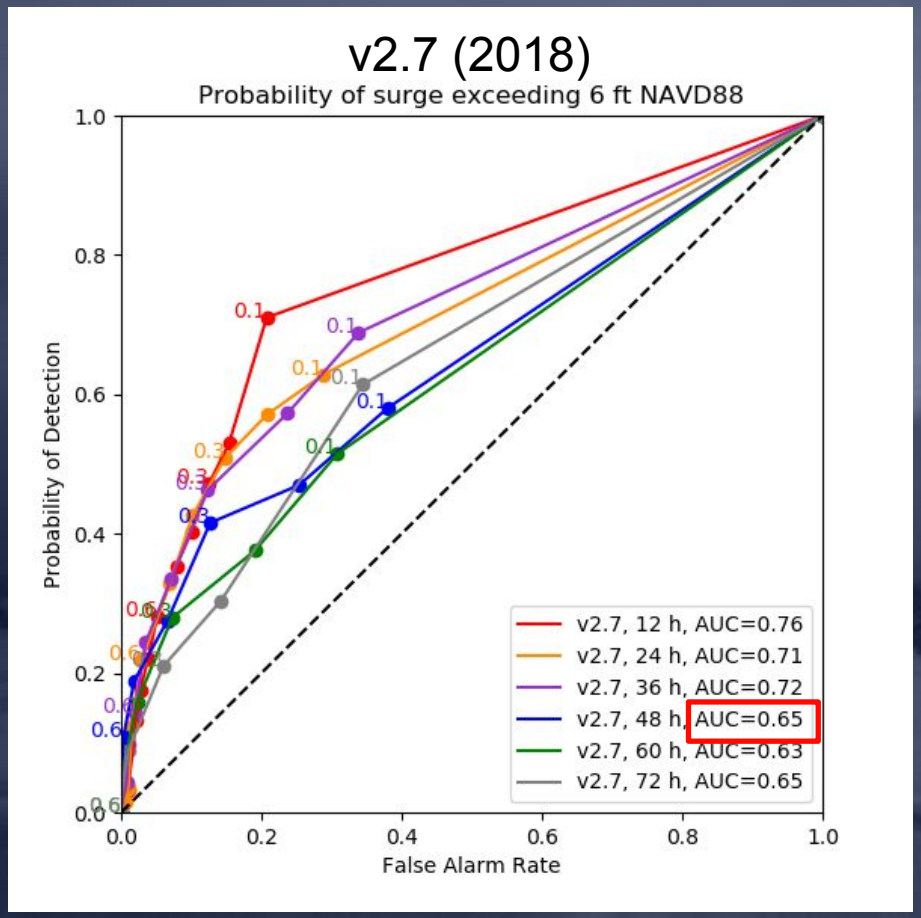


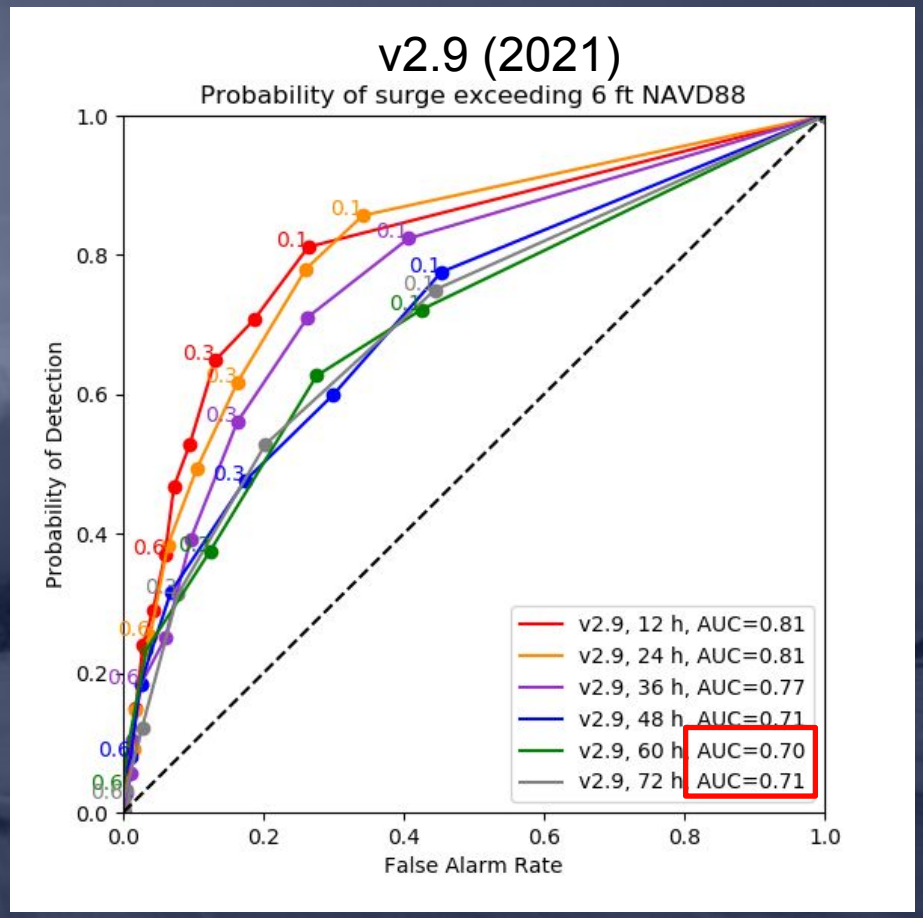
Improved RMW Forecasts

P-Surge v2.7 vs v2.9

ROC Curve

- Make a contingency table for each threshold (10%,20%,30%,..)
- Calculate POD/FAR and plot each pair as a point on the curve





Higher Area Under Curve (AUC) for v2.9, i.e. increased skillfulness

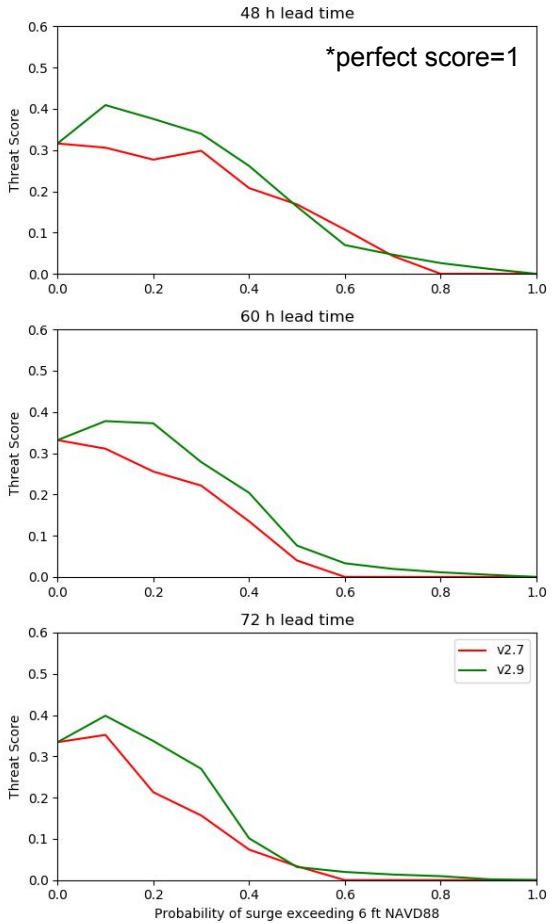
Improved RMW Forecasts

P-Surge v2.7 vs v2.9

Threat Score and Brier Score

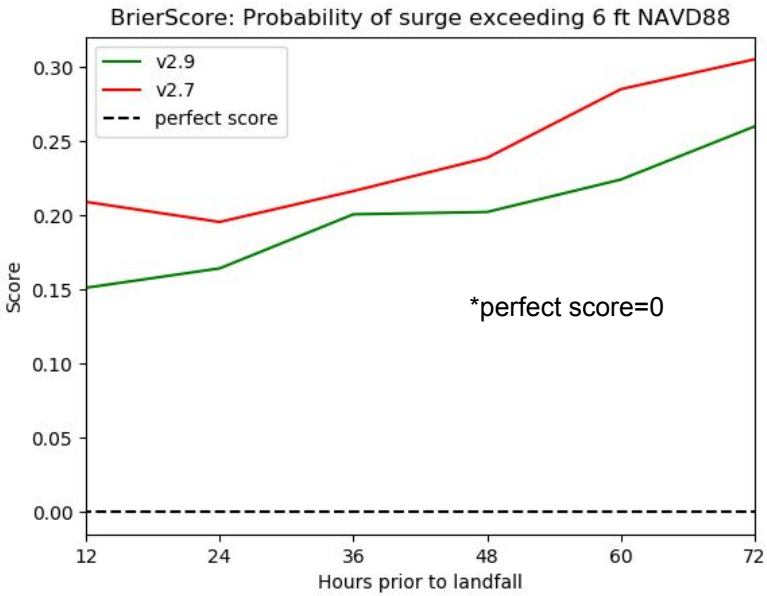
Threat Score

Hits / (Hits + Misses + False Alarms)



Brier Score

"What is the magnitude of the probability forecast errors?"



- v2.9 demonstrates superior performance compared to v2.7

Future Improvements

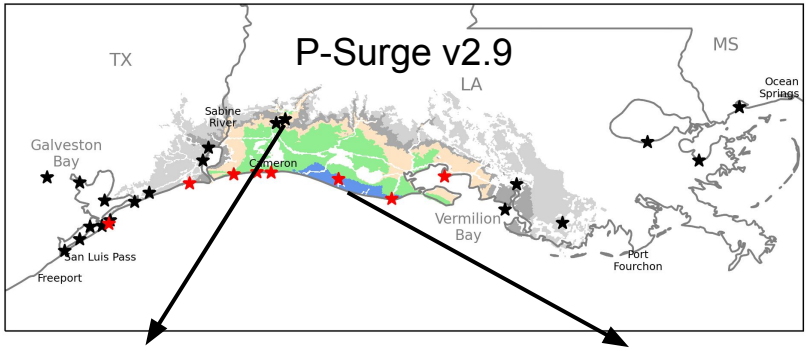
P-Surge v3.0 (early 2023)

Manning-N

(non-uniform bottom slip coefficients)

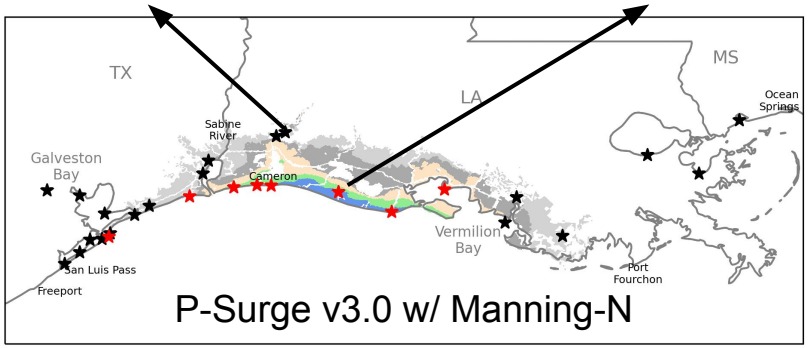
Hurricane Laura 24 h prior to landfall

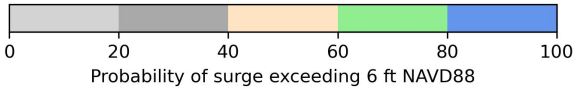
Threat Area

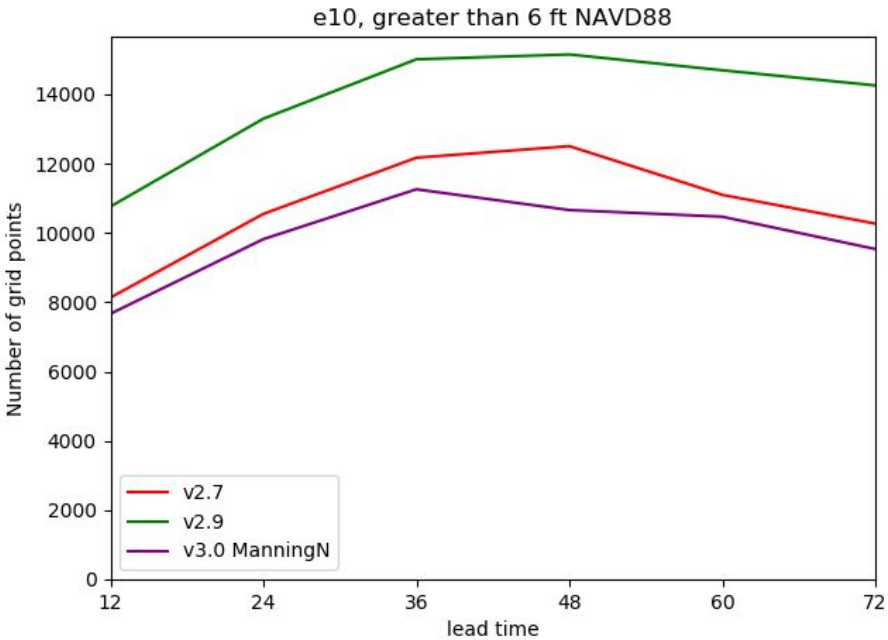


Lake Charles NOAA tide station,
Observation: 5.39 ft NAVD88
Forecast (Non Manning): 69%
Forecast (Manning-N): 44%

LACAM27067 USGS pressure sensor,
Observation: 10.05 ft NAVD88
Forecast (Non Manning): 92%
Forecast (Manning-N): 90%







- Manning-N reduces the inland extent of the Threat Area
- for all storms, the v3.0 Threat Area with Manning-N is smaller than v2.7, while retaining skill

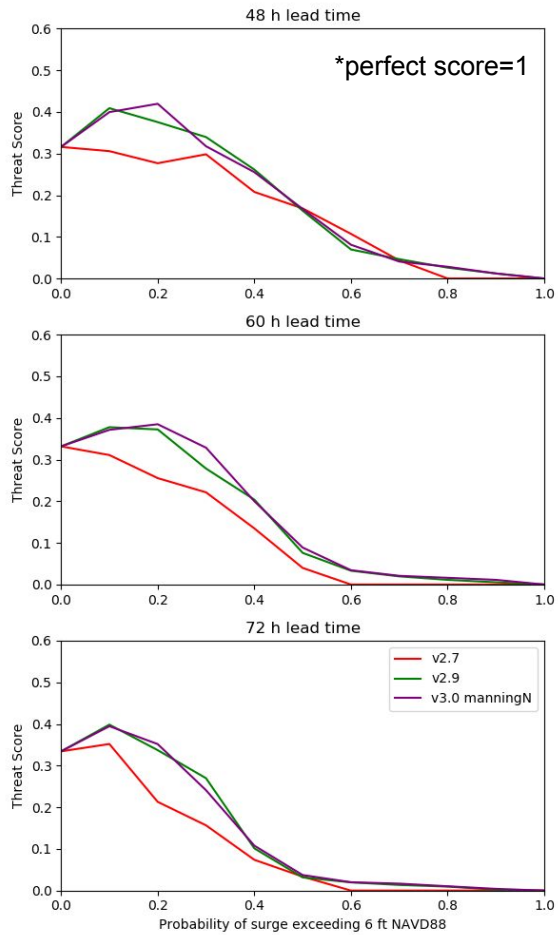
Future Improvements

P-Surge v3.0 (early 2023)

Manning-N
(non-uniform bottom slip coefficients)

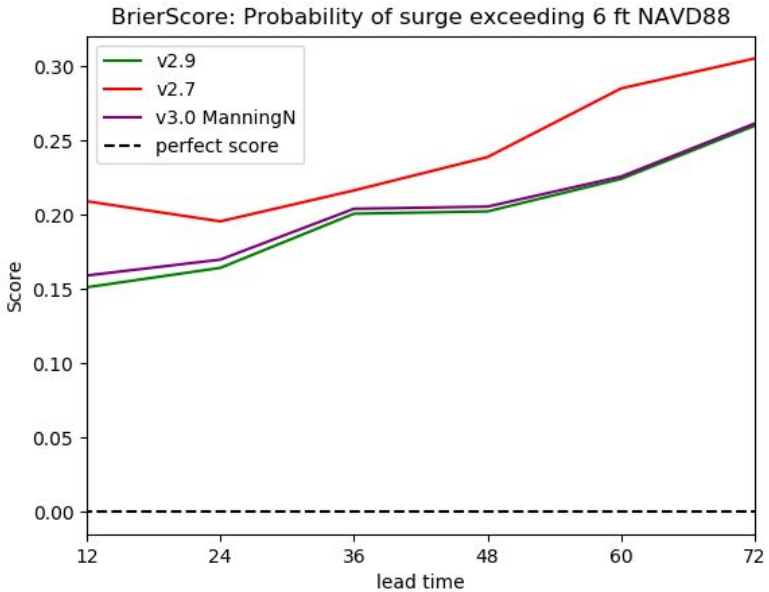
Threat Score

Hits / (Hits + Misses + False Alarms)



Brier Score

"What is the magnitude of the probability forecast errors?"



- v2.9 and v3.0 have comparable skill

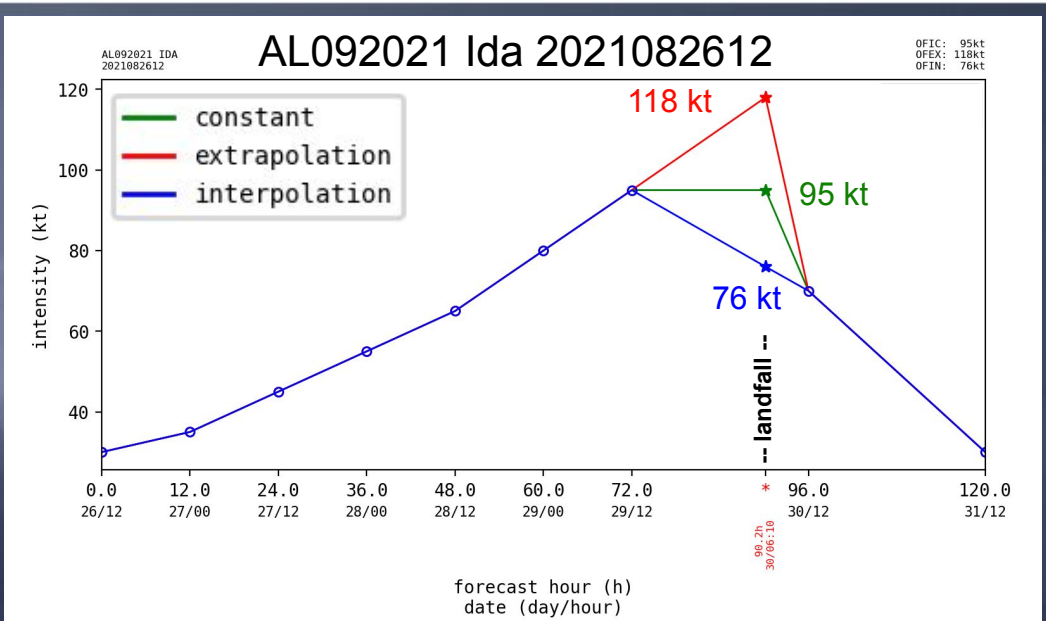
Future Improvements

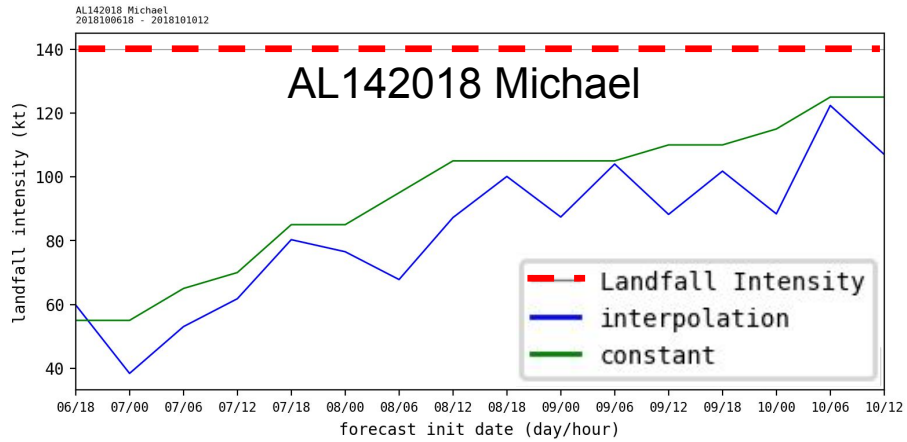
P-Surge v3.0 (early 2023)

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

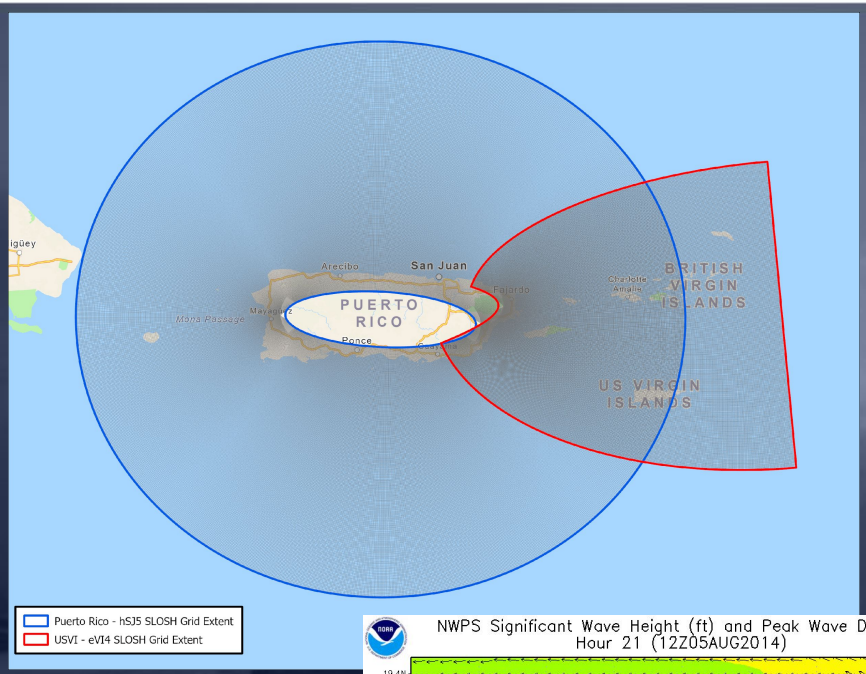


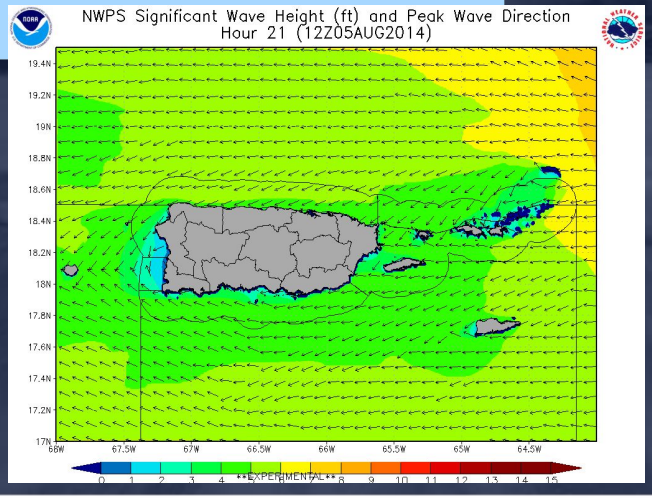


Future Improvements

P-Surge v3.0 (early 2023)

PR/USVI SLOSH Grids
SLOSH-Wave Model Coupling

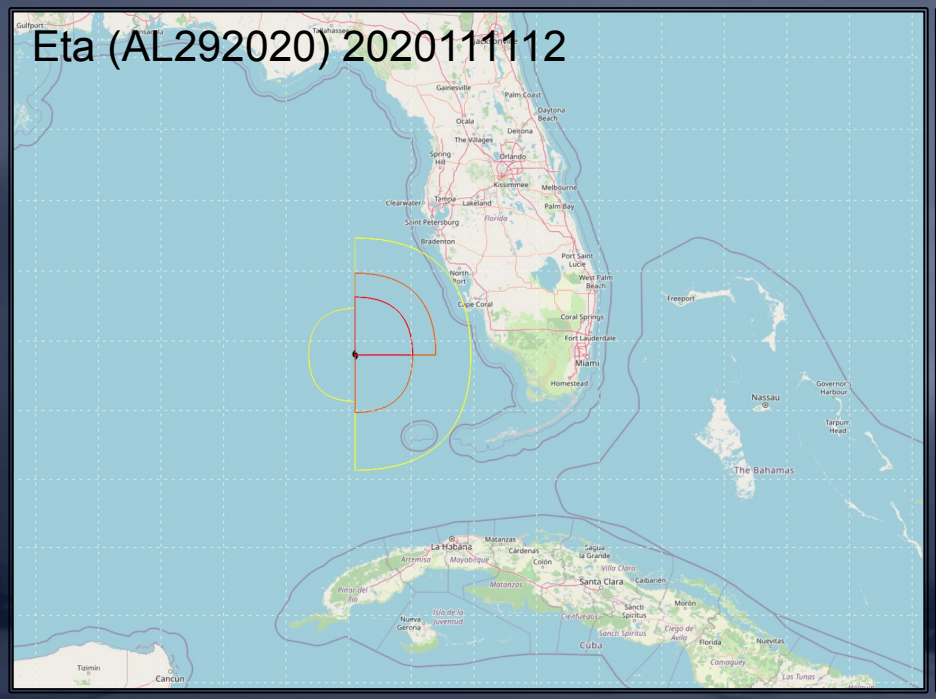


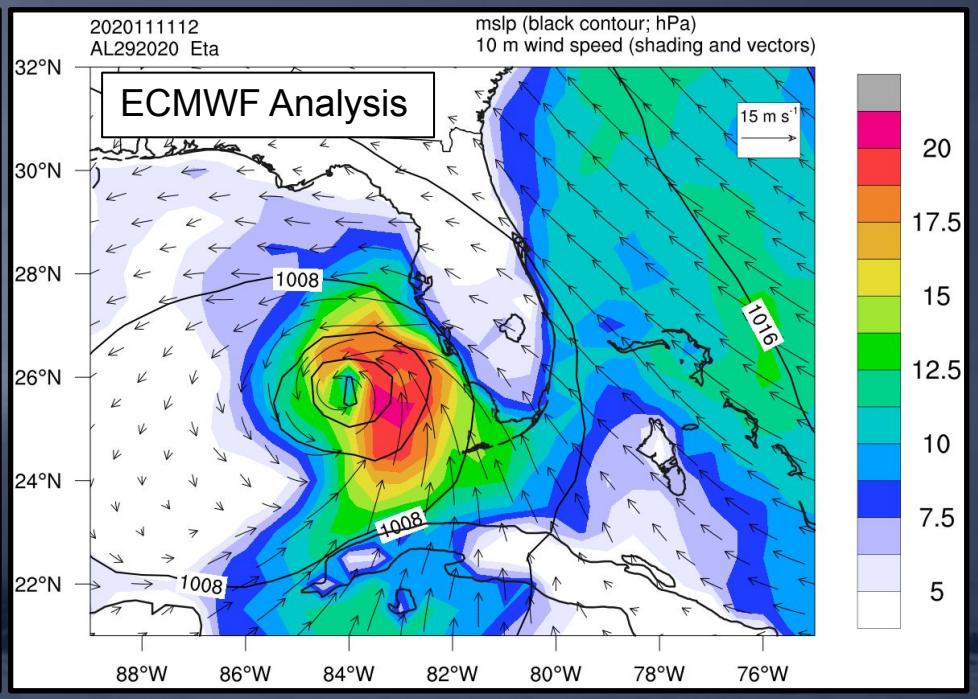


- Initial model development and evaluation of a 2nd generation wave model to couple with SLOSH
- Selected the Great Lakes Wave Model and began adding wave physics parameterizations
- Model uses simplified physics, but is cheaper computationally than SWAN or WW3
- More suitable to couple with SLOSH than SWAN

Future Improvements

Accounting for Wind Asymmetries





- except for storm motion, there are currently no wind field asymmetries in P-Surge/SLOSH
- use a 2D wind field for input wind forcing instead of the parametric wind model
- explore whether ETSS can be used to specify the solution for the background environment away from the tropical cyclone (instead of the tide-only solution)

Summary

- probabilistic guidance was crucial to help identify the areas at greatest risk for storm surge during Hurricane Ian
- a 25-storm verification data set is used to evaluate P-Surge upgrades
- recent upgrades to the input RMW forecasts have helped improve P-Surge forecasts

Future Work: V3.0 (early 2023)

- adopt non-uniform Manning-N bottom slip coefficients to reduce the inland extent of storm surge inundation
- incorporate PR/USVI SLOSH grids and couple with a simple wave model
- correct for the low-bias in intensity (and high-bias in RMW) at landfall (due to interpolation)

Future Work: Down the road….

- specify a 2D wind field for the input wind forcing in P-Surge/SLOSH to handle wind asymmetries
- incorporate dynamic uncertainty information (track, intensity, size, and structure) when generating the P-Surge ensemble