# Operational Storm Surge Modeling

HFIP Annual Meeting

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NHC Storm Surge Unit

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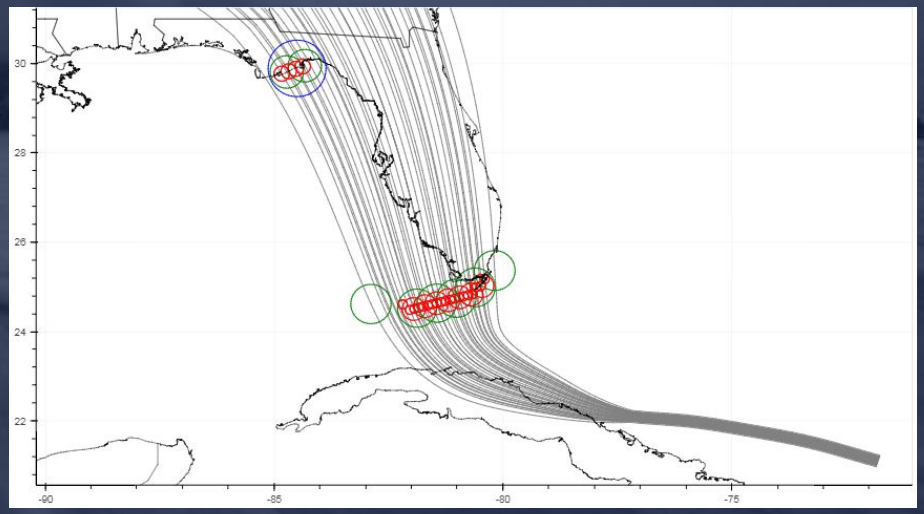
# Introduction to Probabilistic Storm Surge

- 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)

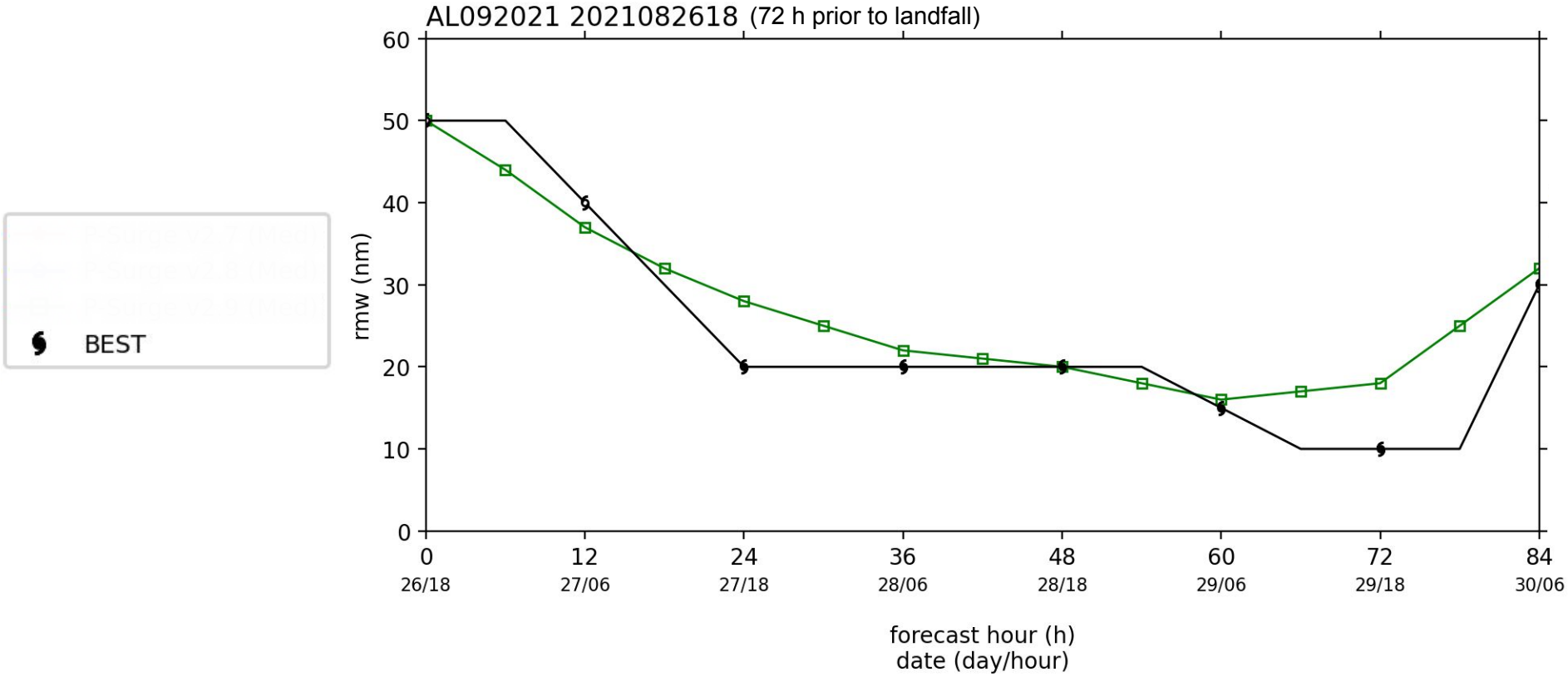
- P-Surge ensemble incorporates uncertainty using a statistical method based on NHC historical errors of:
  - Cross track (landfall location, # members varies) attempts to encompass 90% of cross track uncertainty
  - Along track (forward speed, 7 members)
  - Intensity (3 members)
  - Storm size (RMW,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

Irma (AL112017) 2017090900 P-Surge tracks



# P-Surge RMW forecasts

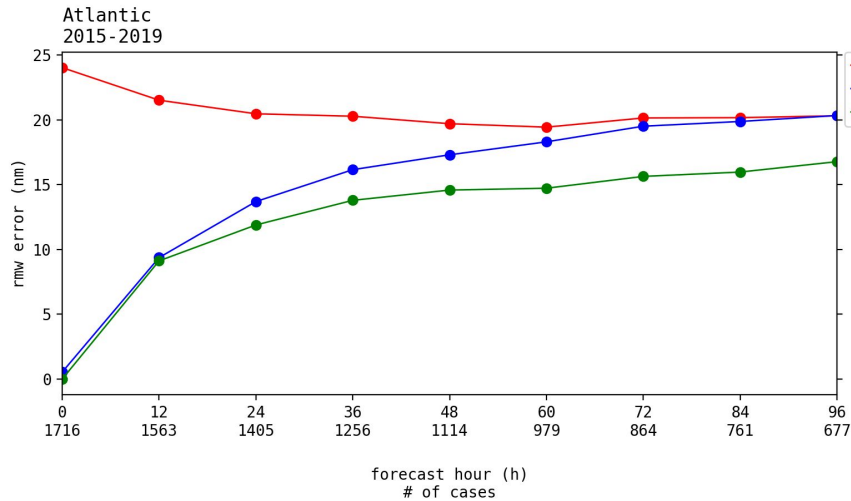
## Hurricane Ida (AL092021) 2021082618



# RMW Forecast Verification (2015-2019)

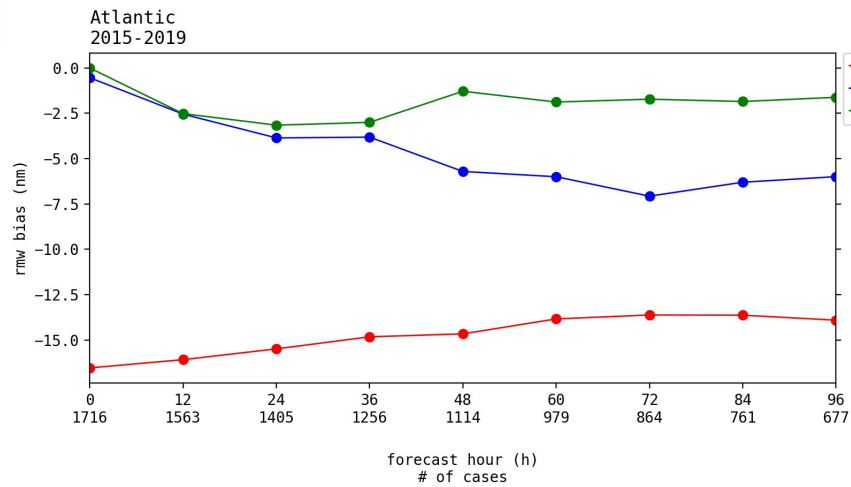
- **P-Surge v2.7:** RMW based on SLOSH parametric wind profile. RMW often inconsistent with observations.
- **P-Surge v2.8:** BEST track RMW used to initialize P-Surge. Led to improvements in storm structure.
- **P-Surge v2.9:** RMW forecasts based on NHC forecast parameters. RMW forecasts have lower MAE and less negative bias.
- Improved RMW forecasts will help efforts to extend the lead time of reliable/skillful P-Surge forecasts

**RMW error**



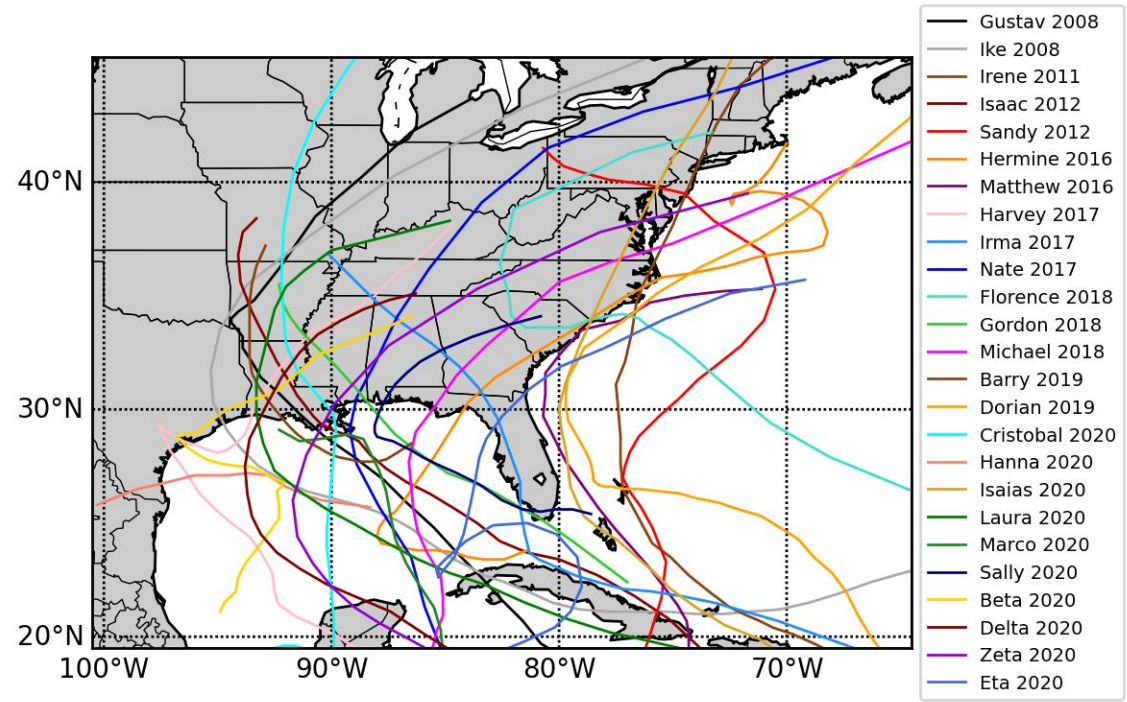

P-Surge v2.7
P-Surge v2.8
P-Surge v2.9

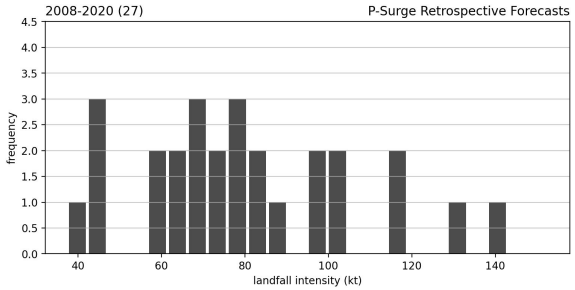
**RMW bias**

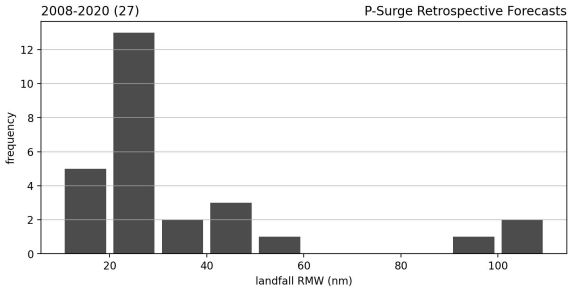


# P-Surge Retrospective Runs

- 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



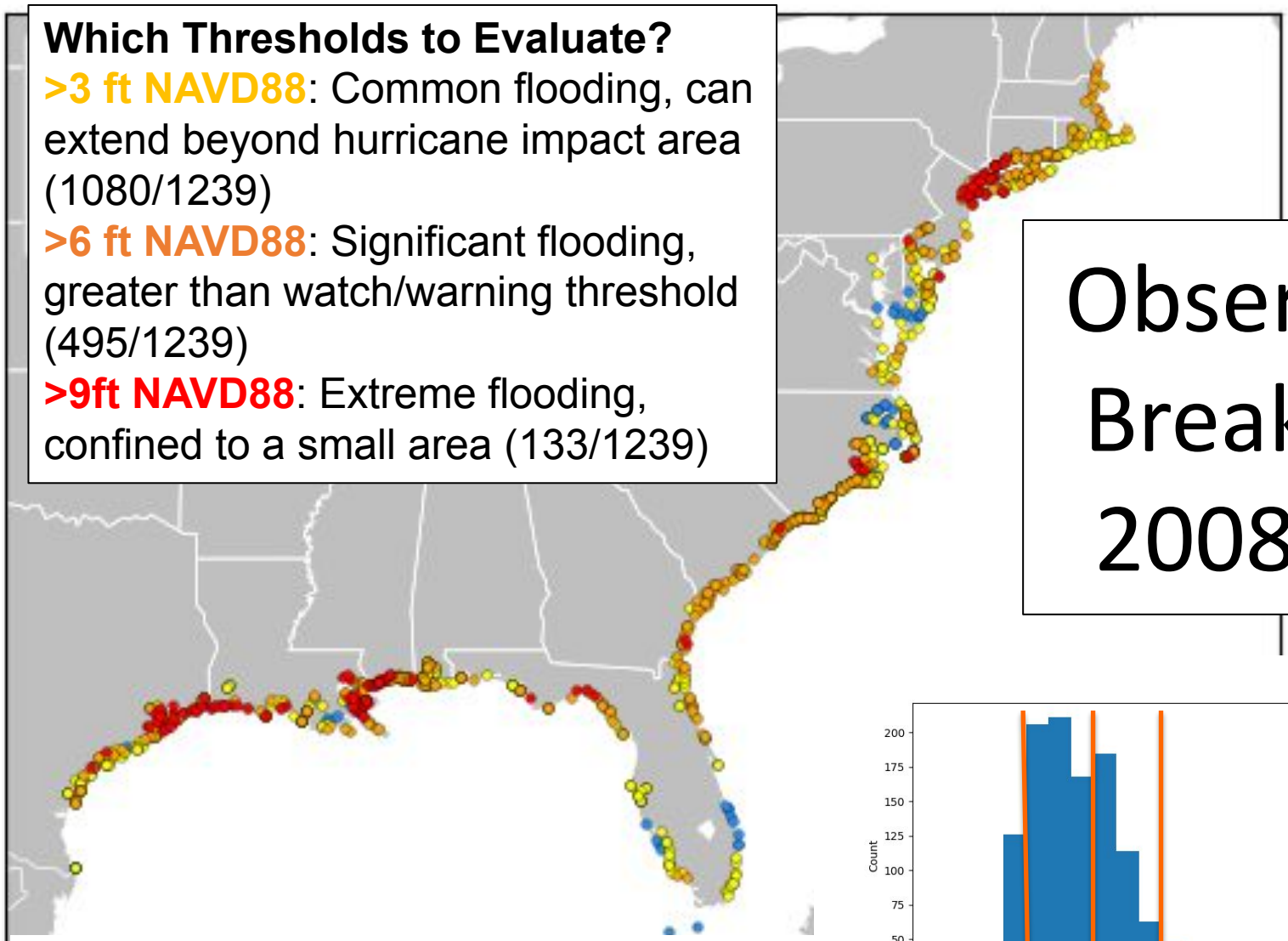
**Which Thresholds to Evaluate?**

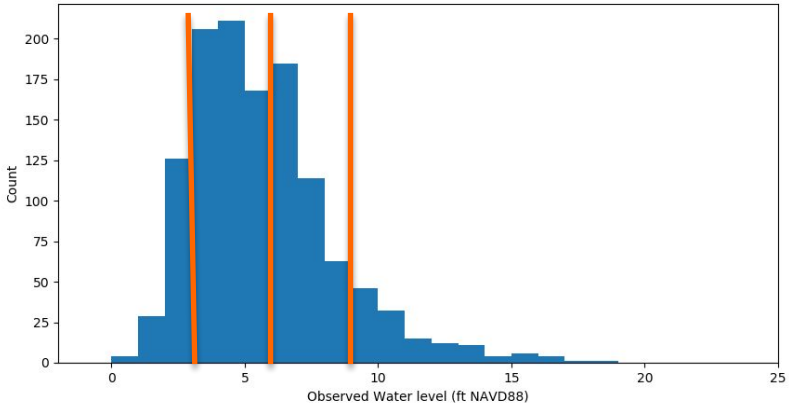
**>3 ft NAVD88**: Common flooding, can extend beyond hurricane impact area (1080/1239)

**>6 ft NAVD88**: Significant flooding, greater than watch/warning threshold (495/1239)

**>9ft NAVD88**: Extreme flooding, confined to a small area (133/1239)

# Observation Breakdown 2008-2020



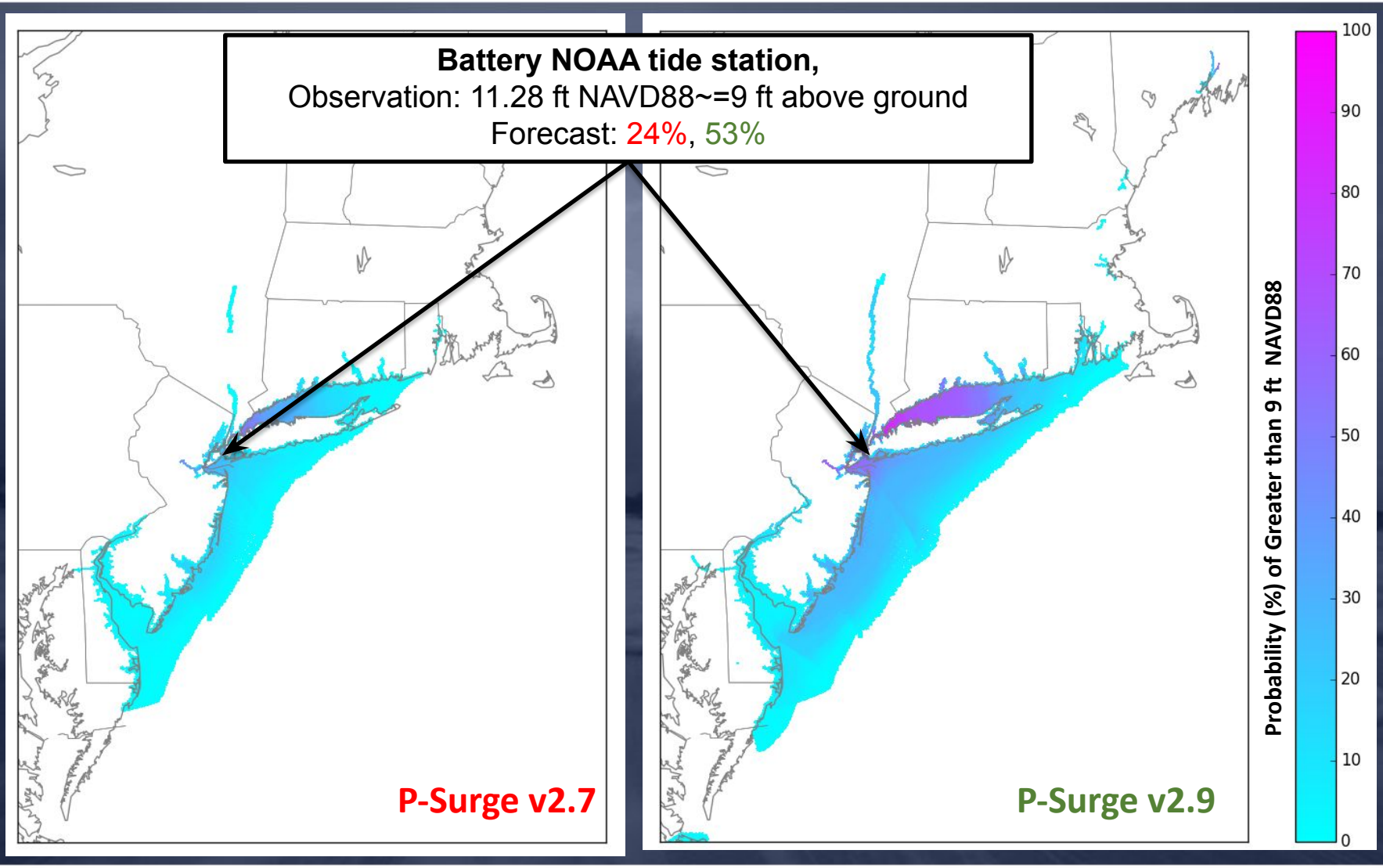



**USGS Stormtide Sensors:** all available deployed sensors

**NOAA tide station data:** subjectively chosen relative to hurricane impact area, and must reference NAVD88

# Forecast/Observation Pairing

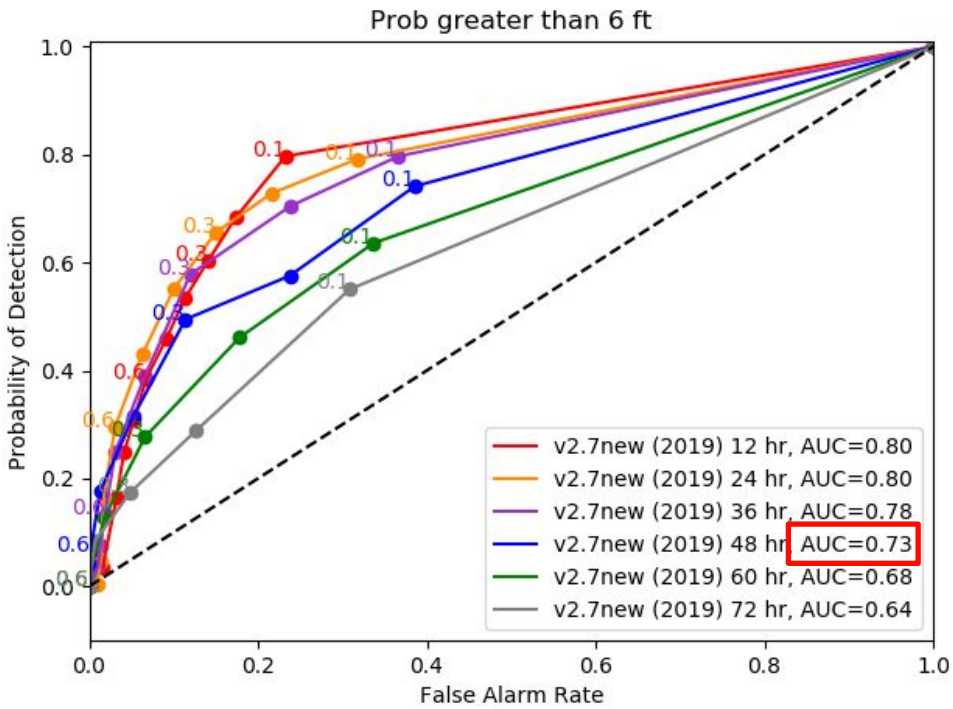
## Cumulative Probability > 9ft NAVD88
## 36 hours prior to Hurricane Sandy's landfall



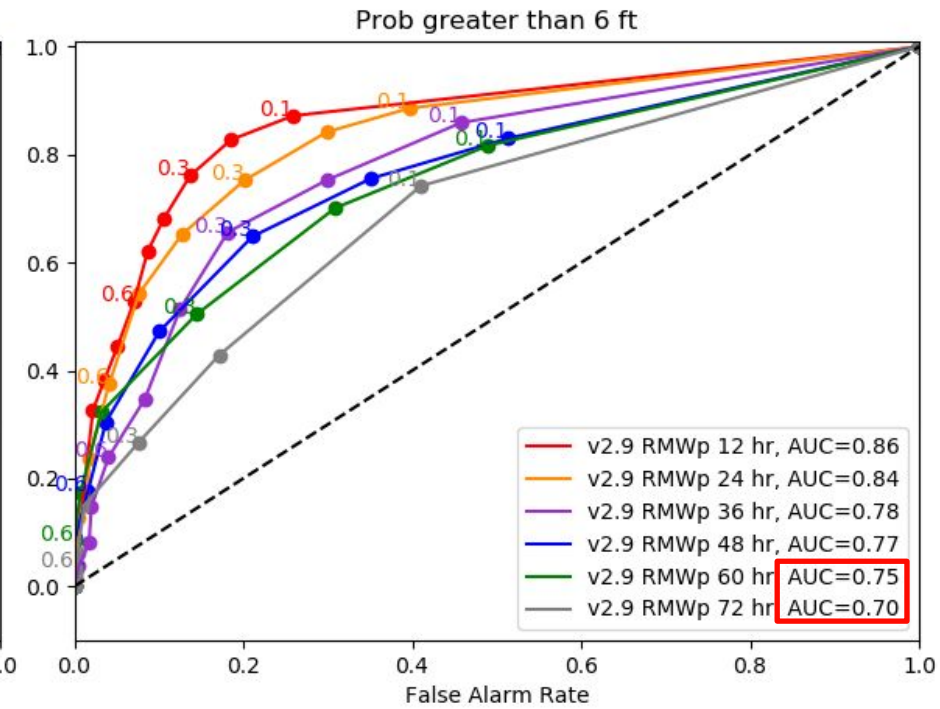
# ROC Curve:

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

v2.7 (2018)



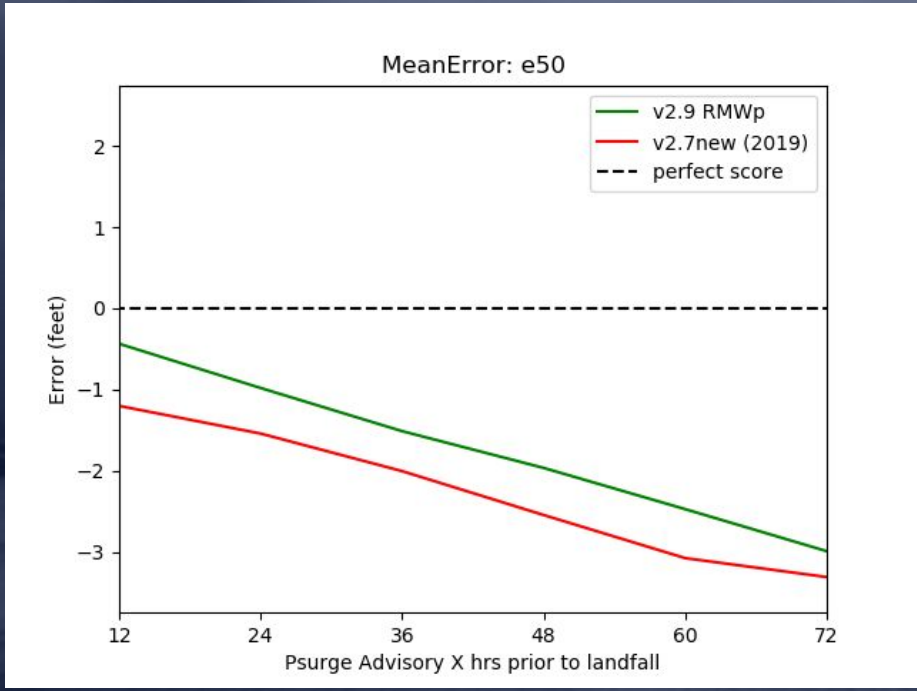

v2.9 (2021)

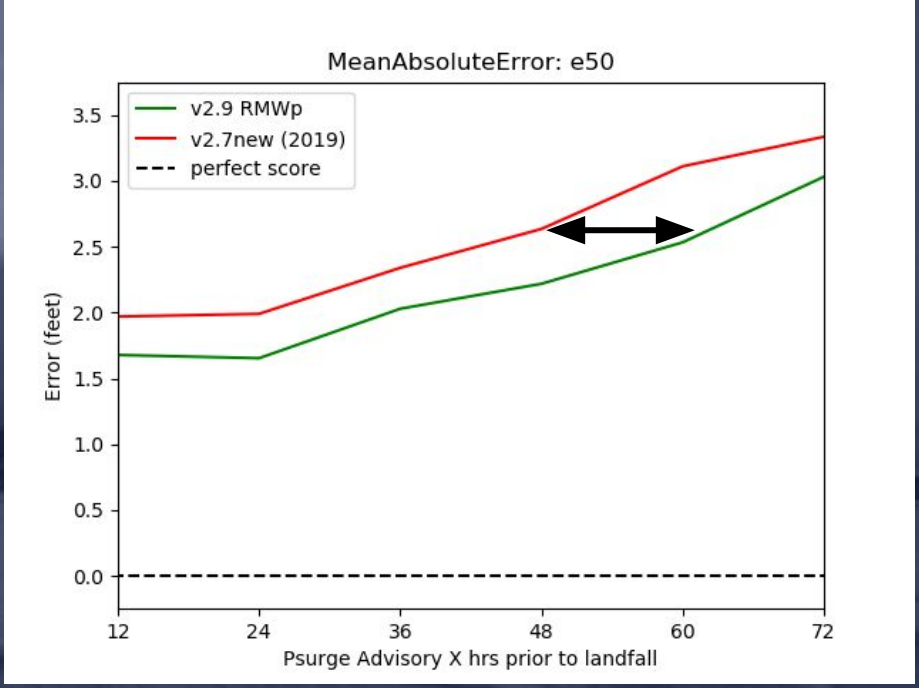



Higher Area Under Curve (AUC) for v2.9, i.e. increased skillfulness

# E50: Bias and Error

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



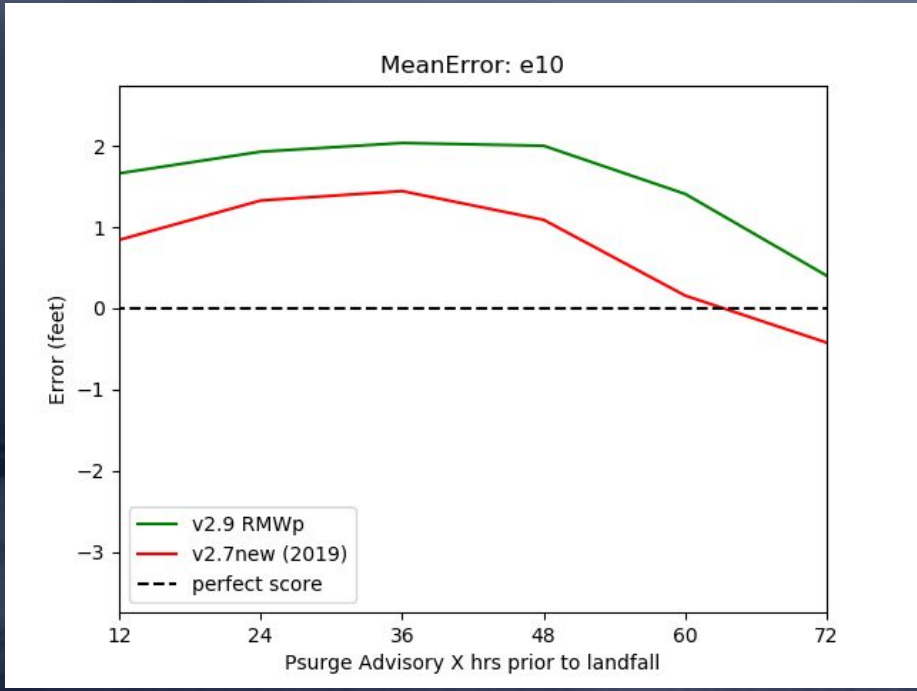



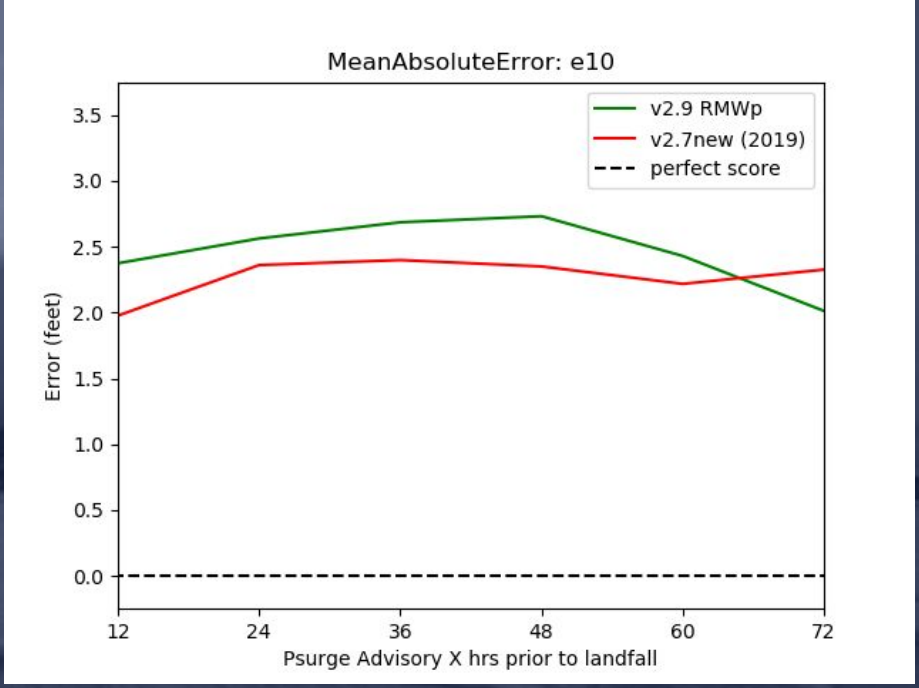

low bias in 'most likely' values at longer leadtimes

v2.9 60-hr errors are comparable to the 48-hr errors in v2.7

# E10: Bias and Error

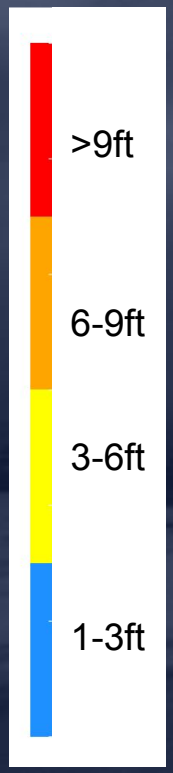
*10% exceedance is used as 'near worst case scenario'



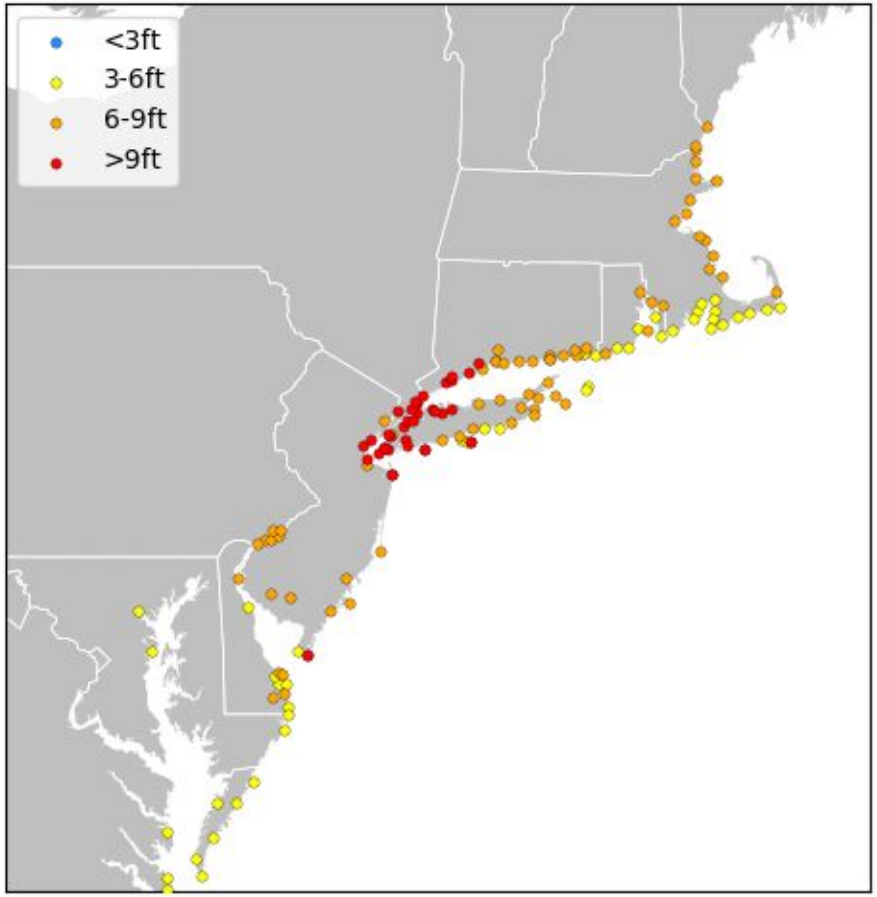




Expected high bias eroded at 60/72-hrs

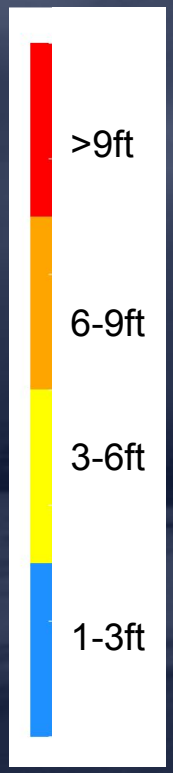
# e10 72 hours prior to Sandy landfall




**OBSERVED**




# e10 72 hours prior to Cristobal landfall

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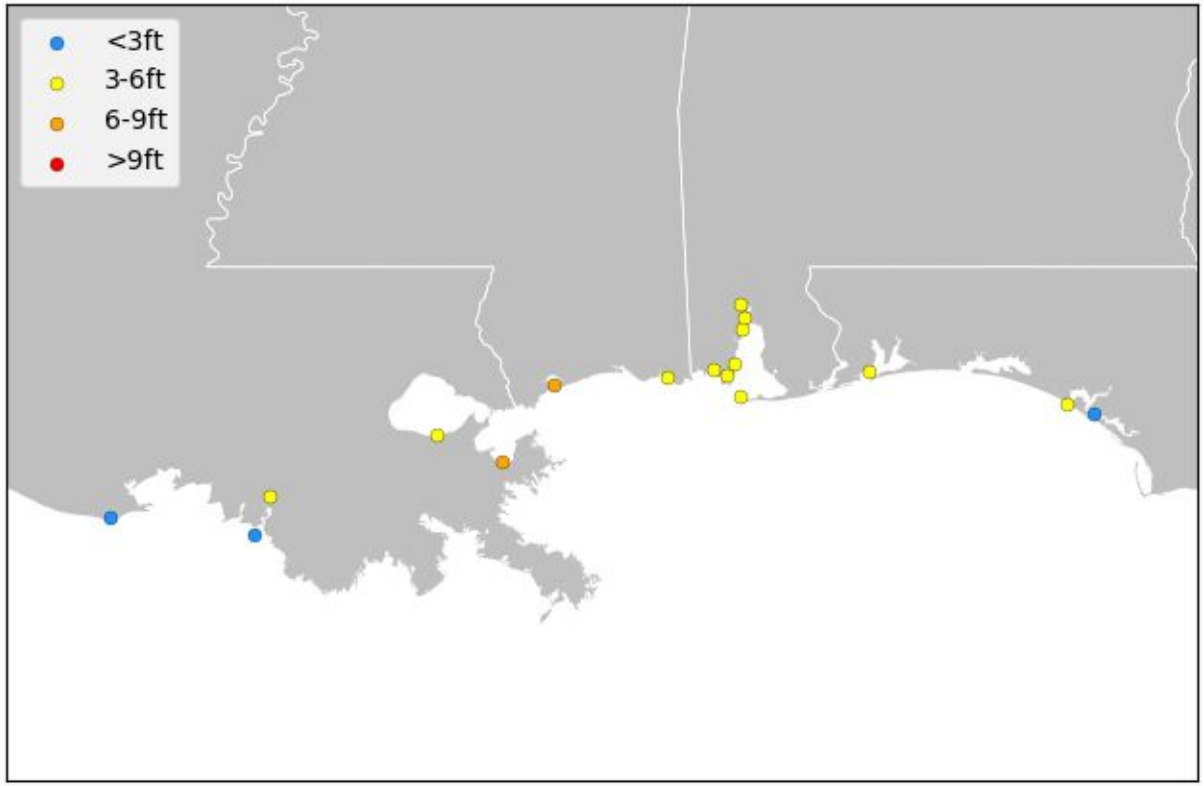
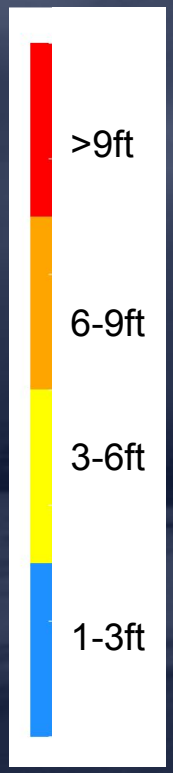
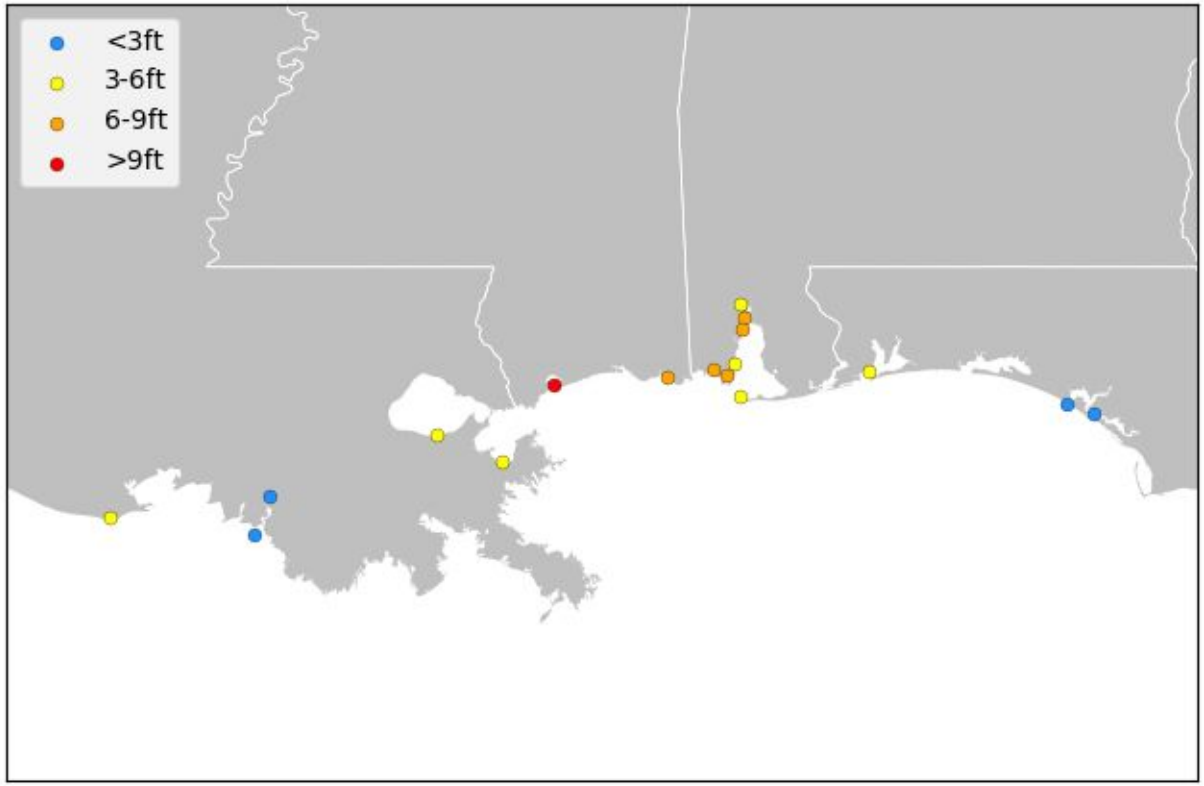



# e10 72 hours prior to Zeta landfall



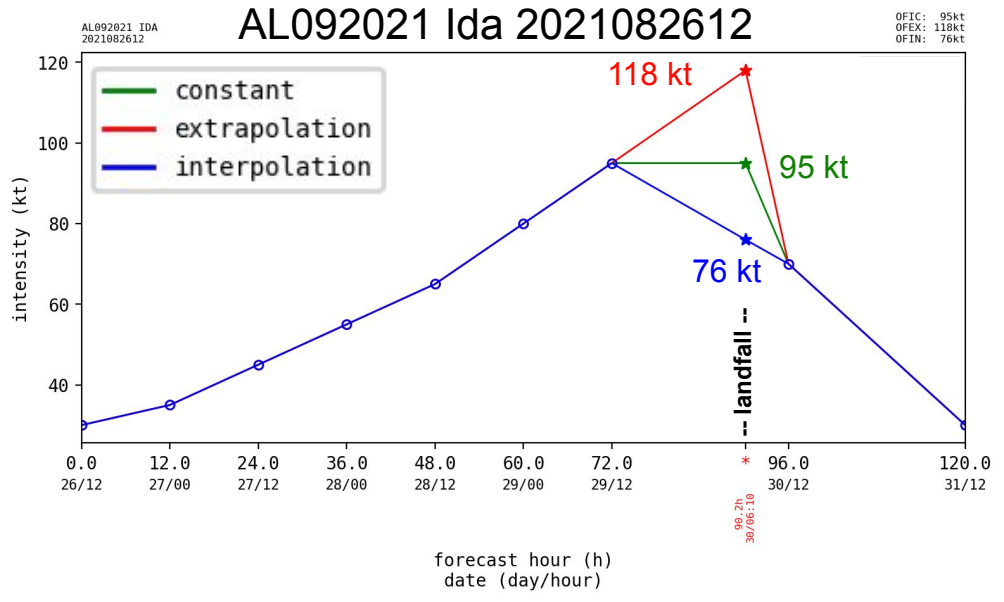

**OBSERVED**




# Landfall Adjustment for Intensity/RMW

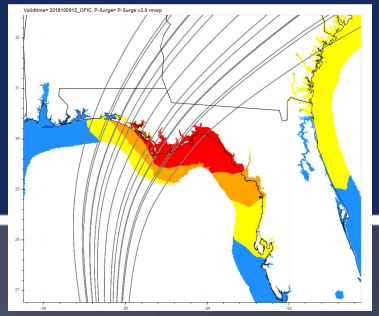
- Interpolation of intensity/RMW at landfall using post-landfall forecast points leads to a low bias for intensity and a large bias for RMW

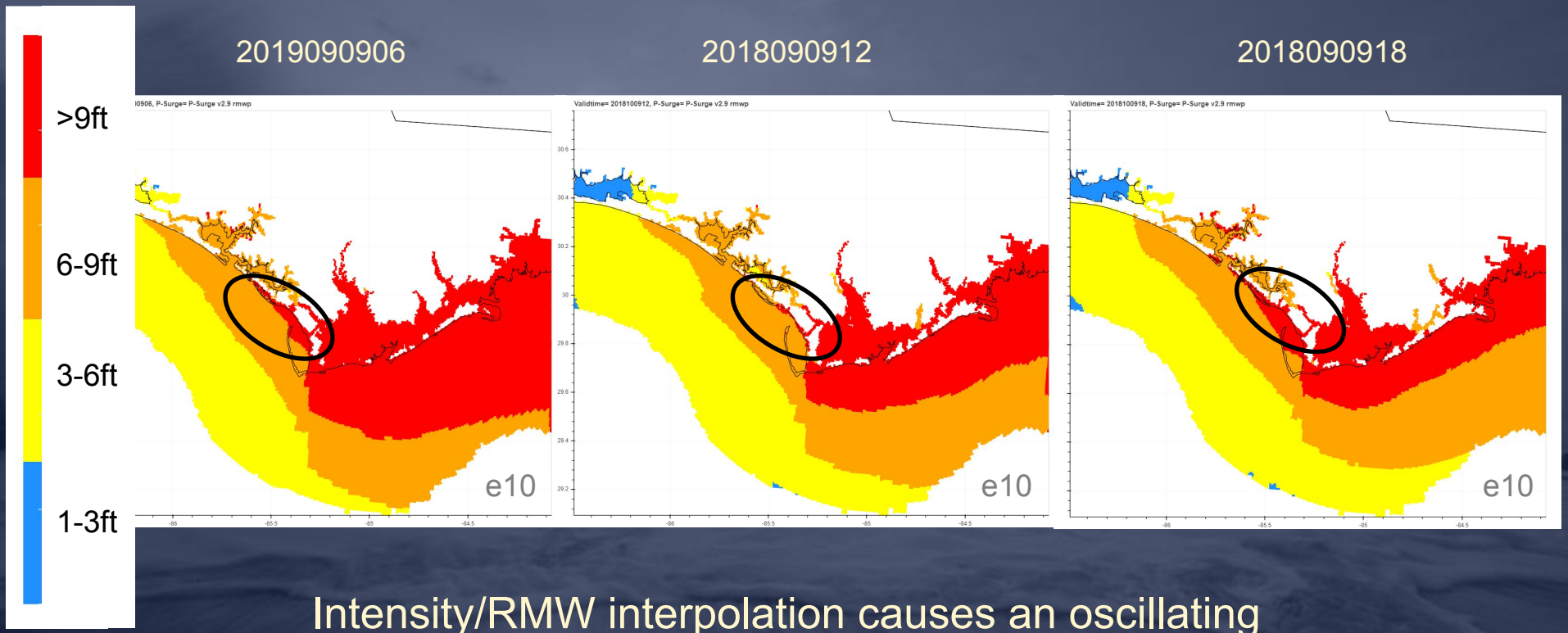
- keeping the intensity/RMW constant (green) reduces the biases, and improves run-to-run consistency



# Michael: Run-to-Run Consistency

15.55ft NAVD88 storm surge observed at Mexico Beach

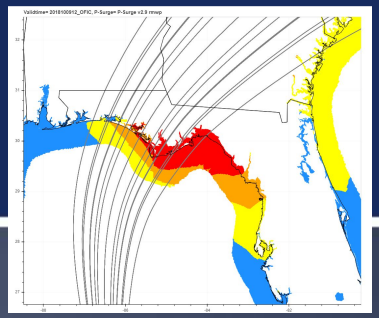





Intensity/RMW interpolation causes an oscillating forecast

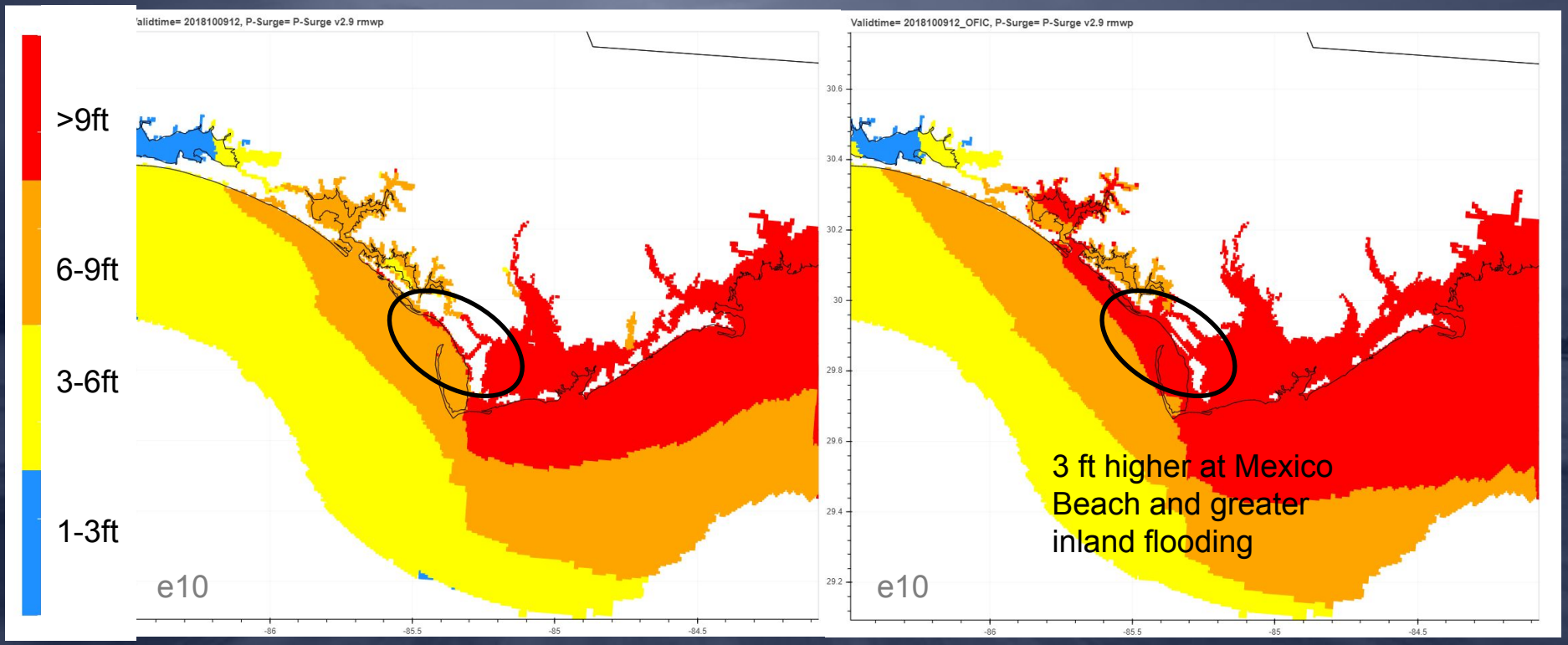
# Michael 2018100912

15.55ft NAVD88 storm surge observed at Mexico Beach



Intensity/RMW Interpolation

Constant Intensity/RMW up to landfall



# 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