Operational Storm Surge Modeling

HFIP Annual Meeting

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NHC Storm Surge Unit

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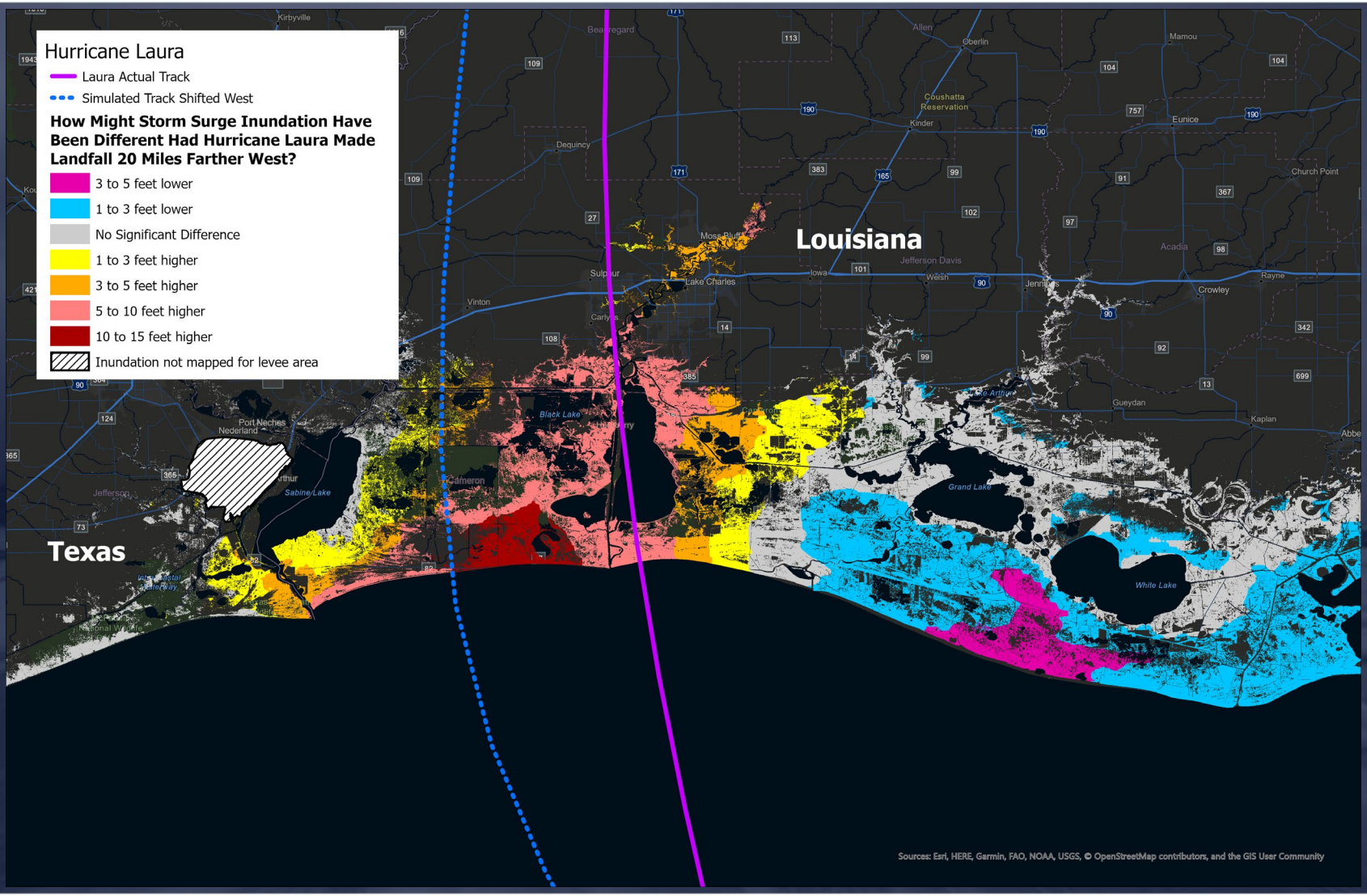
Hurricane Laura

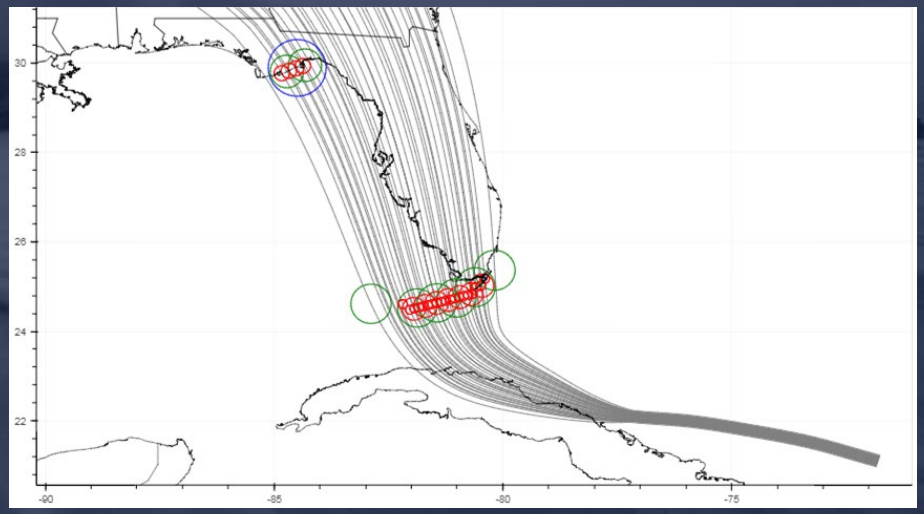


Introduction to Probabilistic Storm Surge

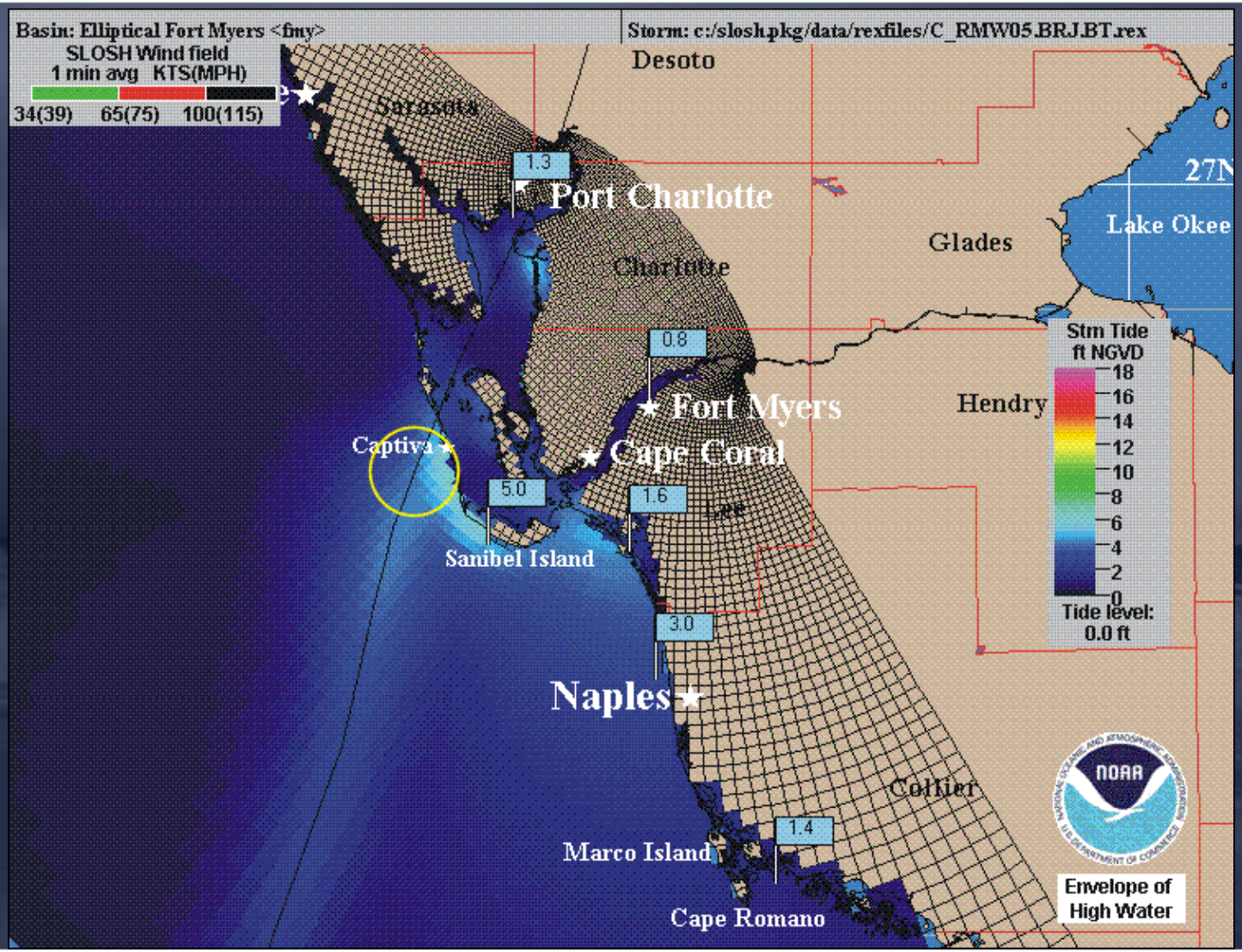
- P-Surge is based on an ensemble of Sea, Lake, and Overland Surge from Hurricane (SLOSH) model runs
  - SLOSH: numerical-dynamic tropical storm surge model
  - SLOSH requires bathymetry and is applied to a 'basin'
  - SLOSH requires meteorological driving forces: "Wind model is just as important– if 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)

2017090900 P-Surge Tracks



Storm Size Matters

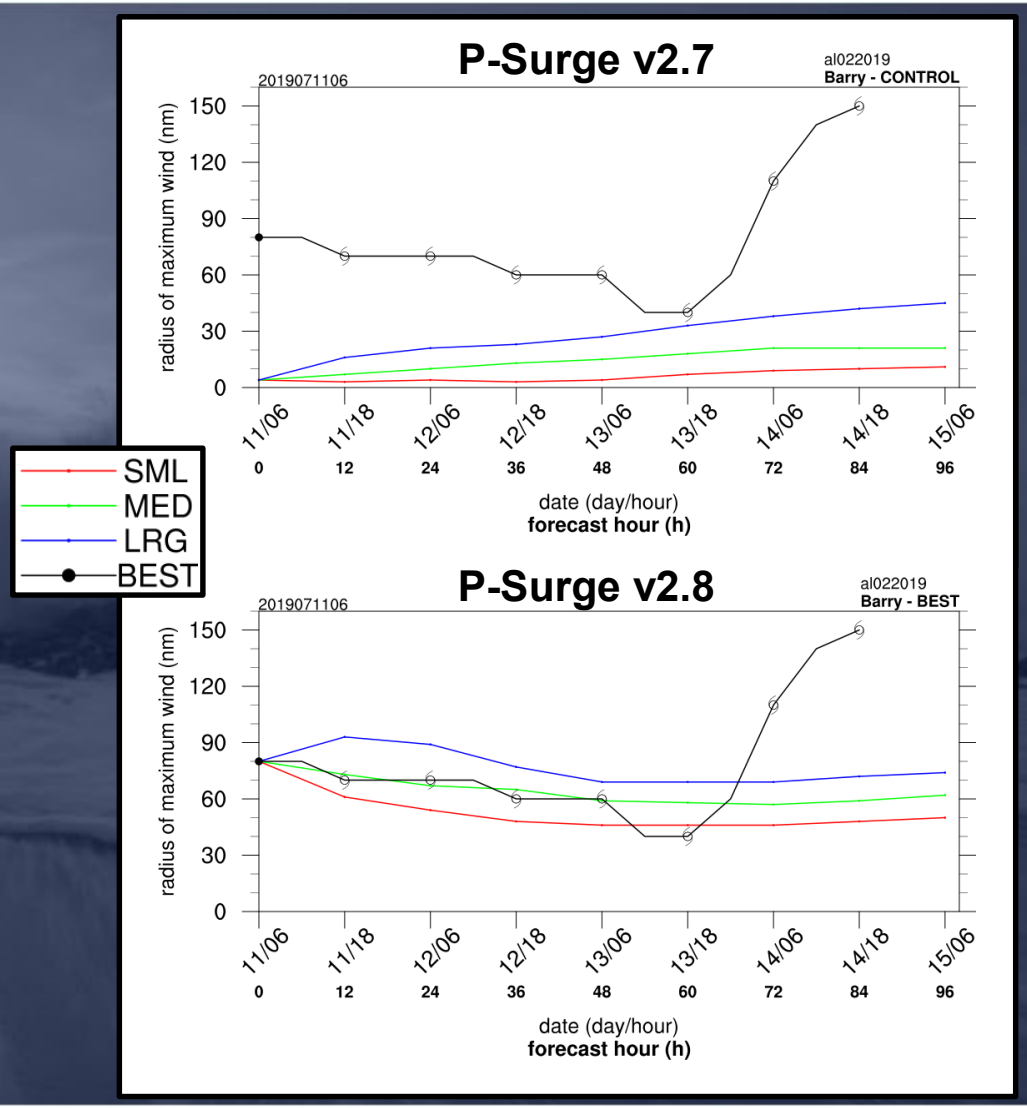


P-Surge Upgrade v2.8

Improvements to initial storm structure

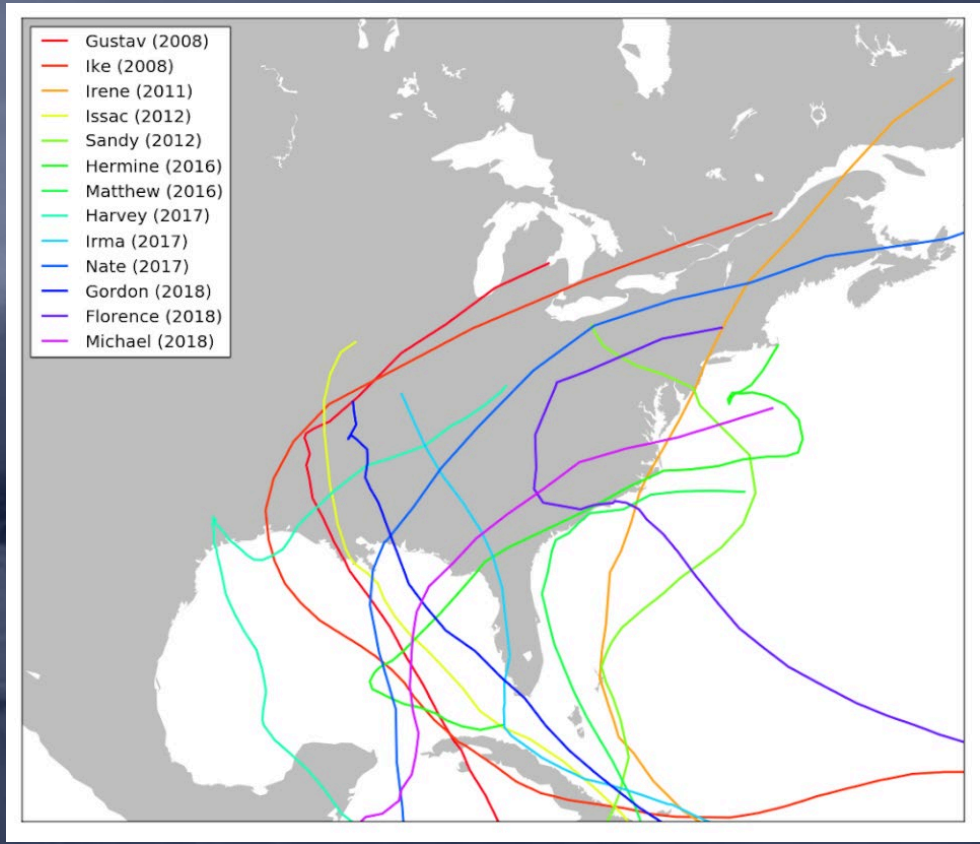
- v2.7: RMW derived from SLOSH parametric wind profile often resulted in P-Surge ensemble failing to encompass observed storm size

- v2.8: improvement when 3-member P-Surge storm size ensemble (small, medium, and large storms) initialized from Best track RMW



P-Surge Retrospective Runs

- 13 storms between 2008-2018: 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



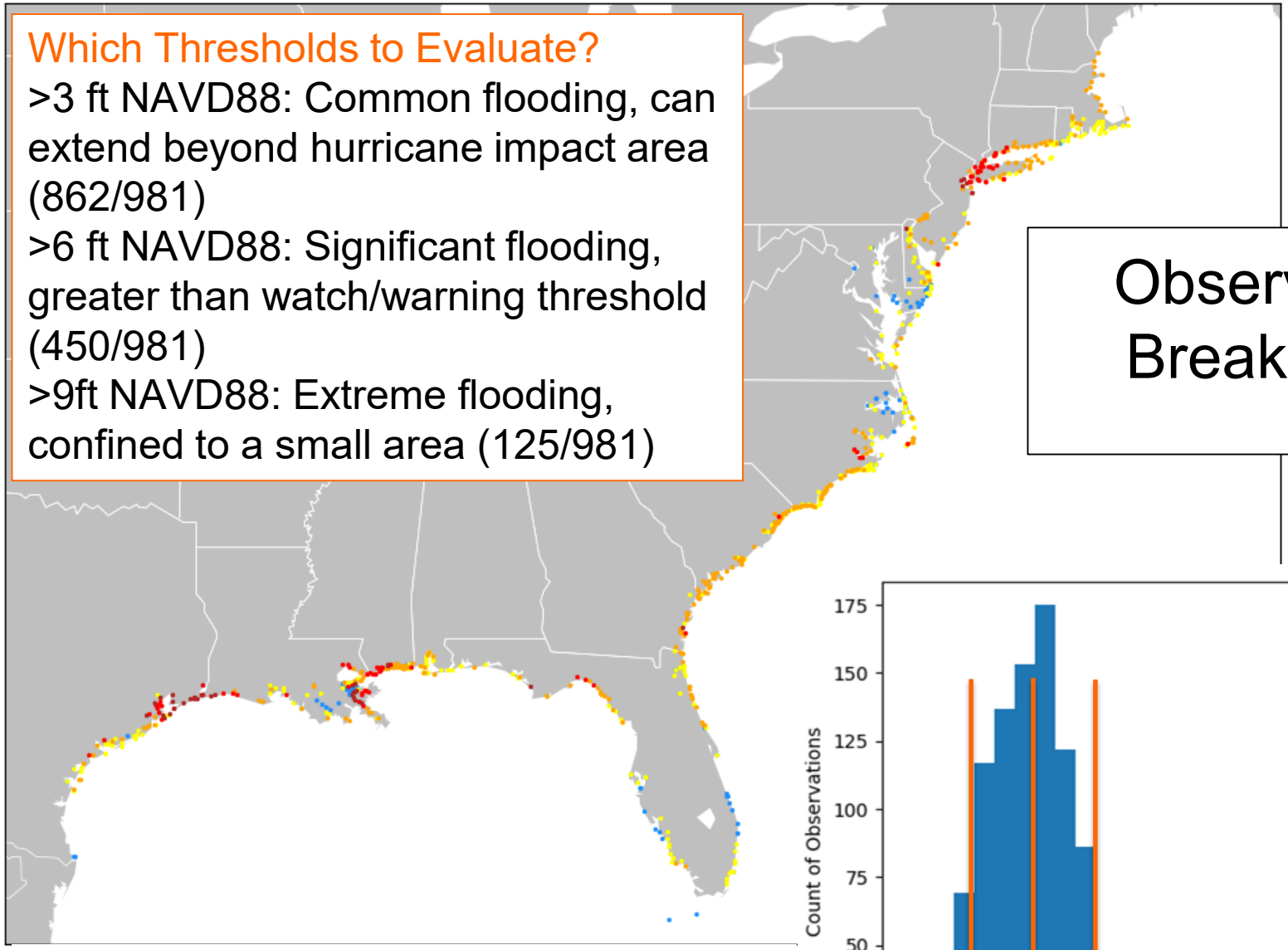
Observation Breakdown

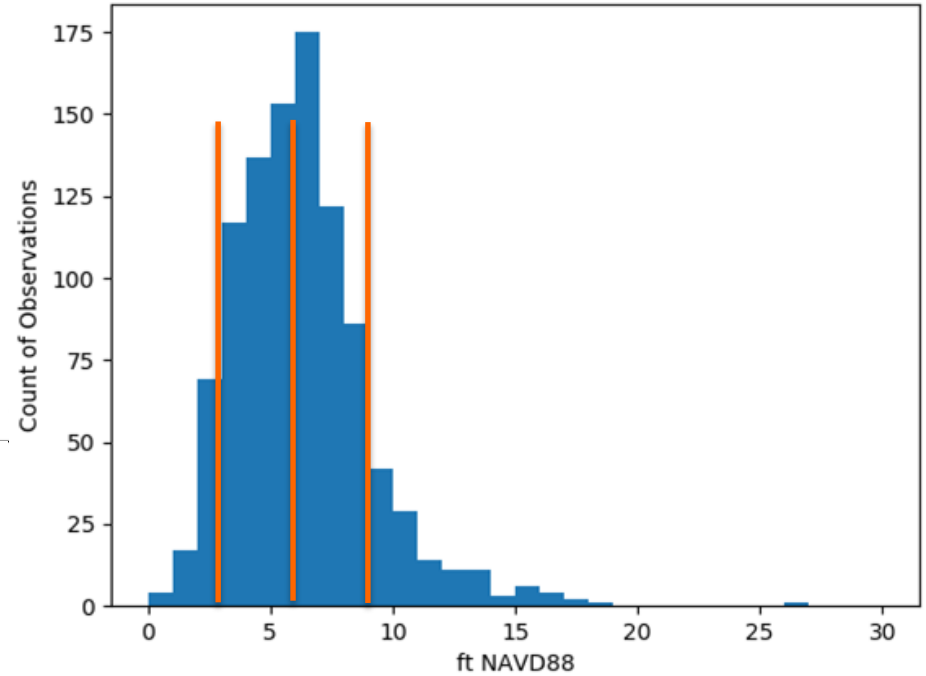
Which Thresholds to Evaluate?

>3 ft NAVD88: Common flooding, can extend beyond hurricane impact area (862/981)

>6 ft NAVD88: Significant flooding, greater than watch/warning threshold (450/981)

>9ft NAVD88: Extreme flooding, confined to a small area (125/981)



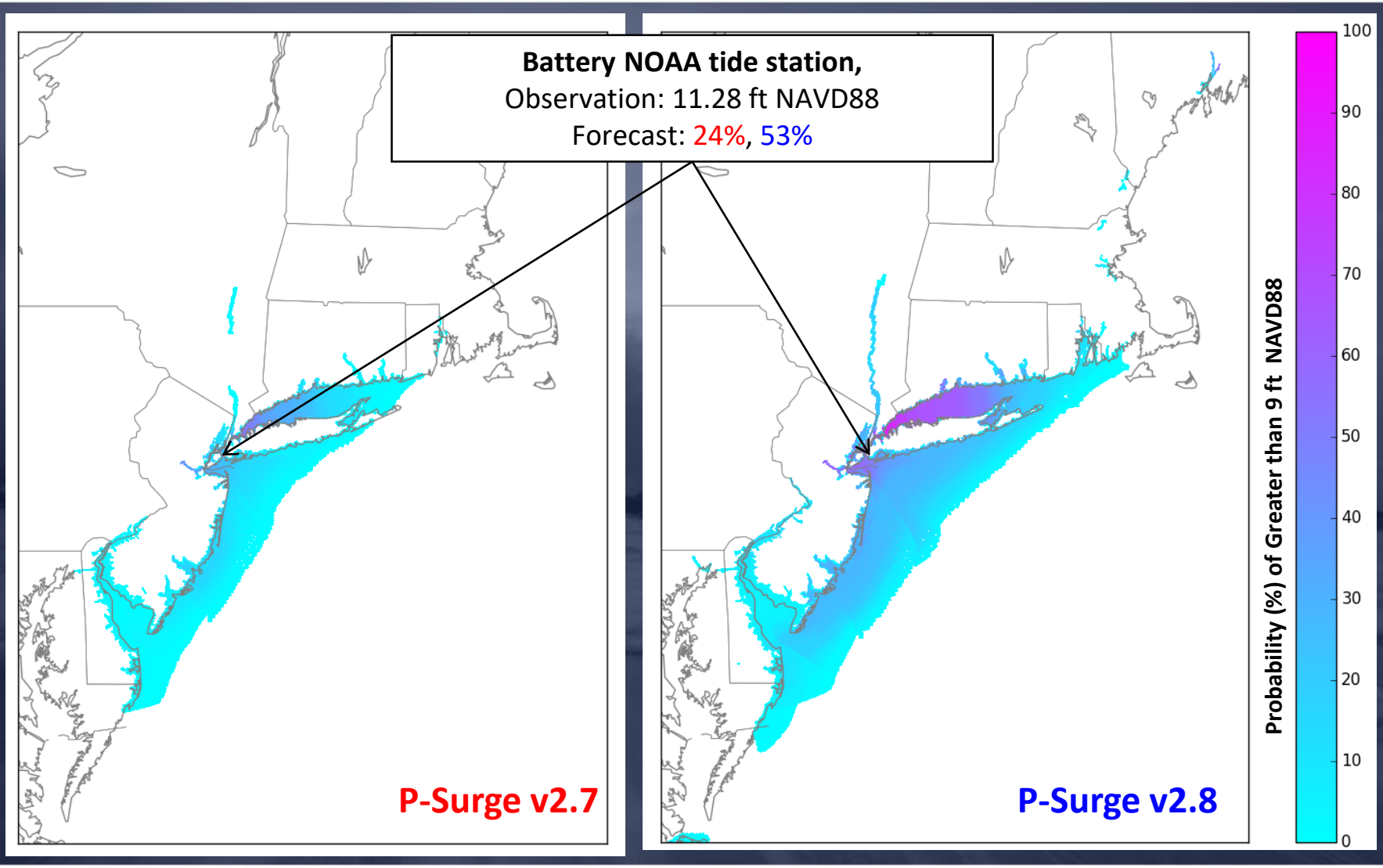


USGS Stormtide Sensors: all available deployed sensors

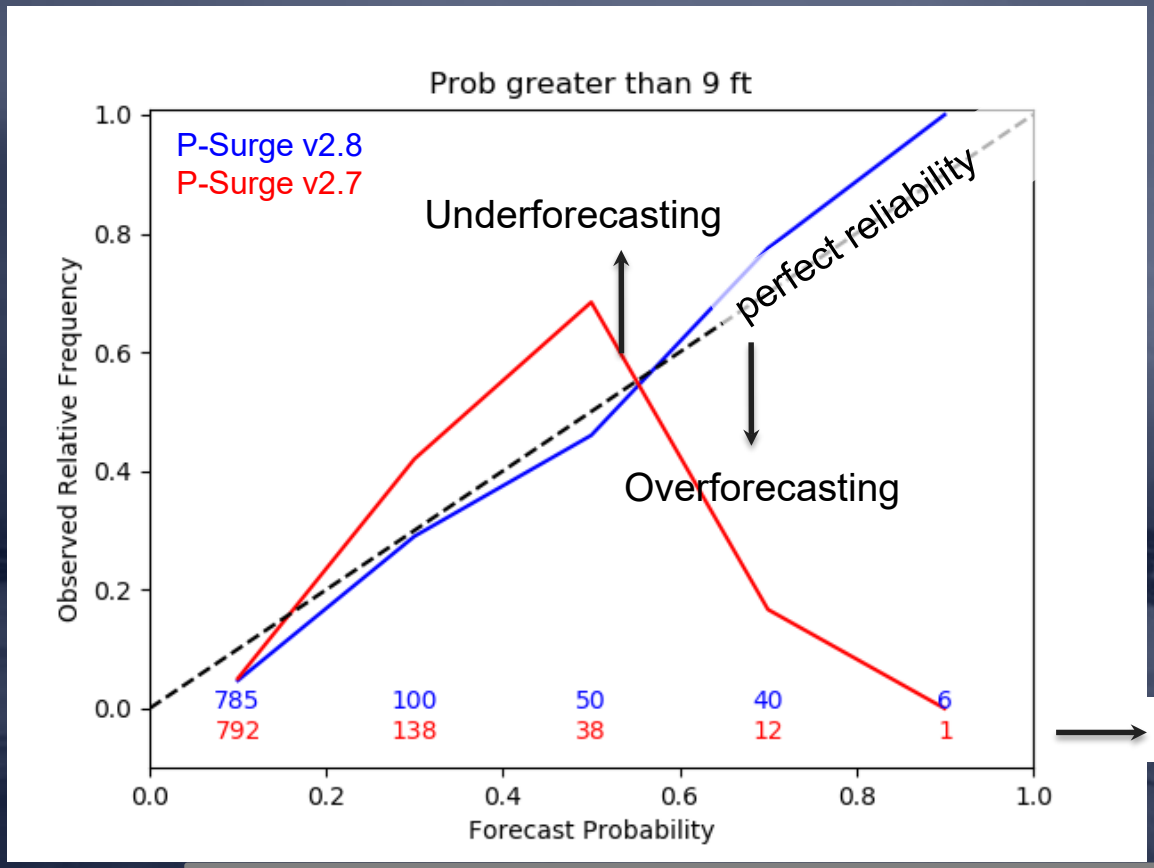
NOAA tide station data: subjectively chosen relative to hurricane impact area, and must reference NAVD88

Forecast/Observation Pairing

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



P-Surge advisories 36-hours prior to landfall

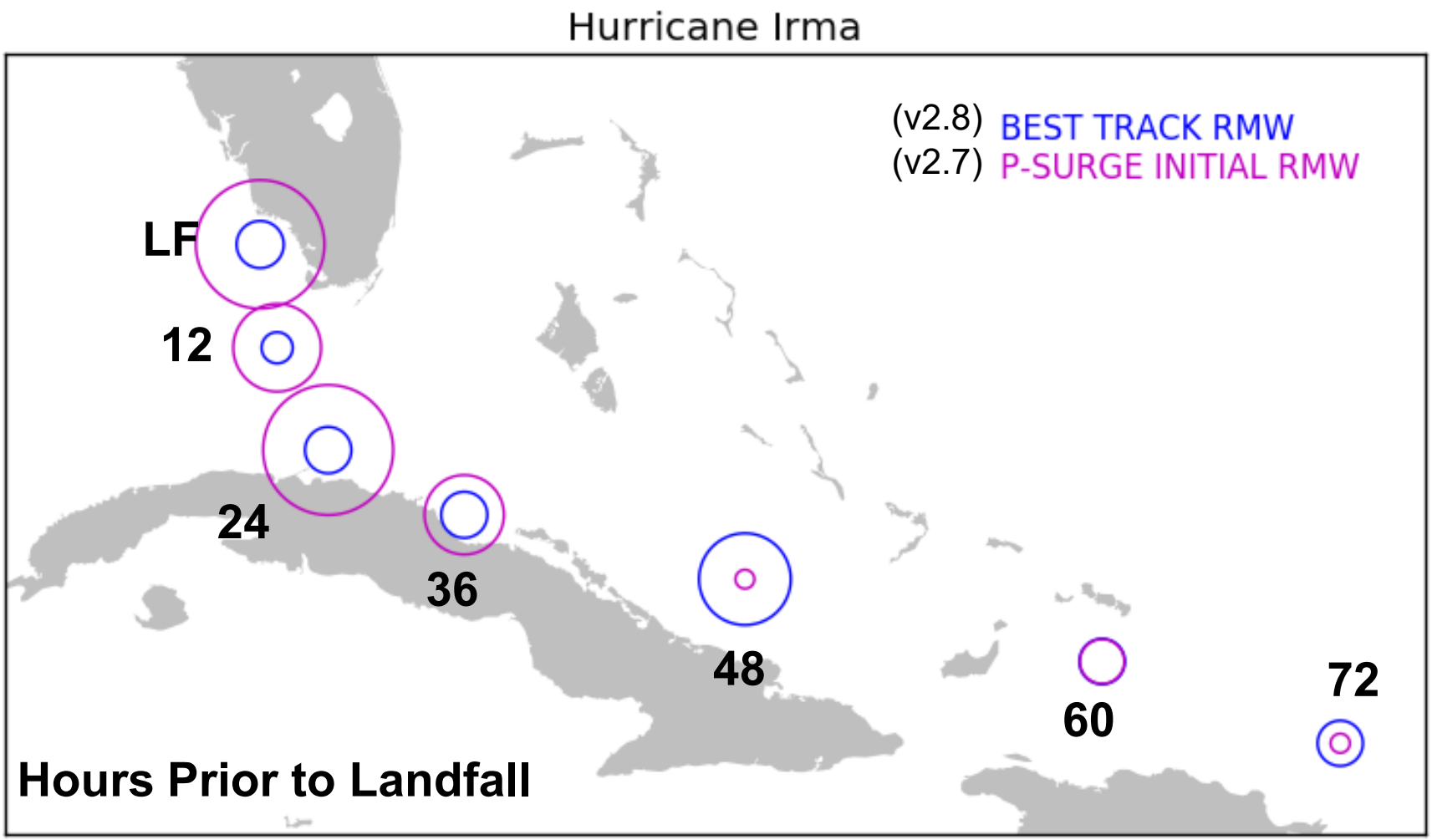


Shows count in each bin

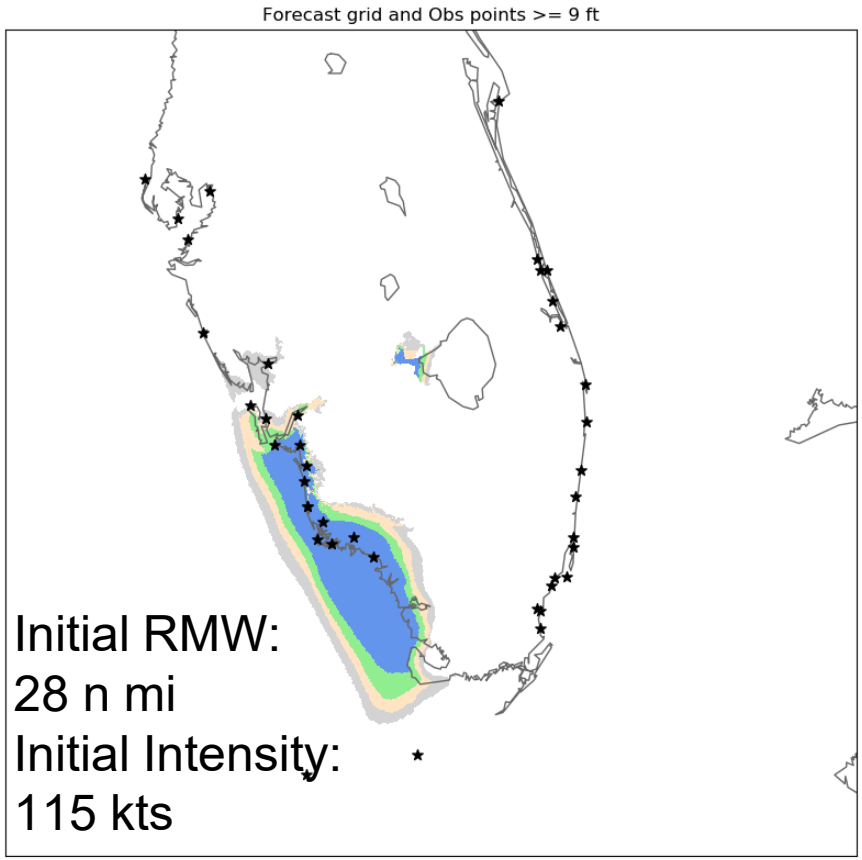
- v2.8 more frequently forecasts higher probabilities of >9ft NAVD88, especially for Sandy and Ike, and is more reliable
- v2.7 is overforecasting during Irma

Interpreting Reliability Diagrams:
How well do the forecast probabilities of an event (e.g. >9ft of Storm Surge) correspond to their observed frequencies?

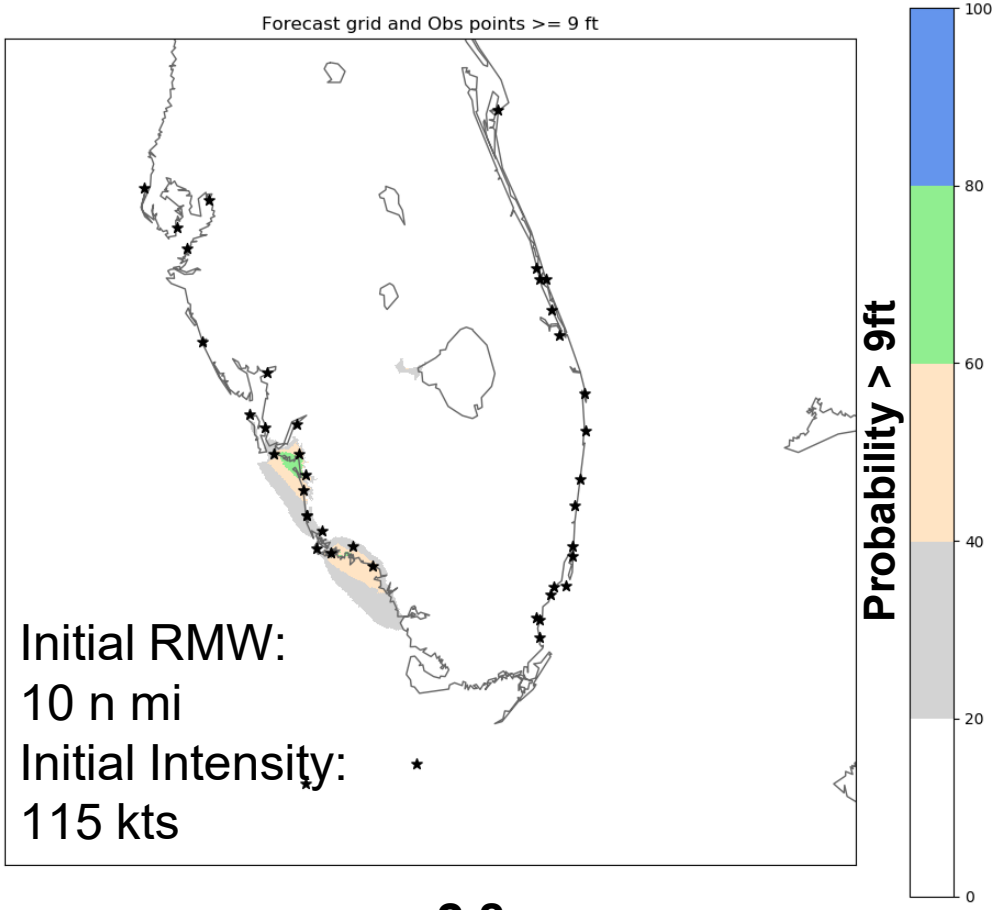
Irma Initial RMW



Irma : 12-hours prior to landfall

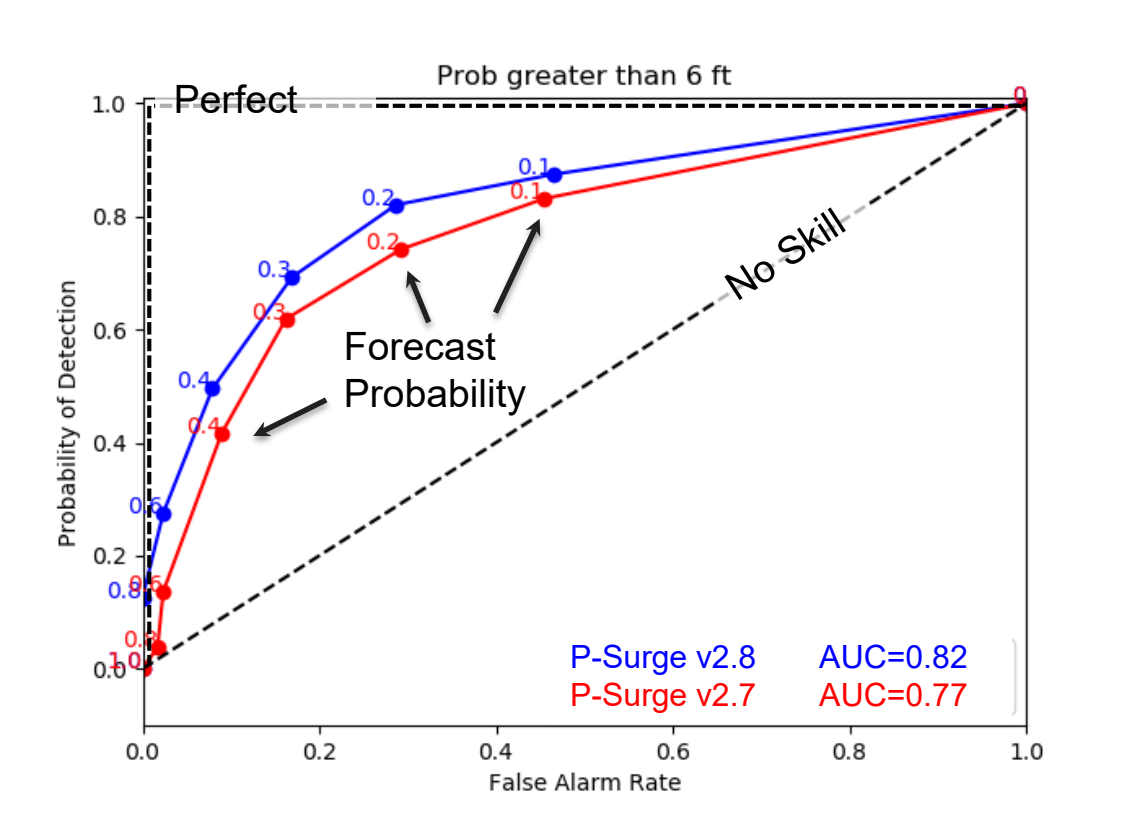


v2.7



v2.8

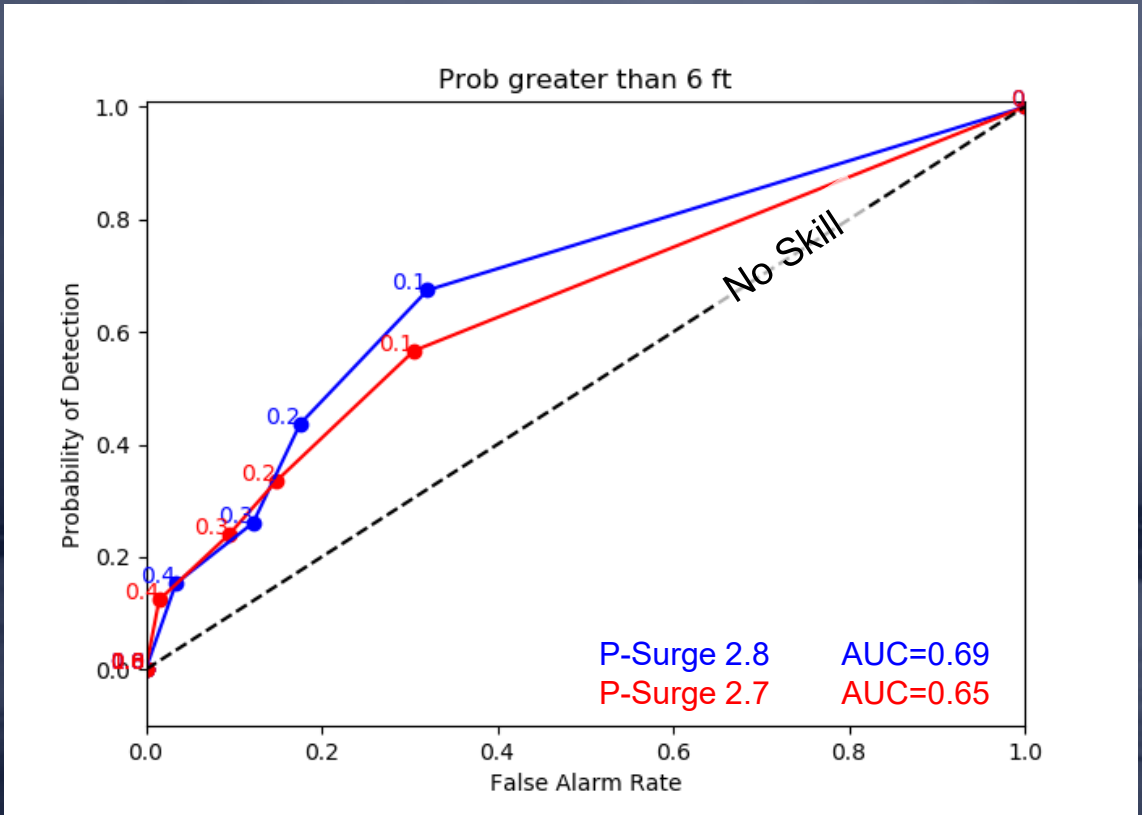
P-Surge advisories 36-hours prior to landfall



- v2.8 increases the detection without increasing the false alarms for a given forecast probability

Interpreting ROC Curve:
Is the forecast able to discriminate between events and non-events?

P-Surge advisories 72-hours prior to landfall

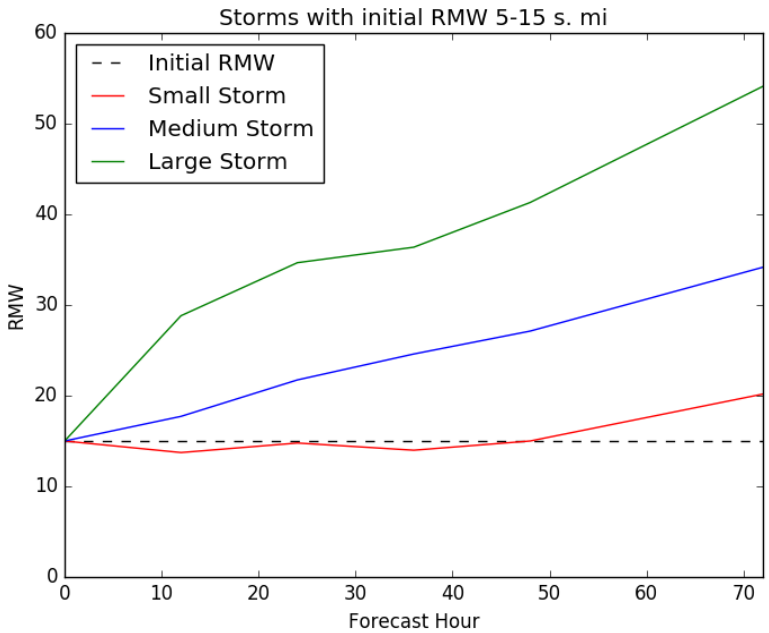


- Improvement still needed with respect to 72-hour P-Surge advisories
- Relatively low probability of detection

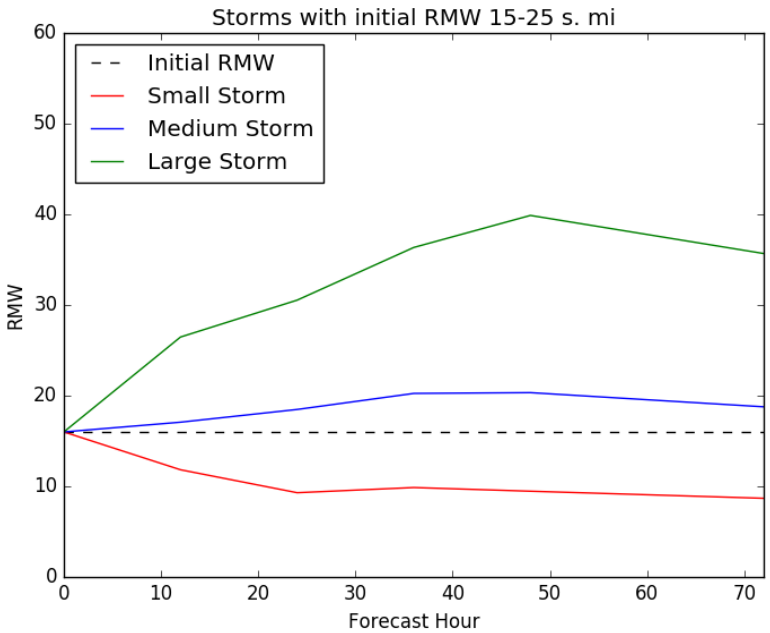
Interpreting ROC Curve:
Is the forecast able to discriminate between events and non-events?

RMW Forecasts from current P-Surge Ensemble

Initial RMW = 15 mi



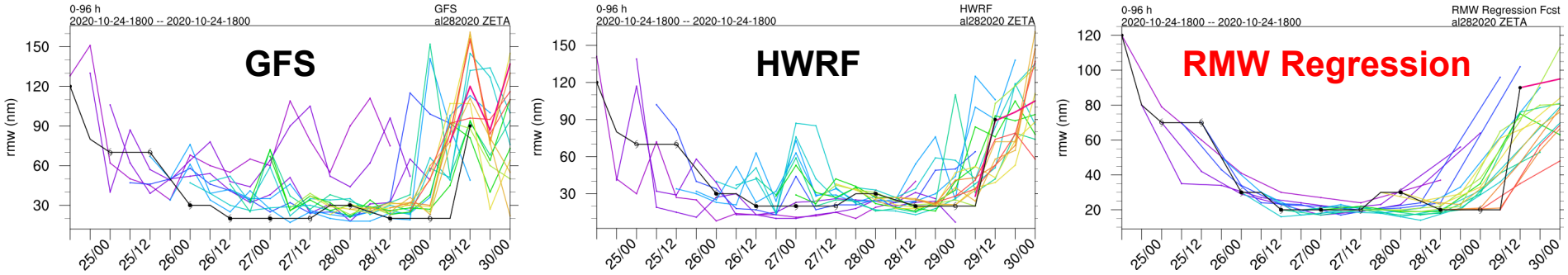
Initial RMW = 16 mi



- RMW forecast is ONLY a function of the initial RMW
- leads to inconsistencies in storm size when initial RMW is close to “bin” boundaries

RMW Forecasts

Hurricane Zeta RMW Forecasts



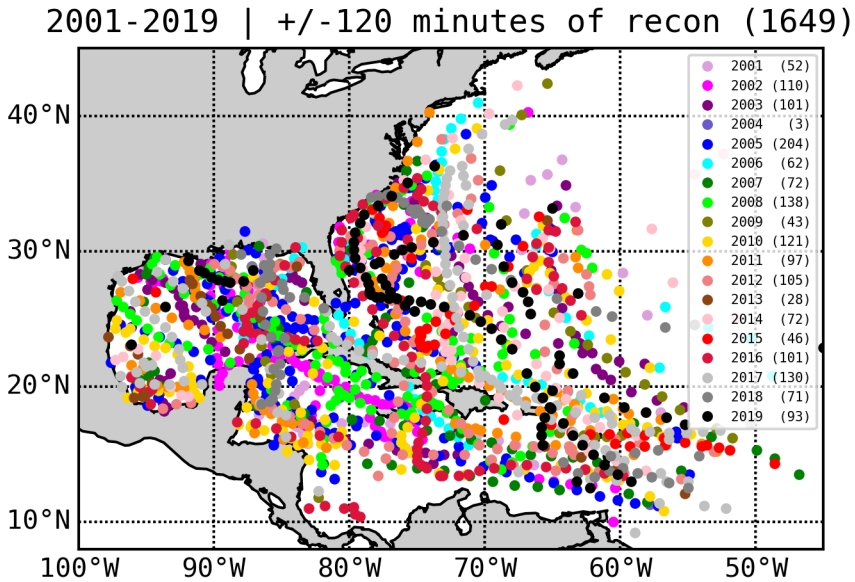
- consensus and corrected consensus forecasts based on global/hurricane models are skillful at longer lead times, but are too noisy
- RMW forecasts based on NHC OFCL forecast parameters have highest skill and are more consistent

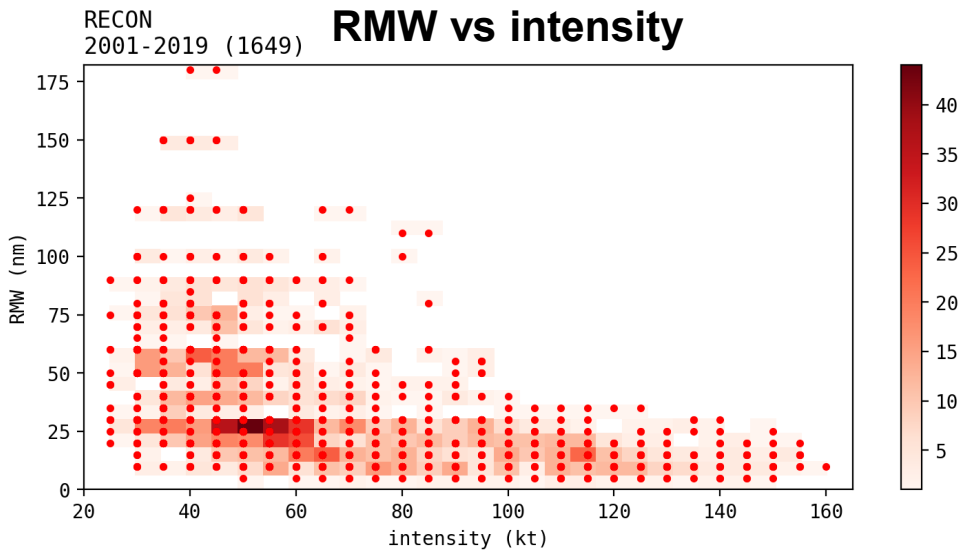
RMW Regression Forecasts:

RMW_0
Intensity
Latitude
R_{34}
R_{50}
R_{64}

RMW Climatology

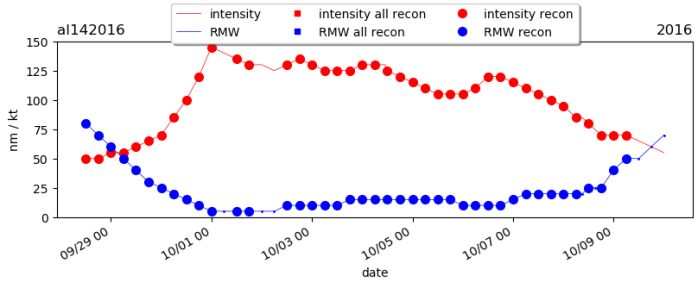
BEST track times within +/- 120 minutes of aircraft reconnaissance from 2001-2019



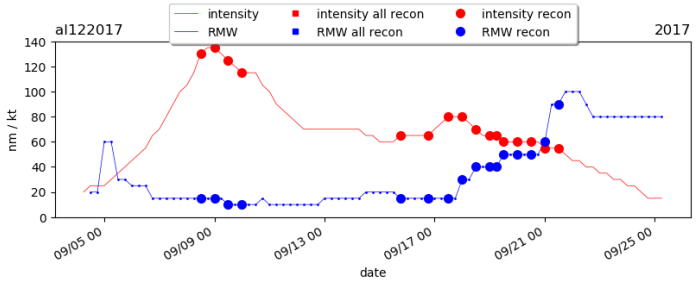


- large amount of variability in the relationship between intensity and RMW from case to case

Hurricane Matthew (2016)



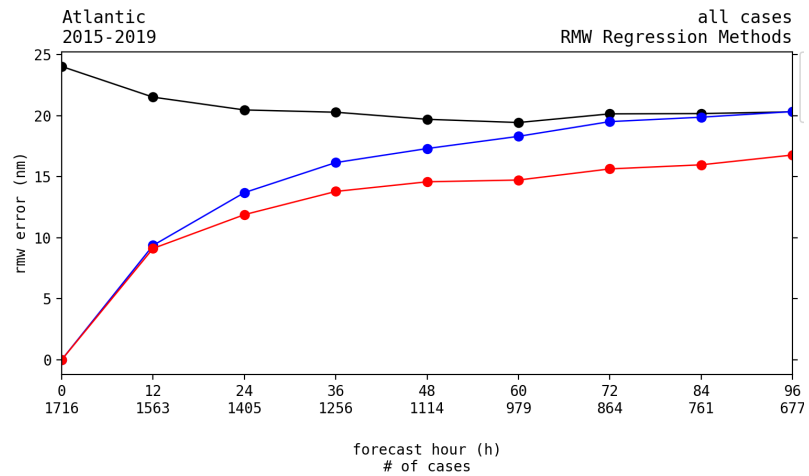
Hurricane Jose (2017)

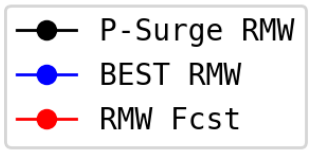


RMW Forecast Verification (2015-2019)

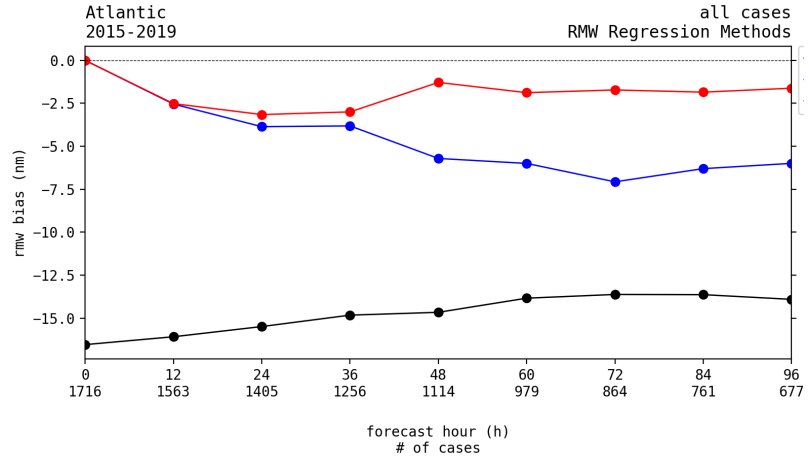
- **P-Surge v2.8:** improvement in storm structure when using BEST track RMW to initialize P-Surge
- RMW forecasts have lower MAE beyond 24 h and less negative bias
- improvement in skill for RMW forecasts will help efforts to extend lead time of reliable/skillful P-Surge forecasts

RMW error



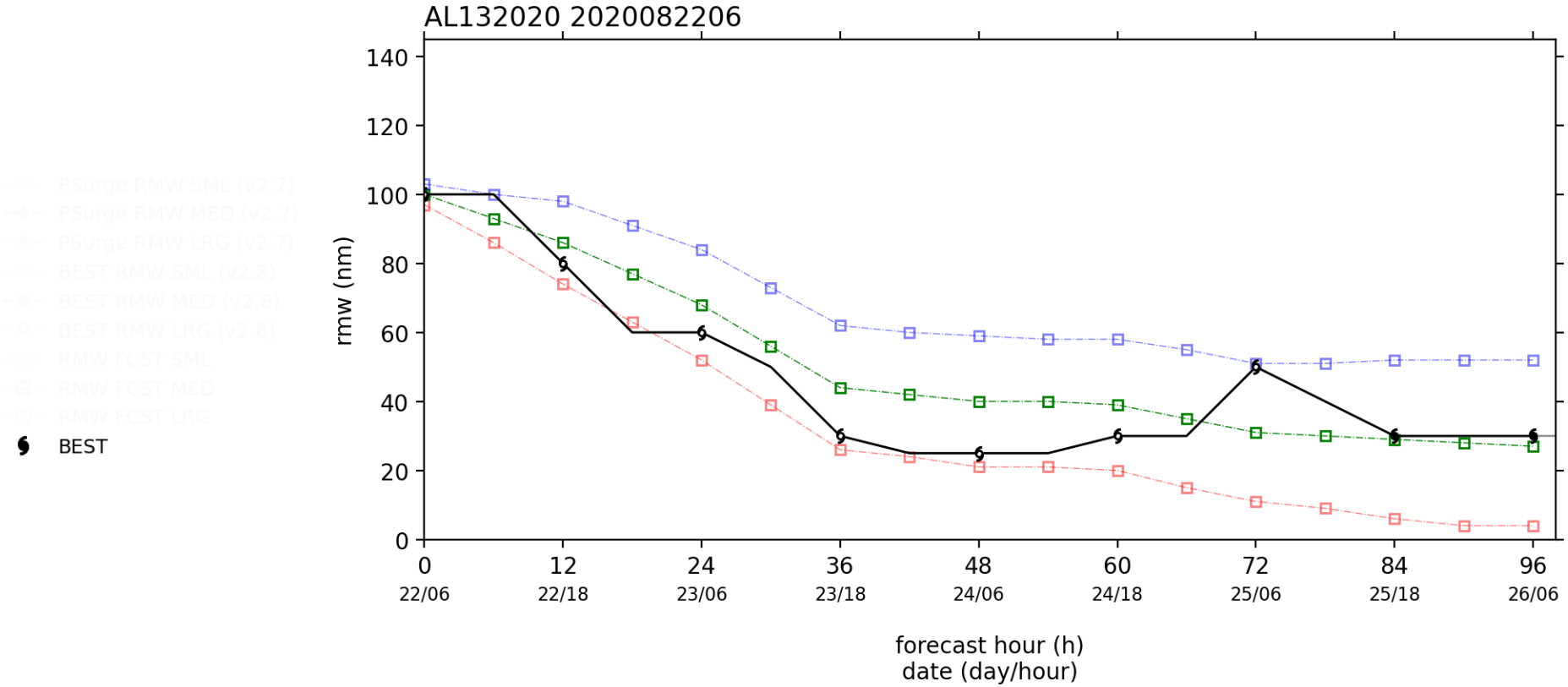


RMW bias



P-Surge RMW ensemble

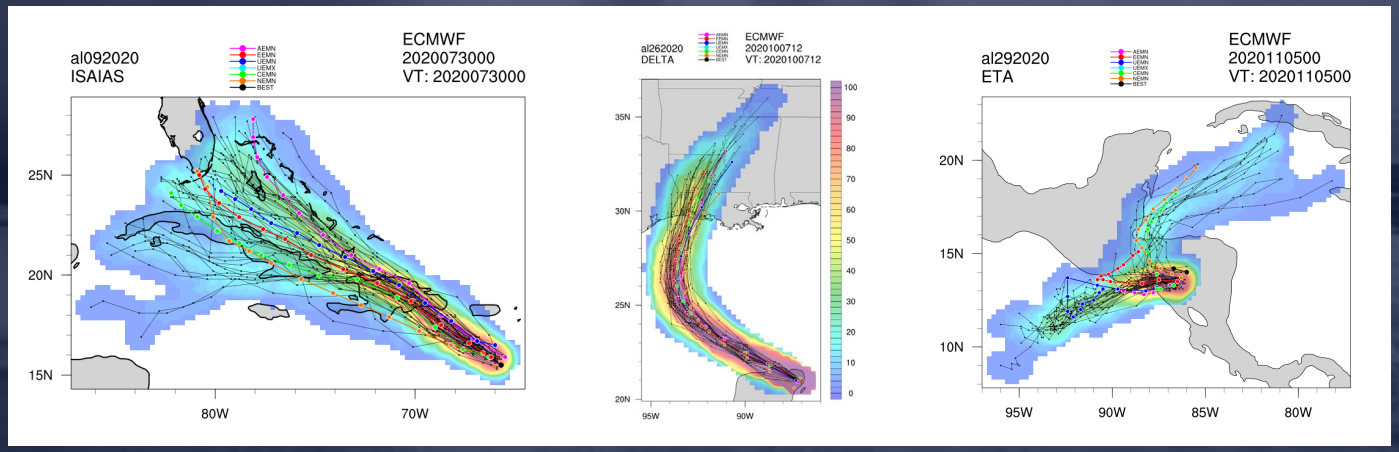
Hurricane Laura (AL132020) 2020082206



Plans for future improvements

Extend reliability of storm surge forecasts to 72 h lead time

- evaluate skill/reliability of retrospective P-Surge forecasts that use RMW regression forecasts to generate storm size ensemble
- couple SLOSH + waves and integrate into P-Surge with code optimization
- add the capability to account for storms w/ an asymmetric wind structure
- incorporate dynamic uncertainty information when generating P-Surge ensemble



- extend operational storm surge modeling to Pacific regions (Southern California, Guam, and American Samoa)

Questions?

Extra Slides

Updated error characteristics for P-Surge

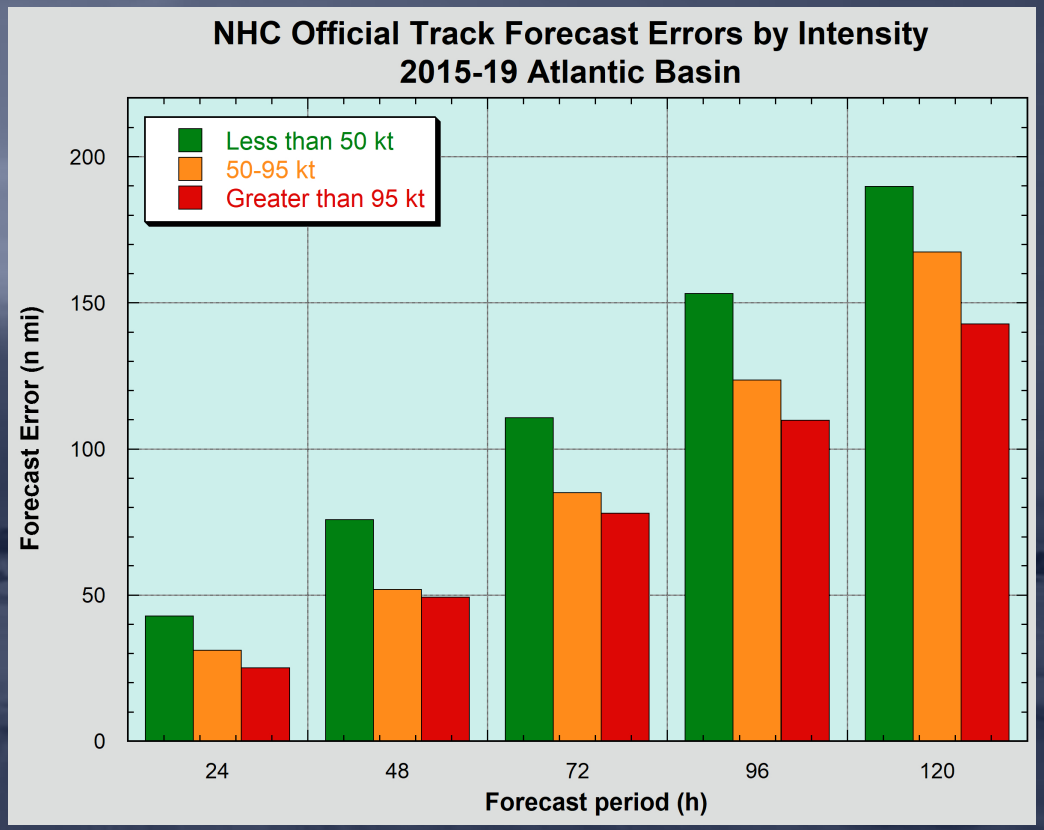
Average (5-yr) NHC OFCL track and intensity errors are used to create the P-Surge ensemble (2014-2019)

Previously, separate errors used for TDs, TSs, and HUs

- limited sample size for TDs
- error characteristics for H1 different from H5!

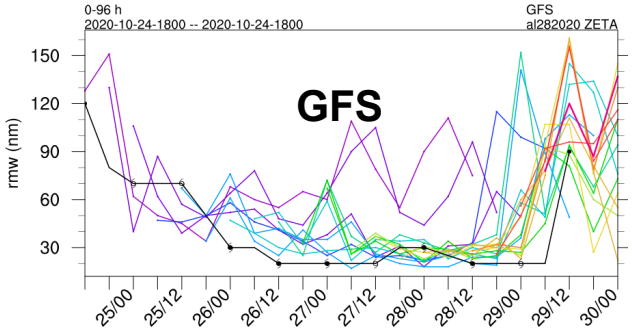
Errors now separated by initial intensity:

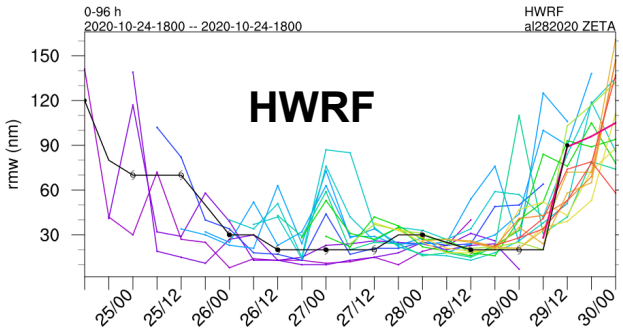
< 50 kt, 50-95 kt, > 95 kt



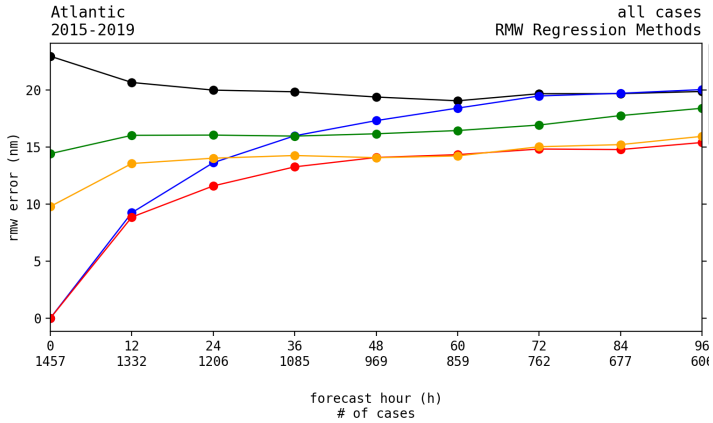
RMW Regression Forecasts

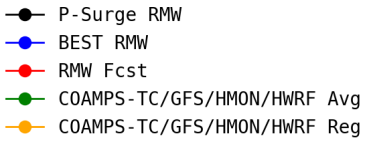
Hurricane Zeta RMW Forecasts

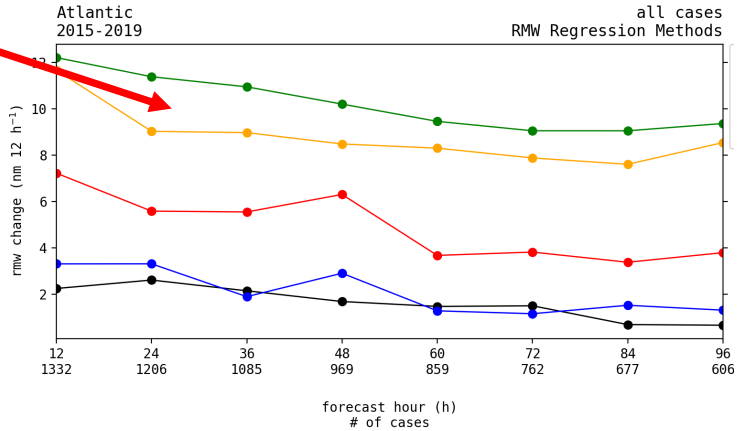




- although RMW corrected consensus forecasts based on GFS/COAMPS-TC/HMON/HWRF are skillful at longer lead times, large fluctuations in forecast RMW are not ideal for operational forecasting



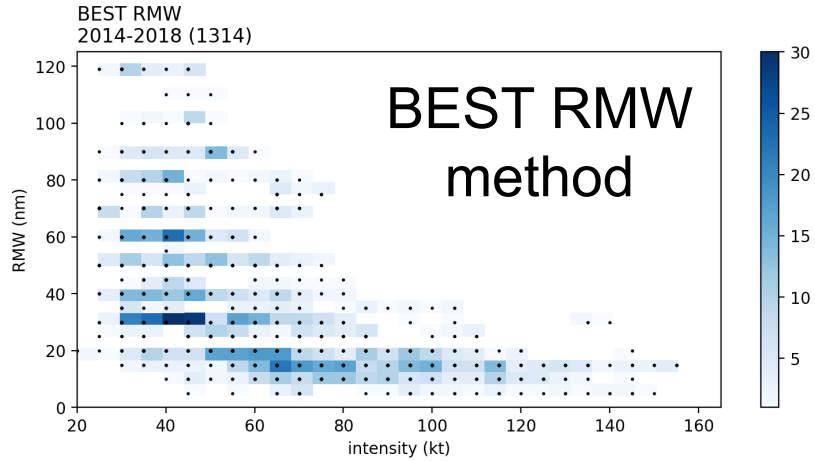


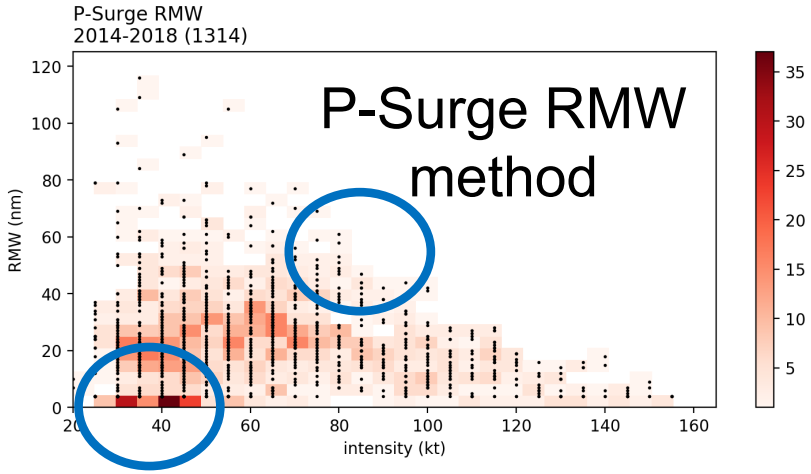


Initial RMW: P-Surge vs. BEST track

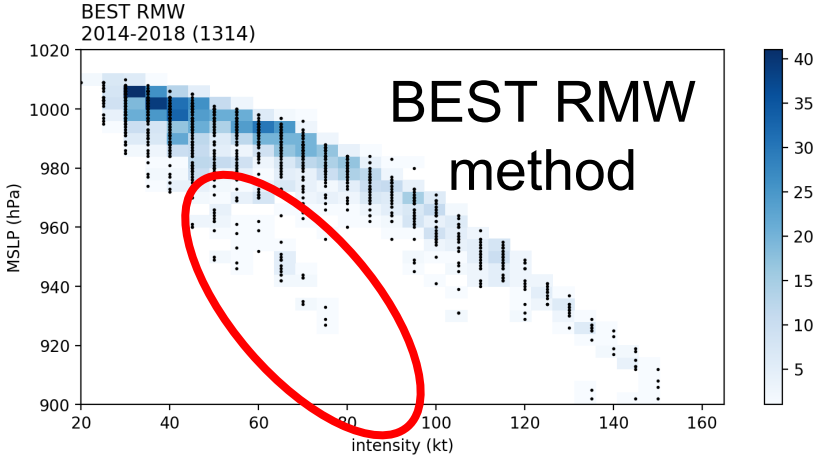
2014-2018

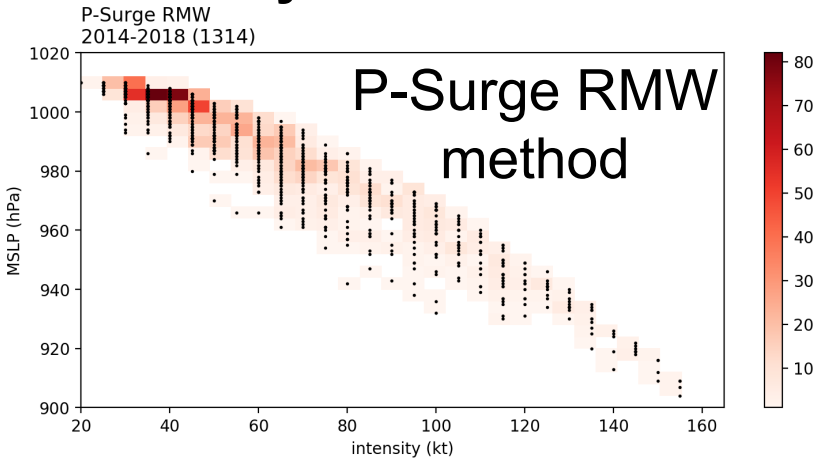
RMW vs. Intensity





Minimum Pressure vs. Intensity





Example RMW Forecasts

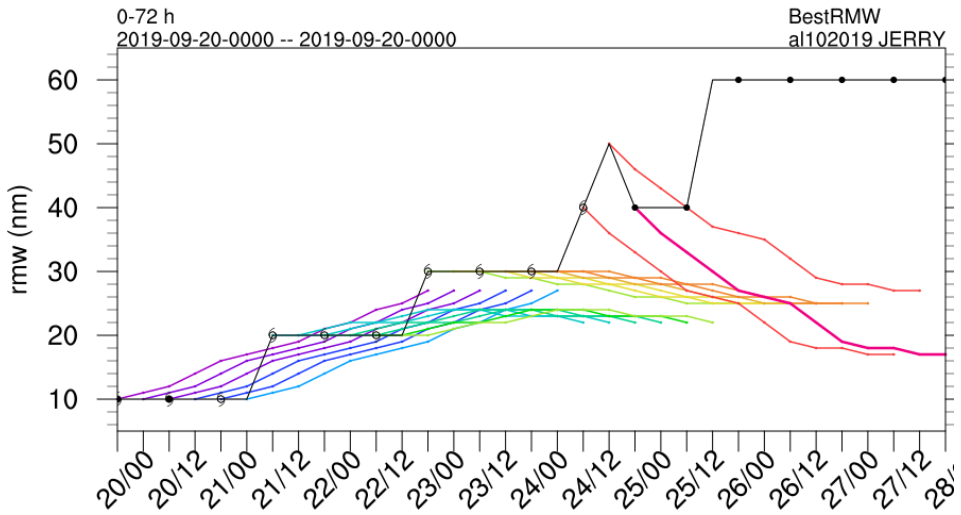
Hurricane Jerry (2019) AL102019

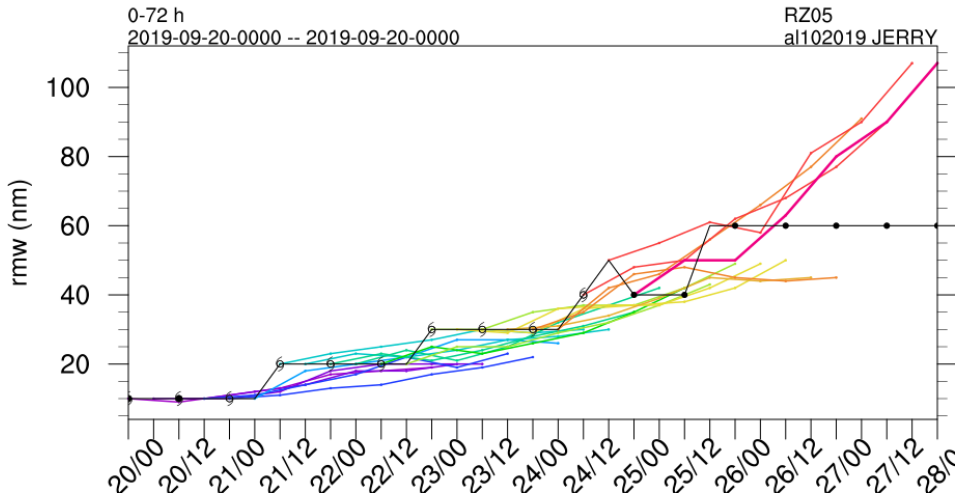
P-Surge v2.8

- RMW forecast is ONLY a function of the initial RMW

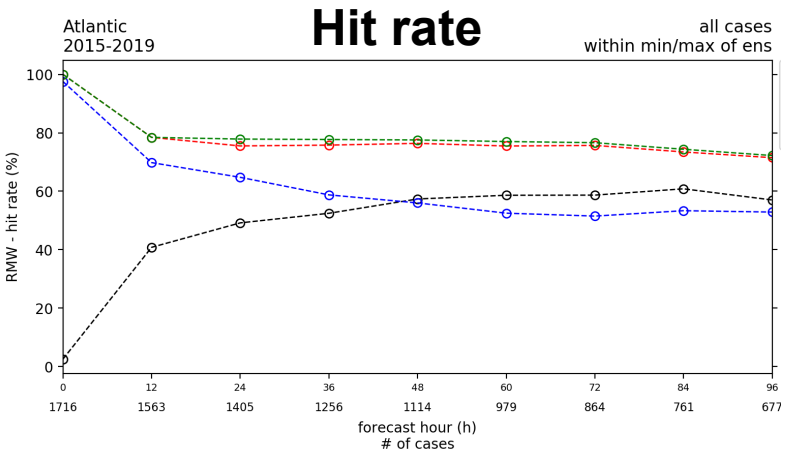
RMW Regression Forecast

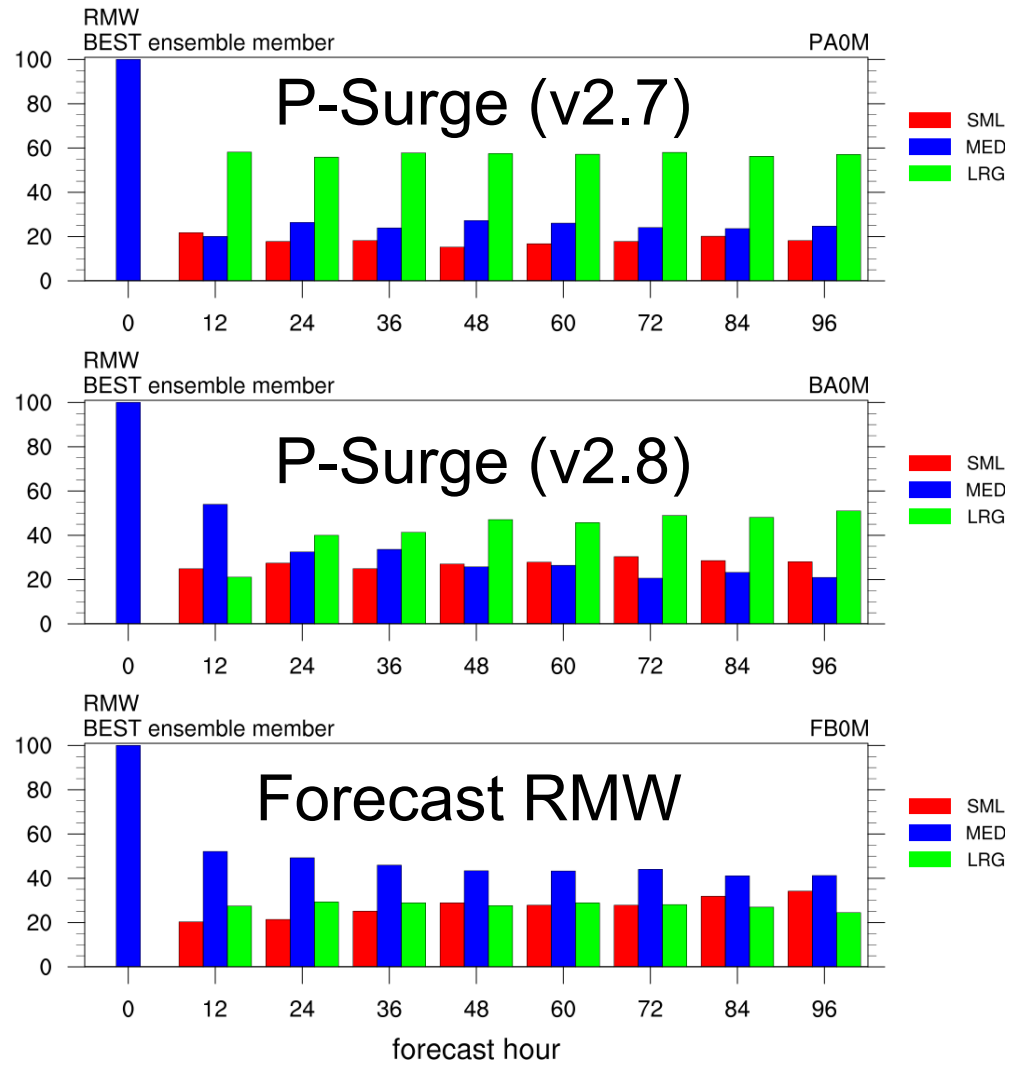
RMW_0, Intensity, latitude, R_{34}, R_{50}, R_{64}





P-Surge RMW Ensemble Verification





- using RMW regression forecasts to generate P-Surge storm size ensemble better encapsulates true RMW