Operational Storm Surge Modeling

HFIP Meeting
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NHC Storm Surge Unit

Laura Alaka
laura.alaka@noaa.gov

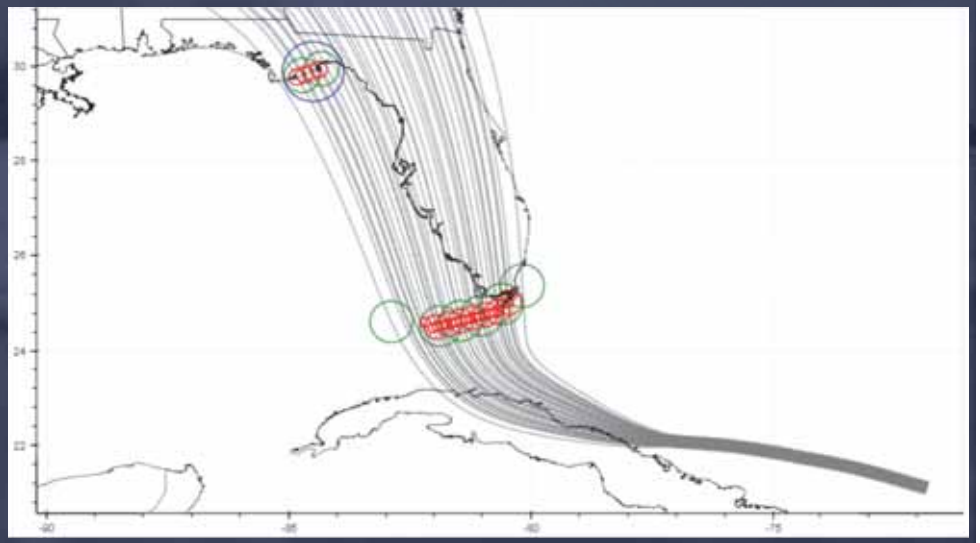
Andrew Penny
andrew.penny@noaa.gov

Introduction to Probabilistic Storm Surge

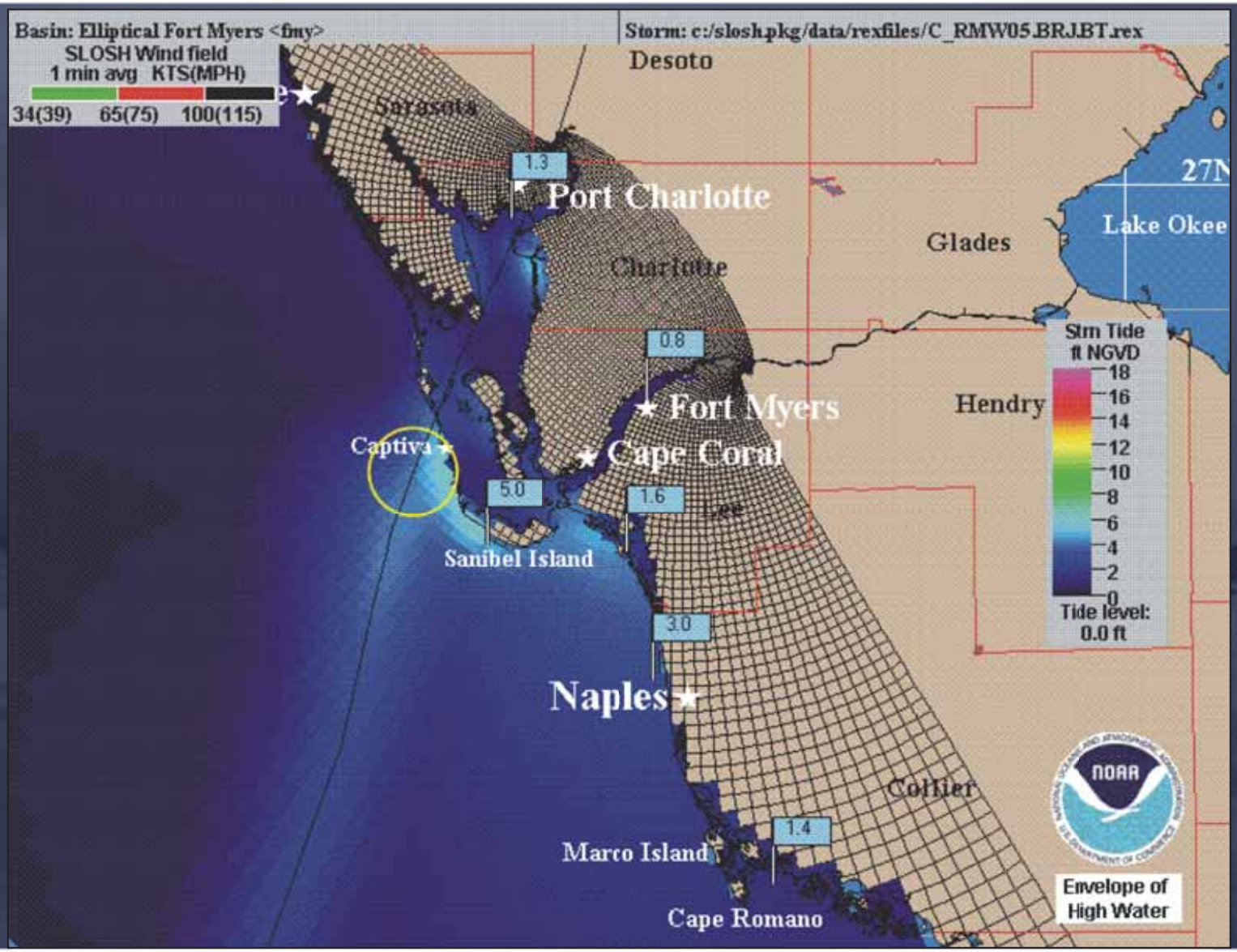
- P-Surge is based on an ensemble of Sea, Lake, and Overland Surge from Hurricane (SLOSH) model runs
  - SLOSH: numerical-dynamic tropical storm surge model
  - SLOSH requires bathymetry and is applied to a 'basin'
  - SLOSH requires meteorological driving forces: "Wind model is just as important– if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

2017090900 P-Surge Tracks



Storm Size Matters

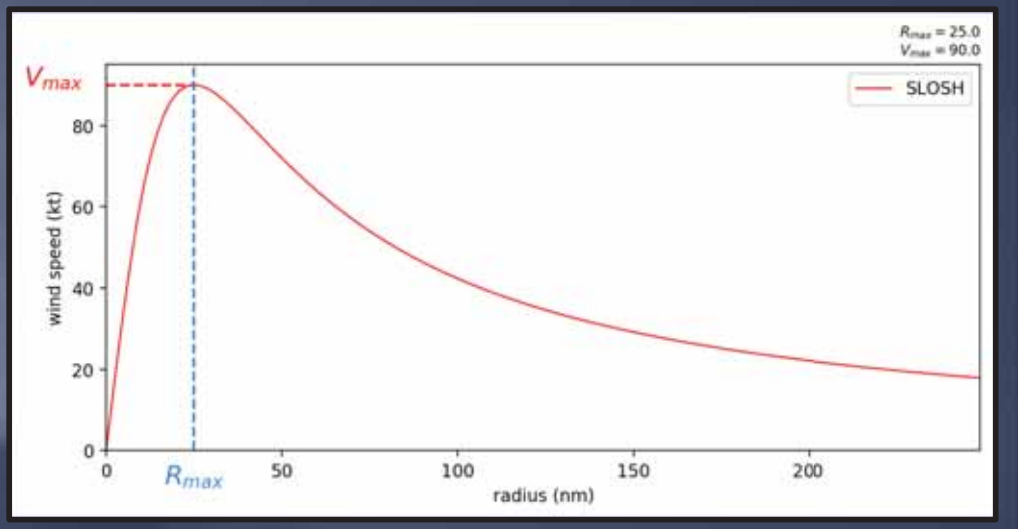


P-Surge RMW ensemble

"Spin-up" portion of track:

SLOSH parametric wind profile:

$$v(r) = \frac{2 * V_{max} * R_{max} * r}{R_{max}^2 + r^2}$$



Current method:

From Best Track: ΔP & V_{max} → Solve for → R_{max}

New proposed method:

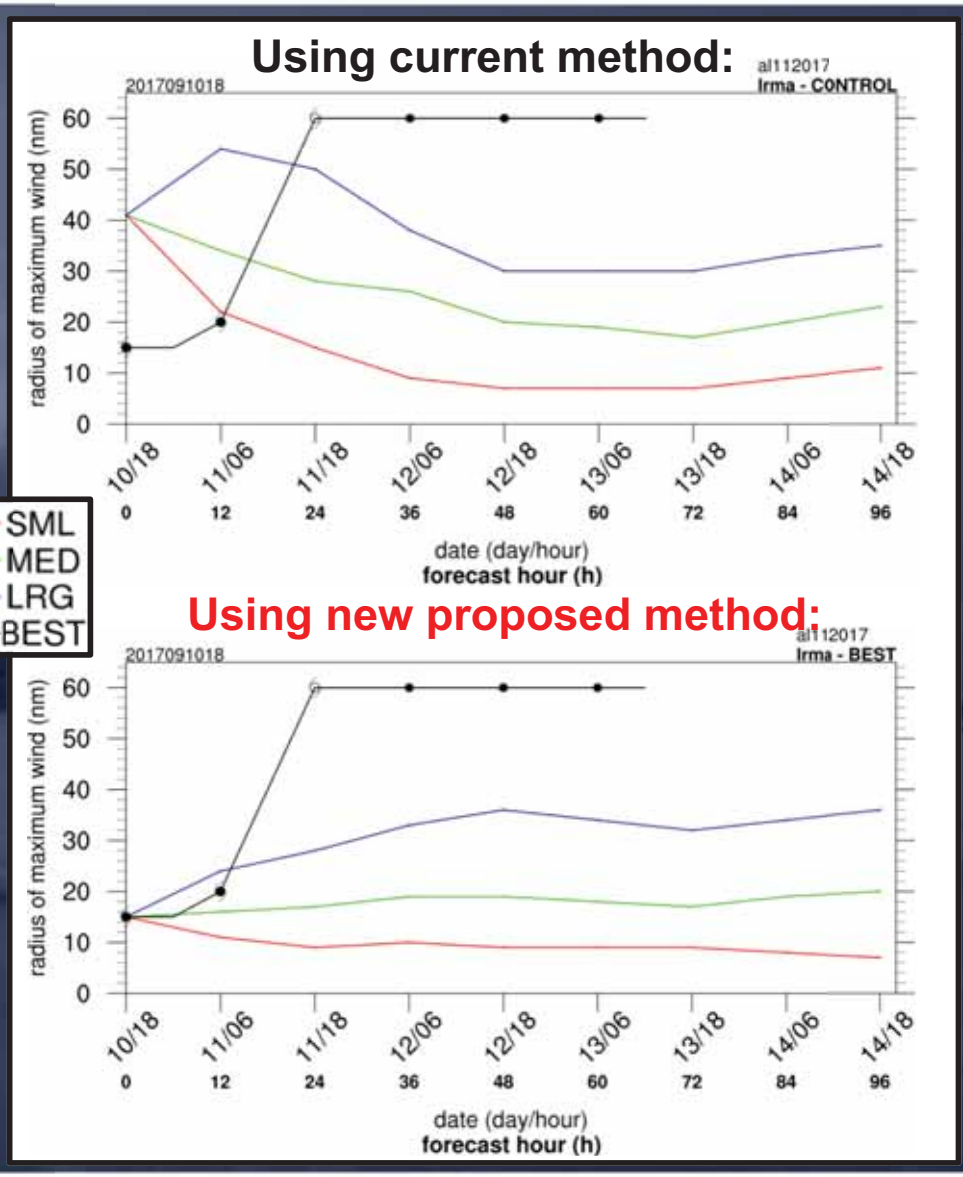
From Best Track: R_{max} & V_{max} → Solve for → ΔP

P-Surge RMW ensemble

Forecast portion of track:

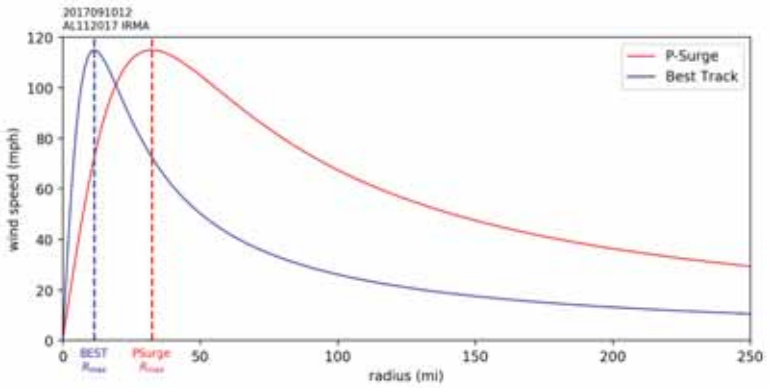
Perturb R_{max} from the last of the historical values to create a 3-member ensemble (small, medium, and large RMW)
*based on the current R_{max}

Find ΔP : using perturbed R_{max}, iterate over ΔP values until the corresponding V_{max} computed from the SLOSH parametric wind profile matches the forecast intensity.



P-Surge RMW ensemble
Example forecast: Irma 2017091012

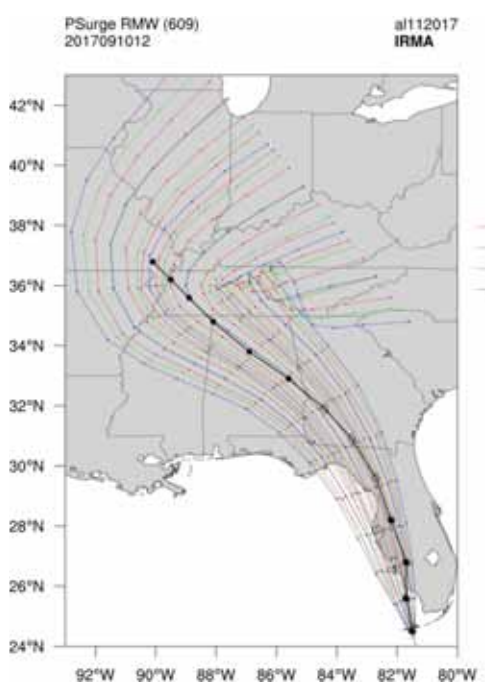
- often there's a large mismatch between the P-Surge-derived RMW and the "observed" Best-track RMW, which can change the number of required cross-track perturbations



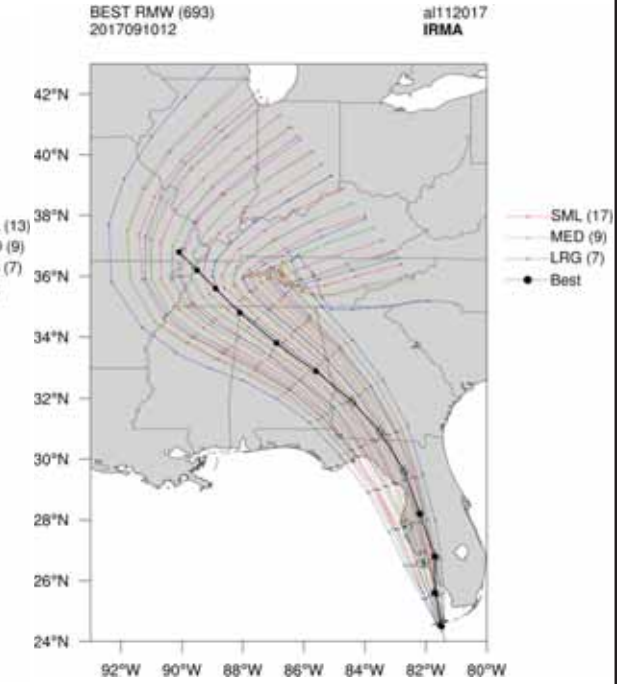
- new method uses a smaller initial RMW; more tracks are required in the cross-track direction

- 609 total P-Surge tracks vs. 693 for new proposed method

Current method:

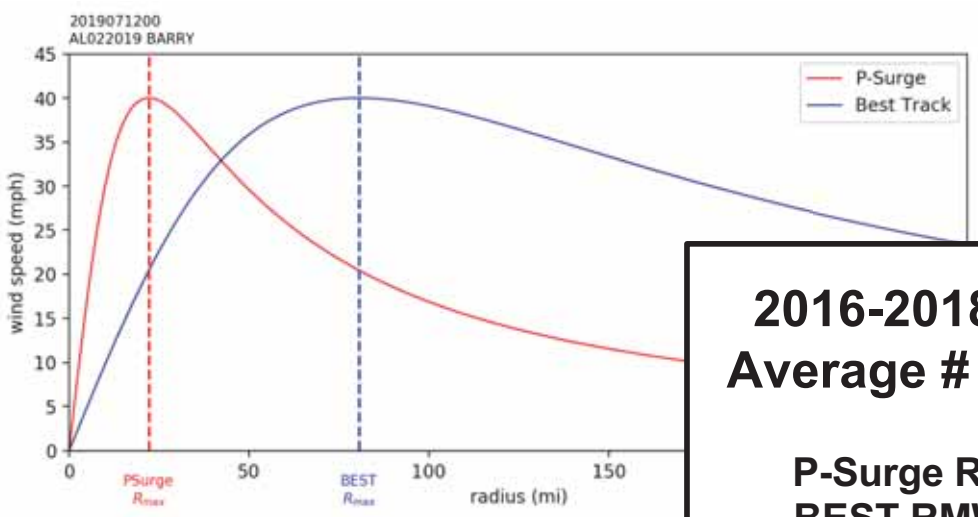


New proposed method:



P-Surge RMW ensemble

Example forecast: Barry 2019071200



2016-2018 (>= 50 kt)
Average # of Tracks

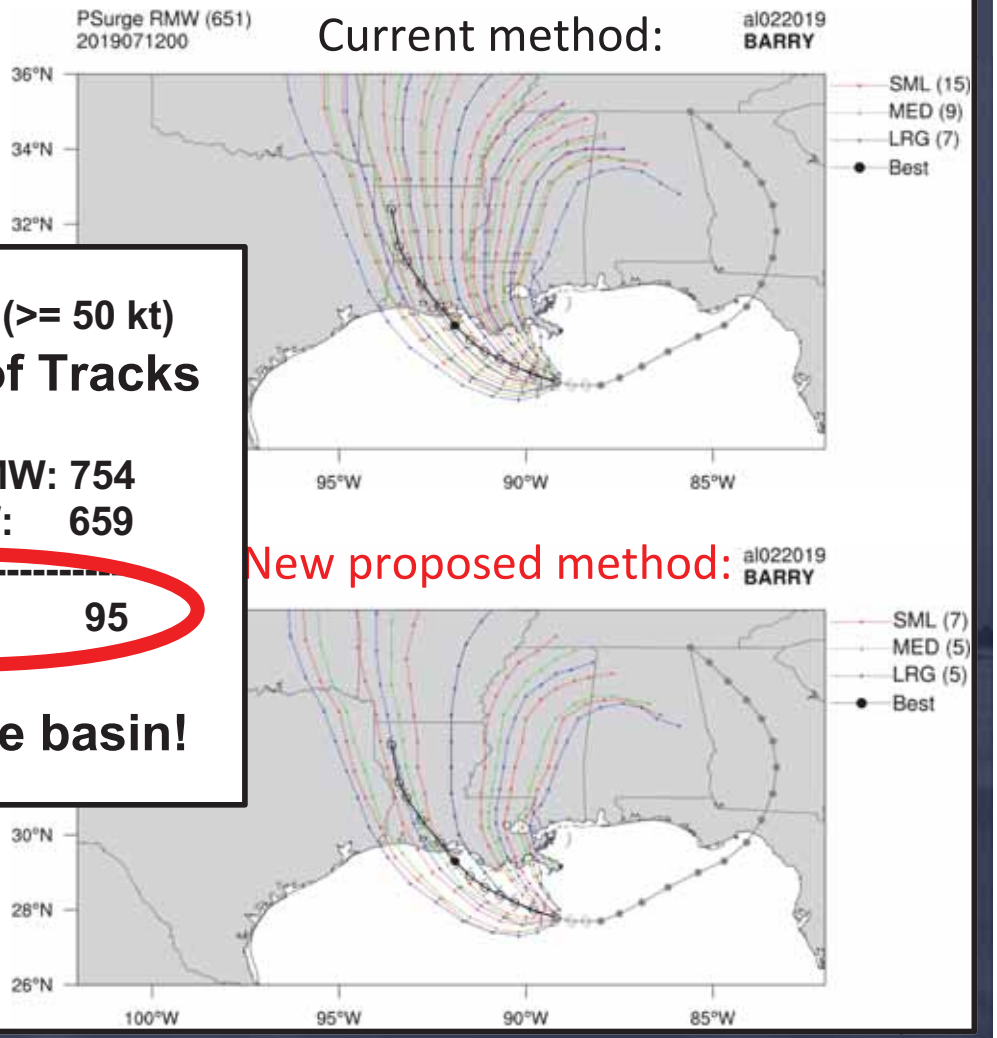
P-Surge RMW: 754
BEST RMW: 659

Difference: 95

For a single basin!

- because of the weak intensity, the l
derived RMW is much too small, res
more cross-track perturbations (31 v

- 651 total P-Surge tracks for the current method vs. 357 tracks for the new proposed method



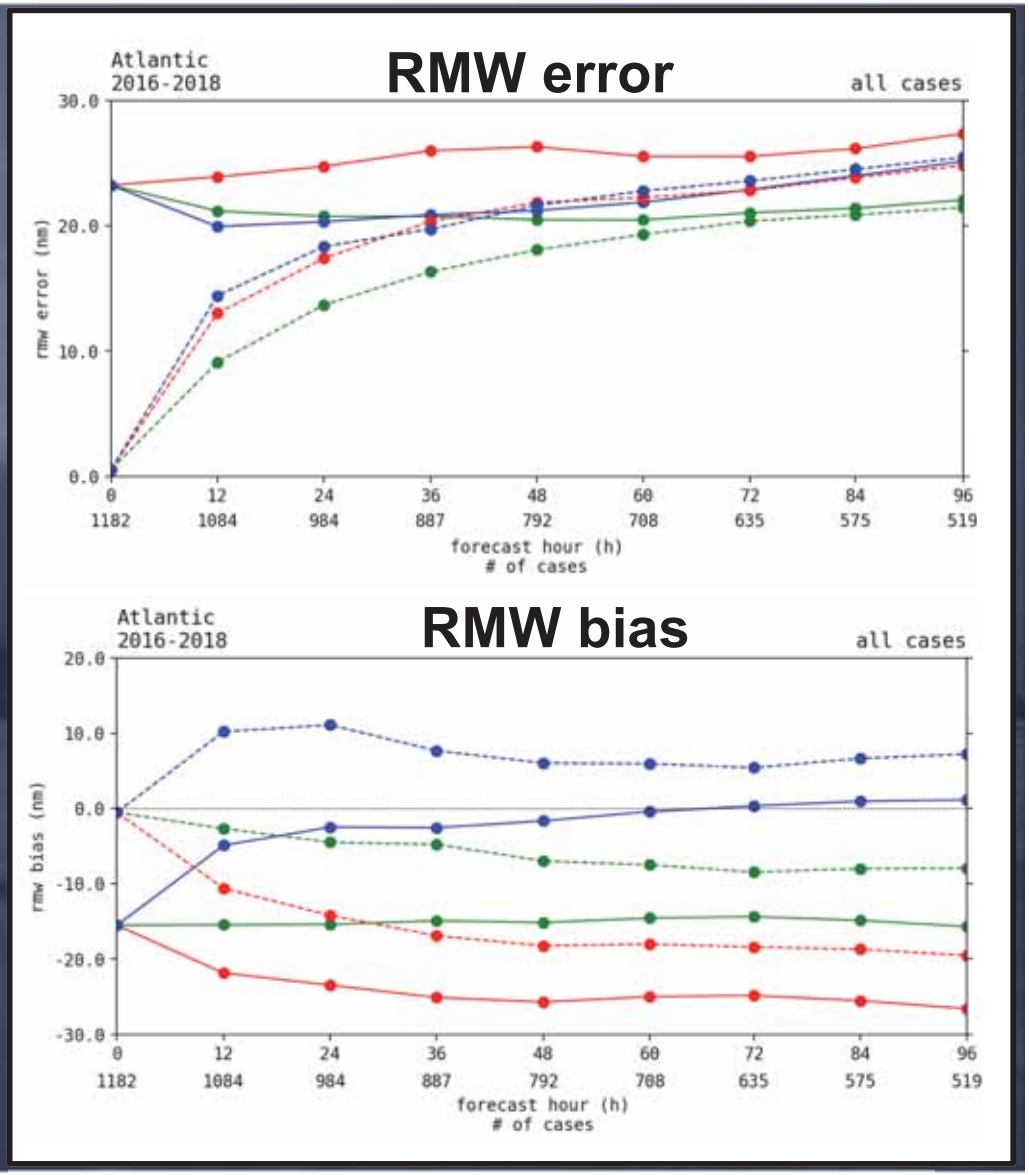
RMW Error and Bias

- P-Surge-derived RMW values (solid lines) have increased error from 0 – 36 h compared to when using the BEST track for the initial RMW (dashed lines), especially for ”small RMW” cases

Current Method

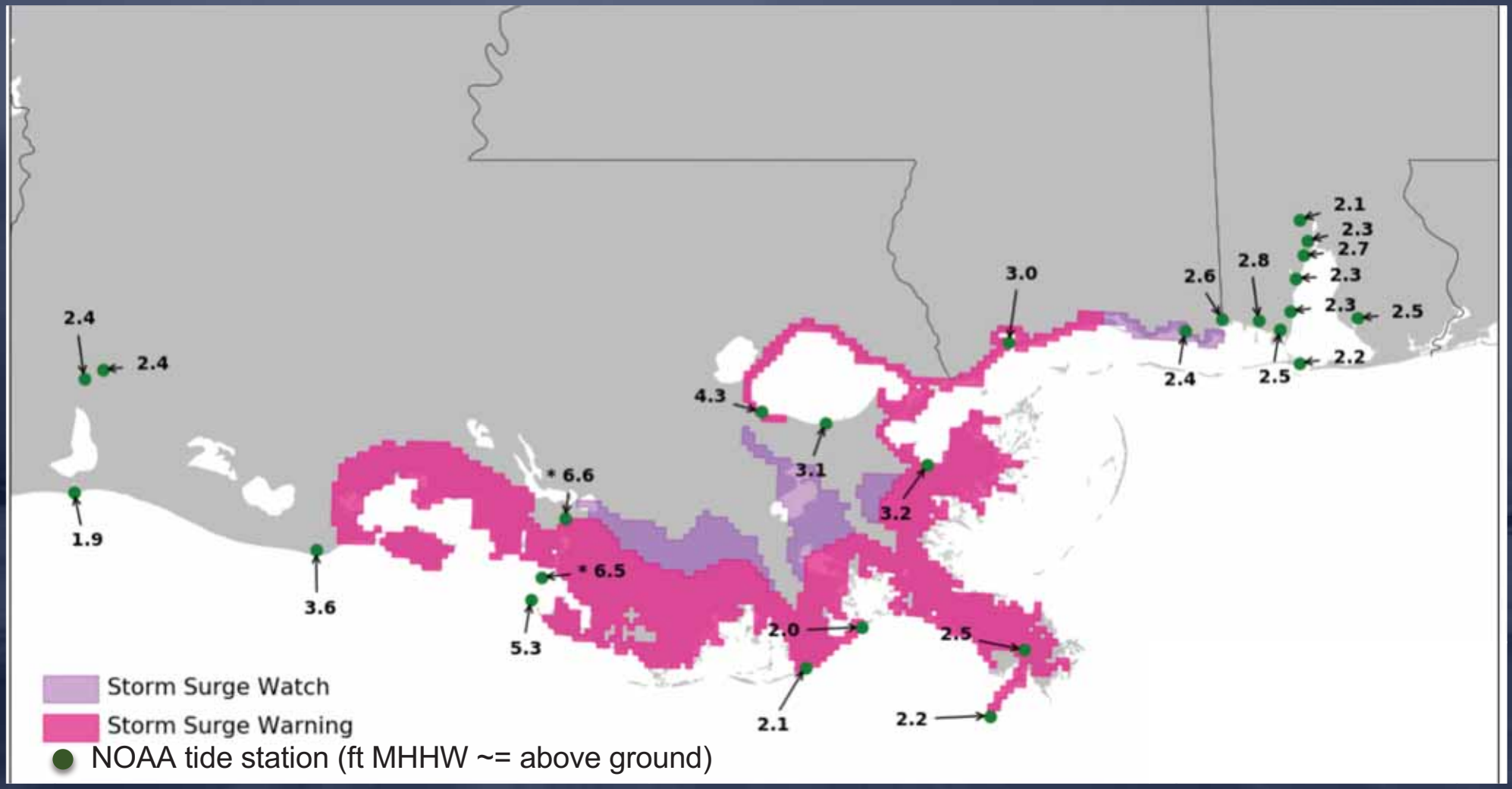
Proposed Method

sml RMW PSRG
med RMW PSRG
lrg RMW PSRG
sml RMW BEST
med RMW BEST
lrg RMW BEST



- P-Surge-derived RMW values are, on average, smaller than the BEST track values throughout the forecast, and have a larger negative bias

Barry


2.4
2.4
1.9
3.6
* 6.6
* 6.5
5.3
4.3
3.1
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2.0
2.1
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2.4
2.8
2.5
2.1
2.3
2.7
2.3
2.3
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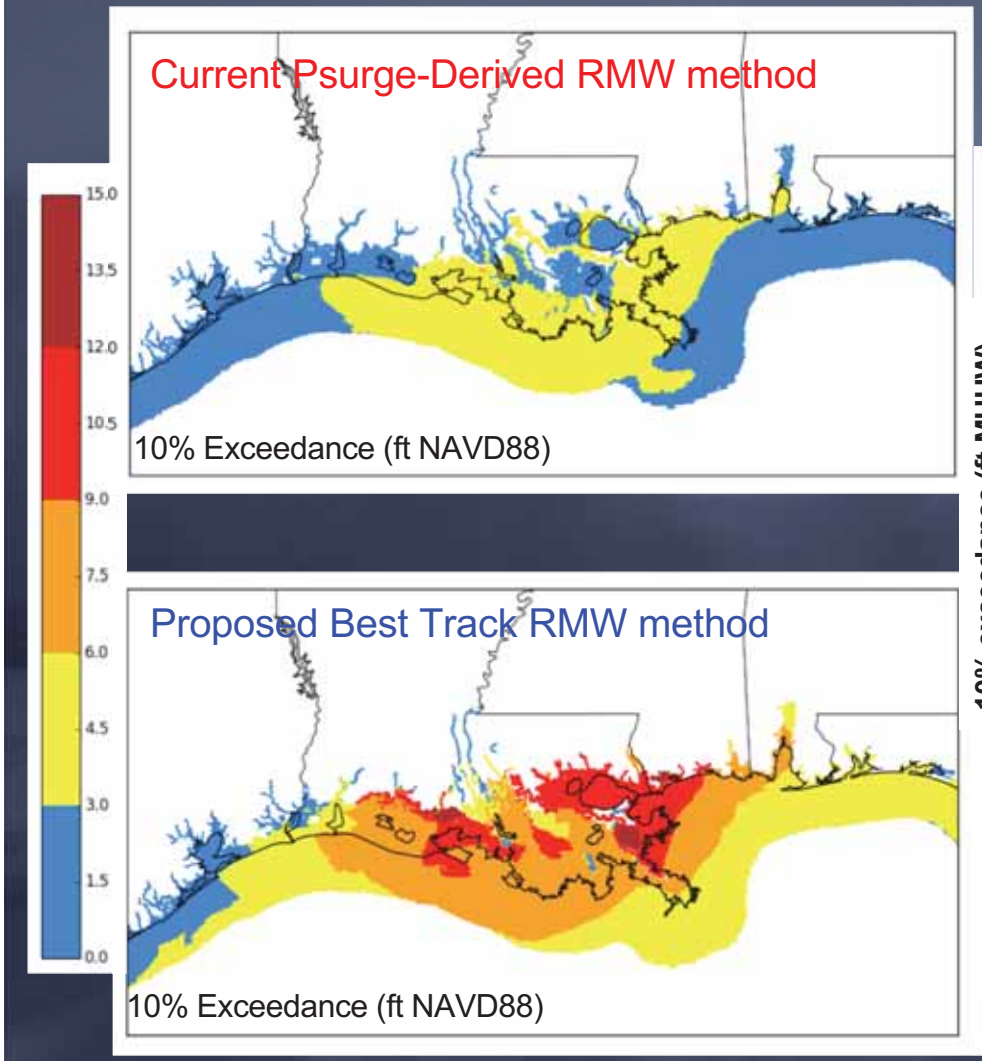
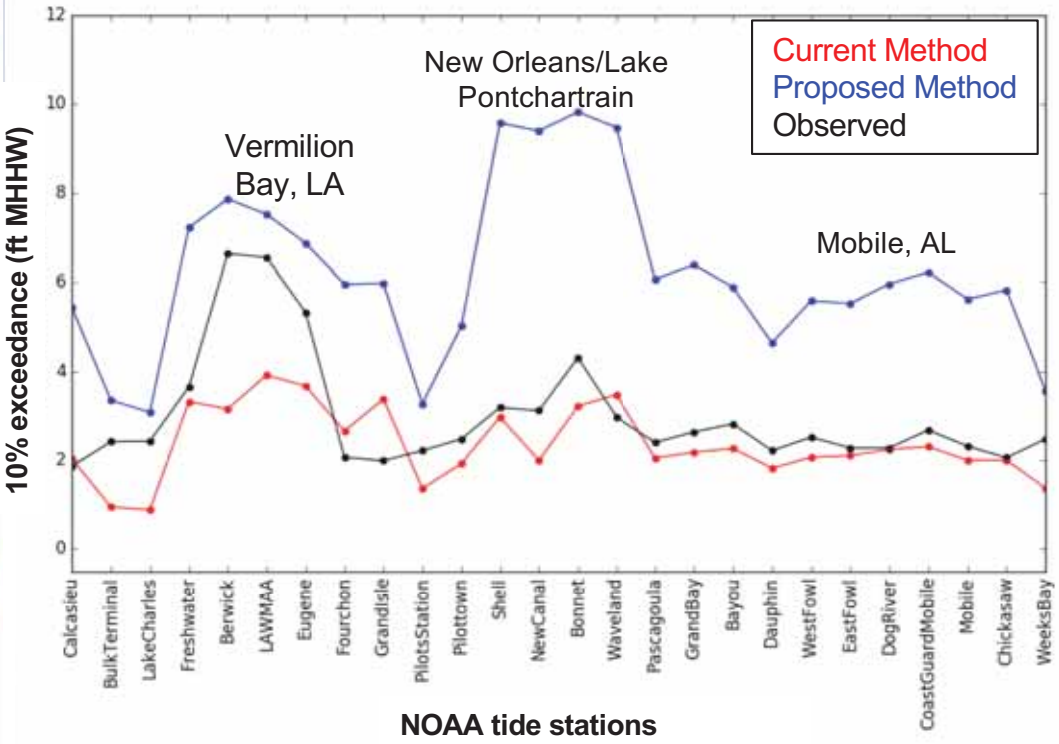
2.2
Storm Surge Watch
Storm Surge Warning
NOAA tide station (ft MHHW ~= above ground)

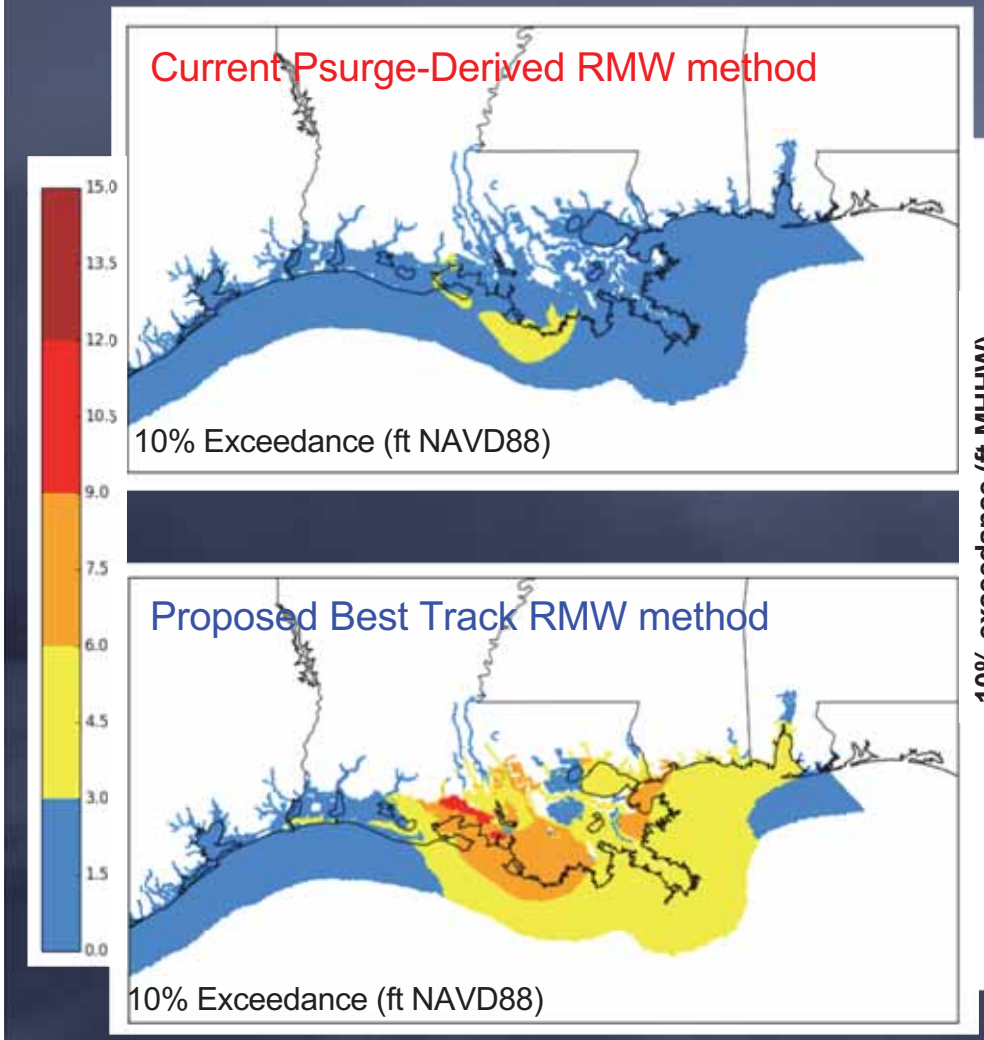
Barry 20190071106 (~54 hours prior to landfall)



Proposed Method better encapsulates the storm surge risk



Barry 20190071312 (~landfall)



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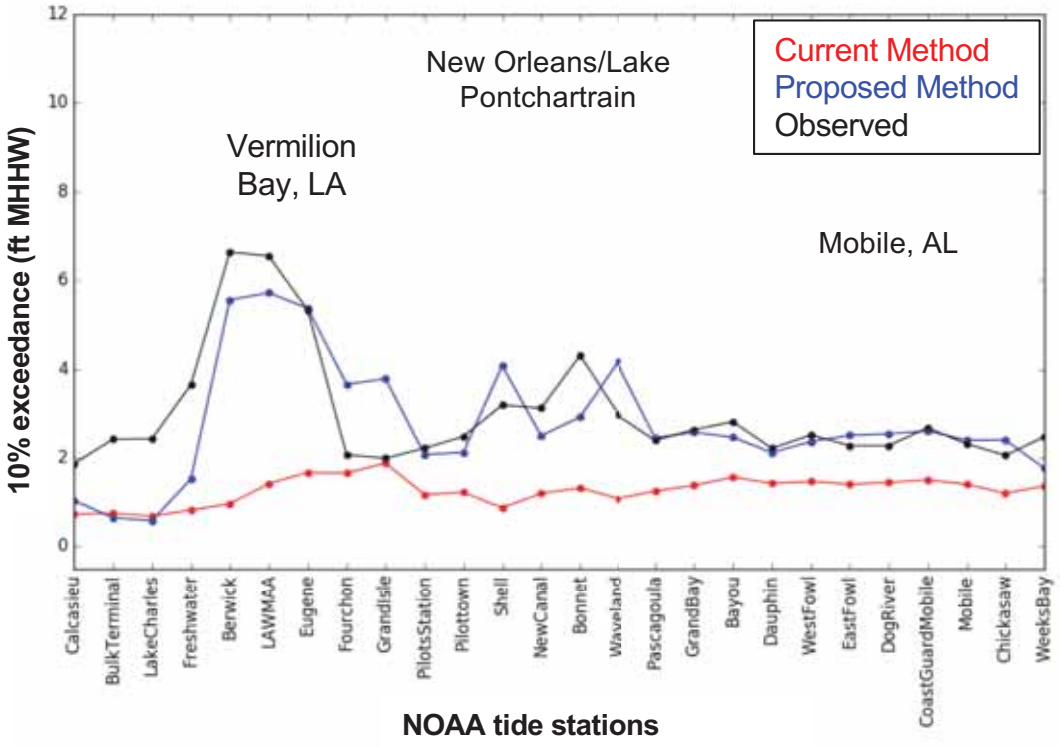
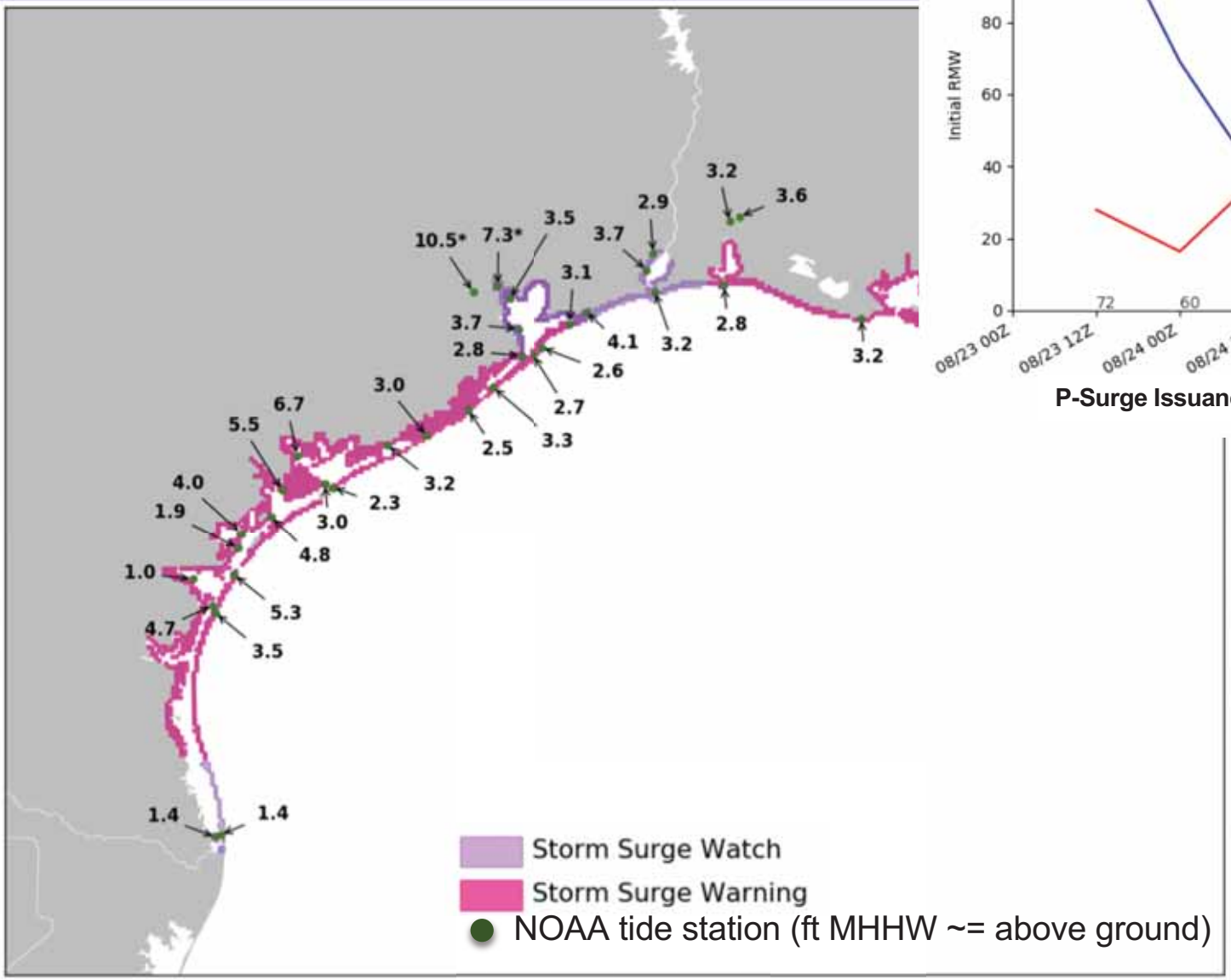
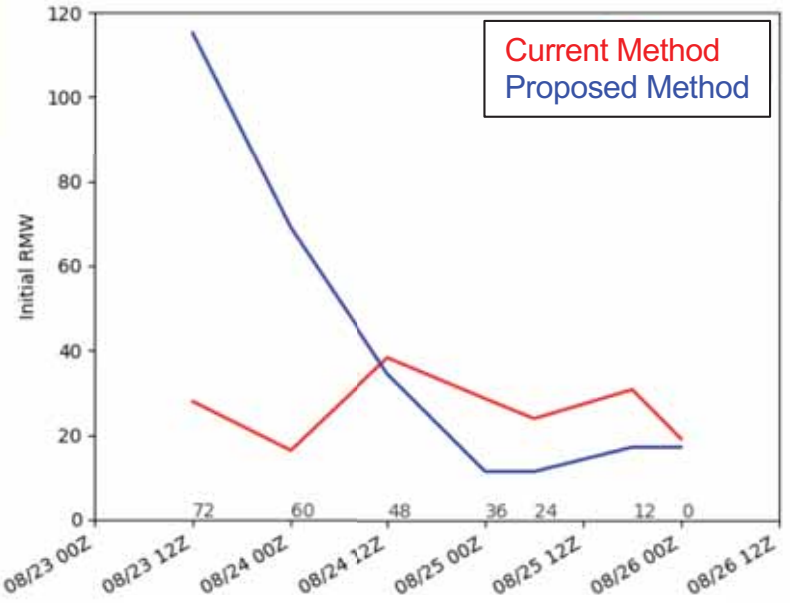


Harvey Results



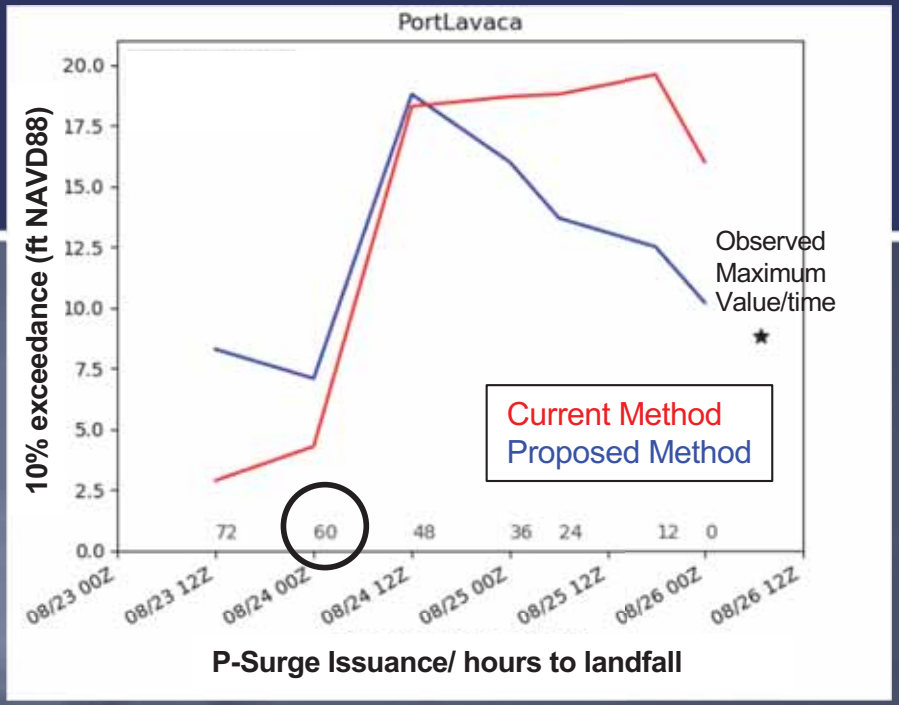


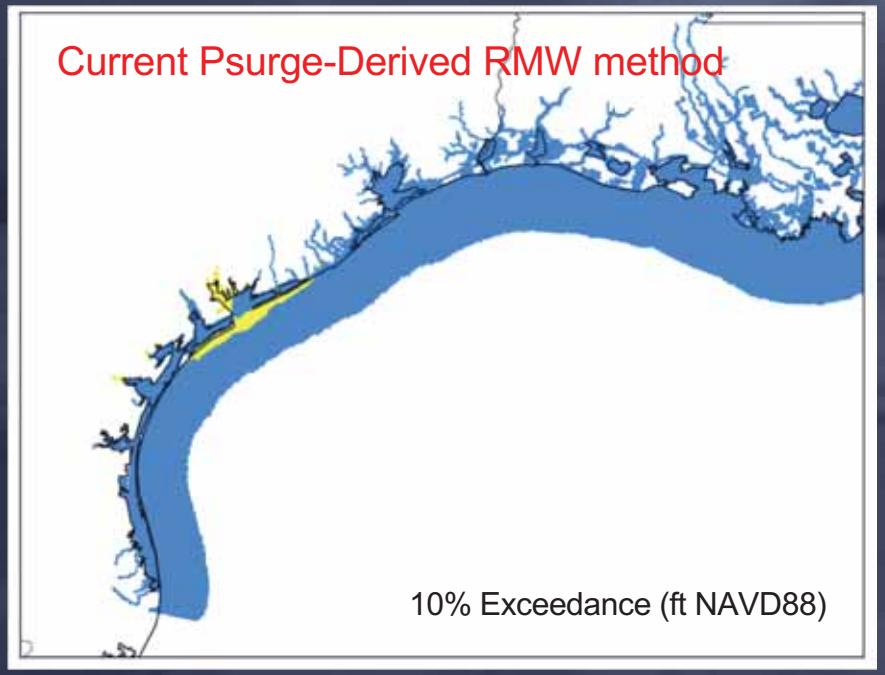
P-Surge Issuance/ hours to landfall

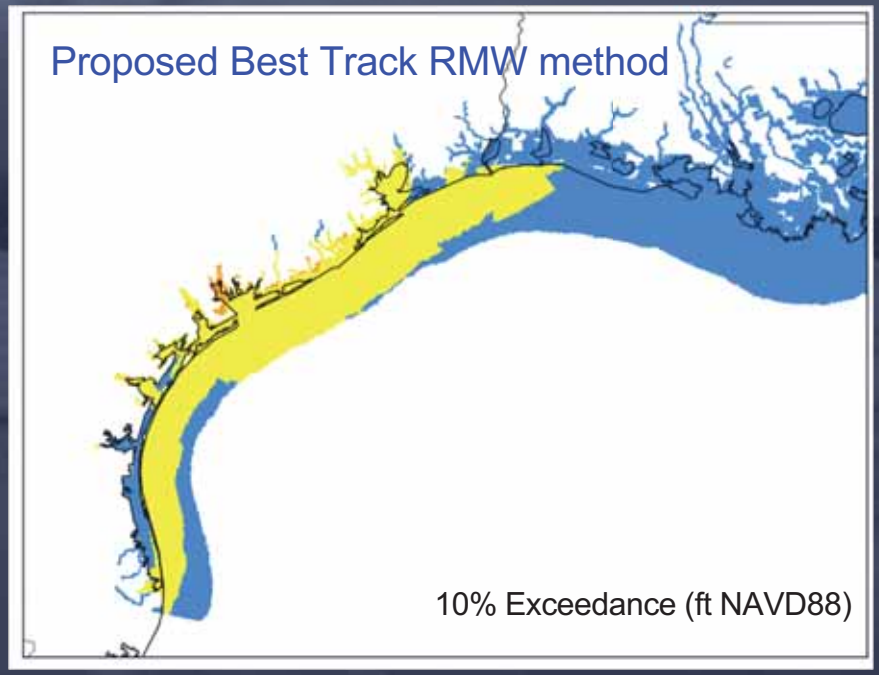
Current P-Surge derived RMW Method has large initial RMW errors

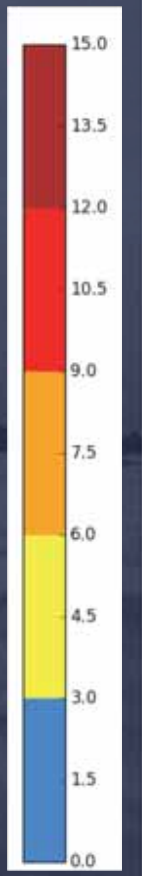
Harvey Results

Proposed method better represents the storm surge risk at 60/72-hr lead times because it initializes with a much larger RMW that is consistent with observations



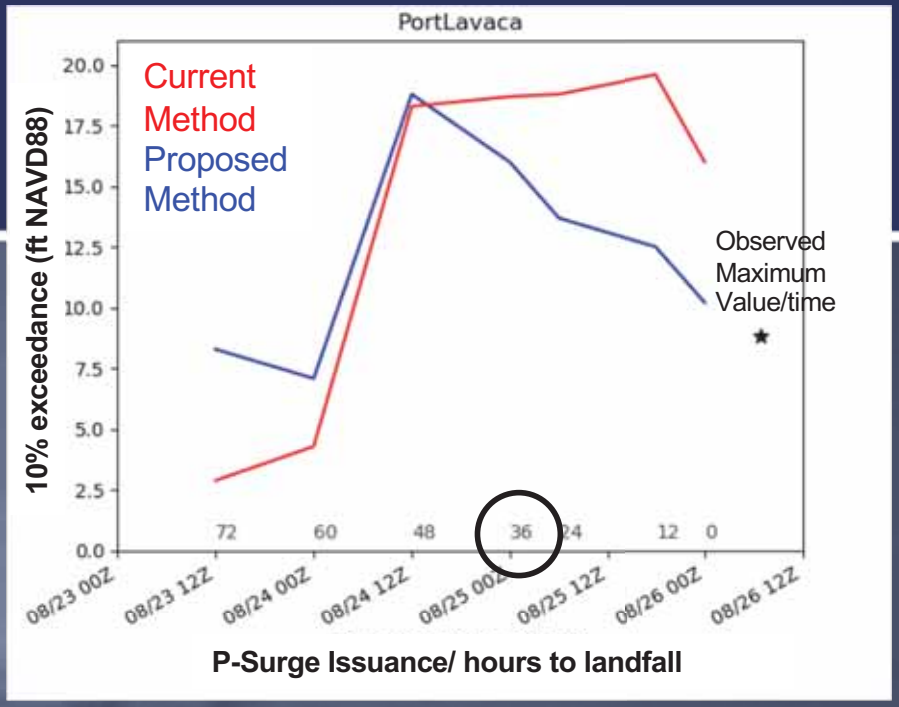


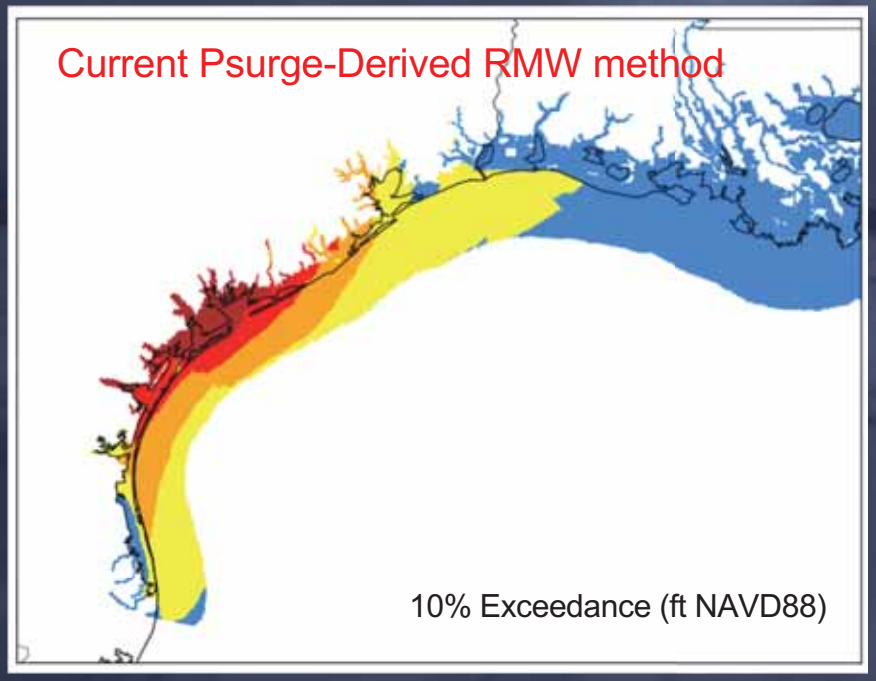


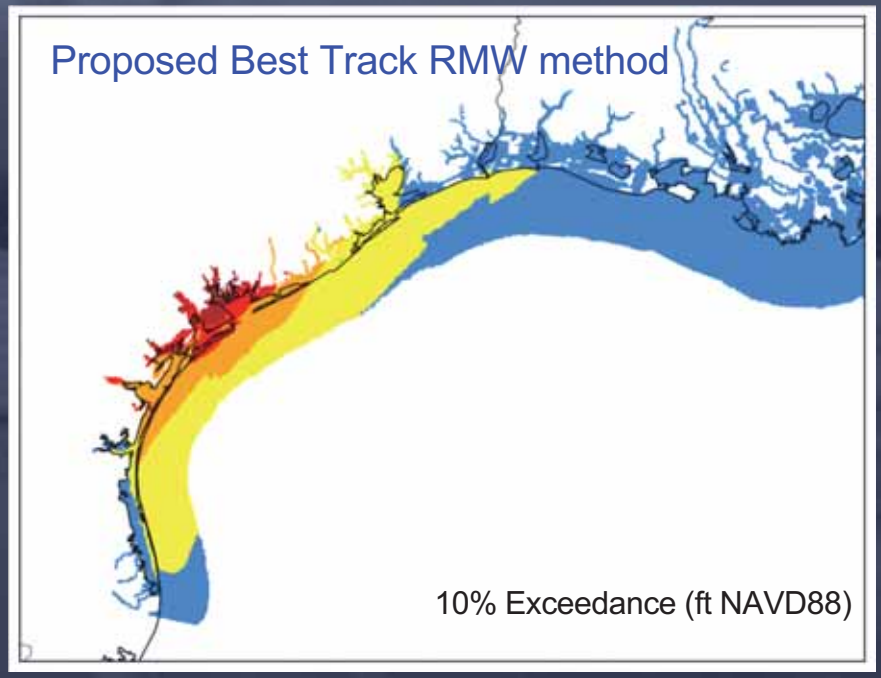


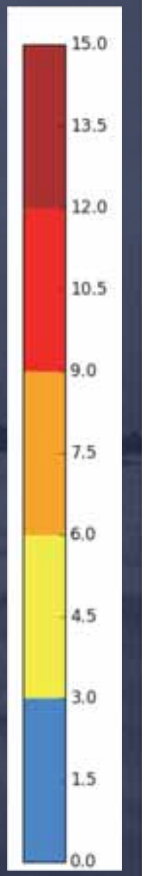
Harvey Results

Current method overstates the storm surge risk close to landfall because the RMW is too large







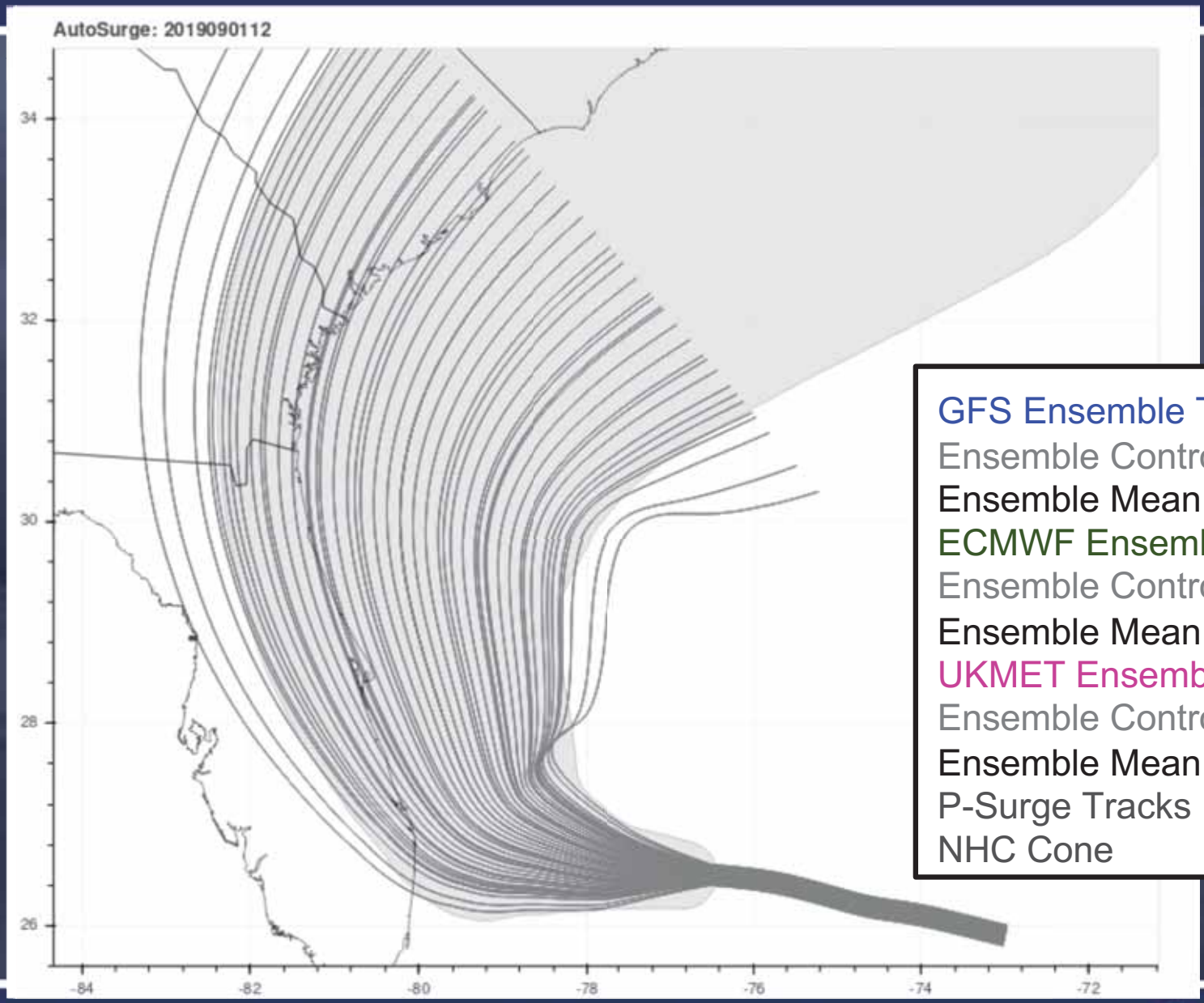


Future Work

- Continue to evaluate the effect of using Best track initial RMW
- Attempt to forecast RMW and create more realistic RMW perturbations based on climatology
- Instead of solely relying on historical errors to generate the P-Surge ensemble, also incorporate flow-dependent uncertainty
- Update P-Surge interpolation to create more realistic track shapes and landfall intensities
- Improve the outer wind field (beyond the RMW) in SLOSH by using parametric wind profiles that can be constrained by wind radii observations

Dorian Ensemble: Adv 33

SS watch issued

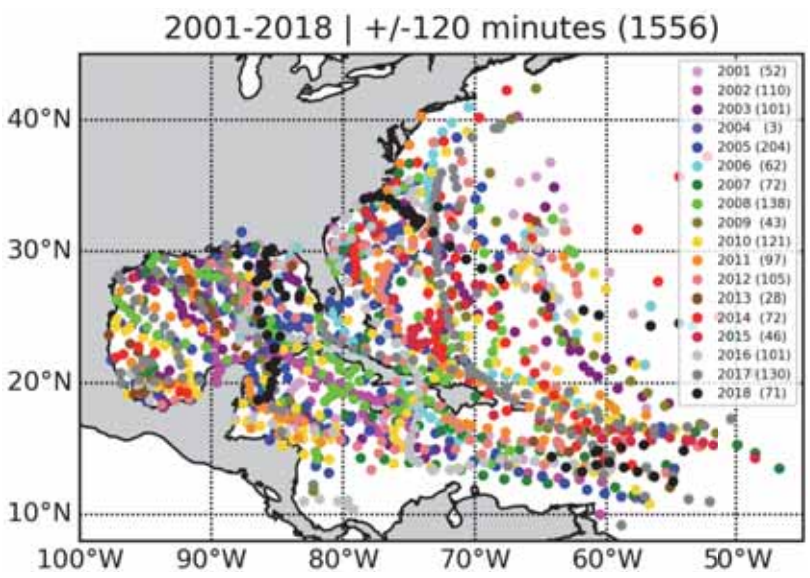


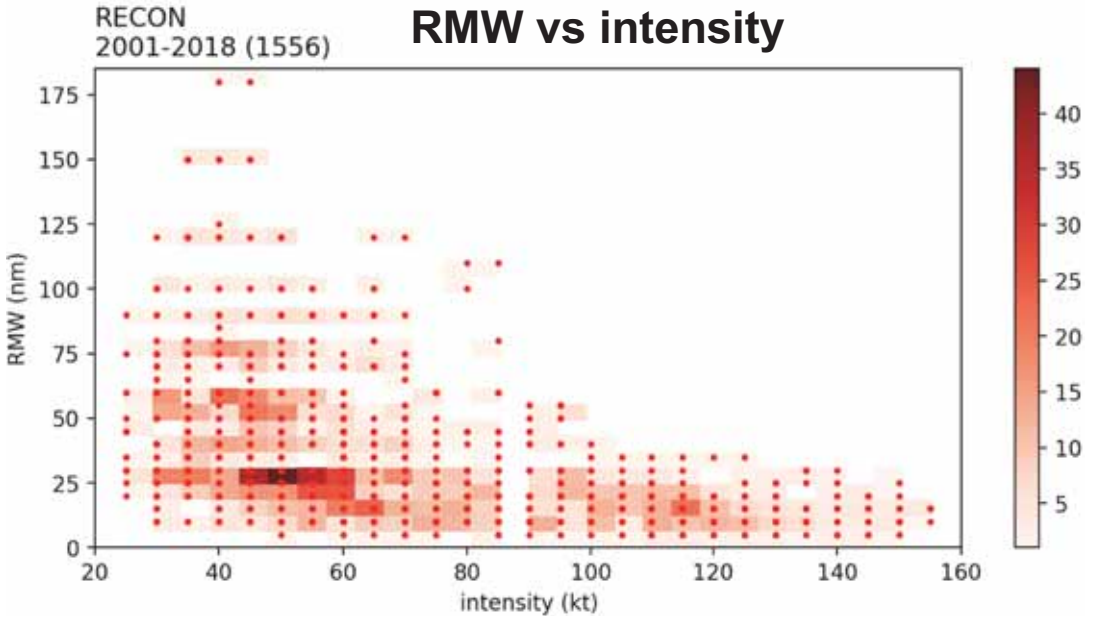
GFS Ensemble Tracks
Ensemble Control
Ensemble Mean
ECMWF Ensemble Tracks
Ensemble Control
Ensemble Mean
UKMET Ensemble Tracks
Ensemble Control
Ensemble Mean
P-Surge Tracks
NHC Cone

Extra Slides

RMW Climatology

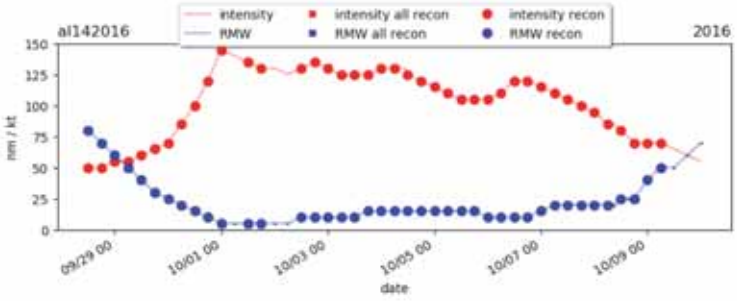
BEST track times within +/- 120 minutes of aircraft reconnaissance from 2001-2018



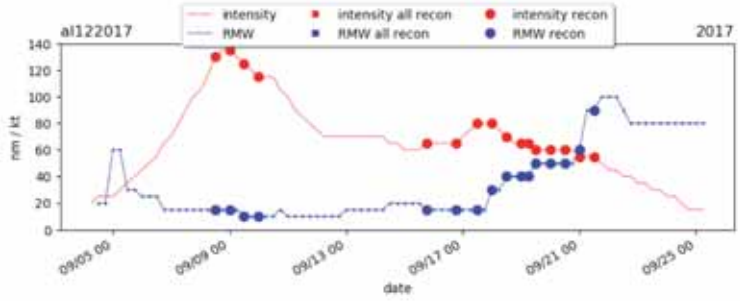


- large amount of variability in the relationship between intensity and RMW from case to case

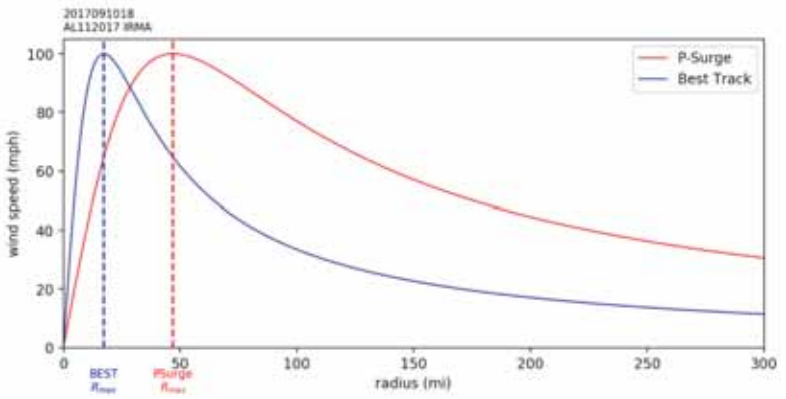
Hurricane Matthew (2016)



Hurricane Jose (2017)



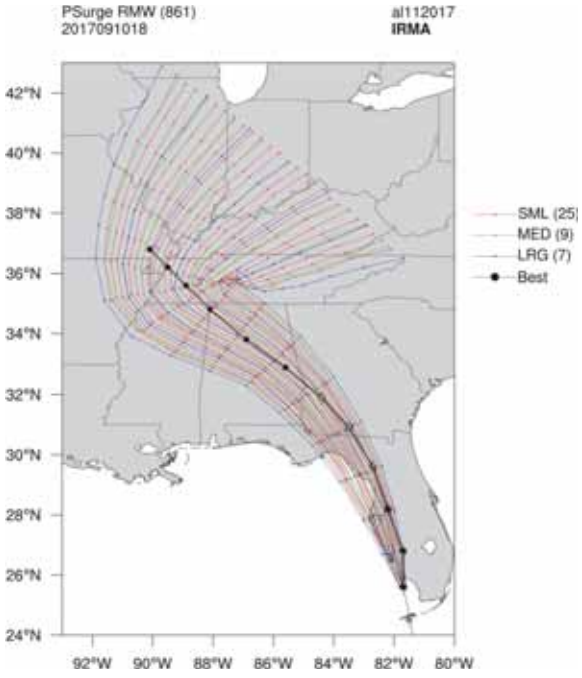
P-Surge RMW ensemble
Example forecast: Irma 2017091018



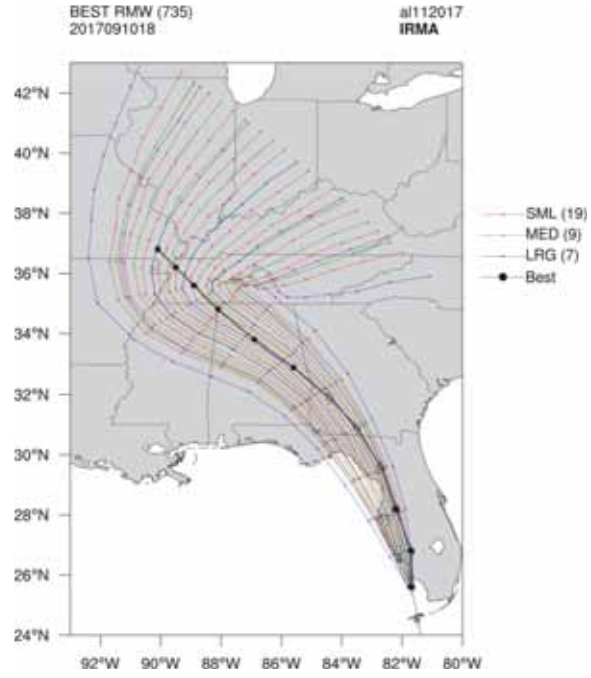
- new method uses a smaller initial RMW, but more tracks in the cross-track direction are required for the current method since the 48-h "forecast" RMW is smaller

- 861 total P-Surge tracks vs. 735 for new proposed method

Current method:



New proposed method:



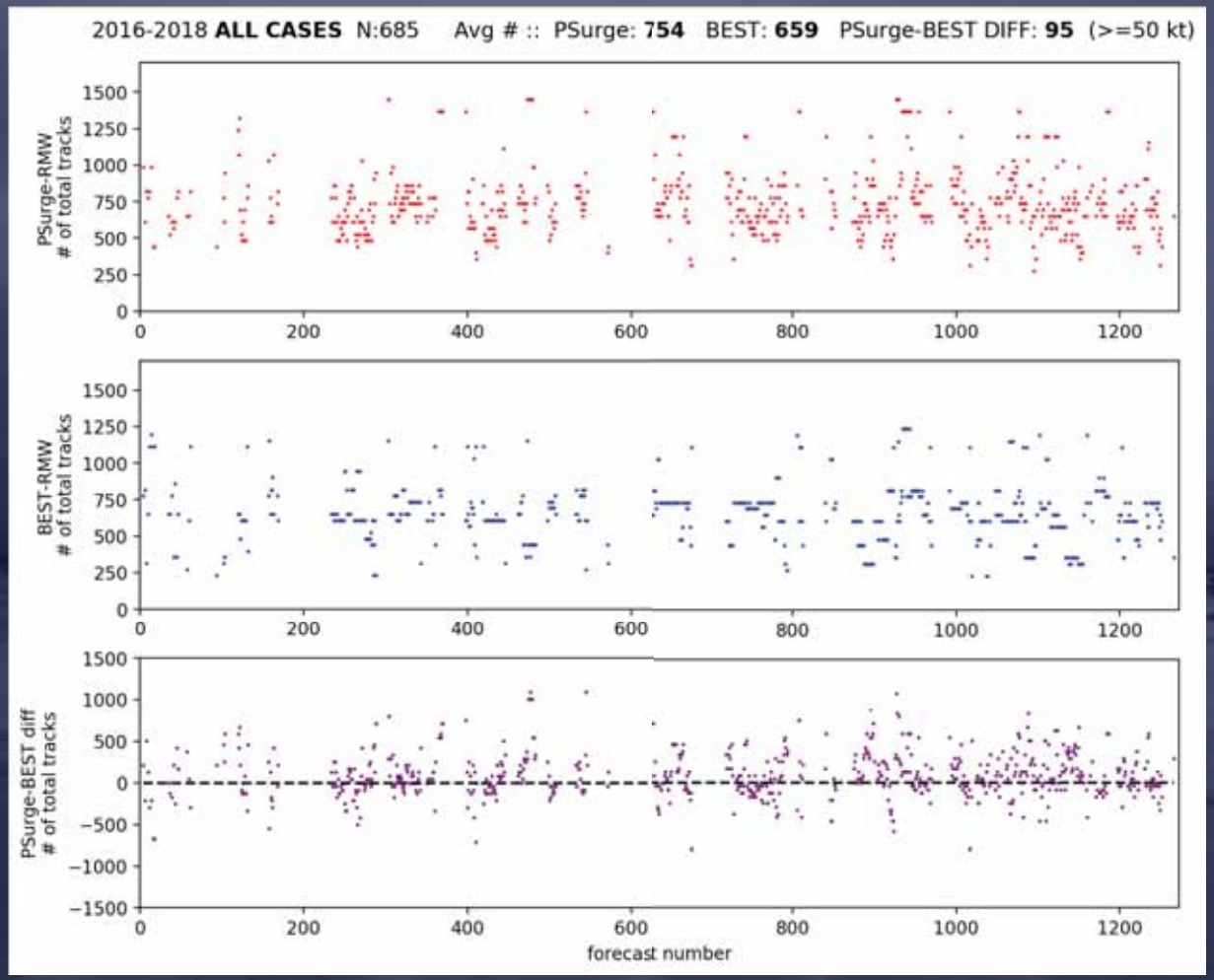
How RMW affects # cross-track perturbations

P-Surge derived RMW

BEST RMW

difference (P-Surge – BEST)

2016-2018 Number of P-Surge tracks (>=50 kt)



Average # of Tracks

P-Surge RMW: 754
BEST RMW: 659

Difference: 95

For a single basin!

- Using the larger BEST track RMW values causes the cross-track perturbations to be spaced farther apart, reducing the required number of cross-track perturbations

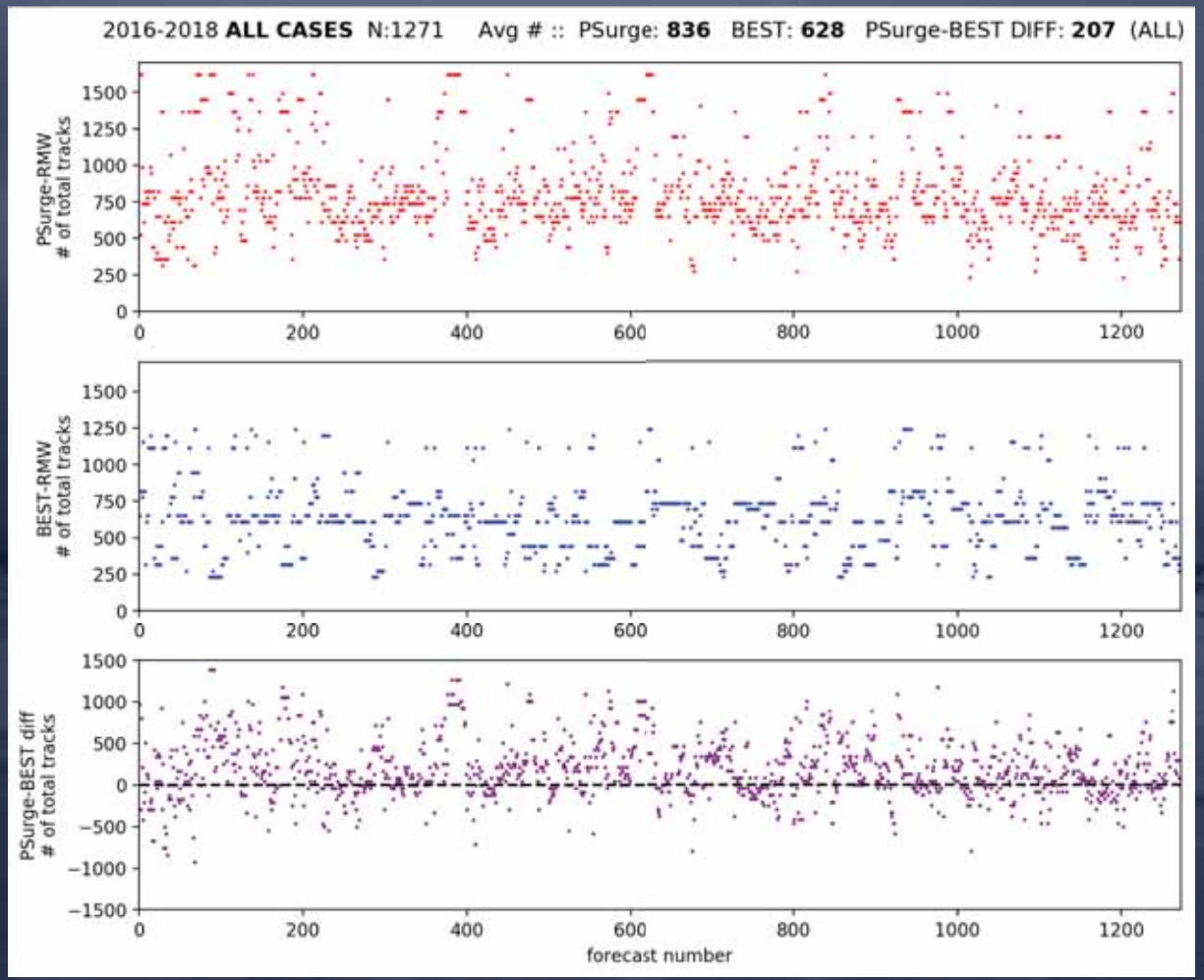
How RMW affects # cross-track perturbations

P-Surge derived RMW

BEST RMW

difference (P-Surge – BEST)

2016-2018 Number of P-Surge tracks



Average # of Tracks

P-Surge RMW: 836
BEST RMW: 628

Difference: 207

For a single basin!

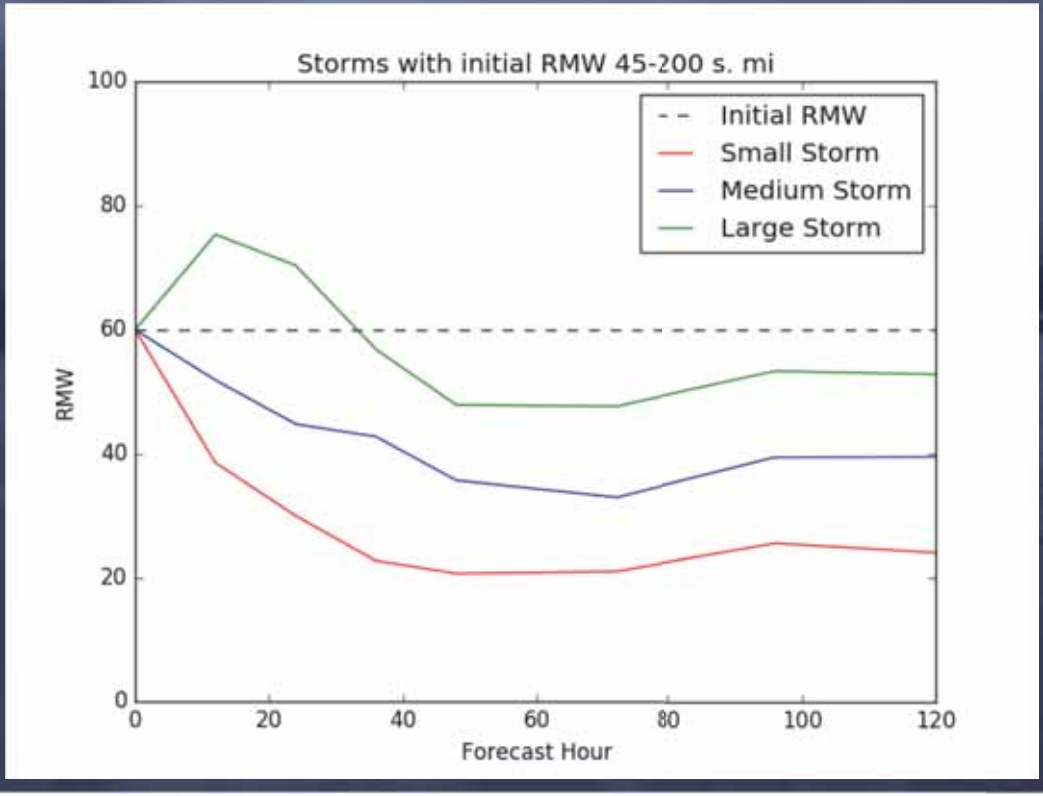
- Using the larger BEST track RMW values causes the cross-track perturbations to be spaced farther apart, reducing the required number of cross-track perturbations

Current RMW Forecast Methodology

Initial RMW
(Psurge-derived or Best Track -derived)

Growth Bins

5-15 mi	15-25 mi	25-35 mi	35-45 mi	45-200 mi



***Intensity not used in RMW Forecast**