# NOAA Storm Surge Modeling Gaps and Priorities

HFIP Meeting

November 9th, 2017

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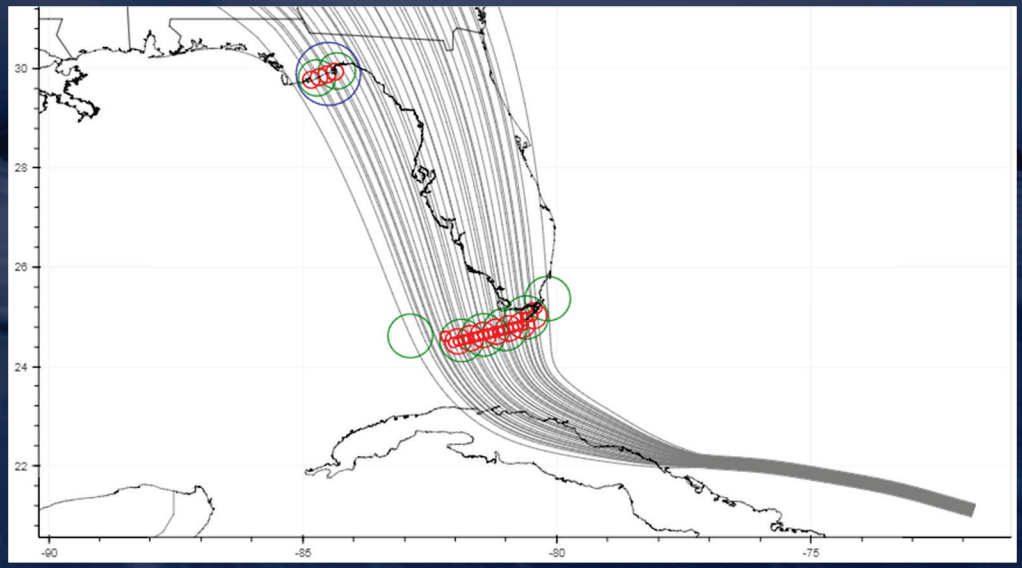
# Introduction to Probabilistic Storm Surge

- 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)

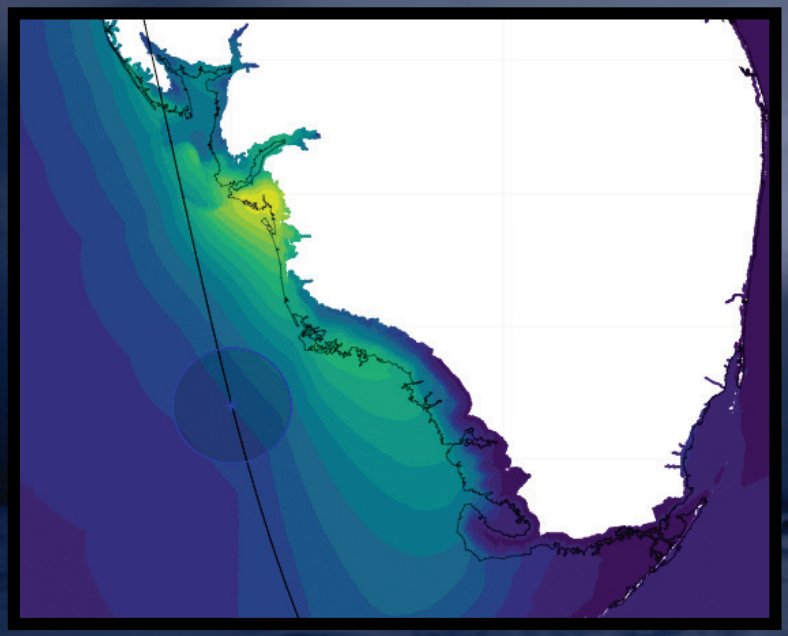
- P-Surge ensemble incorporates uncertainty using a statistical method based on NHC historical errors of:
  - Cross track (landfall location) : includes 90% of possible cross track
  - Along track (forward speed)
  - Intensity
  - Storm size

2017090900 P-Surge Tracks

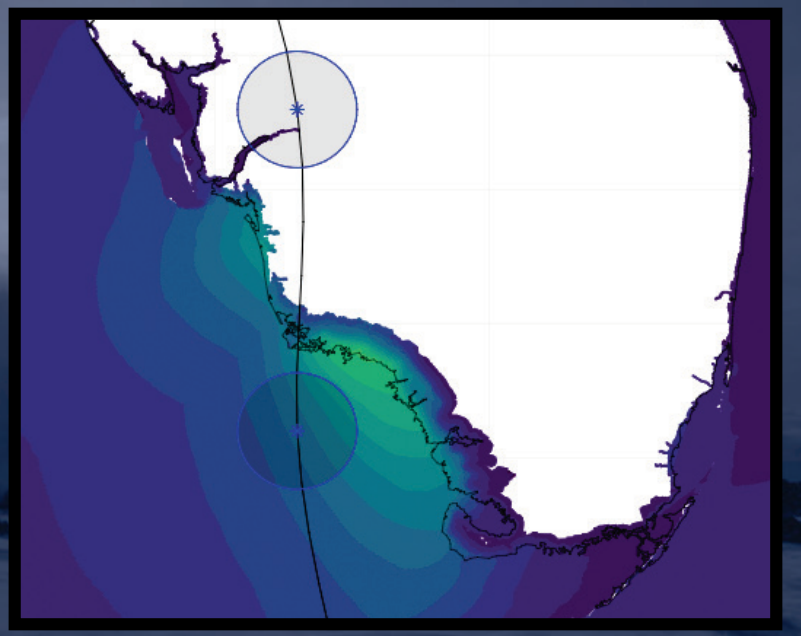


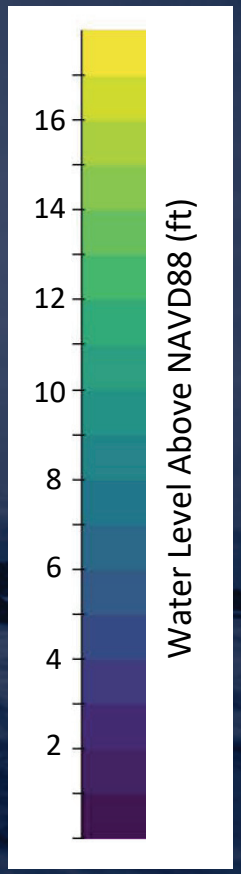
# Irma Single Track Deterministic SLOSH

Advisory 43: Saturday September 9th 5:00pm



Landfall Marco Island: Sunday 10th 3:35 pm

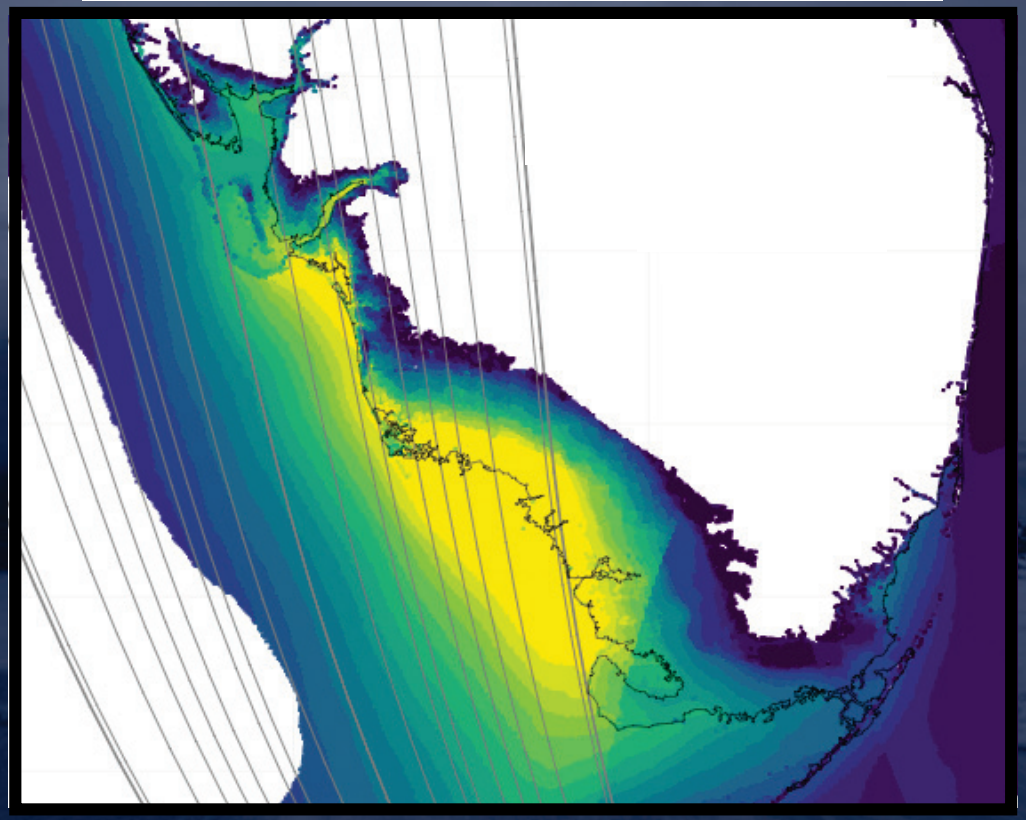


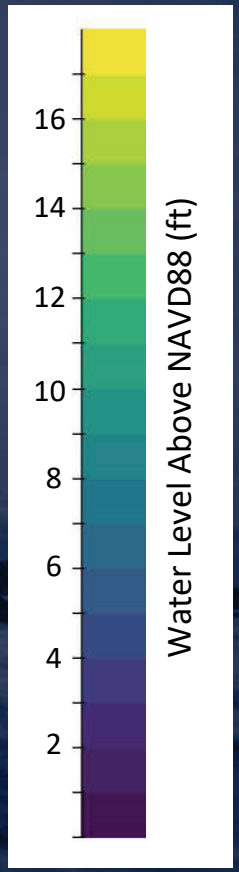



Track errors even at short lead times produce significantly different Surge footprints

# Irma Probabilistic Guidance (P-Surge)

Advisory 43: Saturday September 9th 5:00pm





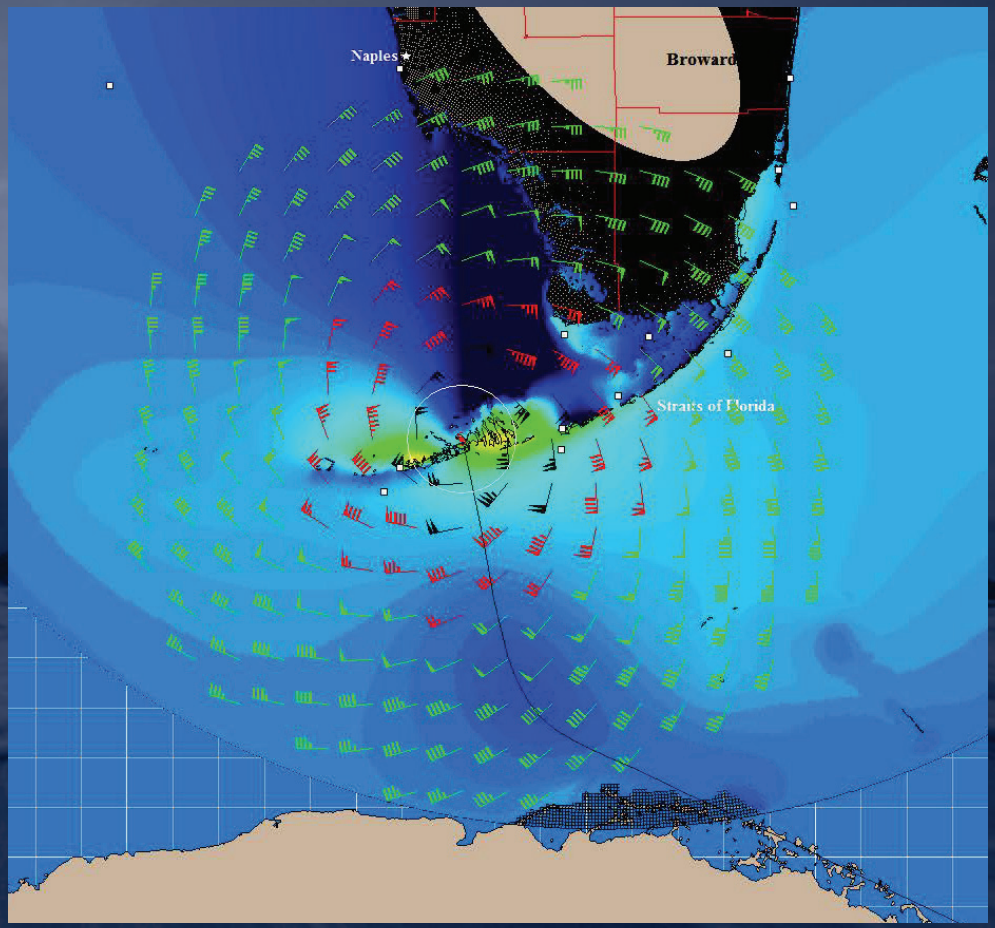

**Scientifically and ethically imperative to issue warnings and advise evacuations based on probabilistic guidance**

# Outline: The Gaps and Priorities

1. **Improve the Probabilistic Ensemble**
   - Replace SLOSH's parametric wind model
   - Incorporate wind structure information into P-Surge Ensemble
   - Move from a Statistical to a Dynamical Ensemble
2. **Provide Real-time Storm Surge Forecasts Sooner**
   - Increase use of P-Surge from 48- to 72-hours before landfall
3. **Extend Probabilistic Method to OCONUS**
   - Support wave modeling in real-time probabilistic guidance for Puerto Rico, Virgin Islands, and Hawaii

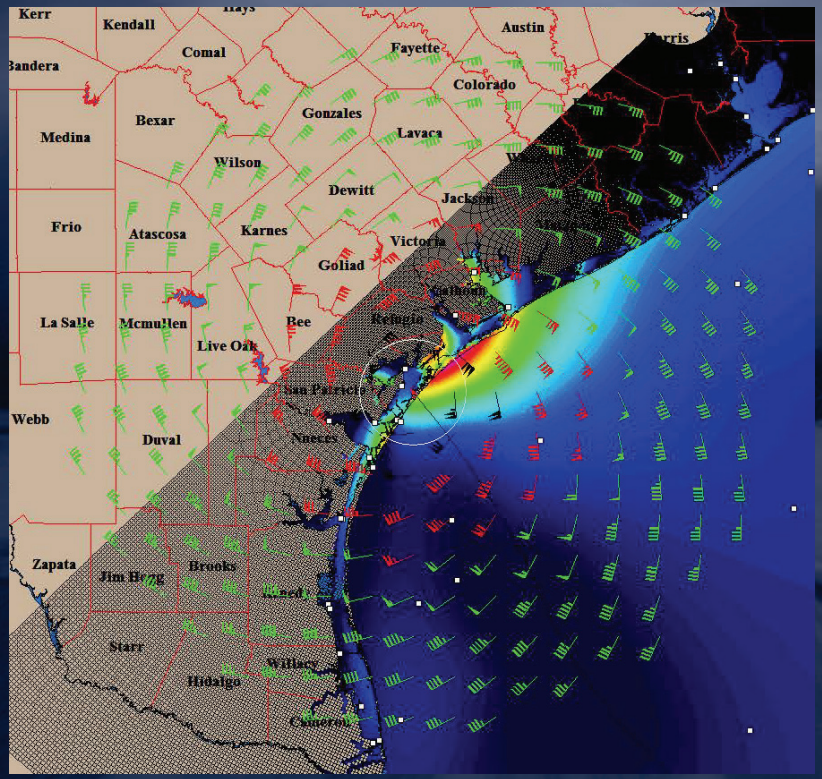
# Replace the Parametric Wind in SLOSH

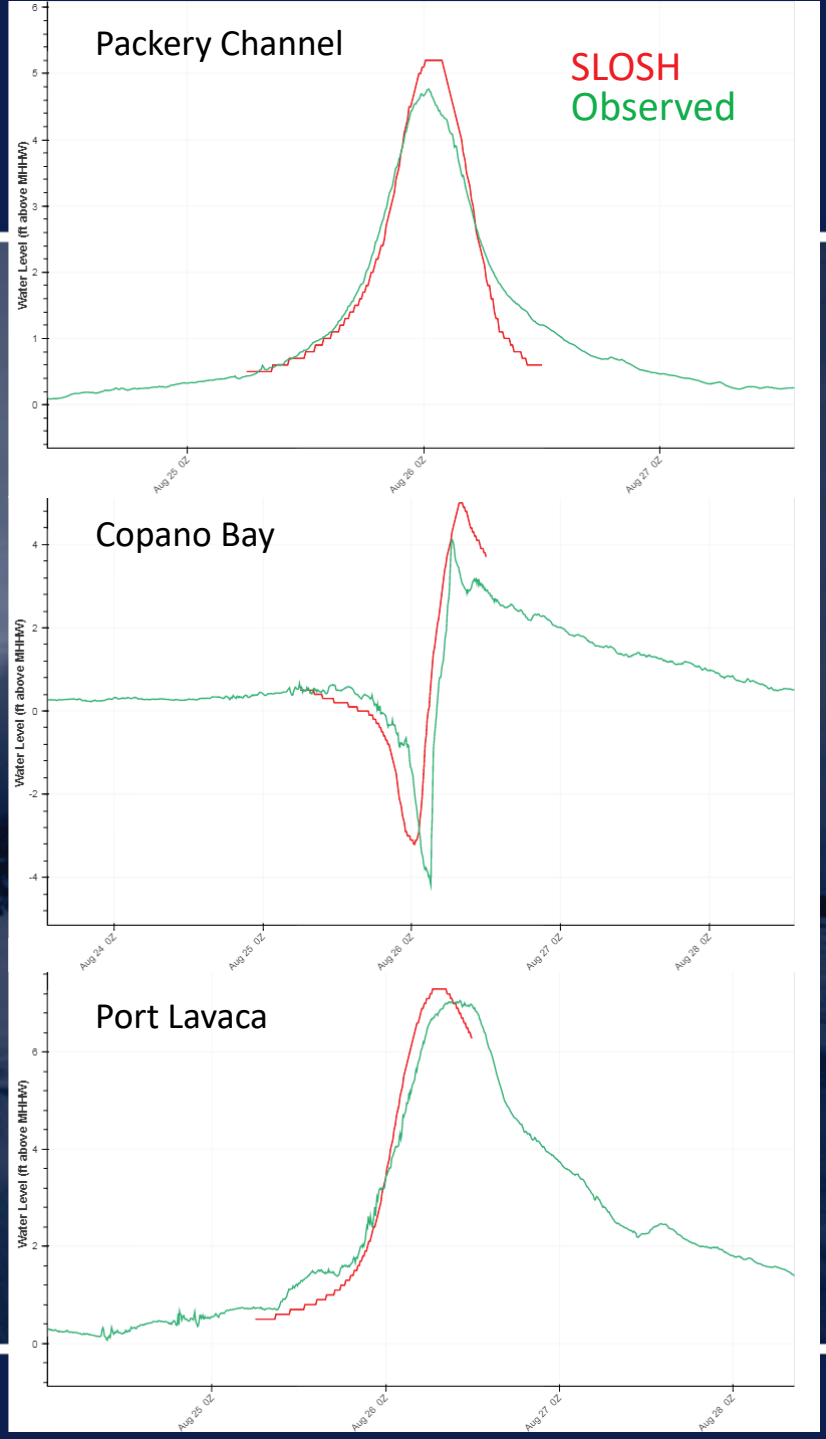
- SLOSH uses a parametric wind field
  - Relates Radius of Maximum Wind (RMW), Delta Pressure, and Intensity
  - Only these parameters dictate the wind field structure
- Works well for classic symmetric hurricane structures
- Does not accurately capture surge for disorganized, asymmetric, and transitional storms



# Example: Harvey

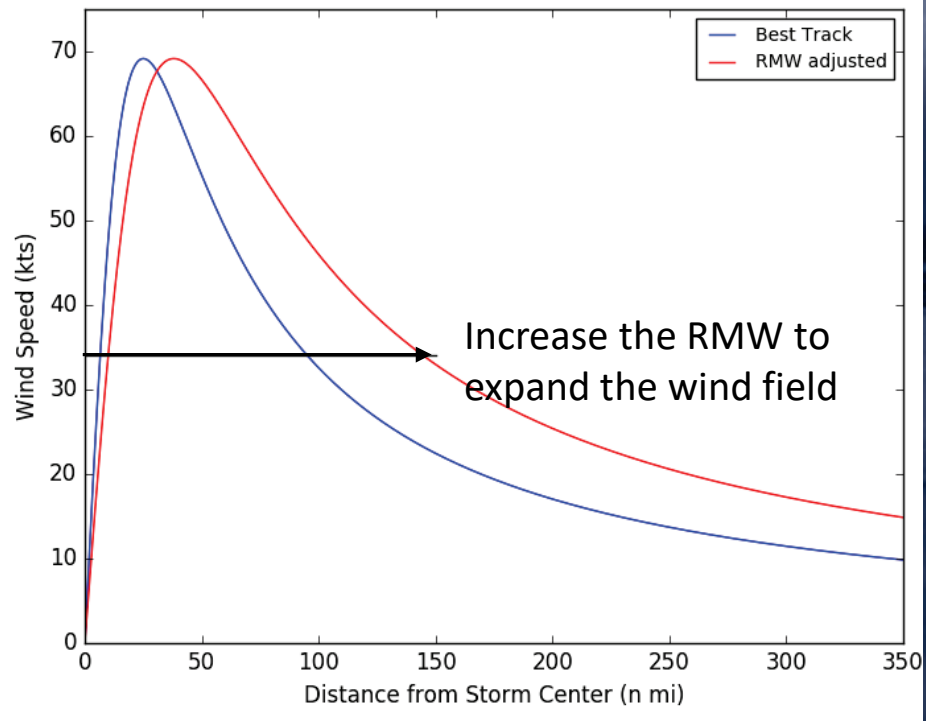
- SLOSH's parametric wind fit Hurricane Harvey relatively well and produced realistic results at the NOAA tide stations



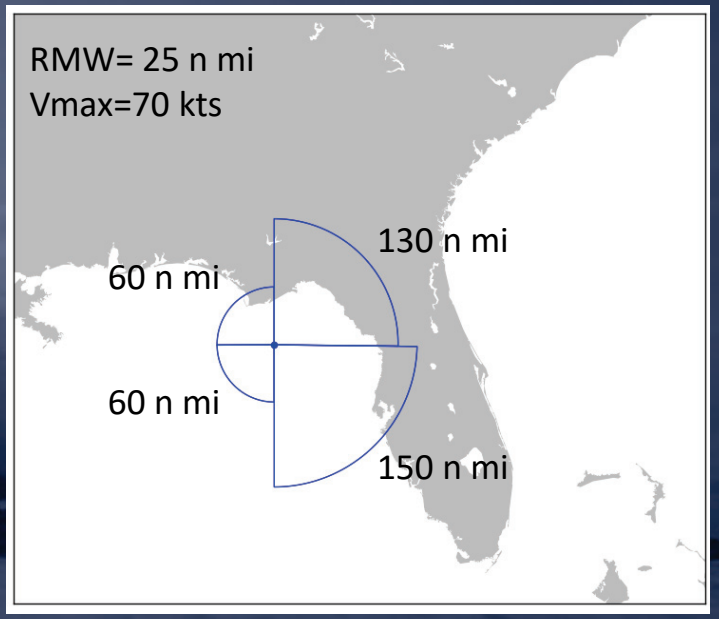



# Example: Hermine's Asymmetric Structure

- **Parametric wind field based on Best Track RMW underestimates the Surge at Cedar Key and in Tampa Bay**
- **Expanding the wind field fixes this, but overestimates Surge at and west of the landfall location**



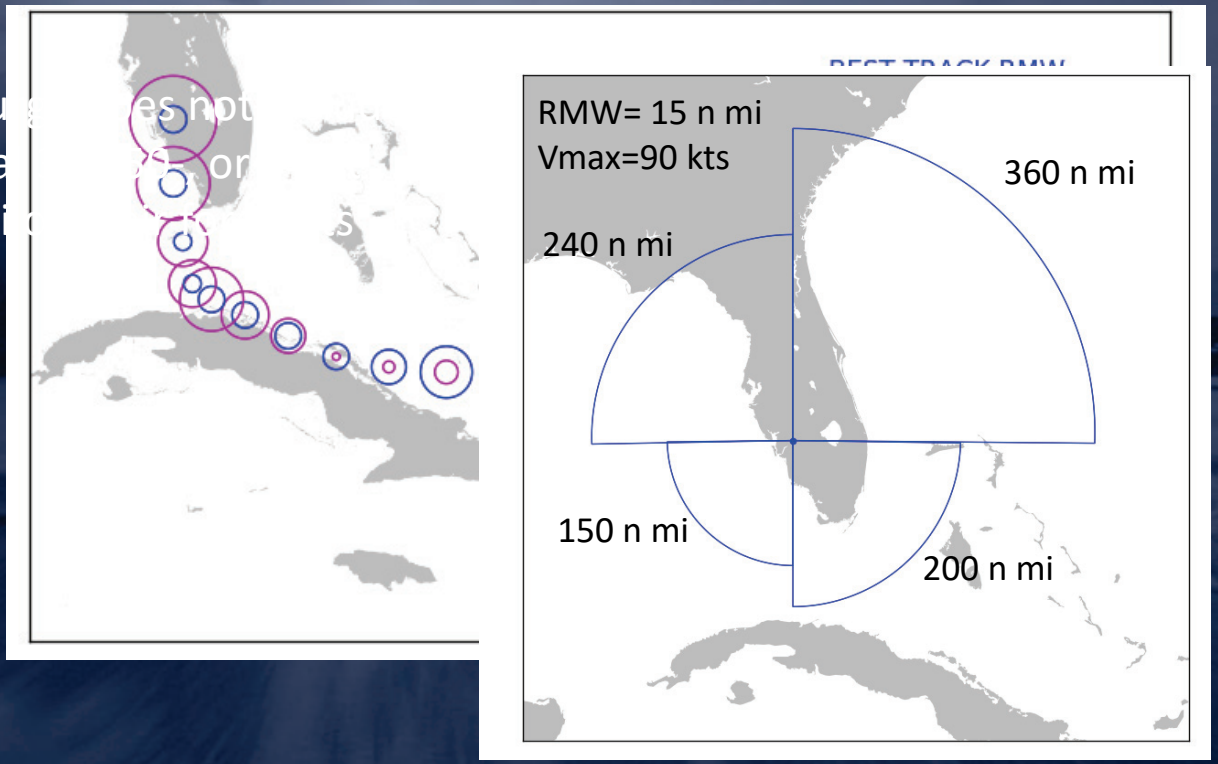

2016090200 NHC 34-kt Wind Quadrants




**For Hermine, a single SLOSH run cannot accurately depict the Surge footprint**

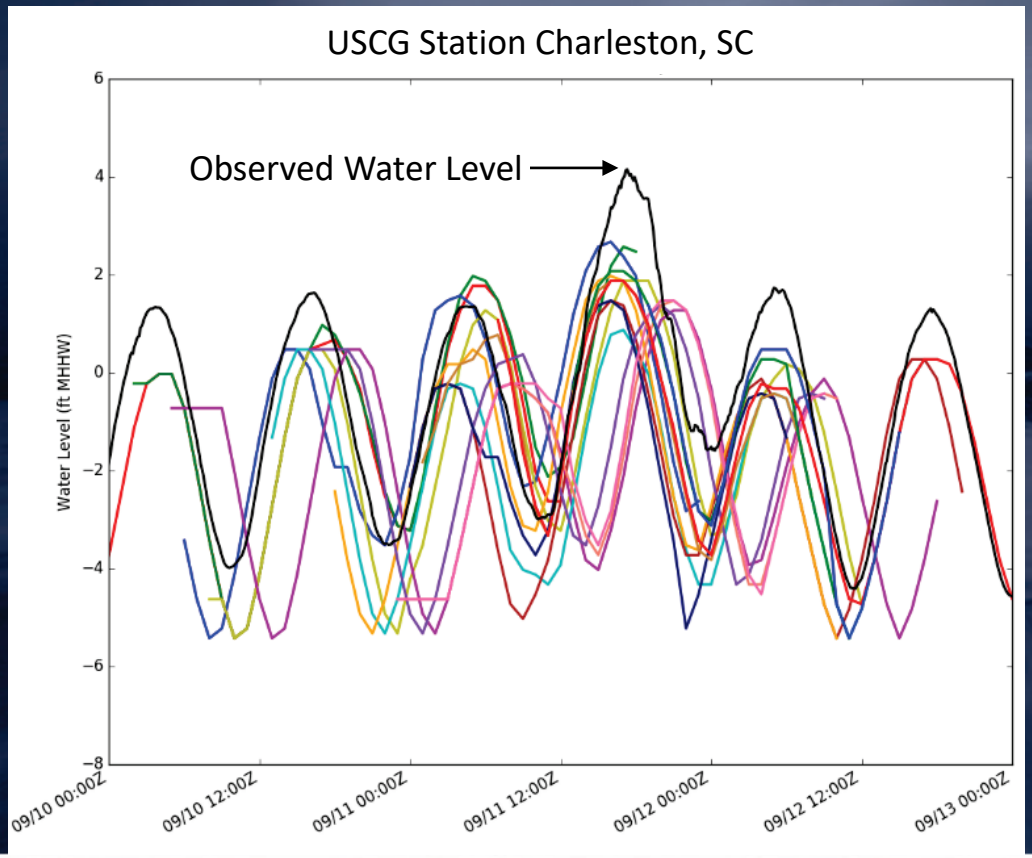
# Include Wind Structure in P-Surge Ensemble

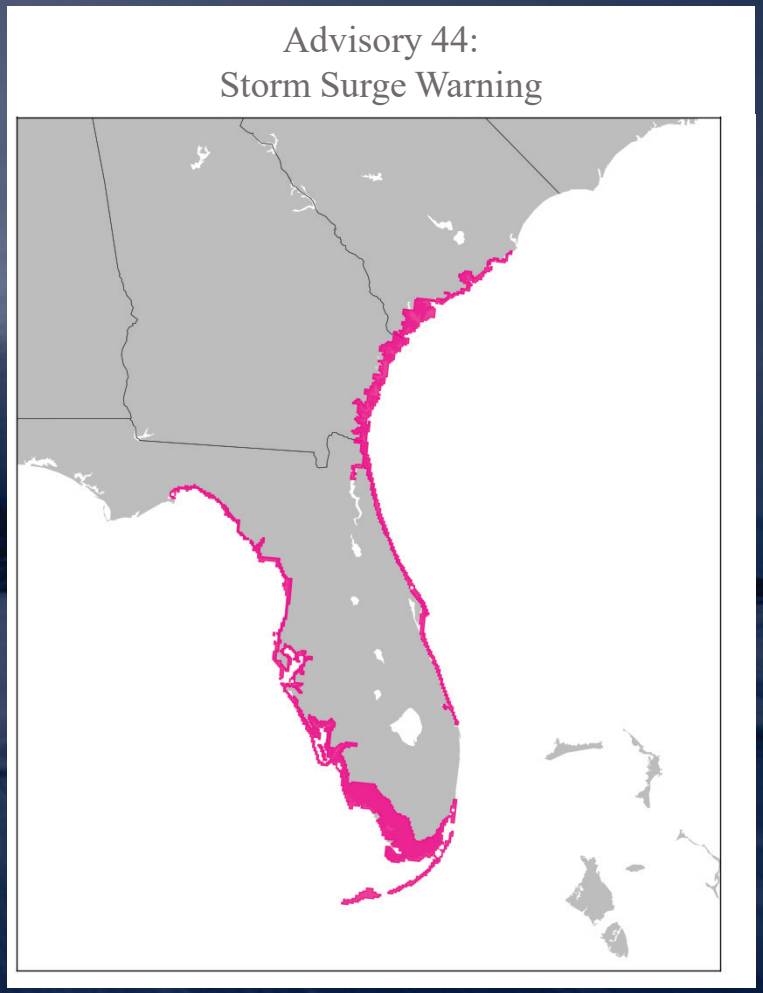
- P-Surge does not include initial RMW from NHC Best Track
  - Uses the current pressure and intensity to calculate the RMW (parametric wind)
  - led to large RMW initialization errors during Irma
- Also, P-Su[illegible]es not[illegible] NHC initia[illegible]or[illegible] wind radii[illegible]s



# Example: Irma's Large Wind Field

- P-Surge is unable to predict the Surge in Charleston, SC due to the size of the wind field
- Extra-Tropical Storm Surge model provides better guidance

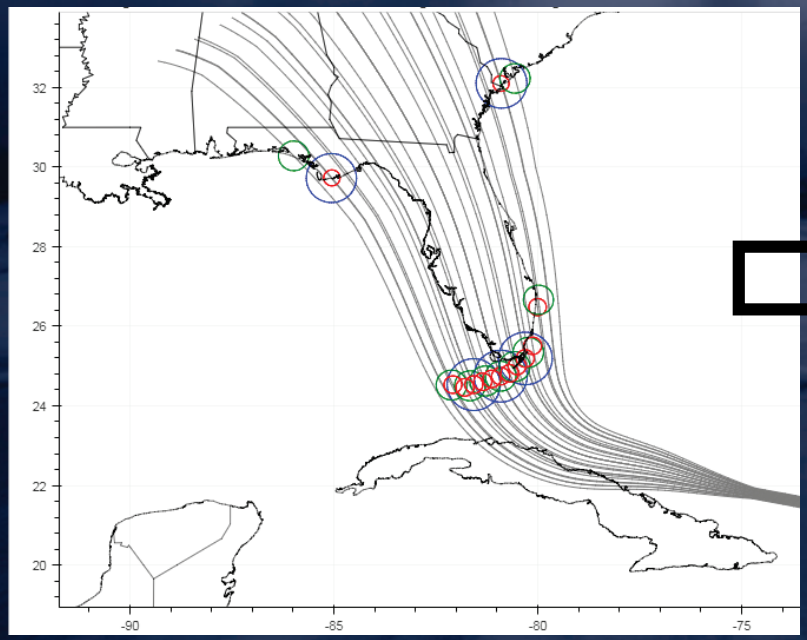


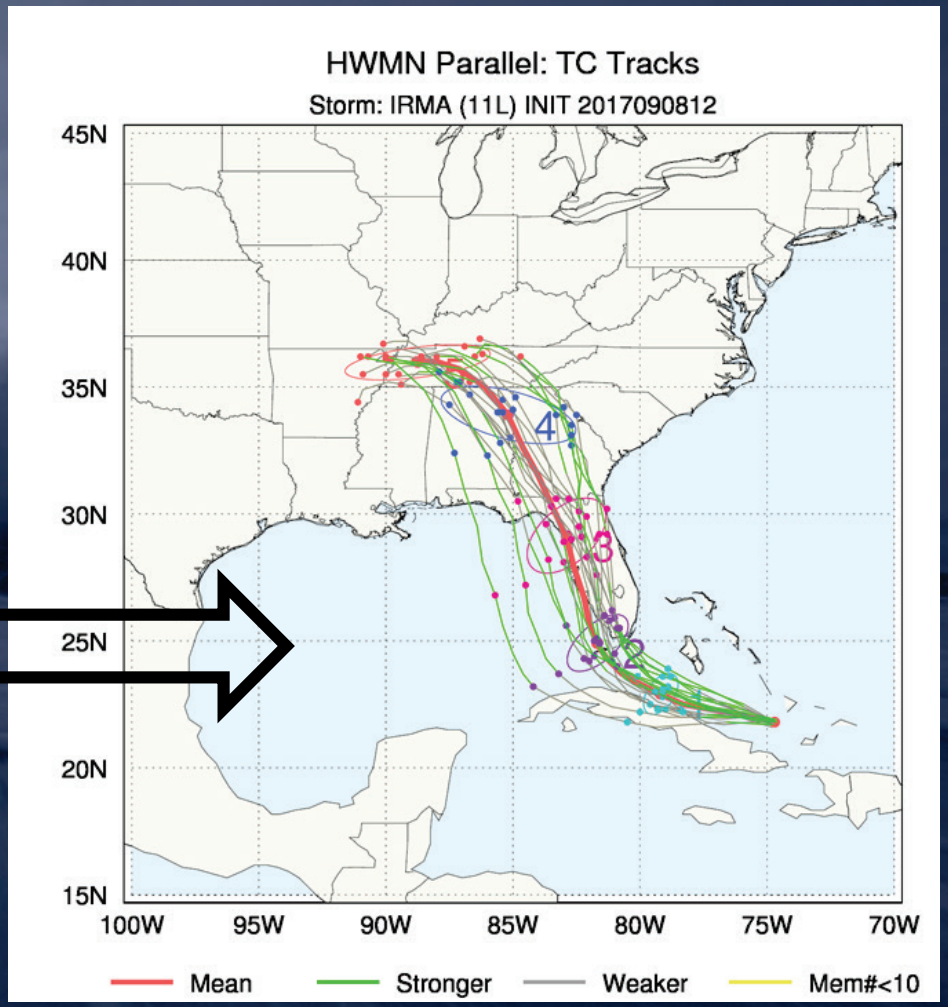



# Statistical to Dynamical Ensemble

- As ensemble forecasts improve, they can provide more information on ideal cross track spread, intensity uncertainty, and wind field size relative to the event at hand

2017090812 P-Surge Tracks

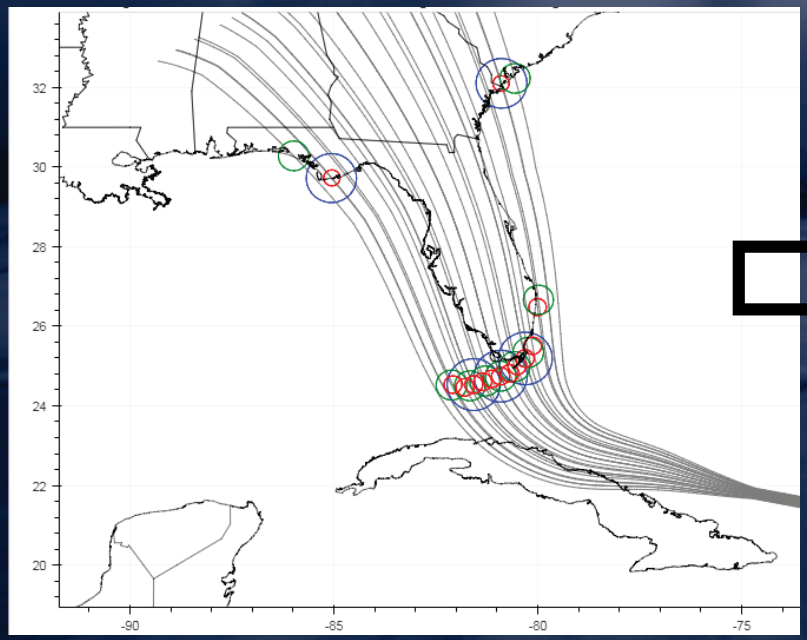


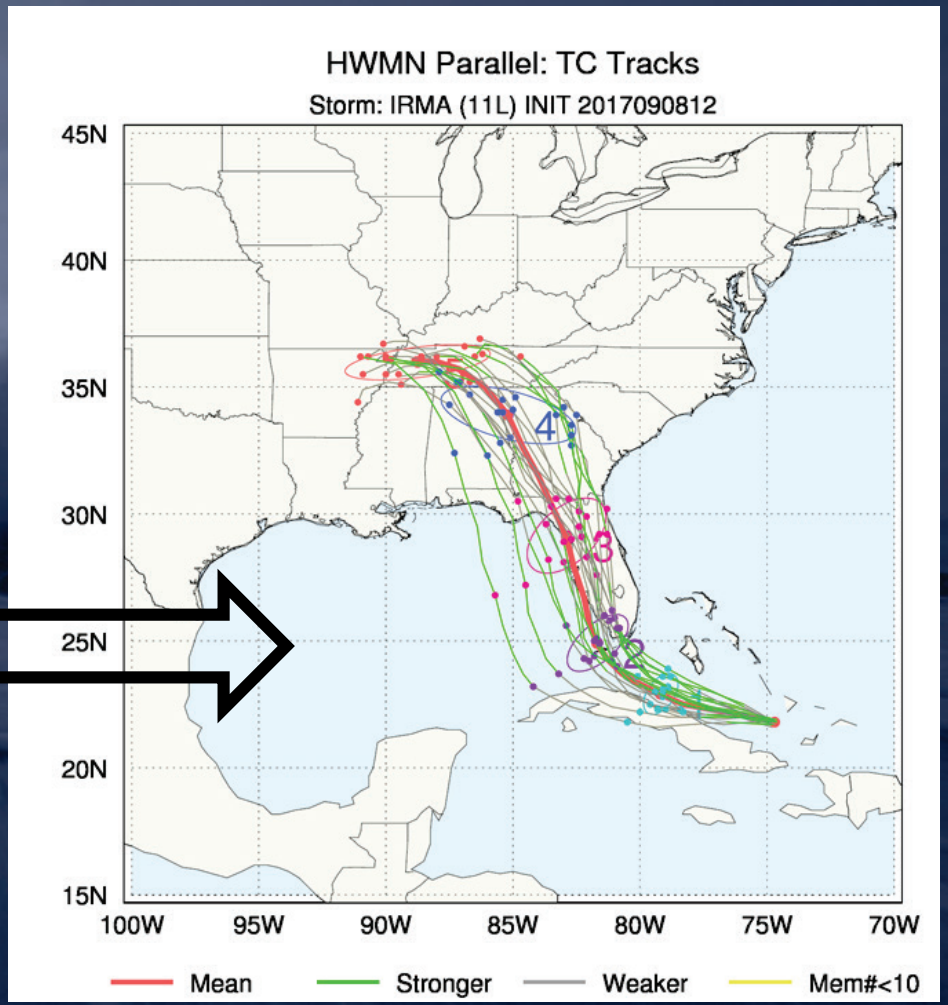



# Provide Real-time Surge Forecasts Sooner

- At long lead times (>48hrs), the statistically based P-Surge ensemble has large spread
- Including more wind structure information and moving to a dynamic ensemble can reduce the spread and make P-Surge useful at longer lead times

2017090812 P-Surge Tracks

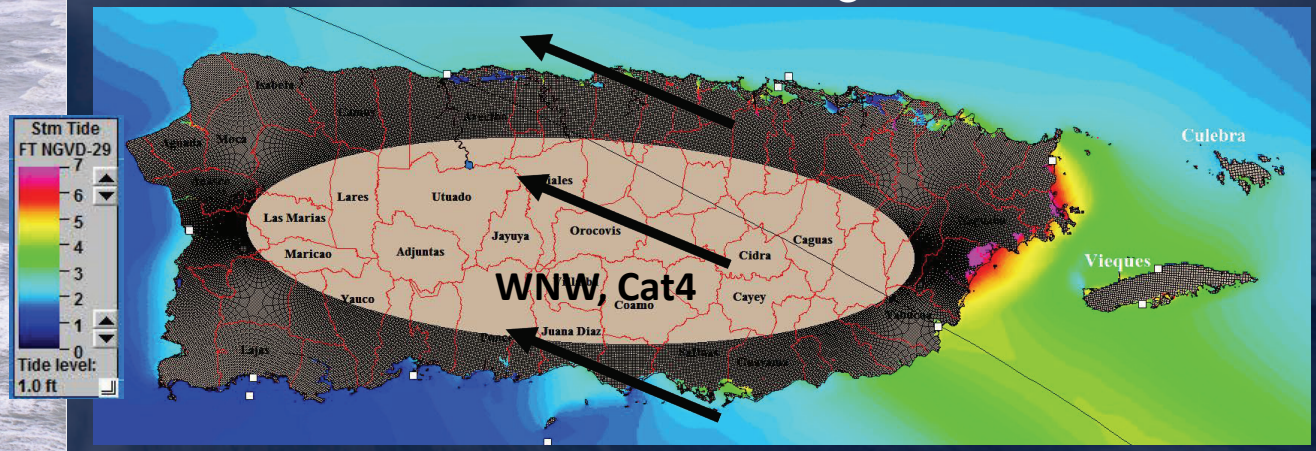


# Provide the Same Level of Service to OCONUS

- Waves can be a significant contributor to the total water level rise and cause substantial damage to property
- During Hurricane Maria, MEOWs were used to advise risk but are unable to run P-Surge
- Also ran single track SLOSH+SWAN run (computationally expensive) to advise emergency response post-storm

Hurricane Maria SLOSH+SWAN: Single Track



# 2nd Gen (Parametric) Wave Model

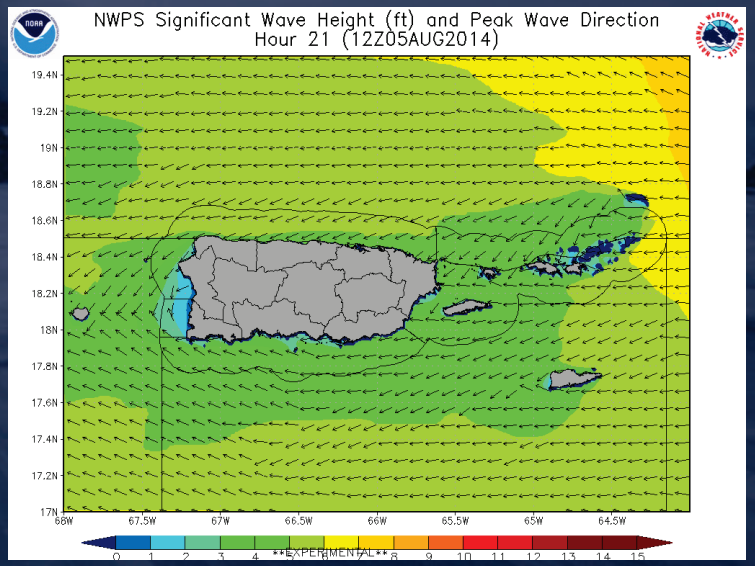
- An efficient parametric wave model to couple with SLOSH (within P-Surge)
- Parametric models that reduce full solution space N(t,x,y,$\sigma$,$\theta$), to e.g. M(t,x,y) (Schwab et al. 1984)
- Simplified physics, but significantly cheaper than SWAN or WW3

**Path toward real-time probabilistic guidance for OCONUS**

$$\frac{\partial \vec{M}}{\partial t} + \vec{v} \cdot \nabla_{x,y} \vec{M} = \vec{\tau}_w$$

$$\vec{\tau}_w = 0.028 \rho_a D_f \left| \vec{U} - 0.83 C_p \right| \left( \vec{U} - 0.83 C_p \right)$$

$$\sigma^2 = 6.23 \times 10^{-6} \left( \frac{f_p U}{g} \right)^{-10/3} \frac{U^4}{g^2}$$



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