Determination of Model Accuracy & Uncertainties During Severe Events Using Point Observations, Satellite Data & Model Ensembles

Max Schneider[2]

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BEST TRACK INFORMATION

TC vitals provided by NHC

Desktop — vi aal112017.dat — 98×17

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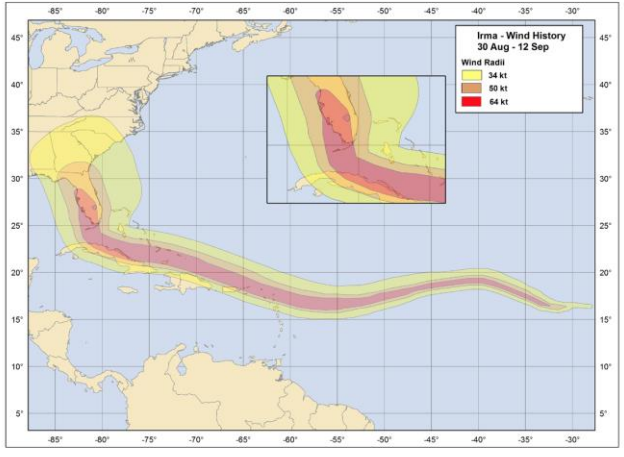
Wind swath depicting the radius of 34-, 50-, and 64-kt



HWRF generates the same file for 000 and 006 hr for 40 ensembles

	Time	Lat.	Lon.	V_{max}	P_c	Threshold	radii				P_n	R_{max}
							NE	SE	SW	NW		
	hr	deg	deg	kn	hPa	kn	nm				hPa	nm
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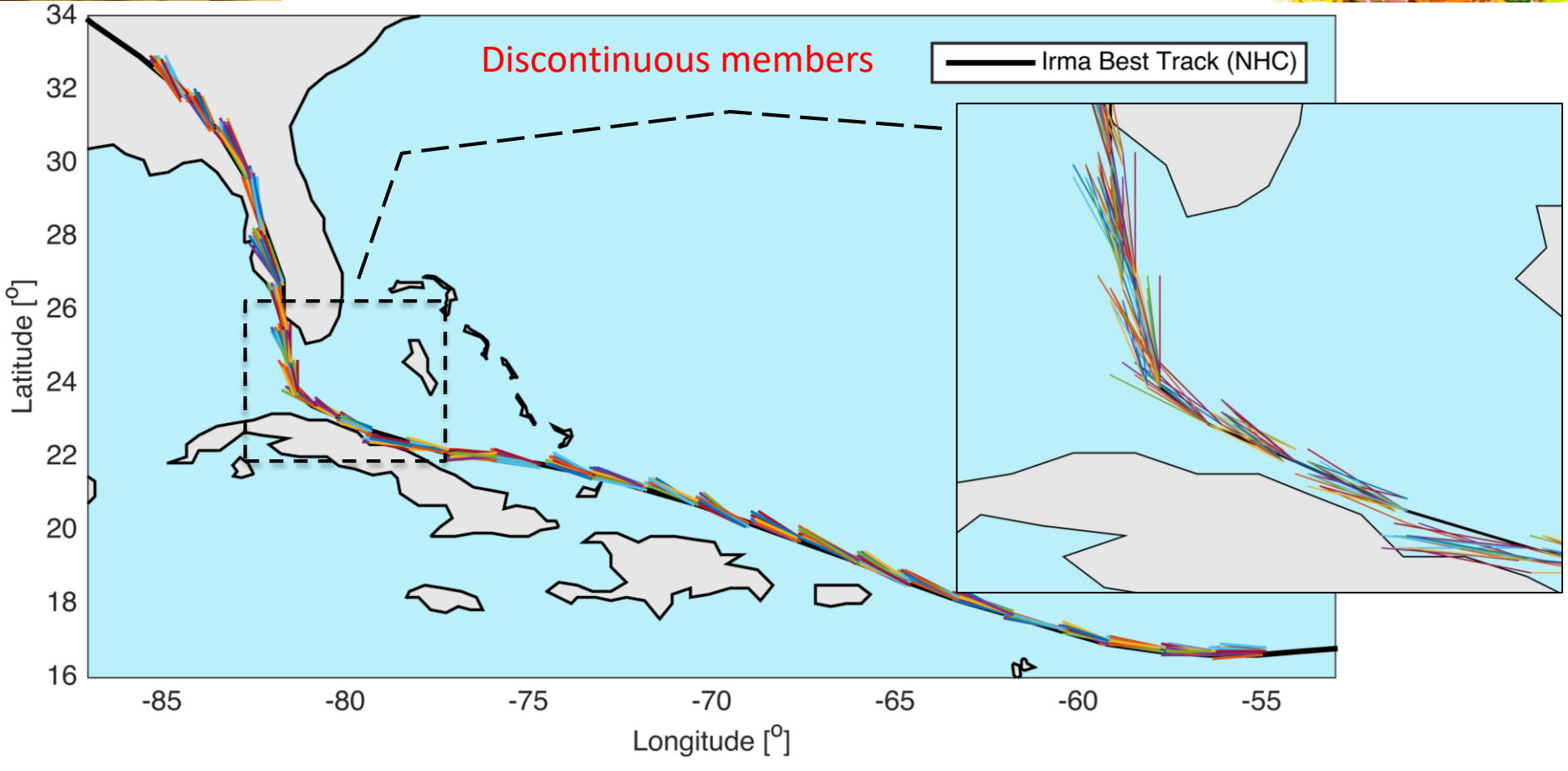
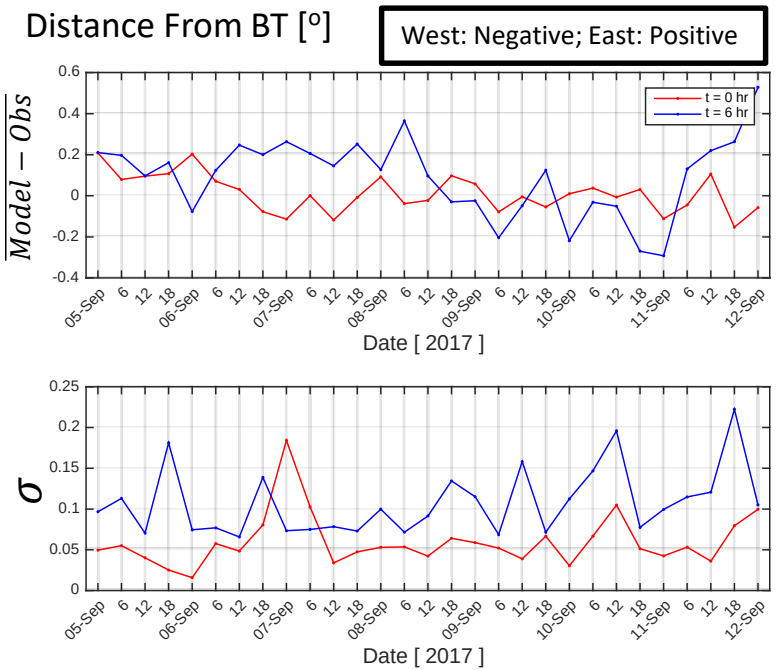
WHY HWRF DISTRIBUTION ???

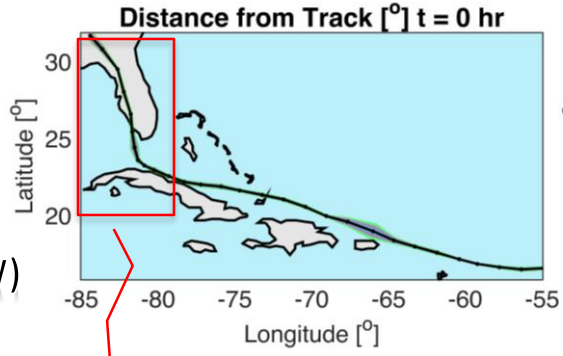
ITALIANS don’t break Long SPAGHETTI, but HWRF does !!!

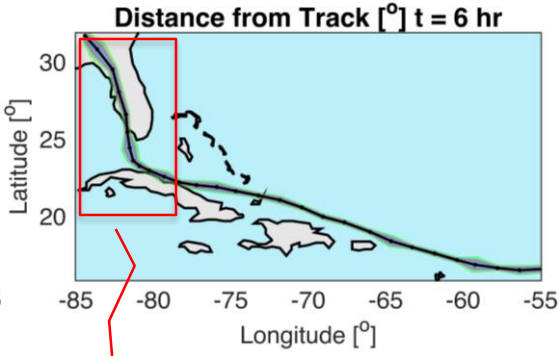


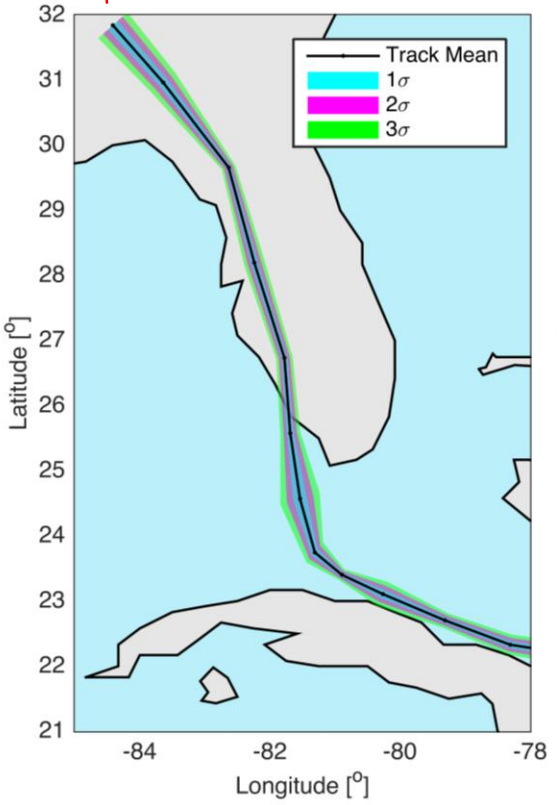
HWRF ENSEMBLE MEMBERS STATISTICS

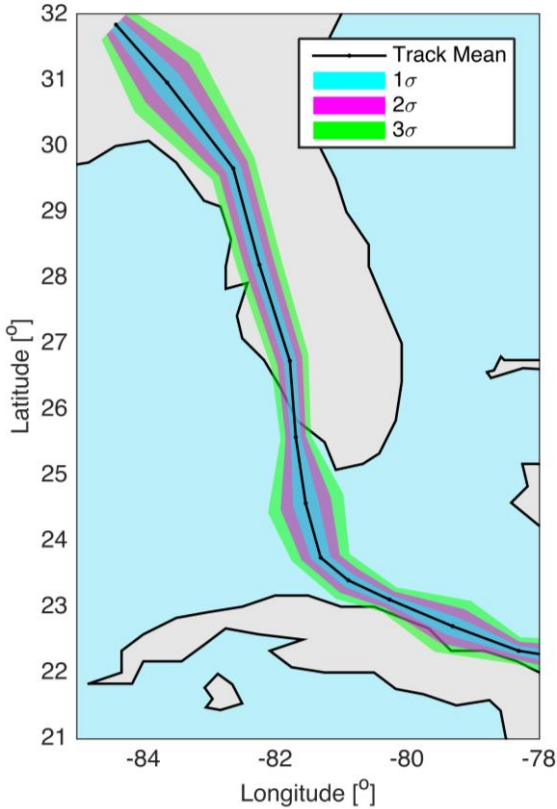
- HURRICANE BEST TRACK
- MAXIMUM WIND SPEED
- PRESSURE AT MSL
- MAXIMUM WIND SPEED RADIUS (RMW)
- RADII FOR 34, 50 & 64 THRESHOLDS











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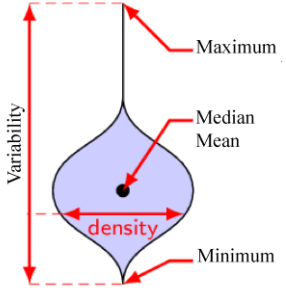

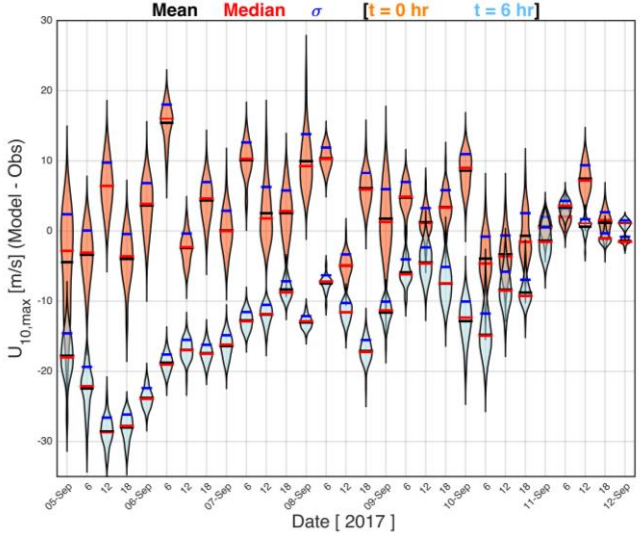

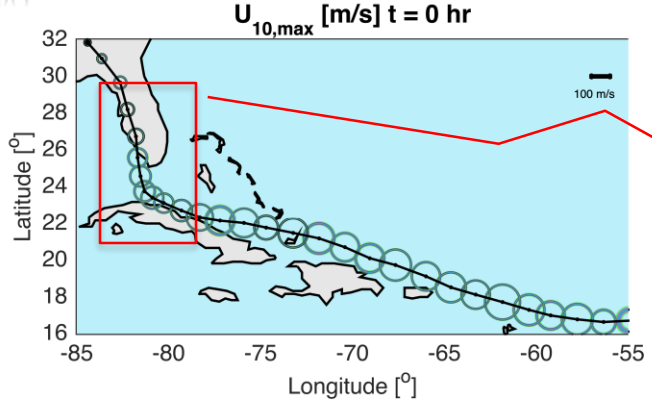

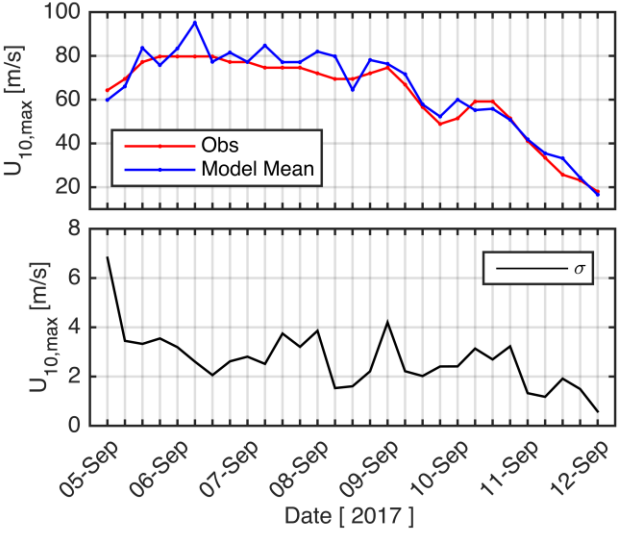

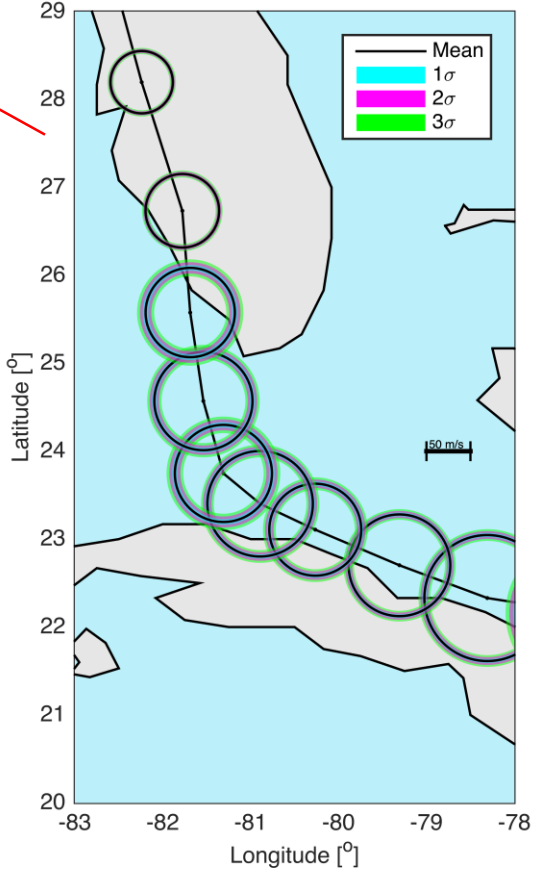

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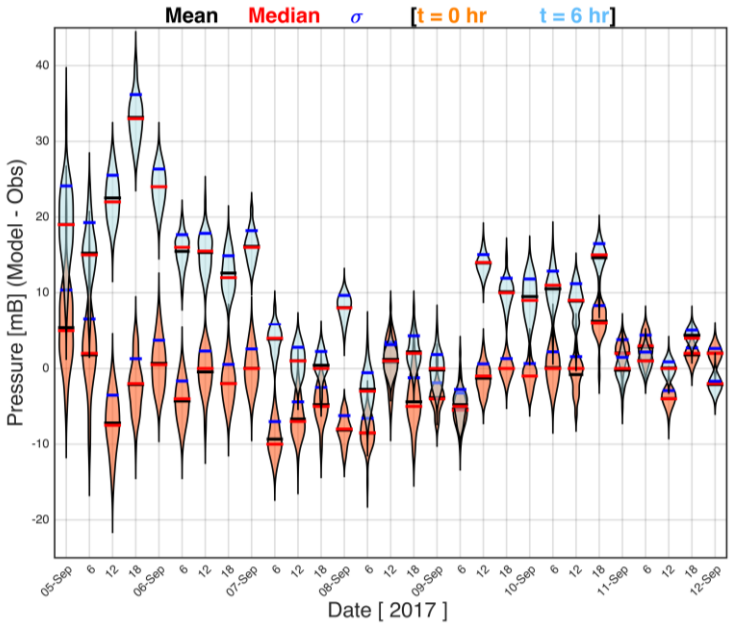
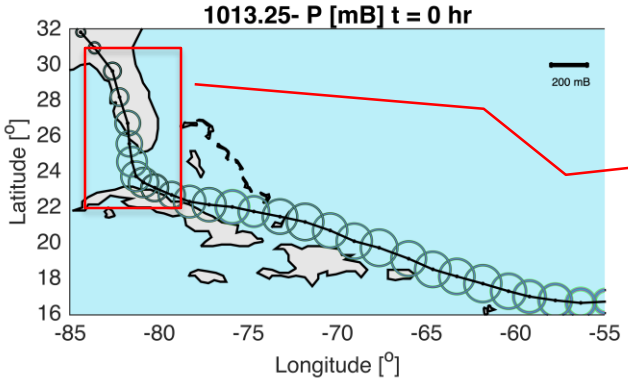
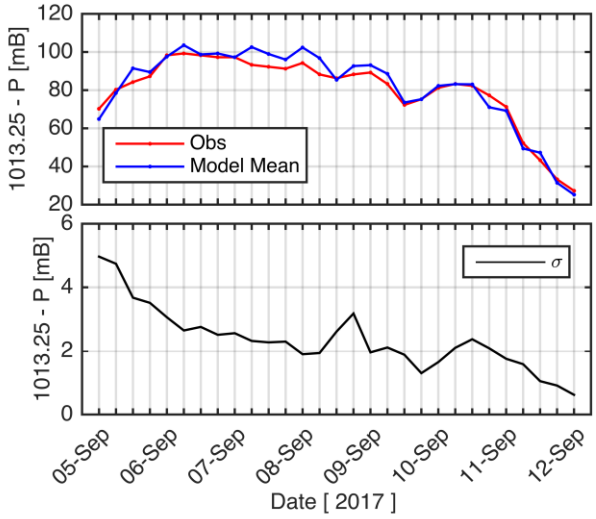
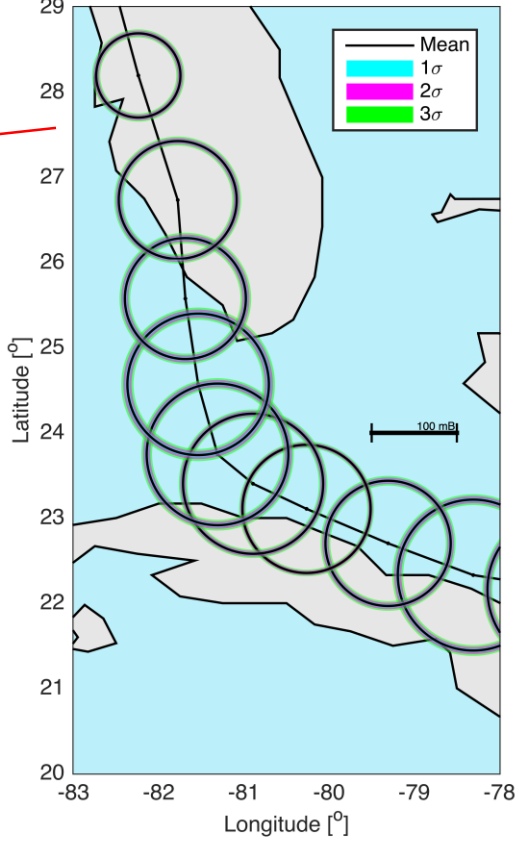






Reference PMSL =1013.25 mB



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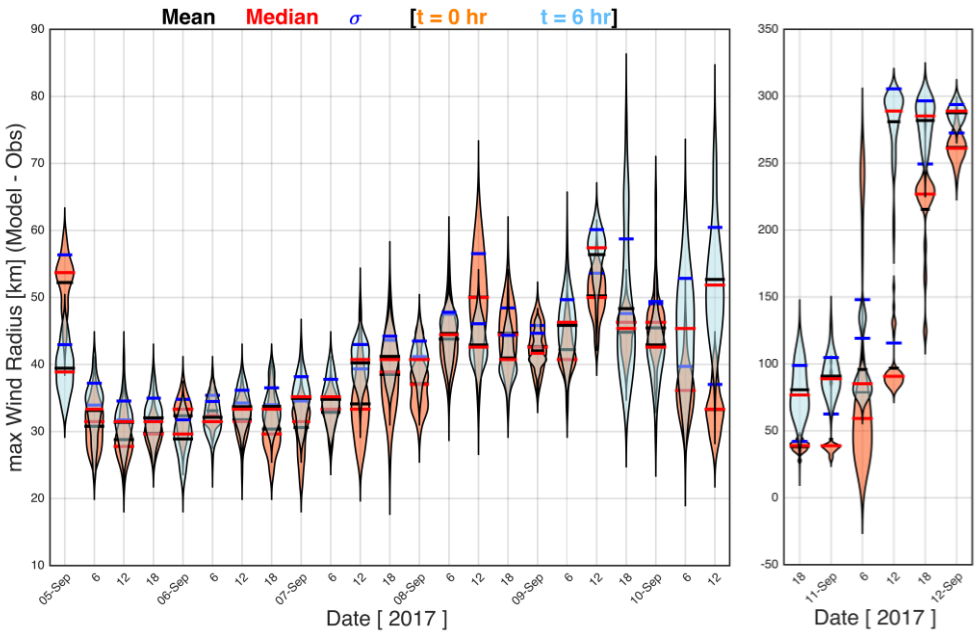

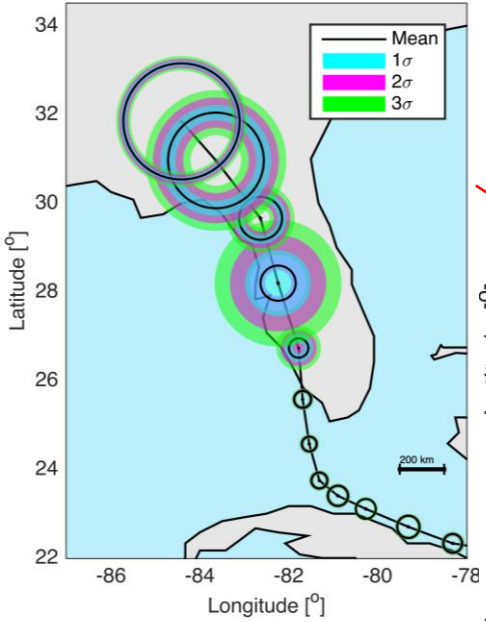

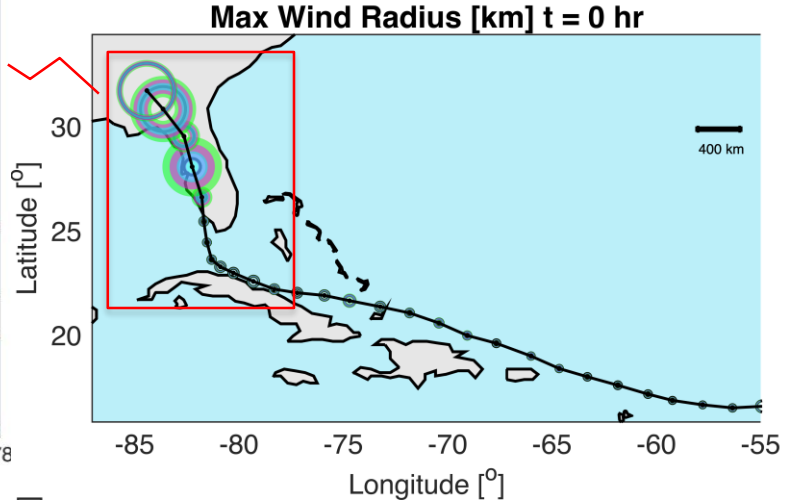

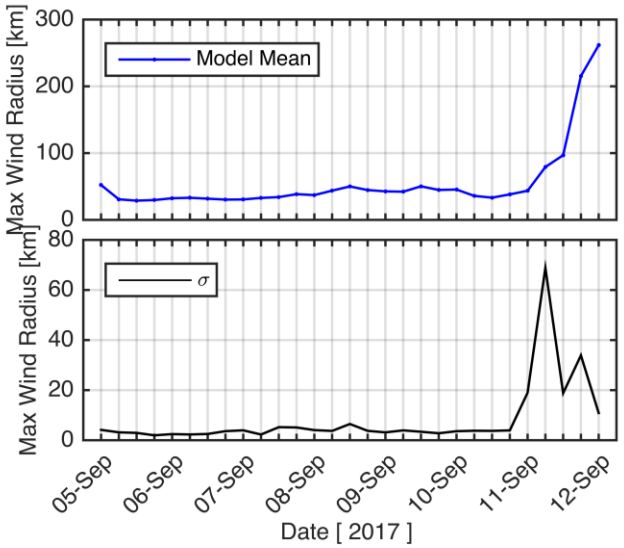

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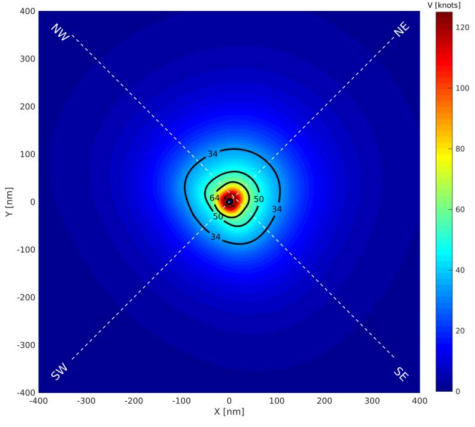
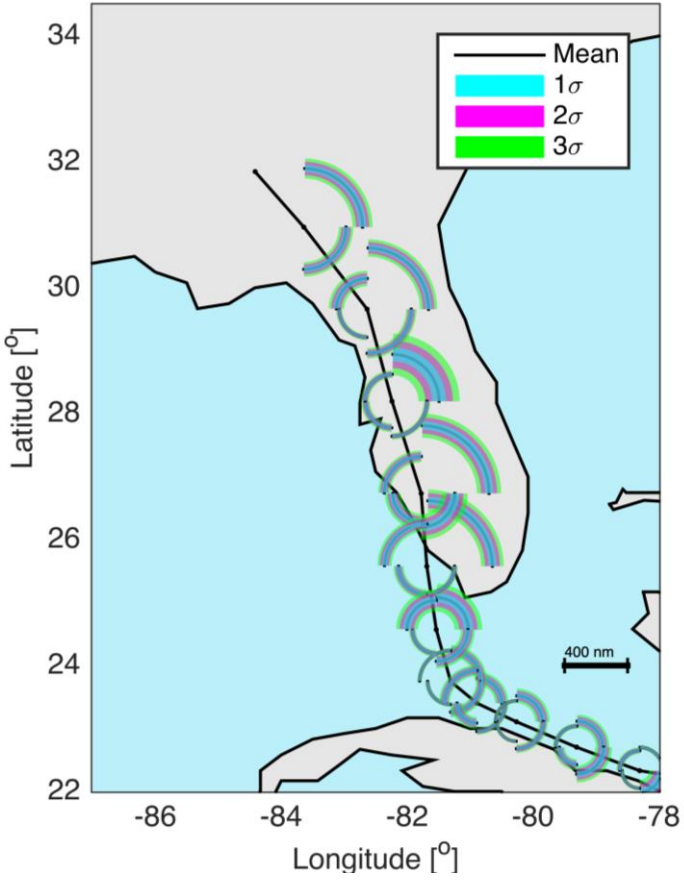
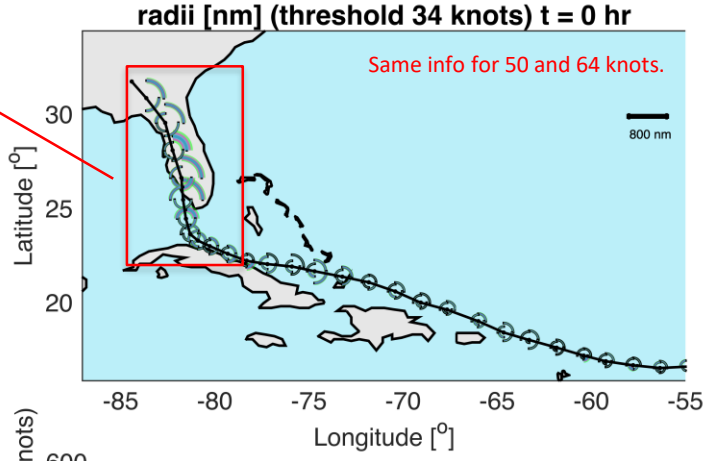
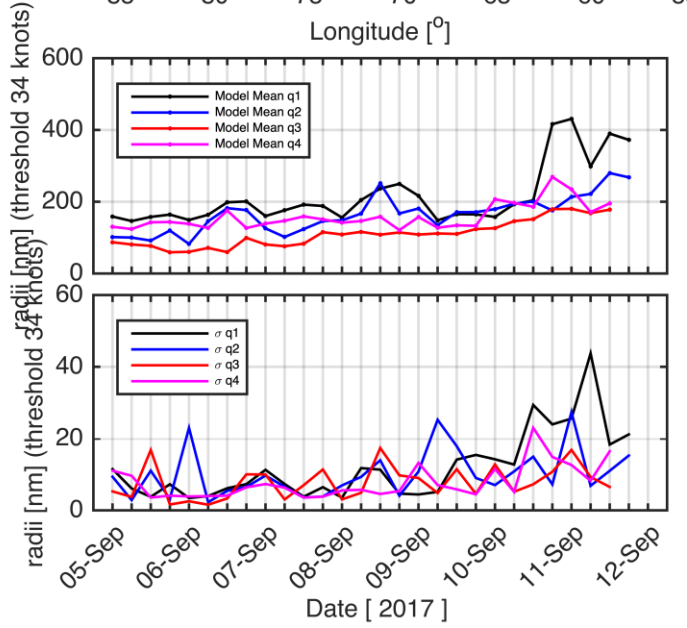


1 nm =1.852 km



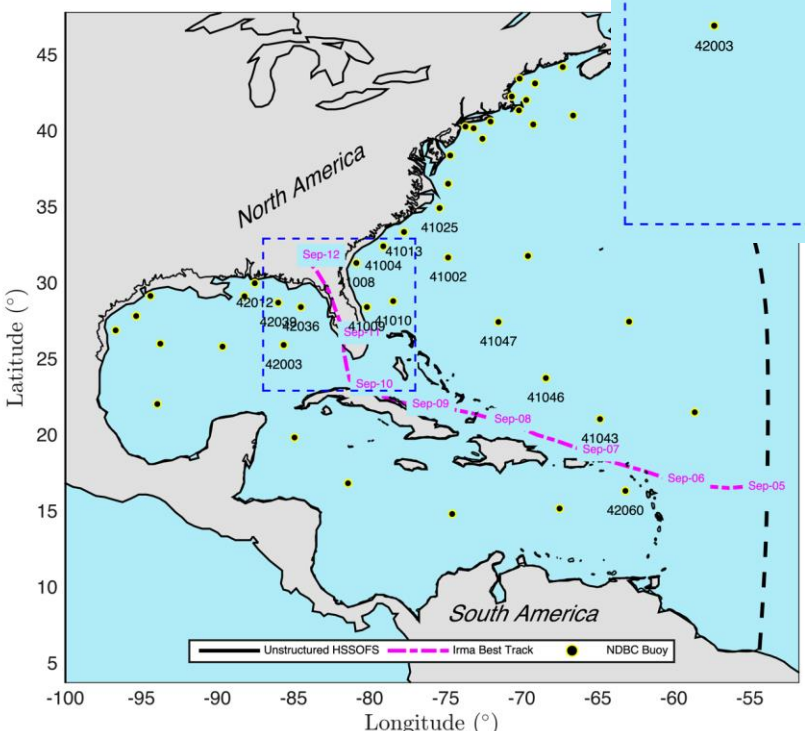


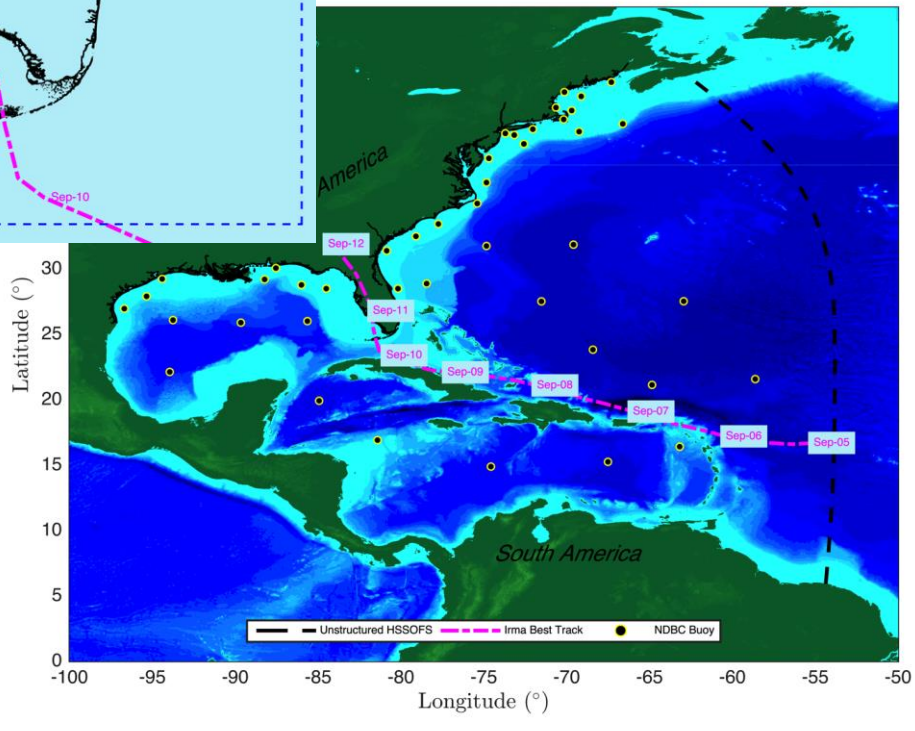


Large Scale Application

HURRICANE IRMA
SEPTEMBER, 2017

HSOFS Mesh
~1.8 M nodes
~3.5 M elements
lowest resolution.: ~200m





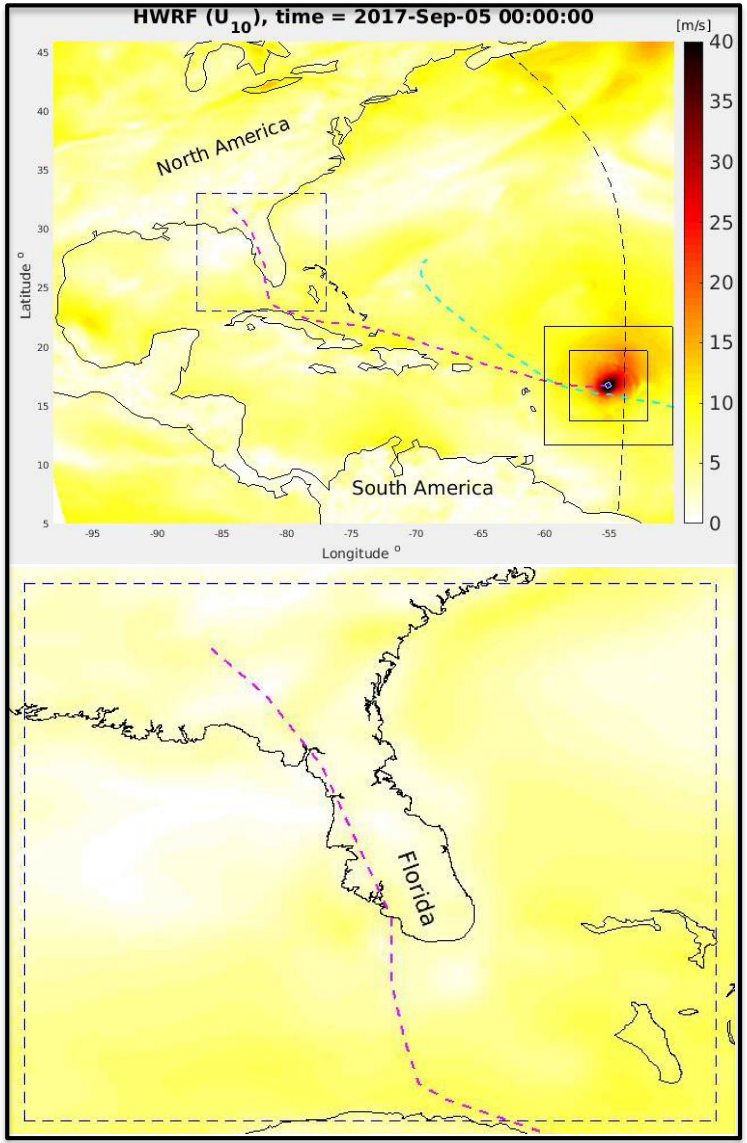
DETERMINISTIC RUN

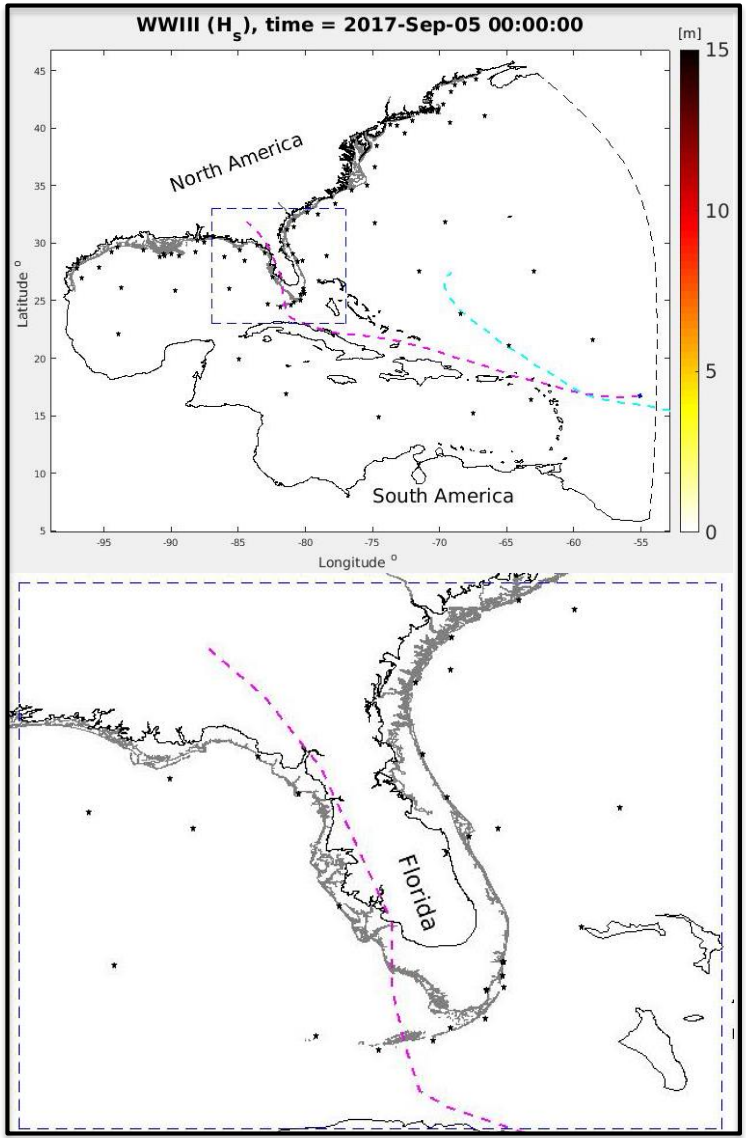
WW3

WW3 v6.07
Parallelization: Domain Decomposition
Scheme: Implicit
Abdolali et al 2019

HWRF

Three moving nested grids
Data Assimilation
Ocean Coupling
40 Ensemble Members





ENSEMBLES (16)

t=0

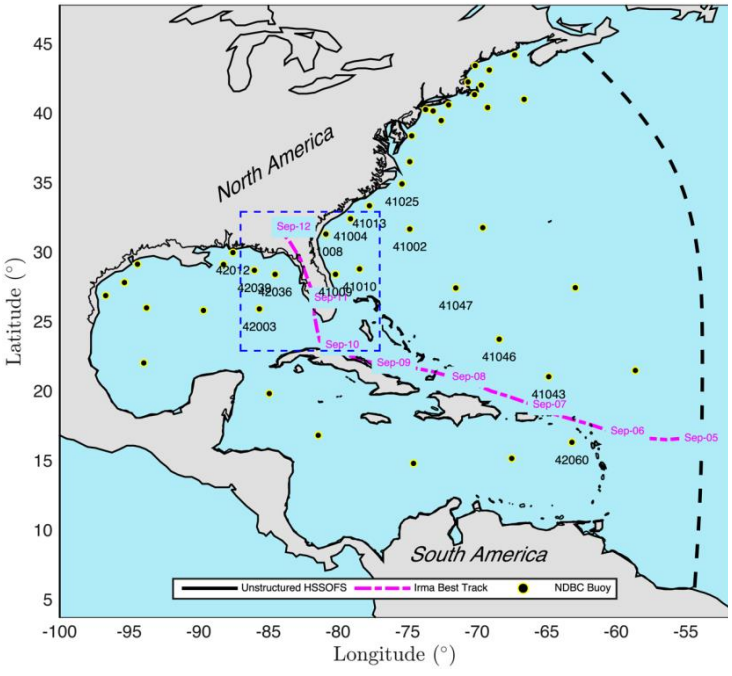
1) $U_{10} = U_{10} \times \left(1 + \frac{\sigma_{U_{10}}}{V_{max}}\right)$
2) $U_{10} = U_{10} \times \left(1 - \frac{\sigma_{U_{10}}}{V_{max}}\right)$
3) *Hurricane Center shifted to the east side of Best Track* (σ_{BT})
4) *Hurricane Center shifted to the west side of Best Track* (σ_{BT})
5) *Hurricane Center shifted ahead of Best Track* (σ_{BT})
6) *Hurricane Center shifted behind the Best Track* (σ_{BT})
7) Wider *Hurricane cone* $(\sigma_{r_{max}})$
8) Narrower *Hurricane cone* $(\sigma_{r_{max}})$

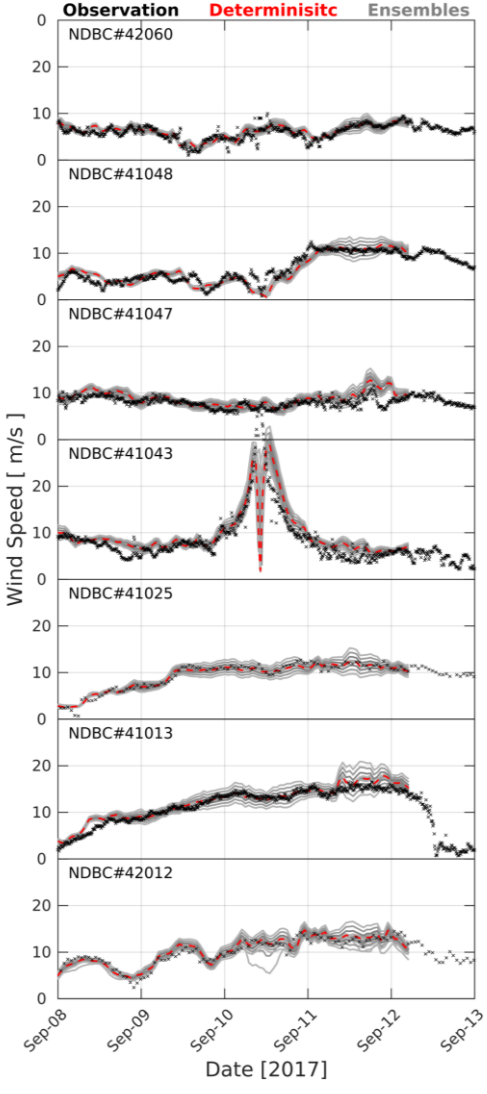
t=6

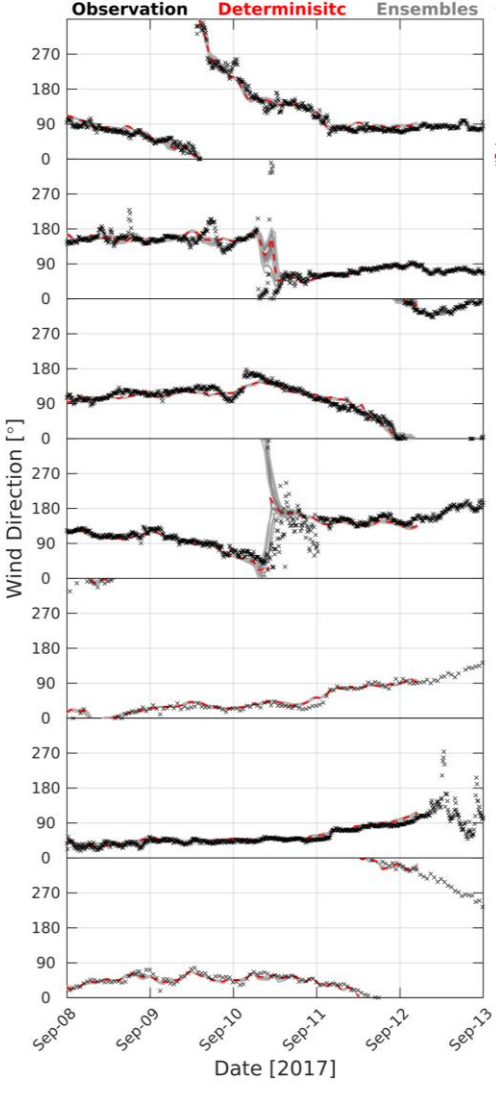
9) $U_{10} = U_{10} \times \left(1 + \frac{\sigma_{U_{10}}}{V_{max}}\right)$
10) $U_{10} = U_{10} \times \left(1 - \frac{\sigma_{U_{10}}}{V_{max}}\right)$
11) *Hurricane Center shifted to the east side of Best Track* (σ_{BT})
12) *Hurricane Center shifted to the west side of Best Track* (σ_{BT})
13) *Hurricane Center shifted ahead of Best Track* (σ_{BT})
14) *Hurricane Center shifted behind the Best Track* (σ_{BT})
15) Wider *Hurricane cone* $(\sigma_{r_{max}})$
16) Narrower *Hurricane cone* $(\sigma_{r_{max}})$

- More members can be generated using spread of radii, pressure or a combination of all parameters with different weights. We are limited by computational resources.
- See Abdolali et al. 2019 for more info on HWRF field post-processing and new features of WW3

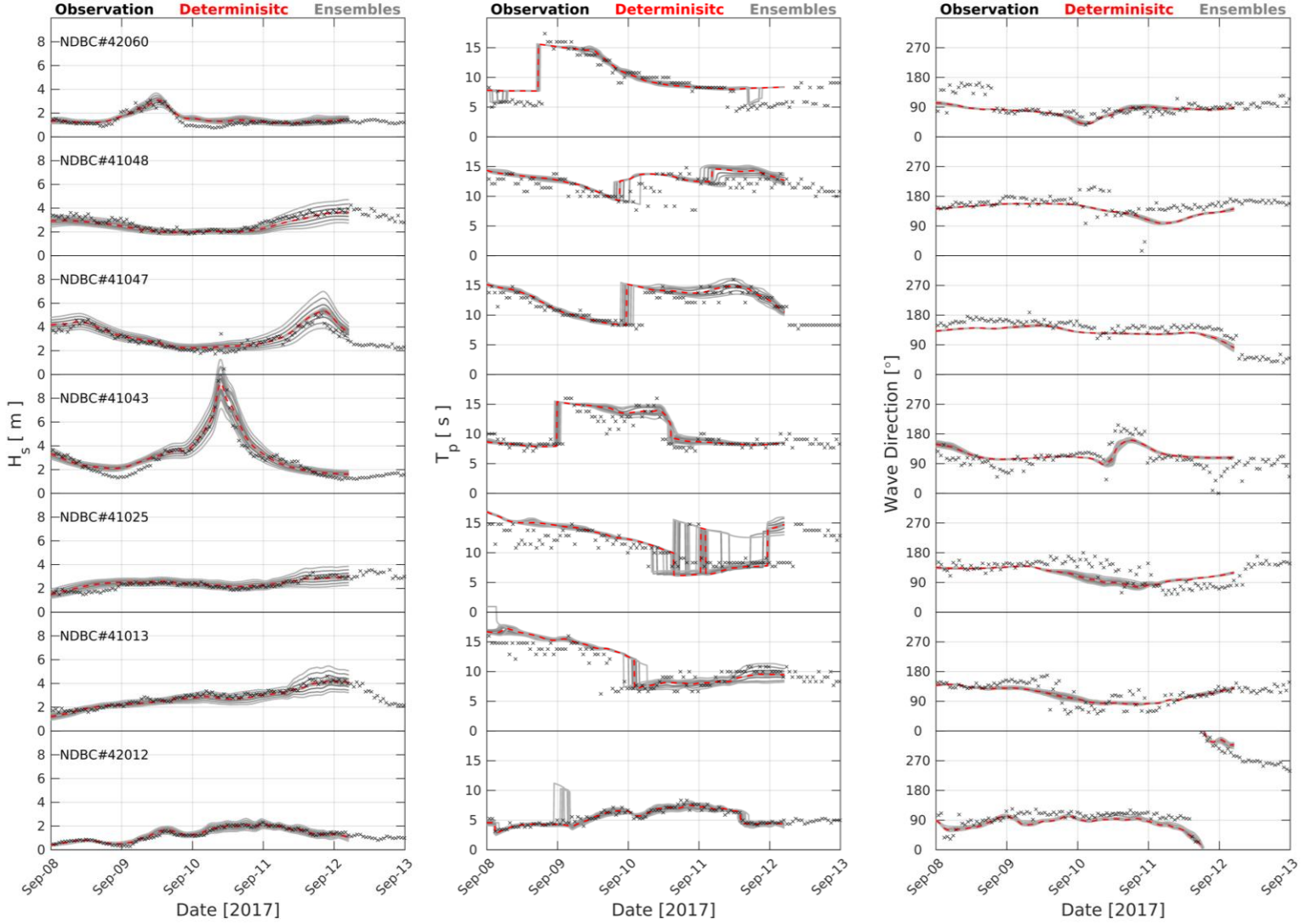
OFFSHORE VALIDATION (HWRF)



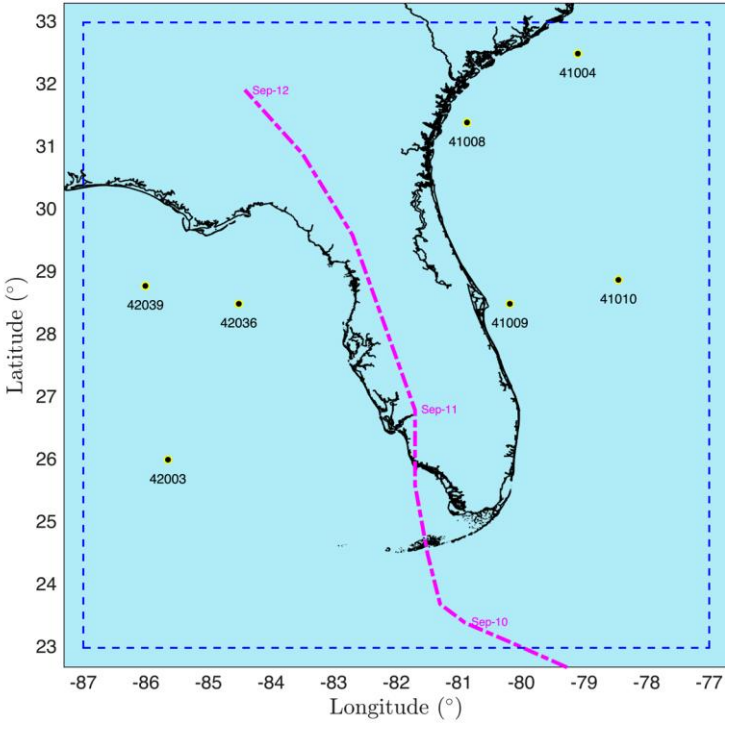


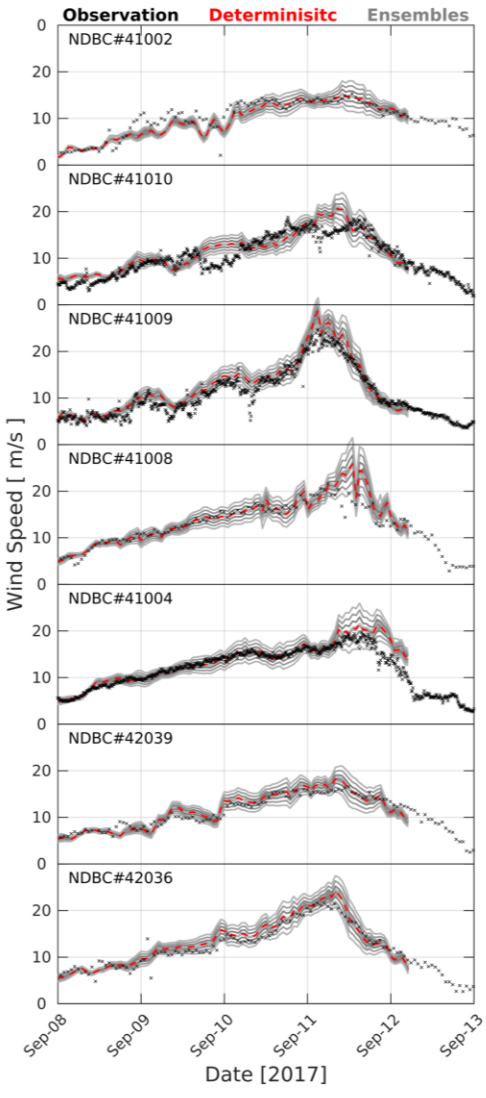


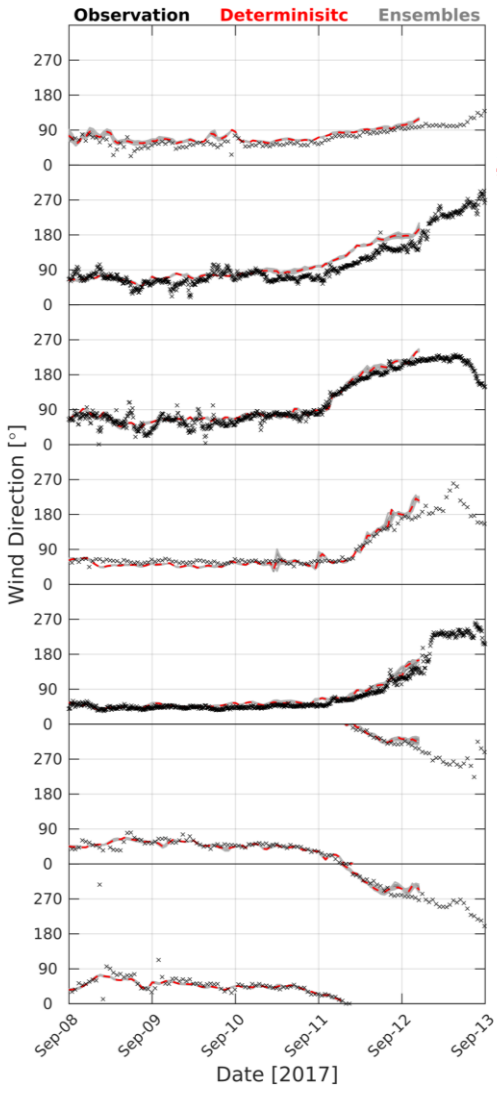
OFFSHORE VALIDATION (WW3)



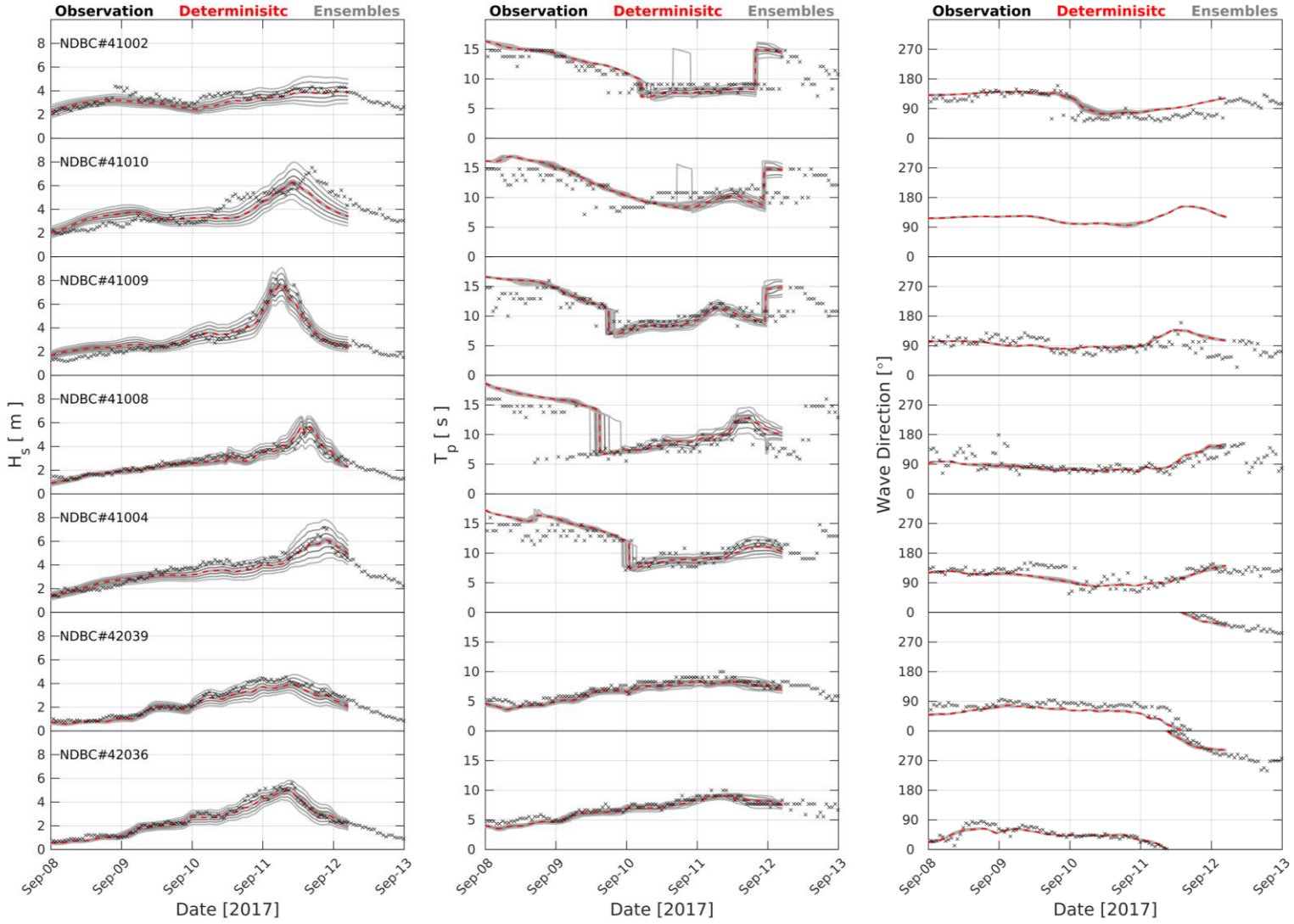
NEARSHORE VALIDATION (HWRF)





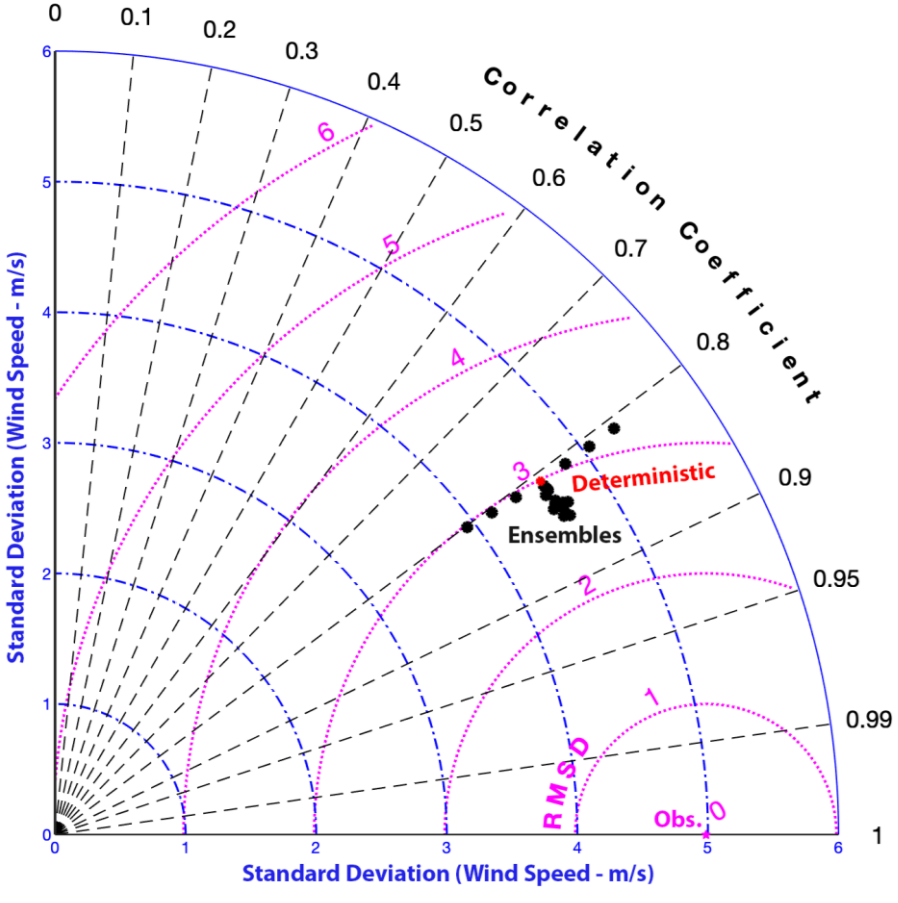


NEARSHORE VALIDATION (WW3)

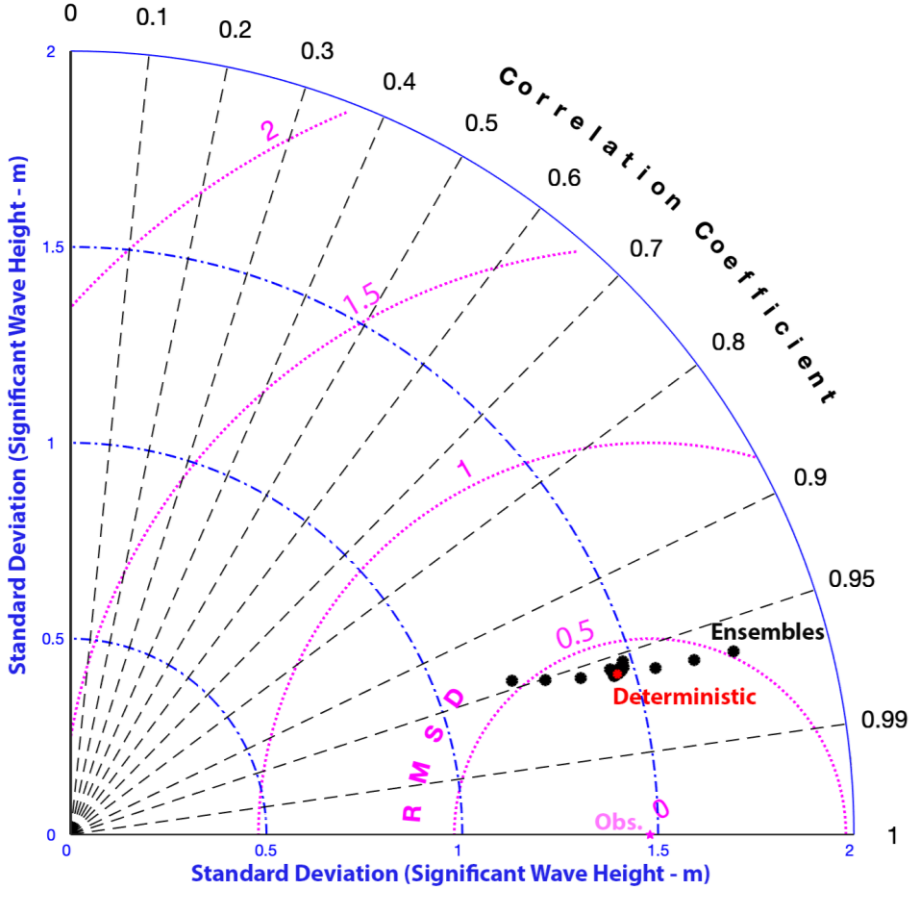


TAYLOR DIAGRAM

HWRF



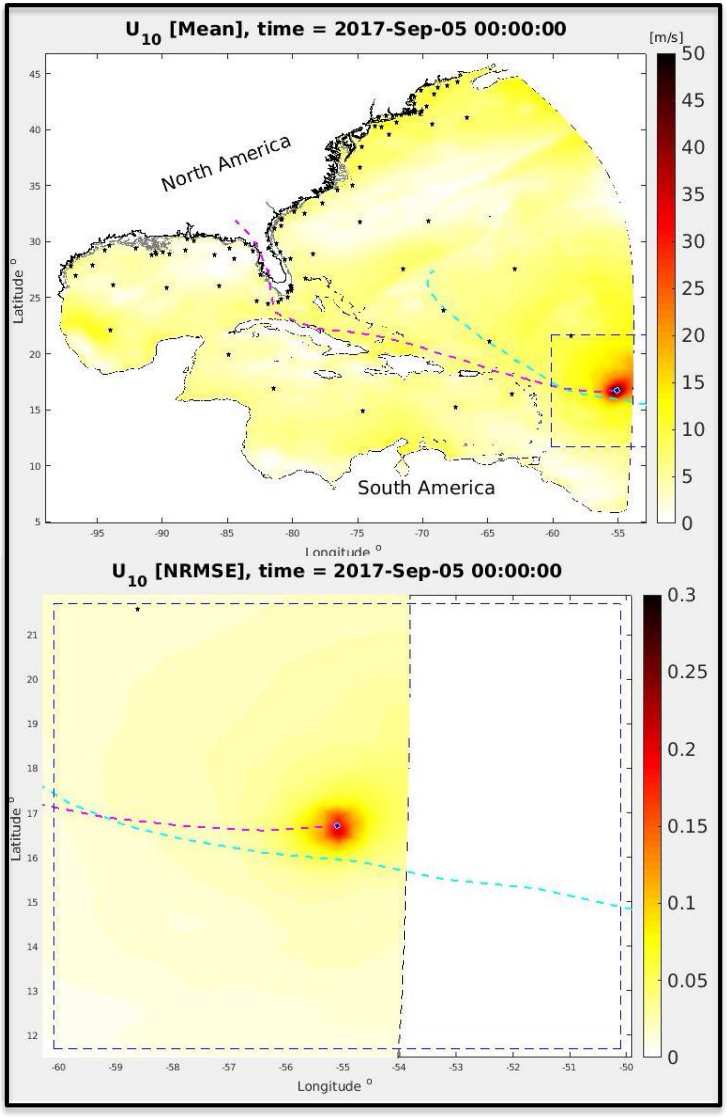
WW3

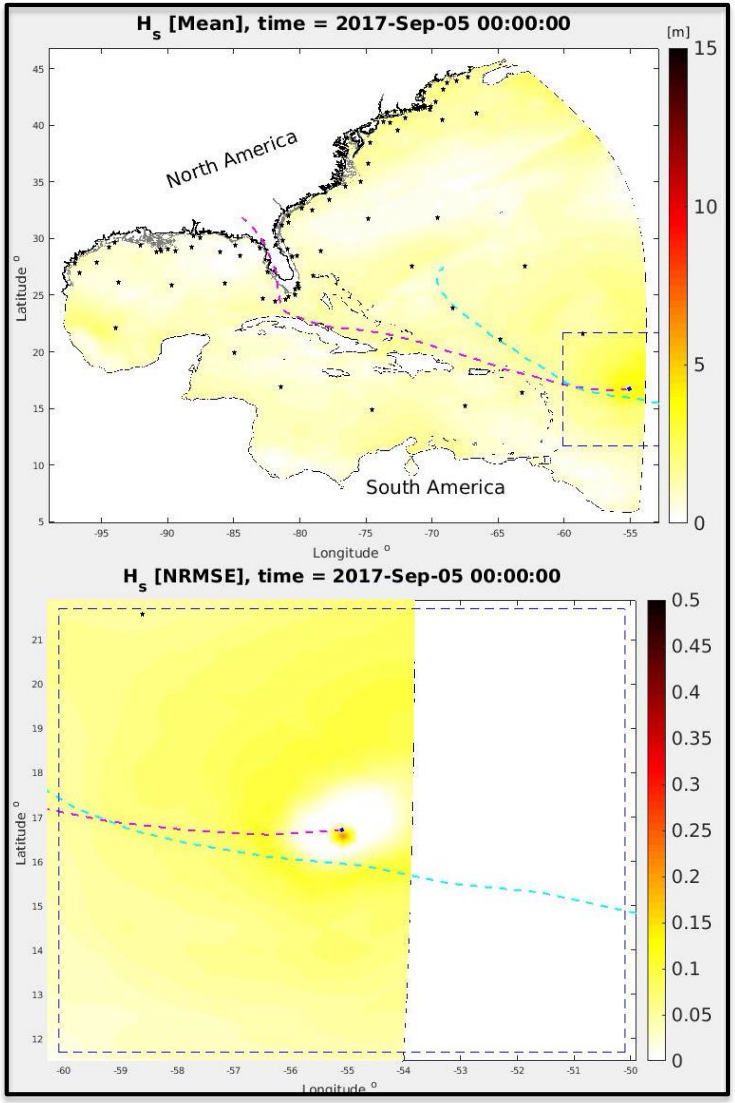


NRMSE

WW3

HWRF





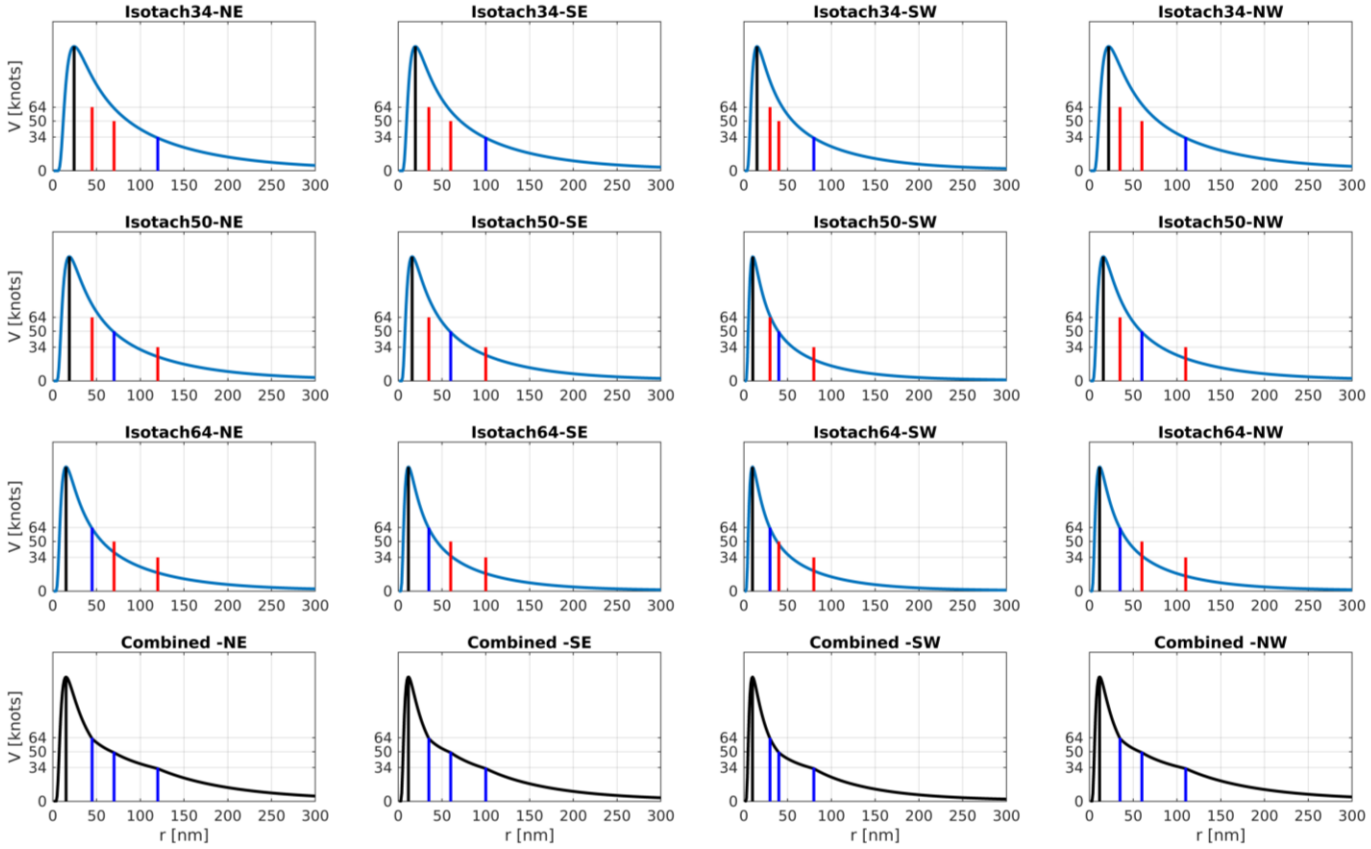
GENERALIZED ASYMMETRIC HOLLAND MODEL

$$\phi = 1 + \frac{1/R_0}{B_g(1 + 1/R_0)}$$

$$B_g = B\left(\frac{(1 + 1/R_0)e^{\phi - 1}}{\phi}\right)$$

$$\frac{\partial V_g}{\partial r} = 0, \qquad r = R_{max}$$
$$V_g = V_{max} \qquad r = R_{max}$$
$$V_g = 34 \qquad r = R_{34}$$
$$V_g = 50 \qquad r = R_{54}$$
$$V_g = 64 \qquad r = R_{64}$$

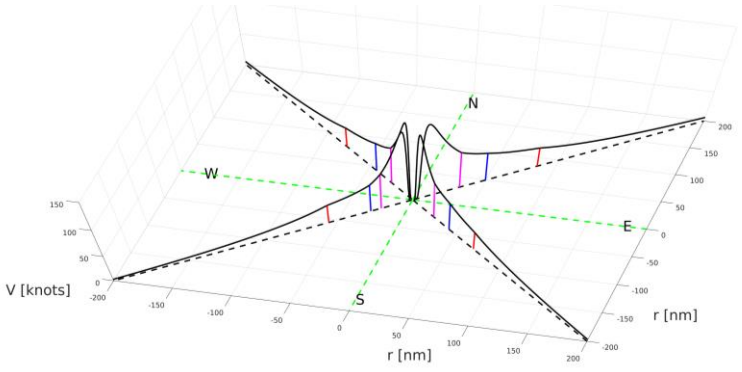
R_0 = Rossby number
P_c = Central Pressure
P_n = Background Pressure
ϕ = Intermediate factor

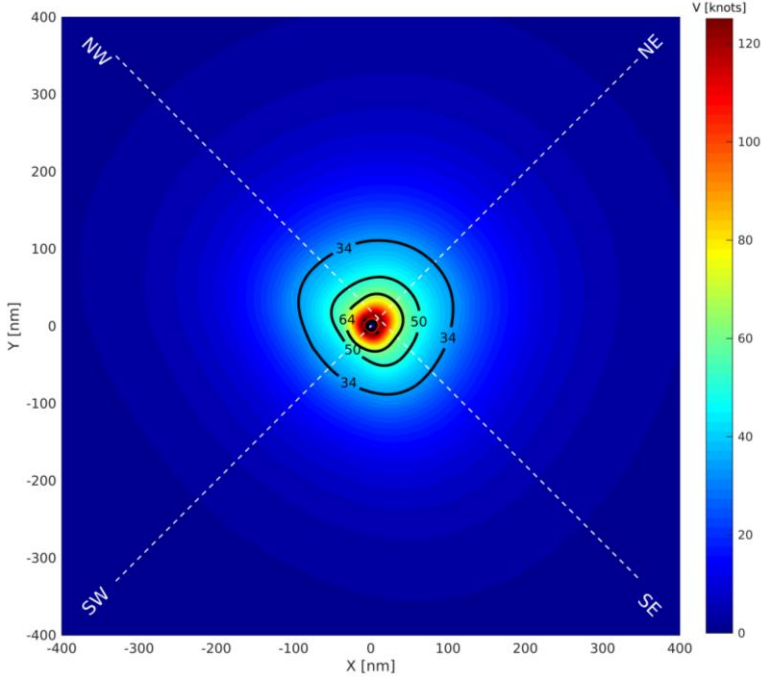


$$P(r) = P_c + (P_n - P_c)e^{-\phi\left(\frac{R_{max}}{r}\right)^{Bg}}$$

Gao et al, 2015

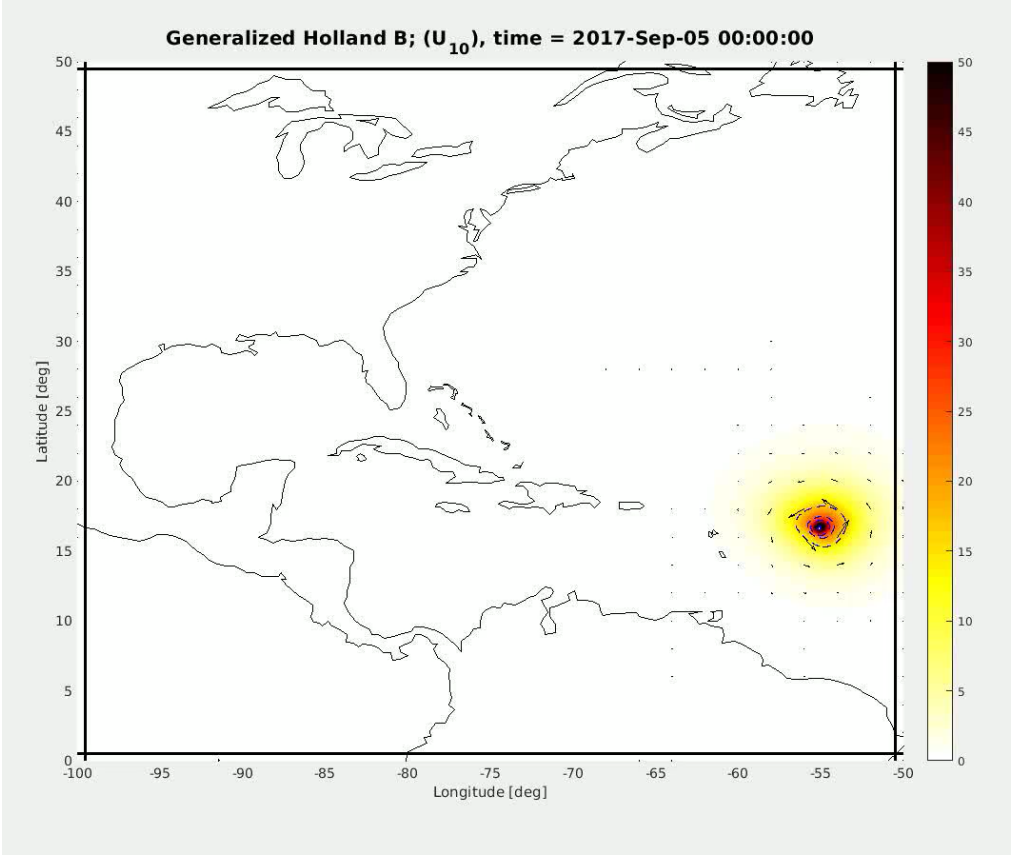
$$V_g(r) = \sqrt{V_{max}^2\left(1 + \frac{1}{R_0}\right)e^{\phi\left(1 - \left(\frac{R_{max}}{r}\right)B_g\right)}\left(\frac{R_{max}}{r}\right)^{B_g} + \left(\frac{rf}{2}\right)^2} - \left(\frac{rf}{2}\right)$$





Three further steps are performed on the V_g

I. The wind velocity at the top of the atmospheric boundary layer to U_{10}.
II. Sampling time adjustment from 1 min wind to 10 min winds.
III. Adding the tapered translation velocity.



CONCLUSION

① HWRF provides hourly gridded outputs on d2/d3 domains for 40 ensembles from t=0 to t=6 hr, which can be used for determining the distribution of wind and pressure fields. Error distribution can be assessed wherever observations exist and uncertainty can be shown for each grid point.

② HWRF provides the track, max wind speed, pressure at MSL and size of storm at t=0 and t=6 hr for 40 members. So the distribution of aforementioned parameters can be determined.

③ The same idea of #1 can be done for wave and surge, but we need continuous ensembles, which represent the HWRF model to force Wave-Surge Model (Modified HWRF or a parametric model).

④ Generalized HOLLAND B is a good candidate to generate adequate number of ensembles from 7 parameters. This combination should be assessed via sensitivity analysis for a case study.

⑤ HOLLAND B is a simplified model, which has 4 directions and does not have HWRF fanciness. The idea is using HWRF deterministic run for Wave-Surge deterministic simulation and wave-surge members, forced by HOLLAND B, for the uncertainty evaluation.

⑥ A tool in MATLAB is developed to perform statistical analysis on the HWRF ensembles.

⑦ This tool is extended to modify the HWRF deterministic run to generated ensembles members compatible with WW3 format from HWRF spread.

⑧ This tool is extended to generate atmospheric fields from TC vital (NHC or mean of HWRF) for the cone of hurricane and background from other atmospheric models.

⑨ The anaylsis on the hurricane Irma (2017) atmospheric and wave fields were performed to evaluate the spread of error and uncertainties migrating from upstream model to downstream one.

QUESTIONS?!?!?