Advanced Hurricane-research WRF (AHW) Retrospective Forecasts for HFIP

- Model Configuration
- Initial Impressions of Results
- Lessons Learned

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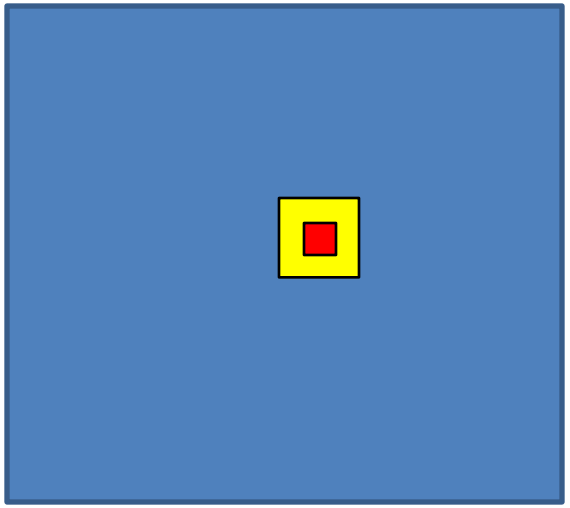
Model Configuration

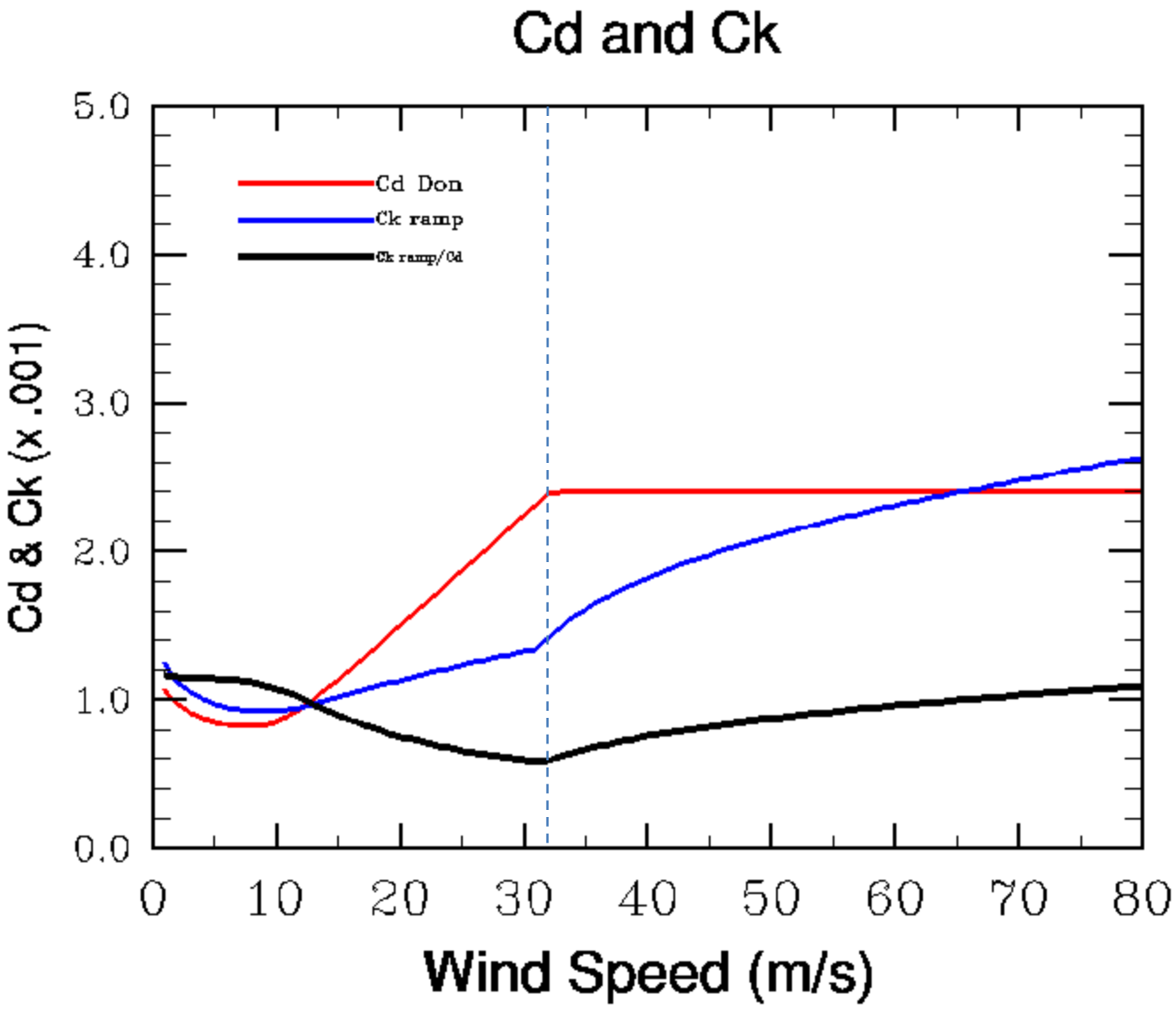
- Model
  - Based on WRF ARW 3.0
  - (a) 12 km (469 by 424) (MMM1)
  - (b)
    - 12 km (469 by 424)
    - 4 km (202 by 202), MMM4
    - 1.33 km (241 by 241), MMM3
  - 34 levels (stretched vertically)
  - 60 s time step on coarse grid



Model Configuration

- Physics

Cumulus	new Kain Fritsch (12 km only)
Microphysics	WSM5
PBL	YSU (1st-order)
Surface Layer	Monin-Obukov
Land Surface	5-layer thermal diffusion soil model
Radiation	RRTM (longwave)/Dudhia(shortwave)
Ocean	1-D mixed-layer model (with Coriolis)
Surface fluxes	Donelan drag: cap Cd at ~30 m/s Ck/Cd ~ 0.6-1.1


Cd and Ck
Cd Don
Ck ramp
Ck ramp/Cd
Cd & Ck (x .001)
5.0
4.0
3.0
2.0
1.0
0.0
0
10
20
30
40
50
60
70
80
Wind Speed (m/s)

Model Configuration

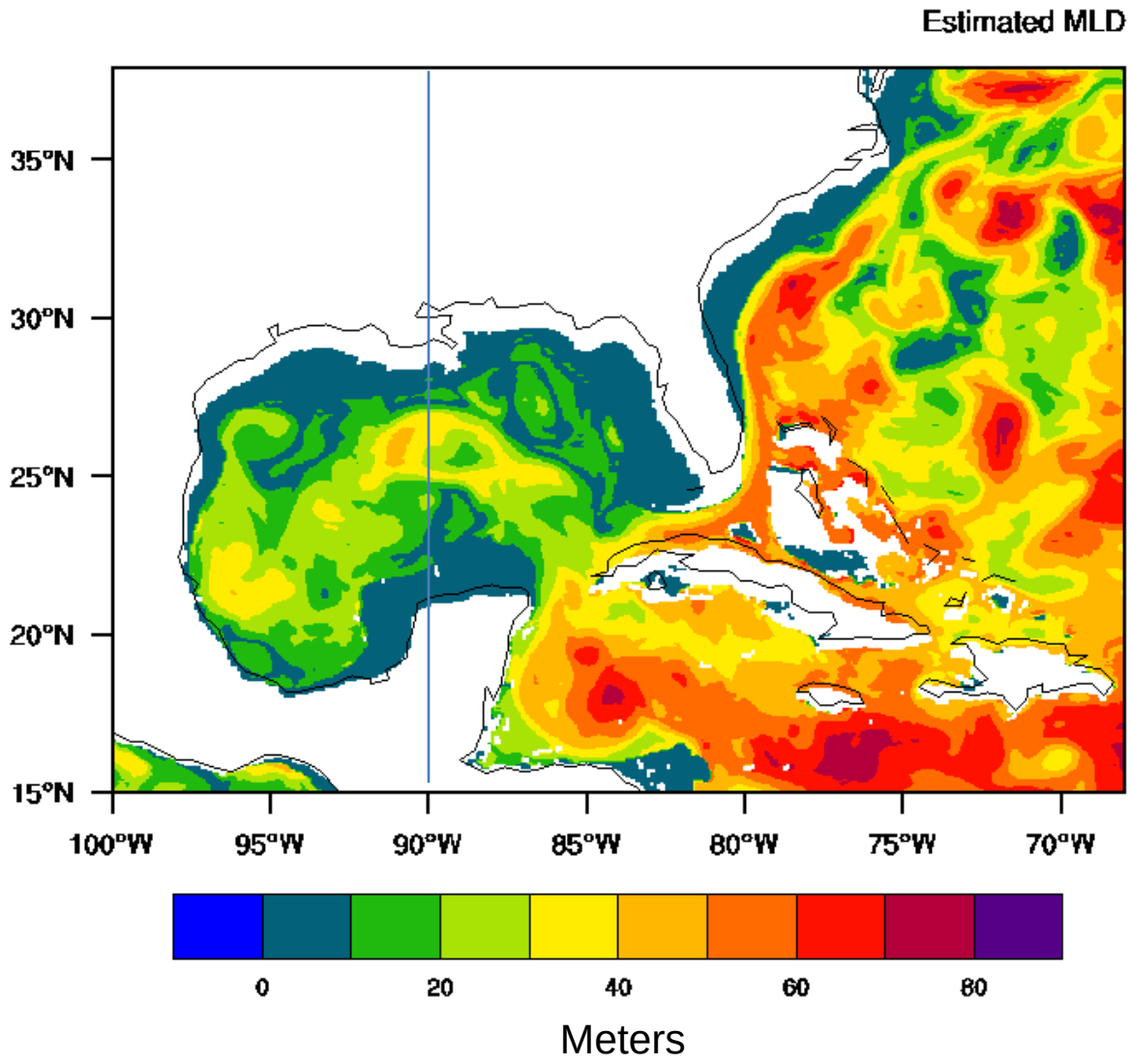
- Ocean feedback
  - Use heat content to determine an effective mixed-layer depth.
  - Horizontal variation of MLD “mirrors” variation of heat content.

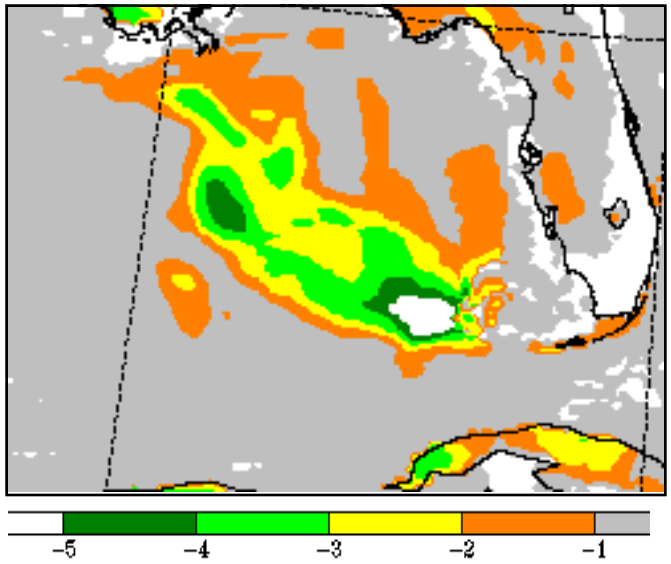
$$D = Z - \left(\frac{2(T_s Z - H)}{\Gamma} \right)^{\frac{1}{2}}$$

  - D=MLD, T_s=SST, Z=100 m, G=0.15K/m, H=Heat Content

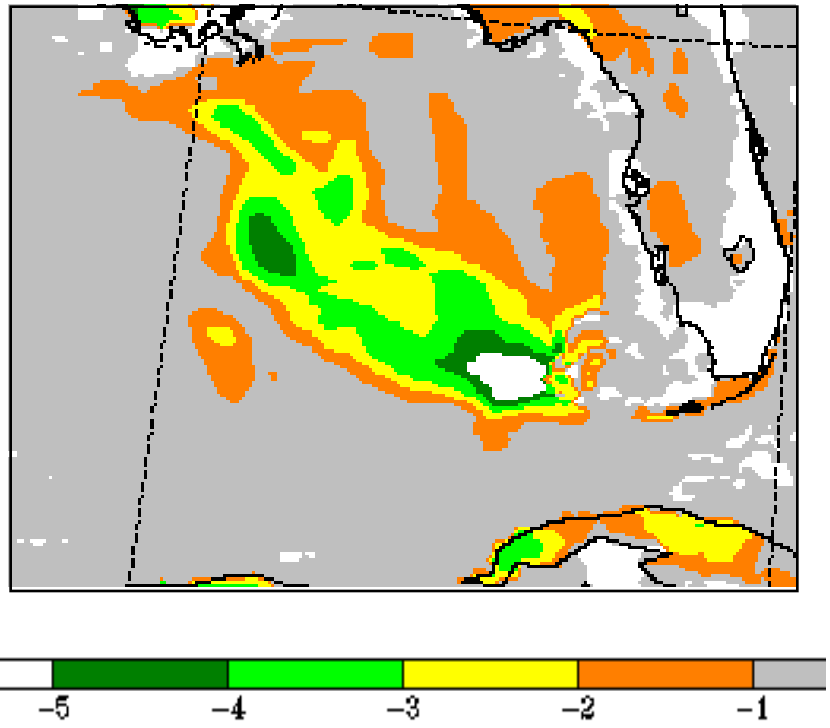
$$H = \int_{Z}^{0} T dz$$

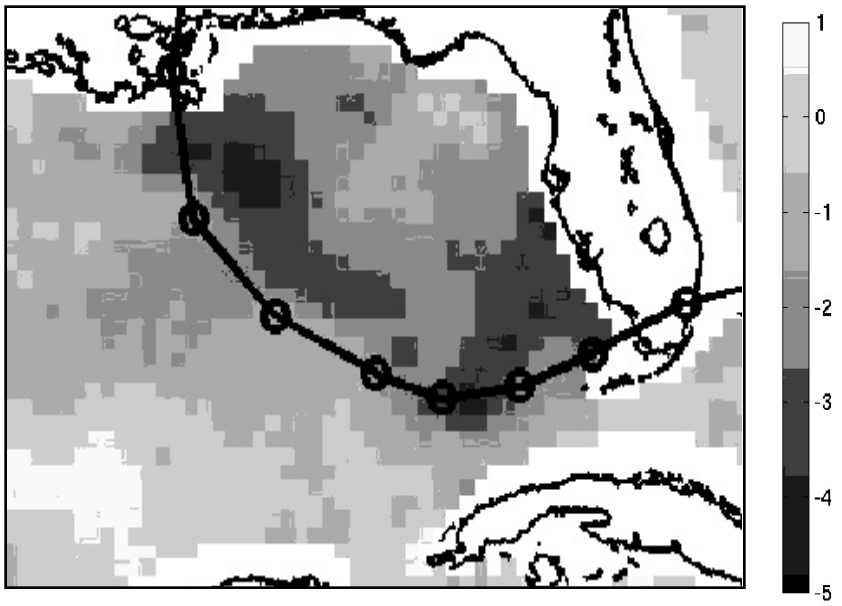
Ocean MLD


Estimated MLD
35°N
30°N
25°N
20°N
15°N
100°W
95°W
90°W
85°W
80°W
75°W
70°W
0
20
40
60
80
Meters


−5
−4
−3
−2
−1

SST Change: Katrina





SST after minus SST before (K)

Model Configuration

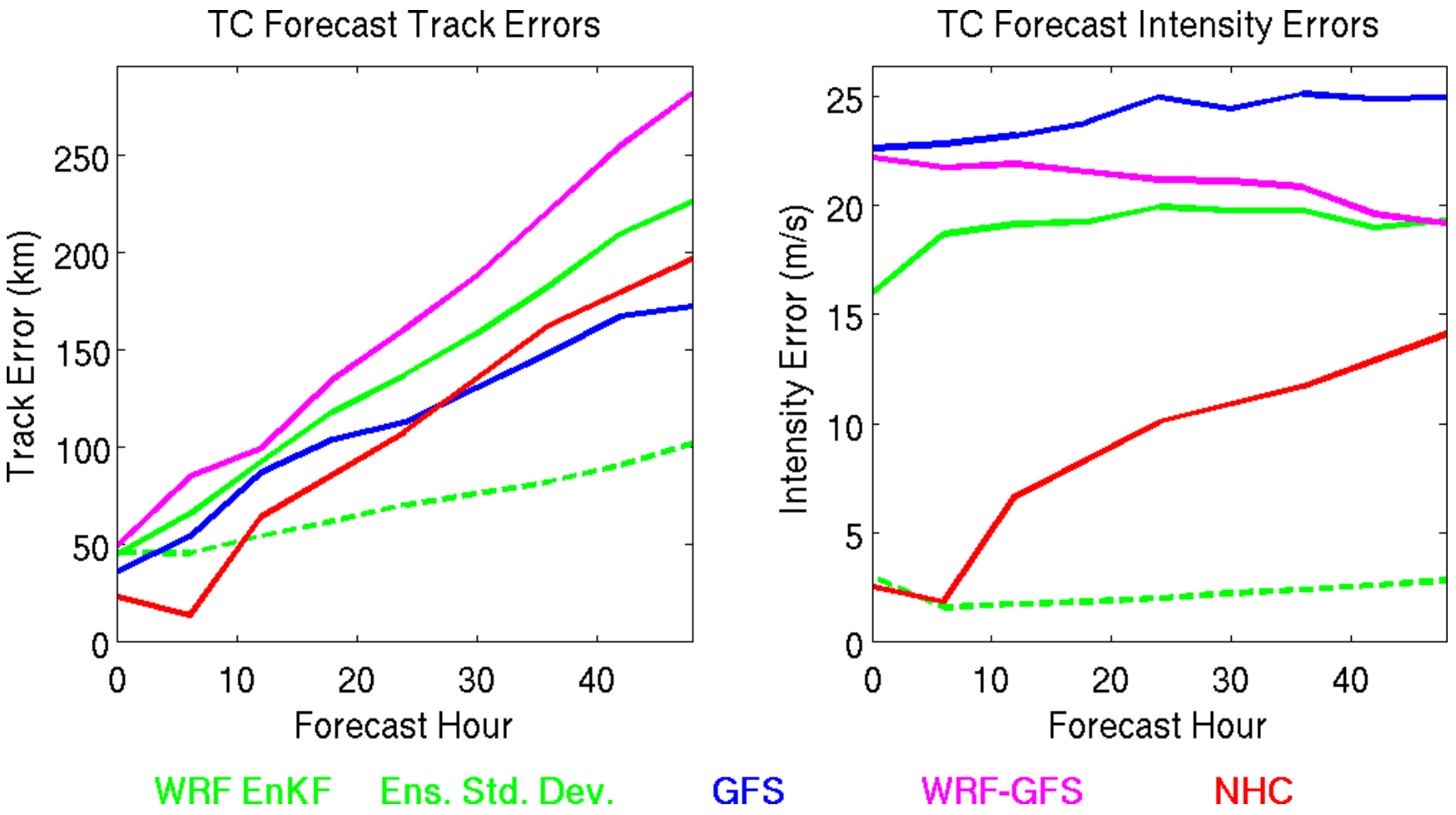
- Initialization
  - EnKF, 96 members
  - 6-hour cycling mode
  - 36-km grid
  - Assimilating surface pressure, rawinsonde (including G-IV dropsondes), ACARS, cloud motion vectors and tropical cyclone best track data each six hours.
  - Six-hour GFS forecasts on lateral boundaries
  - Initialized roughly two days prior to depression stage
  - Balanced perturbations from WRF-Var added GFS 36-h forecast*

*Using an old forecast with high amplitude perturbations helps the ensemble develop a flow-dependent ensemble quicker than starting from short-term forecasts.

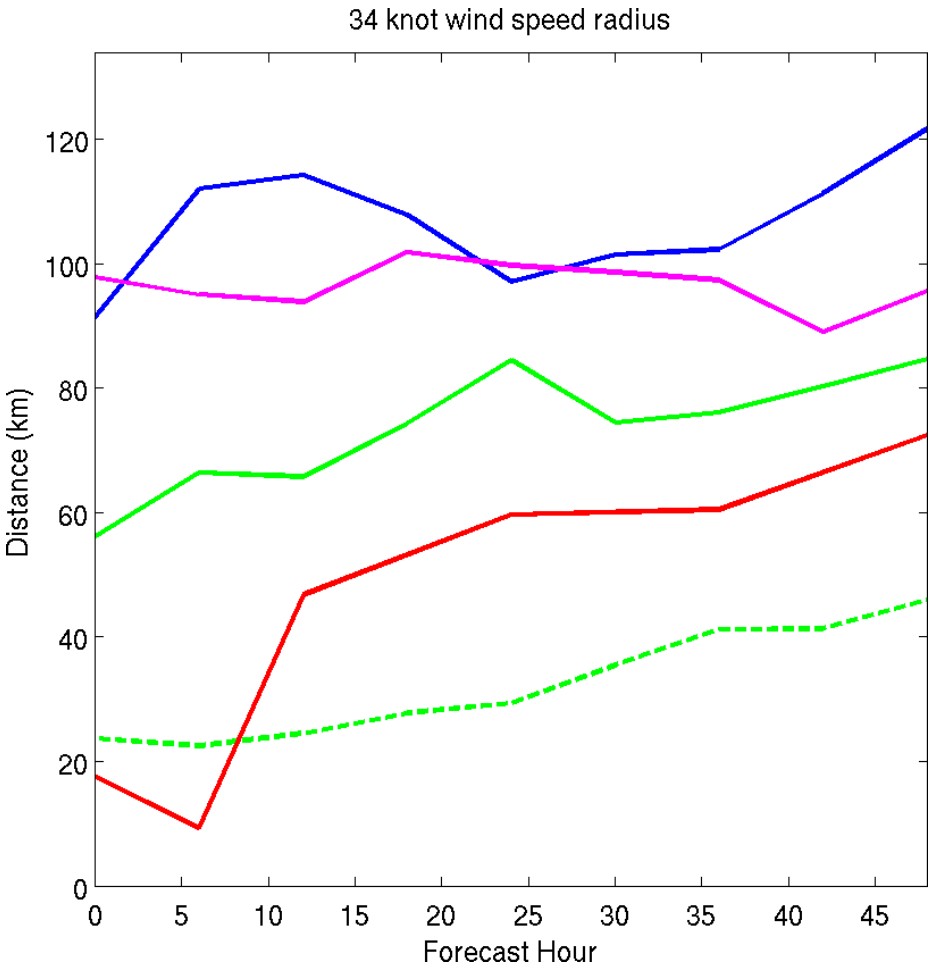
Initial Results: Ensemble

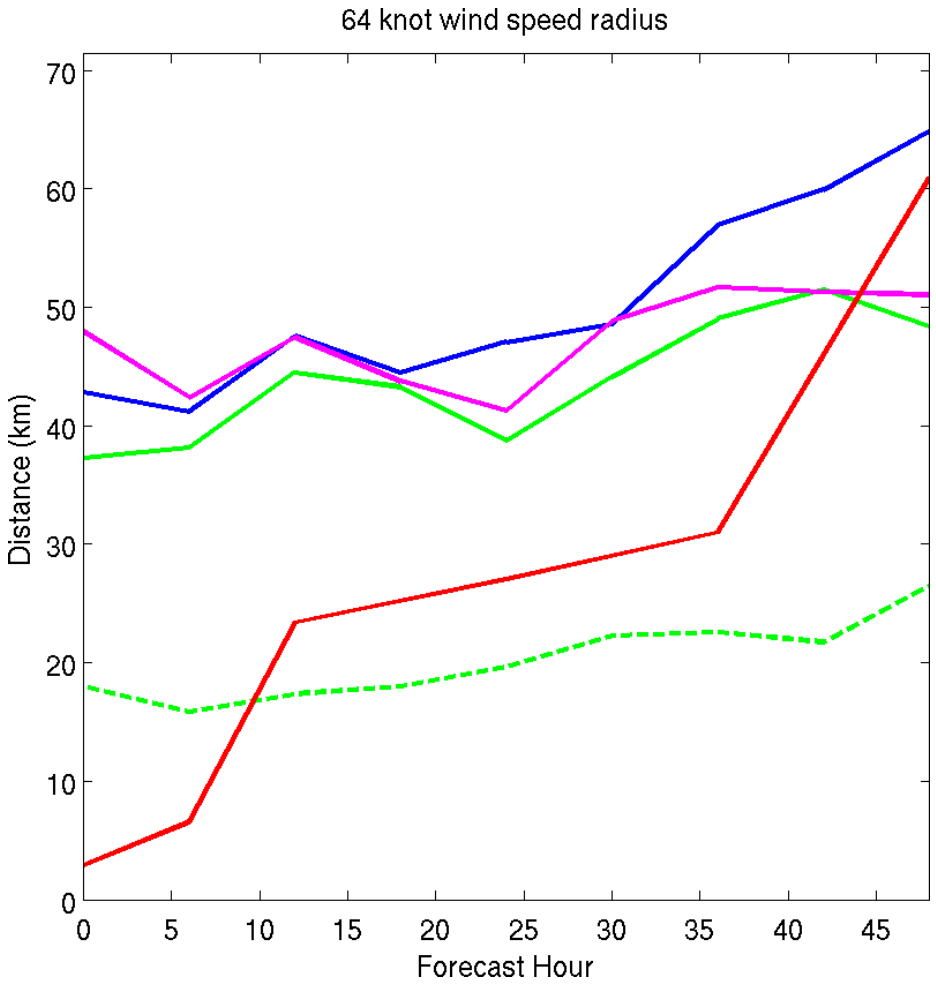
- Ensemble: Limitations in representing intensity and structure in initial condition
- Generally much smoother start to high-res. with cycling than with cold start.
- Reasonable predictability and small bias for TS-force wind radius.

RMS errors


TC Forecast Track Errors
Track Error (km)
0
50
100
150
200
250
0
10
20
30
40
Forecast Hour
TC Forecast Intensity Errors
Intensity Error (m/s)
0
5
10
15
20
25
0
10
20
30
40
Forecast Hour
WRF EnKF
Ens. Std. Dev.
GFS
WRF-GFS
NHC

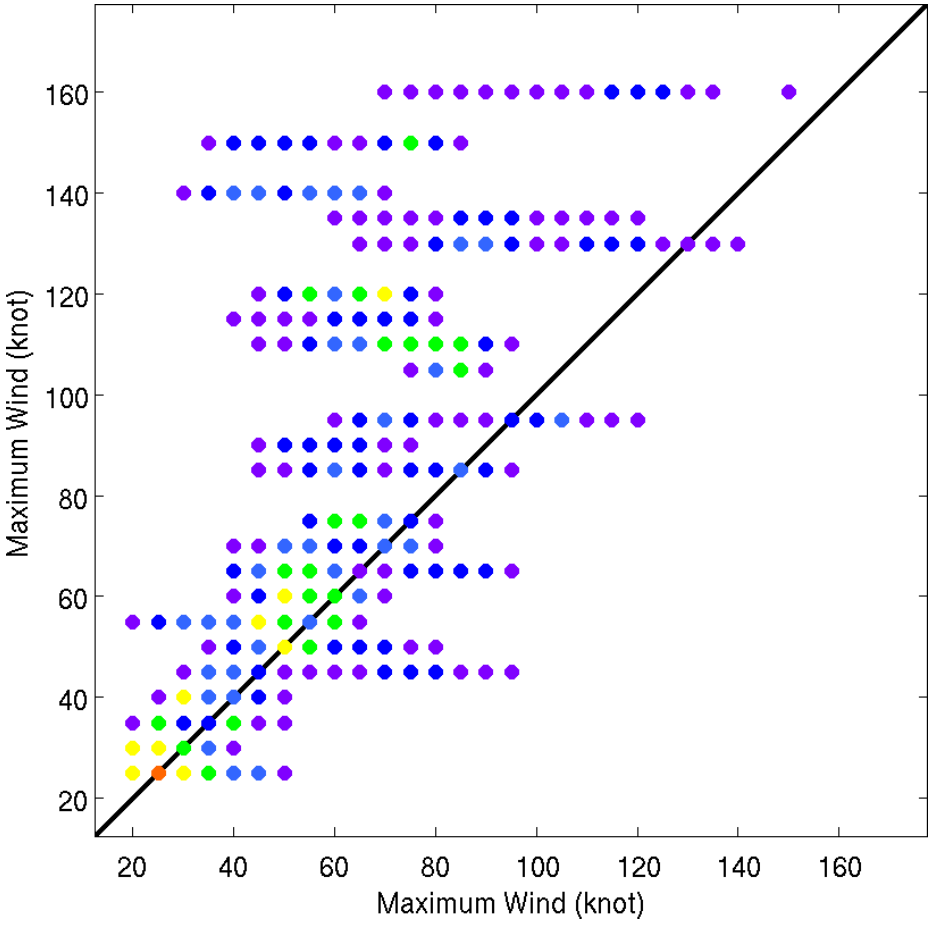
Wind Radii Errors



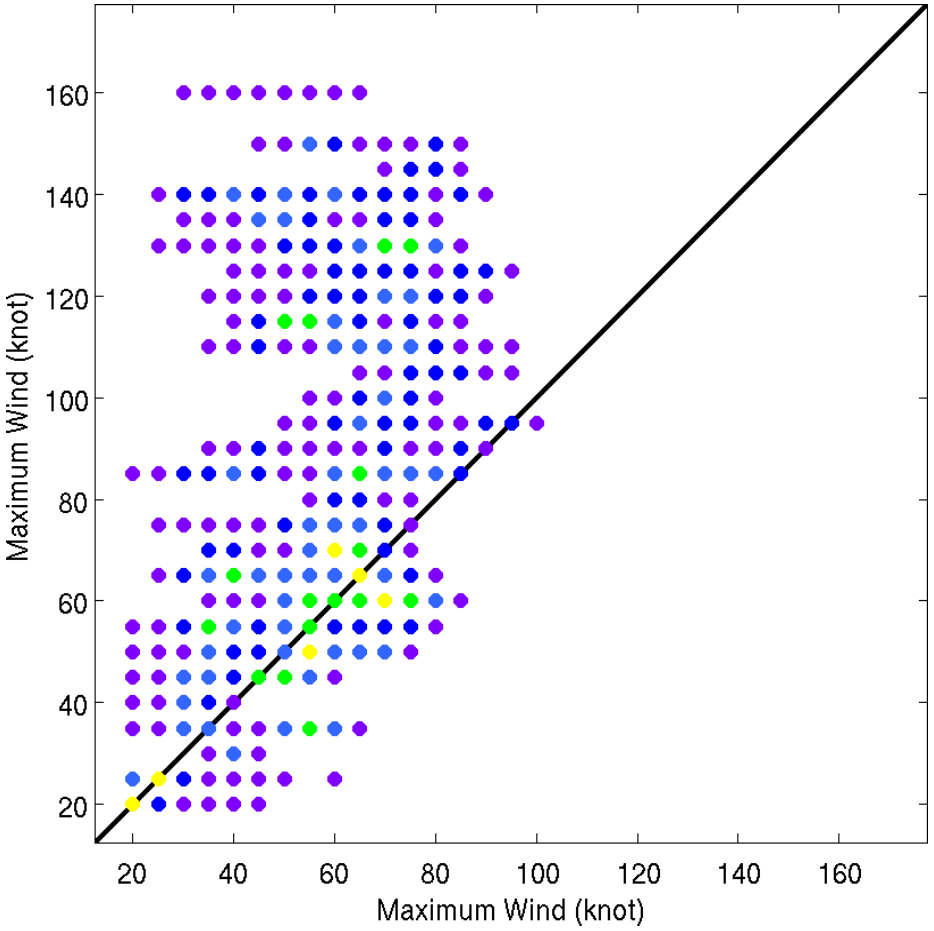


Intensity Verification PDFs

Analysis



36-48 Hour Forecast

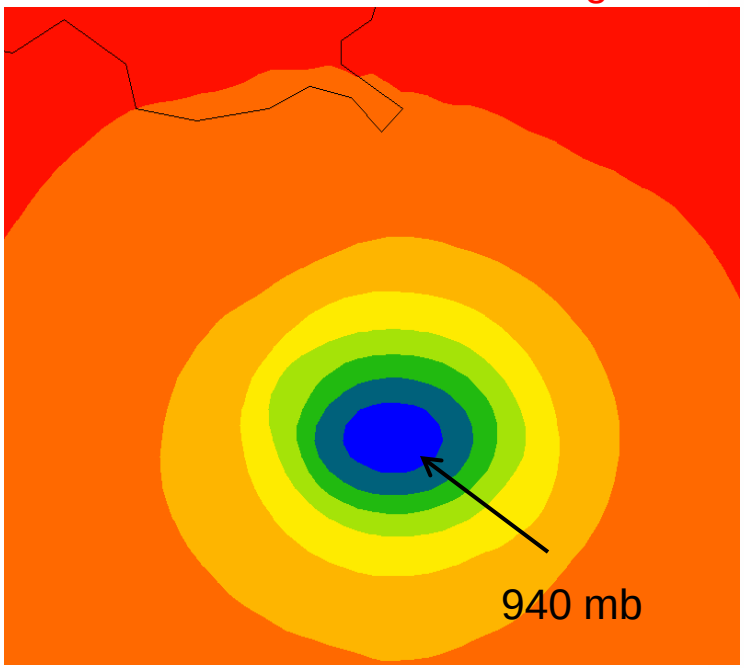


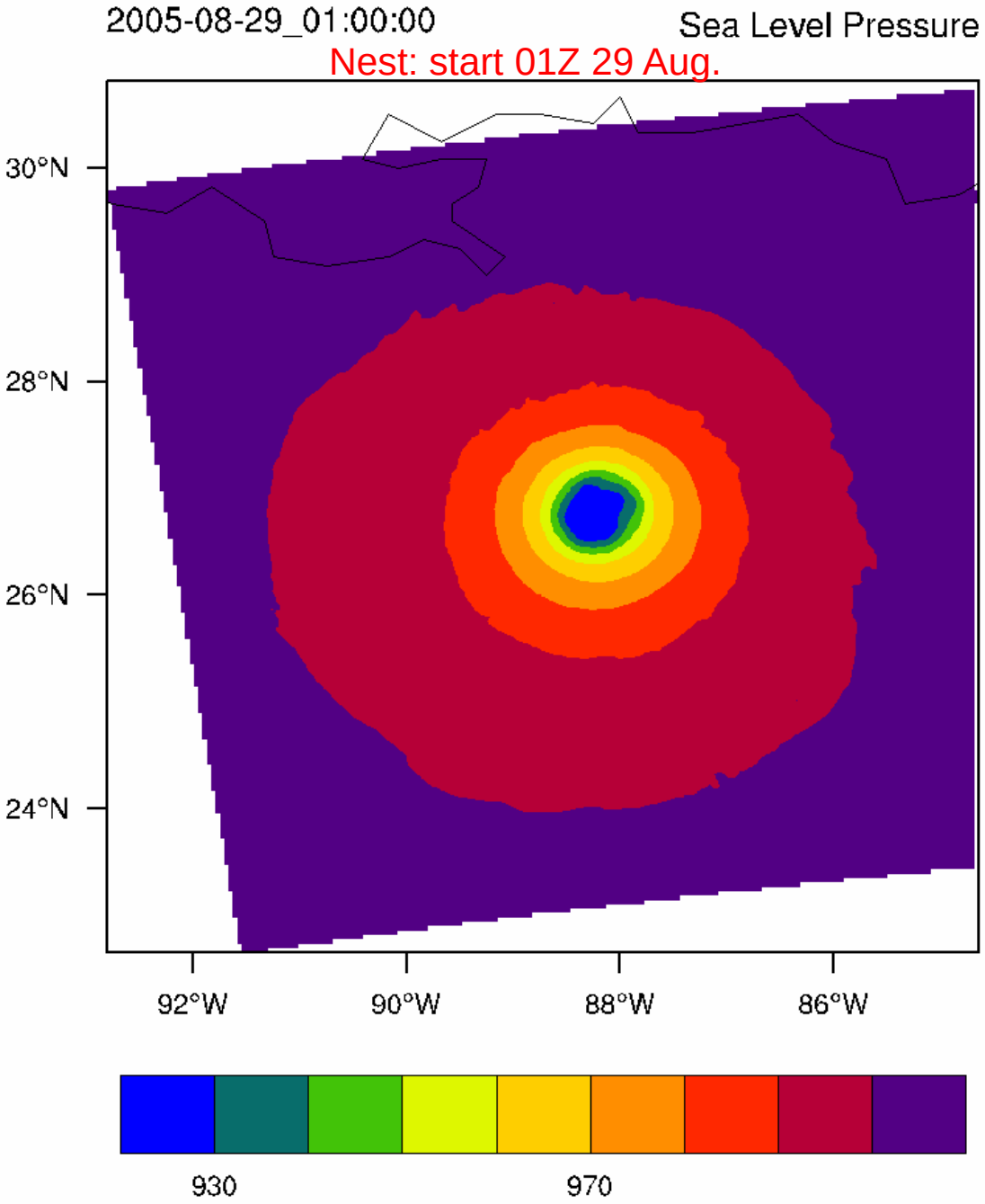
Purple: $0 \le p \le 0.0025$; dark blue: $0.0025 \le p \le 0.005$, light blue: $0.005 \le p \le 0.01$; green: $0.01 \le p \le 0.015$, yellow $0.015 \le p \le 0.025$, orange $0.025 \le p \le 0.05$, red $p \ge 0.05$

Katrina

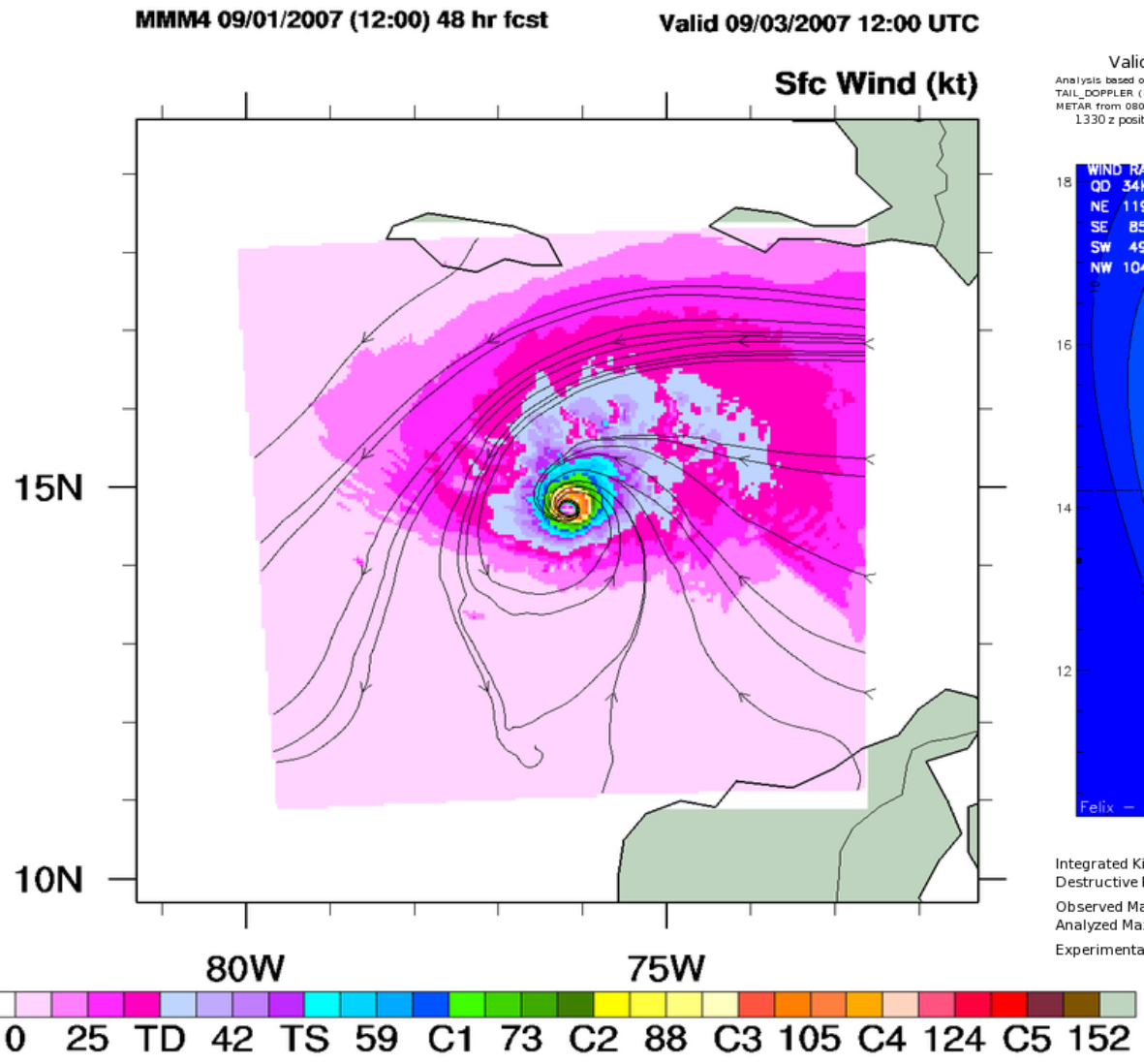
- 12-km wanted to produce elliptical cores. 1.33 km showed various structures, most of which highly transient.
- Track of 12-km systematically west of 1.33-km track. This turned out to be better.

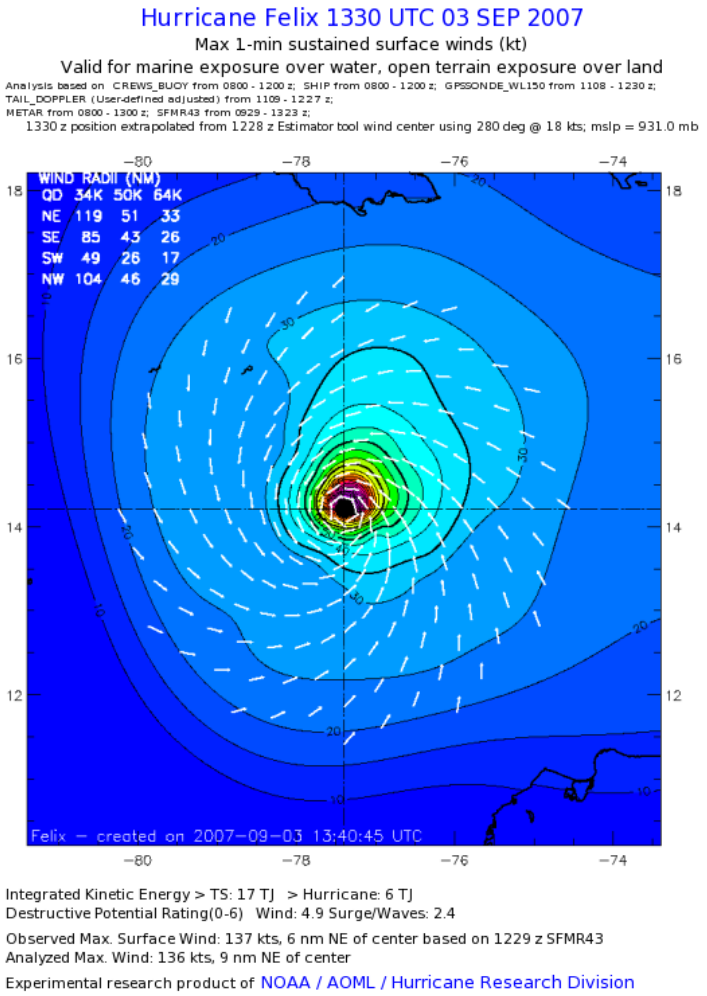
12 km: start 05Z 29 Aug.

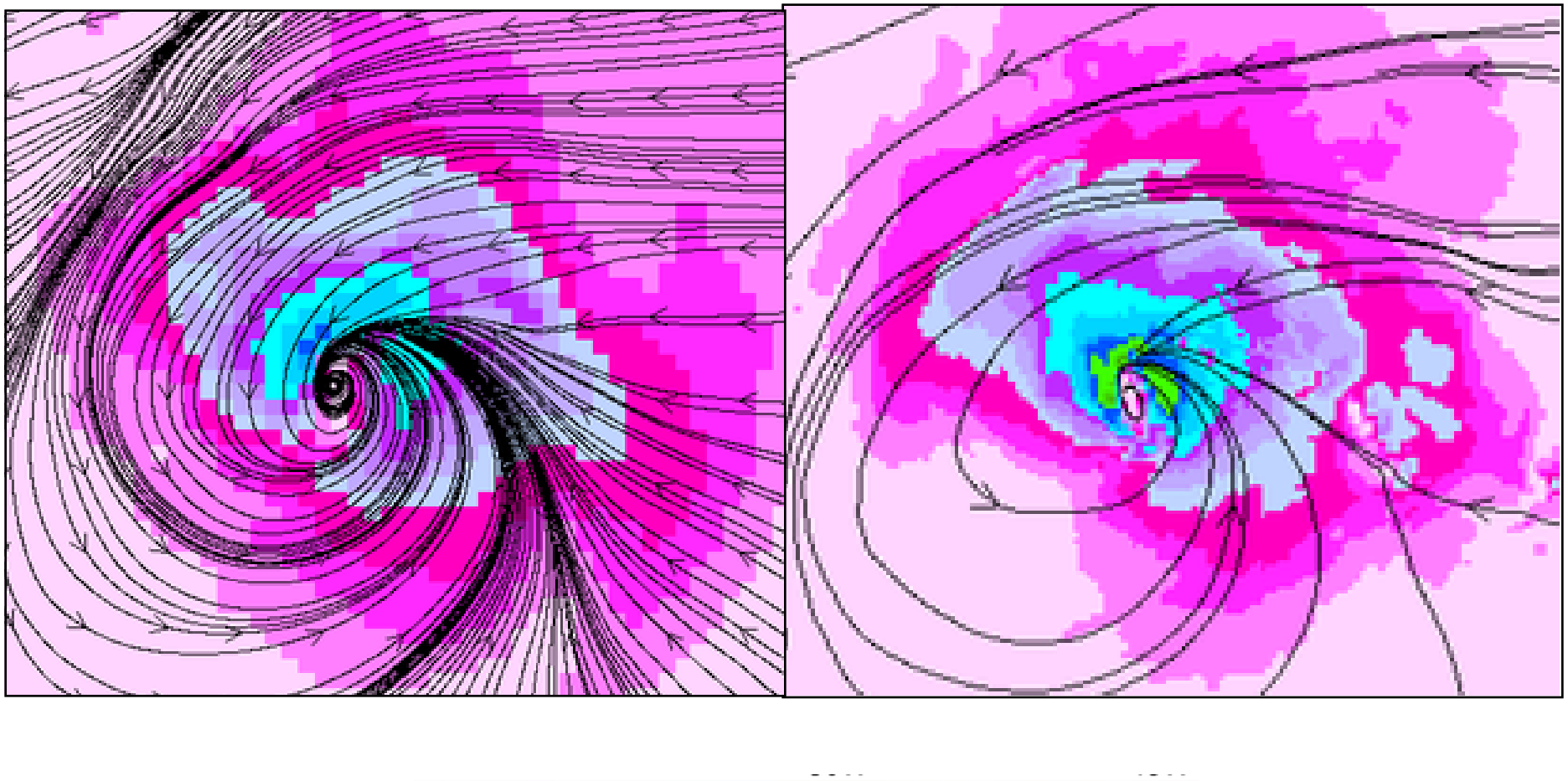




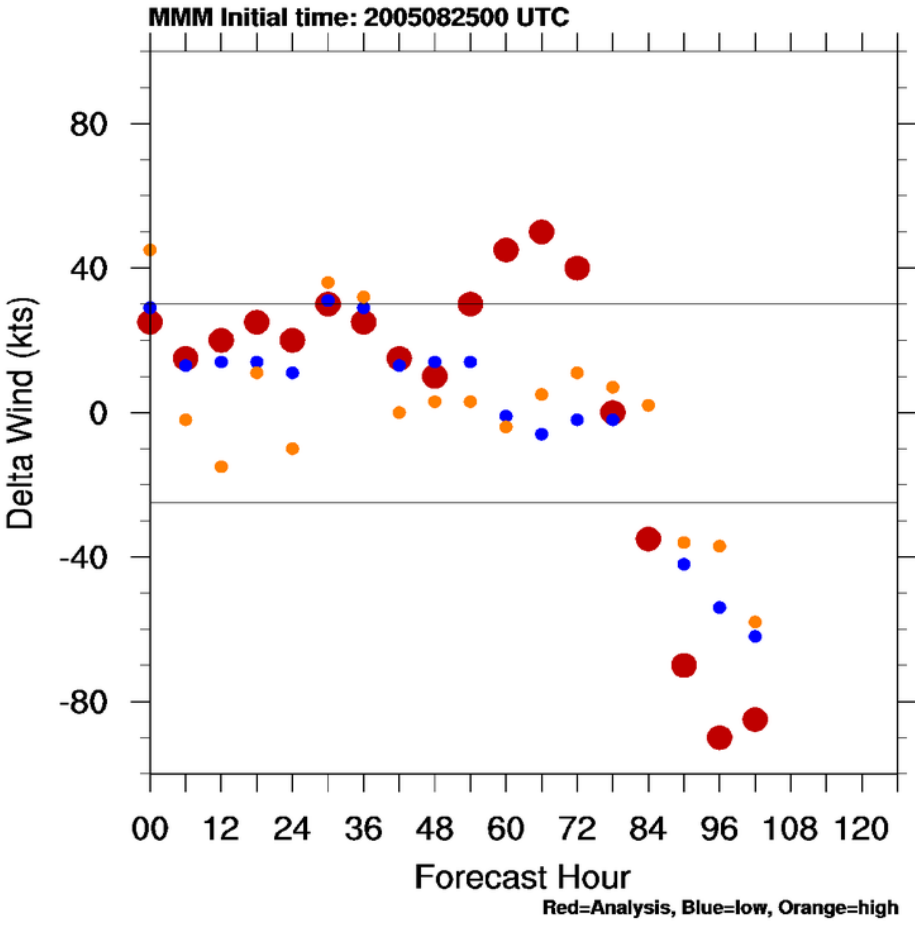
Felix: small inner core

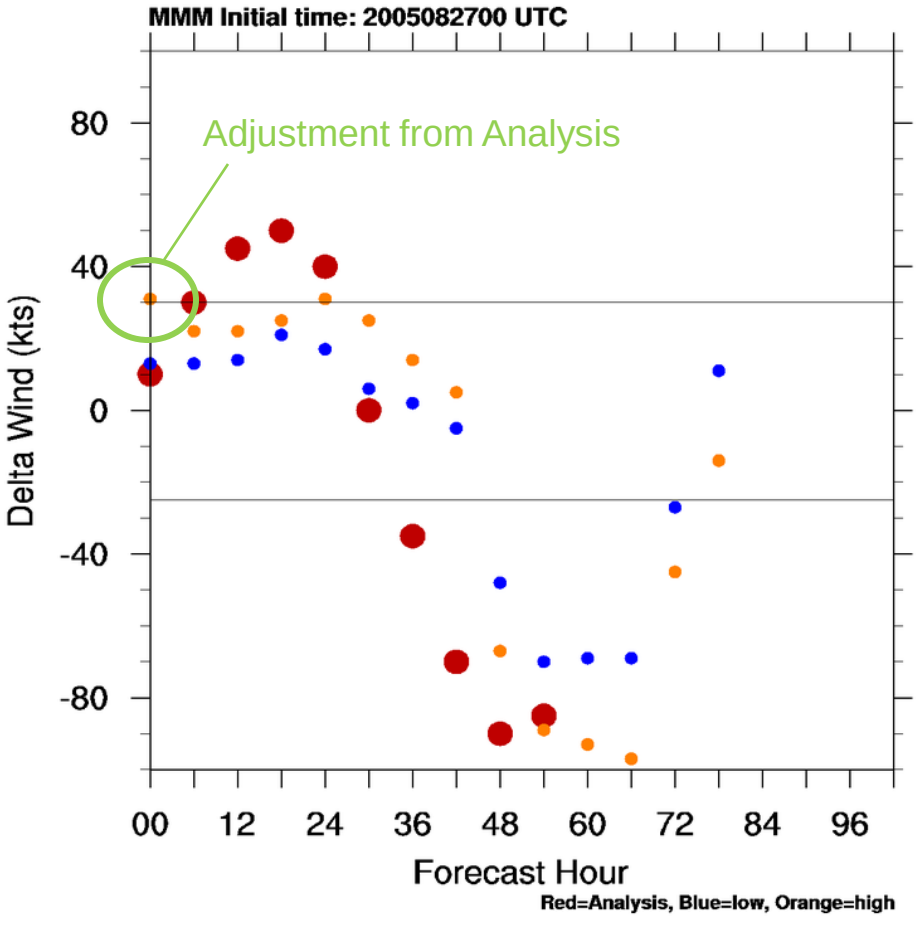





0 25 TD 42 TS 59 C1 73 C2 88 C3 105 C4 124

Intensity Change: Katrina



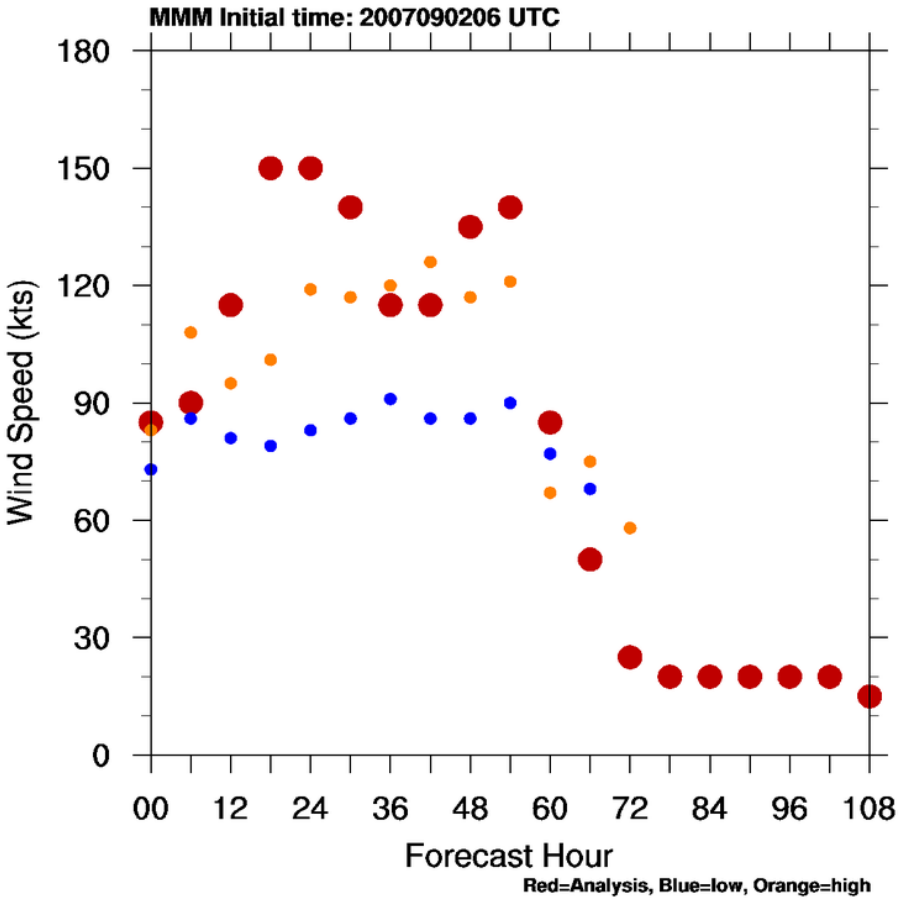


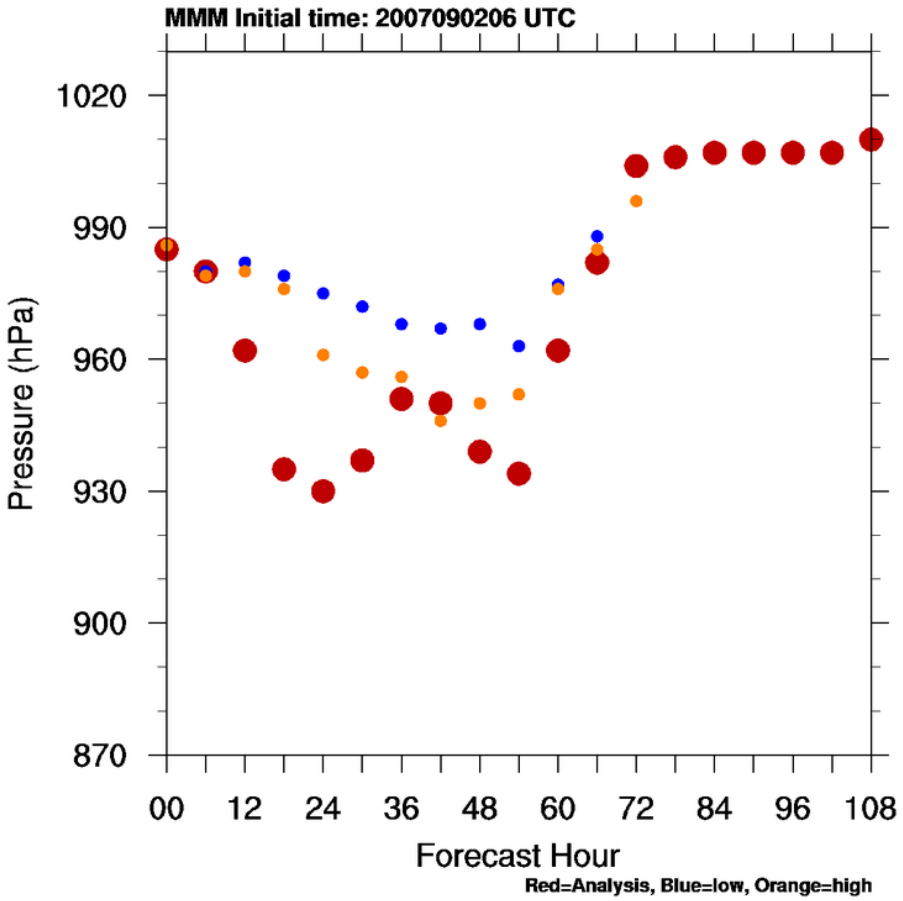
Hypothesis:

Intensity-change predictability limited to ~ 2 days or less.

Felix

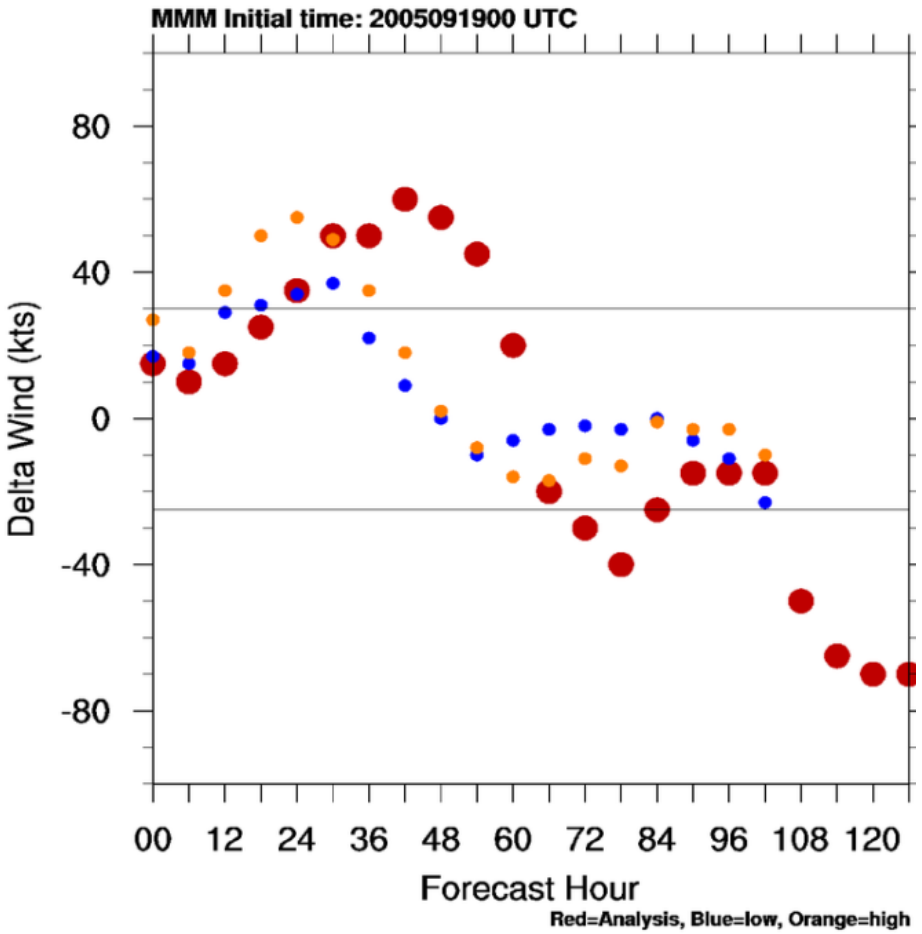
- Coarse-resolution struggles
- Short-time-scale fluctuations of intensity missed

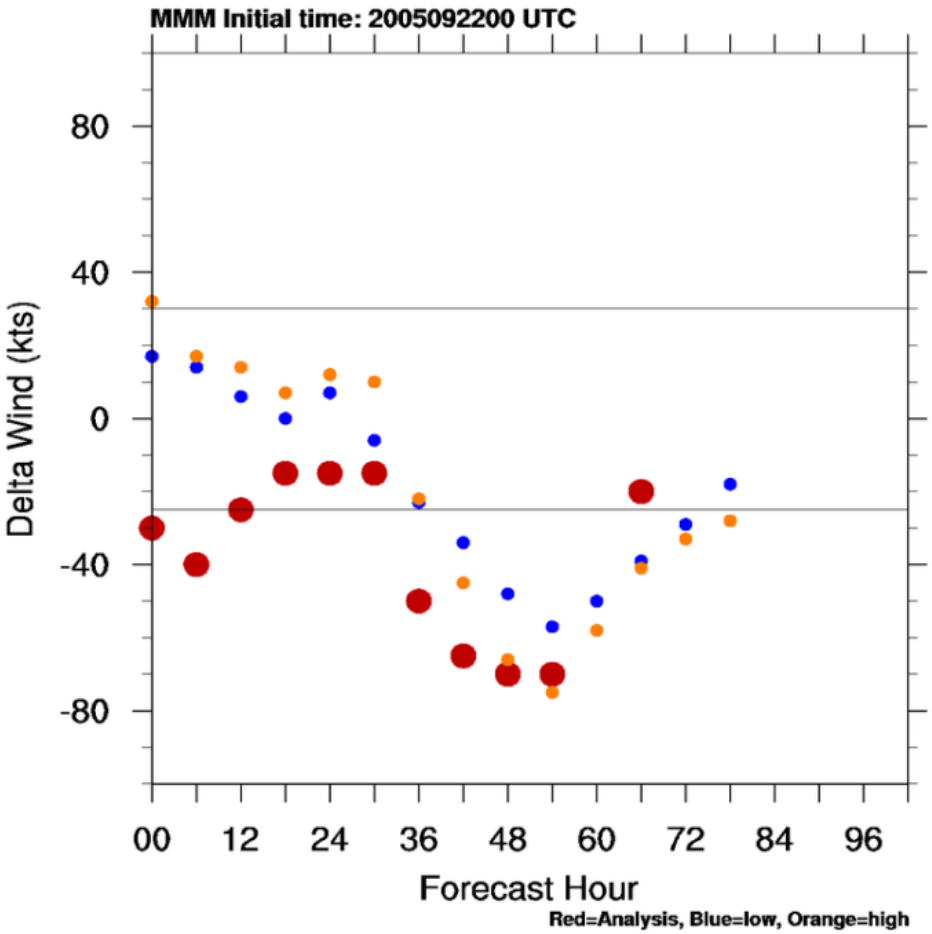


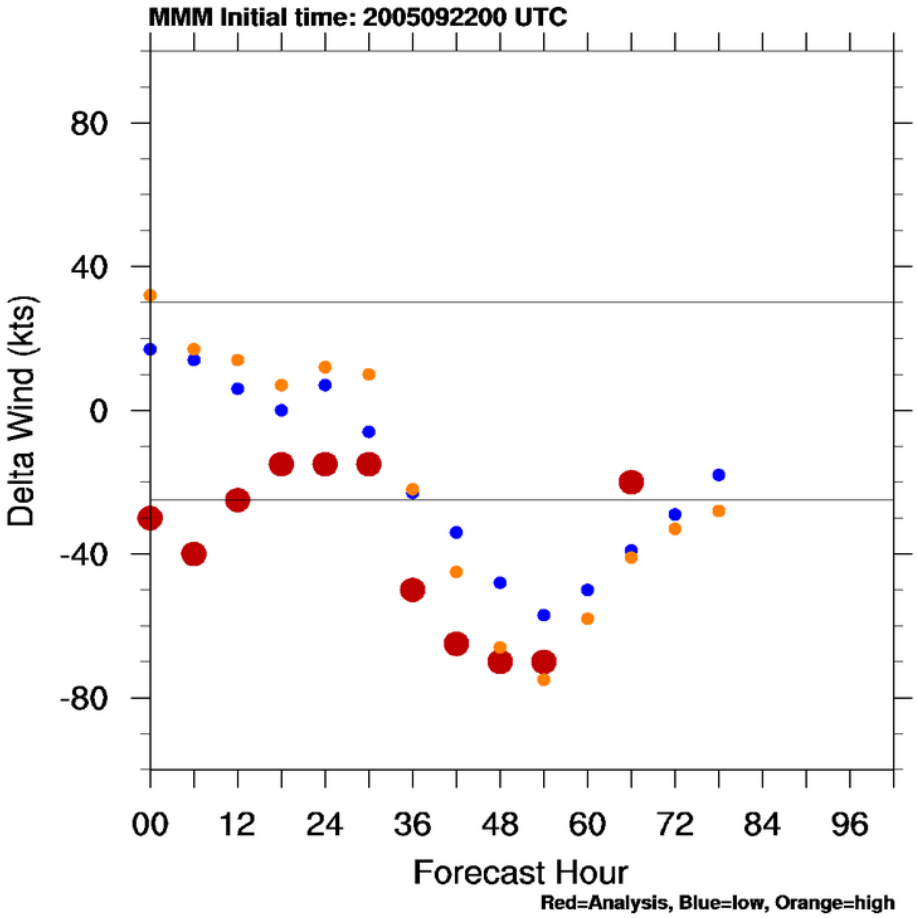


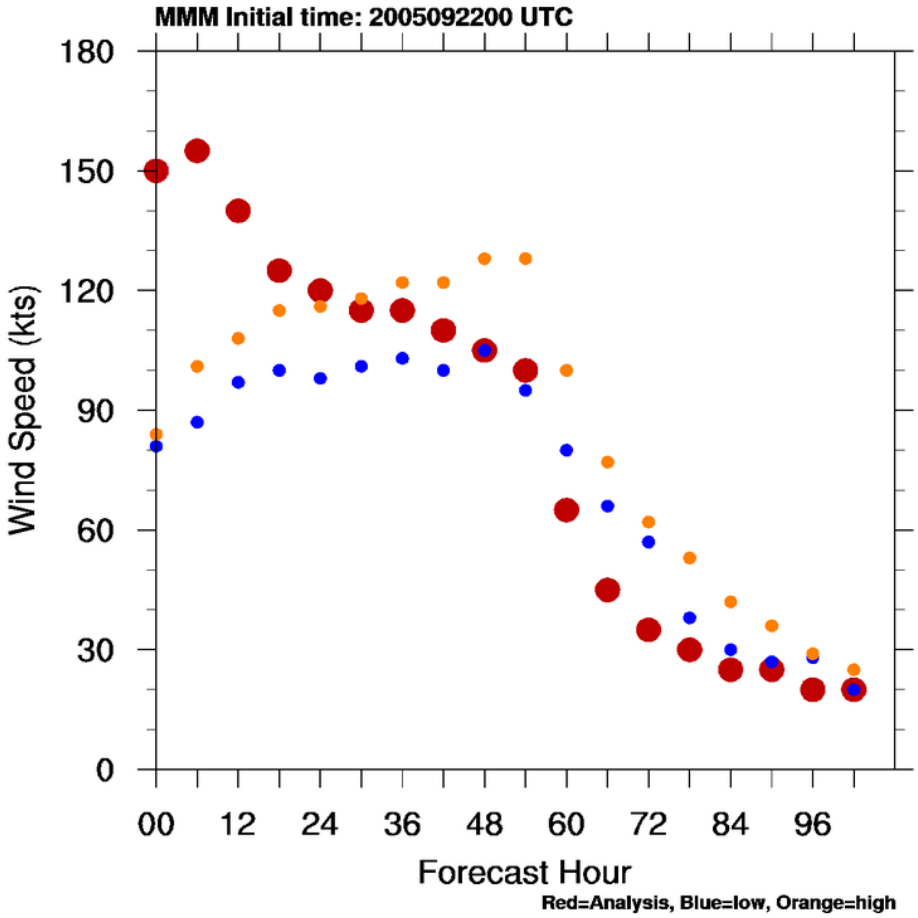
Rita:

Analysis deficient near maximum intensity

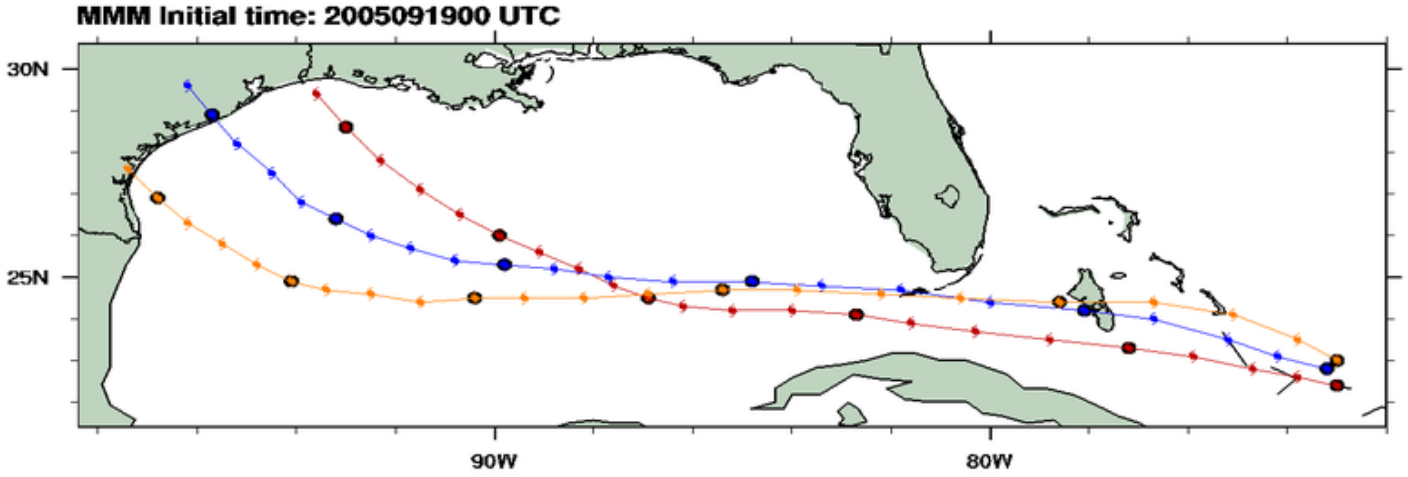





MMM Initial time: 2005092200 UTC
Delta Wind (kts)
80
40
0
-40
-80
00
12
24
36
48
60
72
84
96
Forecast Hour
Red=Analysis, Blue=low, Orange=high

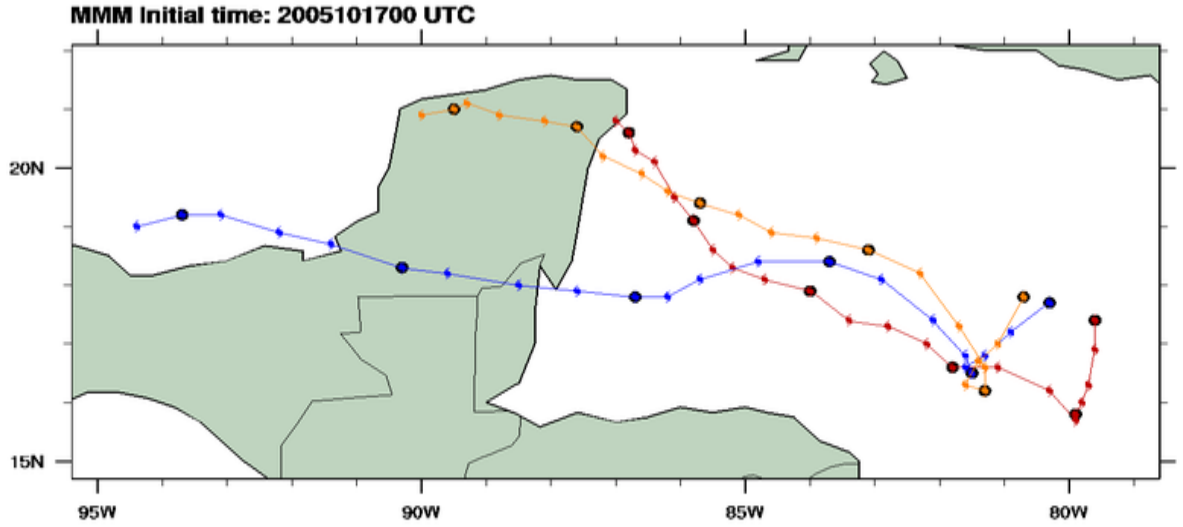

MMM Initial time: 2005092200 UTC
Wind Speed (kts)
180
150
120
90
60
30
0
00
12
24
36
48
60
72
84
96
Forecast Hour
Red=Analysis, Blue=low, Orange=high

Track: Either one can be better



Red=Analysis, Blue=low, Orange=high

Black dots every 24 hours starting at initial time



Red=Analysis, Blue=low, Orange=high

Black dots every 24 hours starting at initial time

Lessons Learned

- No matter how long you think it will take, it will take longer.
- Ocean feedback took a lot of time to implement
- High res. produces lots of interesting structure. Not sure how much of it is right, but it looks plausible.
- Running large outer domain a bigger pain than originally thought.
- Ensemble initialization very promising, but spread still too small and model bias can be large.
- Case-to-case variability is large, but within-case performance of 12-km vs. 1.33 km fairly consistent.