

Predicting Hurricanes with Explicit Convection:

The Advanced Hurricane-research WRF (AHW)

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Acknowledgements:

Wei Wang, Jimy Dudhia, Sherrie Fredrick, Steven Cavallo, Chris Snyder (NCAR)

Ryan Torn (U. Albany SUNY)

NCAR CISL for computing support

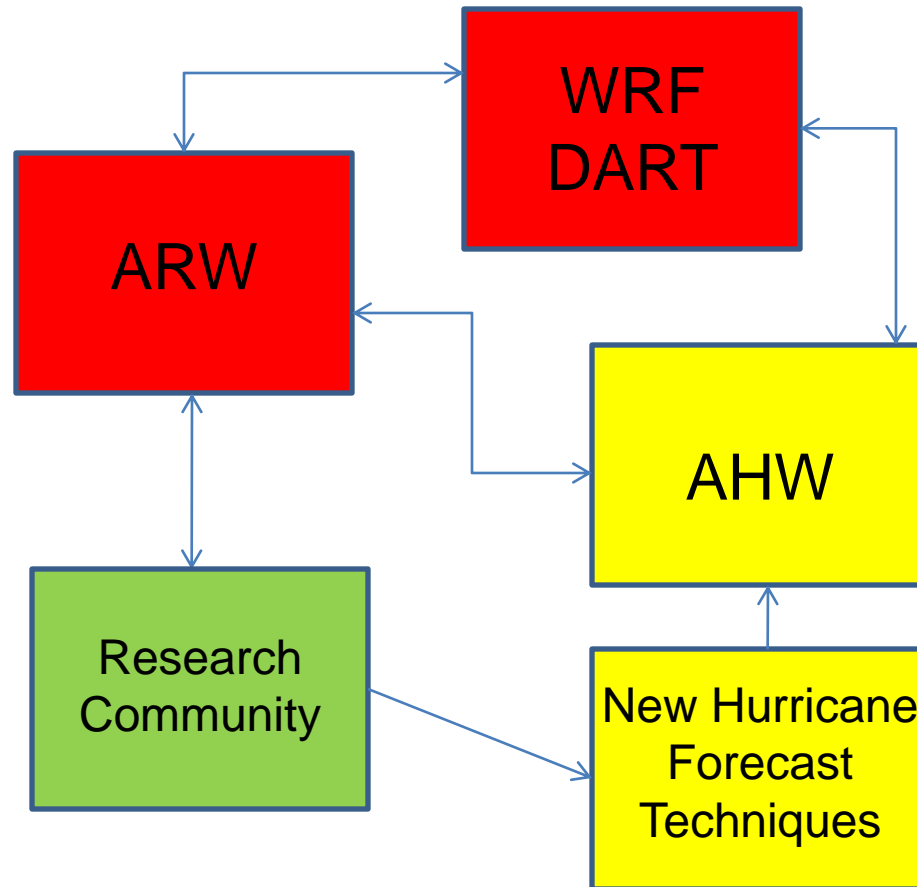
DTC for program coordination and verification

NOAA's Hurricane Forecast Improvement Project (HFIP)



NCAR

WRF ARW and AHW

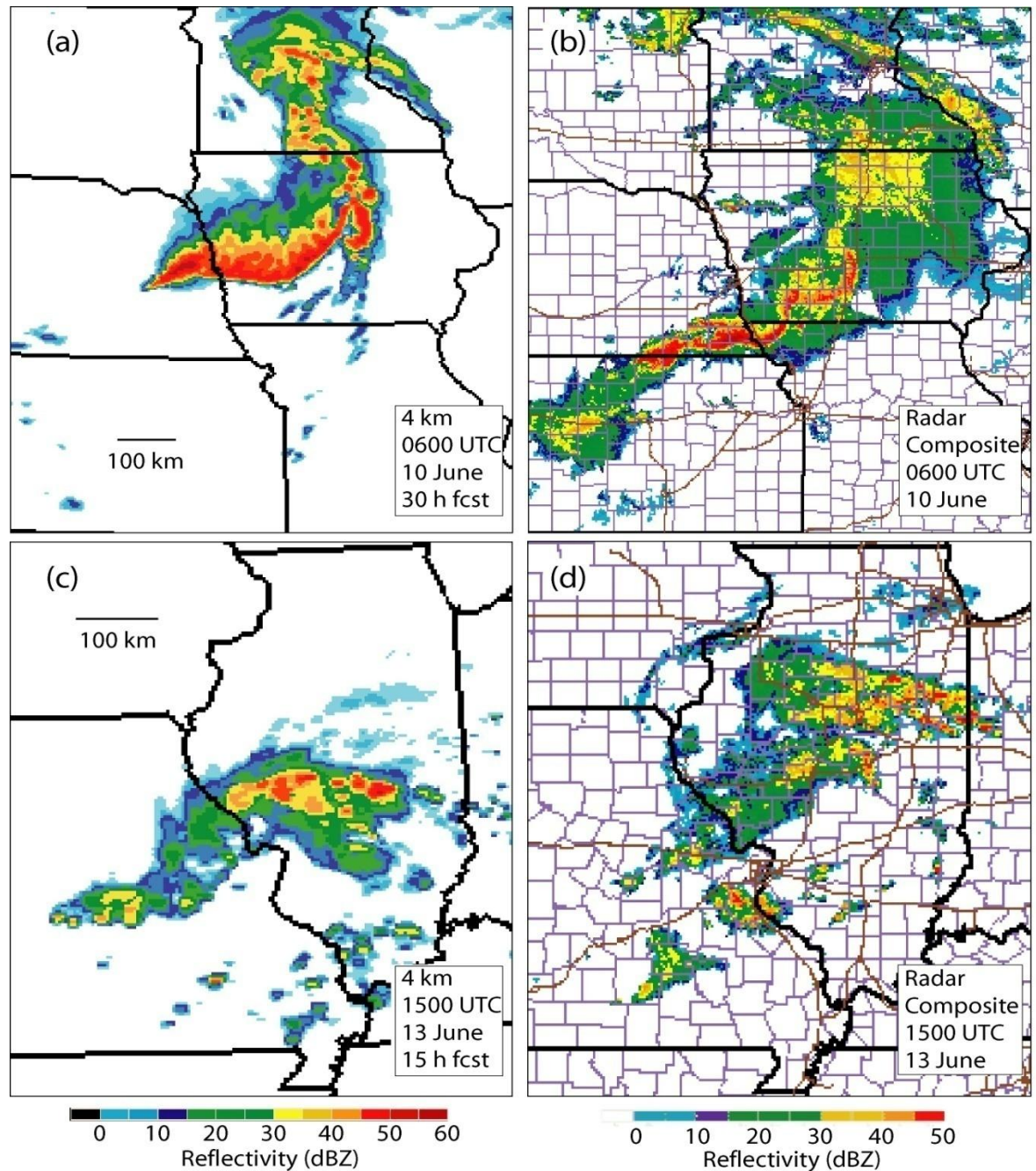


AHW is never much different from ARW

WRF and Convection Forecasting

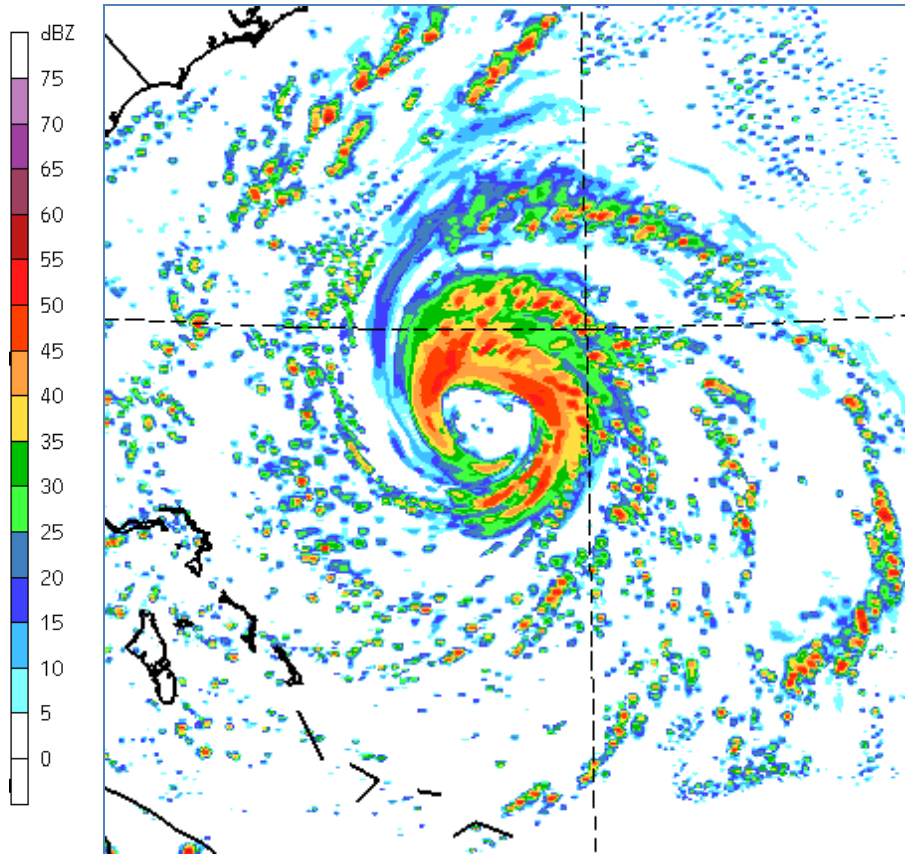
Explicit forecasts
of convection:
 $\Delta x = 4$ km

Done et al. (2004):
Atmos. Sci. Lett.

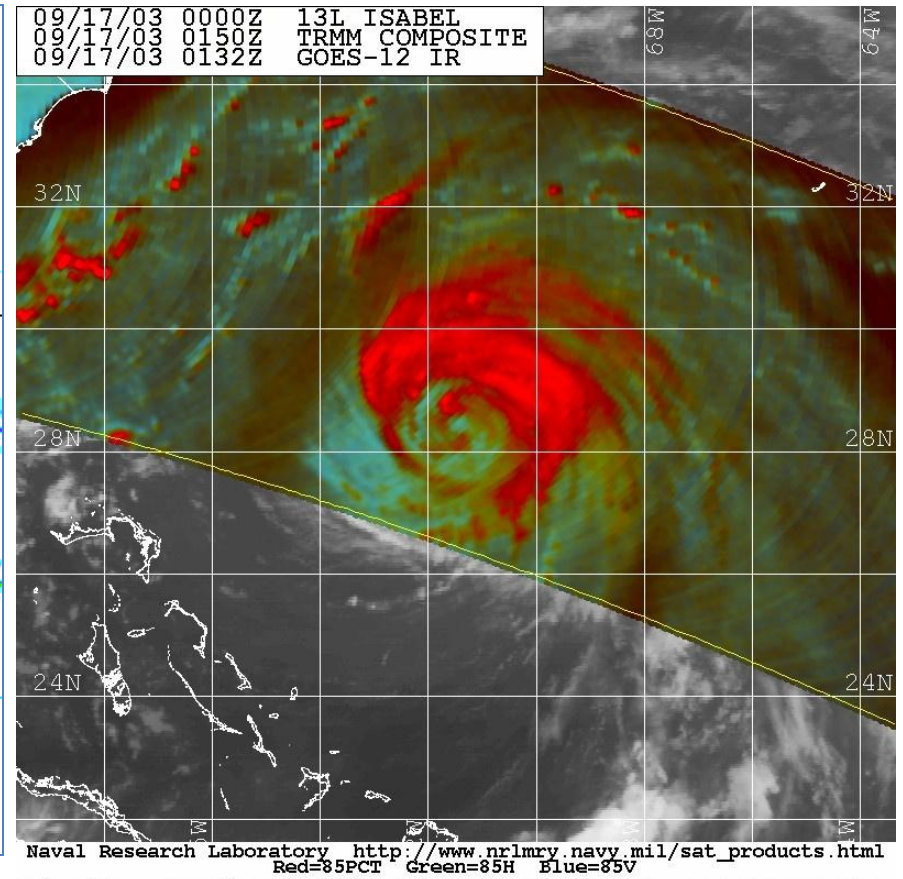


Isabel

$\Delta x = 4$ km, no cu scheme, GFS i.c.



38 h forecast valid
02 UTC 17 Sept. 2003

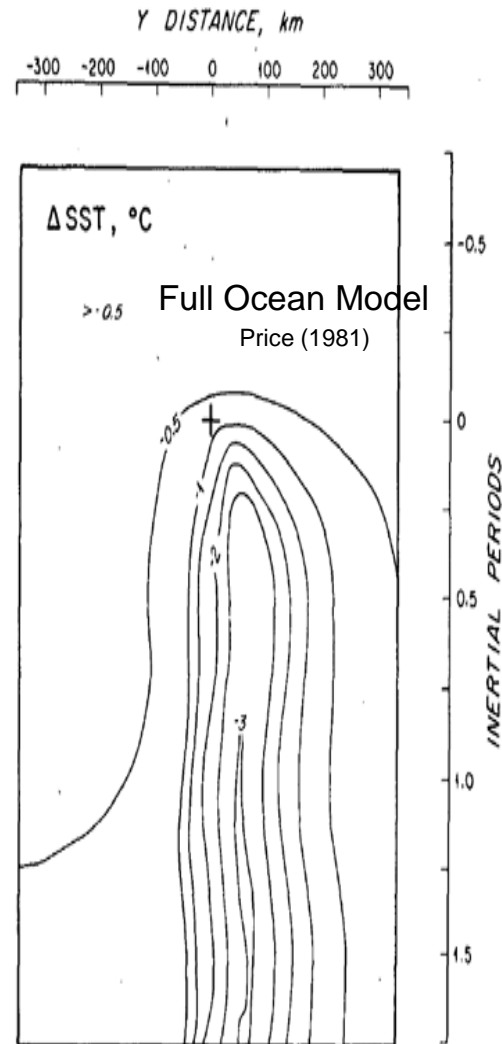
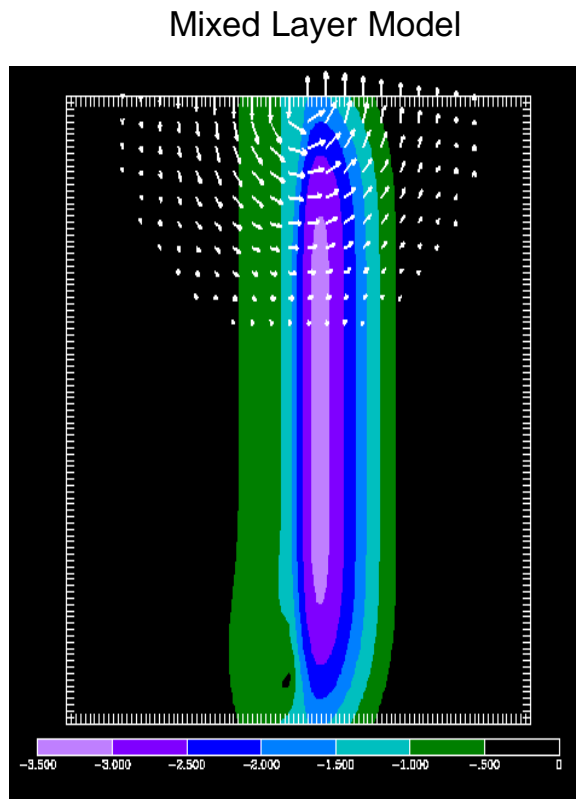


Developments since 2003

- Moving nest
- Various WRF upgrades
- Improved flux formulation
- 1-D ocean (3-D in progress)
- Advanced data assimilation (EnKF)

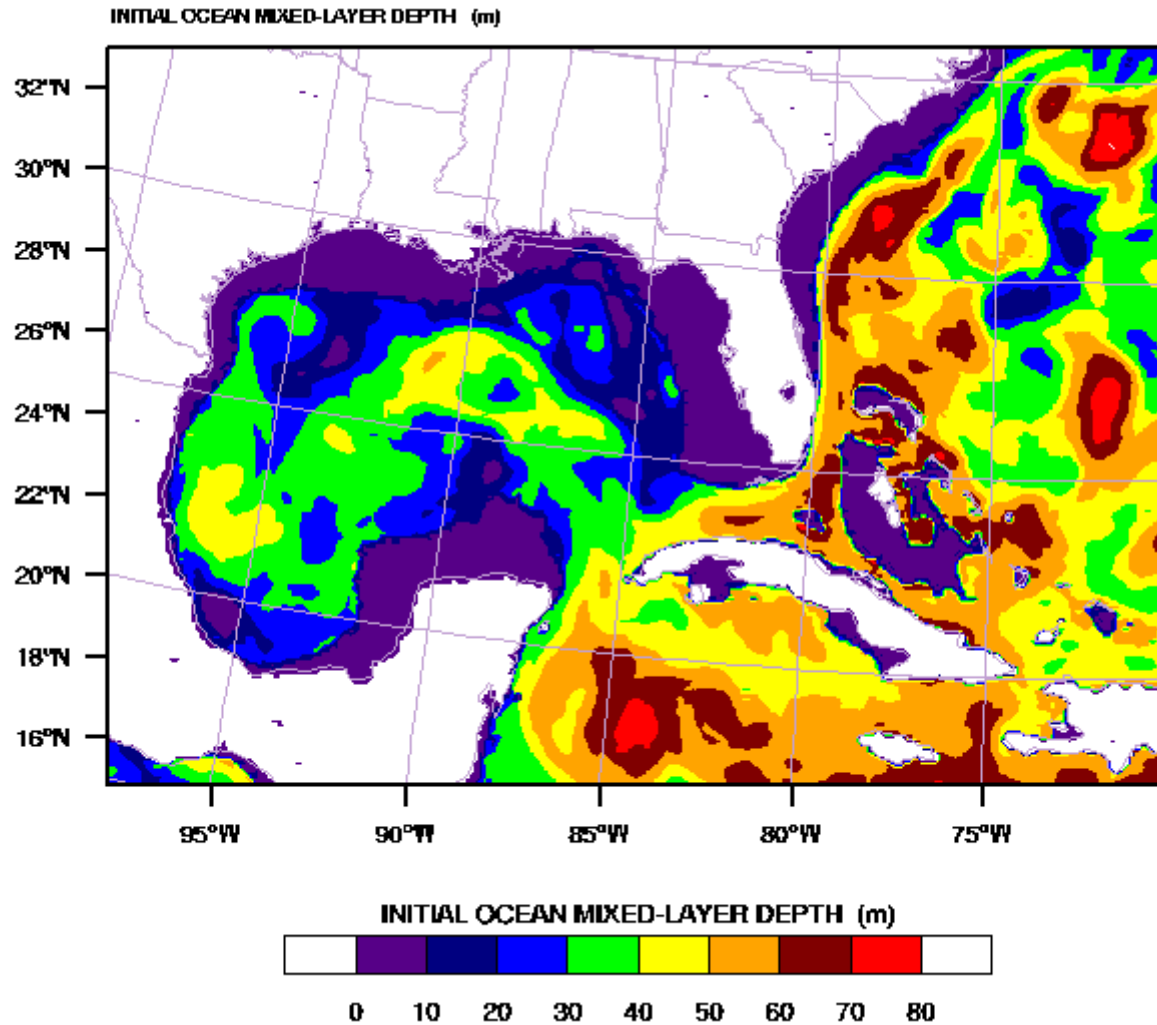
Ocean Mixing

Comparison of OML and Full Ocean Models for Idealized Vortex



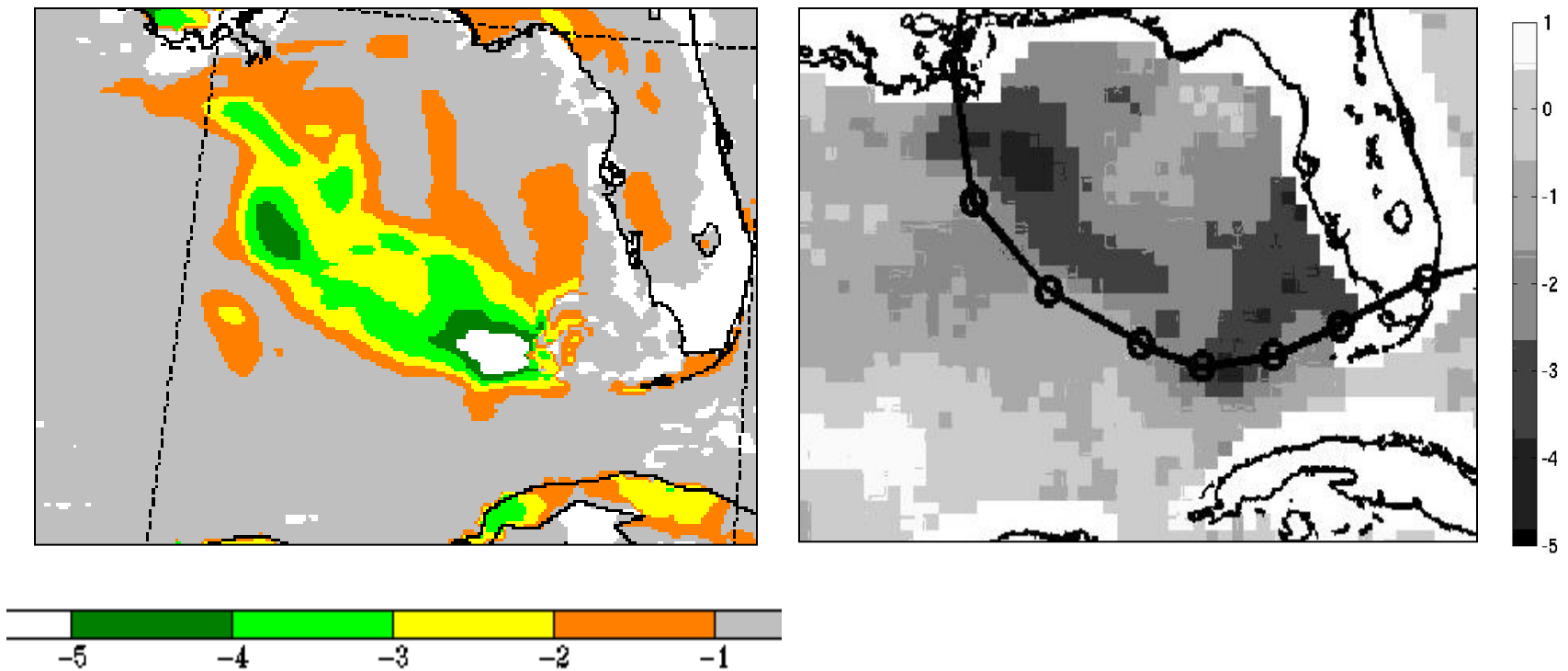
Maxima in both idealized calculations is 3.1 K

Ocean MLD



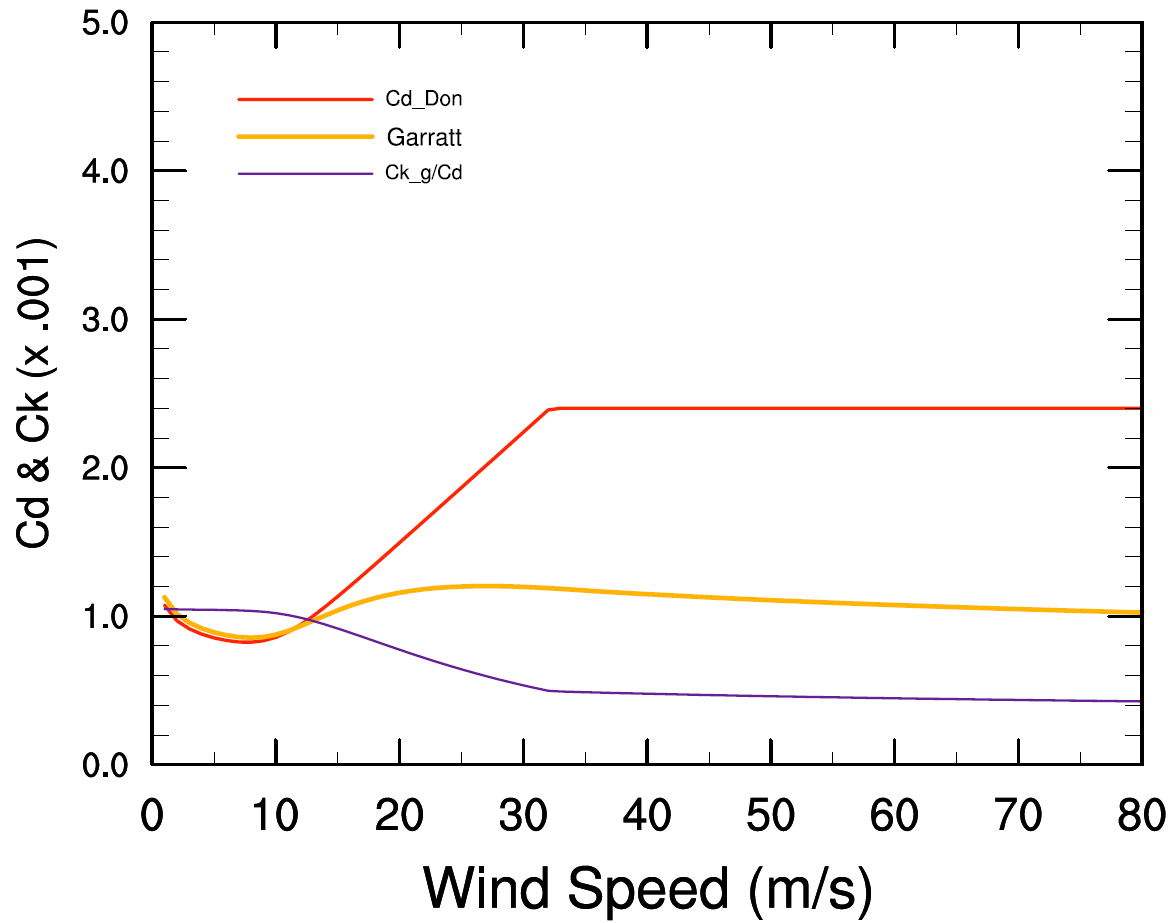
Meters

SST Change: Katrina



SST after minus SST before (K)

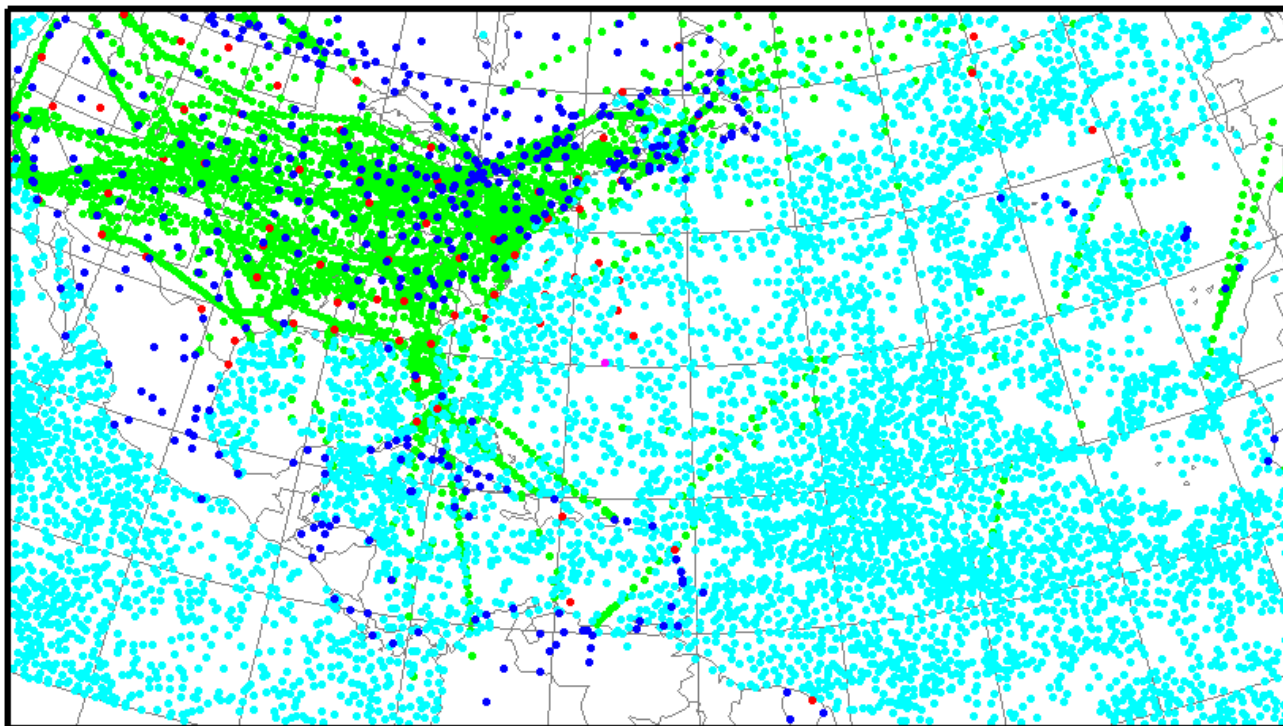
Surface Flux Formulation



2010 AHW Assimilation System

- 96 member cycling Ensemble Kalman Filter (EnKF)
- WRF DART
- Observations assimilated each six hours
- Forecasts initialize from one or more ensemble members

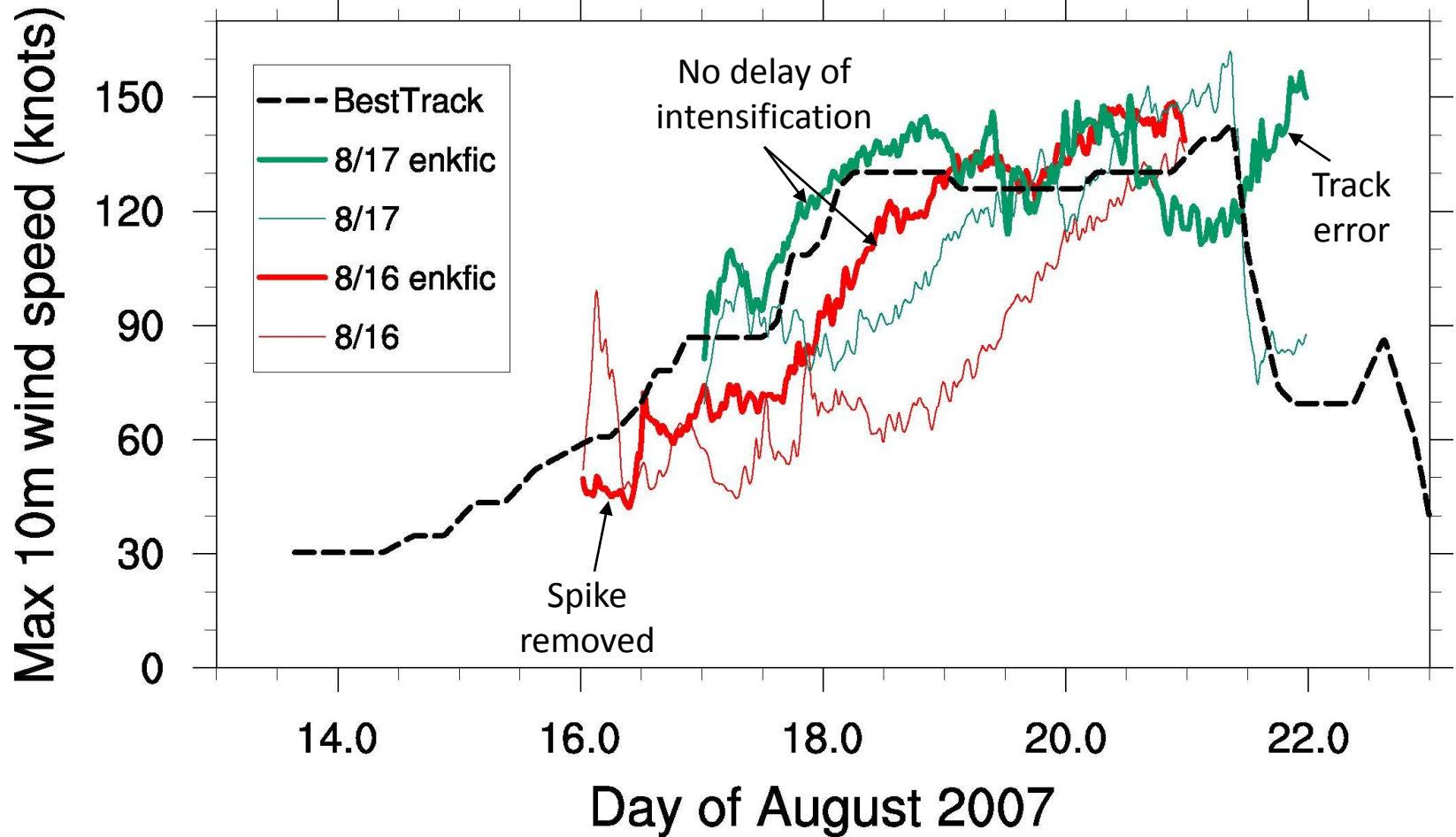
Observation distribution valid 2009082200



•	RAWINSONDE	•	ACARS	•	SAT WIND	•	LAND SFC	•	MARINE SFC
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Results Using Cycling Ensemble Kalman Filter

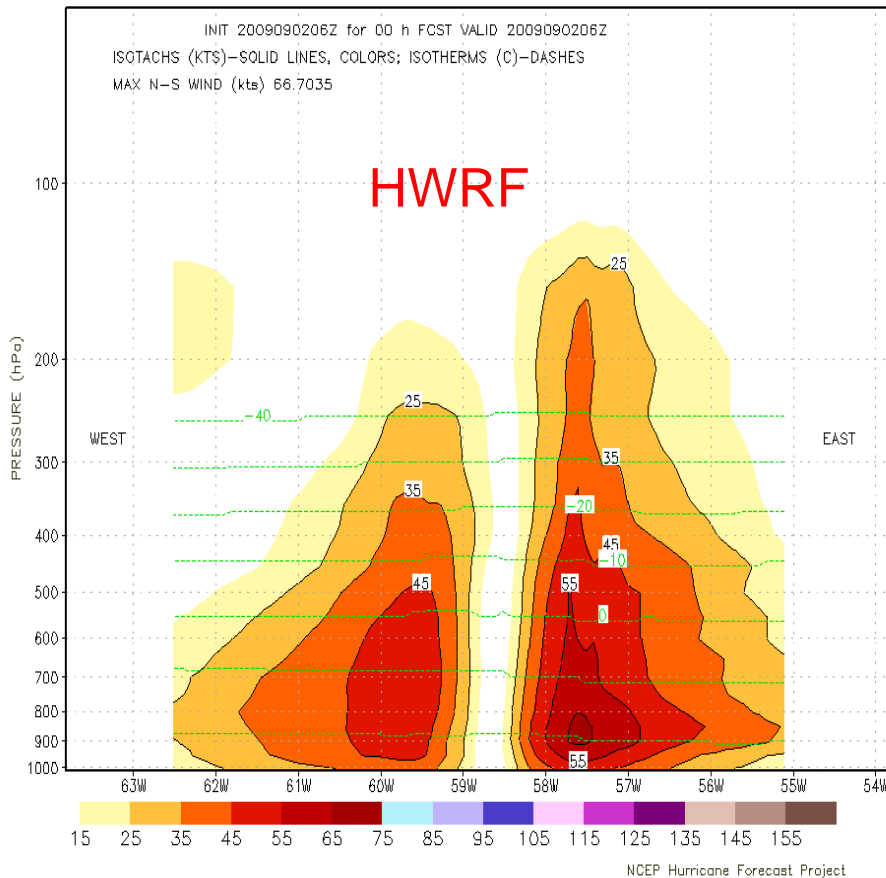
5-day Dean Reruns from 00Z daily



Initial Conditions for Erika 0902/06Z

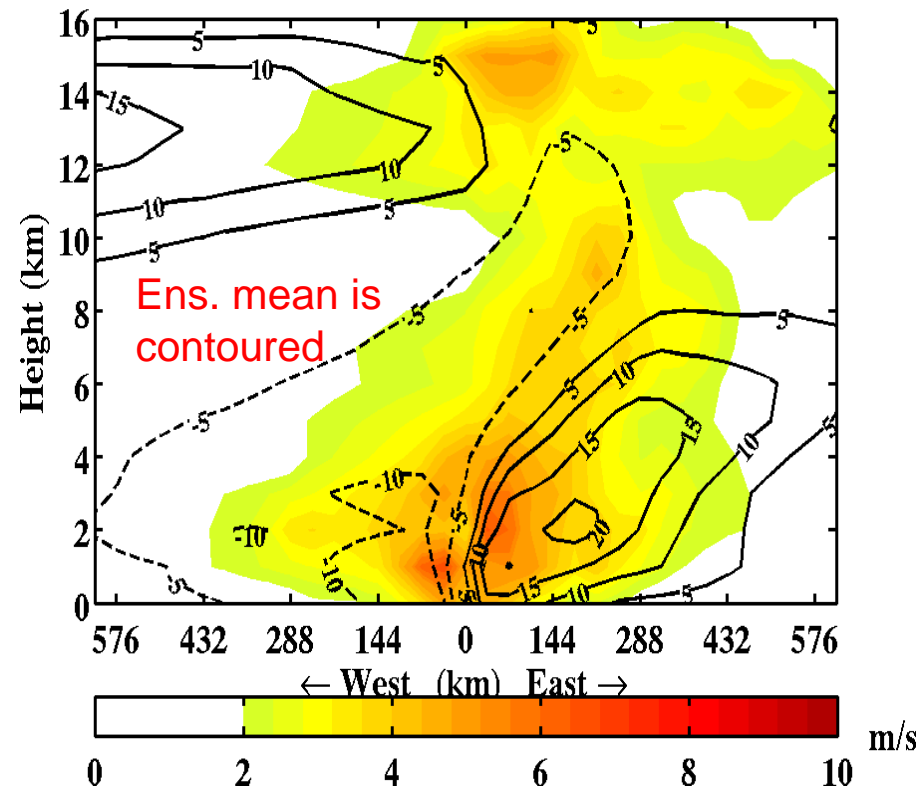
(cross section of meridional velocity)

HWRF PROD ERIKA 06I E-W CROSS SECT LAT=16.90

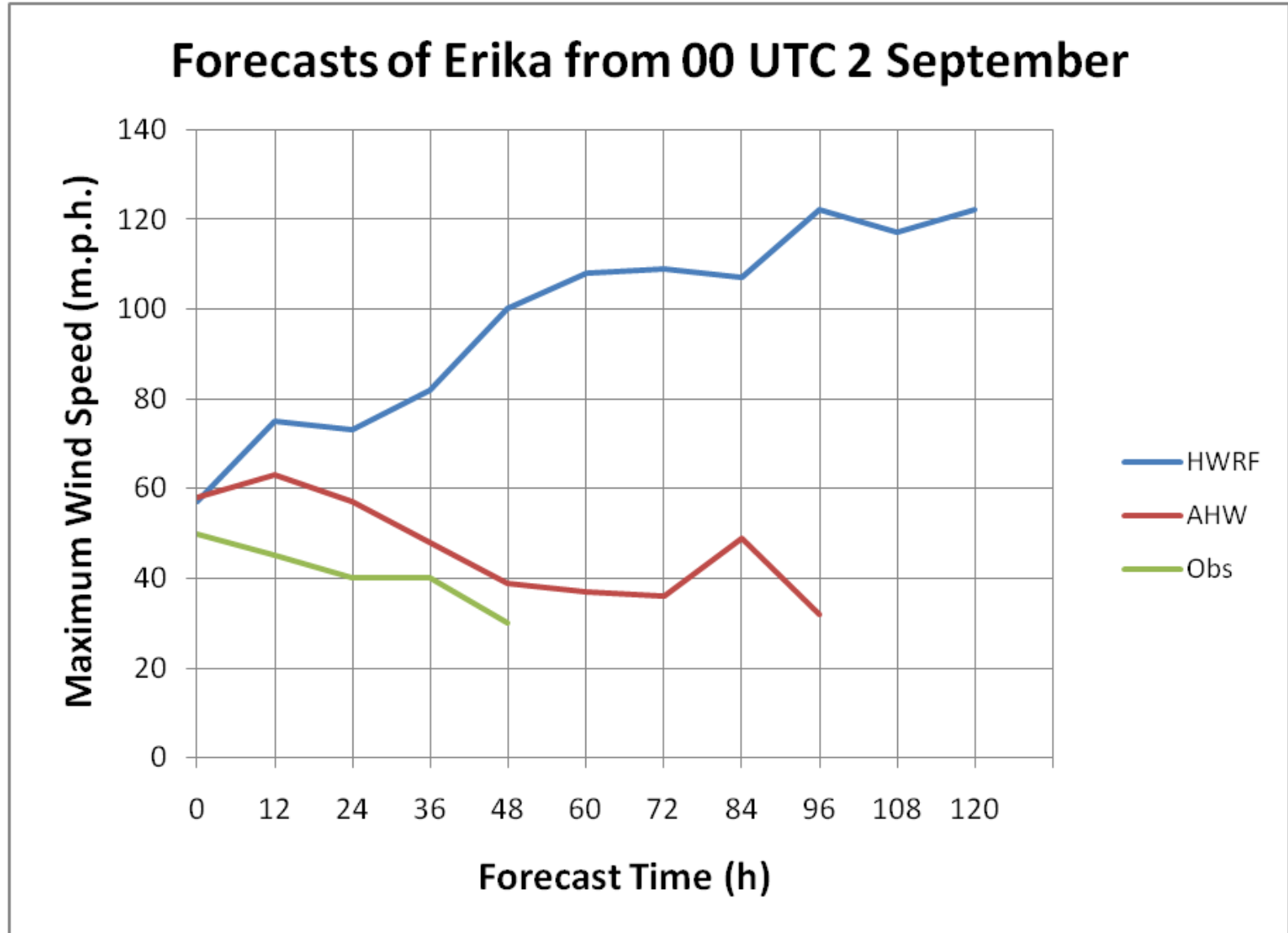


**No tilt (HWRF)
vs. tilt (AHW)**

f000 mean wind and spread valid 2009090206



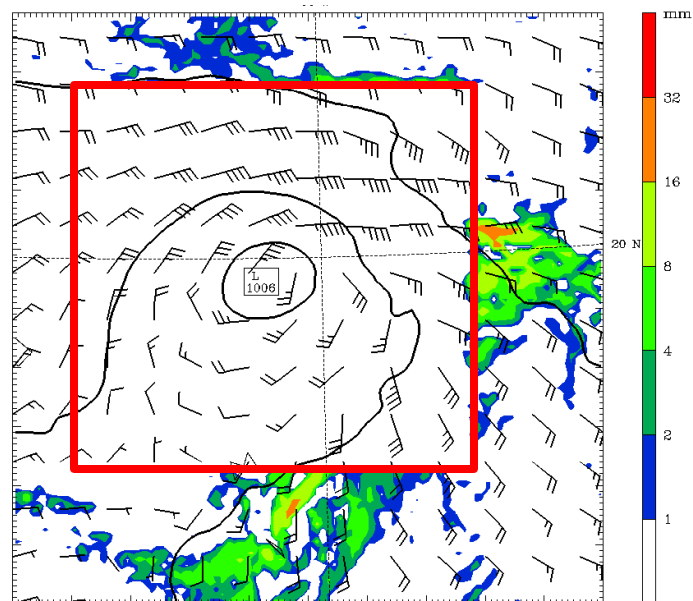
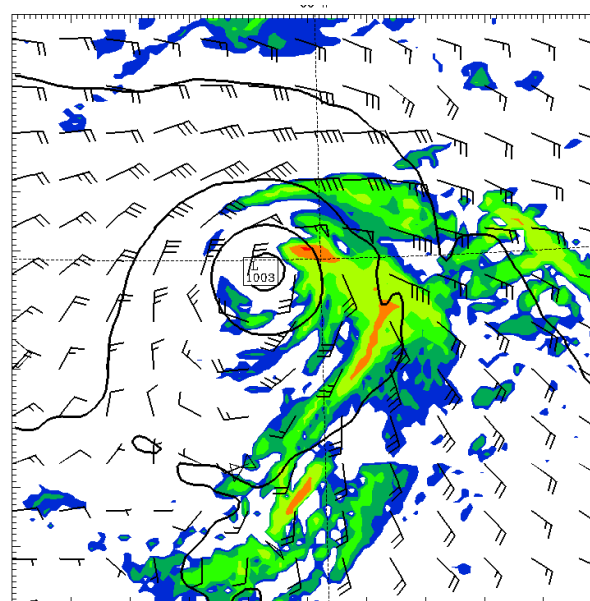
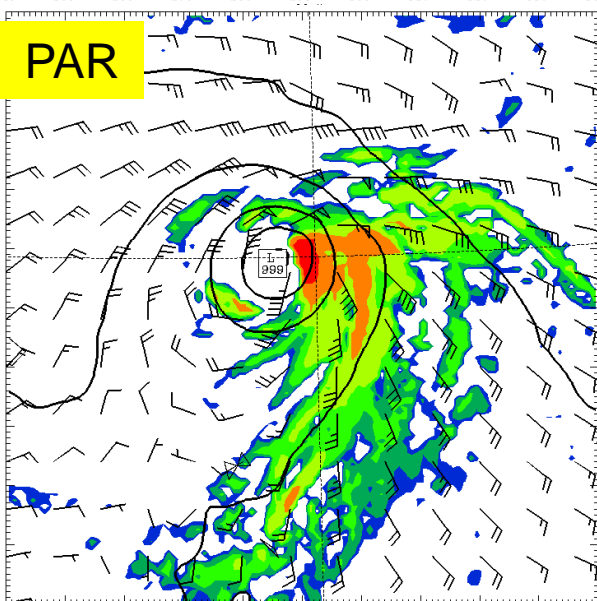
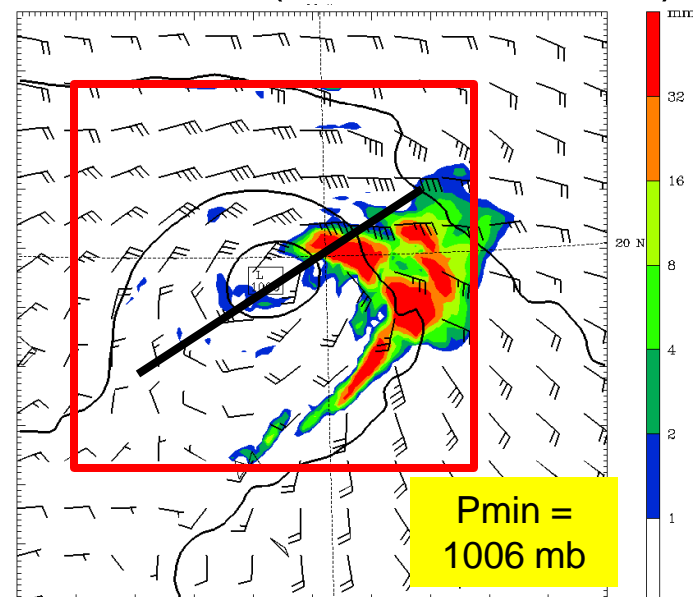
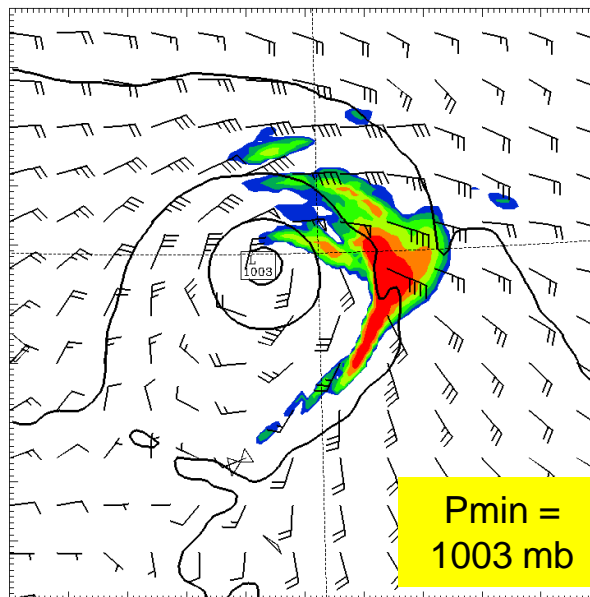
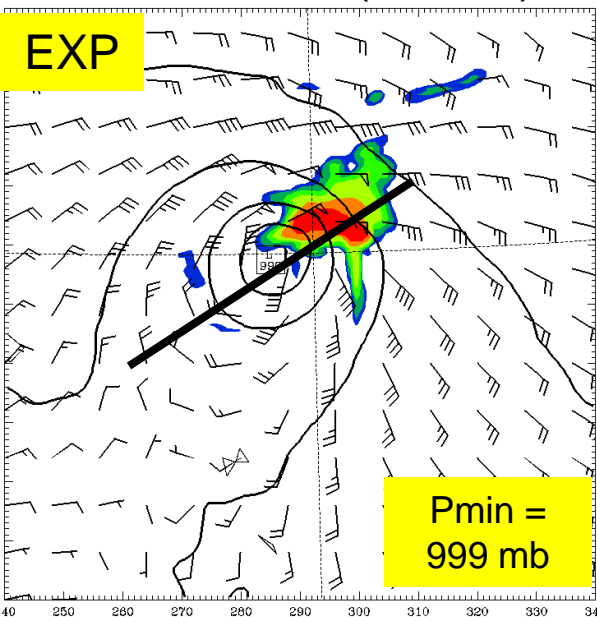
Example of model differences for weak storms (2009)



ERIKA 24-h Fcsts Valid 00 UTC 3 September

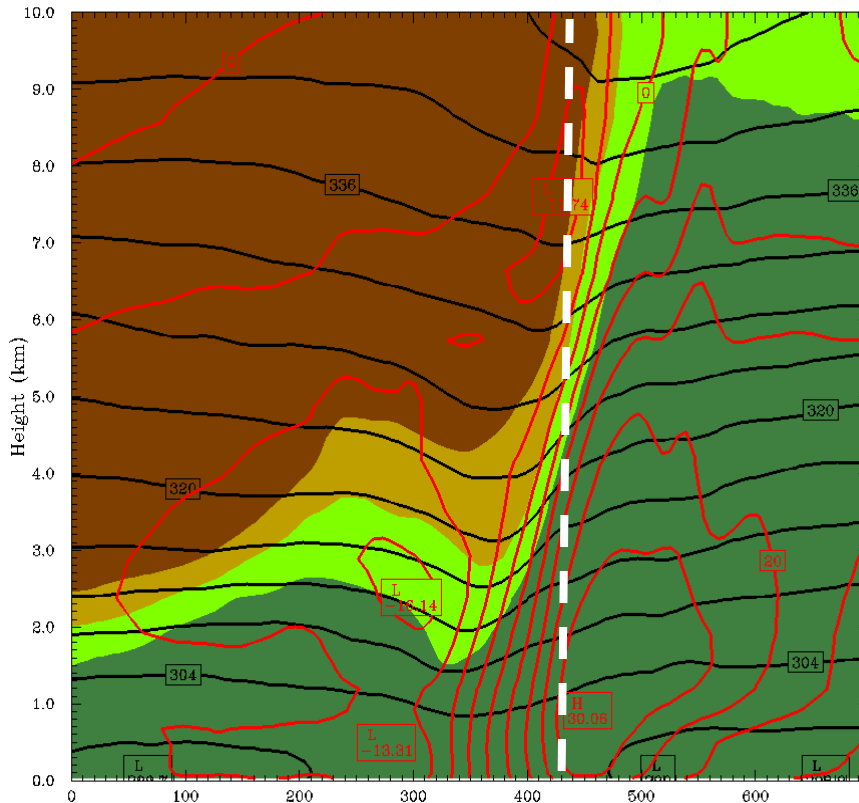
1-domain (12-km)

2-domain (K-F on 4 km) 3-domain (no K-F on nests)



Explicit vs. Parameterized Convection

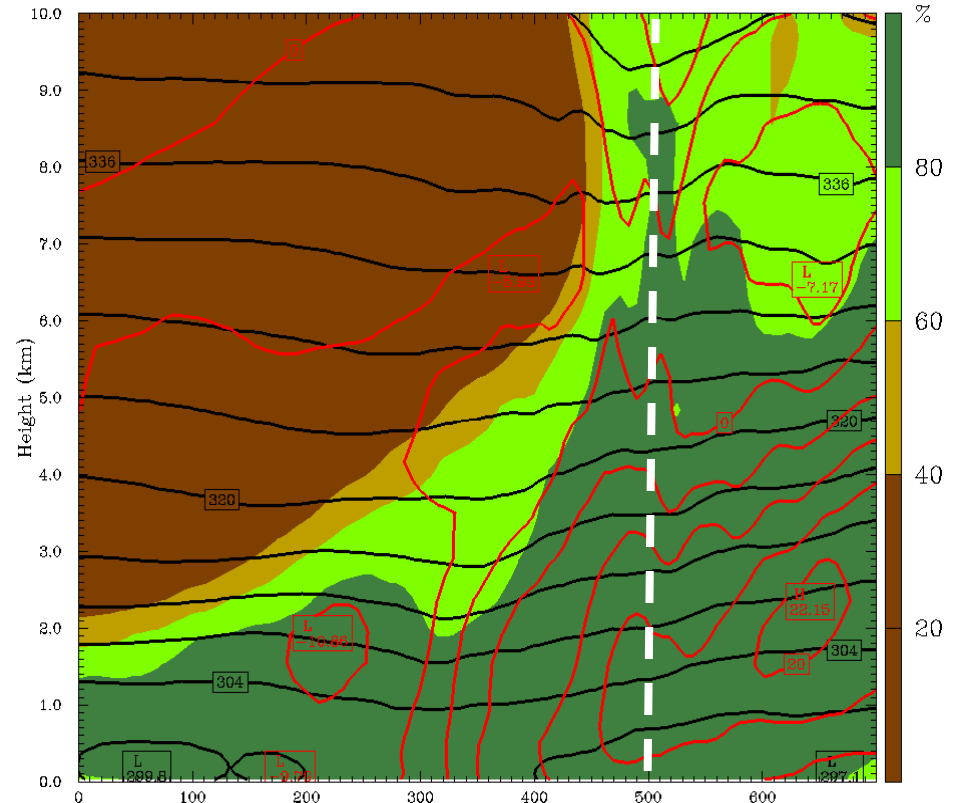
1 Domain



SW-NE Distance (km)

White dashed line: convection edge

3 Domain



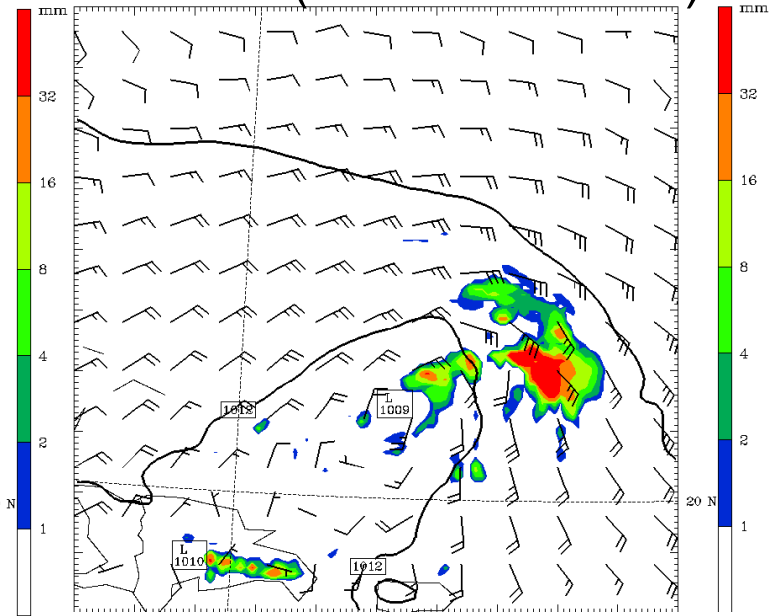
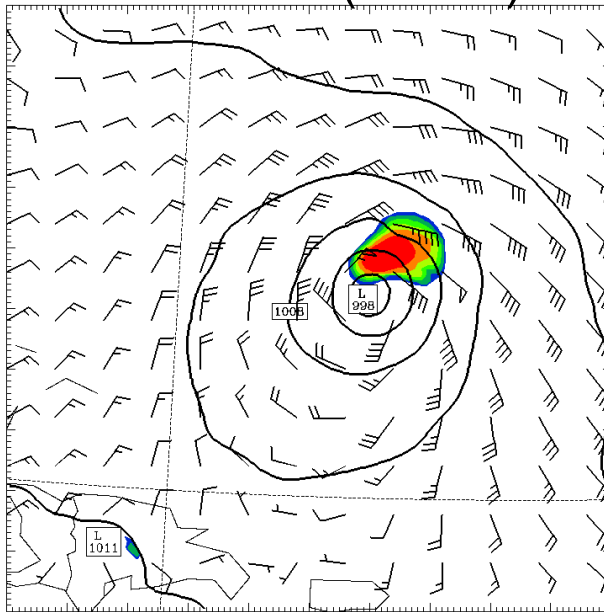
Shaded: RH
Black: θ_e
Red: Zonal wind

ERIKA 72-h Fcsts Valid 00 UTC 5 September

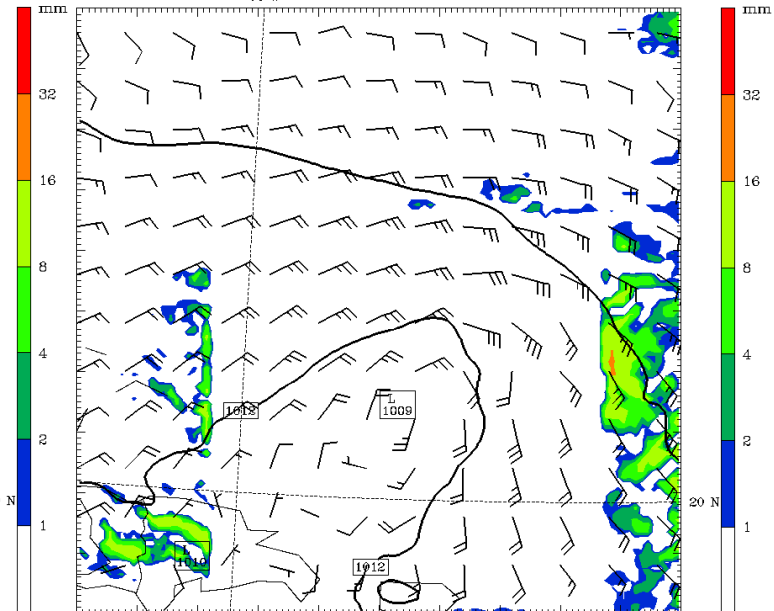
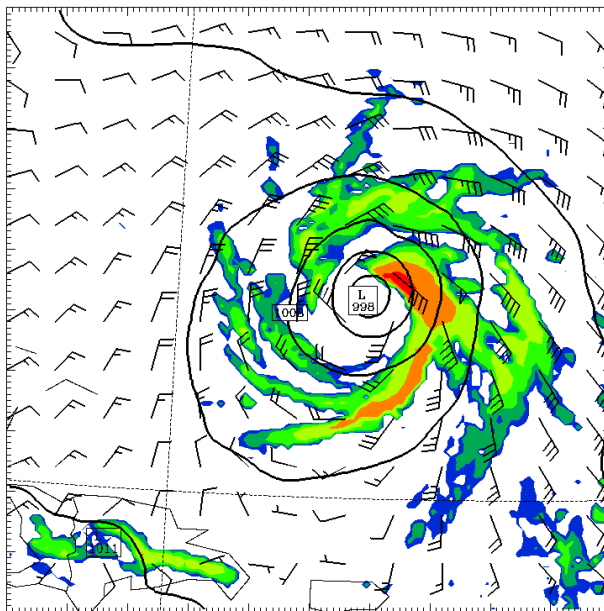
1-domain (12-km)

3-domain (no K-F on nests)

EXP



PAR



Effects of Vertical Shear

THERMODYNAMIC VERTICAL PROFILES

(a) at point of maximum downward displacement

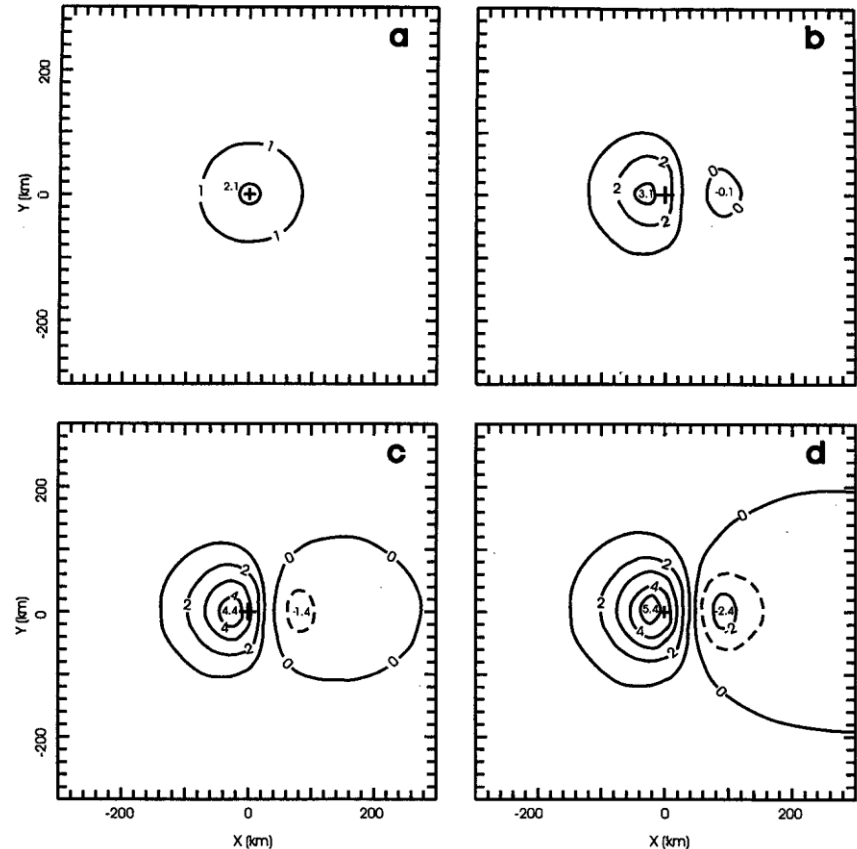
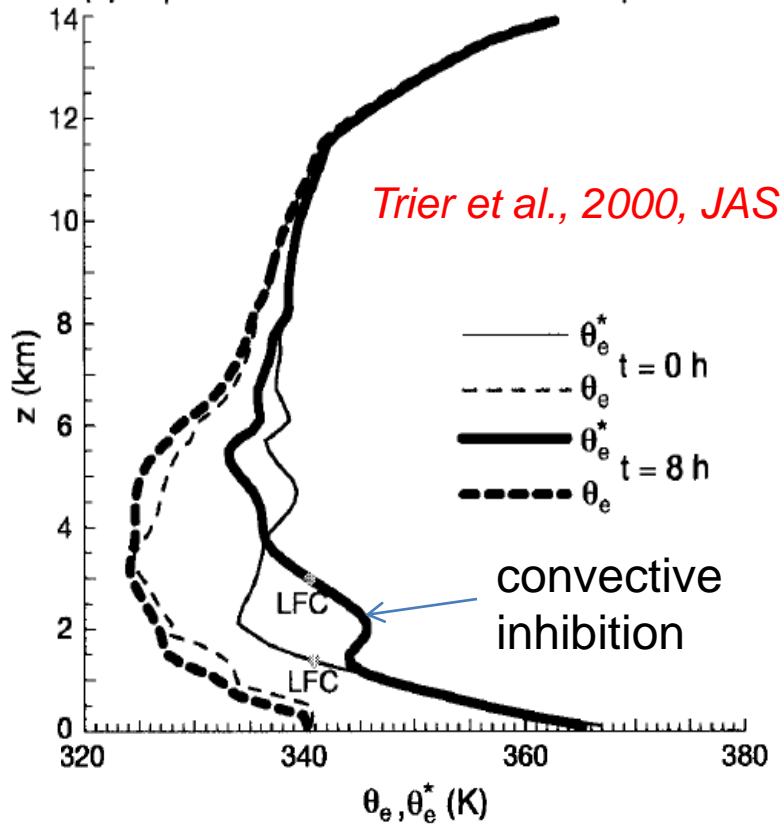
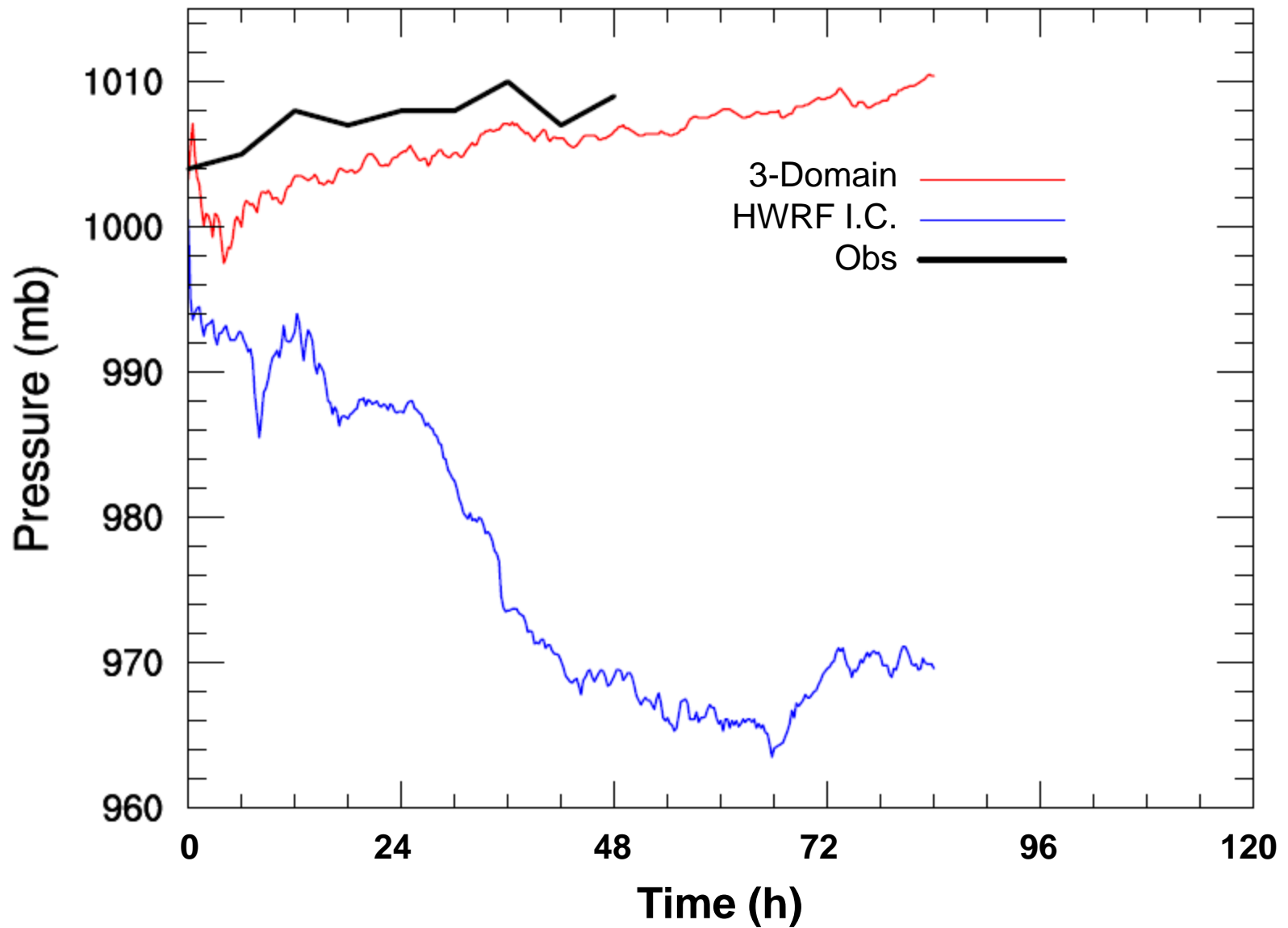


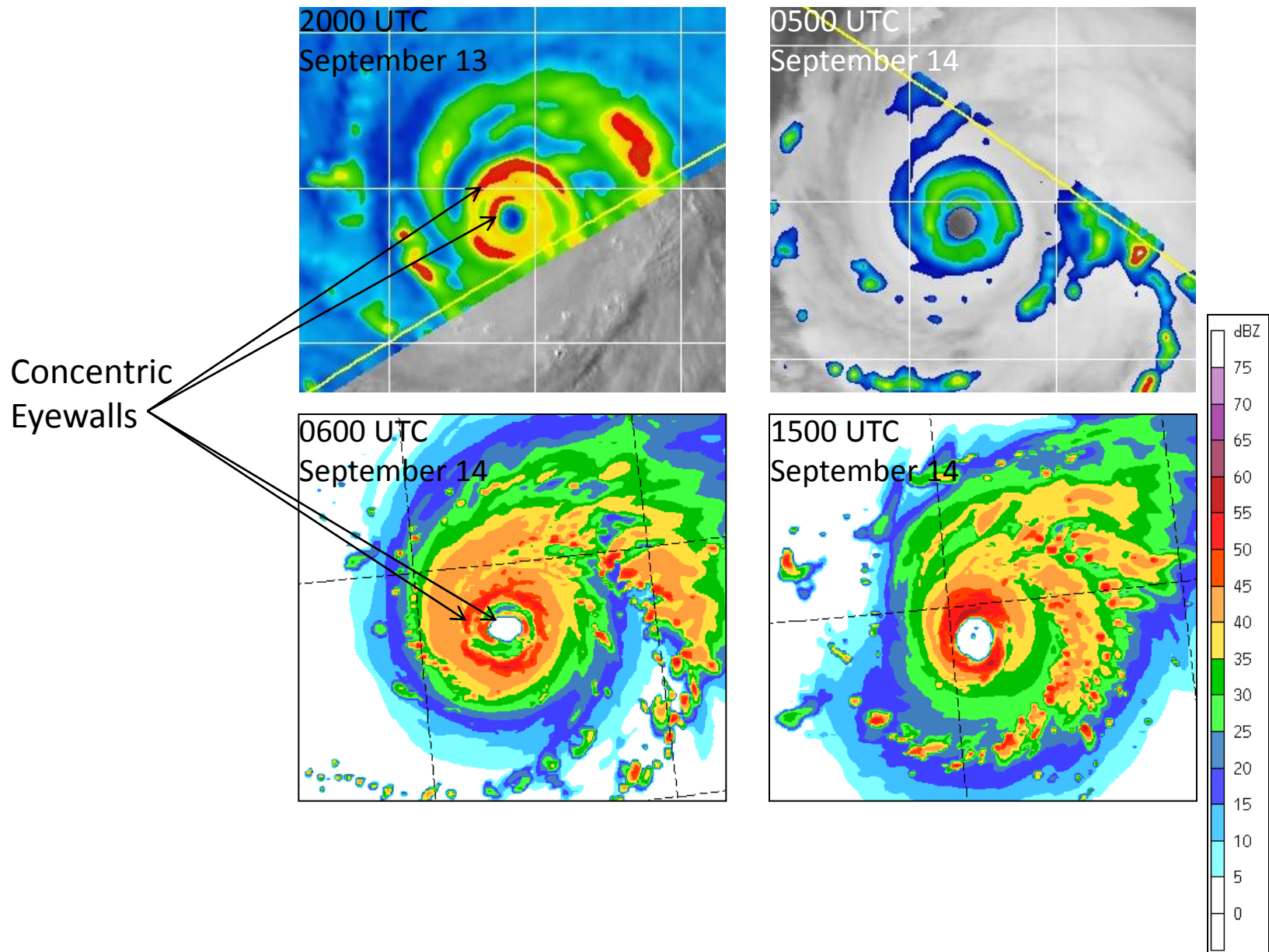
FIG. 3. The midlevel potential temperature anomaly when the upper-layer PV anomaly is displaced eastward by 0, 20, 40, and 60 km relative to the lower-layer PV anomaly, (a)–(d), respectively. The fields are displayed on the inner 600 km \times 600 km of the 2400 km \times 2400 km domain.

DeMaria 1996, JAS

AHW with HWRF Initial Conditions



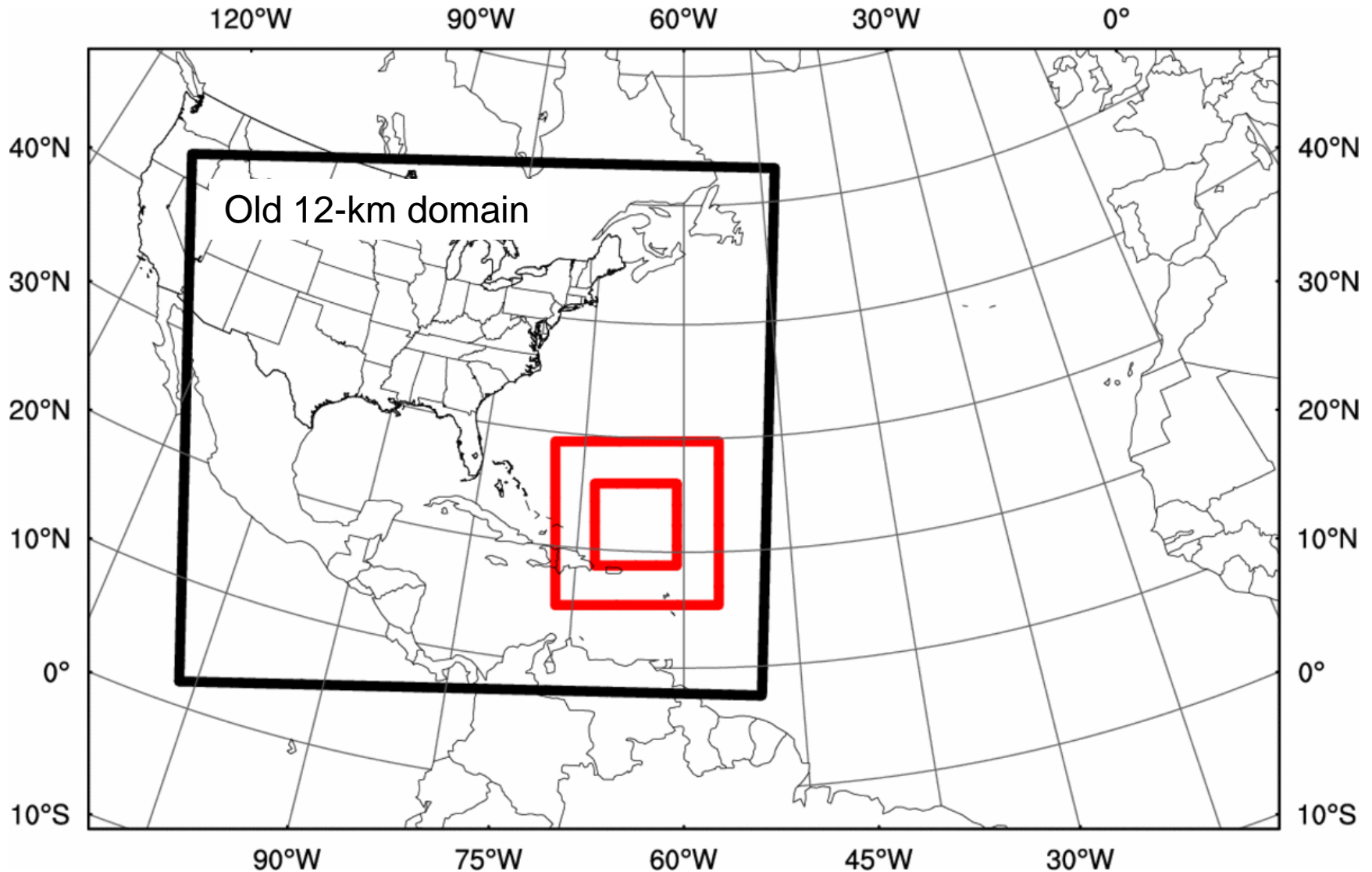
Eye Wall Replacement in Igor (initialized 00 UTC 11 September)



AHW: Most Recent Configuration

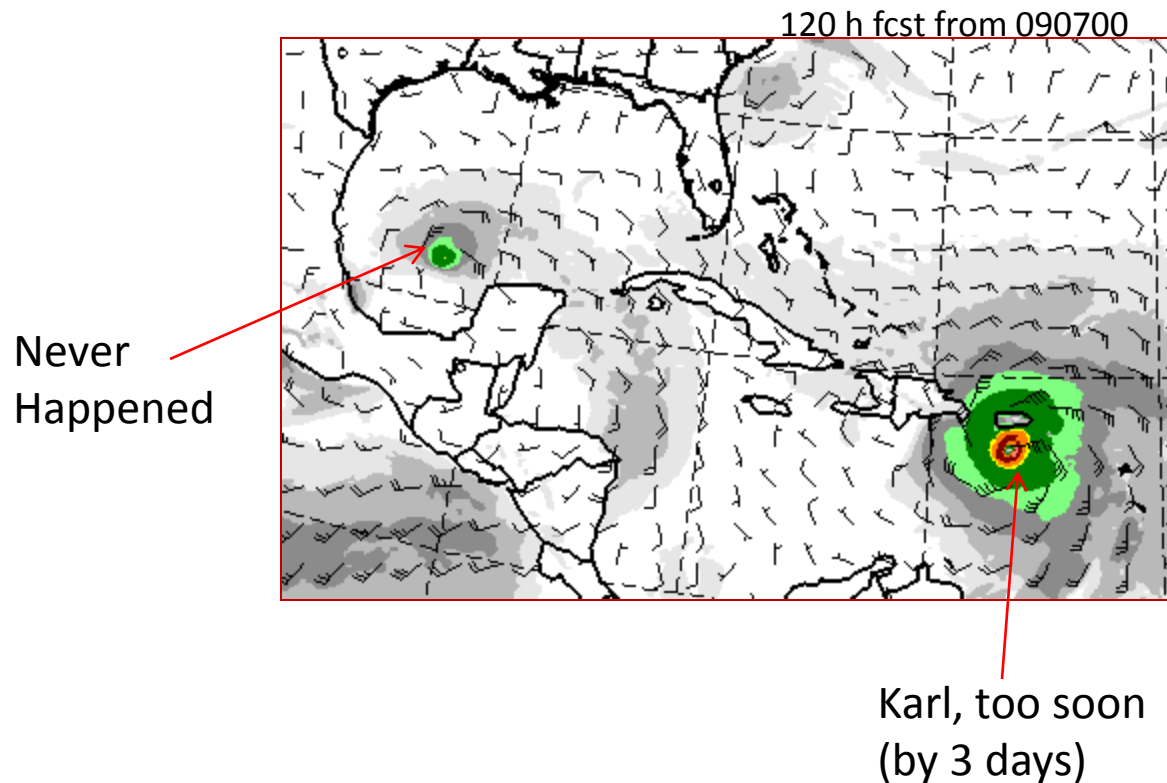
- Use of large 36-km outermost domain with 12-km and 4-km nests
- Merger of the assimilation and high-resolution forecasting system
 - High resolution forecast integrated over entire 36 km domain from assimilation system
 - Removes need for human-specified 12 km domain
 - 12 km domain now follows the TC center
- 36 and 12 km domains now use Tiedtke cumulus parameterization
 - Includes robust shallow convection in the western Atlantic
 - Significant impact on track biases in this region through thermal wind balance

Advanced Hurricane-research WRF (AHW): *Domain Configuration*

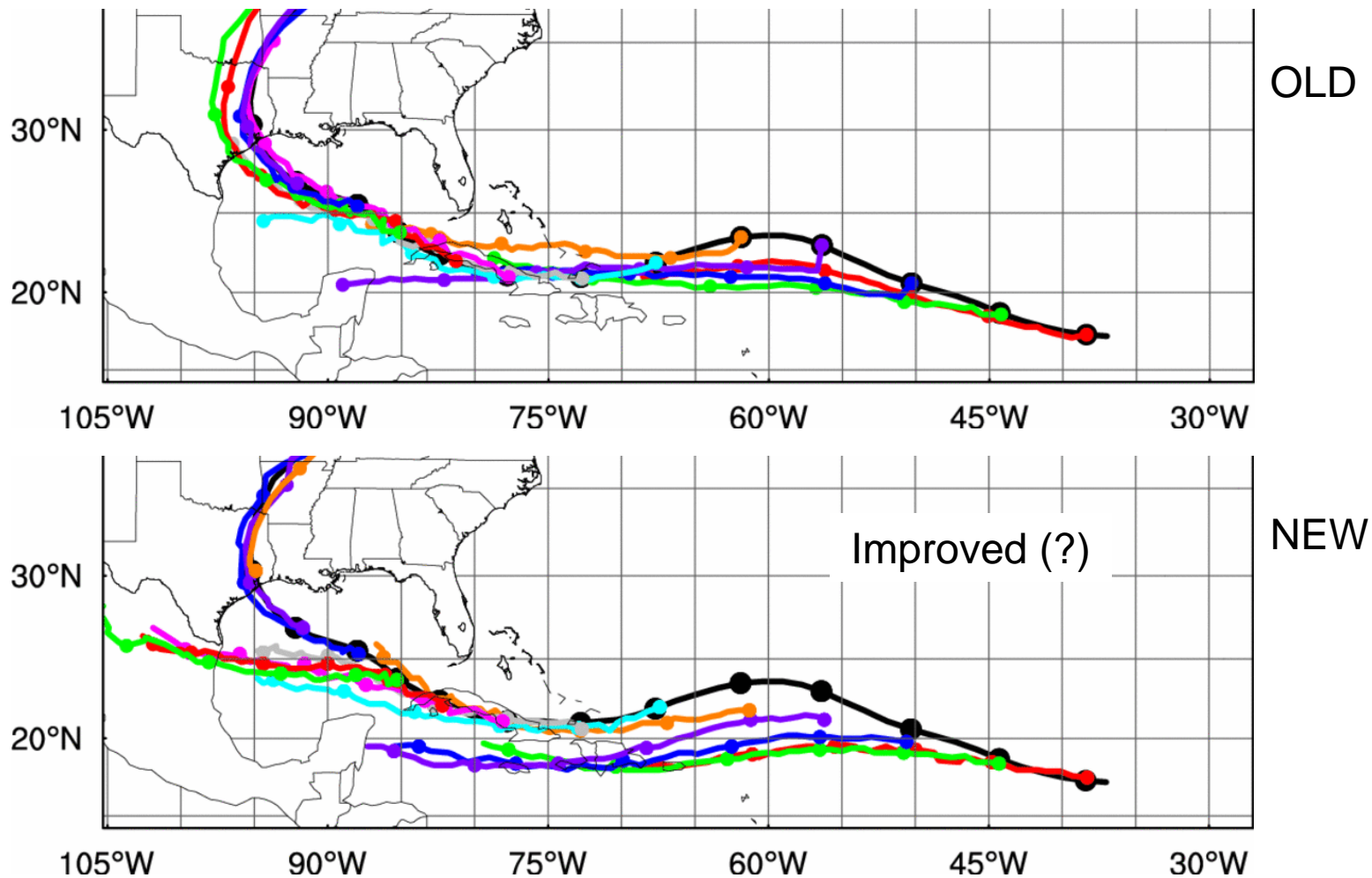


Behavior on the 12-km Domain

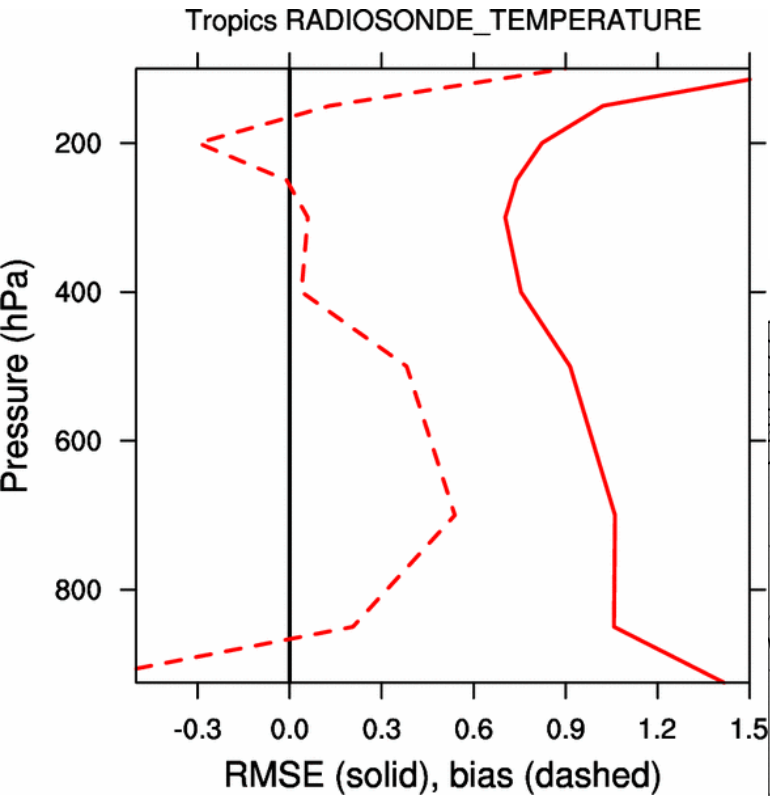
- Fictitious spinups



Ike Track Forecasts

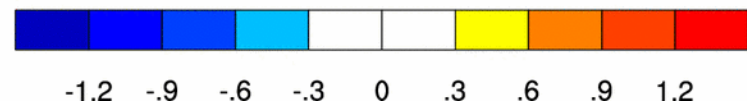
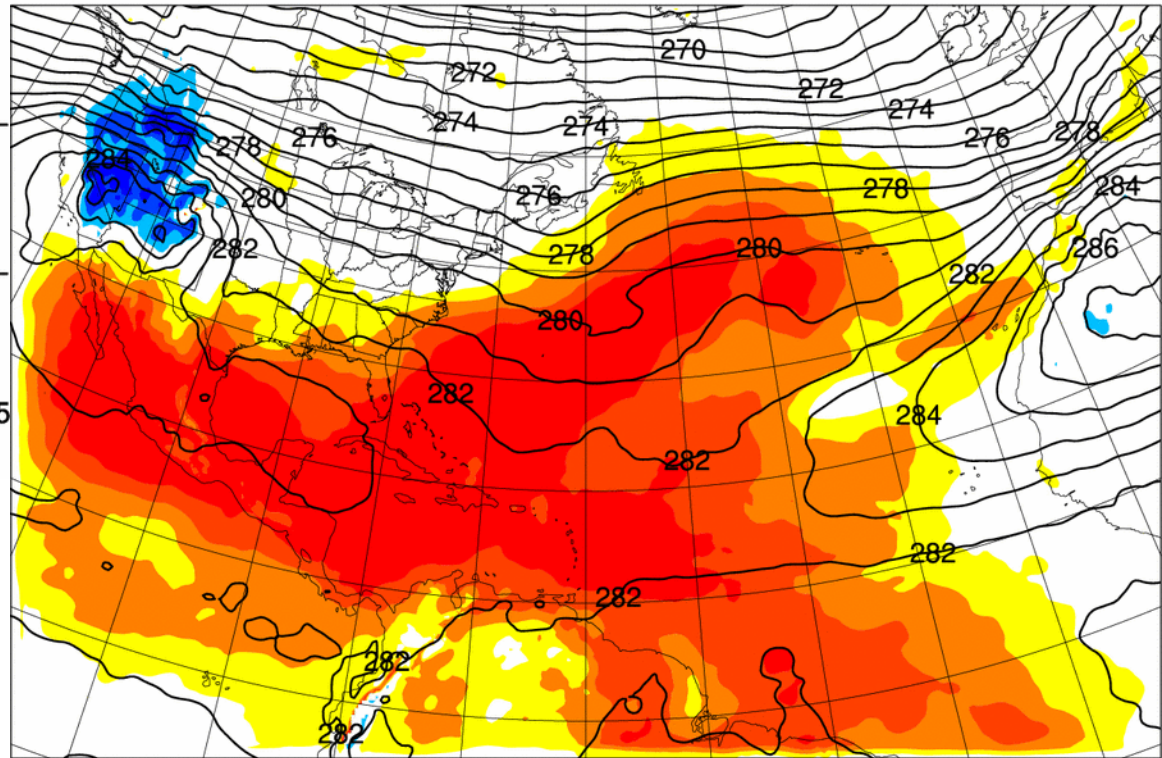


6 h Forecast Errors



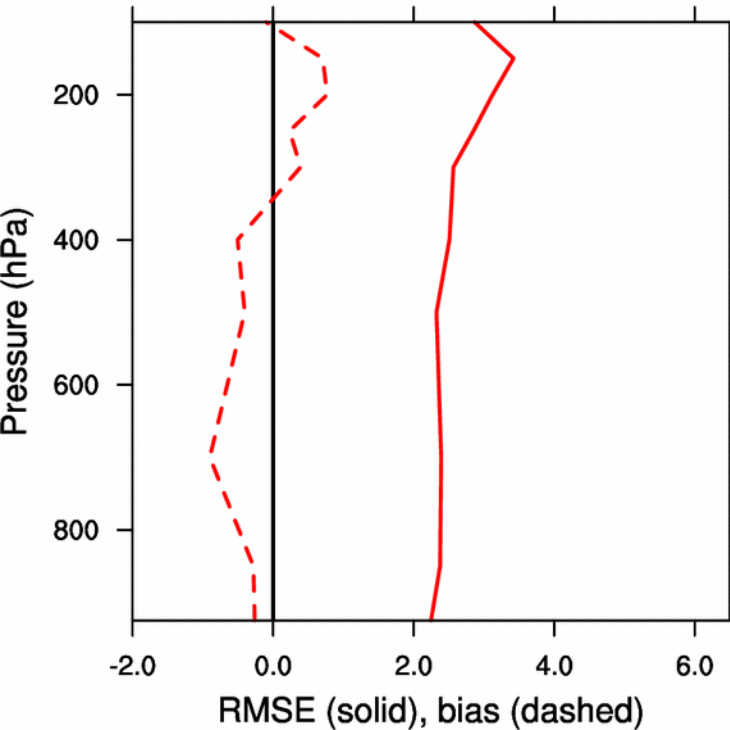
6 h AHW forecasts
against rawinsondes
south of 30 N from 14
Aug. – 14 Sept. 2008

Difference between AHW 6 h fcst and GFS
6 h fcst. from 14 Aug. – 14 Sept. 2008
700 hPa temperature



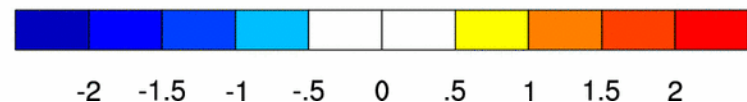
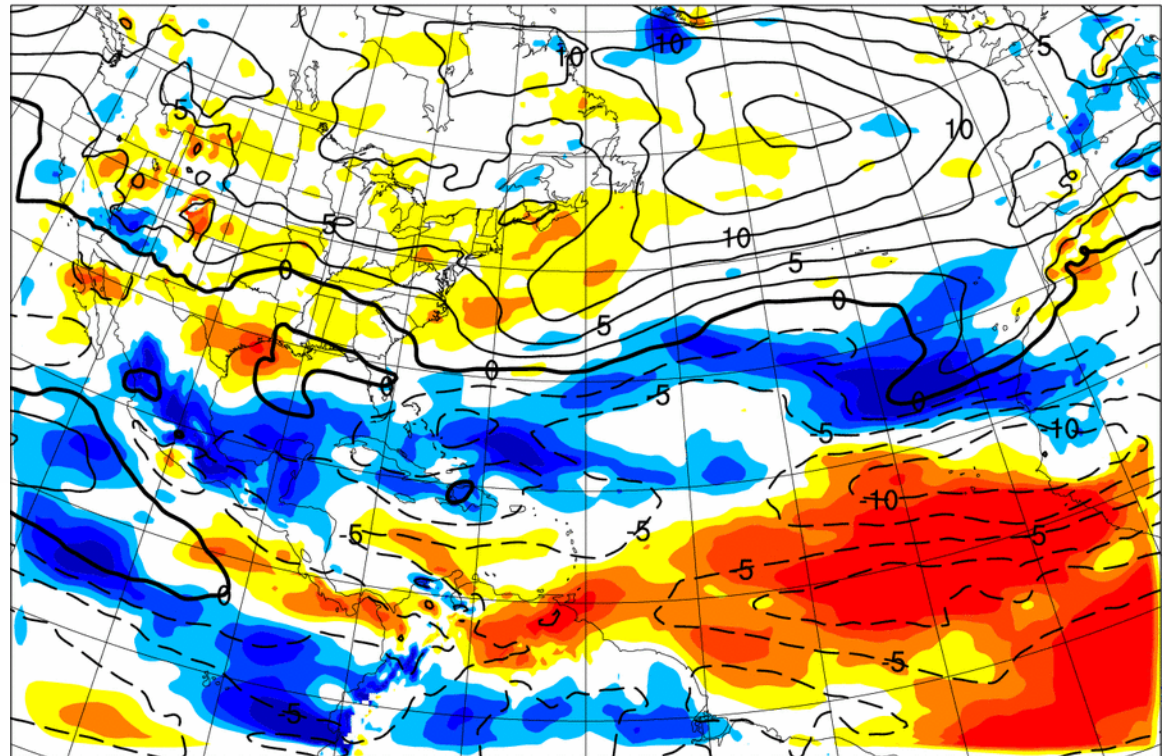
6 h Forecast Errors

W. Caribbean RADIOSONDE_U_WIND_COMPONENT



6 h AHW forecasts
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700 hPa u wind component

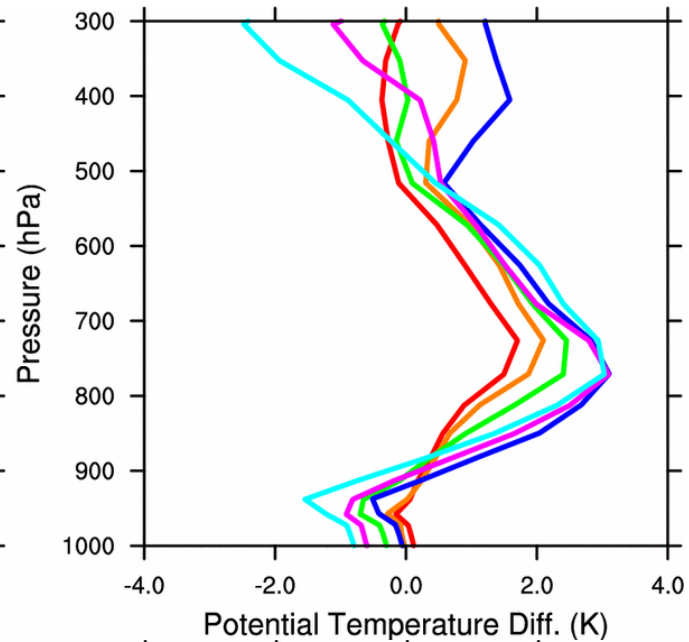
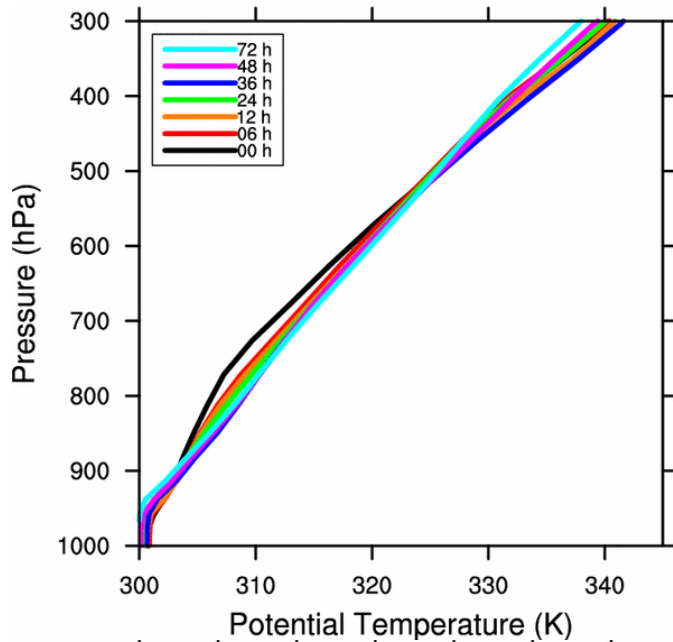


Experiments

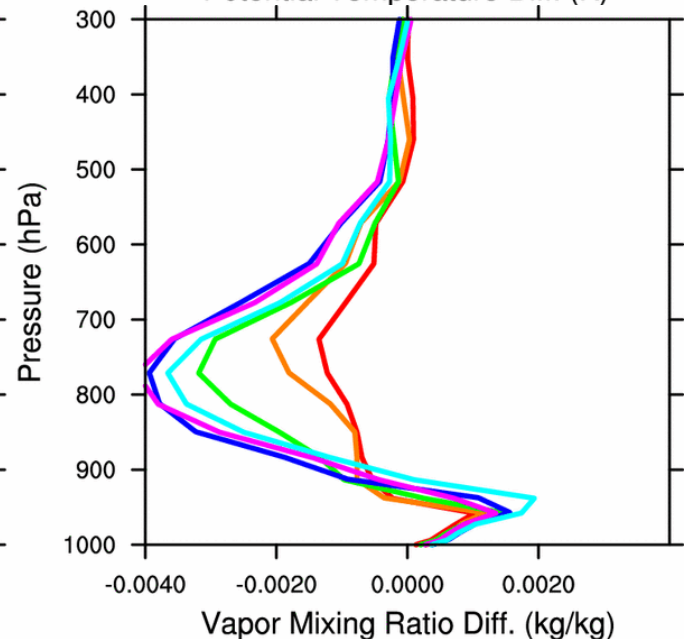
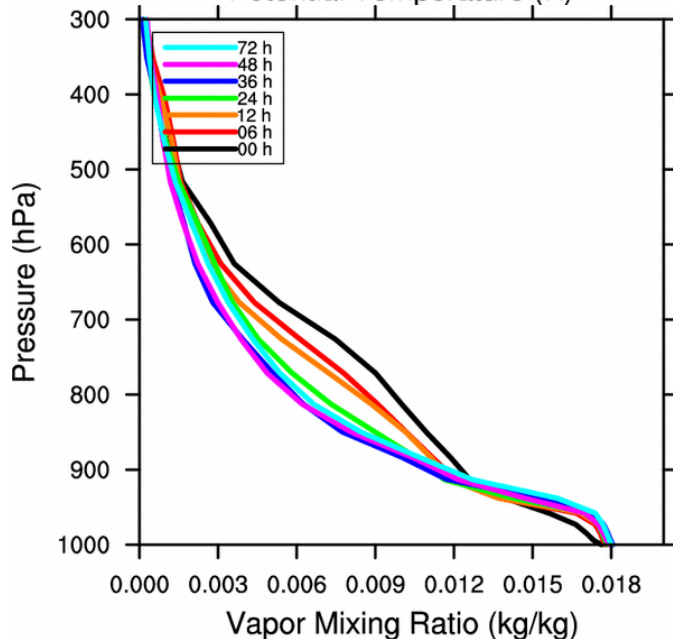
- Run 3 day WRF forecast initialized from GFS analysis
- Output instantaneous physics tendencies hourly, average over entire forecast
- Horizontally average over western Caribbean (ocean only) where the bias appears strongest

K-F. Eta Vertical Profiles

Theta

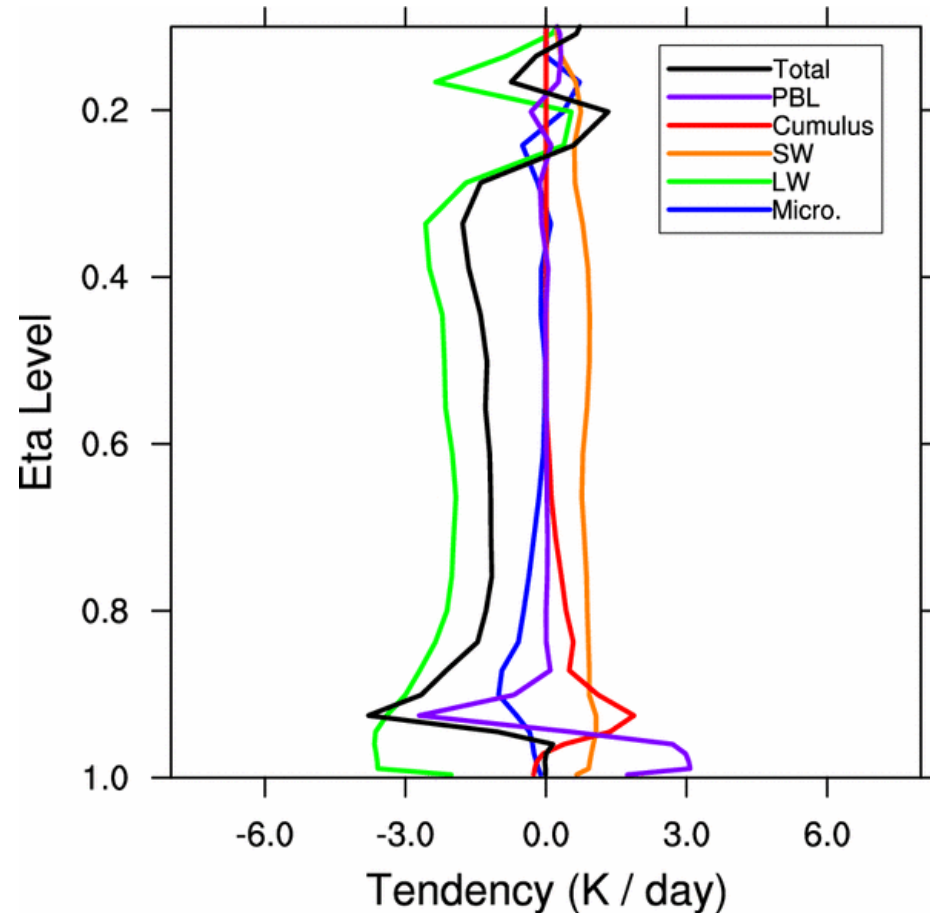


Mixing Ratio

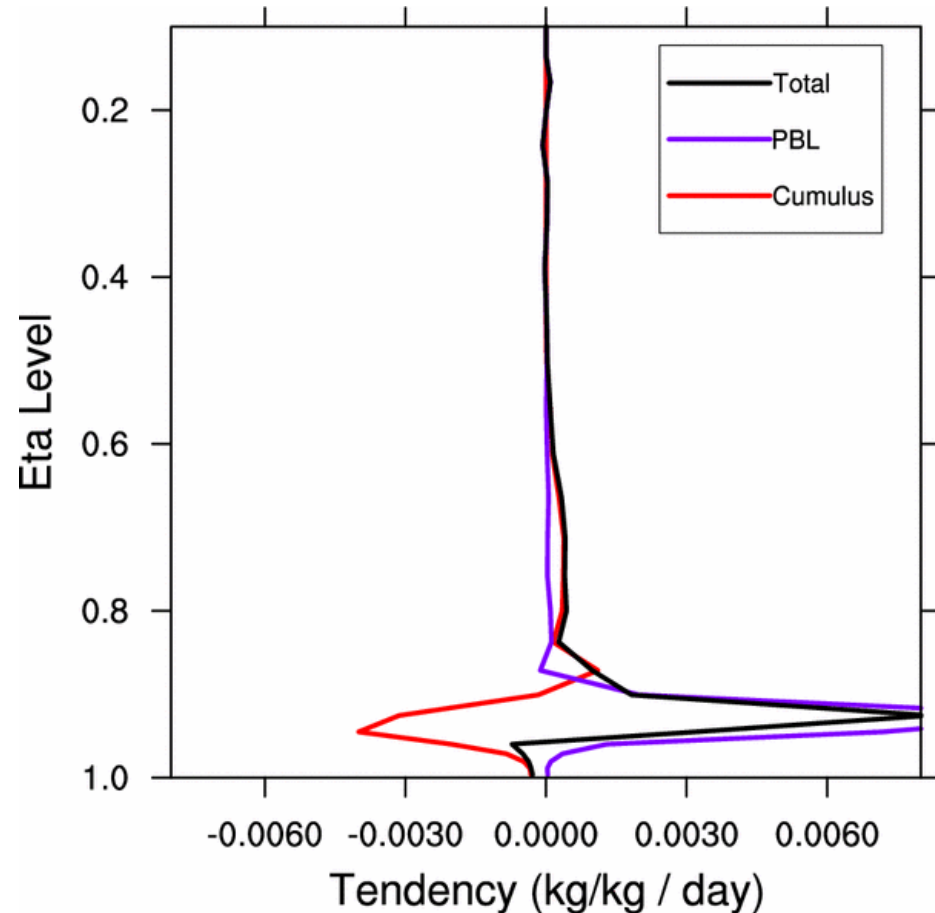


K-F Eta Physics Tendencies

Theta

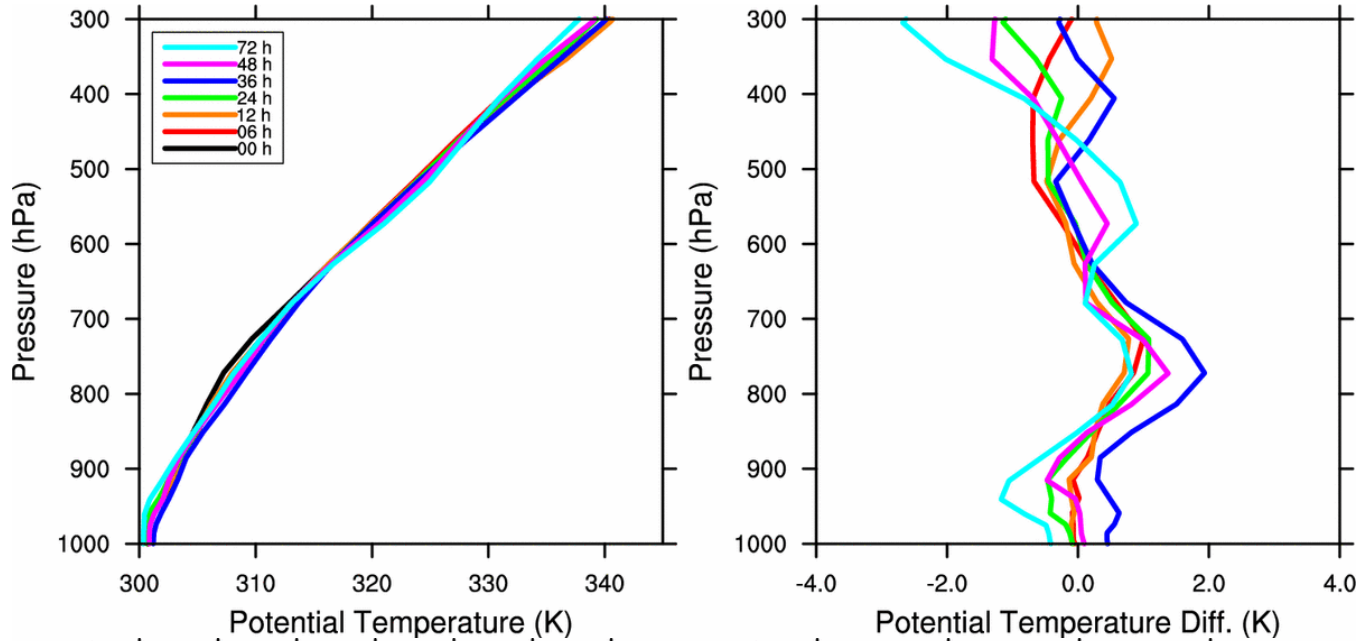


Mixing Ratio

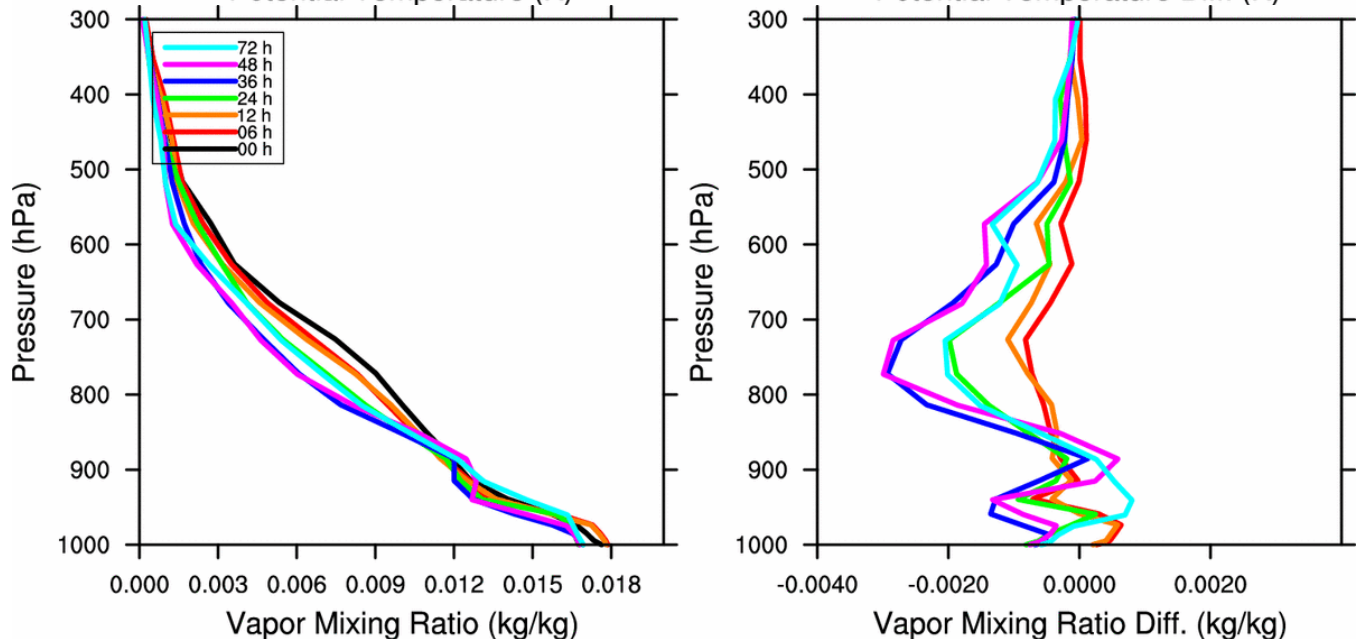


Tiedtke Vertical Profiles

Theta

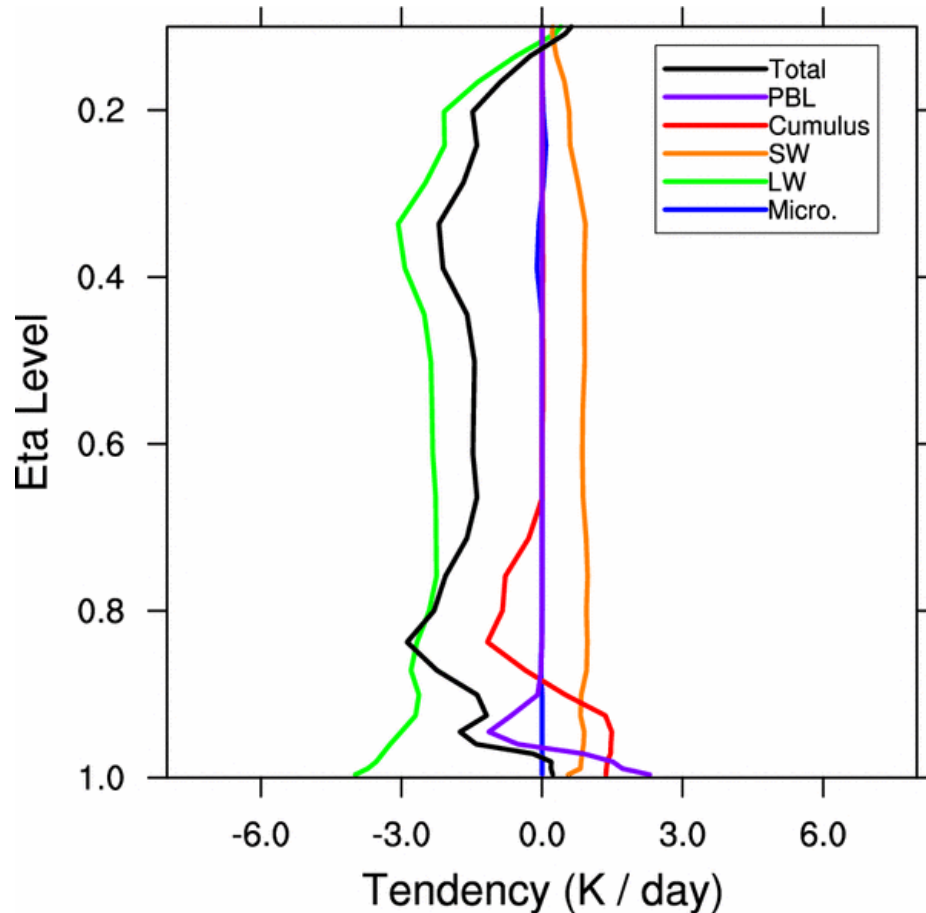


Mixing Ratio

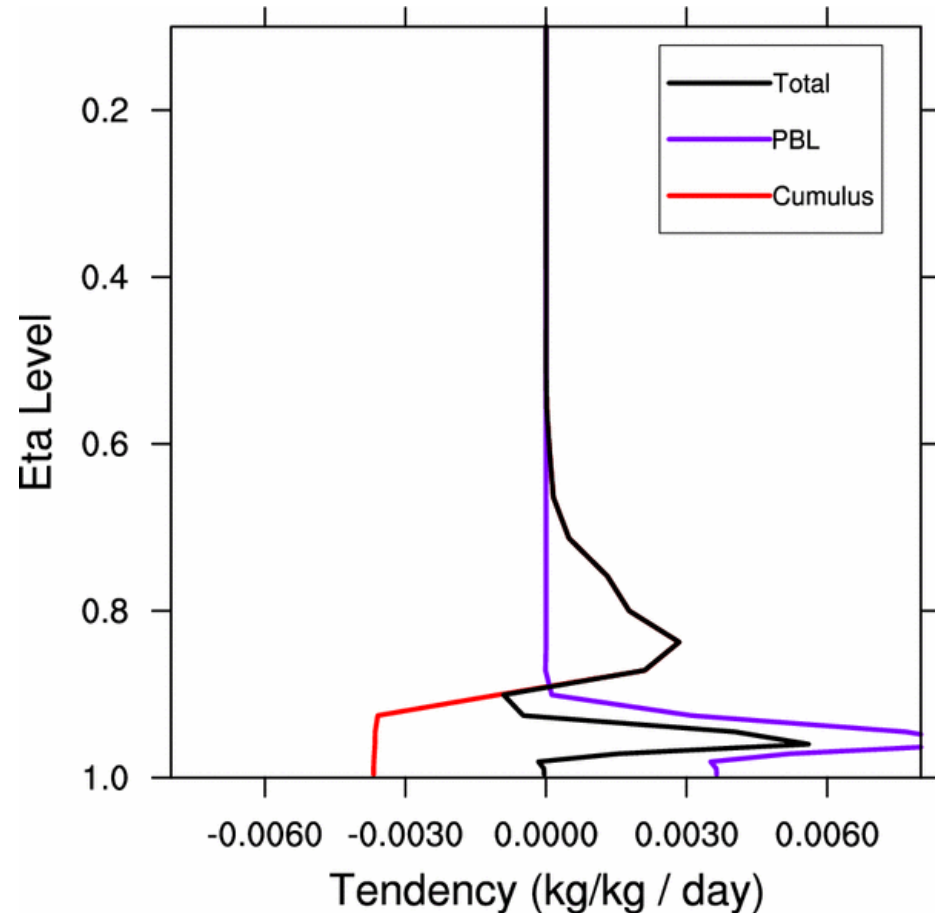


Tiedtke Physics Tendencies

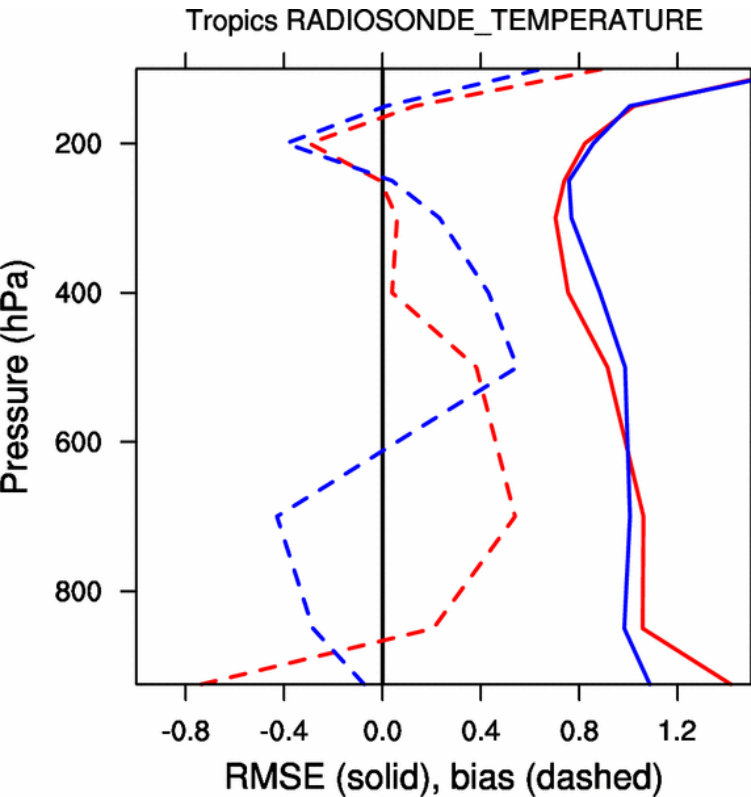
Theta



Mixing Ratio

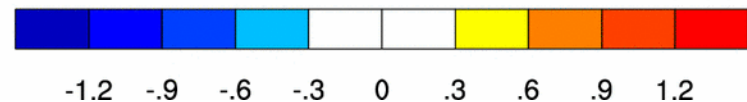
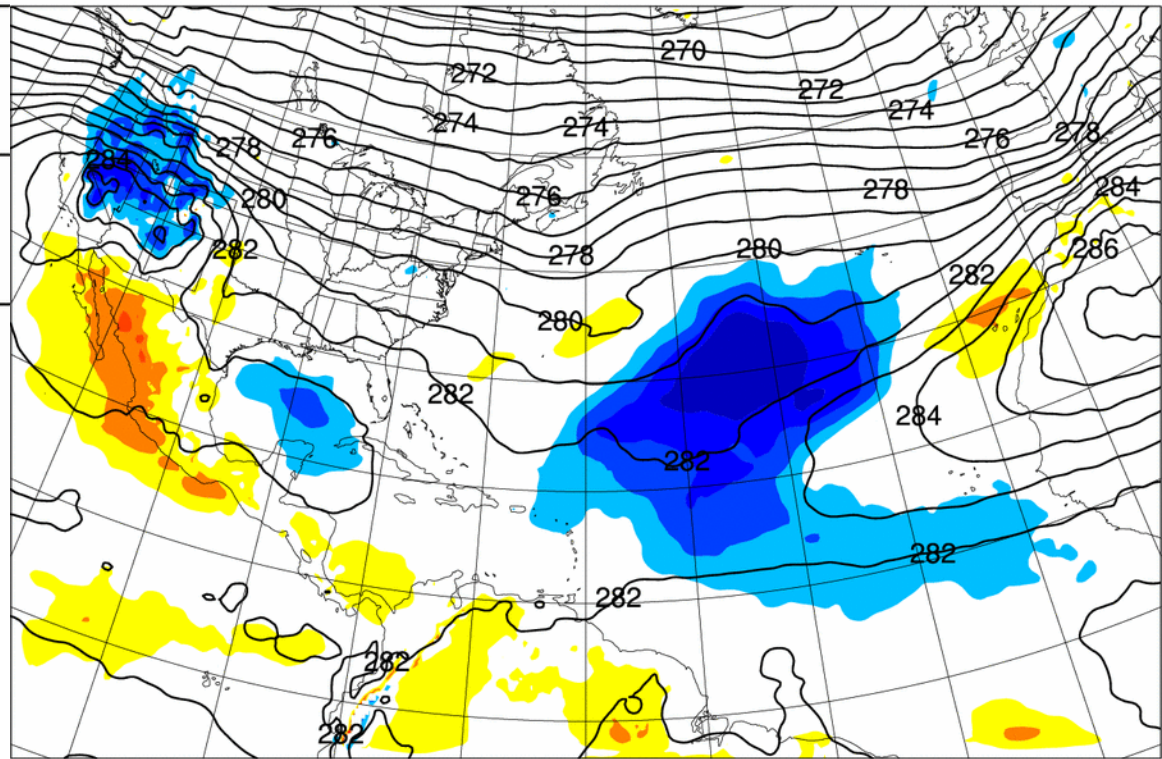


Tiedtke Cycling 6 h Errors



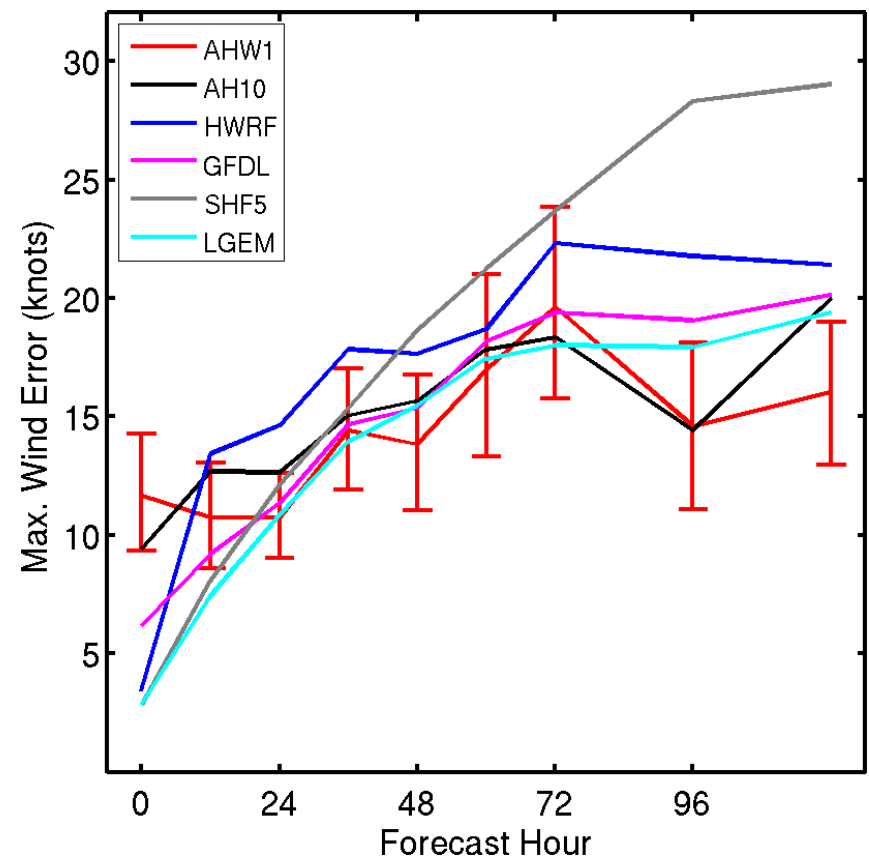
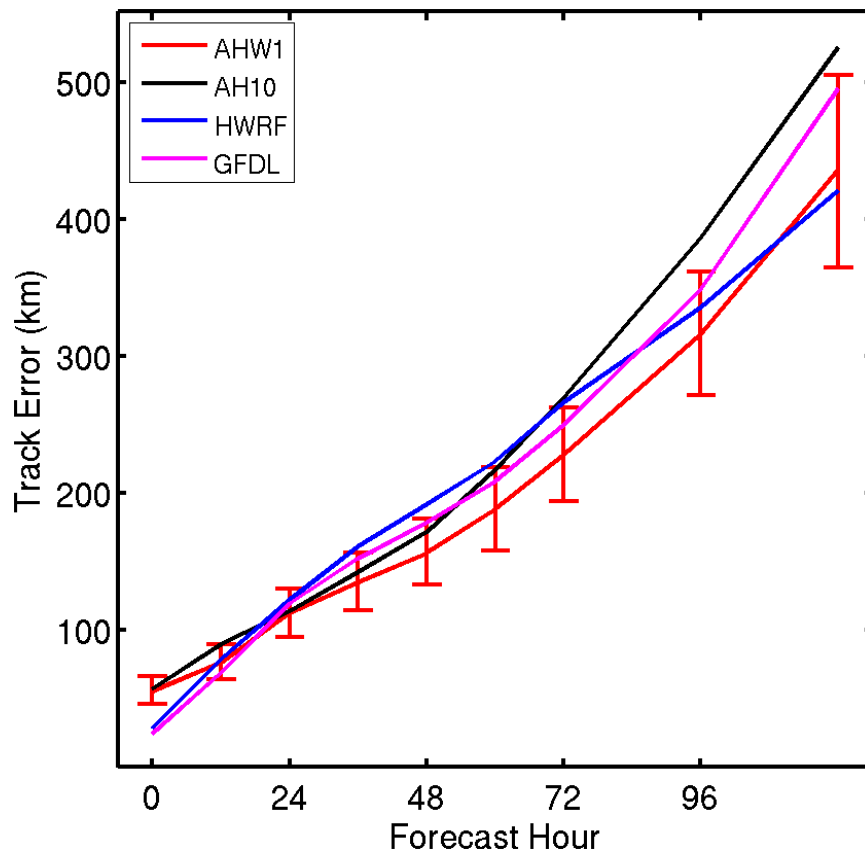
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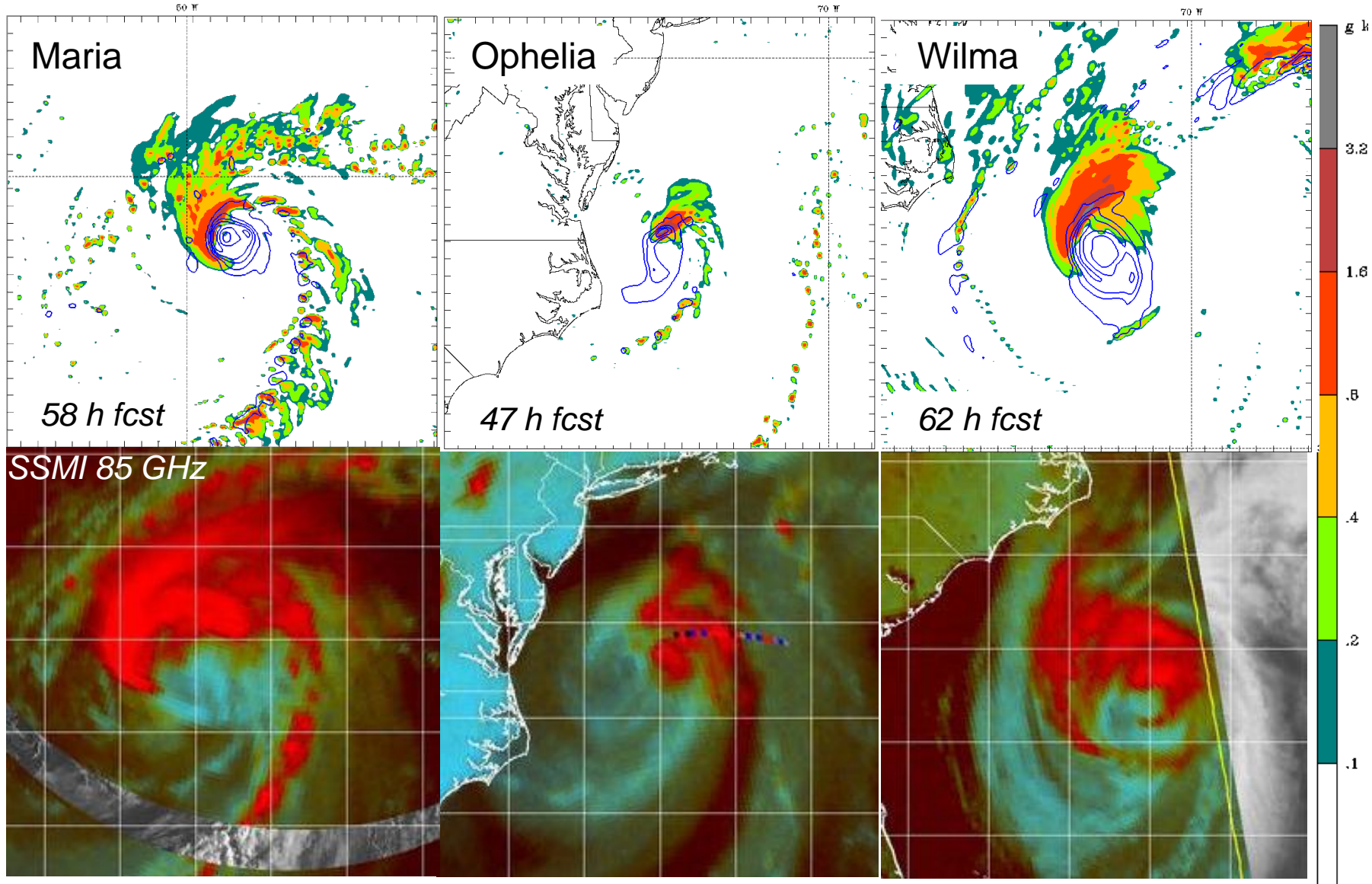
Advanced Hurricane-research WRF (AHW): *Forecast Performance for 2010*

AHW1 (new) AH10 (old)
42 cases (homogeneous)



Structures of Simulated Transitioning Cyclones

ARW Rain Water at 40 m (g/kg) PV at 1 km (PVU)



Vision for AHW

TC prediction system that is:

- Globally Relocatable
- Portable
- Computationally affordable
- Driven by cycling EnKF
- A community resource
- Straightforward to use
- Well-tested

