High Resolution Hurricane Tests Using COAMPS®-TC for the Hurricane Forecast Improvement Program

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Model Description (I)

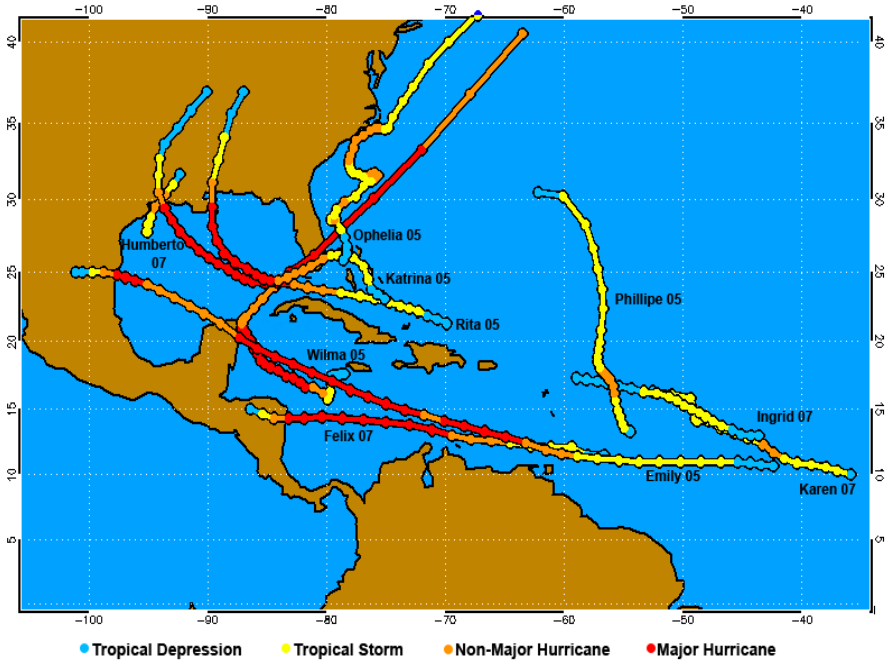
Model: Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) – Tropical Cyclone (TC)

- Model Overview
  - Finite-difference, fully compressible, non-hydrostatic
  - Arakawa C grid in horizontal and sigma-z grid in vertical
  - A family of moving nested, 2-way interactive domains for TC forecasts
- Physics
  - KF parameterization (> 9 km)
  - 5-specie microphysics
  - Shallow cumulus parameterization
  - Mellow-Yamada TKE parameterization
  - sea-spray
  - Level-off drag coefficient for high winds
  - Dissipative heating

Model Description (II)

- Domain resolution
  - Horizontal:
    a) 81 / 27 / 9 km; NRL1: 9 km grid
    b) 81 / 27 / 9 / 3 km; NRL2: 3 km grid; NRL5: 9 km grid
  - Vertical: 40 levels with model top at 32 km
- Initialization
  - NOGAPS as initial condition for a cold start
  - 12-hour update cycles for warm starts
  - Vortex relocation and synthetic data
  - Data assimilation using NAVDAS (3DVAR)
  - NCODA (univariable VAR) for SST data assimilation
- Boundary condition
  - 6-h NOGAPS forecast output on 1° resolution grid

Domain Configuration



Ten storms in 2005 and 2007 are selected for retrospective track and intensity testing during 2008-09 phase of high resolution test (HFIP documentation).

COAMPS domains using Mercator map projection and including 2-3 nested domains moving with the hurricane center. The 9km domain covers 15^{o}x15^{o}. The coarsest domain 75^{o}x105^{o} extends from 15^{o} S to 60^{o} N.

Model Output

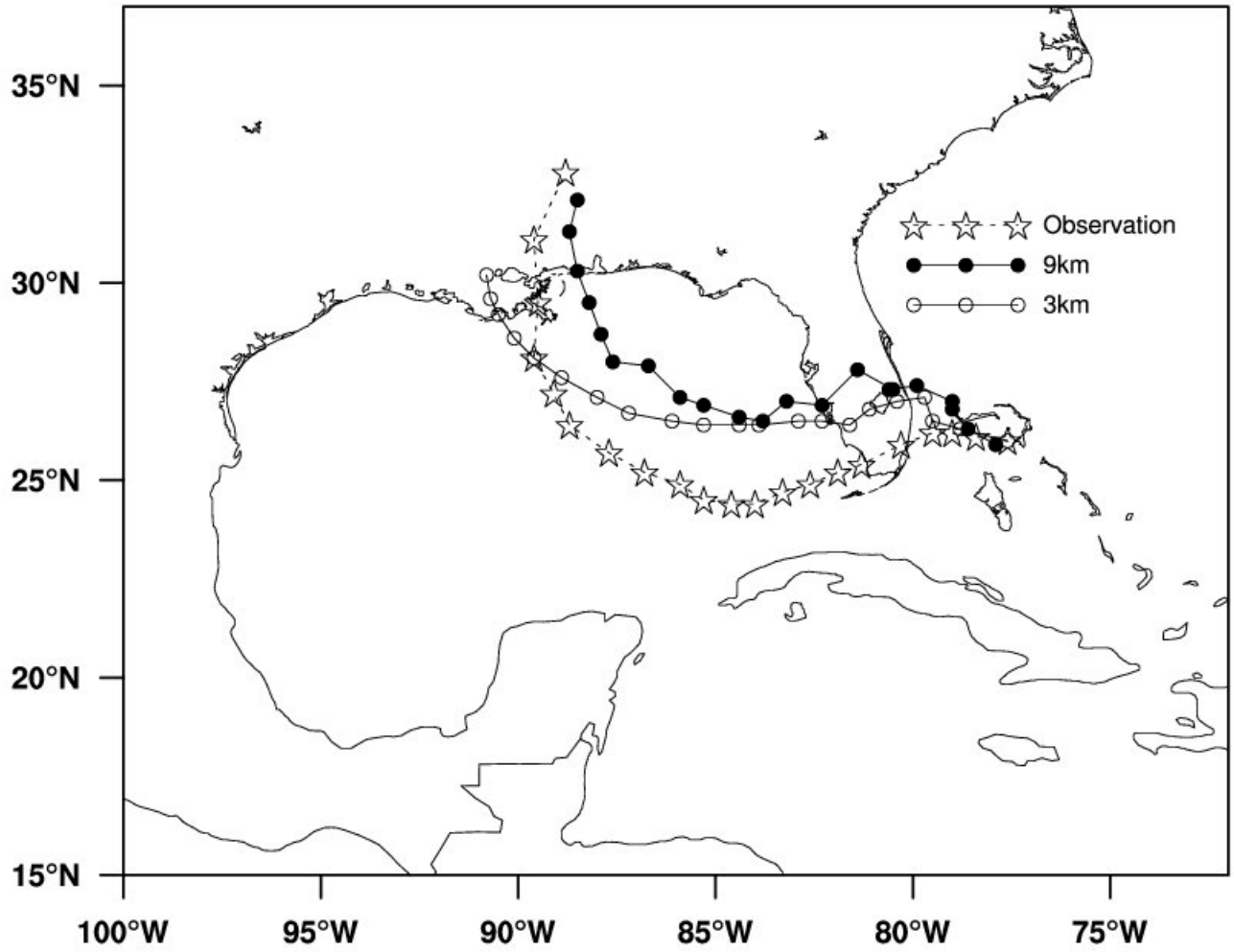
- Created the nested output files based on the requirement of the HFIP test plan: 7 variable (SLP, temperature, dewpoint, geopotential height, absolute vorticity, wind u and v) at 4 vertical levels (surface, 850mb, 700mb, 500 mb) every 30 minutes up to 126 hour.
- Output module is implemented for COAMPS output, which is interpolated to an uniform latitude and longitude grids with a fixed spatial distance.
- Output files are converted to Grib format and verified to meet the DTC requirement, and delivered to DTC for model evaluation.

High Resolution Hurricane Tests

Storm Name	SID	Year	Total cases	Completed cases	Problem cases*
Emily	EMI	2005	10	6	1
Felix	FEL	2007	4		
Humberto	HUM	2007	2		
Ingrid	ING	2007	4		
Karen	KAR	2007	4		
Katrina	KAT	2005	6	6	
Ophelia	OPH	2005	11	6	
Philippe	PHI	2005	6	4	
Rita	RIT	2005	7	5	1
Wilma	WIL	2005	13	10	

* Cases with problems due to the missing TC warning from JTWC.

Track Forecast Errors for Katrina 2005082500



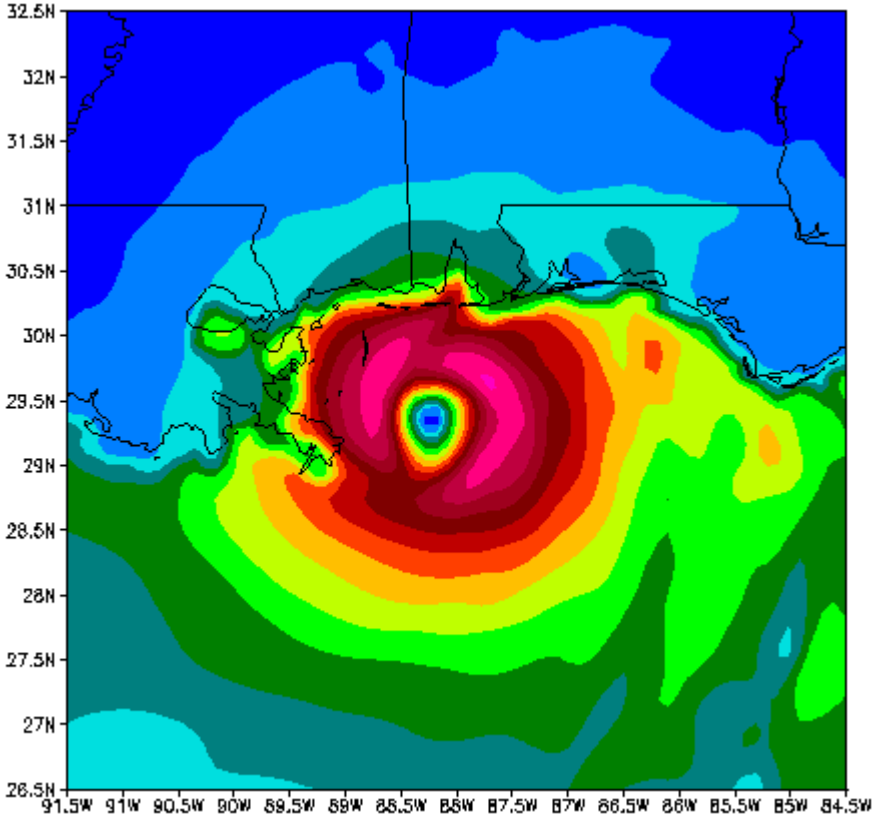
Track Errors (NM)

Hour	3km	9km
12	33.7	33.0
24	69.7	91.9
36	73.2	144.2
48	109.0	140.4
60	117.3	130.2
72	98.7	124.3
84	85.4	139.5
96	61.7	110.0
108	56.4	73.9
120	185.9	43.0

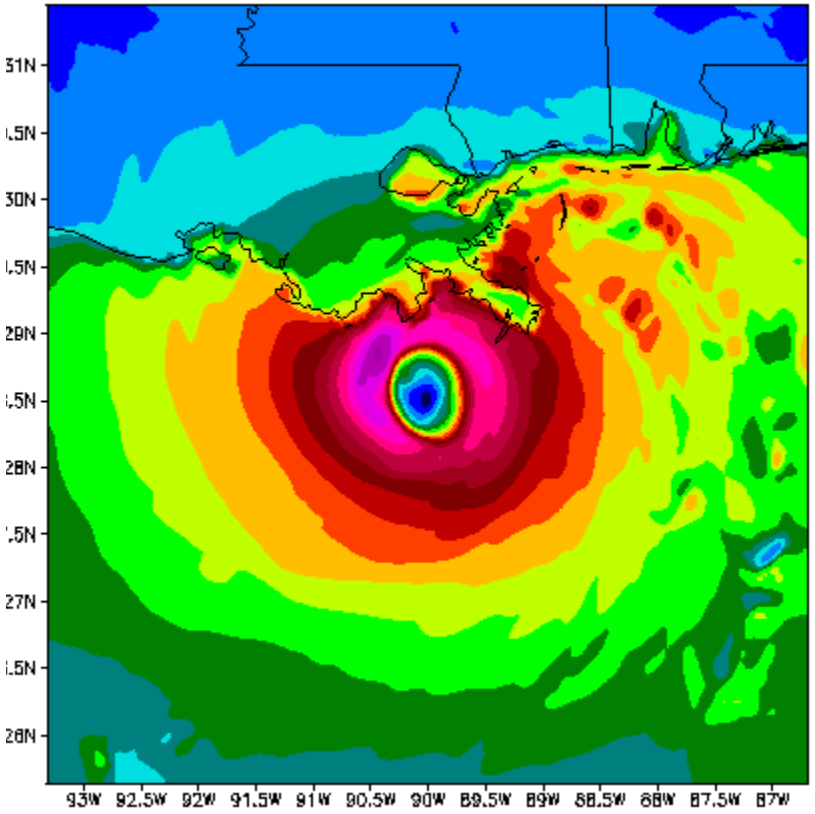
Ave Errors over 120 hrs
9km: 96.2 NM
3km: 84.8 NM

Katrina Surface Wind Distributions 102 h valid for 0600 UTC 29 Aug 2005

9-km

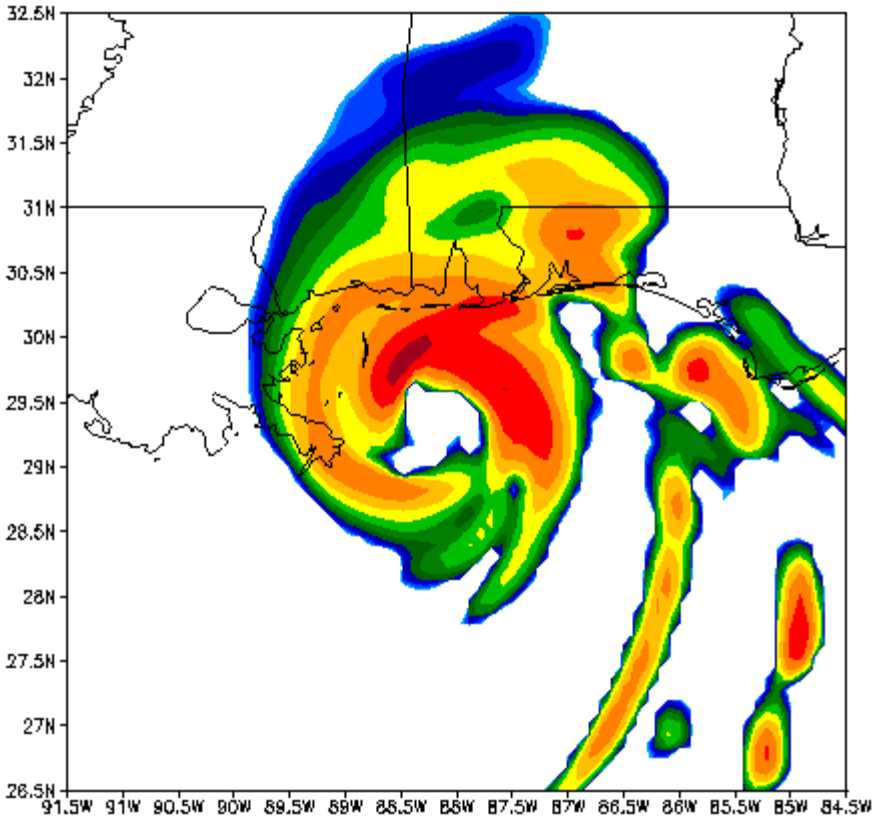


3-km

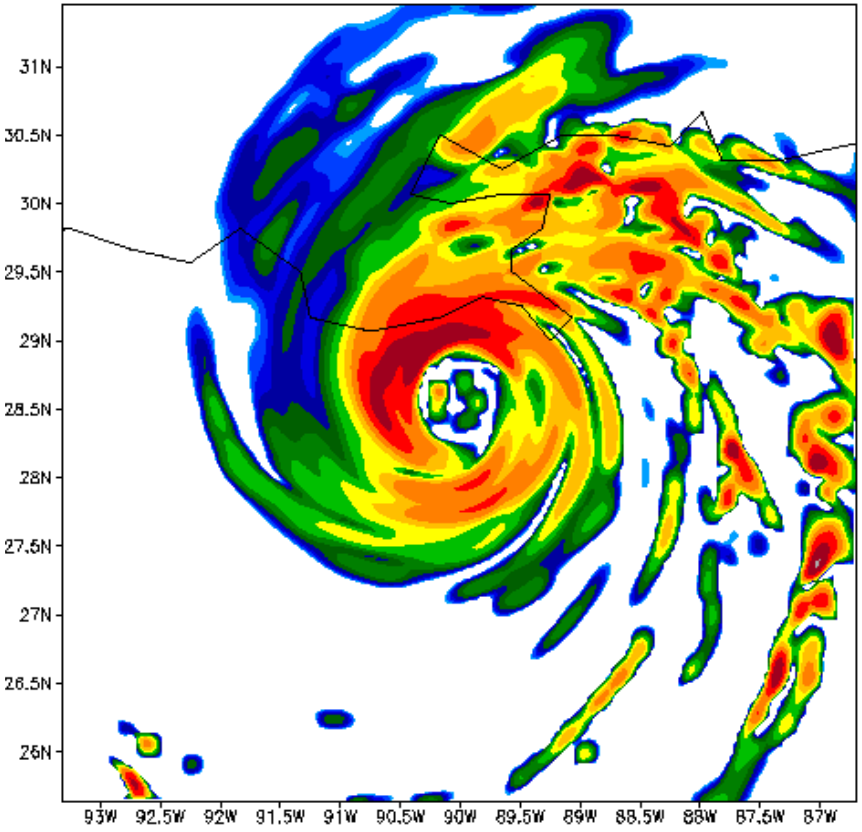


Katrina Surface Radar Reflectivity 102 h valid for 0600 UTC 29 Aug 2005

9-km



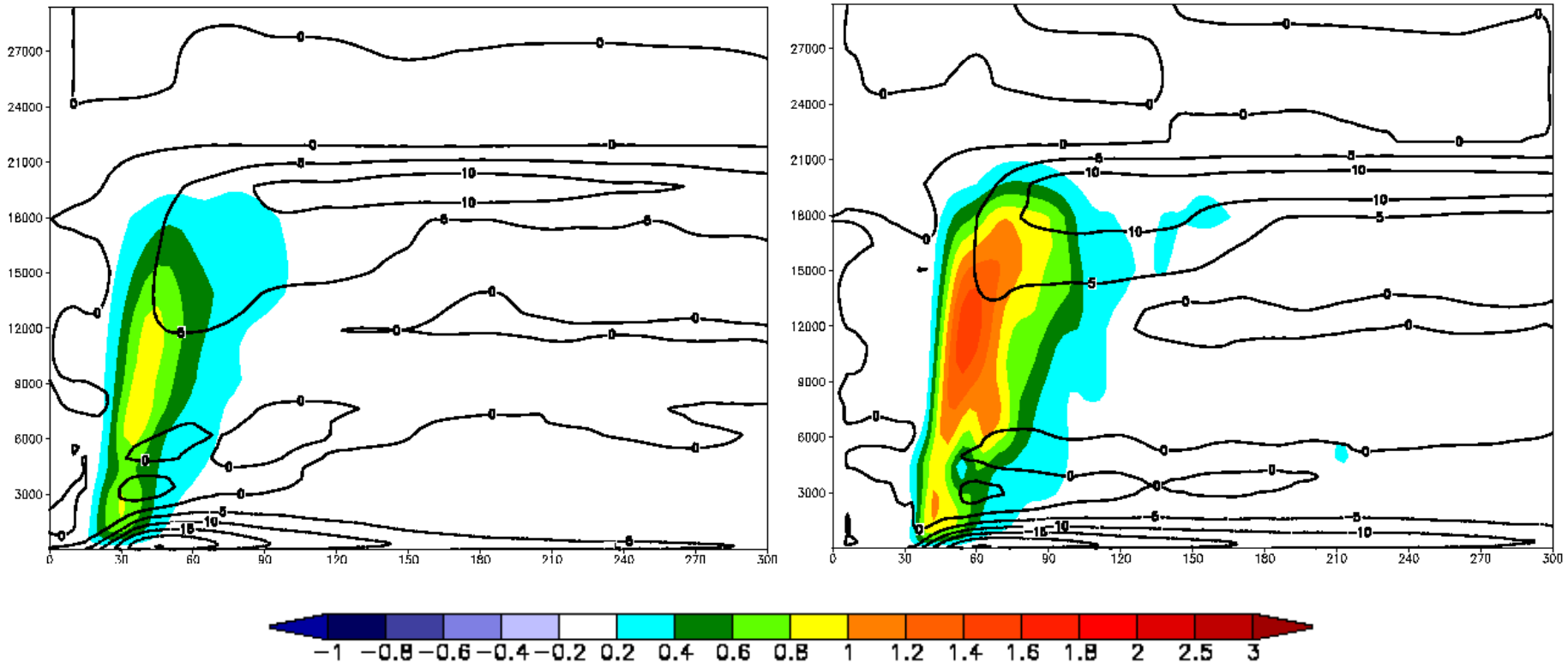
3-km



Katrina Azimuthally Average Structure 102 h

9-km

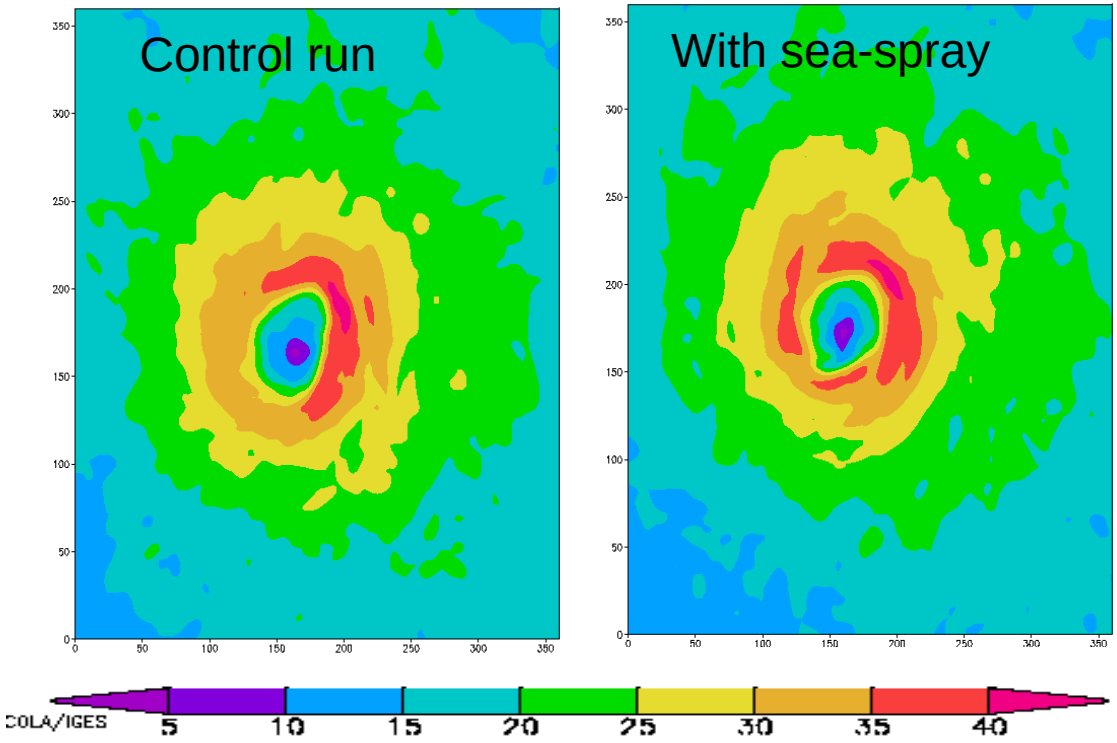
3-km



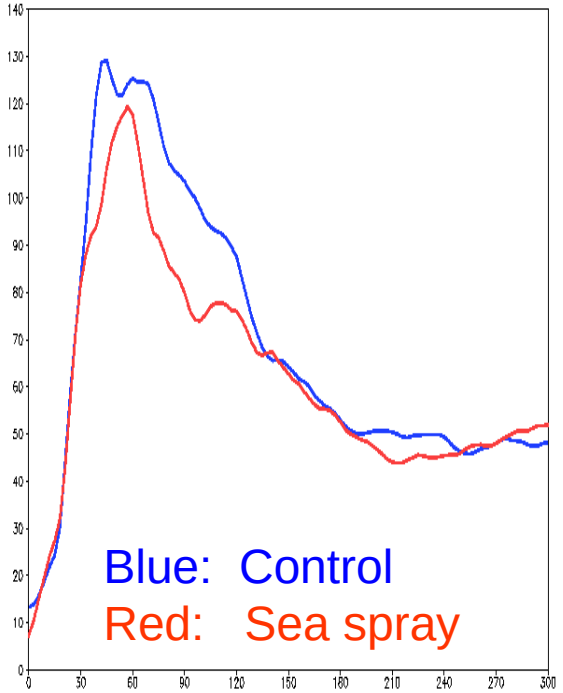
Azimuthally Ave vertical velocity (shaded) and radial flow (contour) (units: m s^{-1})

3-km Simulations of Katrina: Sea Spray Sensitivity
(60 h, valid at 0000 UTC 28 Aug.)

Surface wind speed (m s^{-1})



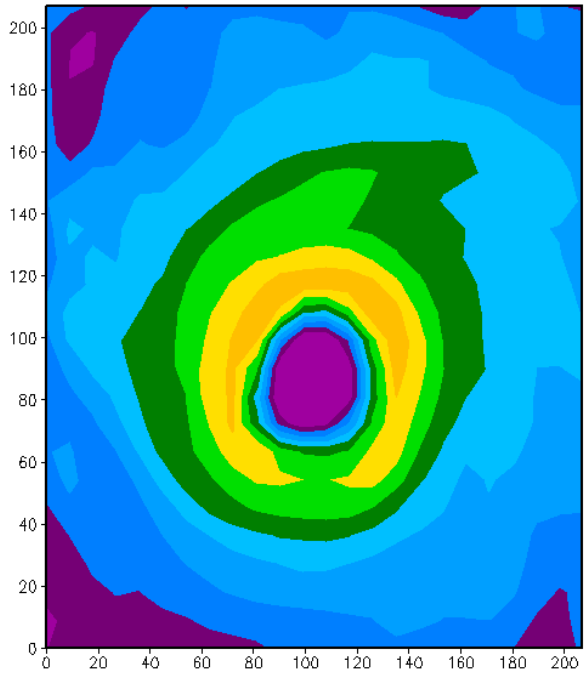
Surface sensible heat flux (W m-2)



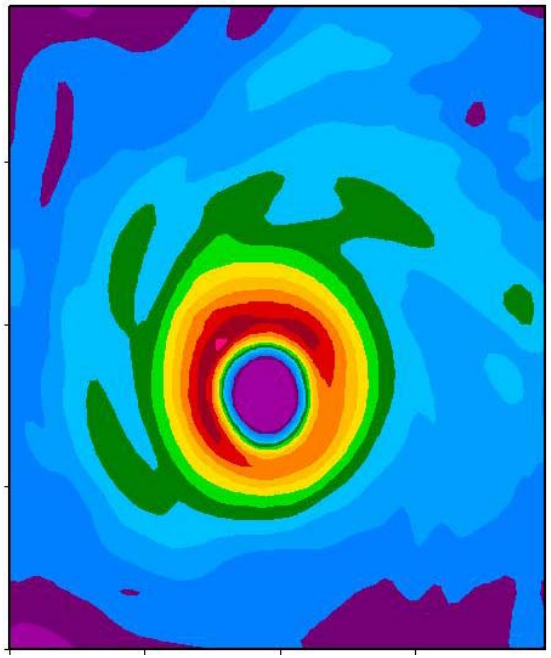
Fairall's sea-spray scheme has been implemented in COAMPS-TC. Initial results suggest that the sea spray impacts the structure in the TC eyewall region as well as the intensity. More tests are underway.

Katrina Inner Core Structure

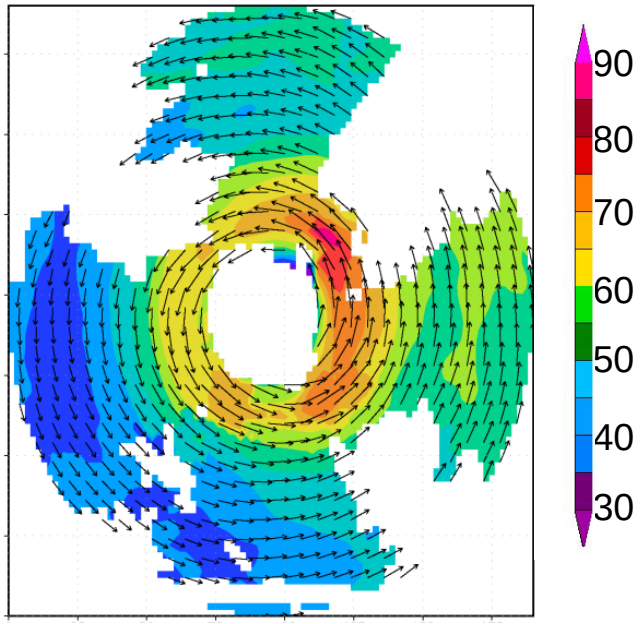
9-km



3-km



Doppler OBS

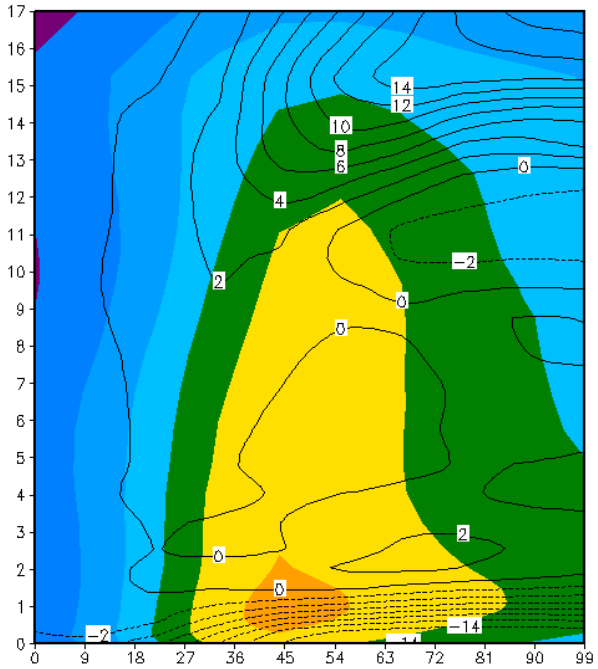


(Courtesy of Rogers et al. of HRD)

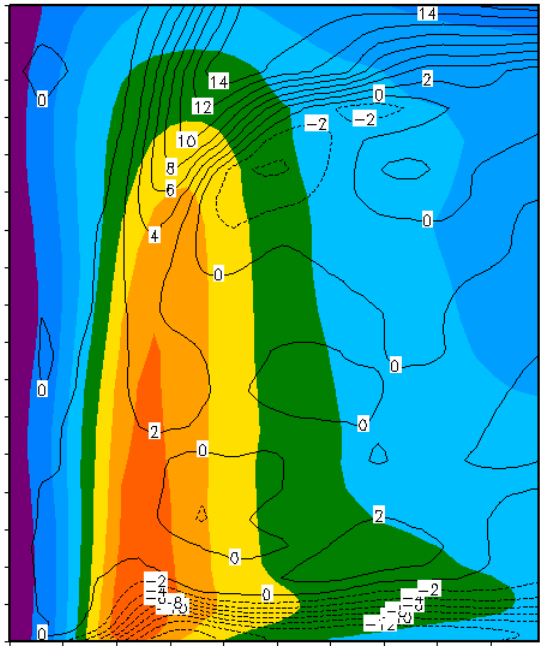
wind speed (m s^{-1}) at 2 km altitude
72 h forecast valid at 00 Z Aug 29 2005)

Katrina Vertical Structure

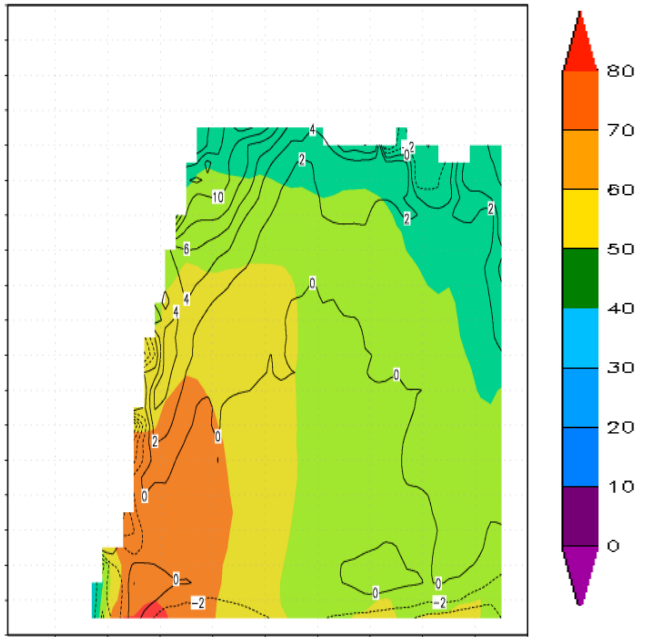
9-km



3-km



Doppler OBS



(Courtesy of Rogers et al of HRD)

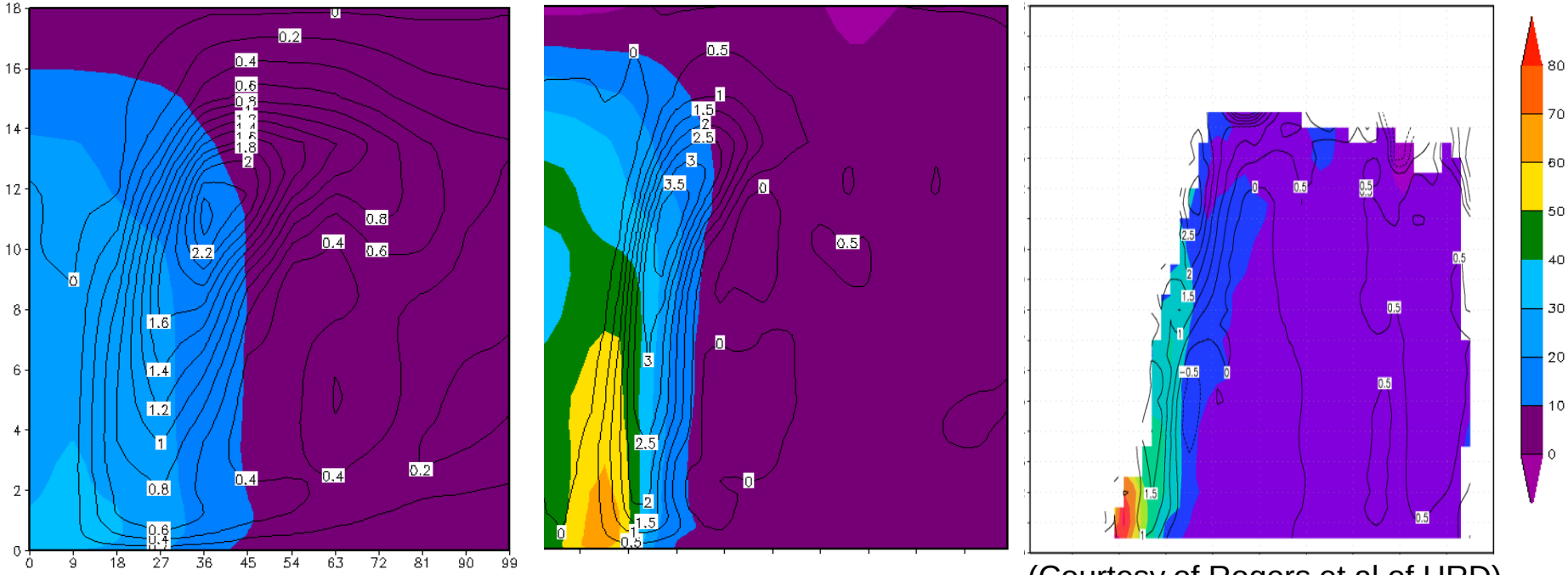
Azimuthally average winds (Tangential winds shaded and radial winds contoured)
(72 h forecasts valid at 00 Z Aug 29 2005)

Hurricane Vertical Structure

9-km

3-km

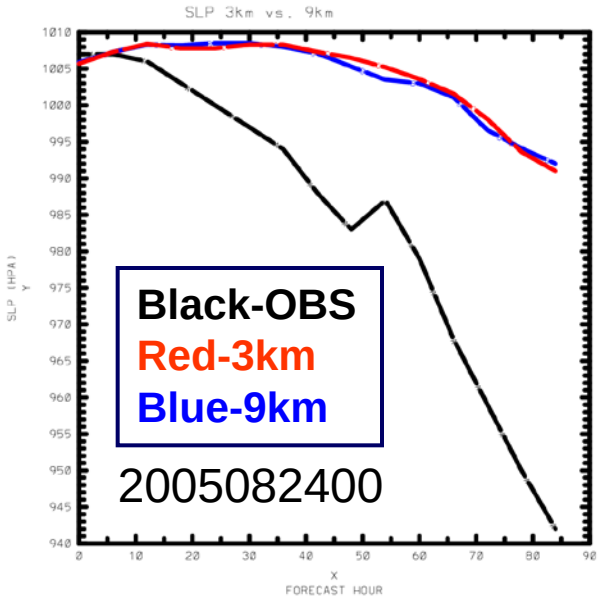
Doppler OBS

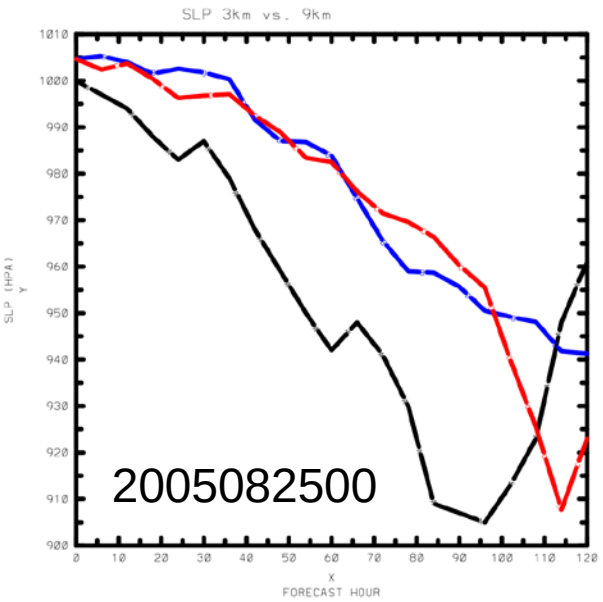


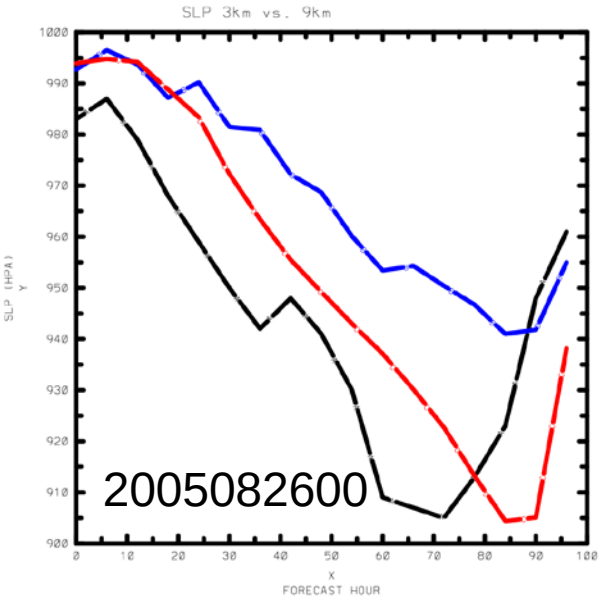
(Courtesy of Rogers et al of HRD)

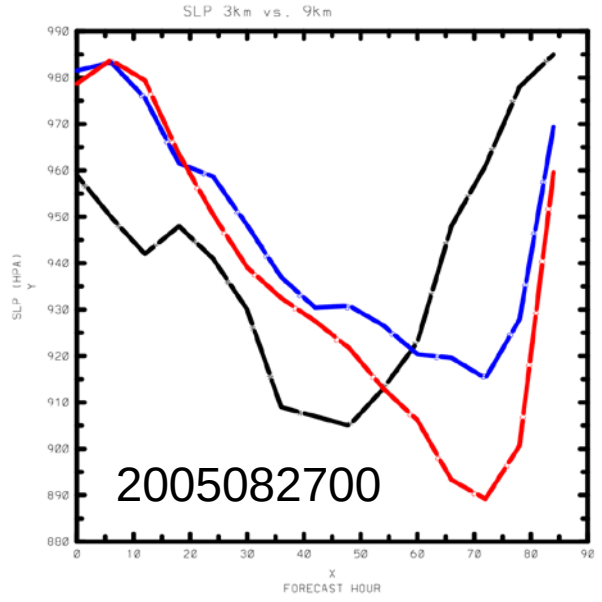
Azimuthally average vorticity (shaded) and vertical motion (contoured)
(72 h forecasts valid at 00 Z Aug 29 2005)

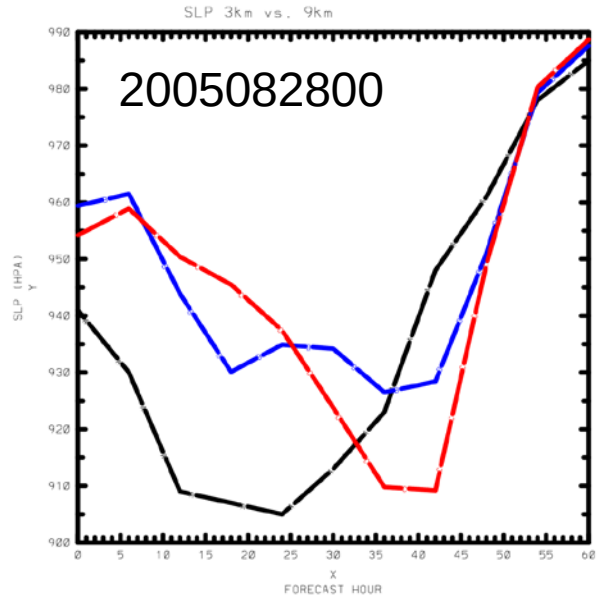
Prediction of Katrina Intensity (MSLP)

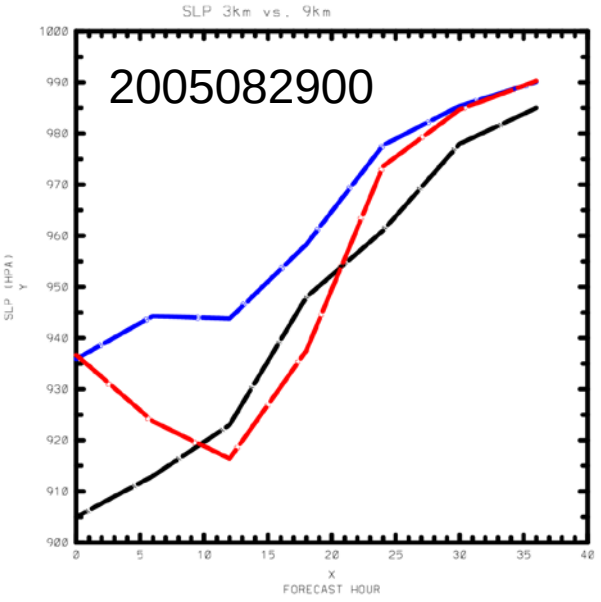




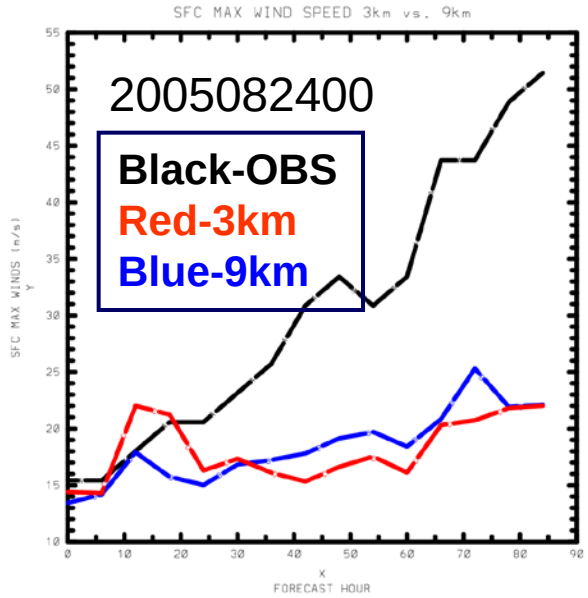


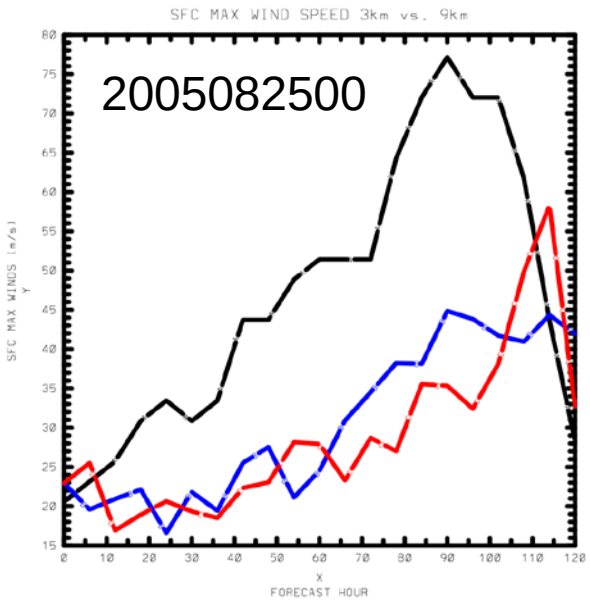


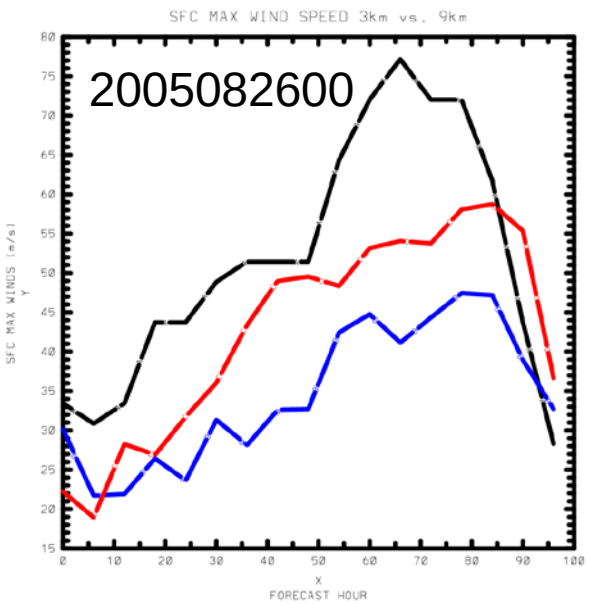


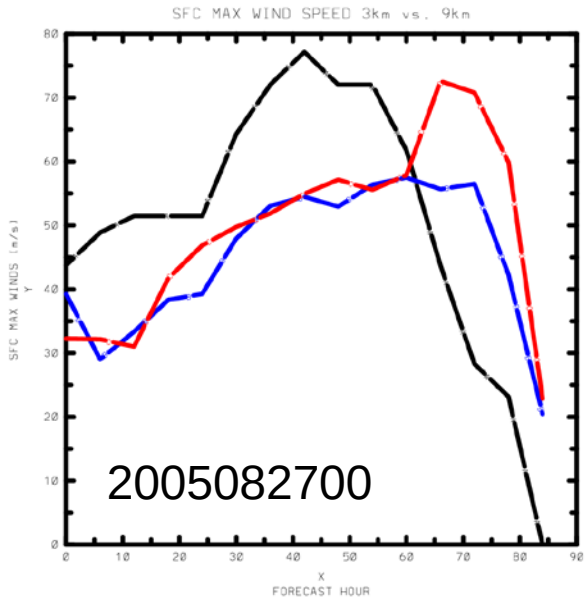


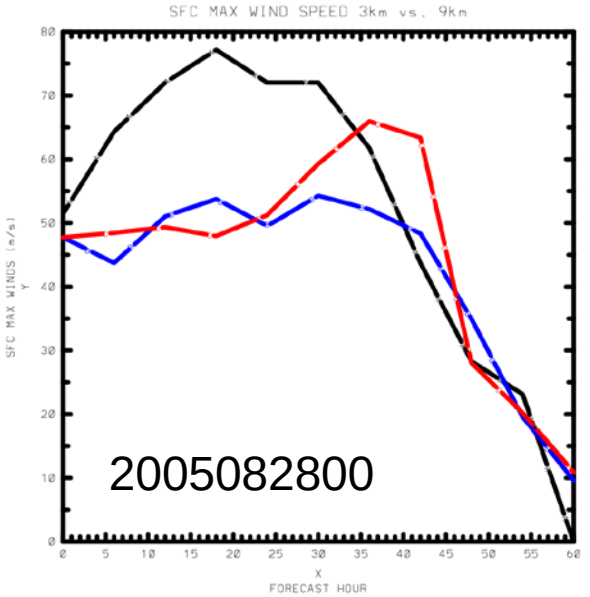
Katrina Maximum 10m-Winds

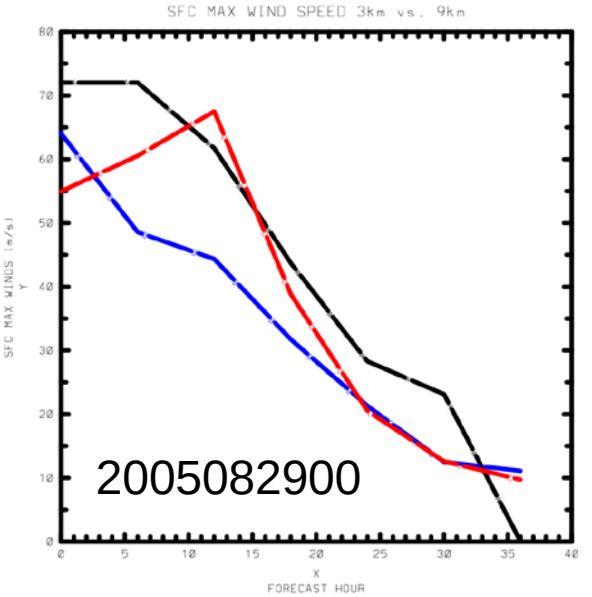




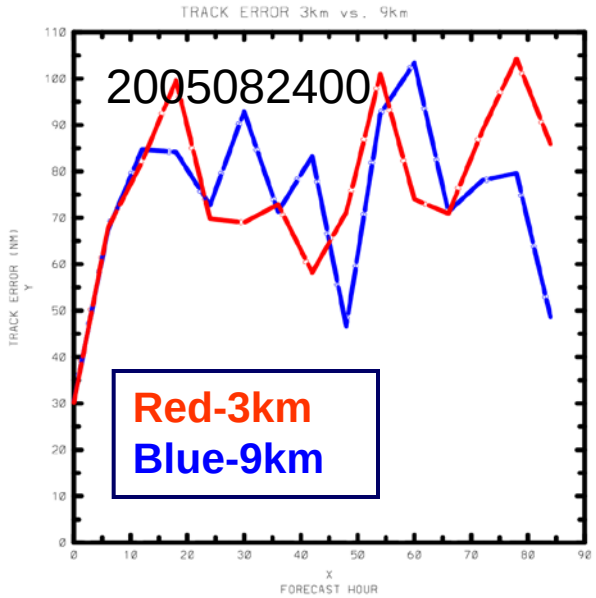


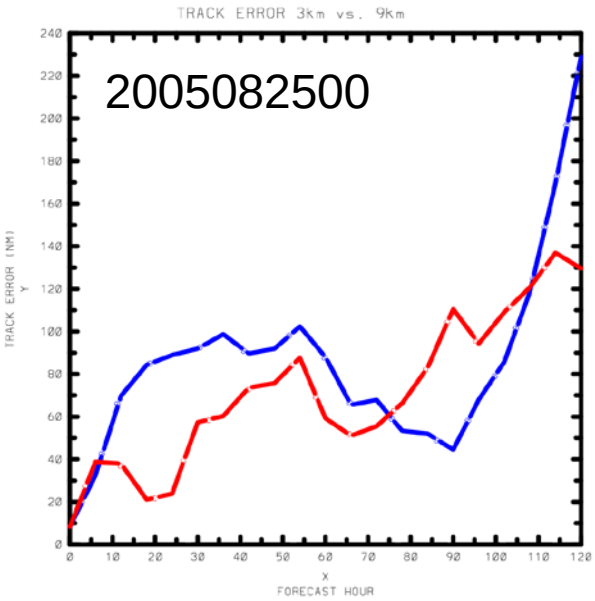


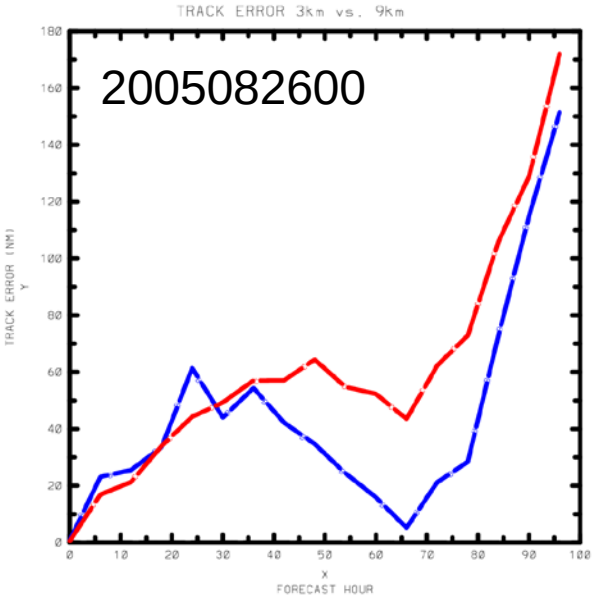


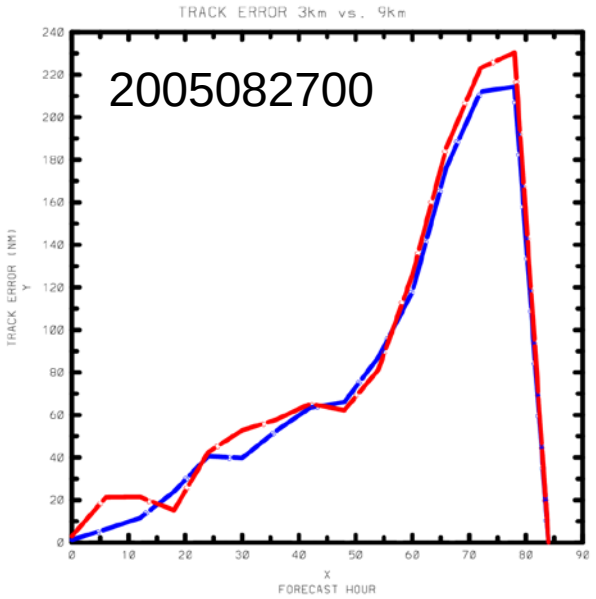


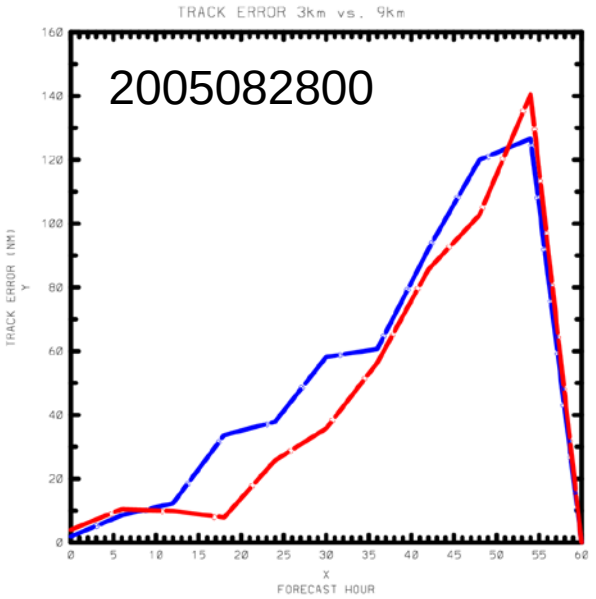
Katrina Track Errors

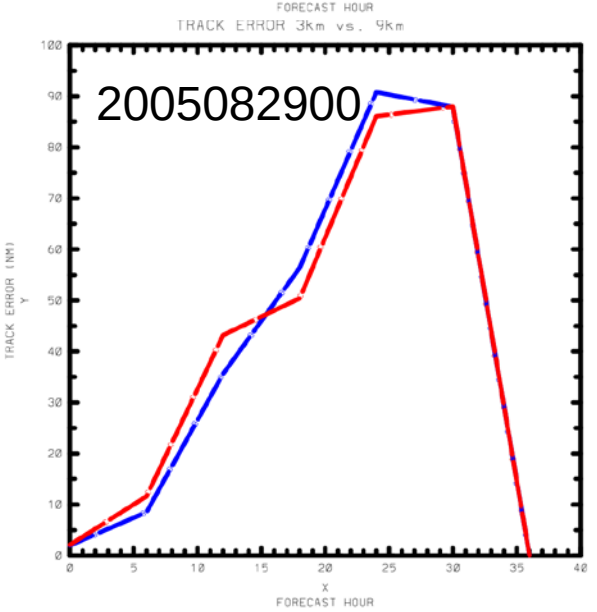








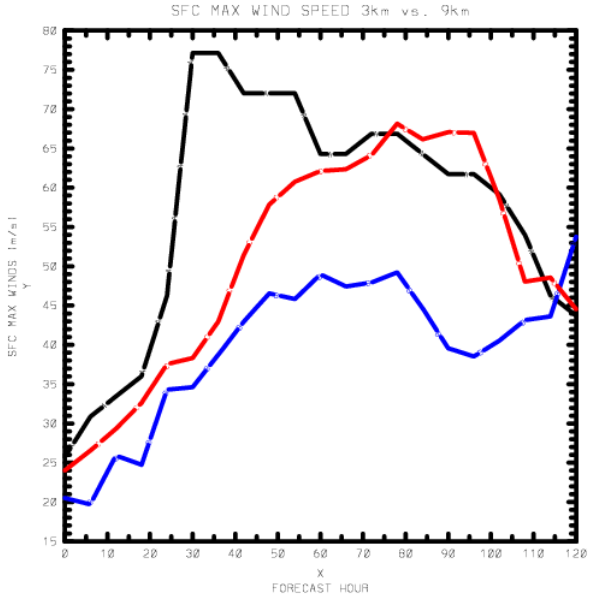




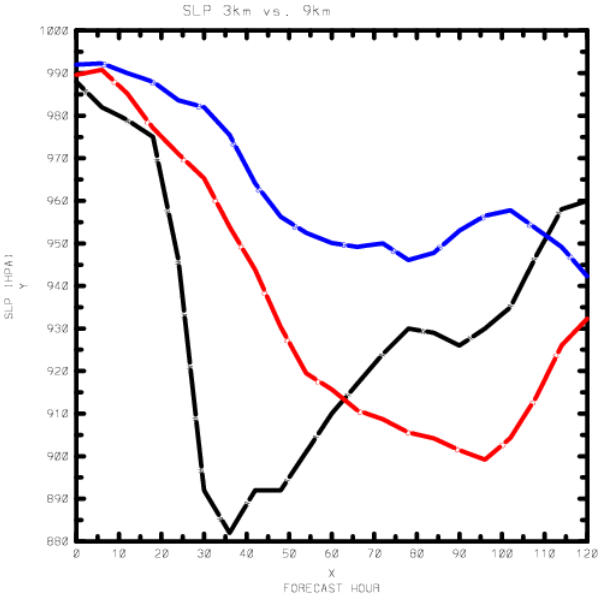
Wilma comparisons (9km vs. 3km) (I)

forecasts starting at 2005101800

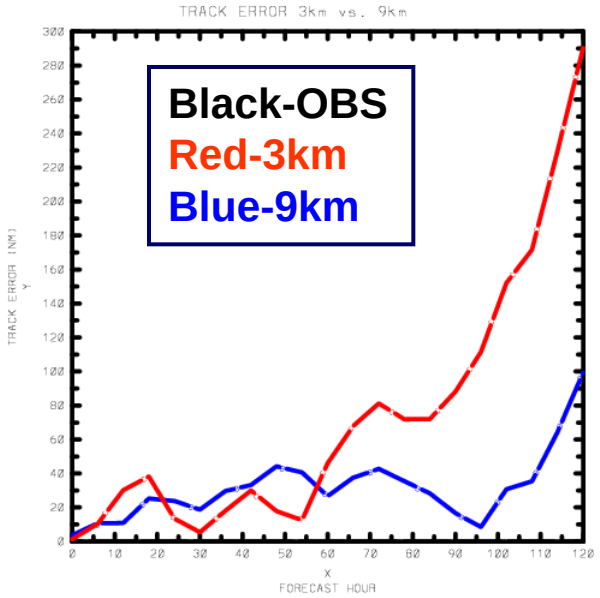
SFC Maximum Winds



MSLP



Track Errors



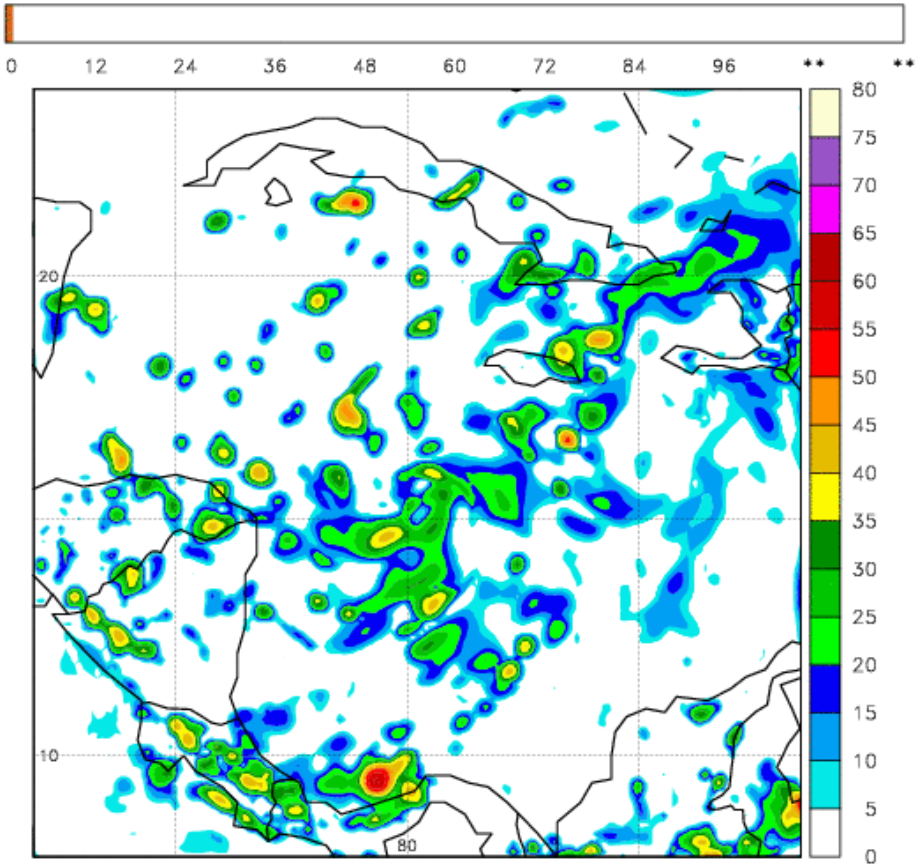
- High resolution forecast provides stronger maximum wind speed and lower minimum sea level pressure.
- High resolution forecast does not improve the TC track forecast in this case.

Wilma comparisons (9km vs. 3km) (II)

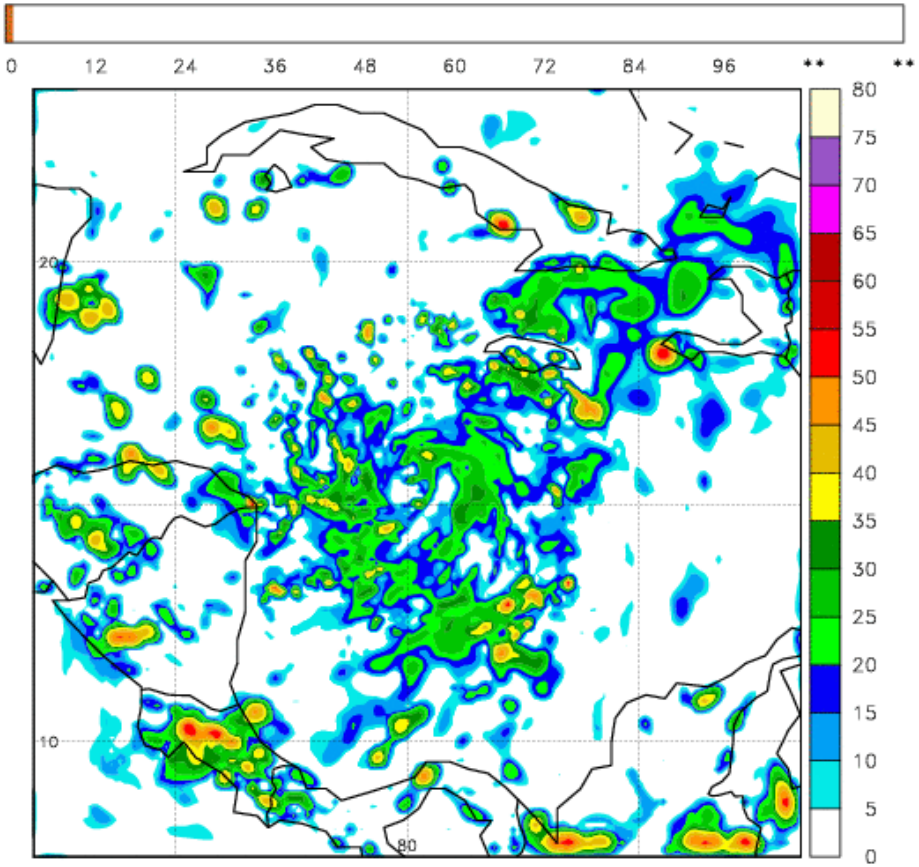
Surface Radar Reflectivity

from forecasts starting at 2005101800

9-km



3-km

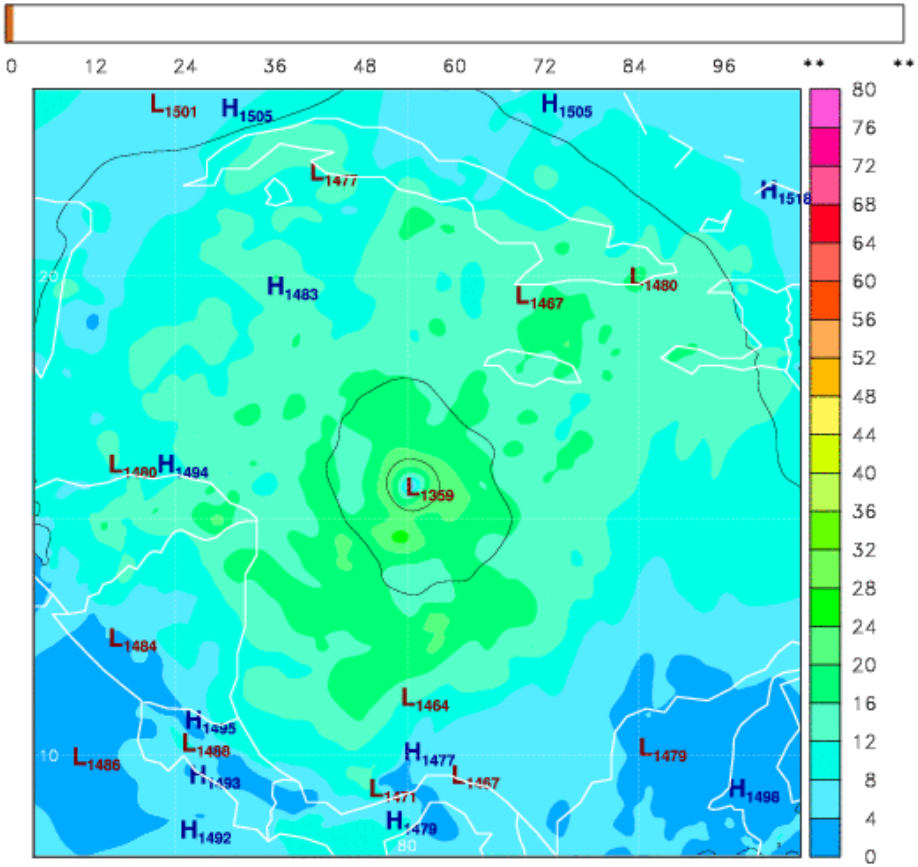


The 3-km run gives a detailed structure in the inner core and outer rainbands.

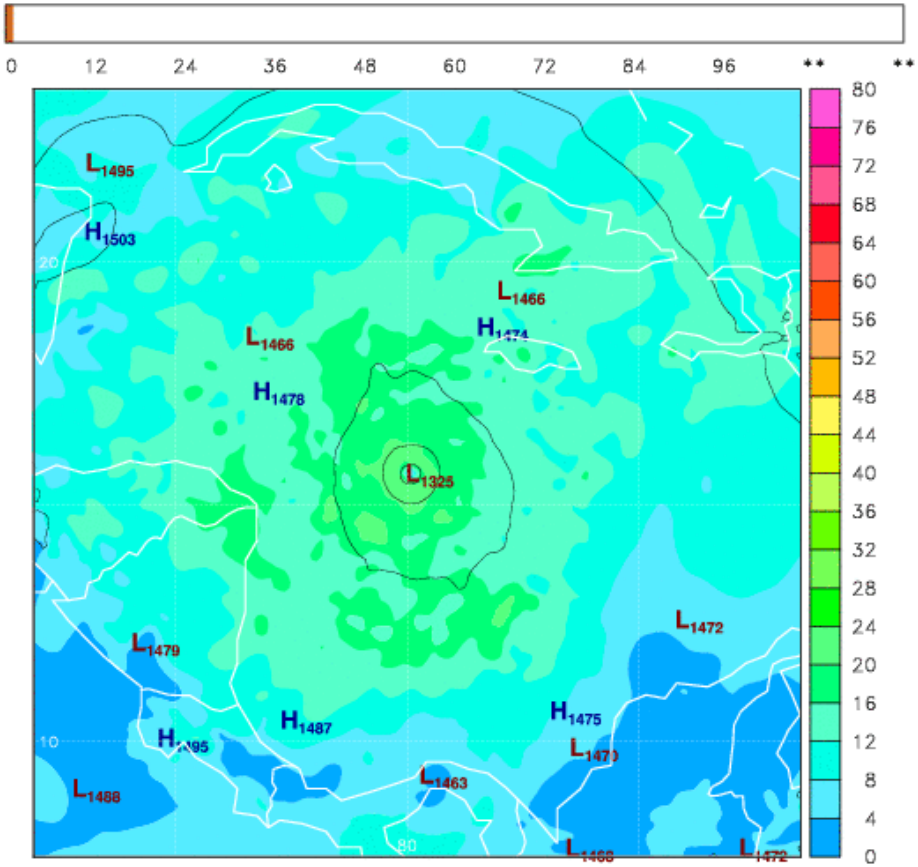
Wilma comparisons (9km vs. 3km) (III)

850hPa Wind Speed (shaded) and geopotential height (contoured) forecasts starting at 2005101800

9-km



3-km

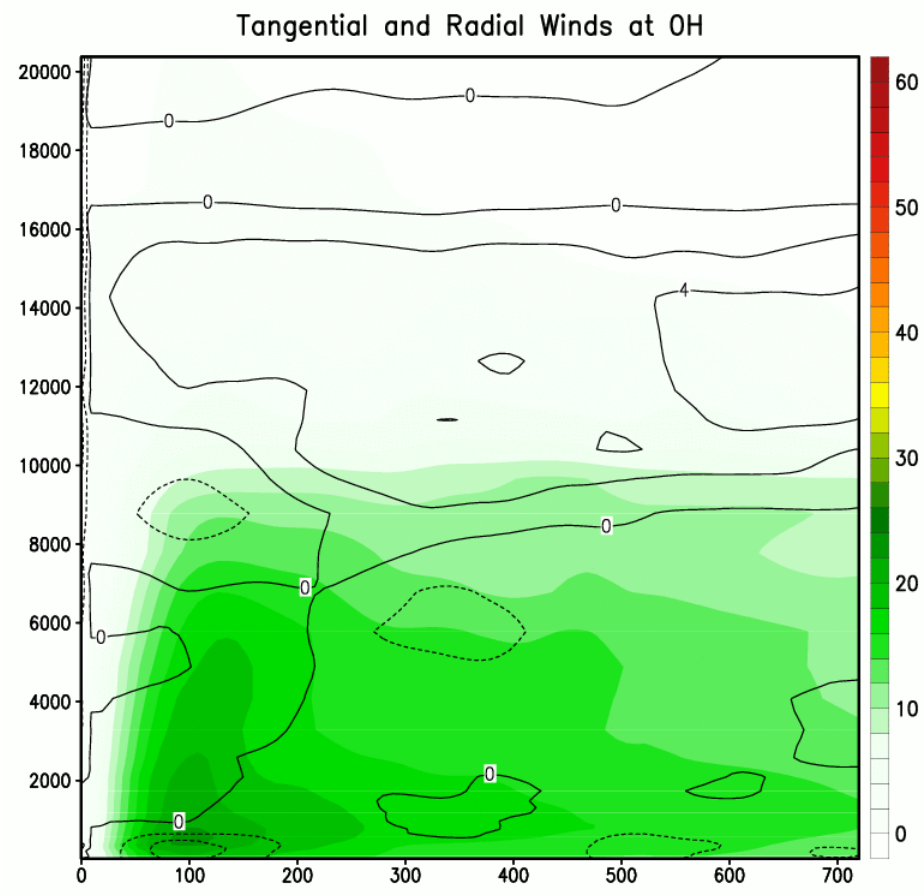


The 3-km run produces much stronger winds and a small eye than the 9-km run

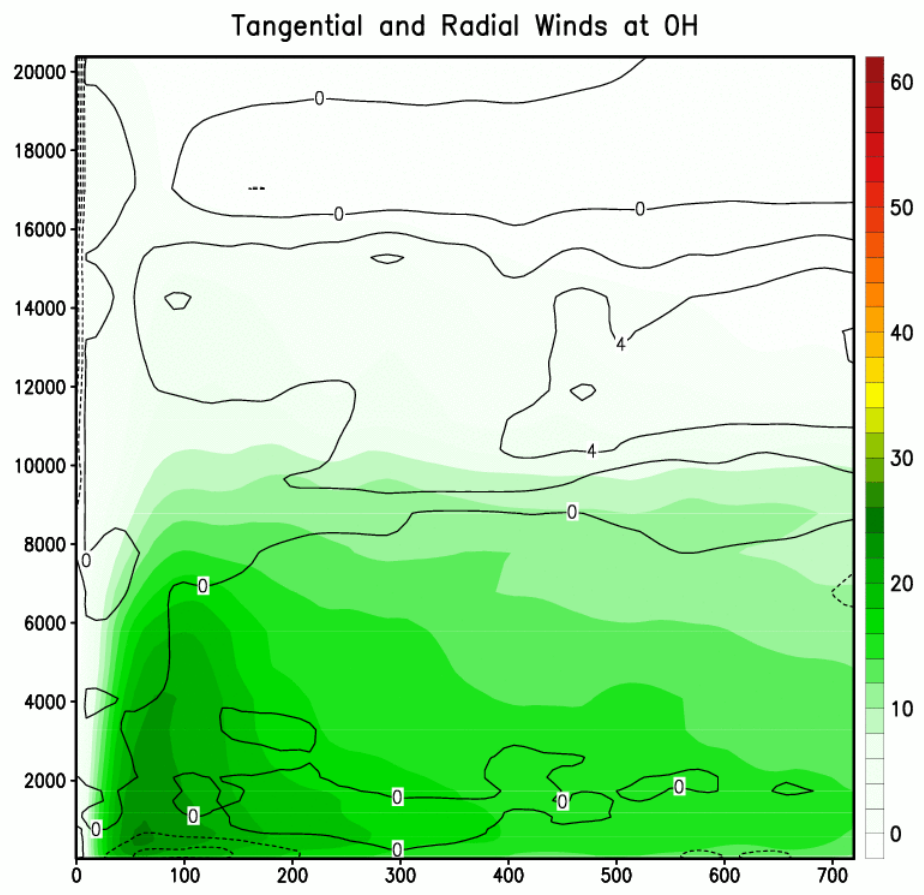
Wilma comparisons (9km vs. 3km) (IV)

Azimuthally averaged Tangential (shaded) and Radial Winds (contoured) from Wilma forecasts starting at 2005101800

9-km



3-km

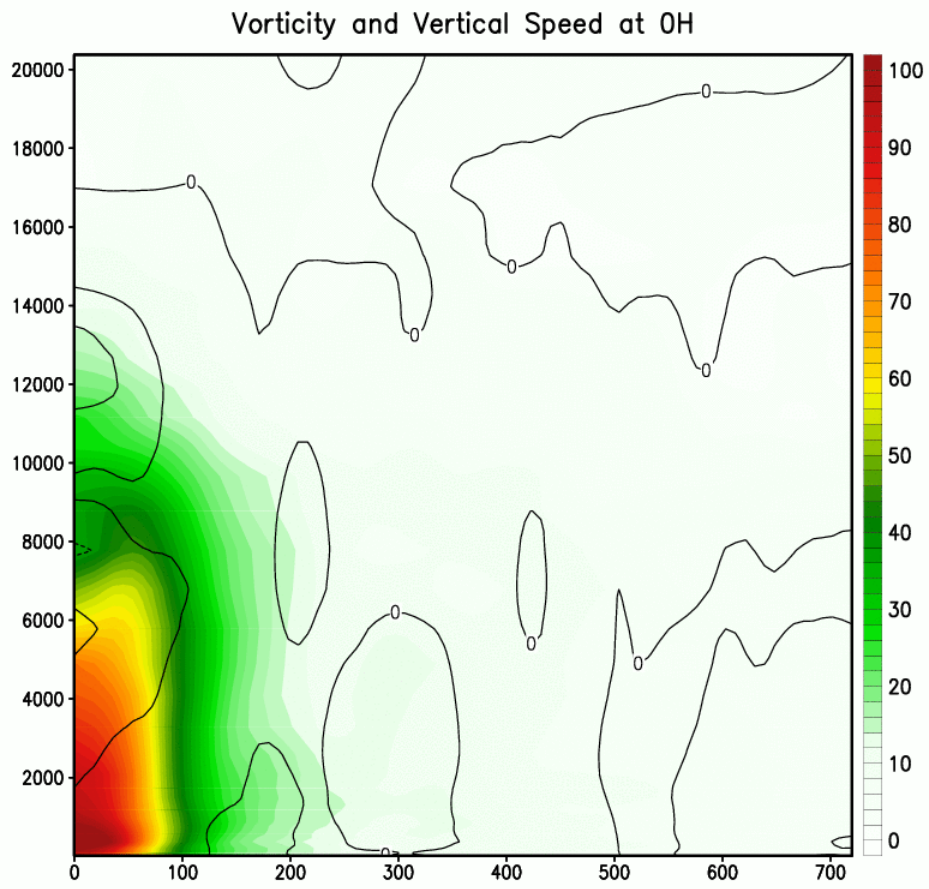


The 3-km run produces much stronger tangential wind in a deeper layer and a small eye than the 9-km run.

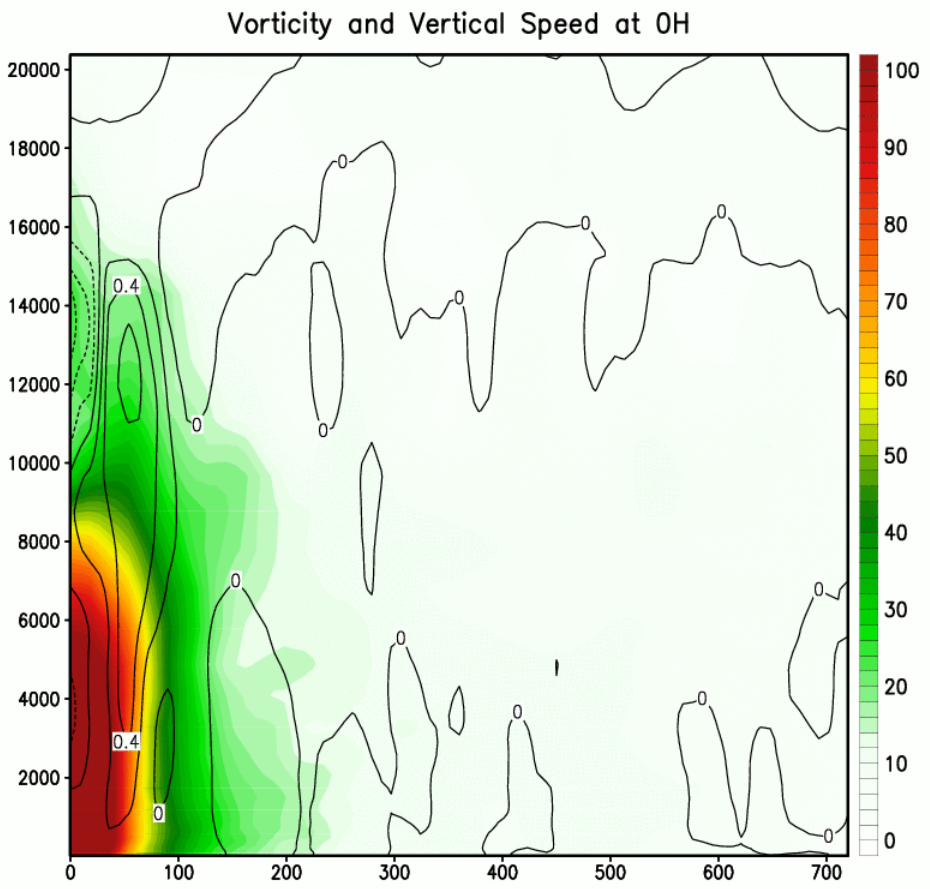
Wilma comparisons (9km vs. 3km) (V)

Azimuthally Averaged Vorticity (shaded) and Vertical Velocity (contoured) from Wilma forecasts starting at 2005101800

9-km



3-km



The 3-km run produces much stronger vertical motion and a small eye.

Summary

- COAMPS-TC demonstrated promise for TC track and intensity predictions with HRH 2005 test cases.
- 60% HRH cases have been tested.
- High-horizontal resolution is beneficial for the structure and intensity.
- Hurricane structure and intensity are sensitivity to the physics parameterizations.
- Results less sensitive to the vertical resolution (40 vs. 60 levels).
- Need to improve balance in initial TC structure.
- Tracking for moving nest needs improvement for weak storms.
- With the moving nested domains in Mercator projection, the grid space changes with time in Lat-Lon space. It is best to have a bigger domain (20% more) to meet the DTC requirement.

Issues and Future Plan

- Continue retrospective tests for 2005 and 2007 seasons and deliver data to DTC.
- To fix the hourly accumulated precipitation output problem with the moving nests
- Continue to improve and test physics (fluxes, microphysics), analysis, and initialization.
- To conduct detailed model evaluation and verifications.
- To perform statistical analysis for HFIP.
- Perform ensemble experiments for a sub-set of cases.