HWRF Simulation of Hurricane Ike (2008)

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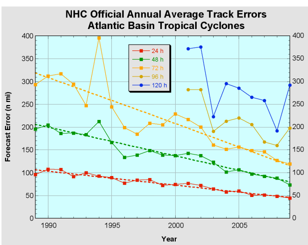
Introduction

One of the greatest challenges in the meteorological community today is improving the intensity forecasts of tropical cyclones (TCs). To do so, a proper understanding of the internal structure and dynamics of tropical cyclones must be achieved. The National Oceanic and Atmospheric Administration (NOAA) Unmanned Aircraft Systems - Observing System Simulation Experiment (UAS-OSSE) was conducted in 2010 to unravel a part of the mysteries of TC intensity forecasting. This poster details the work that was performed by a summer student at the NOAA Earth System Research Laboratory (ESRL) in Boulder, Colorado as part of the 2010 NOAA Practical Hands on Application to Science Education (PHASE) program. Simulations of the rapid intensification of Hurricane Ike (2008) were performed using the Hurricane Weather Research and Forecasting (HWRF) model. Model diagnostics were generated using the Grid Analysis and Display System (GrADS) alongside Diapost, a diagnostic post-processor developed at the Hurricane Research Division (HRD) of the NOAA Atlantic Meteorological and Oceanographic Laboratory (AOML). This poster describes the use of Diapost to help researchers in the Forecast Applications Branch of the Global Systems Division at NOAA ESRL evaluate hurricane structure simulated in HWRF. The work that was performed during the summer 2010 internship serves to enhance the collaboration between scientists at ESRL and the HRD.

Motivation

Over the last several decades, tropical cyclone forecast track errors have steadily decreased, whereas forecast intensity errors have not decreased significantly.



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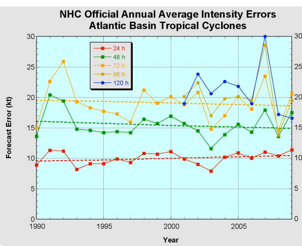

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Background

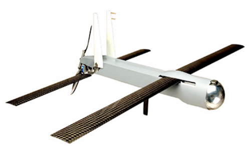
Observing System Simulation Experiment (OSSE)

- Determine the feasibility of observing platform through simulation
- Reduce costs of real test flights
- Conduct two numerical model runs (with different model cores) based on the same initial conditions
  - "free forecast" run deemed the "nature run," which serves as "truth"
  - Forecast run with data assimilation from nature run

http://www.airforce-technology.com/projects/global/images/4_global_hawk.jpg

Regional Unmanned Aircraft Systems OSSE Project

- Hurricane simulation valid 9/2/2008 06 UTC (based on Hurricane Ike (2008))
- WRF-ARW (nature run) – 2 km horizontal resolution
- Simulated data collection from synthetic Global Hawk and Coyote flights
- HWRF (data assimilation run) – nested grid
  - 0.2° (~27 km) outer domain horizontal resolution
  - 0.06° (~6.8 km) inner domain horizontal resolution
- Collaboration between ESRL/GSD, DTC, HRD, NCEP



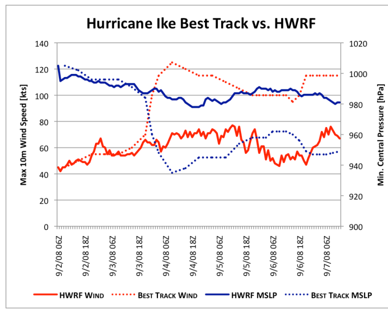
http://www.acrtucson.com/images/UAV/coyote/coyote.jpg

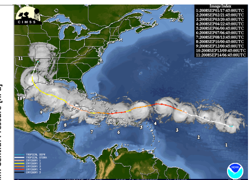
HWRF Modeling System

- Initialization of TC and domain from TC vitals
- WRF Pre-Processing
  - WPS (GFS initialization)
  - Princeton Ocean Model
- Vortex relocation
  - GSI data assimilation
- WRFV3 (NMM v3.2, HRD core)
- WRF Post-Processor
  - GFDL vortex tracker or HRD Diapost

Diapost

- HRD diagnostic post-processor for WRF-NMM varieties such as HWRF
- NetCDF model output at sigma-P levels and rotated E-grid are mapped onto A-grid
- Plots generated with Grid Analysis and Display System (GrADS)
- Designed for hurricane analysis with special features such as cylindrical grid calculations
- **Facilitates collaboration with HRD scientists**



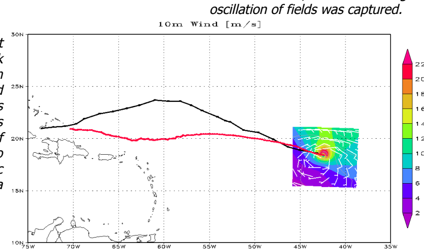


http://www.srh.noaa.gov/lix/?n=ike2008

Top: Hurricane Ike (2008) Best Track

Left: Timeseries of HWRF Wind and MSLP fields initialized at 9/2/08 06 UTC. Compared with Best Track, the HWRF missed the rapid intensification of Hurricane Ike, but the general oscillation of fields was captured.

Right: Comparison between best track (black) and HWRF track (red) beginning at initialization time (9/2/09 06 UTC). Wind magnitude (m/s) at 10 m is shaded with wind barbs overlain. Southward deviation of HWRF track possibly due to underestimation of cyclonic winds and subsequent "Beta Effect" (see below).



Dynamics of the "Beta Effect"

Barotropic, Non-Divergent PV Equation:

$$\frac{d(\zeta+f)}{dt}=\frac{\partial(\zeta+f)}{\partial t}+\vec{v}\cdot\nabla(\zeta+f)=0$$

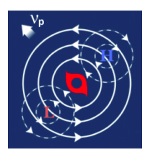
$$\frac{\partial(\zeta+f)}{\partial t}=-\vec{v}\cdot\nabla(\zeta+f)$$

Assume no background flow:

$$\vec{v}=\vec{v}_{TC}+\vec{v}_{gyre}\qquad \zeta=\zeta_{TC}+\zeta_{gyre}$$

Substitute, then ignore small terms:

$$\frac{\partial(\zeta_{TC}+\zeta_{gyre})}{\partial t}=(-\vec{v}_{TC}\cdot\nabla f)+(-\vec{v}_{TC}\cdot\nabla\zeta_{gyre})+(-\vec{v}_{gyre}\cdot\nabla\zeta_{TC})$$



COMET program – Introduction to Tropical Meteorology, Version 1.4.1

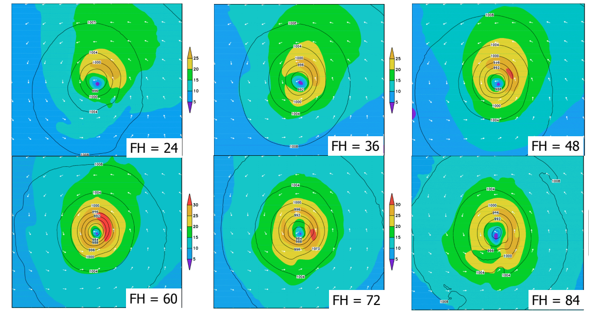
Include background flow:

$$\vec{v}=\vec{v}_{TC}+\vec{v}_{gyre}+\vec{v}_{env}\qquad \zeta=\zeta_{TC}+\zeta_{gyre}+\zeta_{env}$$

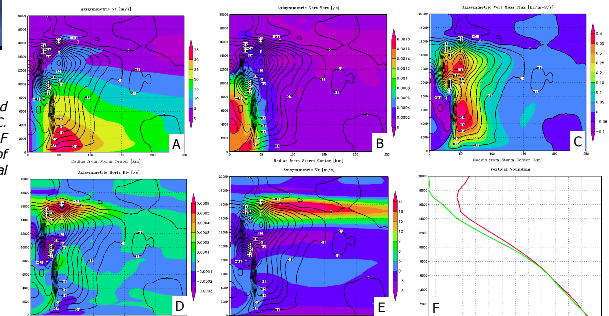
Again substitute, then ignore small terms:

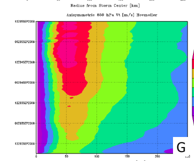
$$\frac{\partial(\zeta_{TC}+\zeta_{gyre})}{\partial t}=\left[-\vec{v}_{TC}\cdot\nabla(\zeta_{env}+f)\right]+(-\vec{v}_{env}\cdot\nabla f)+(-\vec{v}_{TC}\cdot\nabla\zeta_{gyre})+(-\vec{v}_{gyre}\cdot\nabla\zeta_{TC})+(-\vec{v}_{env}\cdot\nabla\zeta_{TC})$$

Taking complex environment into account, Beta gyres may have any orientation!



Top Panels: HWRF output of 10 m wind speed [m/s] (shading), wind vectors (white arrows), and isobars [hPa] (contours) at the indicated forecast hours.





Figures A through F are plotted at forecast hour 78. Axisymmetric vertical velocities are contoured in black. Shading of axisymmetric values are as follows: A: tangential velocity, B: relative vorticity, C: vertical mass flux, D: horizontal divergence, and E: radial velocity. Vertical sounding (F) plot of temperature (red) and dewpoint (green) is characteristic of saturated, moist neutral atmosphere within a tropical cyclone.

G: Hovmoller diagram of 850 hPa axisymmetric tangential winds.

Impacts and Results of Summer STEP Internship

- Developed systematic method to analyze hurricane structure in HWRF simulations using Diapost
- Streamlined analysis by writing documentation and creating GrADS and Diapost scripts for use by NOAA scientists in the Regional UAS-OSSE project that continued after the summer of 2010
- Will facilitate collaboration between scientists at different laboratories (ESRL, AOML, etc.)

Acknowledgments

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