SUMMARY OF HFIP REGIONAL MODEL DEVELOPMENT

Contributors to Talk:
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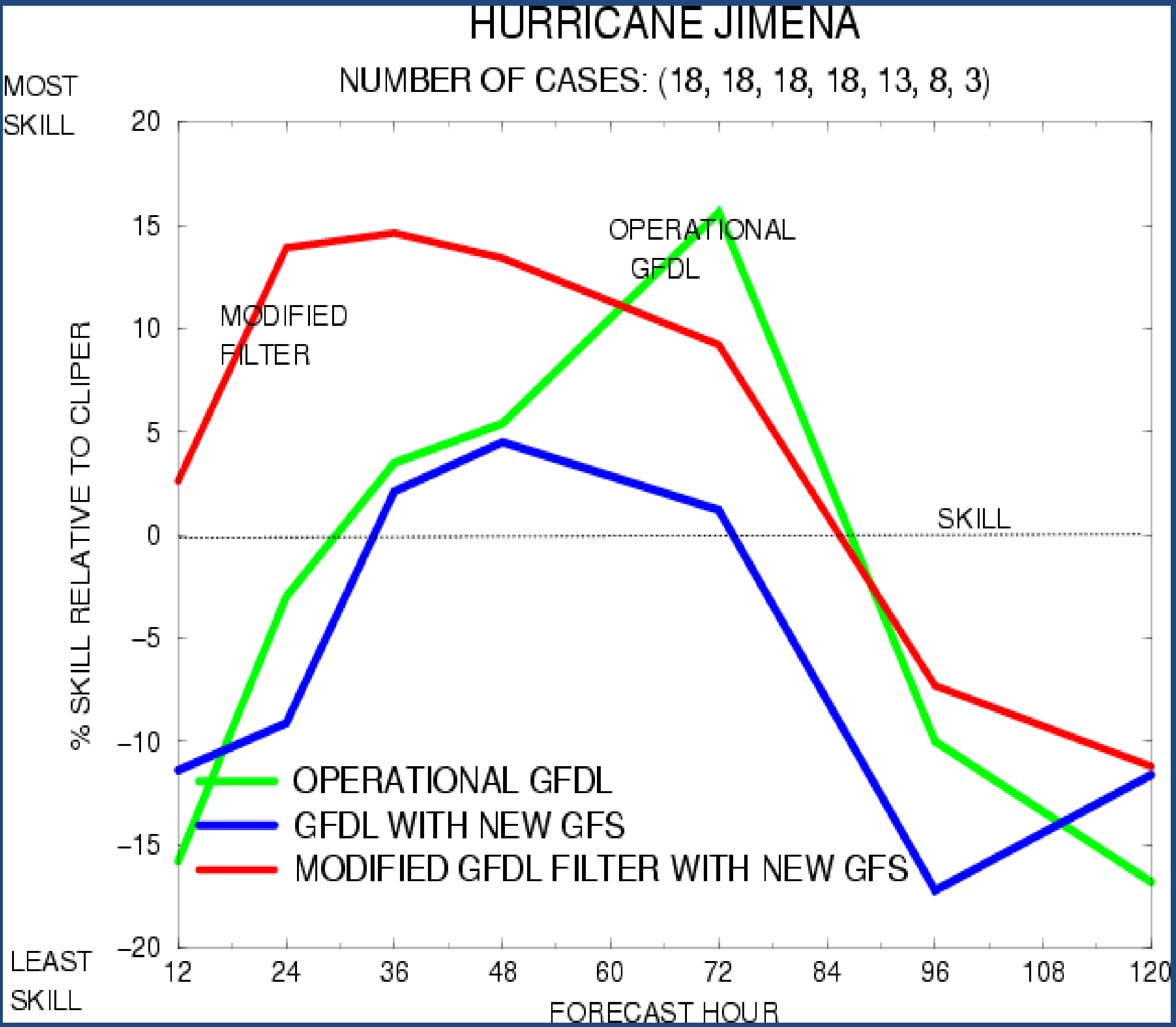
2010 Possible HWRF Upgrades

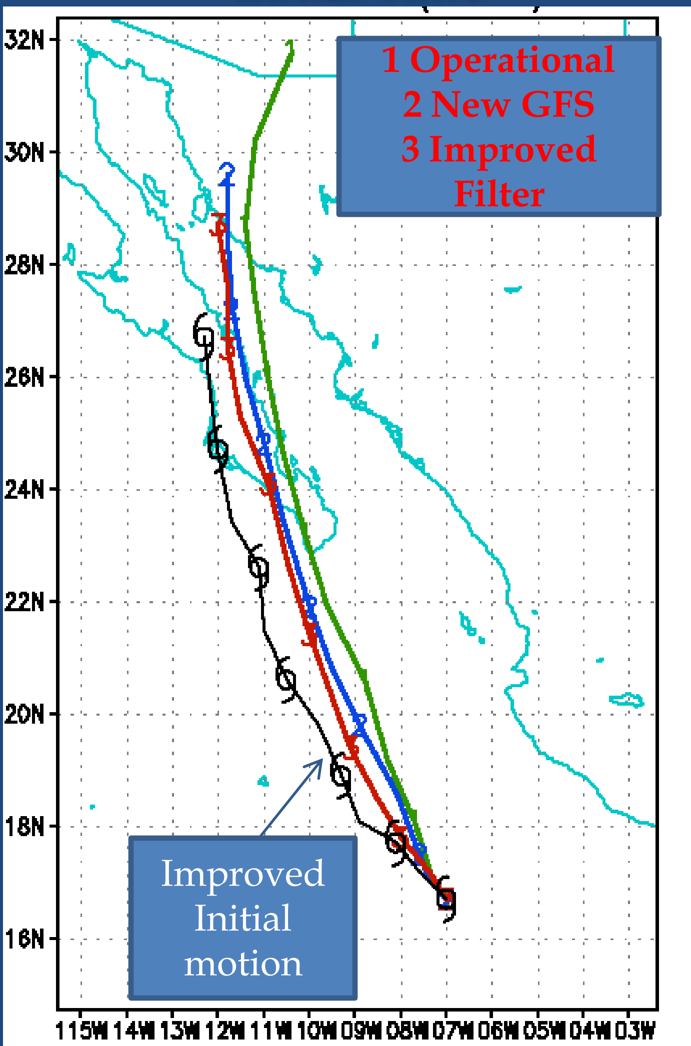
- Gravity wave drag
  - Enhanced EPAC performance
  - Should be neutral in ATL
- Surface physics
- Shallow and deep convection
  - 2-3 year project
- HYCOM (replace POM)
  - Buoy data assimilation
  - Synthetic T-S profiles
- 2011
  - Noah Land surface model
  - Wavewatch III (3 way coupled system)
  - Continued improved surface physics, including sea spray (I. Ginis, J. Bao)
  - Evaluate and revise PBL scheme

Impact of new GFS on GFDL

Unfreeze GFDL Necessary for Modification of Filter



August 31st, 0z
Initial Time



HFIP High-Resolution Hurricane Test

Evaluation by the Developmental Testbed Center (DTC)

- Runs for up to 69 cases at two or more horizontal grid spacing were submitted for evaluation of impact of resolution on track and intensity forecasts.
- **Increased resolution did not substantially improve forecasts for any model.**
- Modest improvement (a few lead times) were seen for HWRF-X (9 and 3 km) and AHW (13.5 and 1.5 km) in track and/or intensity. GFDL (9 and 6) showed no difference and COAMPS-TC (9 and 3) and UW-NM had some degraded tracks.
- **May need better physics and/or initialization to realize benefits of higher resolution.**
- Final Report is at: http://www.dtcenter.org/plots/hrh_test/HRH_Report_30Sept.pdf

OVERALL EVALUATION OF PERFORMANCE FOR ATLANTIC DEMO PROJECT

Regional Models

- In general regional model performance was poor
- High resolution (10km to 1 km) – alone - did not produce desired Improvement

A lesson from Regional models in FY09

- Models did very poorly in highly sheared storms
  - Appears related to model initialization and convection parameterization vs. implicit physics
  - Development new physics needed to address higher resolution

    (e.g.: surface physics, proper tuning of micro-physics)

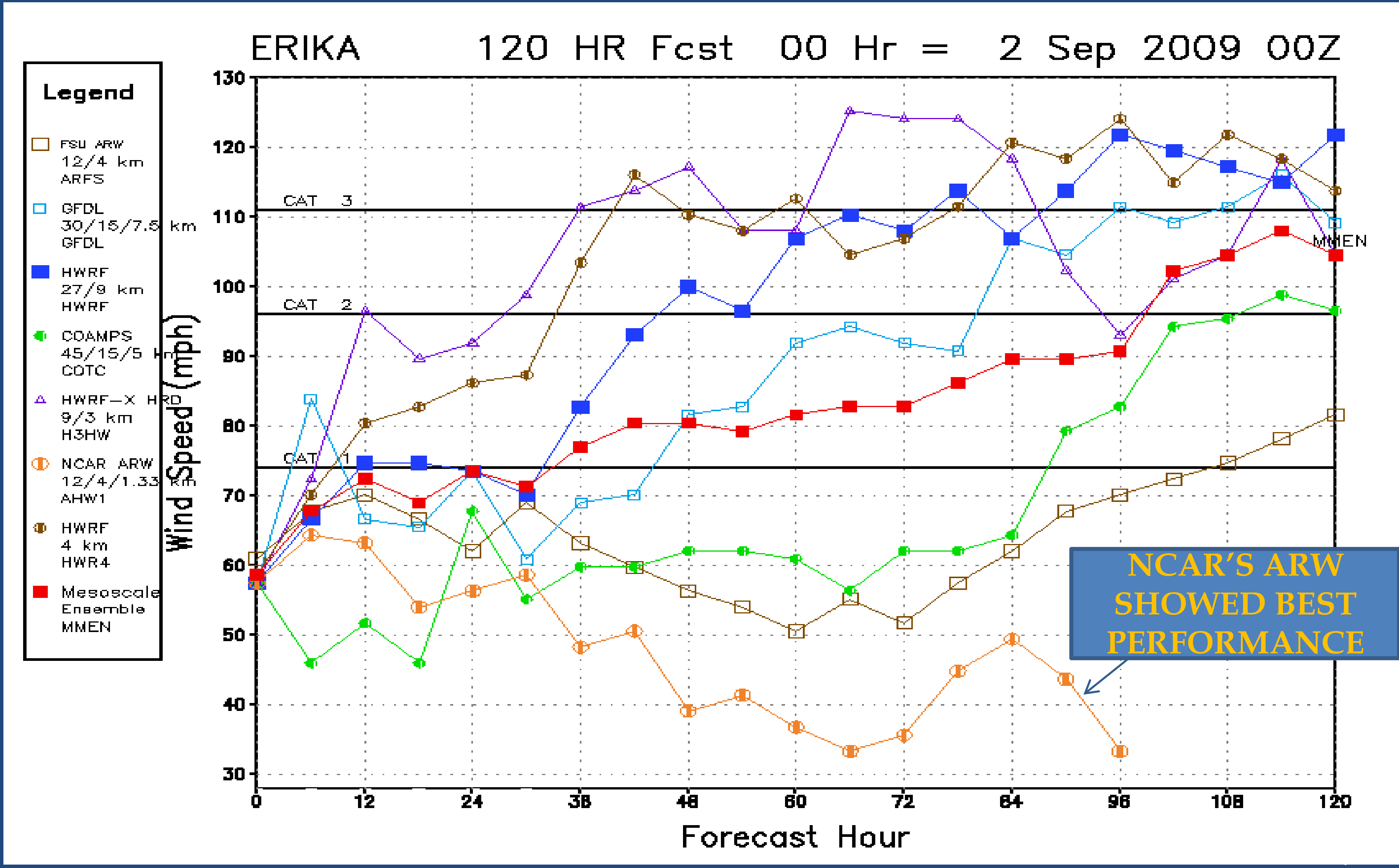
HFIP 2009
HURRICANE SEASON DEMO PROJECT

***Participating Regional models*:**

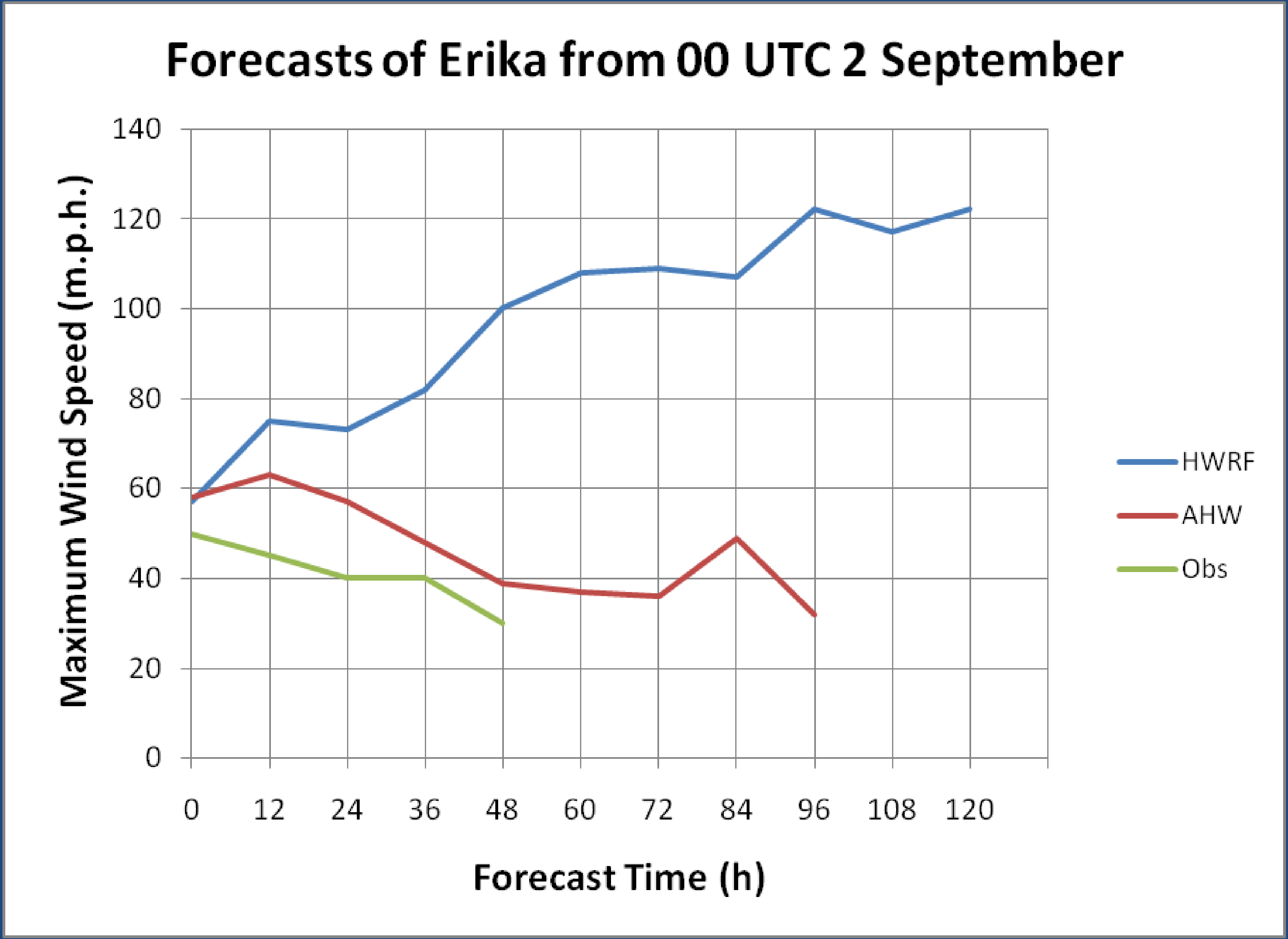
– HWRF (Operational)	9km
– HWRF	4km
– GFDL (Operational)	7.5km
– HWRF-x	3km
– WRF/ARW/NCAR	1.3km
– WRF/ARW/FSU	4km
– COAMPS-TC	5km

Poor Performance of Dynamic Models in Highly Sheared Environment

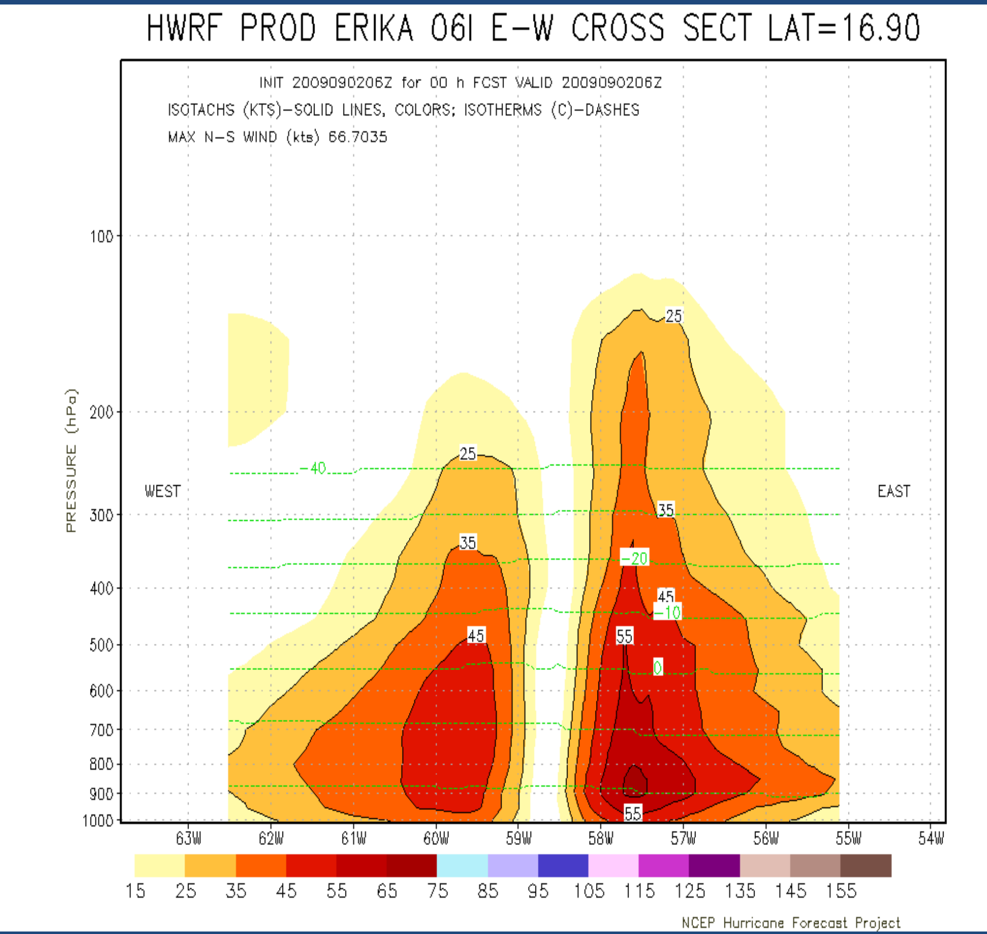
(Problem well known to NHC forecasters)



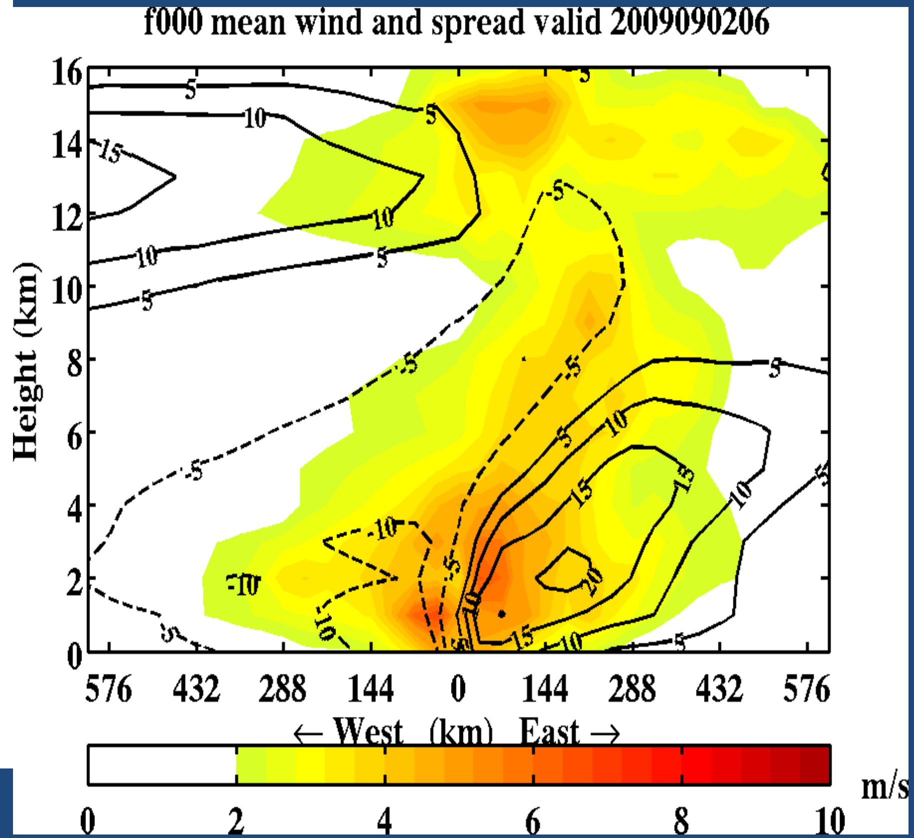
Comparison of Just AHW and Operational HWRF



Erika cross sections 0902/06Z



No tilt (HWRF) vs. tilt (AHW)



Advanced Hurricane-research WRF ARW
Model Design for Summer Demo

- EnKF initialization (6-h cycling, 36 km, 12-km nest)
- 12/4/1.33-km grids for 120 h forecasts, twice per day
  - 4-km (800x800 km) and 1.33-km (320x320 km) domains move
  - Nests interpolated from 12-km domain at start
- 49 forecasts, 2.5 months of continuous EnKF analyses
- Physics
  - Kain-Fritsch (K-F) scheme on 12-km domain; no cumulus on nests
  - Simple microphysics (WSM5); rain, snow, cloud water, cloud ice
  - YSU PBL; first-order closure
  - Modified exchange coefficients (ch, cd)
  - Ocean mixed layer model; horizontally varying MLD mirrors ocean heat content

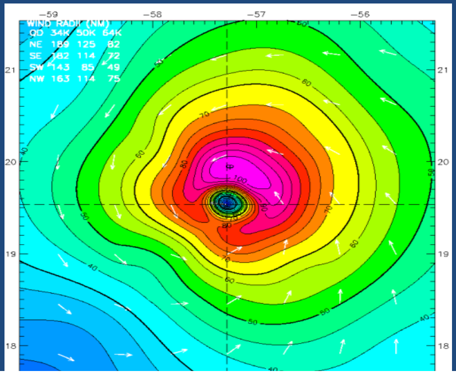
Lessons Learned/Plans for 2010

- Advantage of explicit representation of convection in sheared storms; cumulus scheme tends to produce too much rainfall/heating near storm center
- Cycling EnKF able to represent large asymmetries and tilt better than bogusing
- Tracking issues for weak storms: need improved dynamic tracker (in the model) or at least better post-processing track

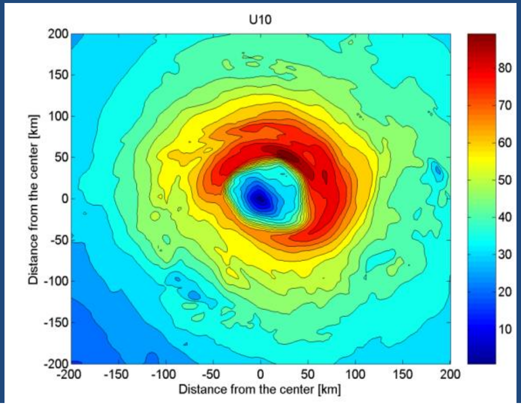
Tentative Plans for 2010 :

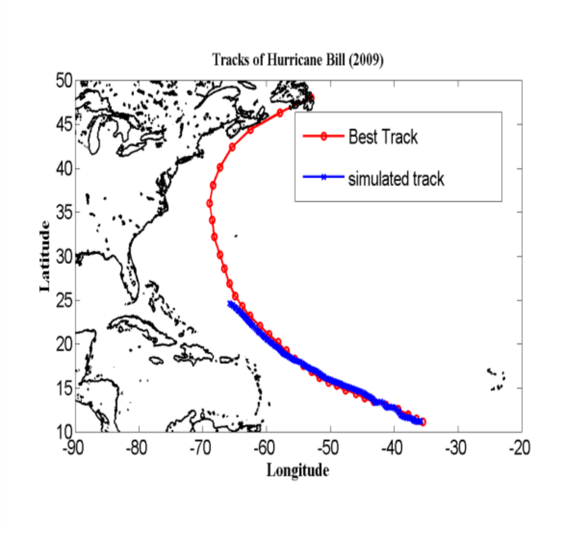
- Need a larger domain in 2010
- Intend to rerun Erika with HWRF or GFDL initial condition
- Have rerun about half of 2008 ATL cases; rerun early and late cases
- Retrospective 2009 for E Pac

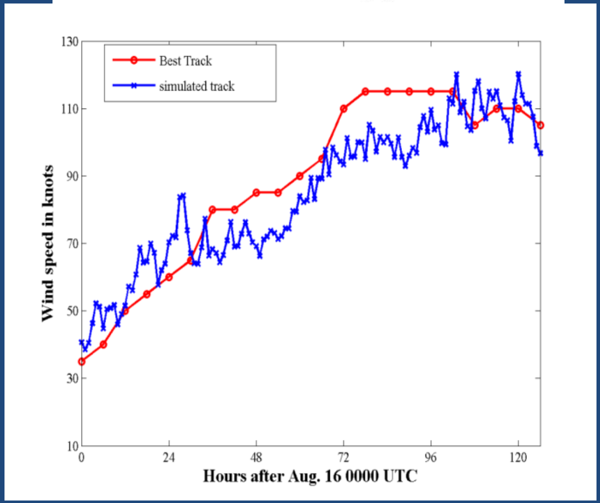
HWRFx: Regional Scale Model Developments at HRD

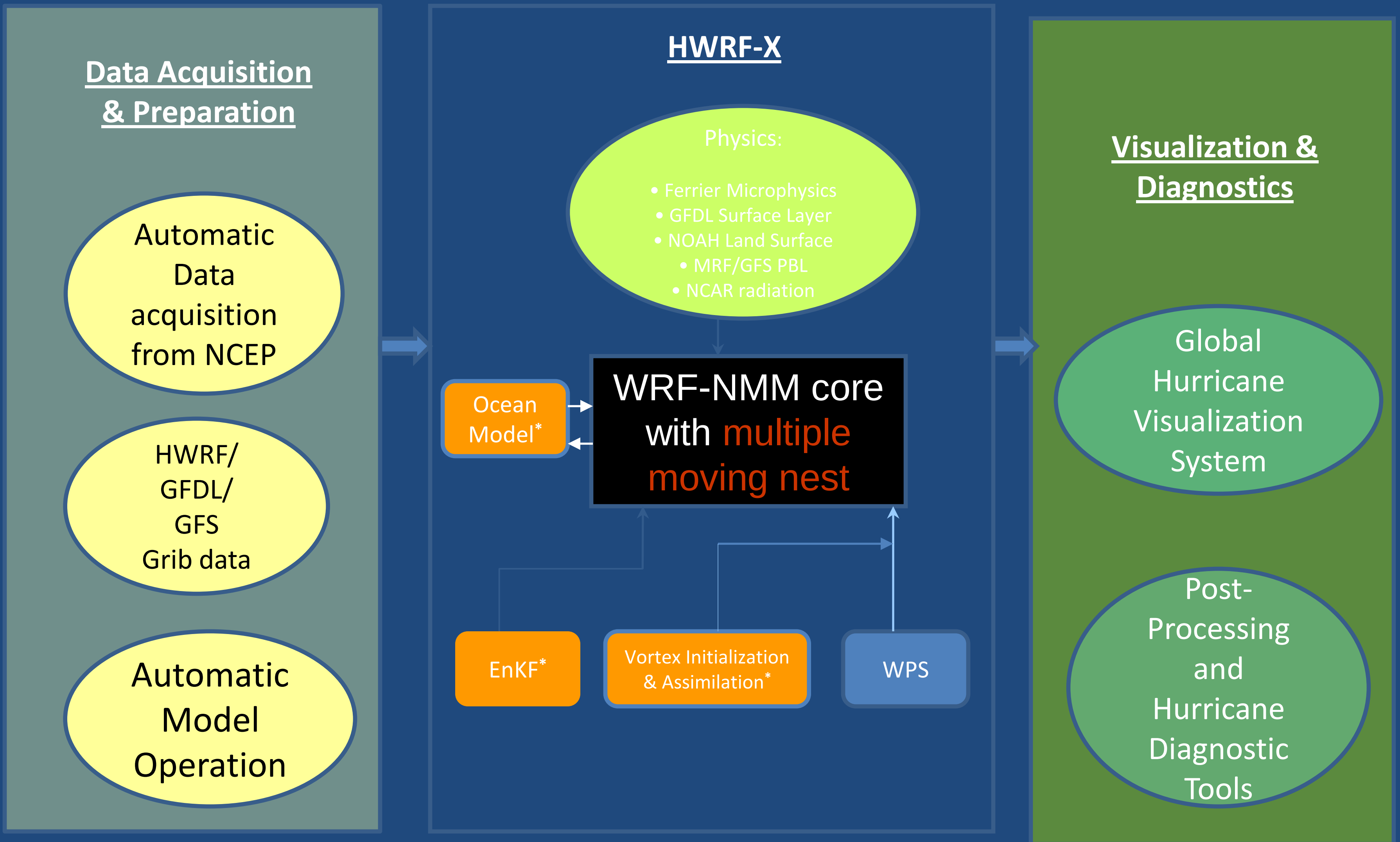


S.G.Gopalakrishnan, Kevin Yeh
Xuejin Zhang,Thiago Quirino &
Robert Rogers
HRD/AOML & CIMAS





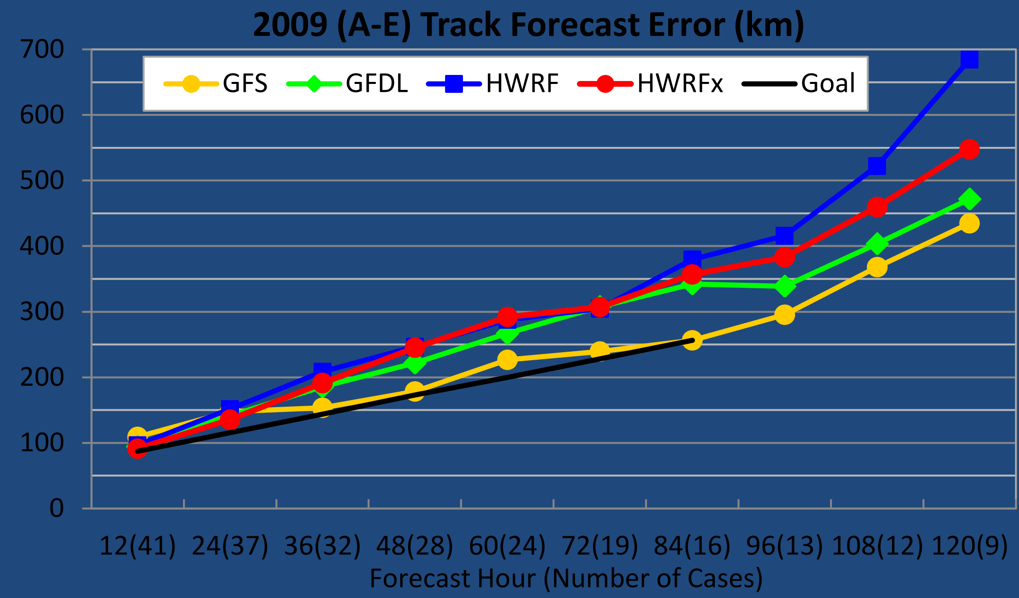




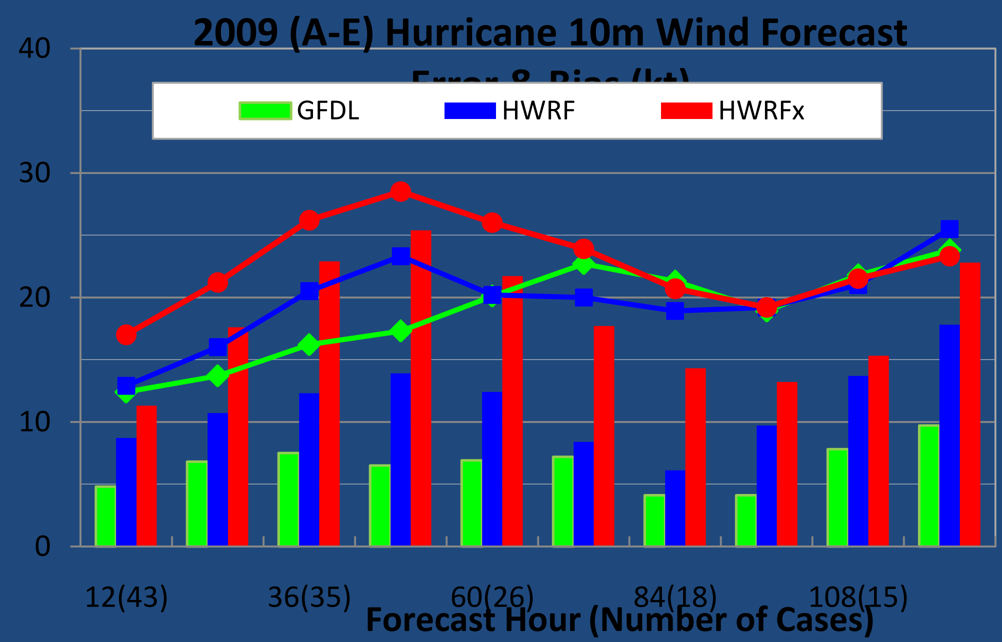
The HWRFX is the experimental version of the Hurricane Weather Research Forecasting system specifically adopted and developed to study the intensity change problem at the highest model grid resolution of about 1 km.

2009 Hurricane Season

- Track performance is comparable to other regional models (similar to HRH result)



- HWRFx intensity bias at 9/3 km with HWRF IC (HRH used GFDL IC) and physics indicates strong need evaluation of physics and IC



HWRFx: Issues and Discussions

1. What are the lessons we learned from the 69 HRH test cases in terms of structure and intensity predictions simply beyond statistics ? (http://www.dtcenter.org/plots/hrh_test/)

2. What is the role of shear during the 2009 hurricane season and how do we improve forecast. Is higher resolution not important for predicting the shear vortex interactions ?

3. What are the outcome of the sensitivity experiments for Erika and Danny ? (https://storm.aoml.noaa.gov/hwrfx/retro-gfs/ & https://storm.aoml.noaa.gov/hwrfx/retro-hwrf-no-sas/

4. Enthalpy fluxes in HWRFx, which are based on the GFDL formulation shows almost twice the value at wind speed of 50 m/s as when compared to obs that shows a constant behavior up to 30 m/s wind speed. A careful re-evaluation of surface layer properties that are consistent with obs should be undertaken.

HRD Perspective
Future Research for HWRFx

- Clearly we need the resolution to even understand the vortex. Otherwise we will be tuning models for wrong reasons!

- However, resolution of about 1 km is only a necessity to understand the multiscale prediction problem. It isn't a solution!

- Physics suite for high resolution (microphysics an PBL.) How do we evaluate the right physics ? Should we not move beyond maximum wind at the lowest model level at least for improving models ?

COAMPS-TC Regional Model Summary

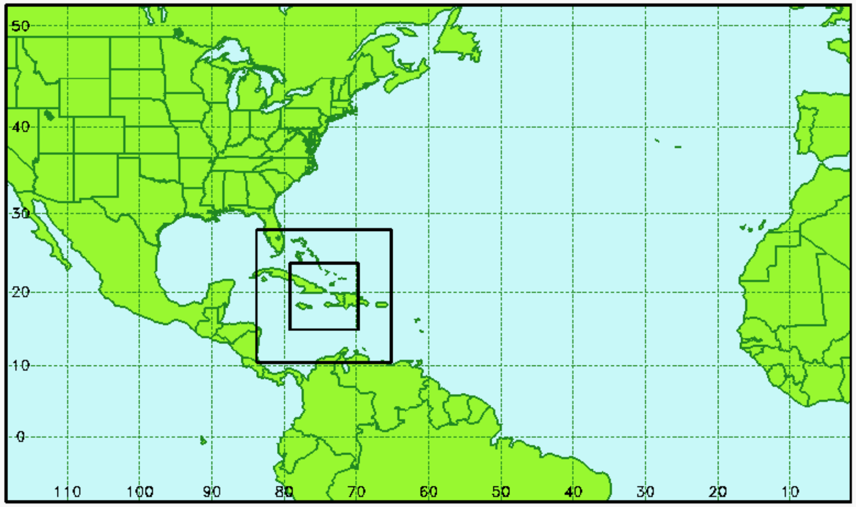
Major Accomplishments

- **Improvements to COAMPS-TC prior to HFIP Demo:**
  - Improvements made to the tracker, nested grid tracker, synthetic observations, data assimilation, physical parameterizations, diagnostics
- **Establish COAMPS-TC skill for 2008 season:**
  - Verified and analyzed results for 2008 season in the Atlantic basin
- **Computational resources:**
  - Computational resources obtained from a High Priority Proposal for a DoD High Performance Computing SGI Altix at Air Force Research Lab (AFRL)
- **Real-time COAMPS-TC forecasts for 2009 ATL:**
  - Developed and automated scripts that ran all Atlantic and E. Pacific storms
  - Developed new web page to communicate real-time results
  - Shared results with HFIP community in real time (DTC, FSU etc.)
- **Diagnosis of HFIP Demo project results:**
  - Identify systematic problems
  - Ran selected coupled model forecasts
  - Formulated next steps for FY10

COAMPS-TC

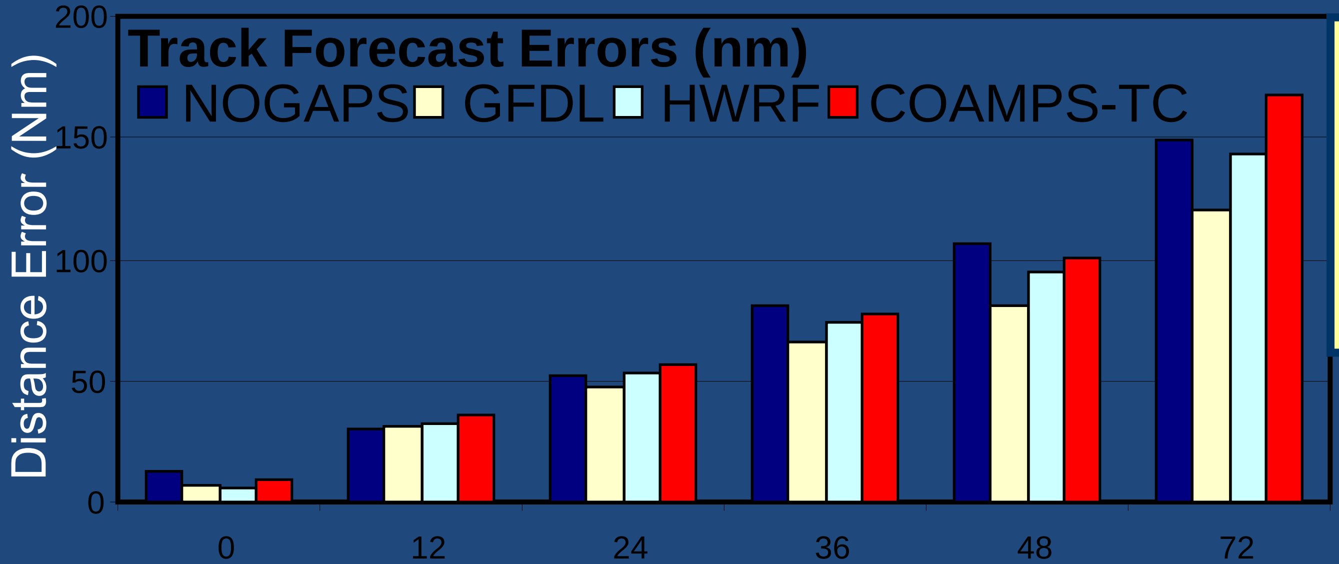
Configuration for HFIP Demo Project

- 45/15/5 km grids over WATL basin
- 45 km grid fixed for all storms
- Inner 2 grids:
  - Automatically centered over TC location at initial time
  - Move with the TC
- 12 hour data assimilation cycle
- Synthetic observations used to construct initial storm structure
- Innermost mesh uses explicit microphysics only
- Tropical cyclones are tracked automatically by the model
- All runs automatically submitted at +0335 of each analysis cycle

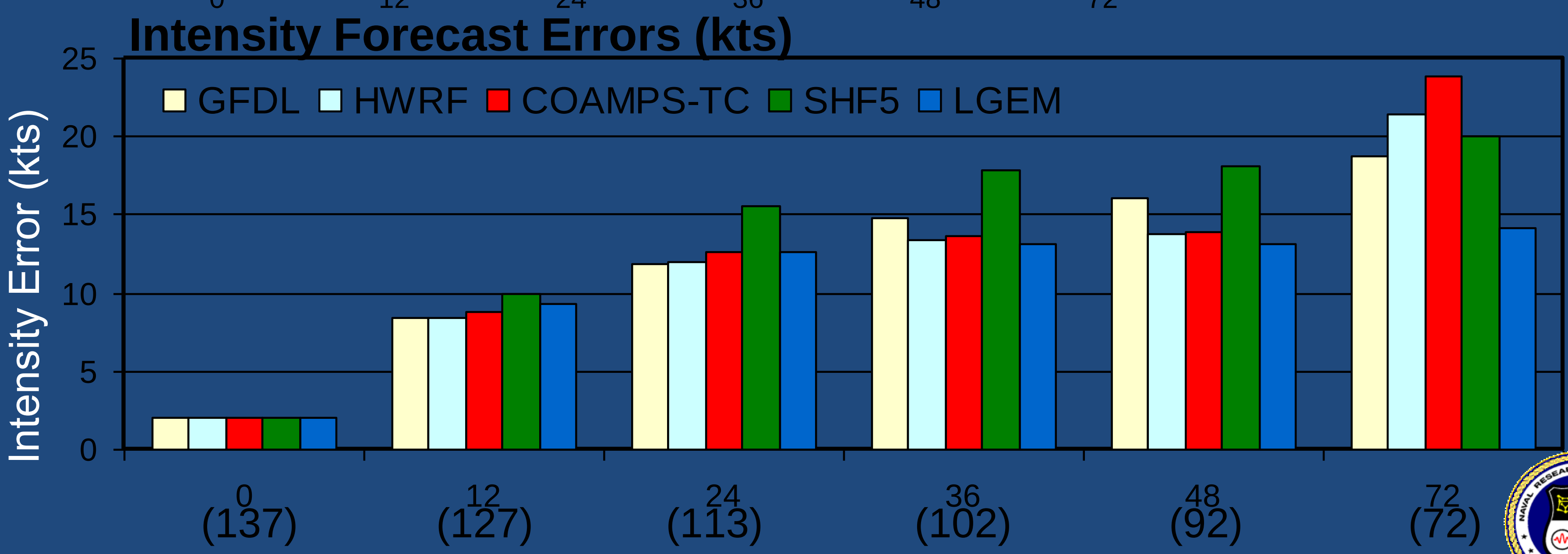


COAMPS-TC Atlantic Forecasts (2008)

Validation of COAMPS-TC



- **COAMPS-TC track is competitive with other TC and global models.**
- **Intensity forecasts in Atlantic are similar to other skillful models.**



COAMPS-TC Regional Model Summary

Lessons Learned !!

- **Challenges of weak and sheared storms:**
  - Identified poor forecasts associated with weak and/or sheared storms
  - Investigation ongoing; analysis (and physics?) improvements needed
- **Initialization and assimilation:**
  - Challenges for initialization of weak storms
  - Initialization step needed (balance equation or digital filter)
  - Possible improvements needed to synthetic observations / 3D-Var
- **Physical parameterization issues:**
  - Shallow convection parameterization improves structure forecasts
  - Spatial coverage of convection is typically too large and too disorganized in weak storms
  - Sensitivity to turbulence mixing parameterization
- **Air-Sea coupling:**
  - Importance for slow moving storms
  - Building towards a 3-way coupled system

COAMPS-TC Regional Model Summary

Plans for FY10

- **Evaluation of 2009 results for ATL, EPAC, WPAC:**
  - Identification and diagnosis of model track, intensity, structure forecasts
- **Improvements to COAMPS-TC:**
  - Initialization step needed (balance equation or digital filter)
  - Improved synthetic observations / 3D-Var
  - Improved linkage between microphysics and turbulence parameterizations
  - Refinements to the coupled system
- **Re-forecast of 2008 and 2009 seasons:**
  - Evaluate the performance prior to the 2010 season
- **Real-time forecasts for 2010 season:**
  - Field the improved COAMPS-TC system
  - Two-way coupled air-ocean system
  - Ensemble forecasts (possibly) with coarser resolution
  - Leverage existing infrastructure (verification, web site, diagnostics… developed in FY09)

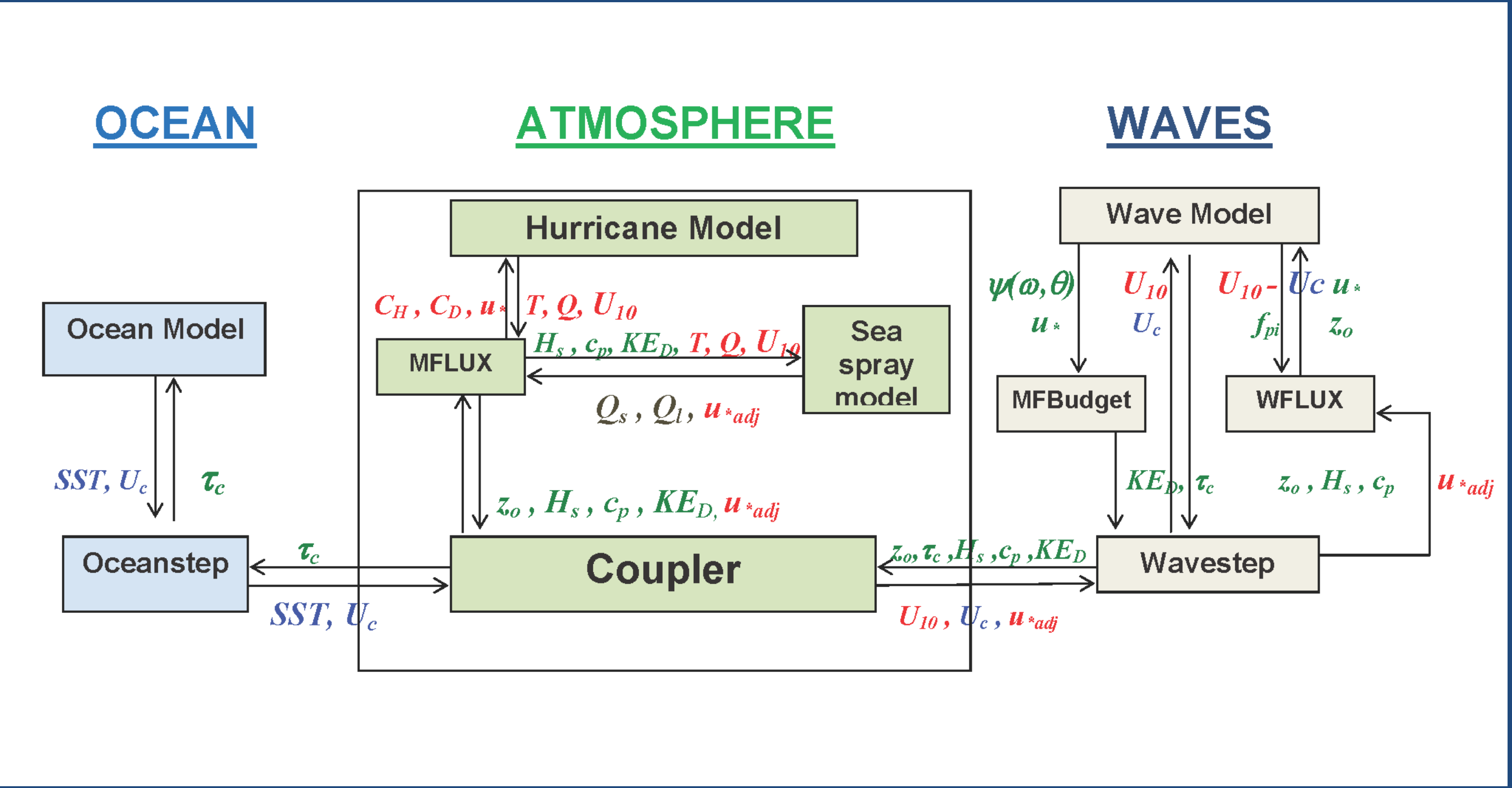
RESEARCH IN DEVELOPMENT OF ADVANCED PHYSICS

- COLLOBORATION BETWEEM ACADEMIC COMMUNITY AND NOAA WILL BE ESSENTIAL TO ACHIEVE NEEDED PHYSICS IMPROVEMENTS

- NEW COLLOBORATIONS NEEDED TO HELP ACHIVE HFIP GOALS

- SUCCESSFUL COLLOBORATION BETWEEN URI, GFDL & EMC: EXAMPLE TO FOLLOW

Coupled Hurricane-Wave-Ocean Framework

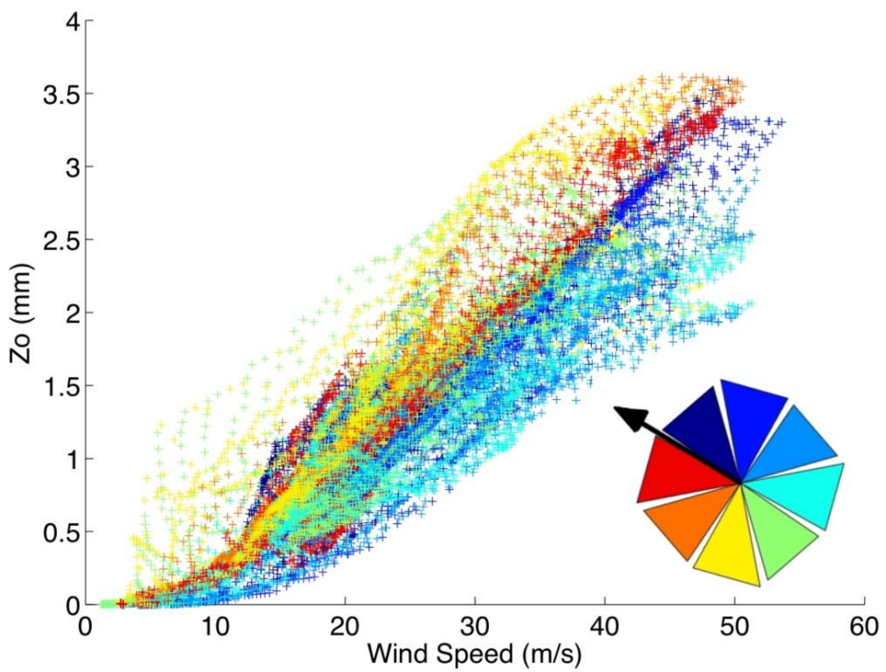


- Implemented in GFDL model in a research mode.
- To be testing in HWRF later this year

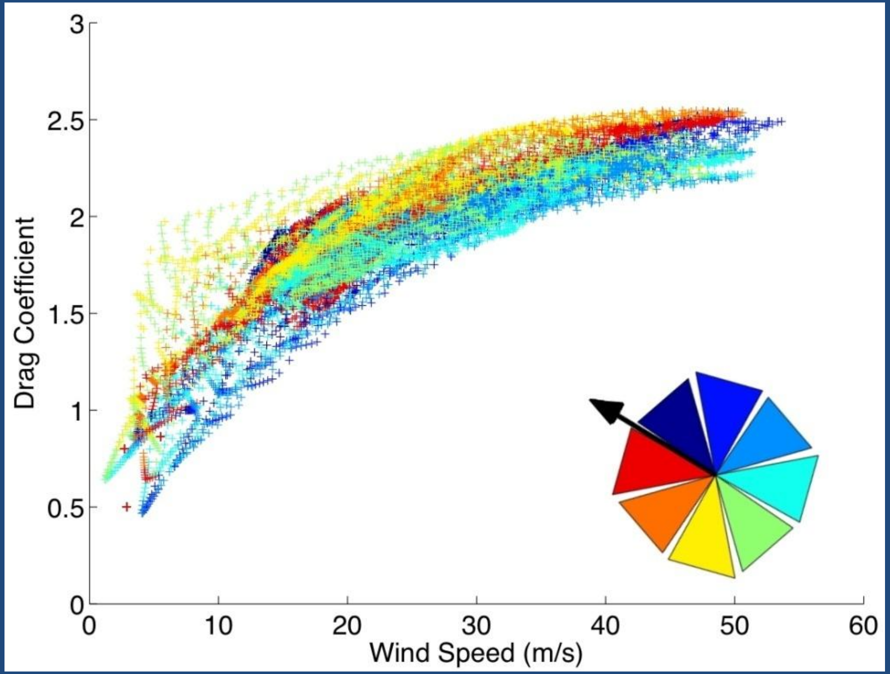
I. Ginis

Sea State Dependence of Surface Parameters

Surface Roughness



Drag Coefficient



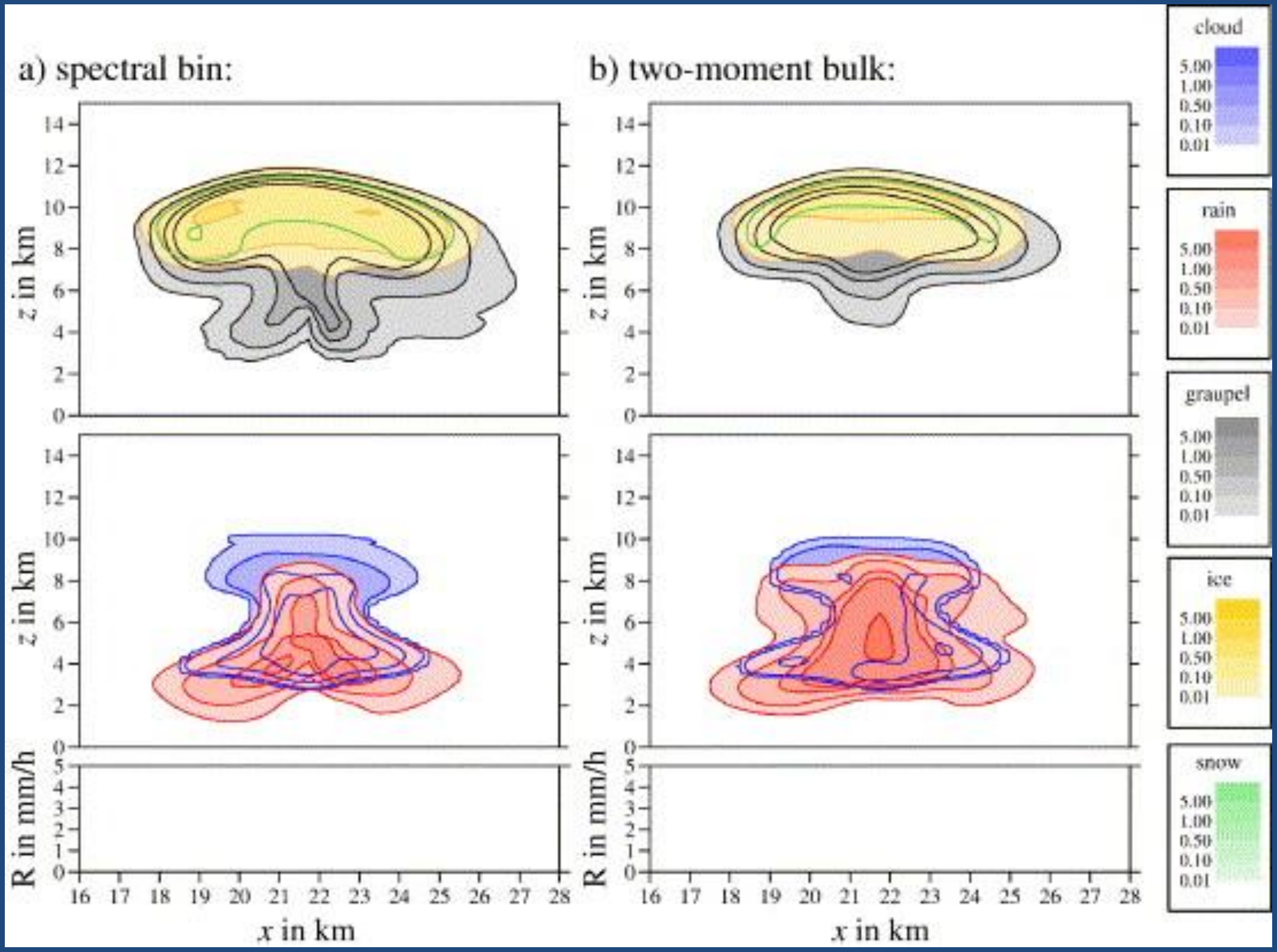
Based on the coupled GFDL hurricane-wave-ocean coupled model simulations

I. Ginis

Applying a Spectral Bin Microphysics (SBM) model as benchmark for tuning (optimizing) simpler bulk microphysics schemes

The Hebrew University Cloud Model (HUCM) with imbedded SBM is used for optimizing the two-moment bulk microphysics scheme in the Relocatable Regional Weather Forecast model in Germany (Seifert et al. 2006)

Hydrometeor mass densities simulations in a deep convective cloud: Midland/Texas, 13 August 1999



Seifert et al, 2006)

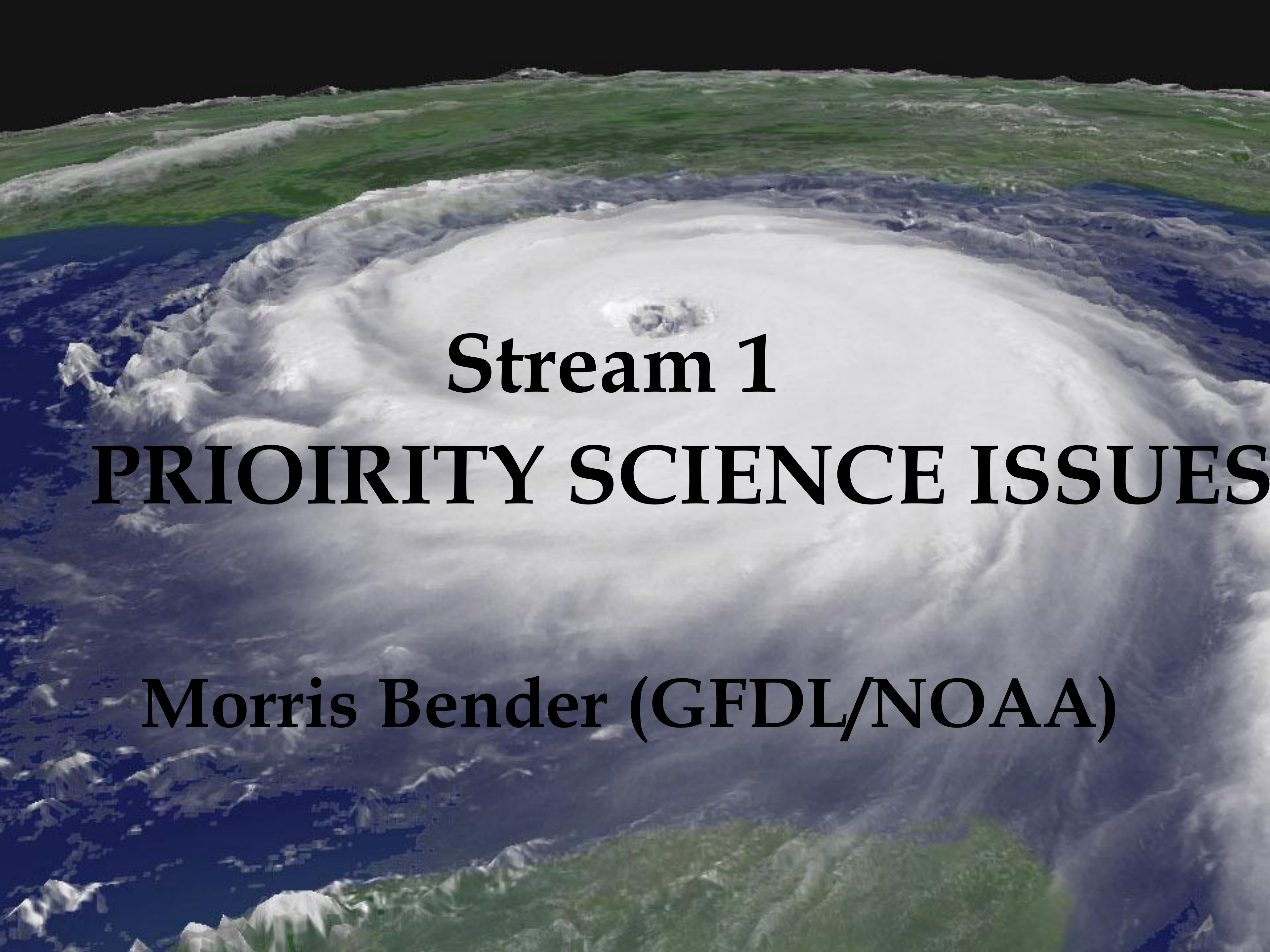
Summary of Lessons Learned

Regional Models did very poorly in the highly sheared storms that dominated the 2009 Atlantic Season.

As a whole higher resolution made little positive impact to improve either track or intensity.

Results demonstrate need for better initialization of vortex.
EnKF technique shows promise in better representing asymmetric vortex structure.

Results demonstrate need for physics development to take advantage of higher resolution.



Stream 1

PRIOIRITY SCIENCE ISSUES

Morris Bender (GFDL/NOAA)

Summary of Lessons Learned (Regional Model Summary)

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Results demonstrate need for better initialization of vortex.
EnKF technique shows promise in better representing asymmetric vortex structure.

Results demonstrate need for physics development to take advantage of higher resolution.

Stream 1 Issues to be Addressed

2009 Summer Project Demonstrated One of Major Problems in Intensity Prediction with Current Numerical Models:
<u>Potential for Dramatic Over-Intensification in Highly Sheared Environments.</u>
Too much emphasis in the past on very intense hurricanes

<u>Cumulus schemes tend to produce too much heating near the storm center</u>

Current schemes assume a vertically coherent structure

Explicit representation of convection has an advantage in sheared environments

Fundemental Questions to be Addressed

To really make progress in intensity prediction:
Effort needs to be focused to address this issue of explicit vs. non-explicit convection.
This is not a stream 2 only issue.

Does convection need to be explicit in the storm region to properly handle the vortex in a sheared environment

OR:

Can current convection schemes be modified to be more responsive to shear in the near term ?

Will we have computer resources in the next few years to resolve convection explicitly ?

More Fundemental Questions to be Addressed

We need to devote resources to find out what is the minimum horizontal resolution needed to resolve convection explicitly in regional models.

(2km, 3km, 4k) ????

How do we properly account for mismatch between inner nests without cumulus parameterization and outer nests with coarser resolution where cumulus parameterization will still be needed ?

Research Focus for Development of Advanced Physics

Shouldn't current physics development **now** be focused on higher resolution rather then resolutions that are known to be insufficient to address intensity issues ?

Collaboration between the academic community and NOAA will be essential to achieve needed physics improvements.

Close collaboration is needed between observational and model development teams to improve physics.

Application of a Spectral Bin Microphysics model as a benchmark for proper development of better bulk microphysics schemes holds great promise.

Research Focus for Development of Advanced Physics (continued)

Improvement of surface physics must be an important HFIP priority both for Stream 1 and Stream 2.

Coupled Hurricane-Wave-Ocean Development shows great promise.

Incorporation of Sea-Spray is essential for correct enthalphy fluxes. Wave model output is essential to do this right !

Initialization Issues

Summer Project clearly demonstrated the need of better representation of the hurricane at the initial time.
This is particularly true for asymmetric vortices and weaker storms.

Cycling EnKF shows ability to better represent storm asymmetries and tilt better than bogusing.

Closer collaboration between government agencies and Academia is going to be essential to address these issues.