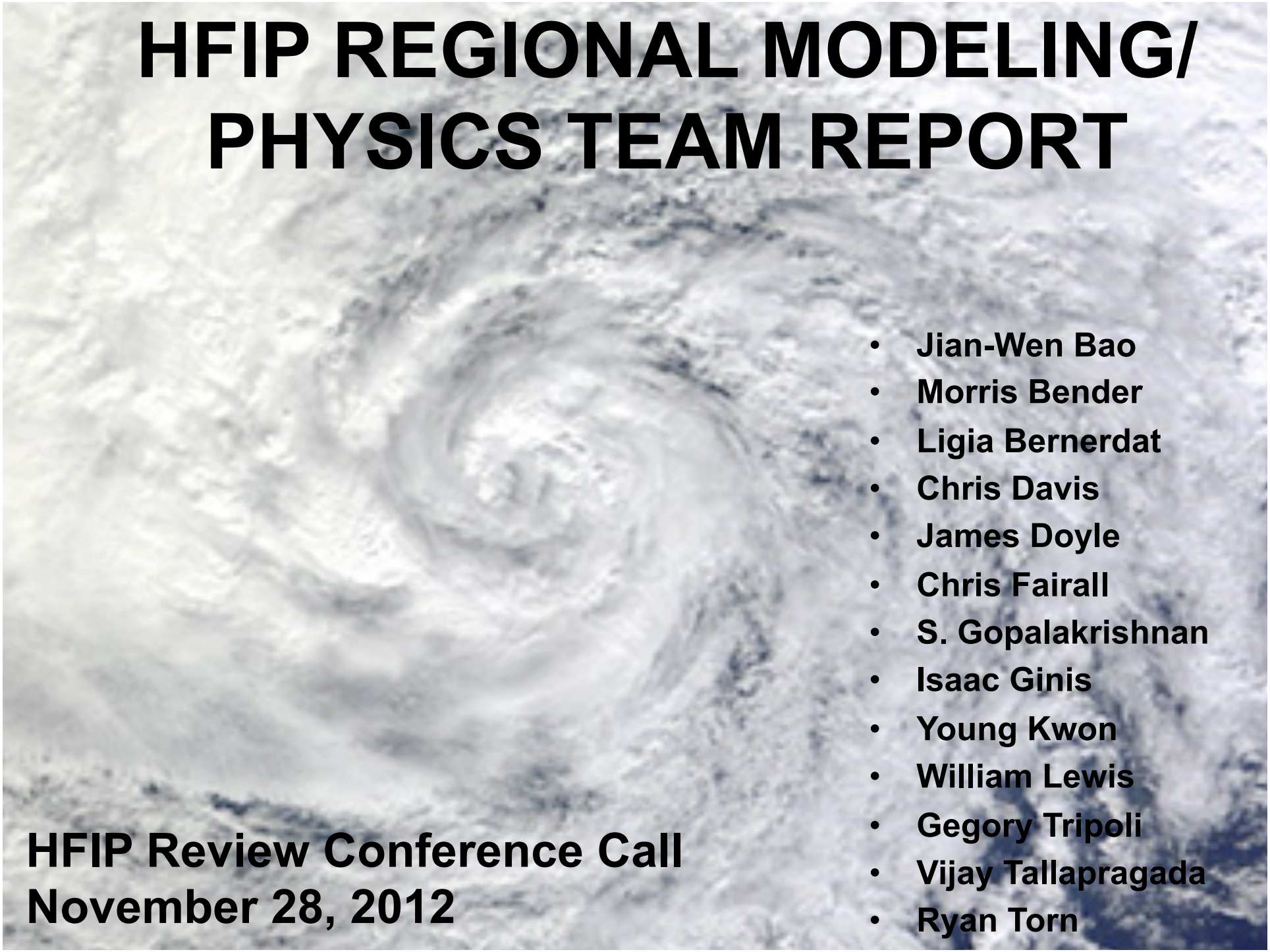
HFIP REGIONAL MODELING/ PHYSICS TEAM REPORT



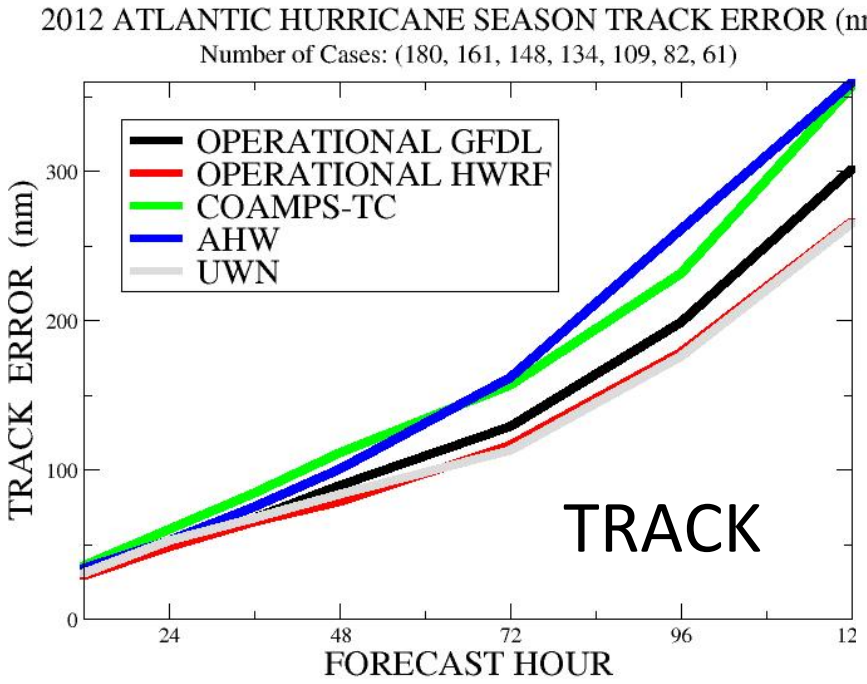
- Jian-Wen Bao
- Morris Bender
- Ligia Bernerdat
- Chris Davis
- James Doyle
- Chris Fairall
- S. Gopalakrishnan
- Isaac Ginis
- Young Kwon
- William Lewis
- Gegory Tripoli
- Vijay Tallapragada
- Ryan Torn

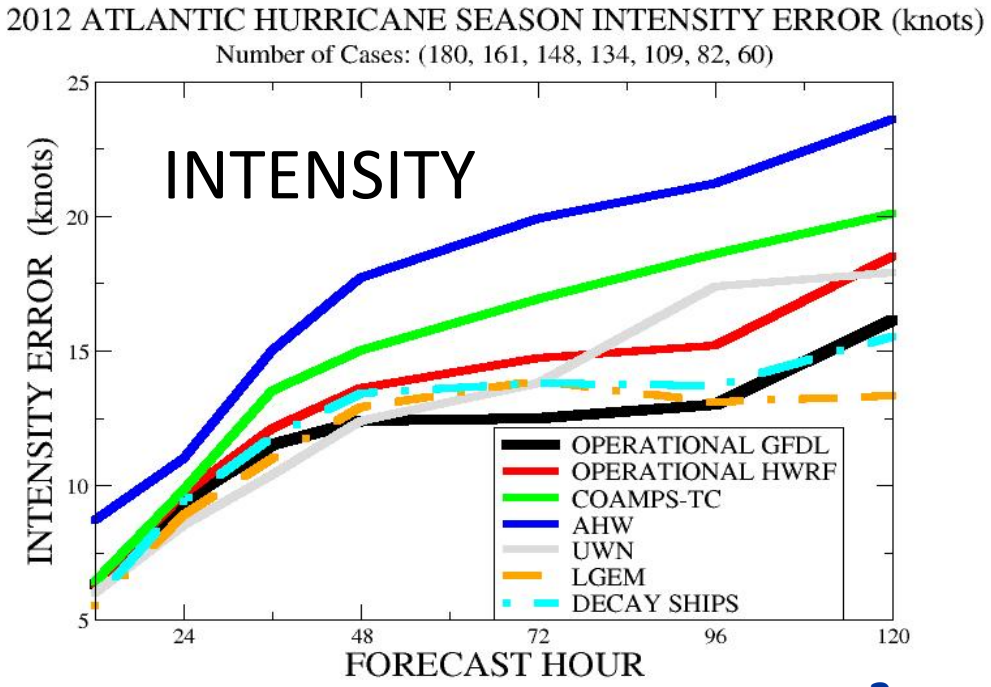
HFIP Review Conference Call
November 28, 2012

2012 HFIP REGIONAL MODEL COMPARISONS AND VERIFICATIONS VS. OPERATIONAL MODELS

ALL VERIFICATIONS ARE HOMOEGENOUS COMPARISONS USING INTERPOLATED MODELS ONLY FROM OPERATIONAL ATCF-DECKS

STATUS REPORT: track & intensity verification (2012)



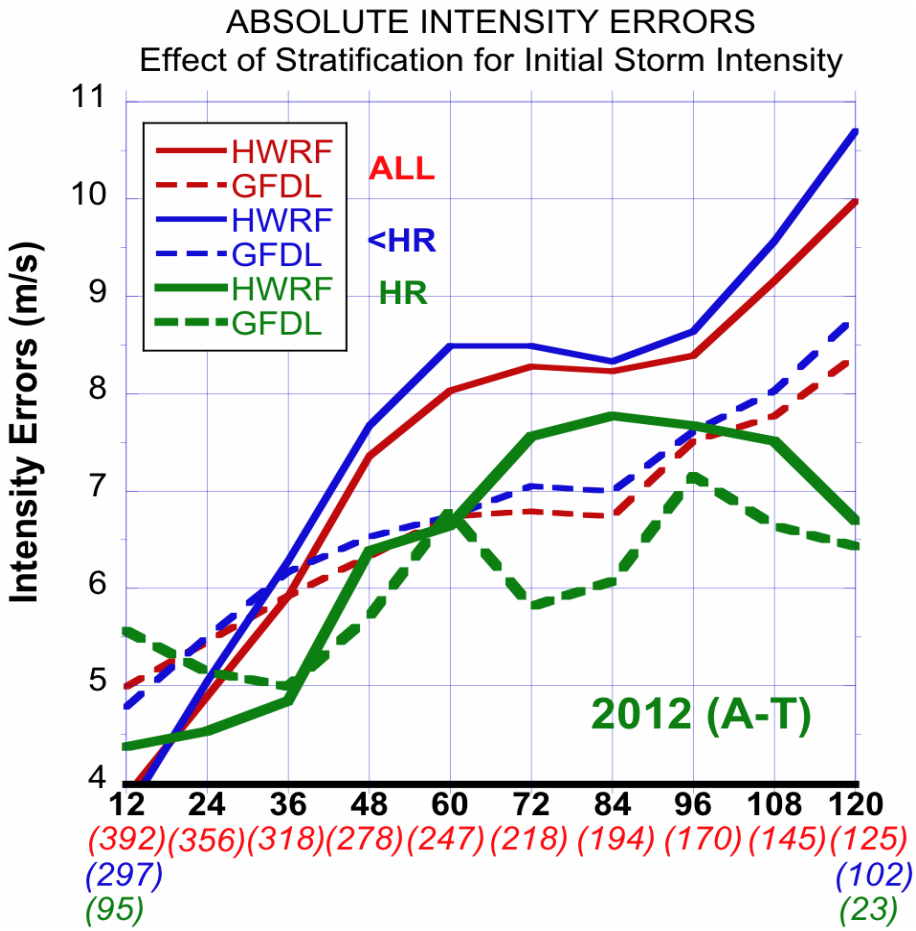


INTENSITY SKILL Stratified by:

. Initial Storm Intensity . Vertical Shear

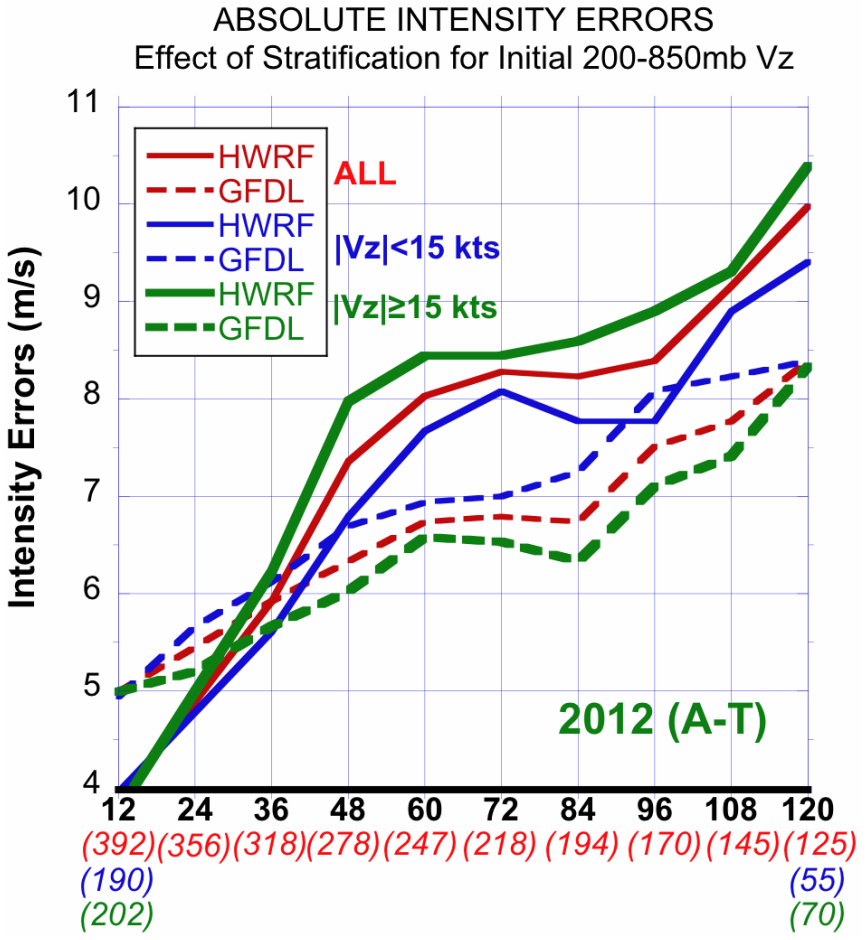
Special Thanks to
Stanley Goldenberg (HRD/AOML)

Intensity Forecast Errors & Skill (2012) Stratified by Initial Storm Intensity



All Cases/Initially <Hurricane/Initially Hurricane

Intensity Forecast Errors & Skill (2012) Stratified by Initial Vertical Shear



All Cases / |Vz|<15 kts / |Vz|≥15 kts

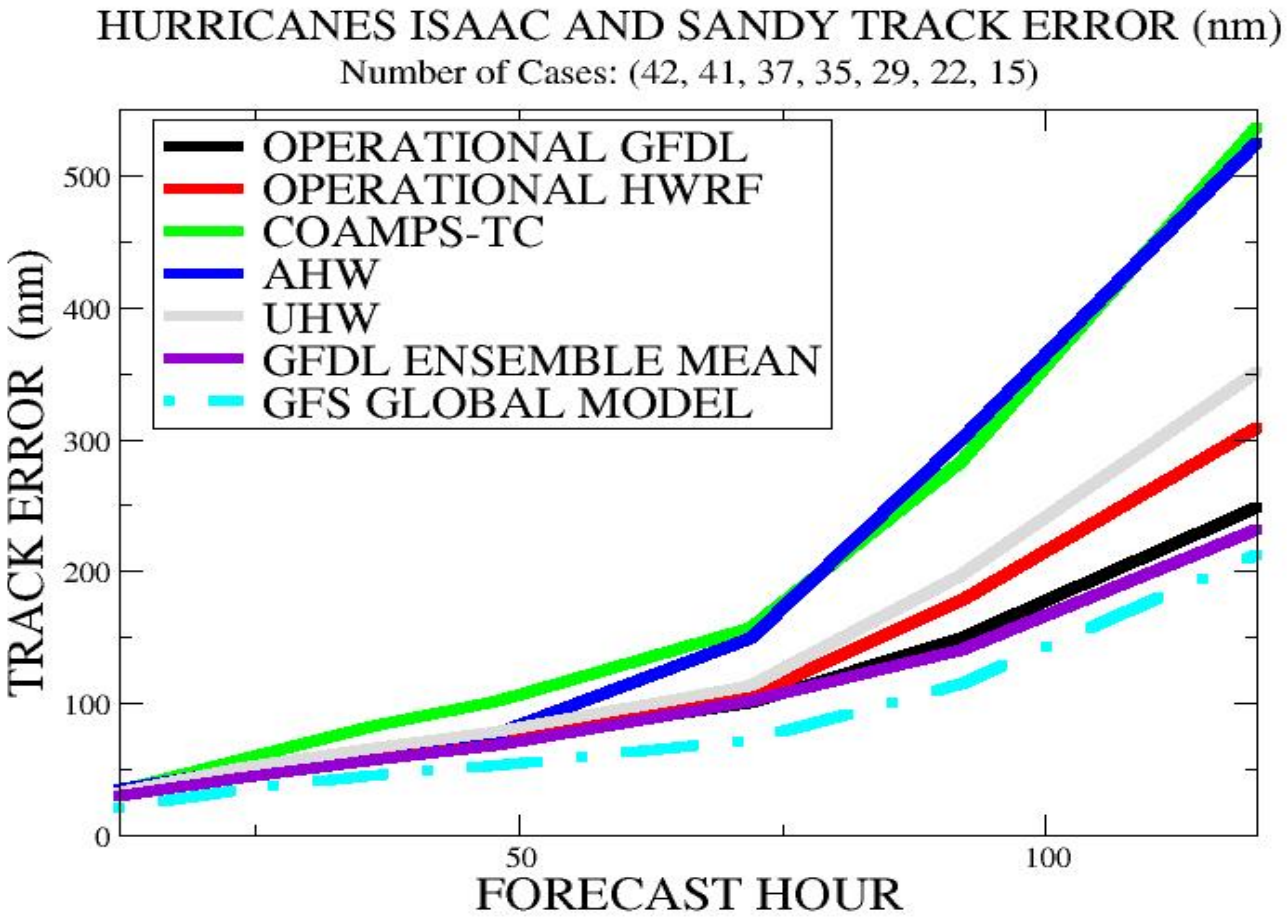
Verifications Two Major Land-falling events of 2012: HURRICANES ISAAC AND SANDY

For Track: Operational Models (HWRF & GFDL) Still Performed Best Overall for Both Storms

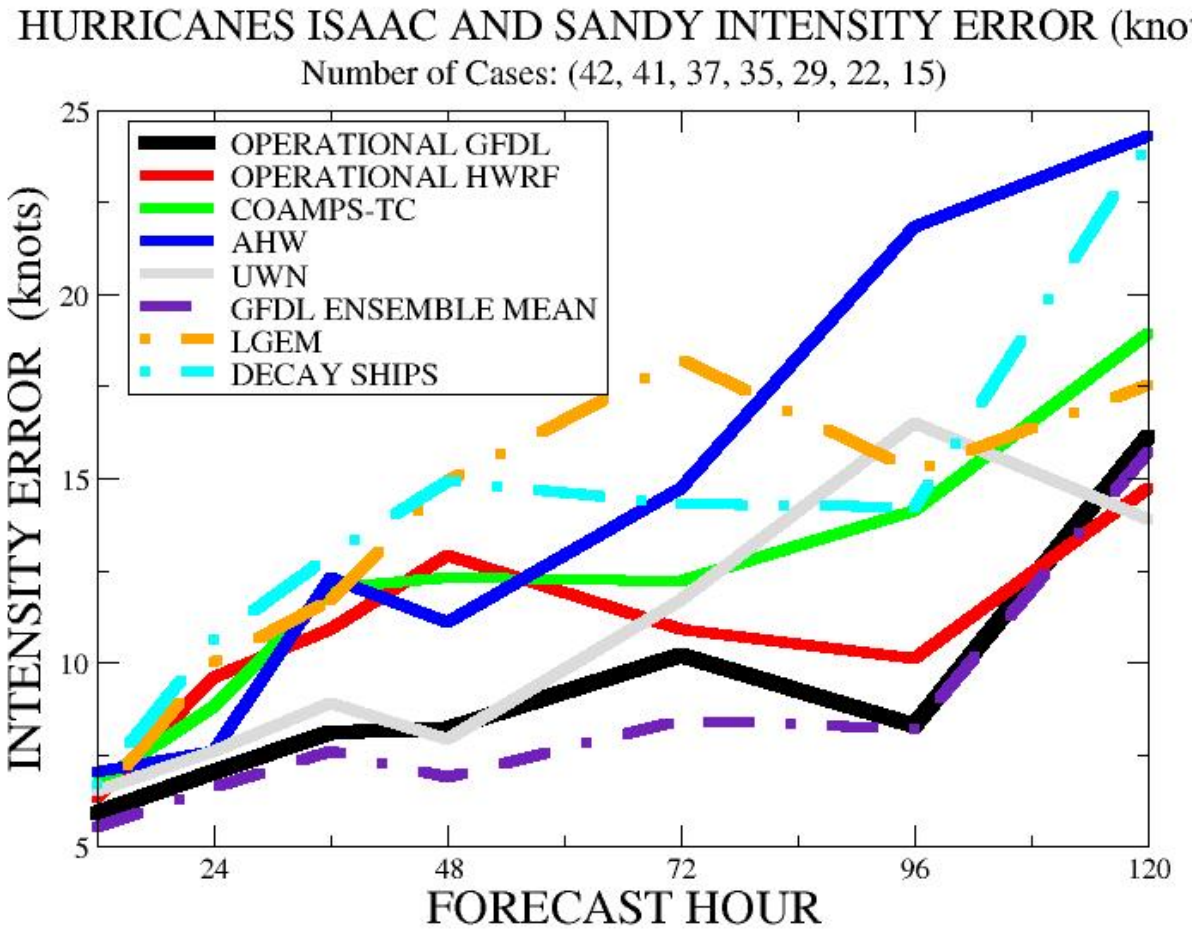
AHW and COAMPS-TC Performed very well for Sandy but not for Isaac

Still GFS the Best Performing Model for Both Storms

(GFDL Ensemble Mean a Close Second)



Combined Intensity stats for Isaac and Sandy

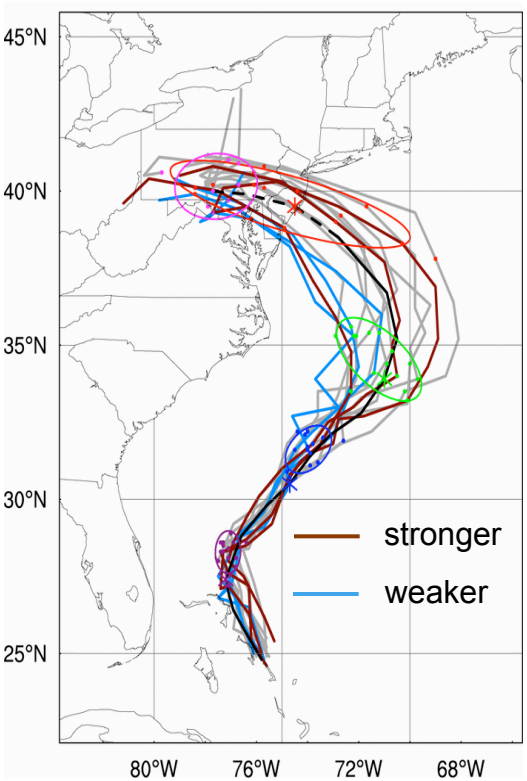


Operational models outperformed other dynamical models for land falling storms this year. (GFDL Ensemble Mean even better).

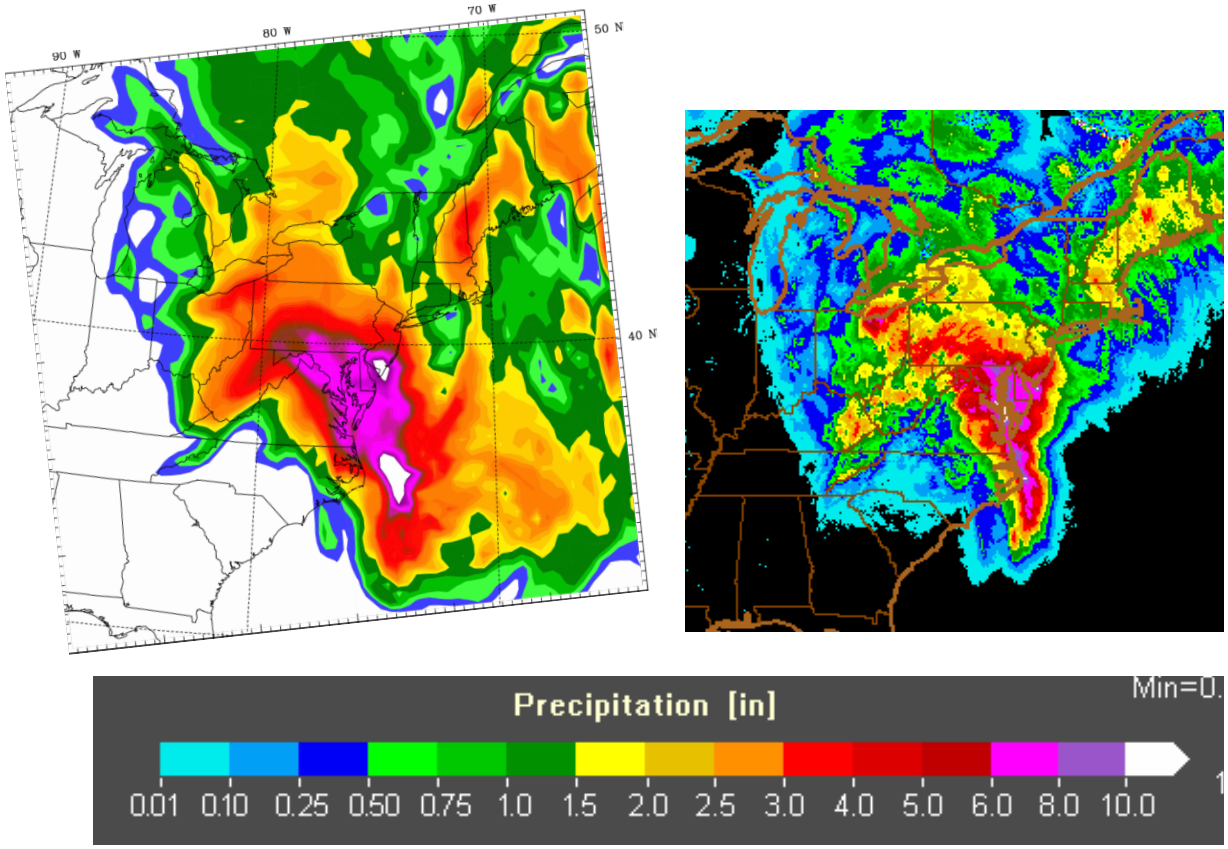
AHW Sandy Results

Comparable to GFDL at 3-5 days

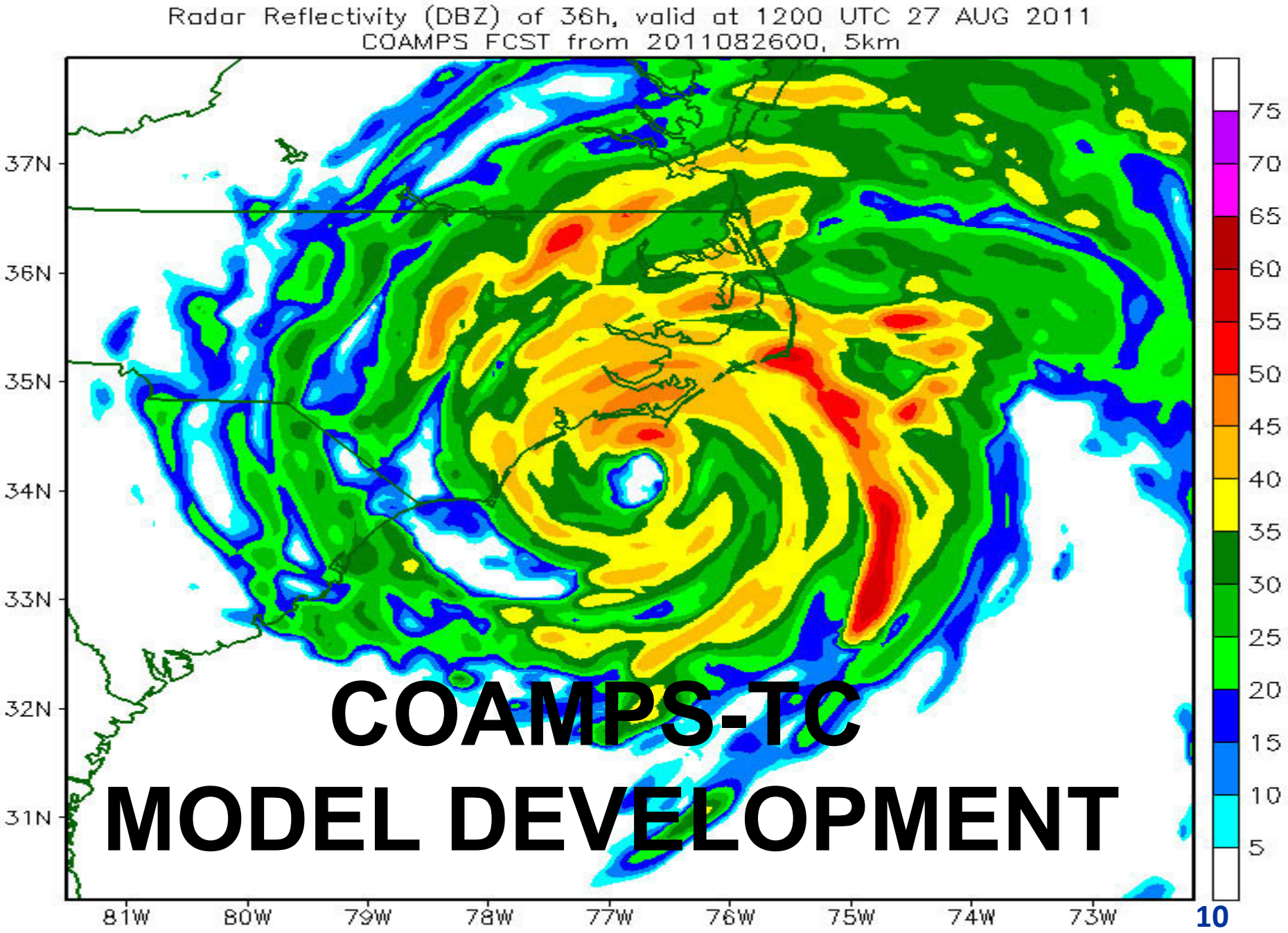
4 km Ensemble Forecasts



Ensemble of forecasts from 0000 UTC 26 October



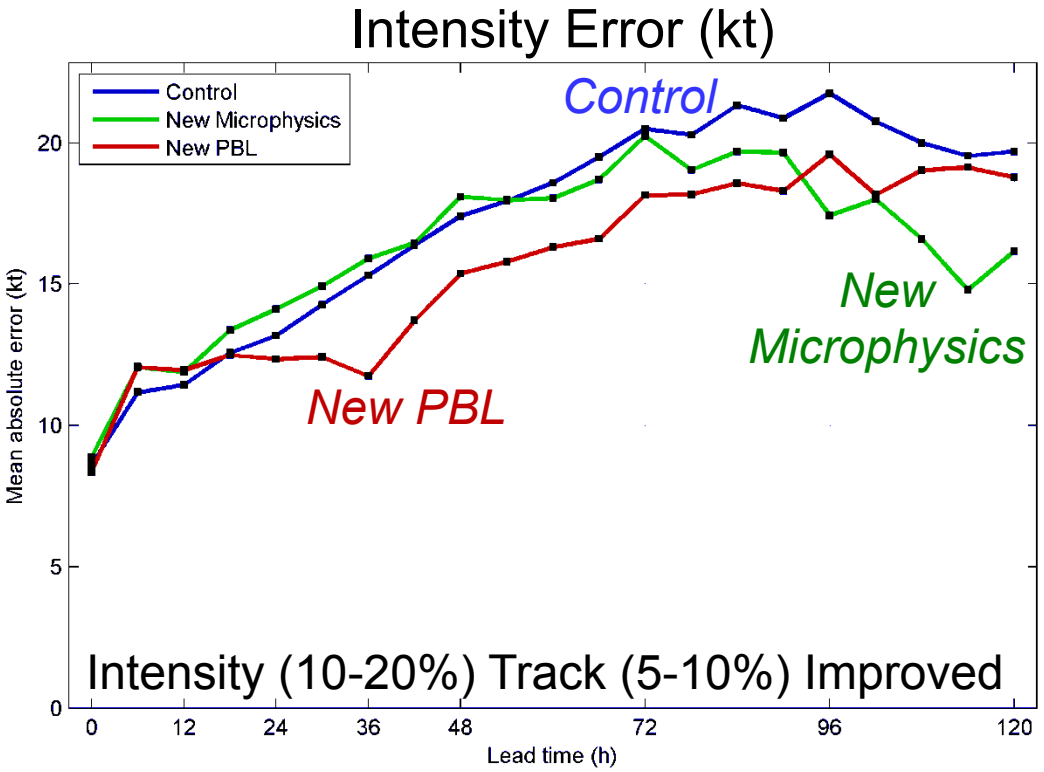
72-h Total Precipitation Ending 8 AM EDT October 31



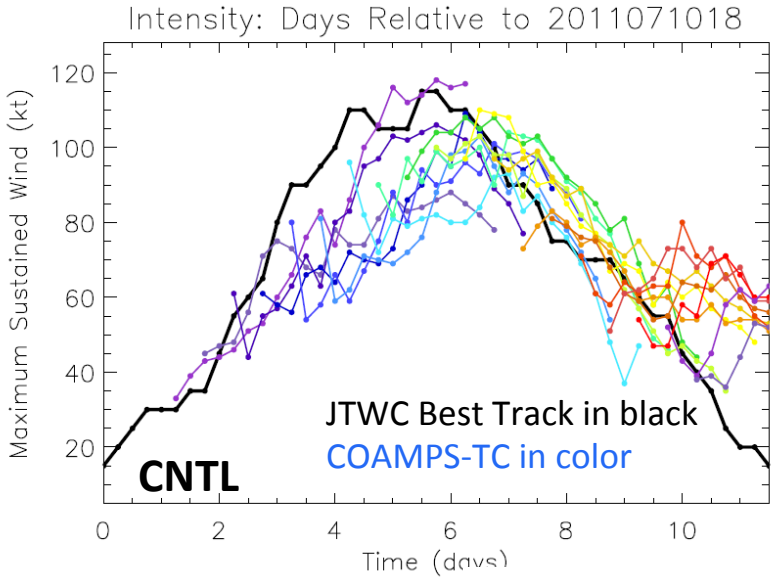
COAMPS-TC MODEL DEVELOPMENT

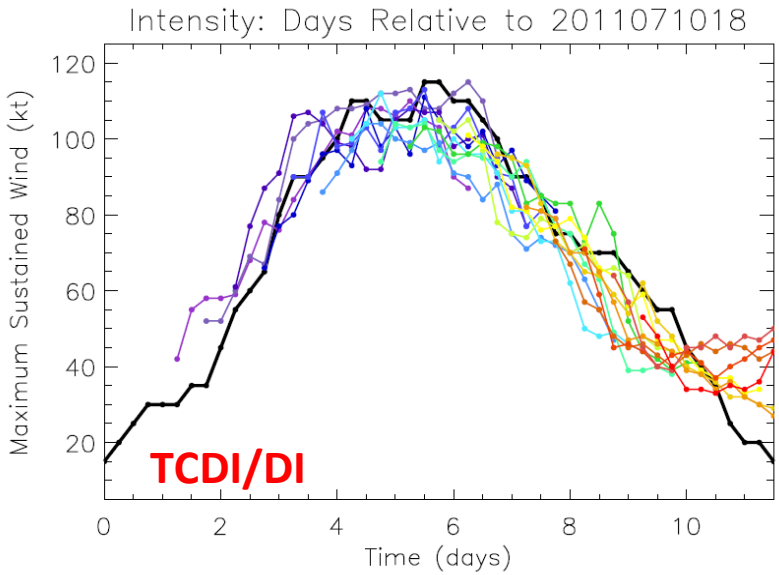
COAMPS-TC Development
2012 Testing and Evaluation

- Analysis and Initialization:
  - **New satellite obs.**
  - **TC Dynamic Initialization (tested in parallel)**
- Physical Parameterizations:
  - **New microphysics**
  - **New Fu-Liou radiation**
  - **Bougeault and M-Y hybrid PBLs**
- Air-Sea Coupled Model:
  - **Generalized coupling interface**
- Ensemble Kalman Filter:
  - **Improved EnKF data assimilation**
- Other Capabilities:
  - **New nest tracker**
  - **New diagnostics (including high-frequency output)**

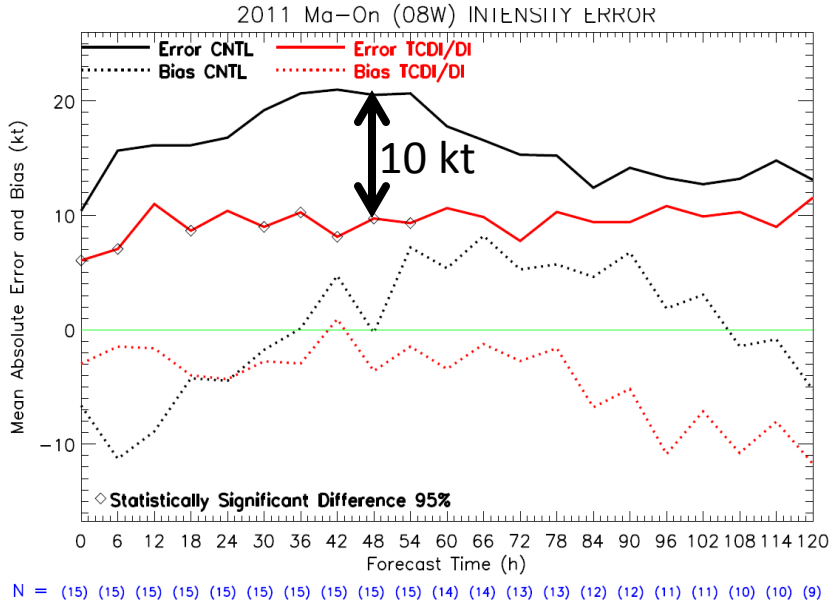


Case Study: 08W (2011) Ma-On





15 cases

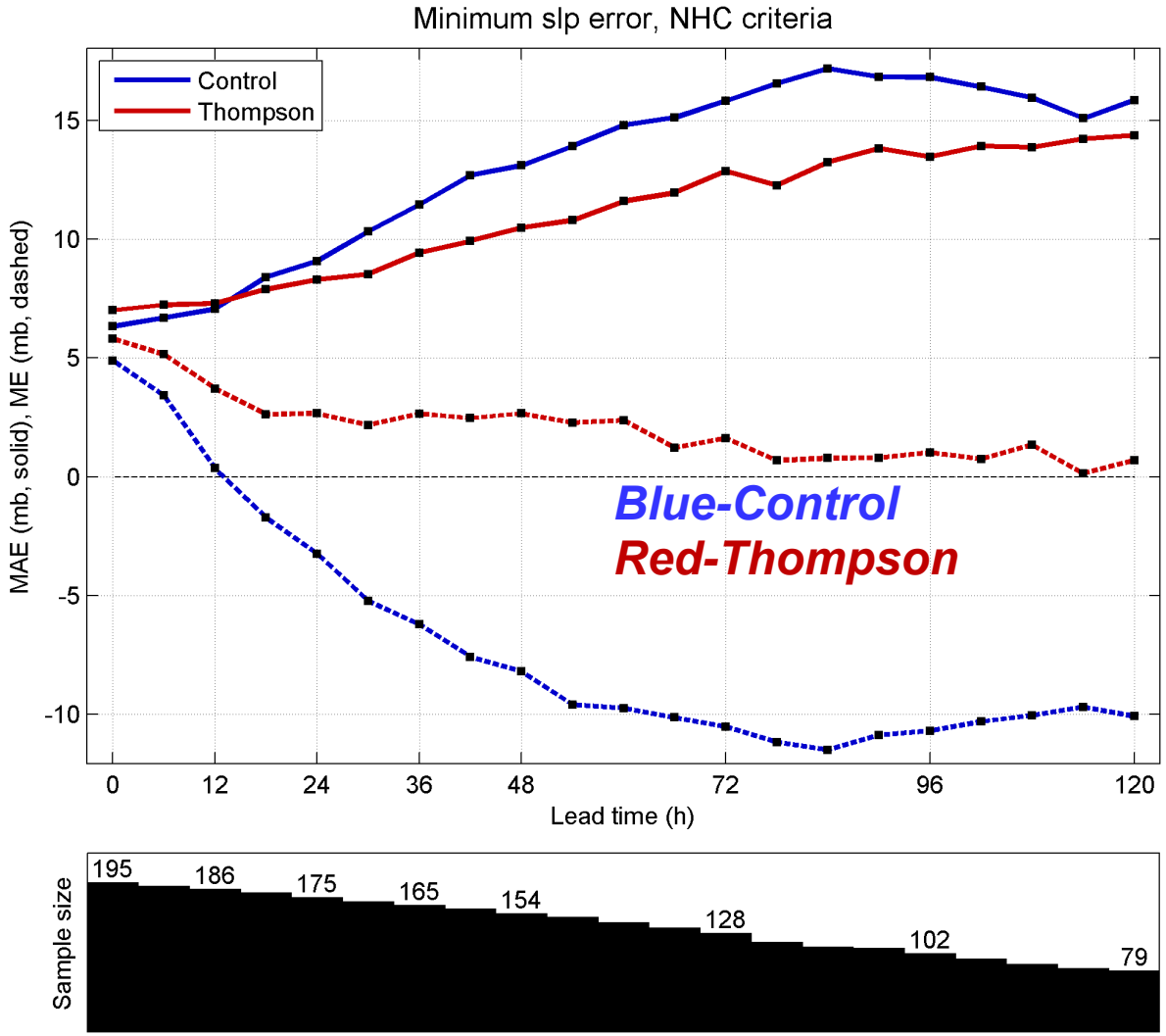


Significant intensity error reductions for Ma-On by using TCDI/DI

COAMPS-TC Microphysics Tests

Comparison of Control and Thompson Microphysics

SLP Intensity Error (hPa): 15 Storms



Thompson Microphysics Improves Intensity (15 storms, 195 cases)

COAMPS-TC
Summary

➢Promising Intensity Skill:

- COAMPS-TC intensity forecasts verified well in 2010-12 in WATL & WPAC
- Improved (in 2012) data assimilation, physics (TC PBL, microphysics)
  - 10-20% improvement in intensity, ~10% improvement in track
- Advancements to the ensemble (EnKF) and coupled capabilities

➢Outstanding Issues:

- Intensity: i) Rapid intensification; ii) Weak storms
- Regional model track skill lags best GCMs
- Vortex initialization, multi-scale DA, physics (PBL and microphysics)

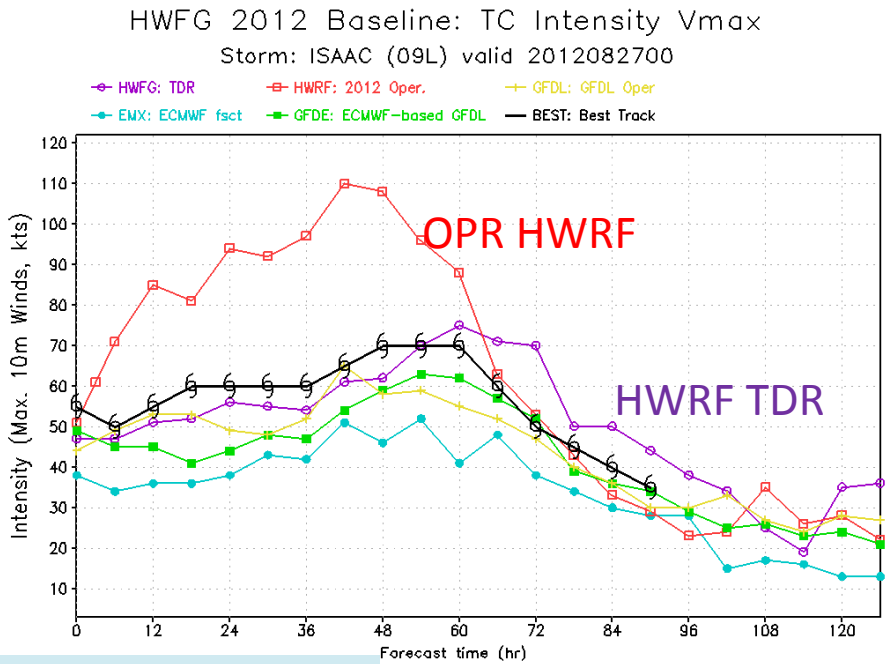
➢Future Plans:

- Transition COAMPS-TC to Navy operations (Ops. Testing underway)
- Advance further COAMPS-TC physics components for 2013
  - consider advanced NRL or Thompson microphysics
  - testing Tiedke cumulus, SAS shallow convection, new PBL mixing
- Coupled air-sea COAMPS-TC (with NCOM) will be run in real time in 2013
- Dynamical initialization will be run in real time in 2013
- EnKF, radar DA, and 4D-Var development underway

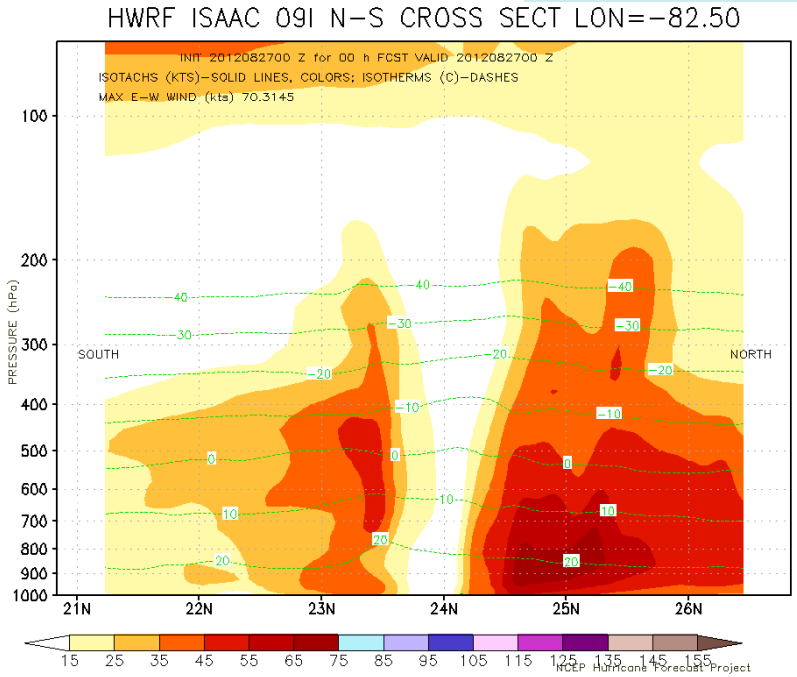
THE OPERATIONALHWRF
NCEP'S OPERATIONAL
3 KM REGIONAL MODELING SYSTEM

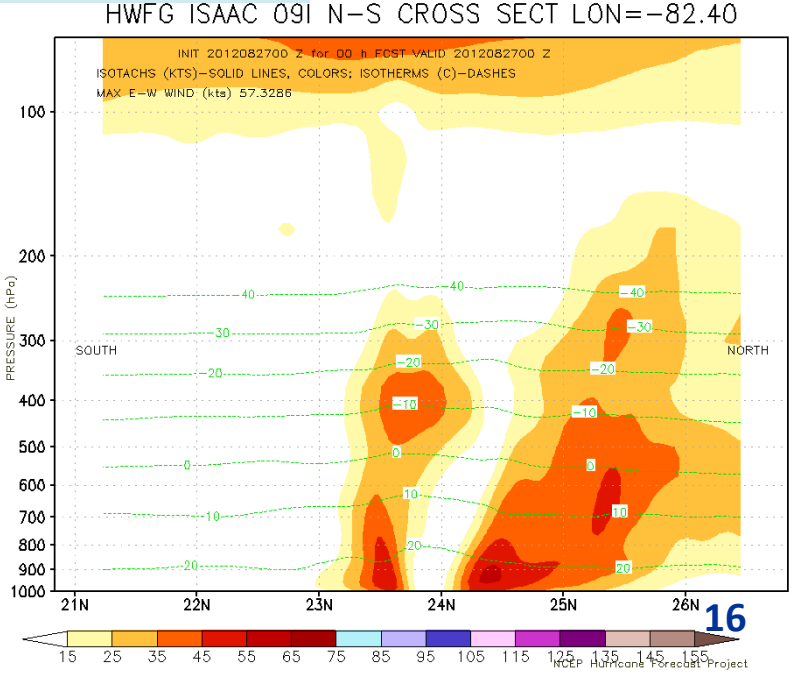
2.2.2 (EMC)
TDR assimilation

Impact of TDR data assimilation to hurricane intensity forecast



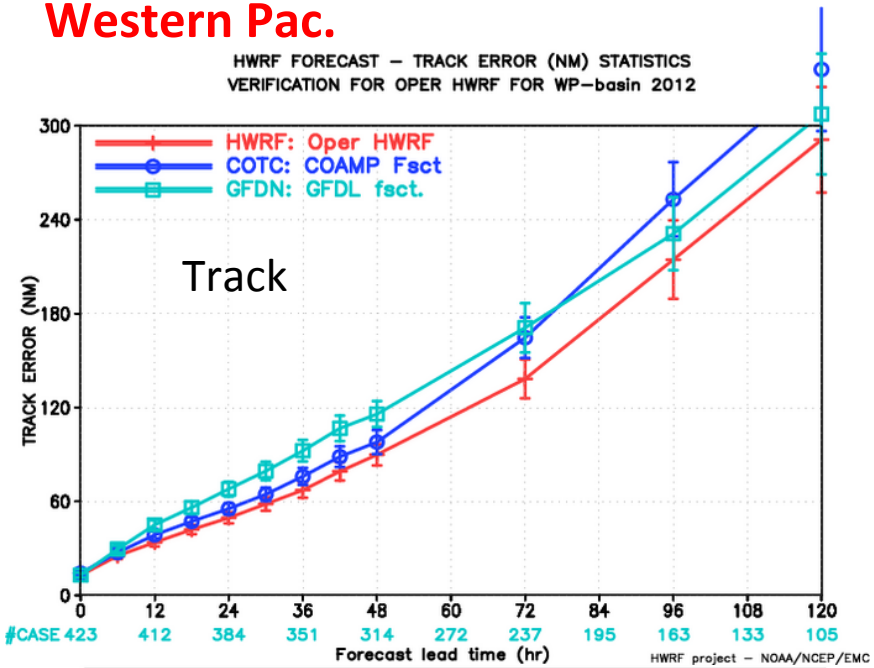
Cross section at initial time

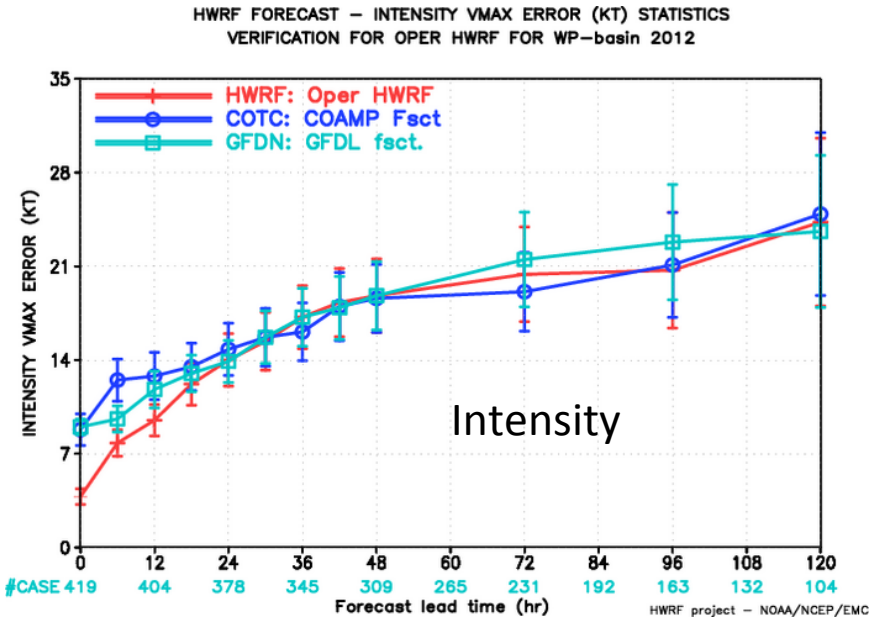


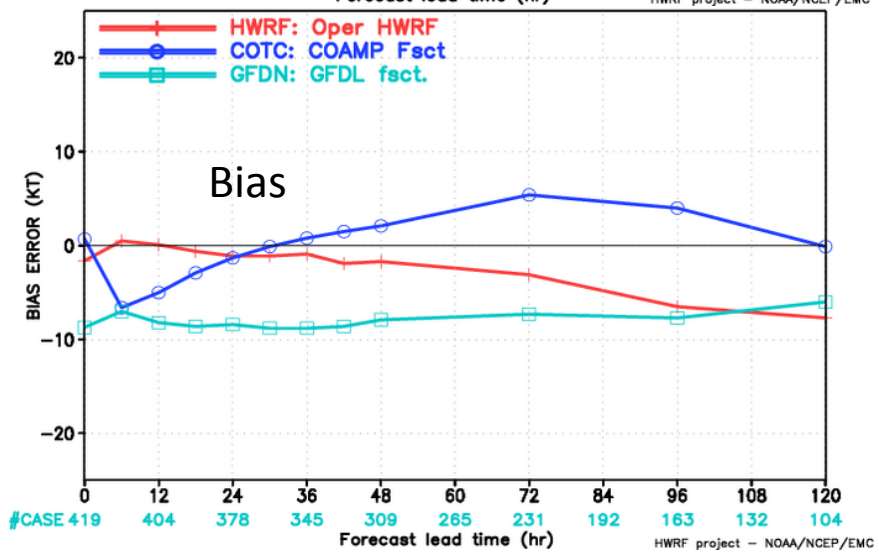


2.1.1 (EMC)
Western Pac.

West Pacific experiment 2012







HWRF track errors better than COAMPS-TC and GFDN

HWRF intensity errors comparable to COAMPS-TC and GFDN

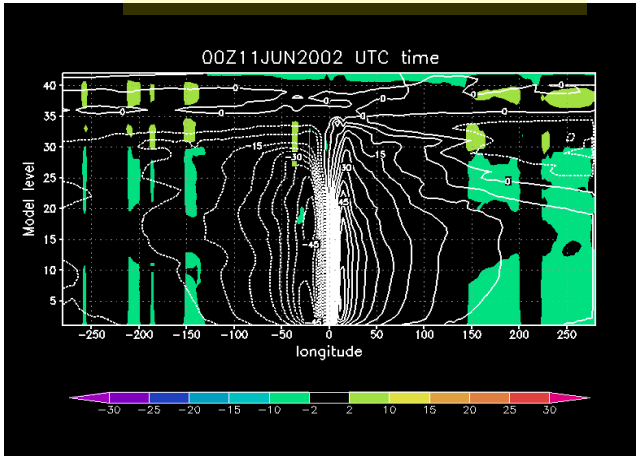
GFDN and COAMPS-TC use NOGAPS while HWRF uses GFS for IC & BC

2.5.1 (EMC, UCLA)
PHYS radiation

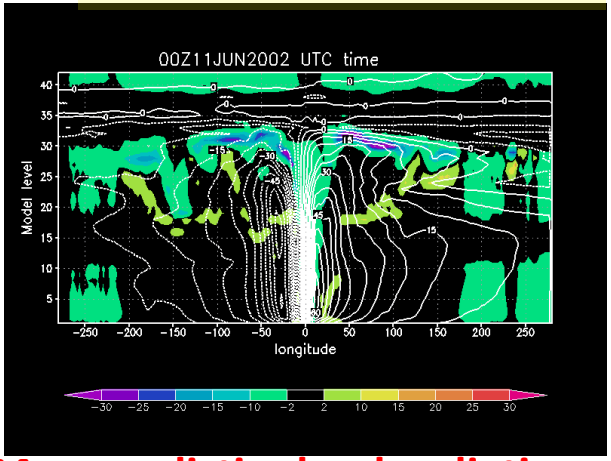
Sensitivity tests on radiation schemes in HWRF

Idealized vortex simulation

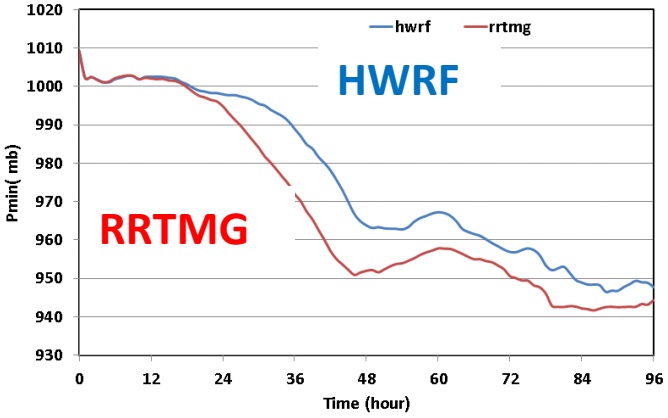
GFDL radiation

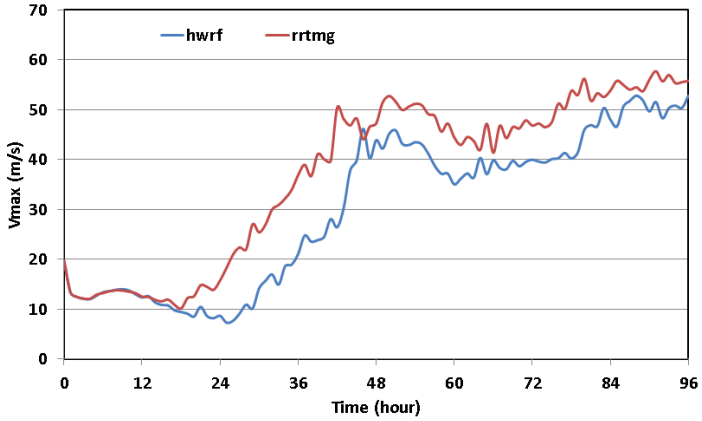


RRTMG radiation



More realistic cloud-radiation interaction in RRTMG



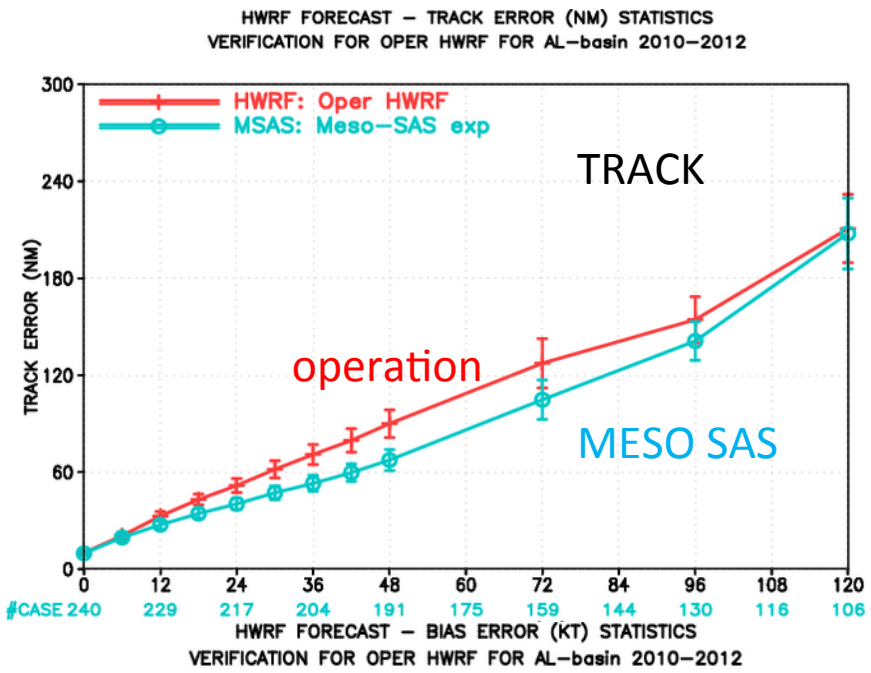


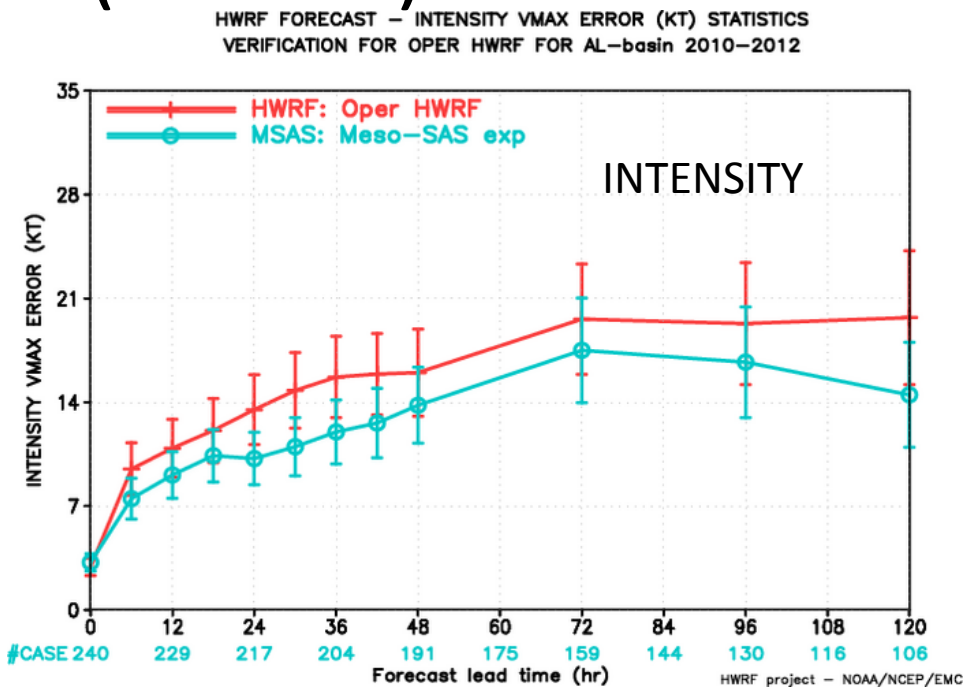
Meso-SAS Scheme

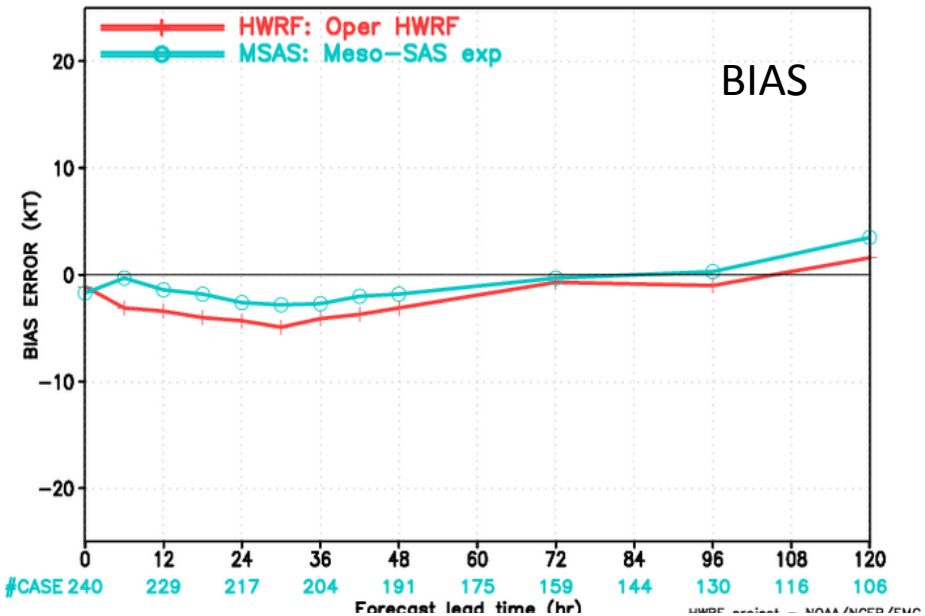
- Operational SAS scheme is not designed for high-resolution models.

  Basic assumption: updraft area is very small compared to the model grid size. This assumption begins to break down when the grid sizes become less than 10 km.
- At 0.5-10km model resolution, the use of the explicit microphysics scheme is still problematic since the vertical motion may not be large enough to smoothly create moist adiabat for the entire grid point. This can and do lead to the so-called grid-point storm, which has small size and strong intensity
- Hua-Lu has re-derived Arakawa-Schubert (1974) scheme by removing the assumption that the updraft area be small, and make it possible to form the meso-SAS scheme which can be used in high resolution models.

MESO SAS (Results)





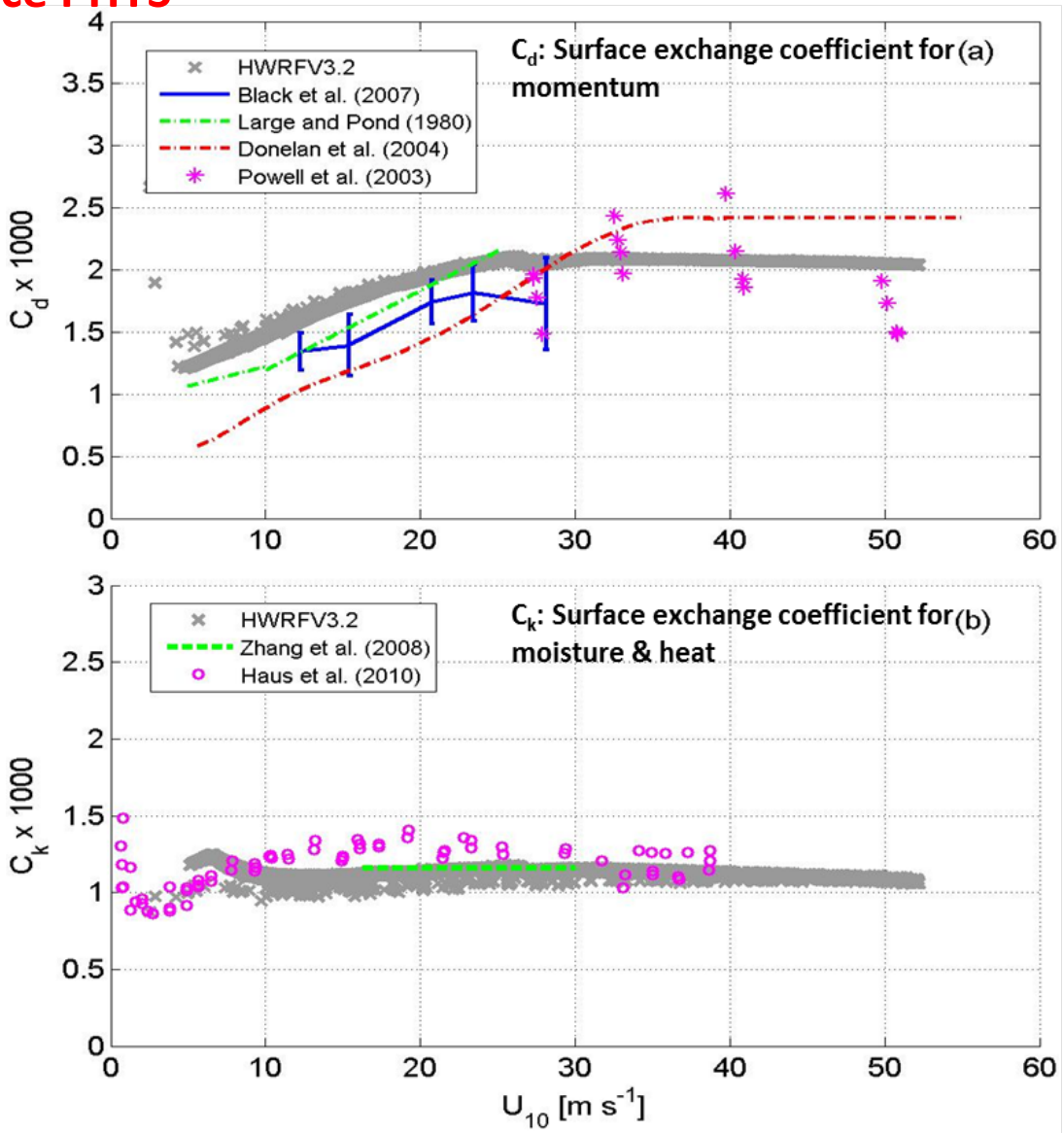


Use of parameterized convection (meso-SAS) in HWRF at 3km resolution showed significant improvement in track and intensity forecast skill *(potential candidate for 2013 HWRF/ GFDL upgrades)*

Using HRD's aircraft observations to improve hurricane model surface layer physics

2.5.1(HRD, EMC) Surface PHYS

(Gopalakrishnan et al. 2012 JAS)



Direct flux observation based estimates of Cd and Ck from HRD's CBLAST field program: Black et al. (2007)
J. Zhang et al. (2008)

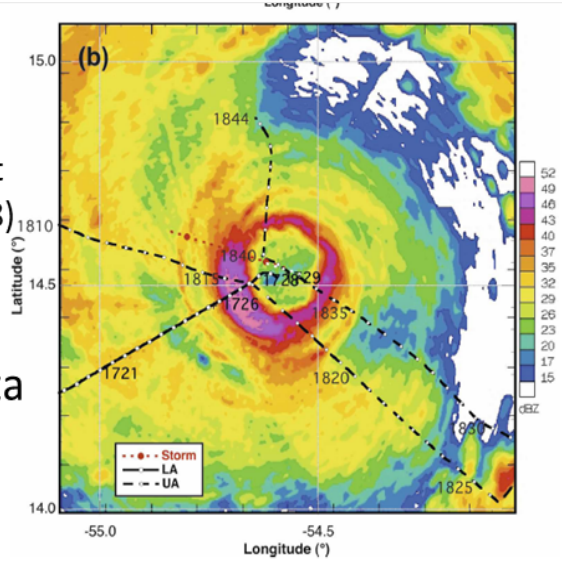
Dropsonde-based estimates of Cd : Powell et al. (2003)

Using HRD's Aircraft observations to improve the PBL physics in HWRF

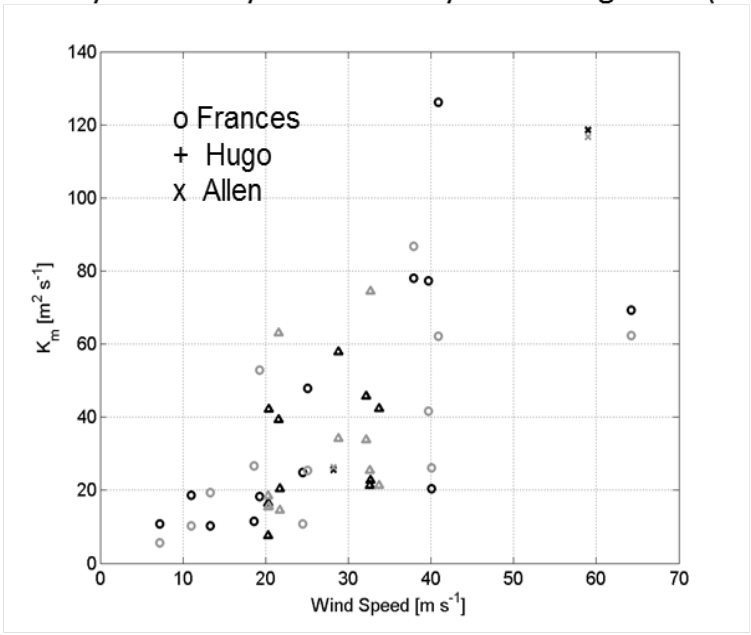
2.5.1 (HRD)
PBL PHYS

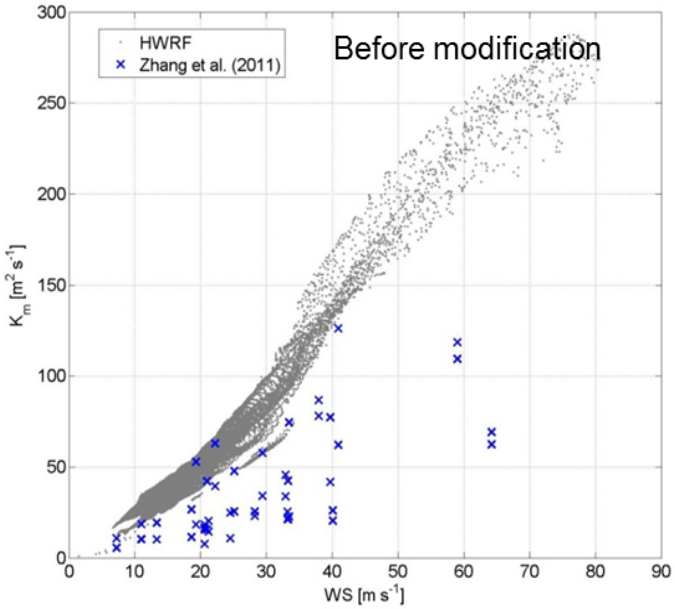
Hugo (1989) flight
Marks et al. (2008)

Flight-level data

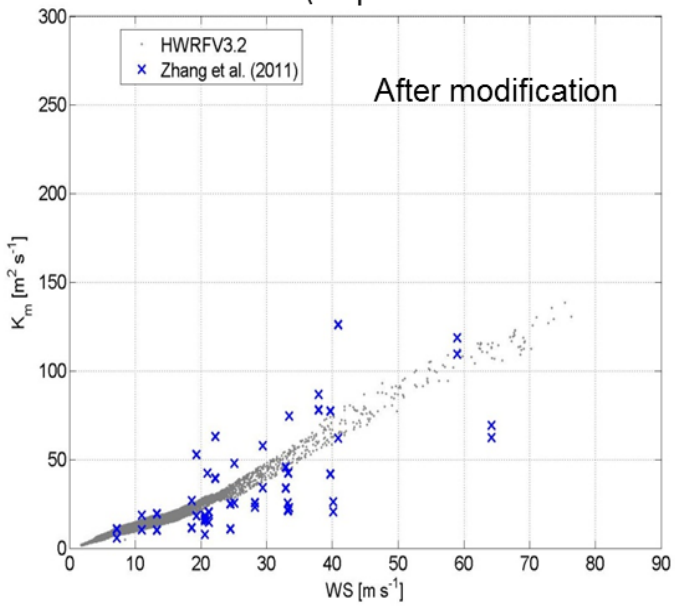


Vertical eddy diffusivity estimated by Jun Zhang et al. (2011)





(Gopalakrishnan et al. 2012 JAS)

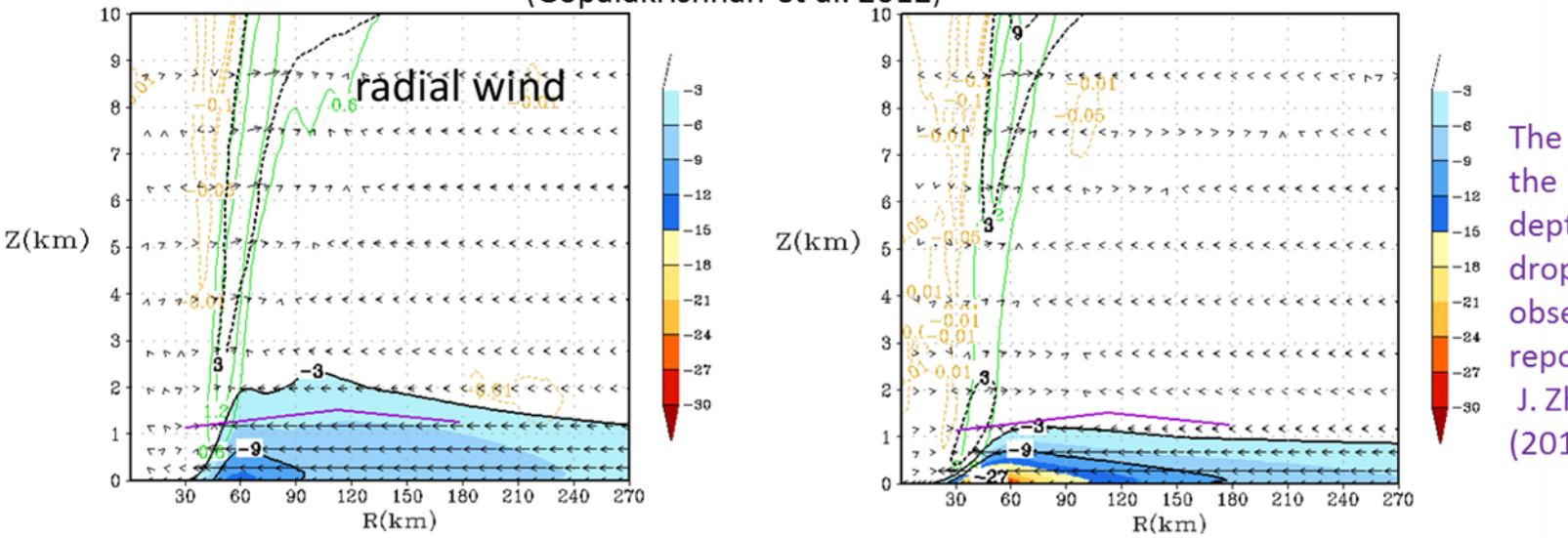


Using HRD's aircraft observations to improve and validate model physics

Original Km in HWRF

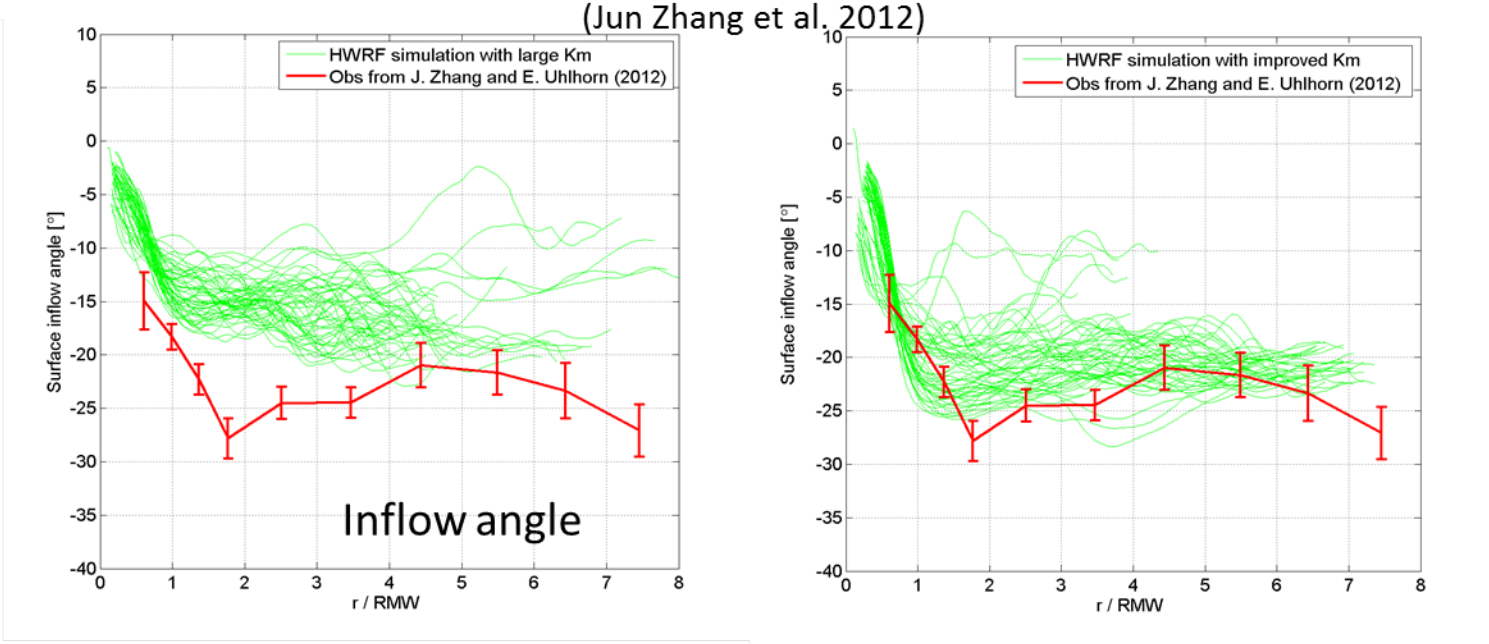
HWRF with modification of Km based on Obs

(Gopalakrishnan et al. 2012)



The purple line is the inflow layer depth from dropsonde observations reported by J. Zhang et al. (2011)

(Jun Zhang et al. 2012)

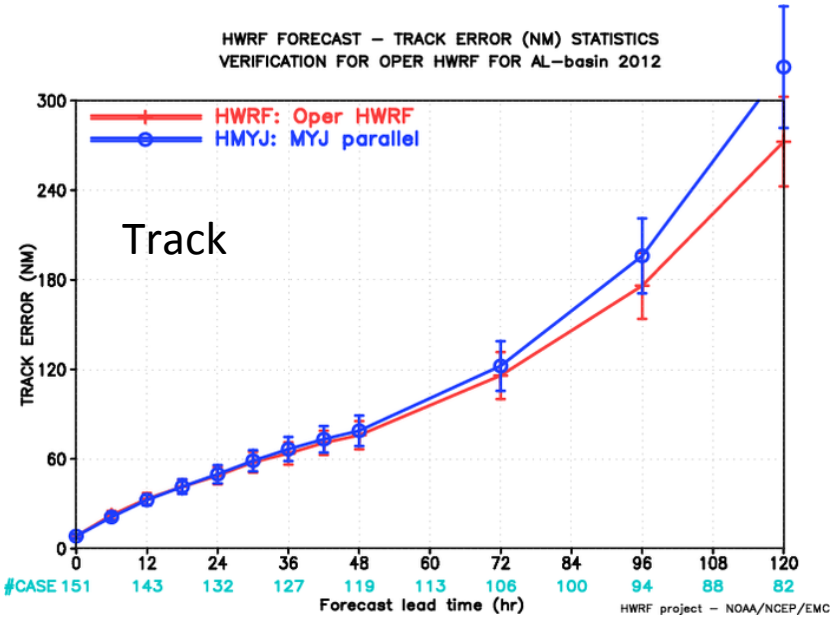


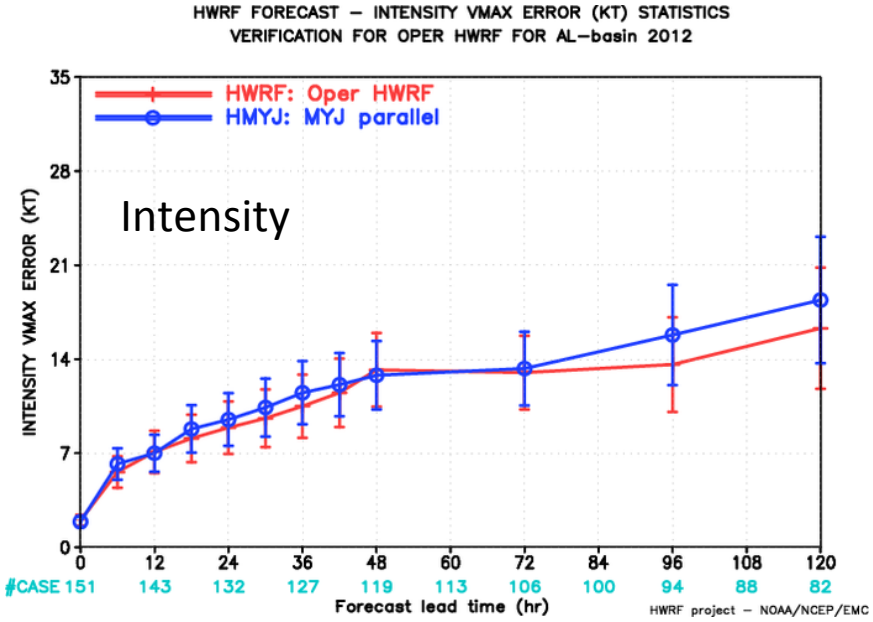
The red line is the axisymmetric inflow angle from dropsonde observations reported by J. Zhang and E. Uhlhorn (2012)

2.5.1 (HRD)
PBL PHYS

2.7.1 (ESRL, EMC, HRD)
MYJ PBL PHYS

MYJ PBL vs GFS PBL (2012 ATL)

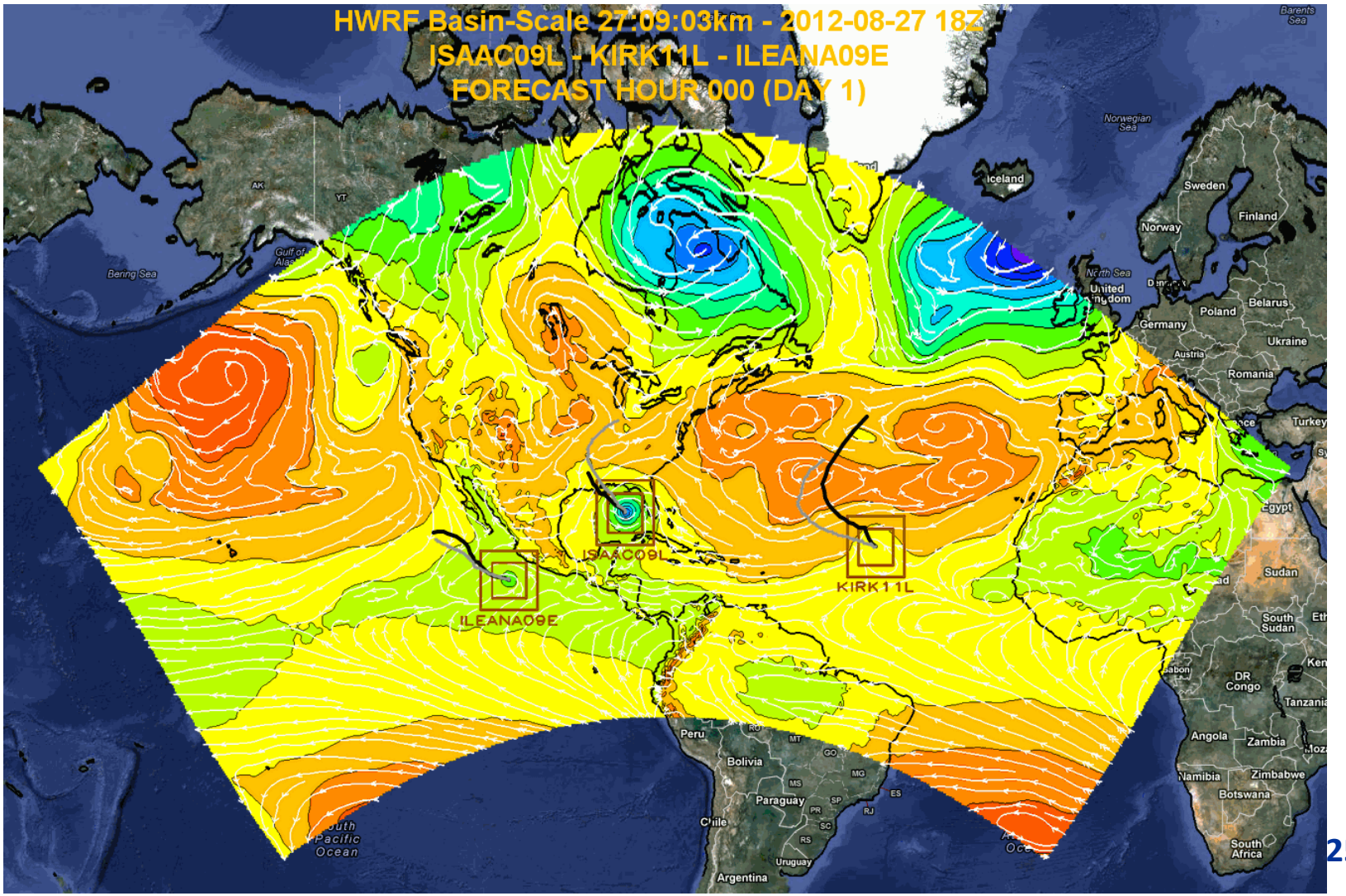




Real-Time HWRF runs with MYJ PBL + GFDL Surface Physics for 2012 season did not show positive impacts.

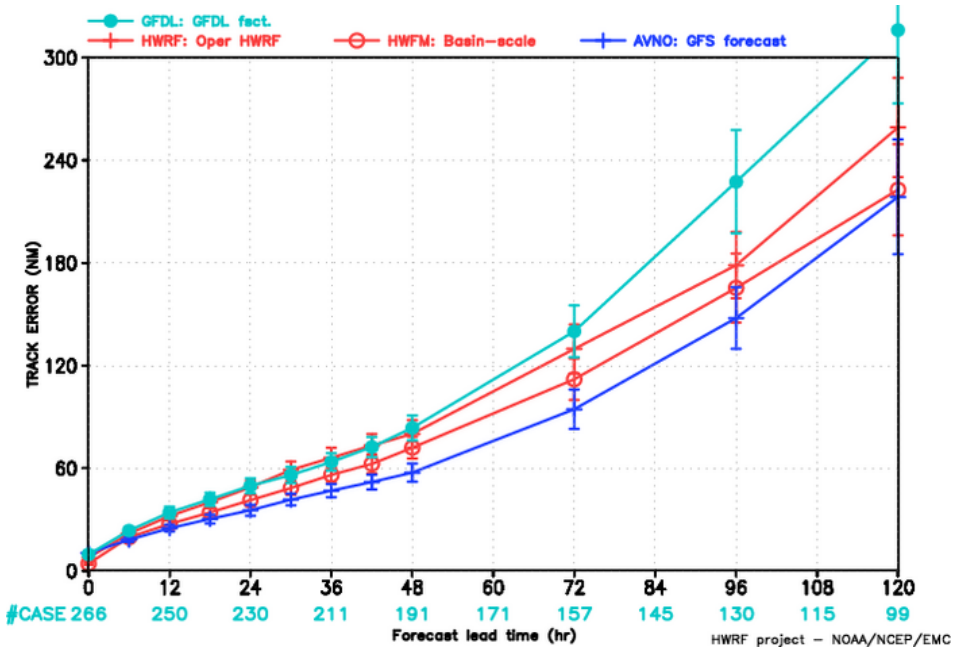
Advancements to Operational HWRF – Basin Scale Configuration with multiple moveable nests

Isaac-Ileana-Kirk real-time forecast

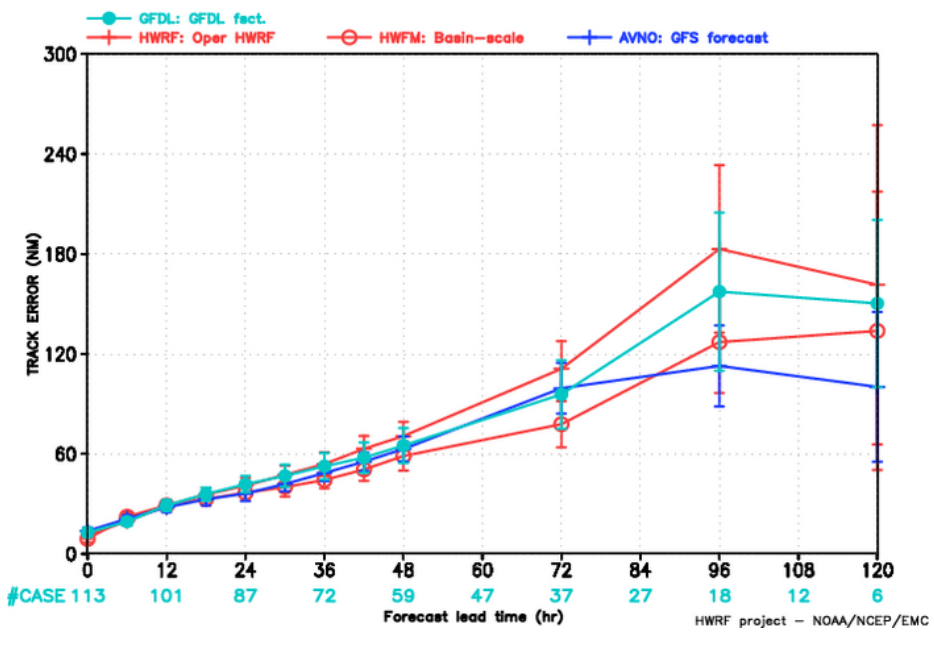


Basin Scale Multi-domain HWRF performance (2012)

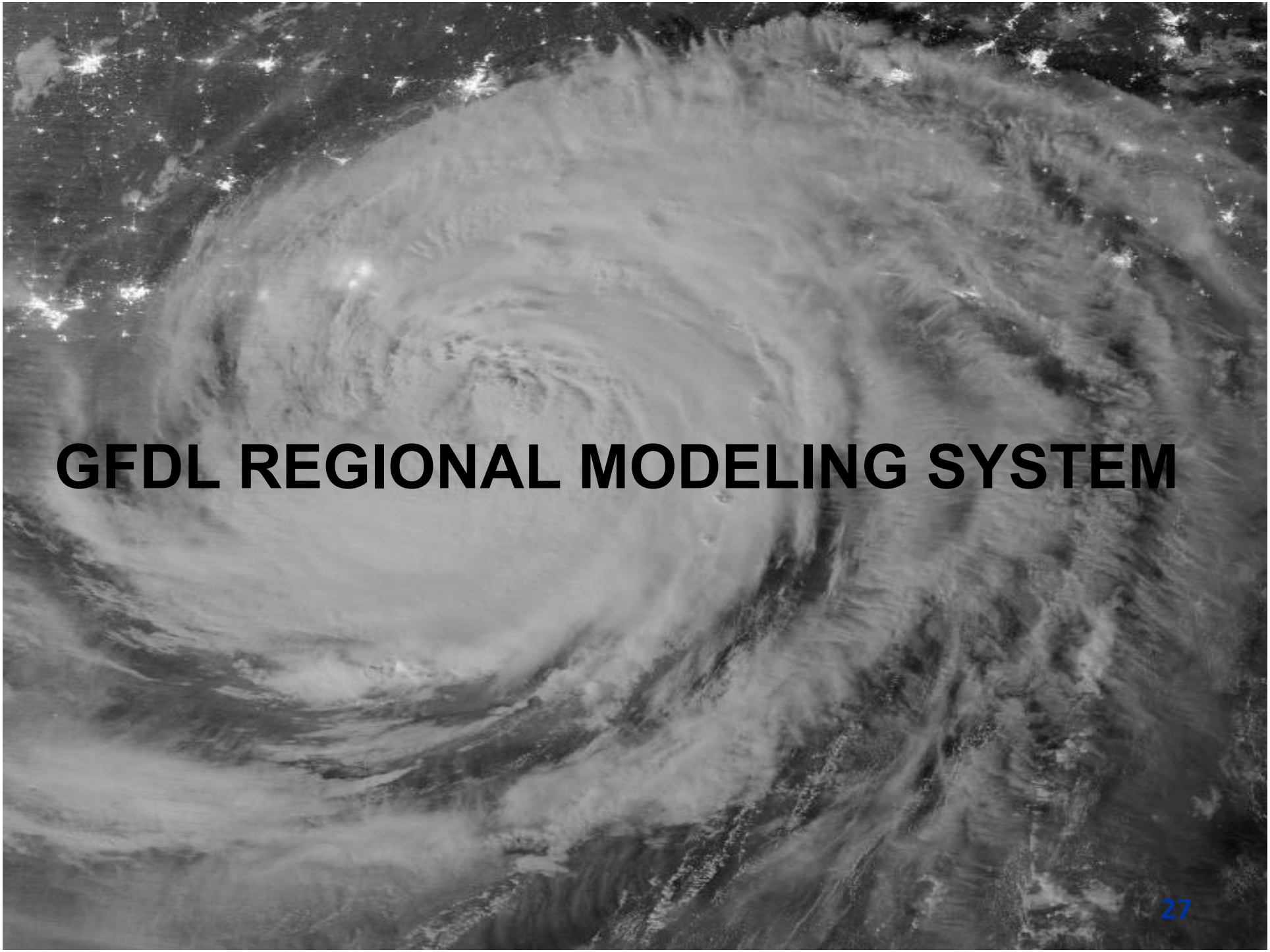
Track error (Atlantic AL09-19)



Track error (East Pacific EP09-17)



Improved track forecast skill from Basin-Scale HWRF


GFDL REGIONAL MODELING SYSTEM

ECMWF based GFDL and HWRF Real Time Parallel System

(requested by NHC for the stream 1.5 parallel)

Configuration:

- Pre-process ECMWF data, convert to readable format for both HWRF and GFDL;
- Initialized at 00Z and 12h, forecast up to 132h;
- Experiment period: August 1, 2012 onwards.

Input:

- Initial Condition
  1. ECMWF: T1279 L91 vs. GFS: T574 L64;
  2. No initialization;
- Boundary Condition

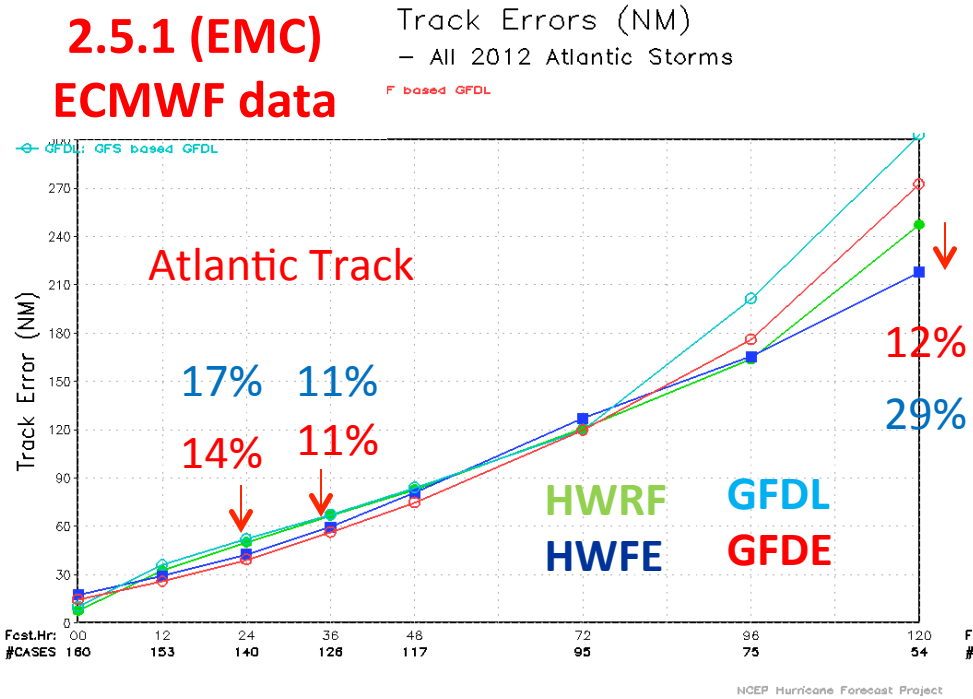
  ECMWF: T319 L91 vs. GFS: T574 L64.

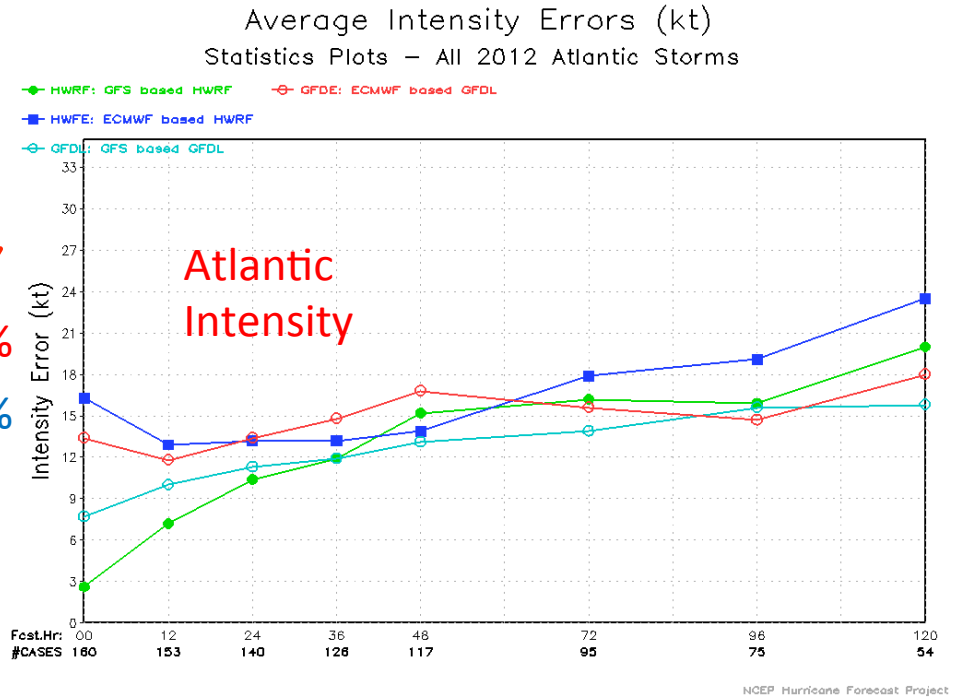
Experiments:

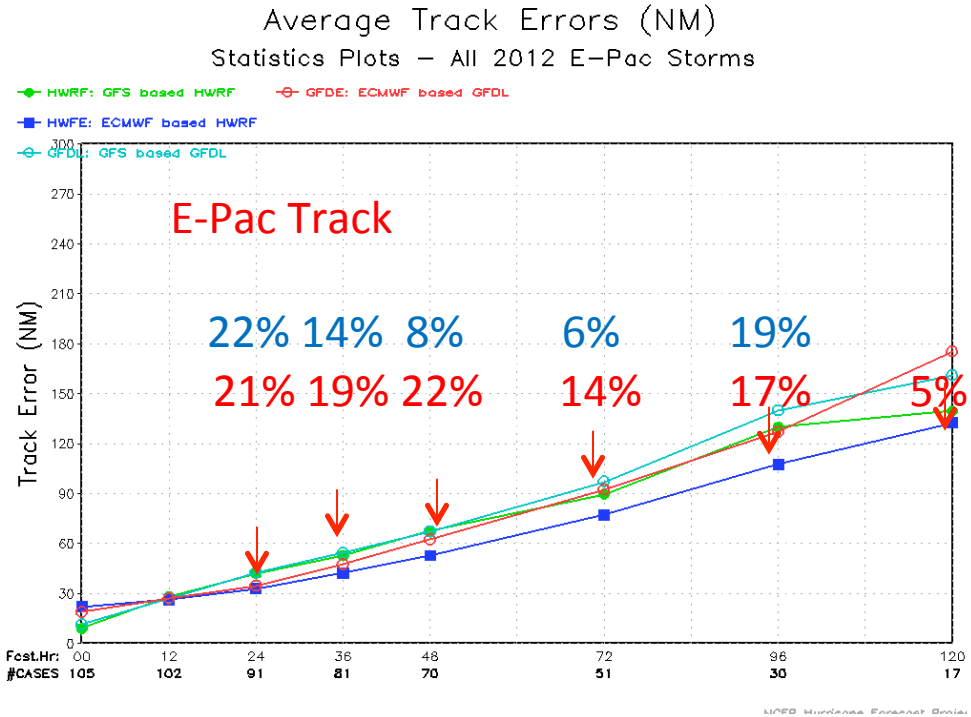
HWFE: Operational HWRF model using ECMWF data for IC and BC

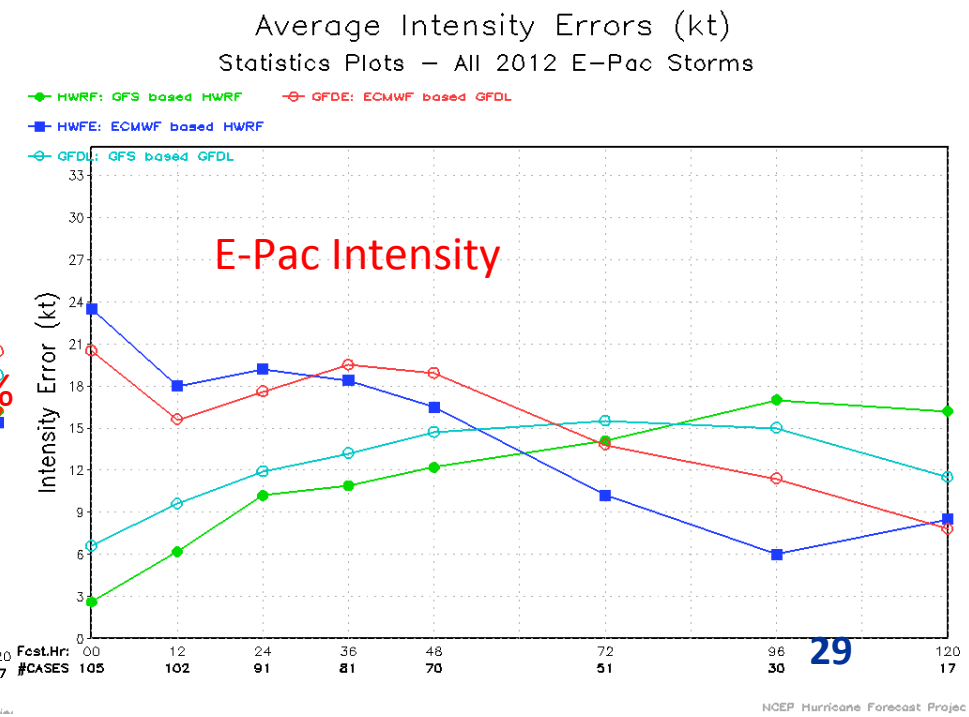
GFDE: Operational GFDL model using ECMWF data for IC and BC

2.5.1 (EMC)
ECMWF data





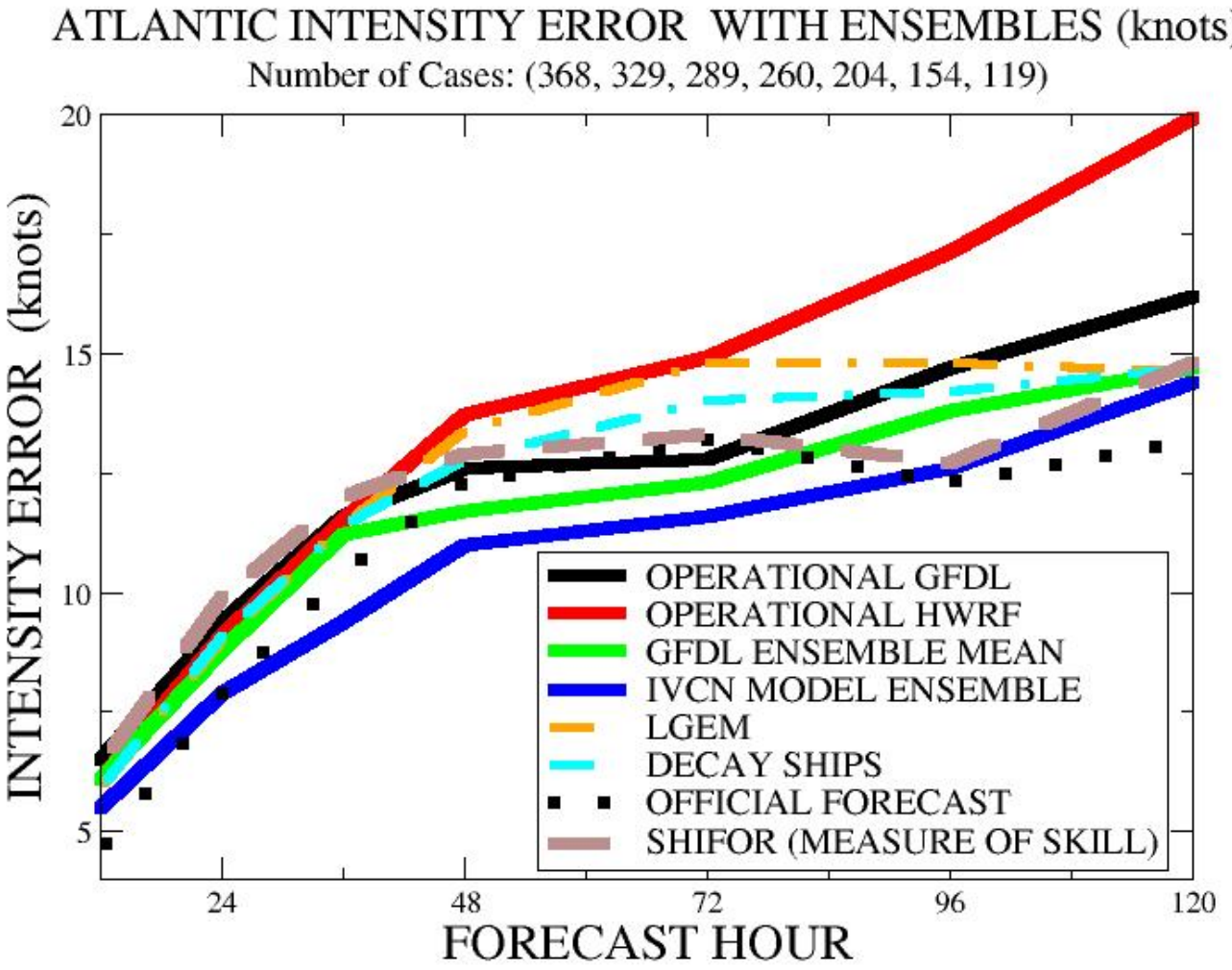




GFDL ENSEMBLE MEAN SHOWED SIGNIFICANT INTENSITY SKILL COMPARED TO OPERATIONAL PRODUCTS

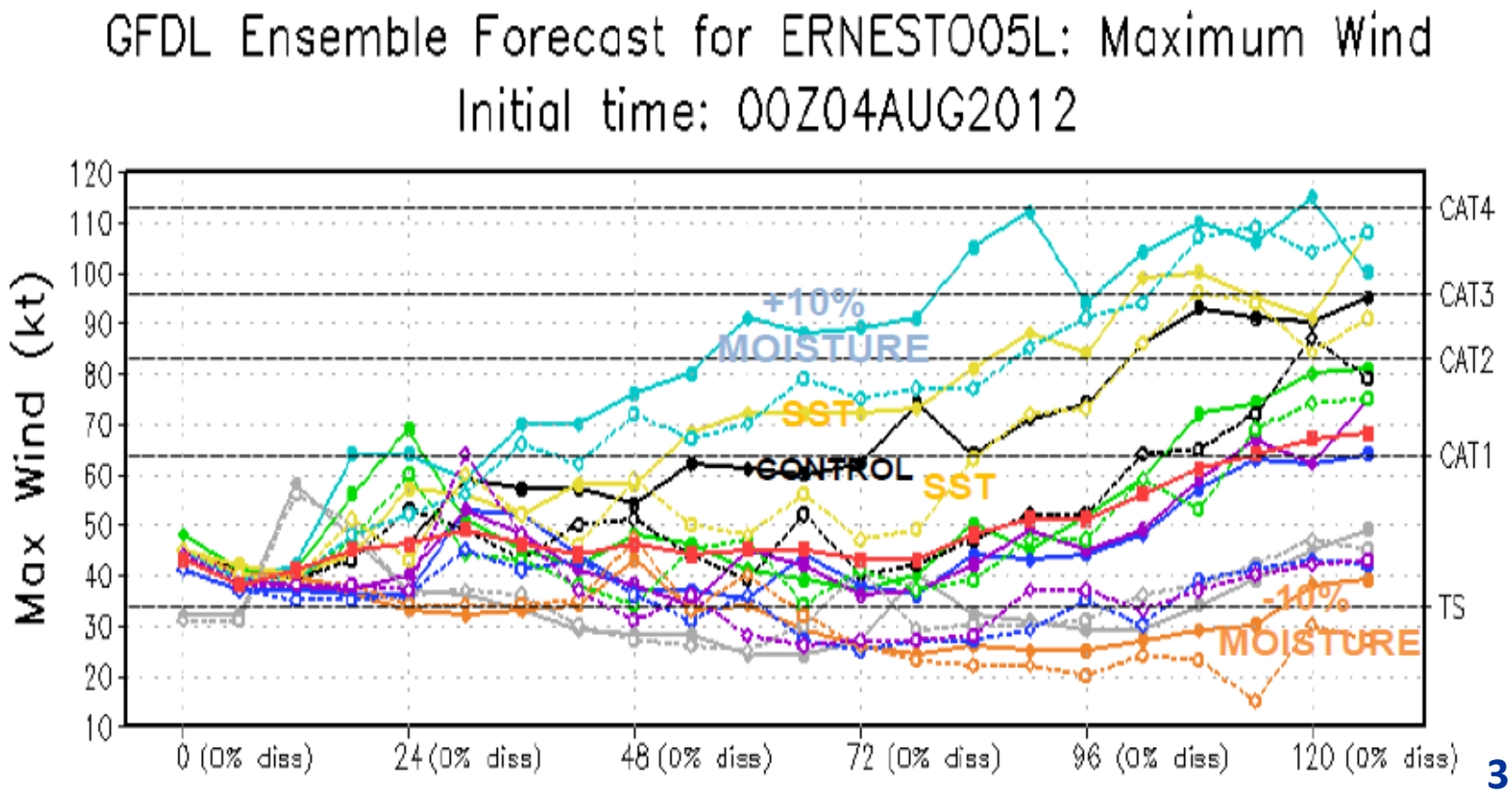
REDUCED IMPACT OF OUTLIERS WITH LARGE ERRORS

PROMISING TECHNIQUE FOR REDUCING INTENSITY ERRORS FROM REGIONAL MODELS



GFDL Model Regional Ensemble System Identifies Impact of Moisture Initialization and Emphasis on Better Moisture Observations

The GFDL ENSEMBLE PRODUCT ALSO SHOWED HUGE SPREAD IN INTENSITY.
LARGEST IMPACT WAS WITH INCREASE /DECREASE OF INNER-CORE MOISTURE BY 10%
(PERTURBATION MAXIMUM AT STORM CENTER)
IMPACT OF MOISTURE MORE IMPORTANT THEN +1 degree C SST INCREASE



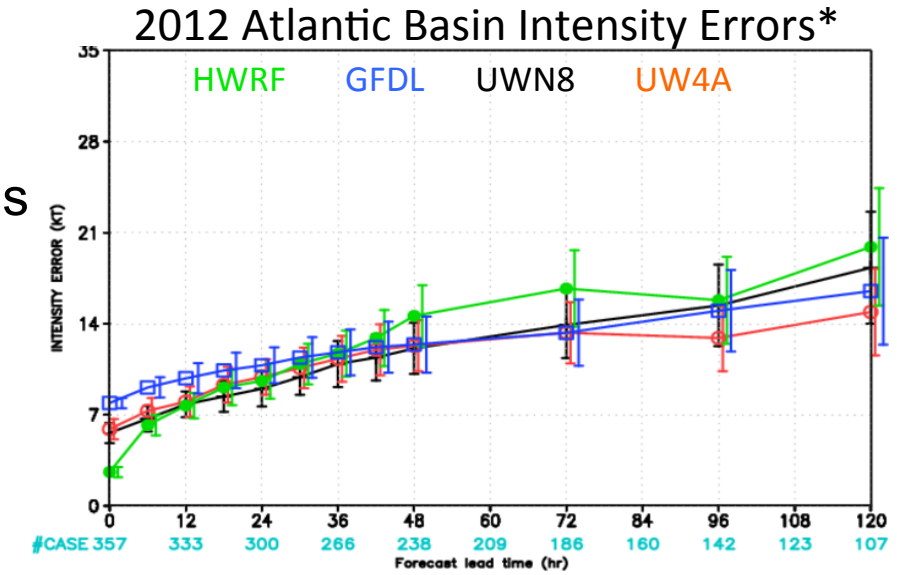
University of Wisconsin 2012 HFIP Modeling Effort

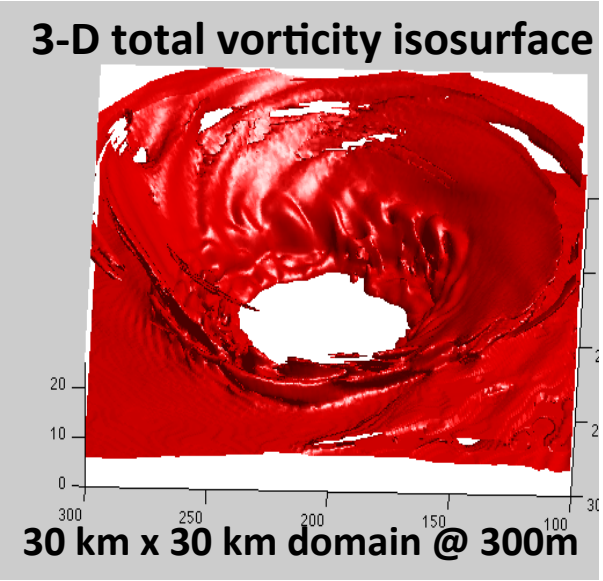
William E Lewis
Gregory J Tripoli
Zachary Gruskin

2012 Stream 2.0 Highlights

- Best performance from member (UW4A) most closely related to stream 1.5 counterpart (i.e. Andreas sea spray)

  Track error essentially unchanged, but noticeable improvement beyond 72 hr for intensity. (*using TCMT a-decks)





- idealized simulations reveal potential interaction b/w PBL rolls and vortical eyewall structures seen in observations.

UWN8: Outstanding Issues

- **Resolution**: stream 1.5 (8 km horizontal) not sufficient to resolve inner core
- **Initialization**: nudged bogus improves upon previous method (cold start bogus), but still suboptimal
- **Physics**: 2 ice categories (snow, pristine crystals) too simplistic; surface fluxes; broader role of PBL in modulating inner core via rolls may be vital for future high-resolution simulations

2012 Stream 2.0

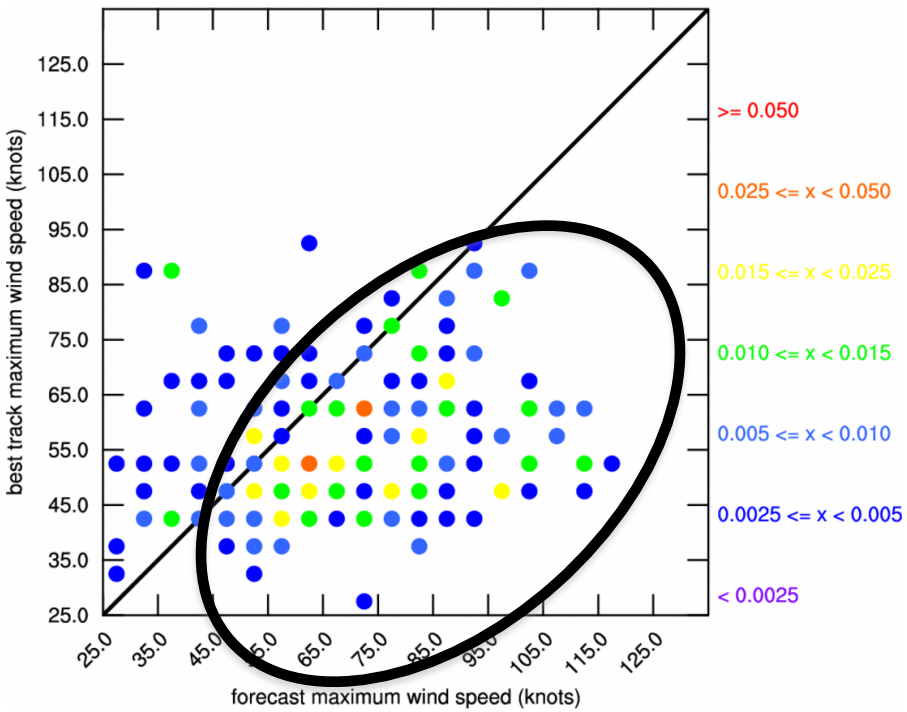
- Decided to address resolution issue first: a 4-member high(er)-resolution ensemble (4.4 km horizontal spacing) with rudimentary physics differences (surface fluxes, eddy viscosity) was run quasi-operationally.
- High-resolution (< 1 km spacing) idealized simulations were also conducted to gain greater insight into PBL-inner core interaction.

UW: Next Steps

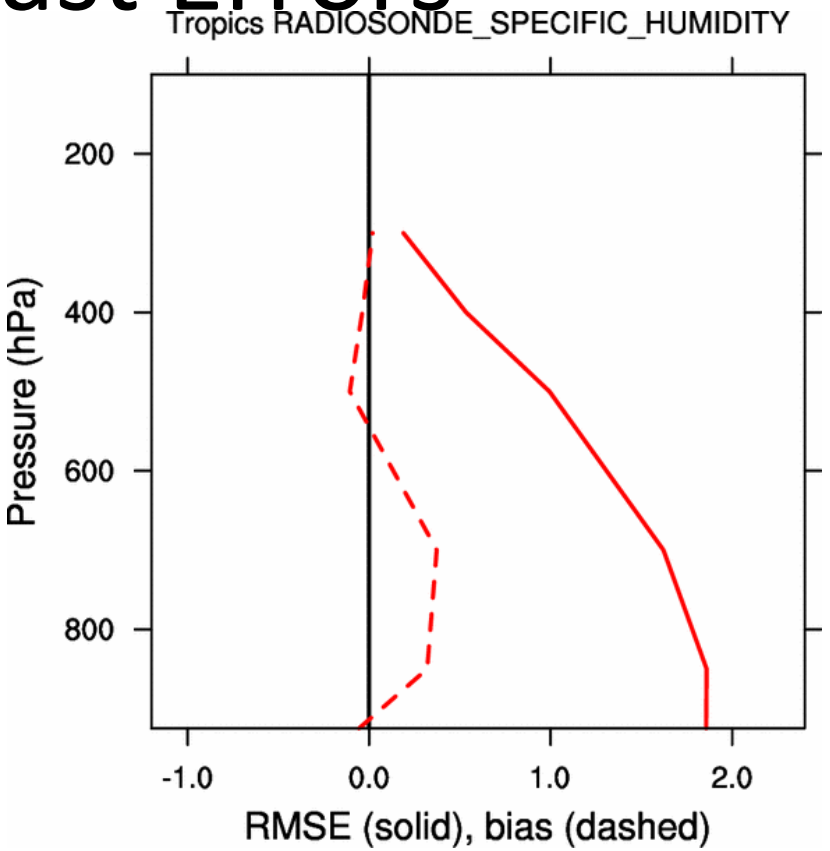
- Retro Test 2012 stream 2.0 configuration for 2013 stream 1.5 (i.e. upgrade from 8km to ~4km min. spacing)
- Large-scale Diagnostics code
  - for SPICE consensus; also, model development (forecast behavior vis-à-vis environment should be revealing)
- 2013 Stream 2.0 plans
  - Higher resolution (~3km), larger ensemble, broader physics sampling (viz. microphysics, surface fluxes, PBL)
  - Replace bogus initialization w/ DA, w/ or w/o cycling
  - Clarify role of PBL rolls w/ regard to eyewall dynamics, structure and intensity change
  - Feed these results to stream 1.5 in 2014

AHW Forecast Errors

72 h Maximum Wind Speed Histogram

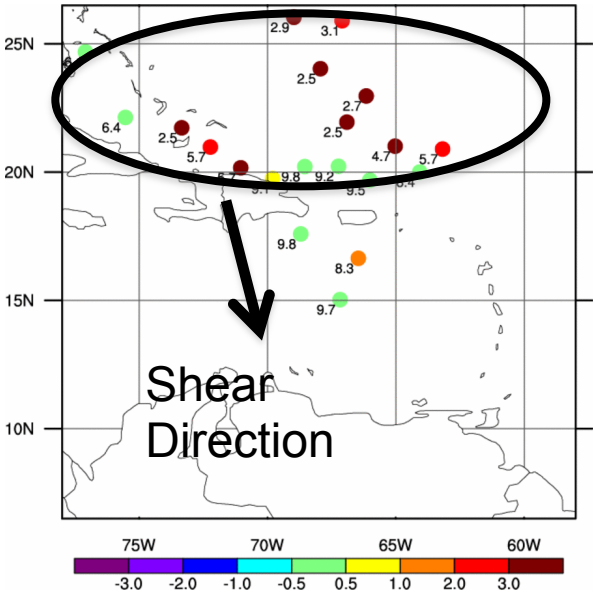


Forecast errors are largest for cases where model predicts a strong TC, but actual storm remains a tropical storm

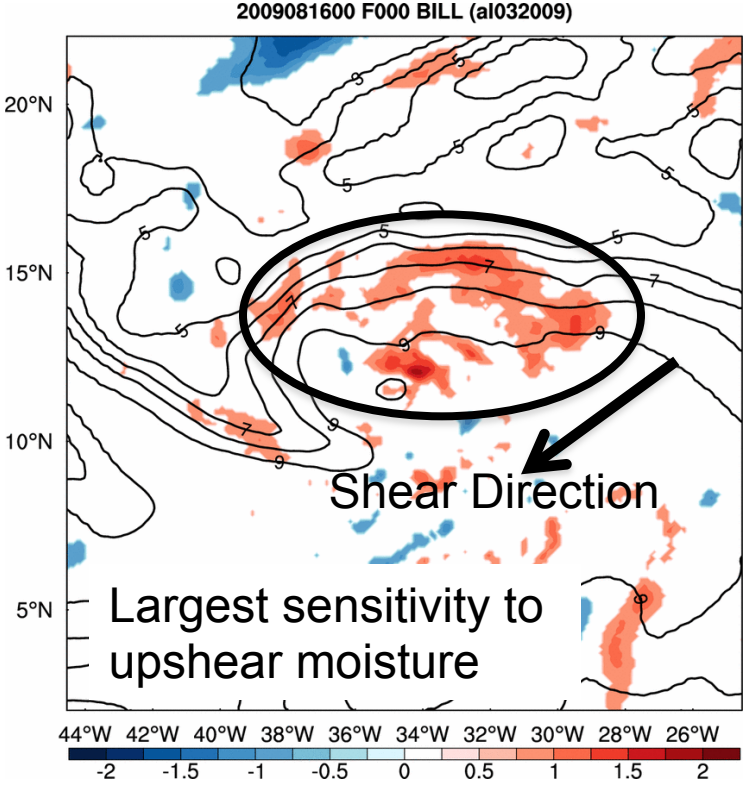


In addition, short-term forecasts characterized by positive midtropospheric moisture bias. HYPOTHESIS: Too much moisture, particularly in the upshear quadrant, leads to more intense and axisymmetric convection, eventually leading to intensity change

Role of Moisture

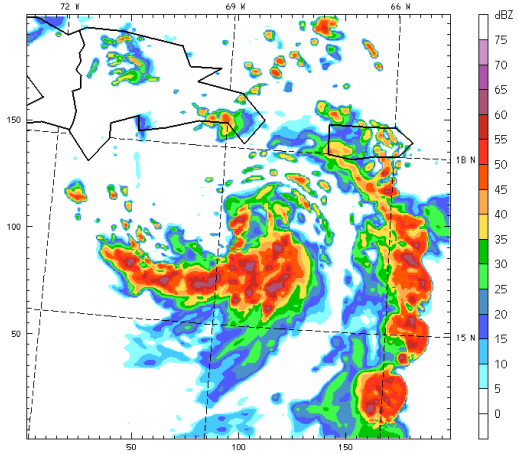


Difference between 6 h forecast 700 hPa Specific humidity and dropsonde observations at 0000 UTC 24 August.

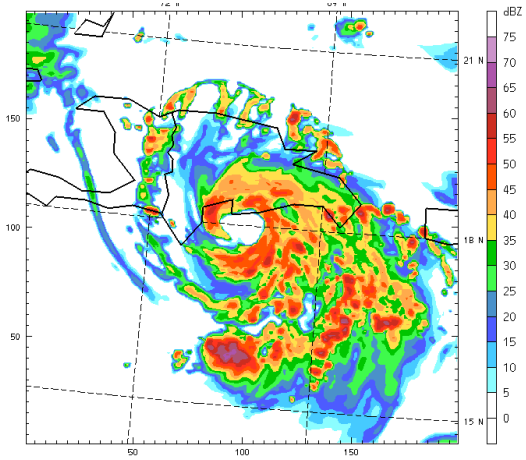


Sensitivity of 72 h forecast of Bill's maximum wind speed to 0 h 700 hPa water vapor mixing ratio initialized 0000 UTC 16 August 2009.

6 h Forecast



18 h Forecast



Moisture surplus could be coming from:

- Overactive shallow convection
- Errors in surface fluxes
- Too weak of decent in the subtropical ridge

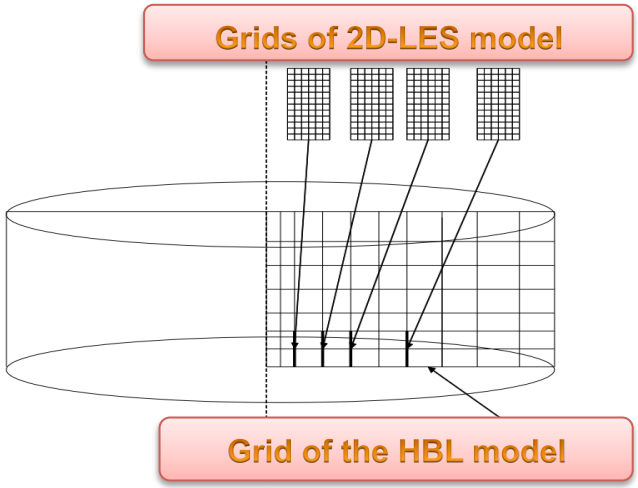
Testing underway to determine role of each and ways to fix.

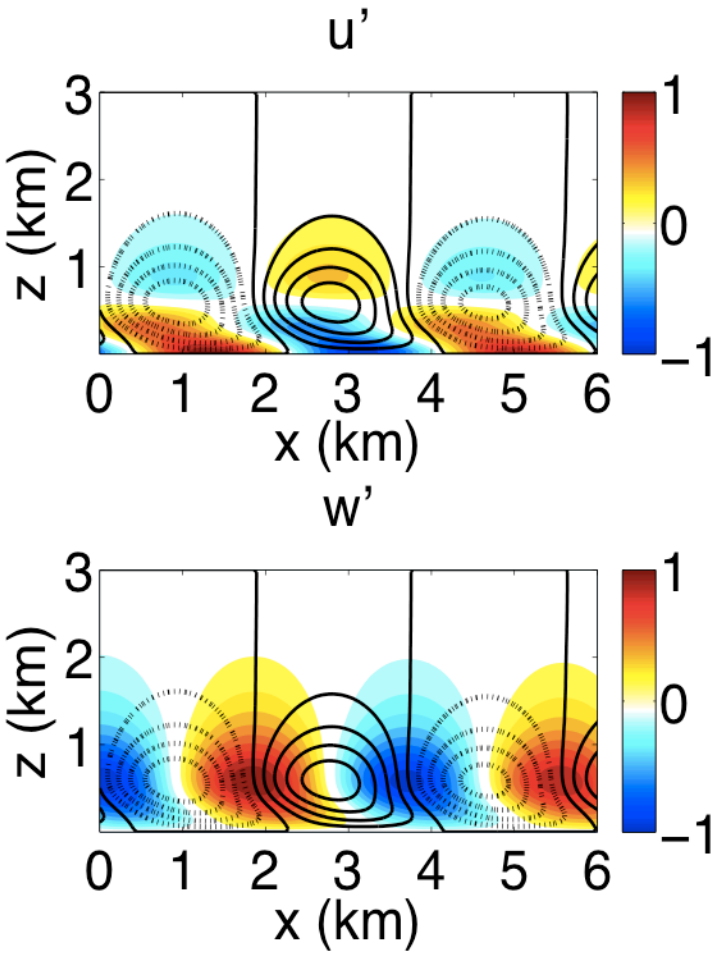
Isaac Reflectivity Forecast initialized 00Z 24 Aug.

Super parameterization of boundary layer roll vortices in tropical cyclone models

Isaac Ginis and Kun Gao, University of Rhode Island

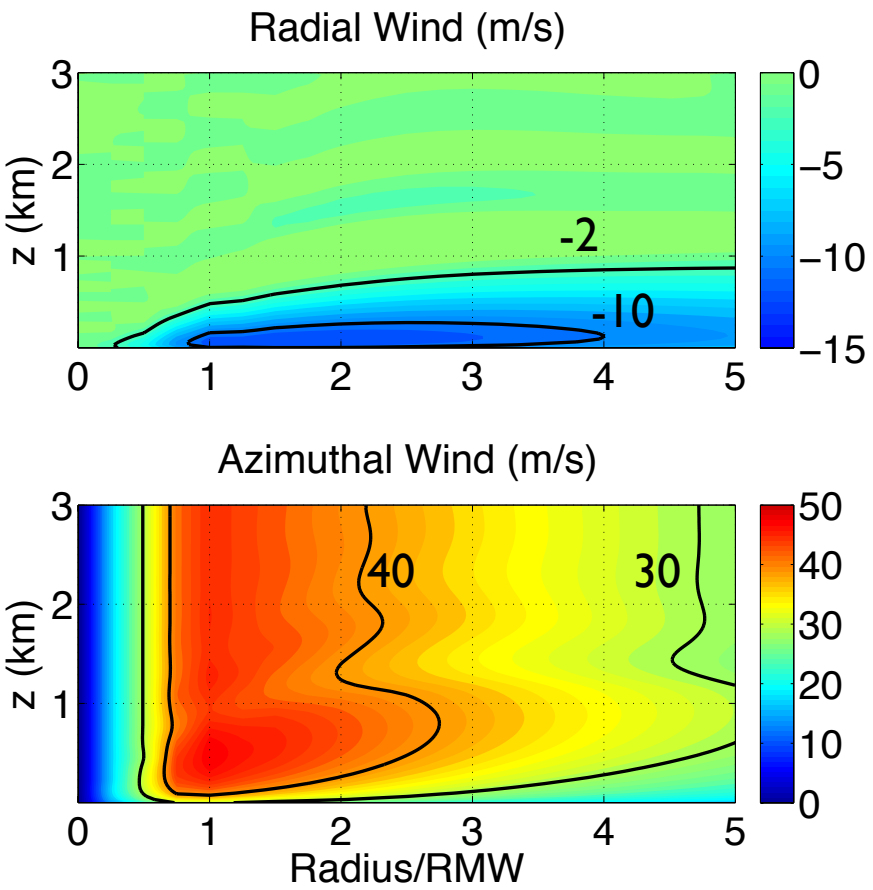
1. A Hurricane Boundary Layer (HBL) with imbedded 2-LES models is developed.
2. Formation mechanisms of roll vortices and their interaction with large-scale flow are investigated.



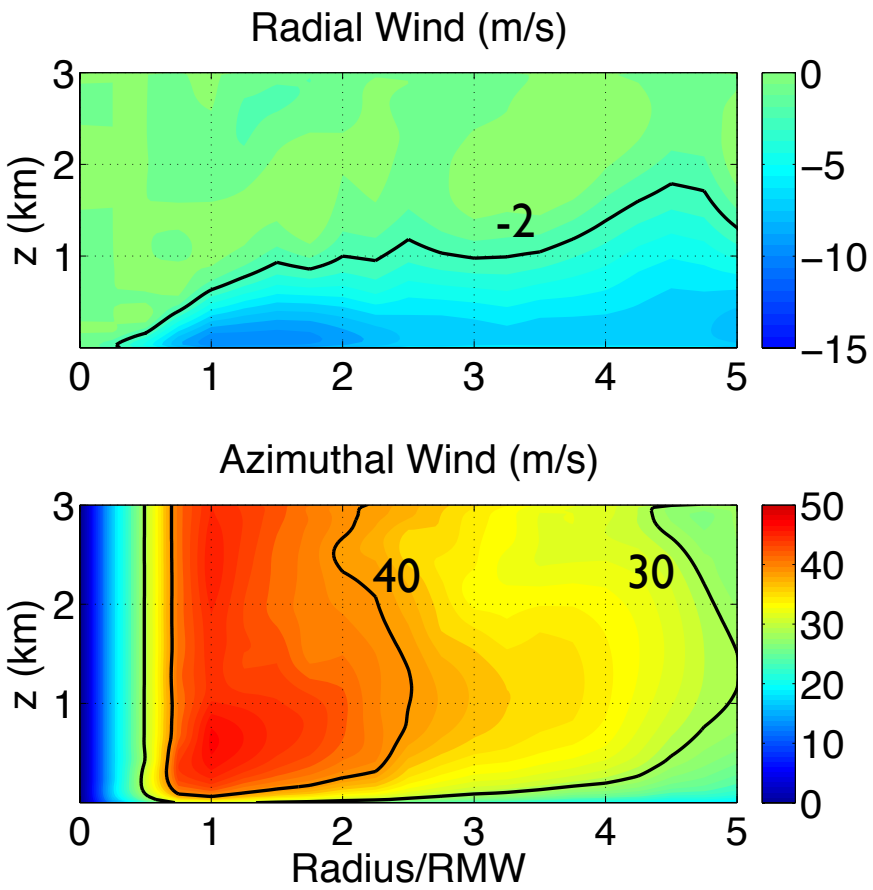


Structure of simulated rolls vortices (linear phase) at the radius of maximum winds in an idealized hurricane

Effect of Rolls on Mean Flow



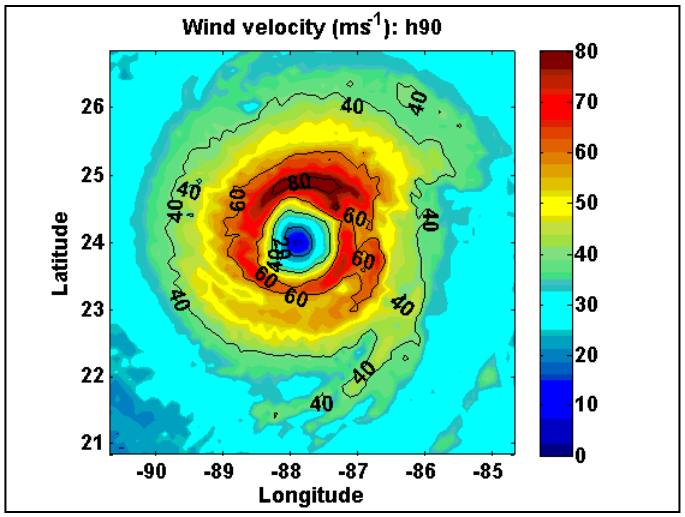
Initial (no rolls)



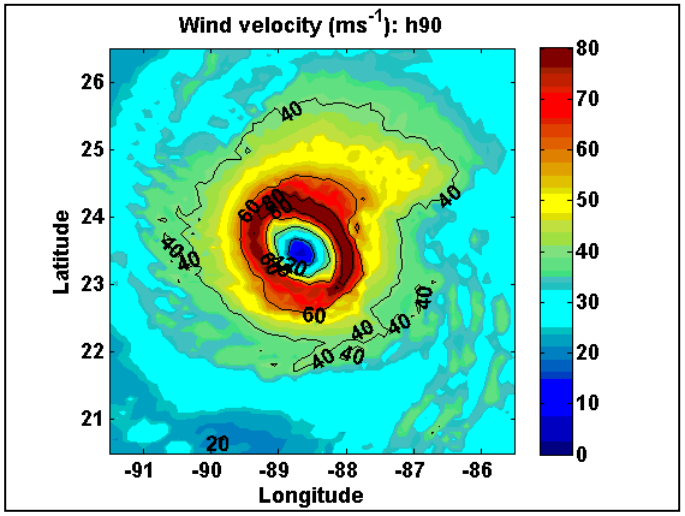
After 10hr (with rolls)

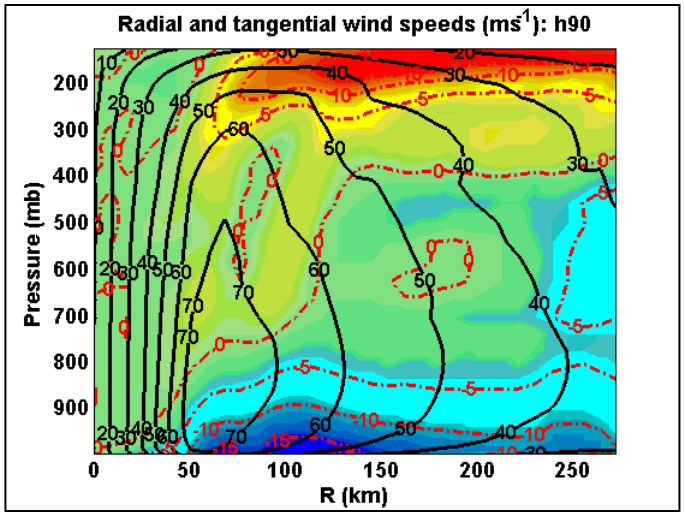
Results from Testing the Improved ESRL Sea-Spray Parameterization in the GFDL Hurricane-Wave-Ocean Model using the GFDL Operational Physics and an Idealized Vortex and Environmental Initialization

left column: without sea spray ; right column: with sea spray
valid at 90 h of simulations

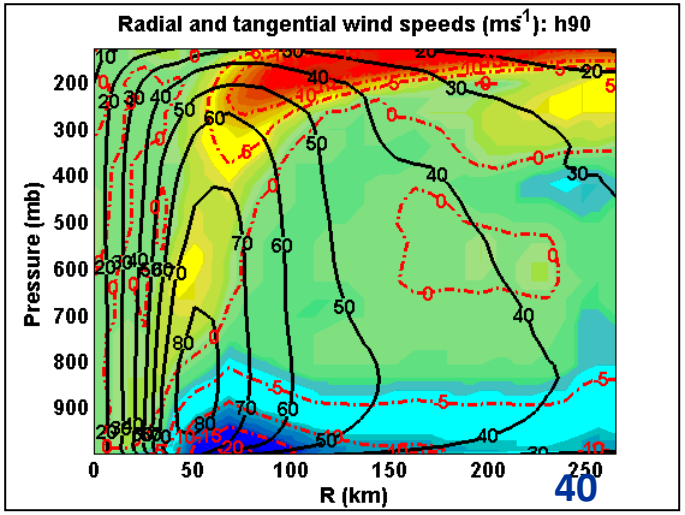


Surface wind speed Increased and structure changed

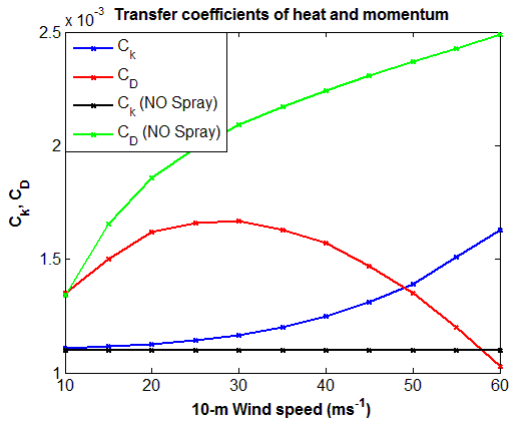


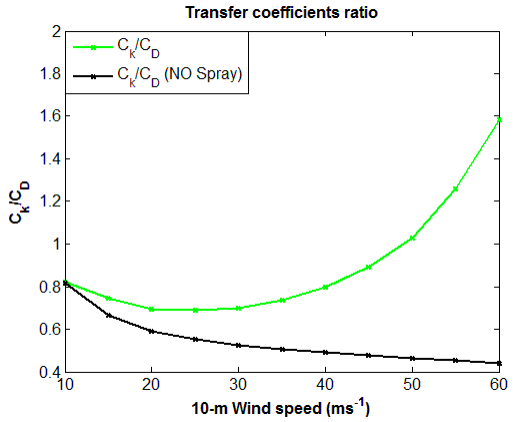


Vertical structure s of tangential and radial winds changed



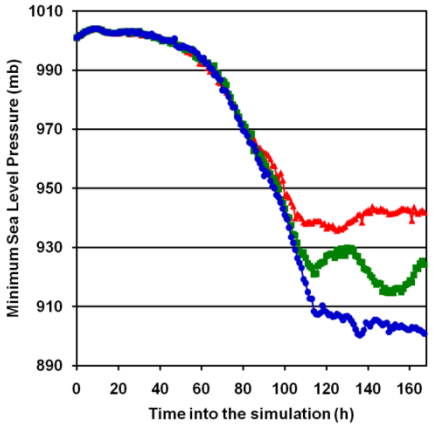
Impact of Sea Spray on Surface Drag and Enthalpy Exchange Coefficients



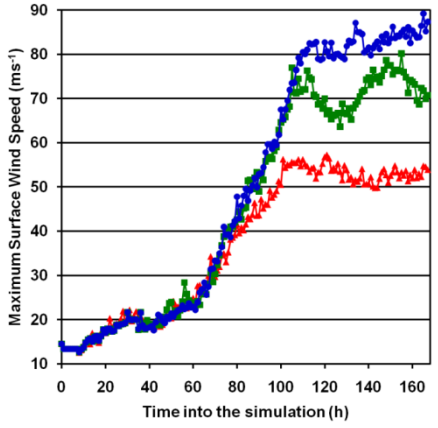


Right panel shows the 10-m neutral drag coefficient and enthalpy exchange coefficient as functions of 10-m wind speed, while the left panel depicts the corresponding ratio of C_k/C_D.

Impact of Sea Spray on Idealized Intensification Using ARW



(a)



(b)

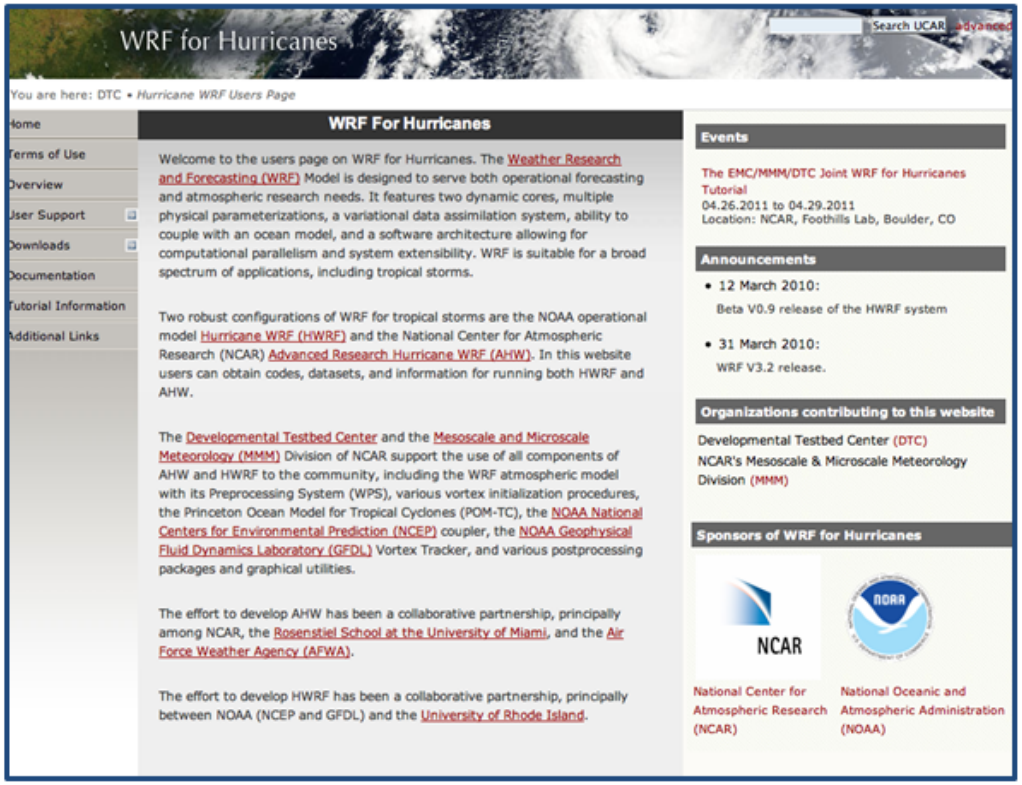
(a) Minimum sea-level pressure (mb) and (b) maximum surface wind speed (ms^{-1}). The control run (without the sea spray parameterization) is in red; the no impact on heat run (with the feedback of sea spray to the momentum flux only) is in green; and the full impact run (with the feedback of sea spray to both momentum and heat fluxes) is in blue

HFIP Regional Modeling Team
Recent DTC Activities

Ligia Bernardet

www.dtcenter.org/HurrWRF/users

HWRF code management and support



HWRF v3.4a (2012 operational): code downloads, datasets, documentation, helpdesk

460 registered users

Code management: excellent integration between operational, developmental, and community codes

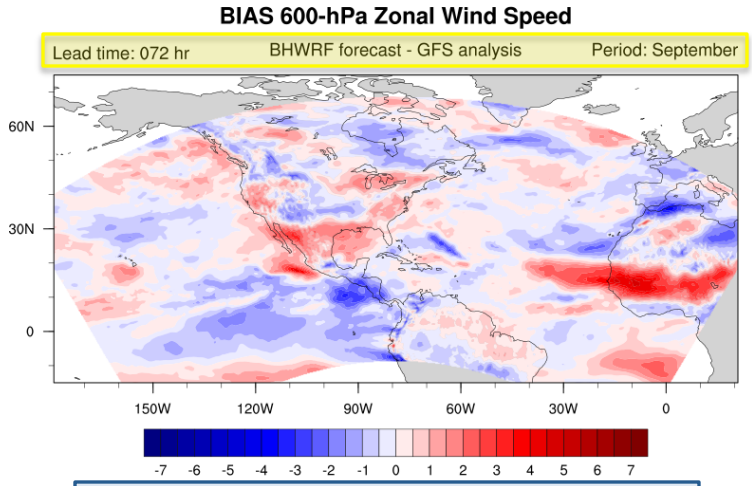
Ongoing repository maintenance and testing

DTC Developmental Testbed Center

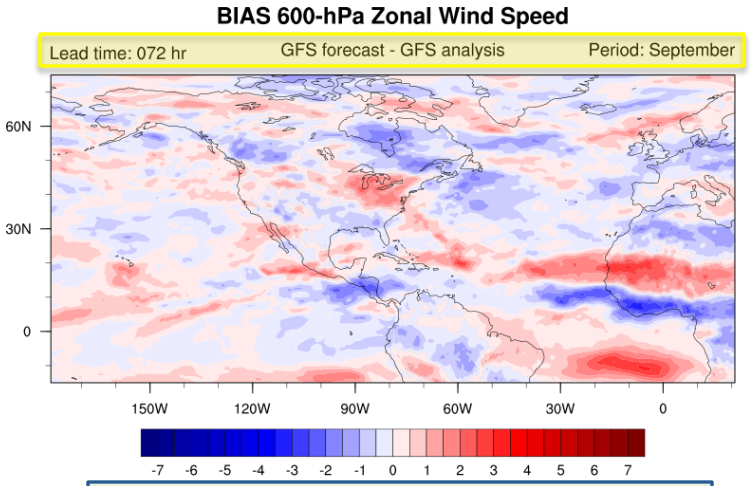
Diagnostics

Accomplishments

- Evaluation of large scale characteristics in HWRF
- Completed comparison between EMC basinscale retro runs and GFS analyses



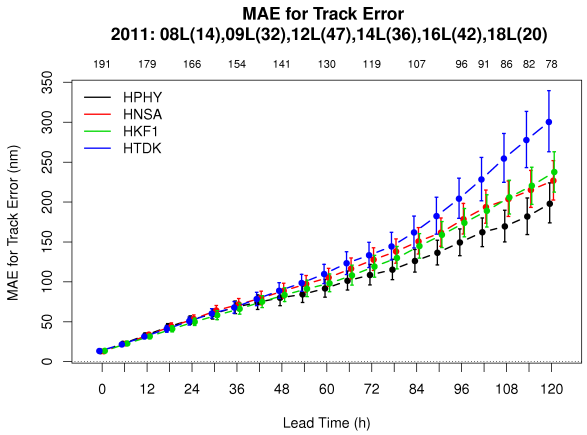
African jet too weak in HWRF

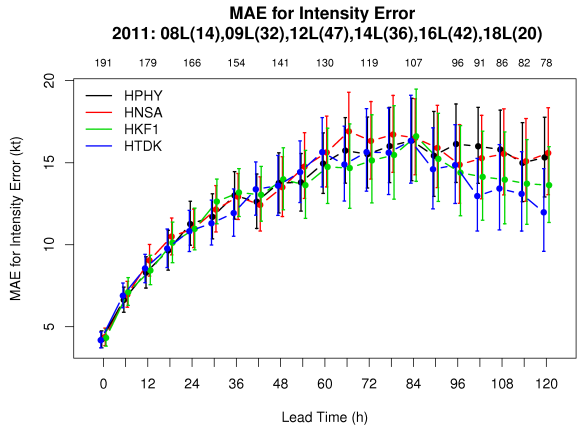


In GFS jet displaced to south

This is just a sample
Many variables, levels, forecast lead times and temporal aggregations available

Test of HWRF sensitivity to cumulus schemes





Tested HWRF SAS, new SAS, Tiedtke, Kain-Fritsh

HWRF SAS performs best for track; differences in intensity have little statistical significance

Track

	12	24	36	48	60	72	84	96	108	120
HNSA										
HKF1										
HTDK										

Intens

	12	24	36	48	60	72	84	96	108	120
HNSA										
HKF1										
HTDK										

Statistical Significance 95%
Green= HWRF SAS better
Red = HPHY SAS worse

DTC Developmental Testbed Center

HFIP Physics Workshop Summary
(Sept. 17-18 2012)

- **Topic**: Improving the intensity forecast skills of regional dynamical models — **Progress ?**
- **Recommendations**

1. **Physics improvement**: consider whole suite of physics rather than focusing on one individual physics scheme. — **NO !!**
2. **Utilization of observation**: need to use the observation data (e.g. HRD, JPL) extensively for evaluating/developing physics schemes. — **Yes**
3. **Diagnostic metrics**: standardization of diagnostic metrics for comparison/evaluation of various dynamical models. — **Somewhat**
4. The proper initializations of hurricane vortex is recognized to be essential for improving the intensity forecast skill in addition to physics. — **Yes**

- **Workshop webpage**:
  http://www.hfip.org/events/physics_workshop_9.12/index.php

Concluding Thoughts

- Significant progress has been made in improving track, structure and rainfall forecast skills from regional models. Intensity skills are starting to show some promise – thanks to HFIP for a coordinated development plan, especially for operational HWRF.
- However, regional models continue to lag behind global models in track skill. Still do not know reason for this track degradation, as better representation of storm structure previously lead to improved tracks. Is this inferior physics, degraded vertical resolution or lateral boundary effects ??? Use of extended domain configuration for HWRF (Basin Scale) is promising.
- The use of observations for model physics improvements and improved initial conditions appears to show some promise for HWRF. However, weak and sheared storms continue to pose severe challenges for intensity predictions.
- Physics workshop recommendations are excellent benchmark to follow. Progress being made, yet physics development greatly in need of coordinated effort (focus on suite of high-resolution physics).
- Do our models lack the advanced physics needed to address intensity change ? If so, should far more resources be devoted to this following guidelines of workshop recommendation one.
- Should more resources be devoted to improved moisture initialization and assimilation of aircraft data based on results ?
- Regional model ensembles show promise in improving the intensity forecasts. Should continue with these efforts with operational HWRF.
- Unified physics approach for all regional models (including high-resolution convective parameterization) would benefit improving our understanding and eventually address the intensity forecast problem.