SUMMARY OF HFIP REGIONAL MODELS

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Contents…

- *HFIP Regional Scale Models*
- *Model Verification/Evaluations*
- *Past and Future Challenges*
- *Advances in physics (team report)*
- *Lessons learned & Challenges*

HFIP Annual Review Meeting
Tuesday, November 8th, Miami, FL

NOAA HURRICANE FORECAST IMPROVEMENT PROJECT

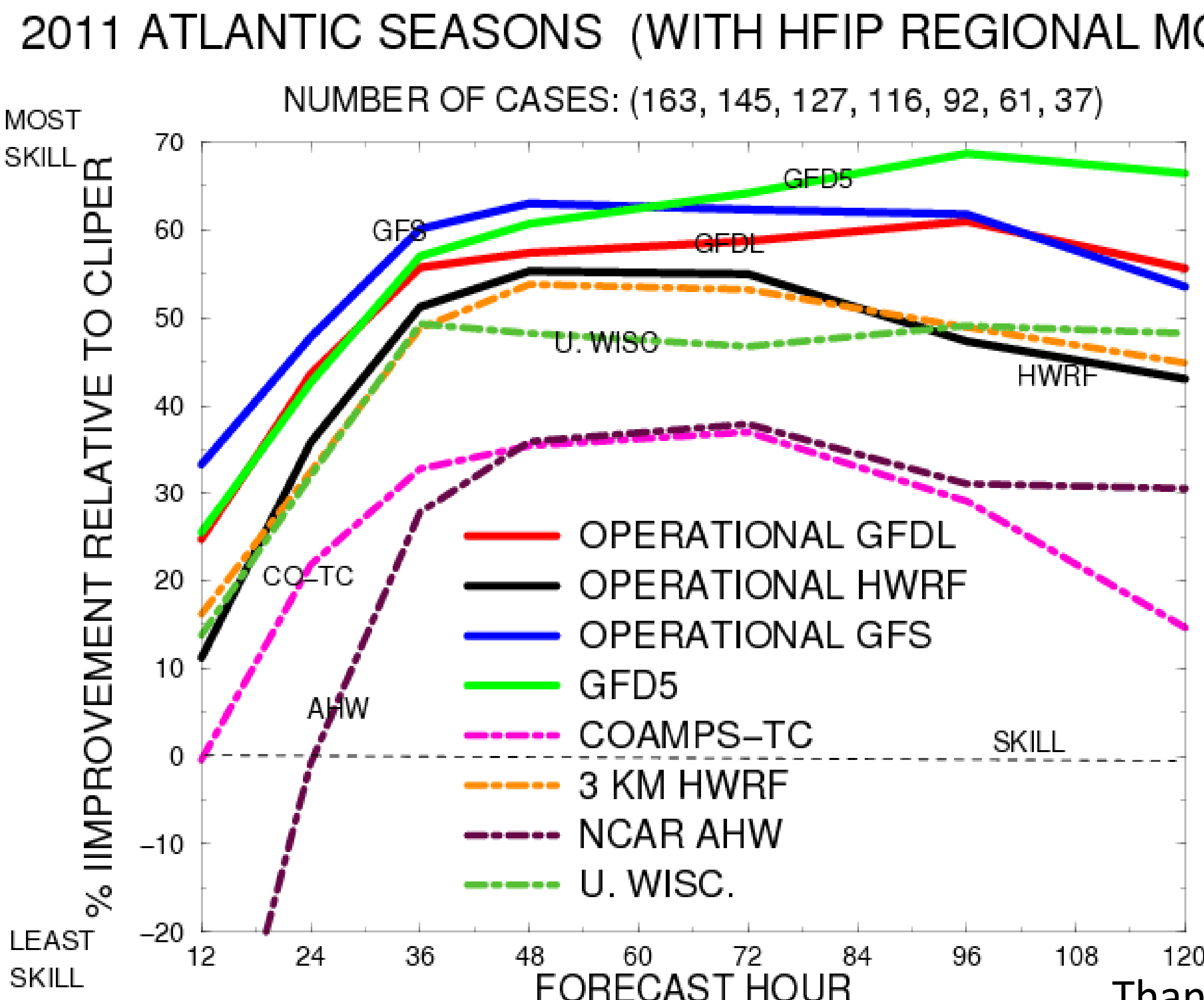
Overview of the HFIP Regional Models

Model/ Details	GFDL	HWRF	3 KM HWRF	COAMPS	NCAR-ARW	U-WISC
Domain	54 KM: ~75˚ X ~75˚ 18 KM: ~11˚ X ~11˚ 9KM: ~5˚ X ~5˚	27 KM: 77.76˚ X 77.76˚ 9 KM: 7.2˚ X 6.0˚	27 KM: 77.76˚ X 77.76˚ 9 KM: 10.56˚ X 10.2˚ 3 KM: 7.6˚ X 6.4˚	45 KM: 251 X 151 15 KM: 121 X 121 5 KM: 181 X 181	36 km, 11,520 km x 7560 km 12 km: 1596 km x 1596 km 4 km: 796 km x 796 km	40 KM: 74° X 54° 8 KM: 6.6° x 6.6°
Vortex Initialization	GFDL Bogus	Vortex relocation and assimilation	Vortex relocation and assimilation	Vortex relocation and DA of synthetic obs.	None	Kwon and Cheong (2010) Bogus
Cycling	No	Yes	Yes	Yes	6-h continuous with EnKF	No
Ocean Coupling	POM	POM	POM	NCOM for Stream 2	1-D mixed-layer model	1.5-level ocean
GSI	No	Yes	Yes	NAVDAS 3DVar	No	No
Platform	IBM	IBM	JET-Linux/ IBM	Cray XT5 at Navy DSRC DoD HPC	TJET	JET-Linux

Model Physics

Model/ Physics	GFDL	HWRF	3 KM HWRF	COAMPS	NCAR-ARW	U-WISC
MP scheme	Ferrier	Ferrier	Ferrier	NRL (modified Lin et al.)	WSM6	Tripoli/Flatau
Radiation (SW)	GFDL	GFDL	GFDL	Fu-Liou	Goddard	RRTM
Radiation (LW)	GFDL	GFDL	GFDL	Fu-Liou	RRTM	RRTM
Surface Scheme	GFDL	GFDL Modified Cd & Ch, 2011	GFDL Modified Cd & Ch using observations	Louis, COARE, CBLAST Modified Cd & Ch	Modified Ck and Cd: Ck/Cd~0.5-0.6	COARE 2.6 + Andreas Sea-Spray
PBL Scheme	GFS	GFS	GFS Modified Km and Kh using observations	NRL (modified MY, level 2.5 predicted TKE)	YSU (1st order)	Level 1.5 TKE w/ TKE production from KE loss
Cumulus	NEW SAS	New SAS	New SAS (27-9) no CP (3 KM)	Kain-Fritsch (45-5) no CP (5 KM)	Tiedtke (deep and shallow)	Kuo
Land Surface	GFDL Slab	GFDL Slab	GFDL Slab	Deardorf Force Restore	NOAH	NOAH LSM
Ensembles	Yes			10 members at 5 km & 80 member EnKF	15 members with IC pert	

COMPARISON OF TRACK SKILL WITH OPERATIONAL MODELS (through Philippe)



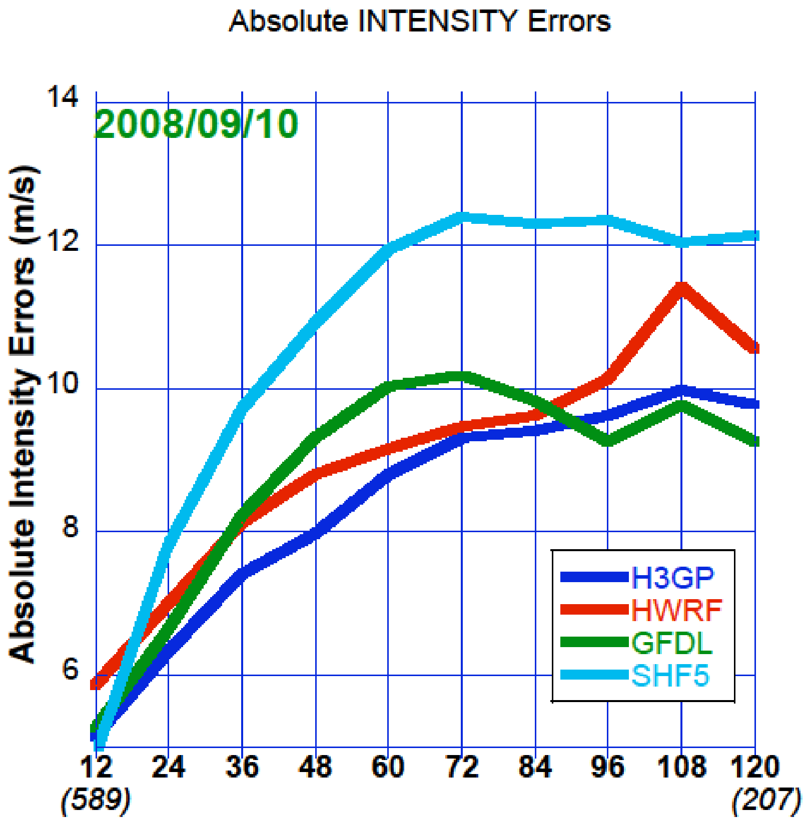
With the exception of GFD5 (parallel GFDL), Global Model (GFS) continue to provide improved track predictions

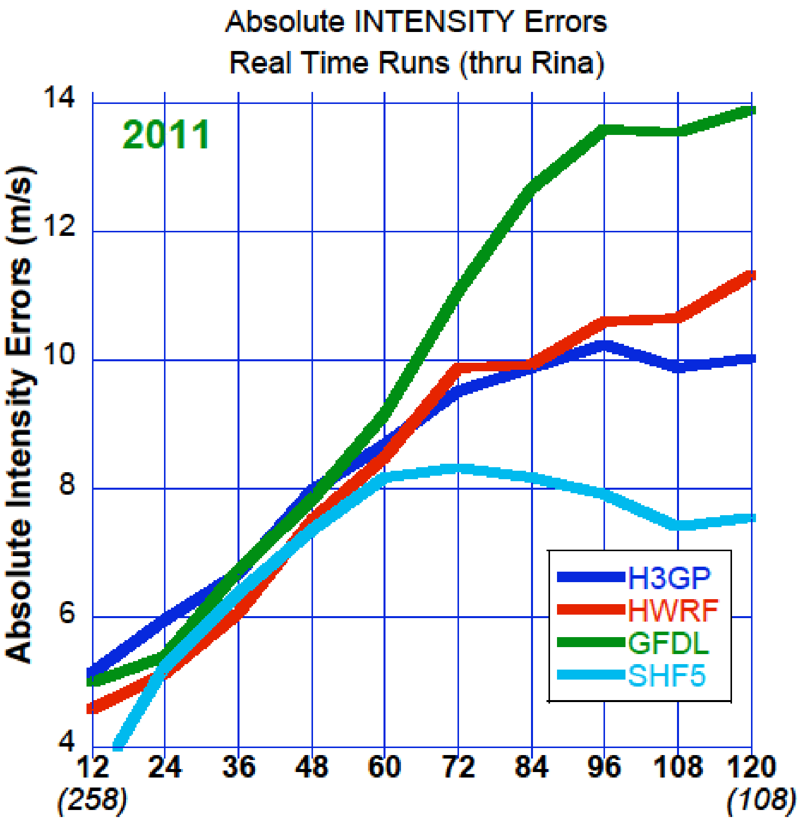
Amongst the 1.5 stream models, AHW and CO-TC lags behind in track prediction skills

3 KM HWRF has track predictions skills comparable with the operational HWRF

Thanks to TCMT for sharing data

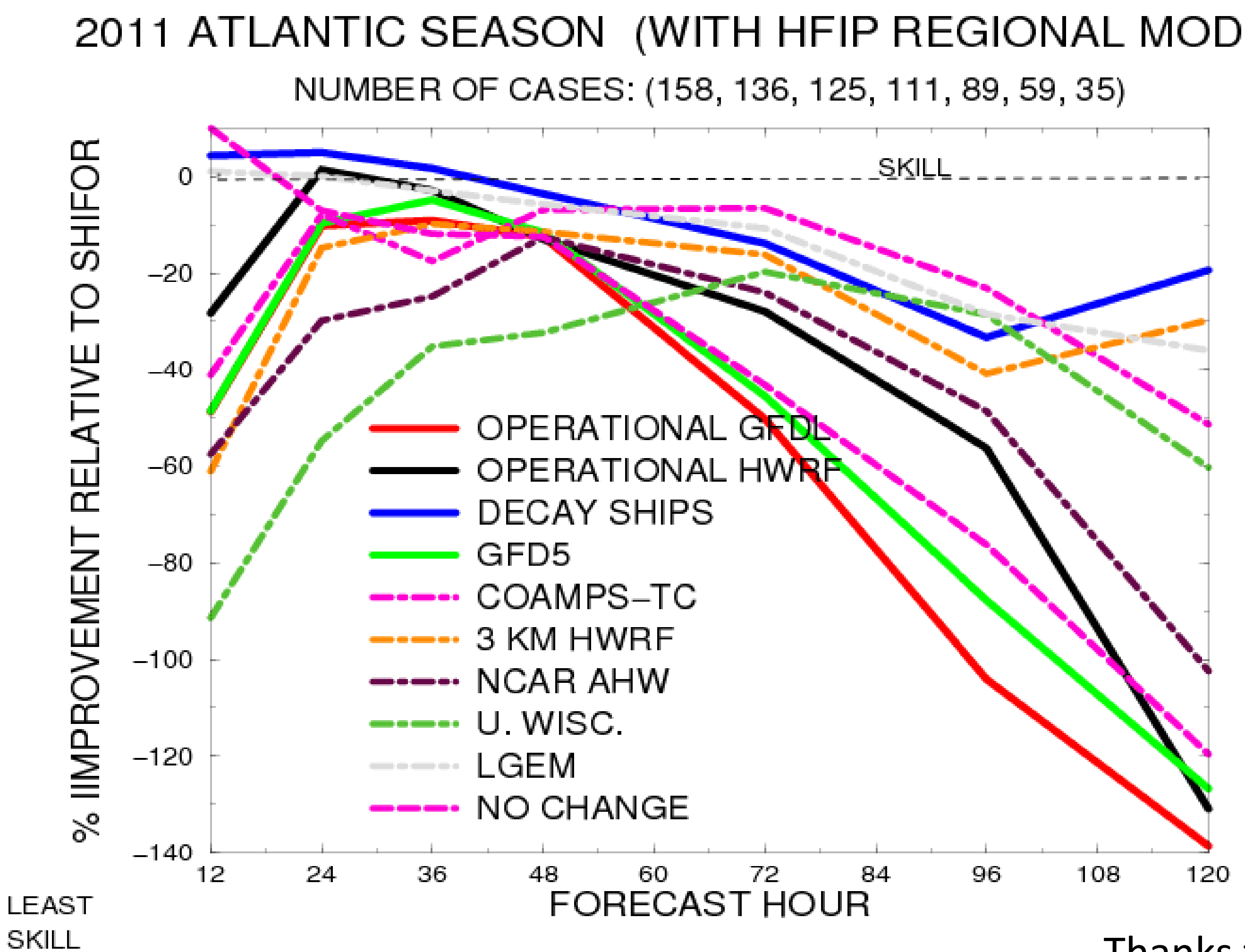
Tell Tale for the 2011 Season





Thanks to Stanley Goldenberg, HRD/AOML

COMPARISON OF INTENSITY SKILL WITH OPERATIONAL MODELS (through Philippe)



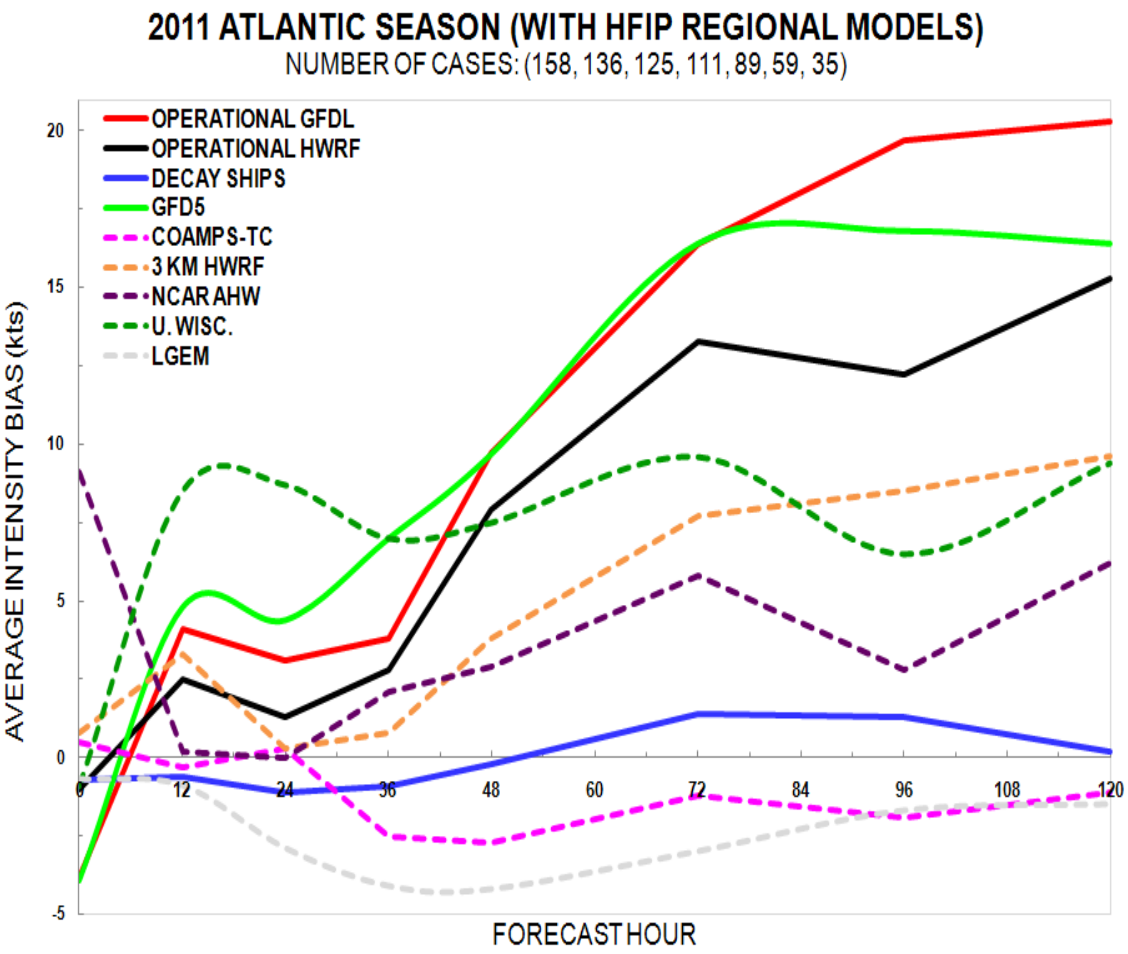
This was a challenging season for dynamical models. All models had less skills compared to SHIFOR

Among dynamical models COAMPS-TC provided the best overall skills and 3 km HWRF providing some consistent skills

3 KM HWRF provided better intensity skills especially over longer range when compared to GFDL and operational HWRF

Thanks to TCMT for sharing data

Model Strength and Weakness: Model Biases



All models except COAMPS-TC had positive bias with the operational models being the outlier especially at longer time ranges

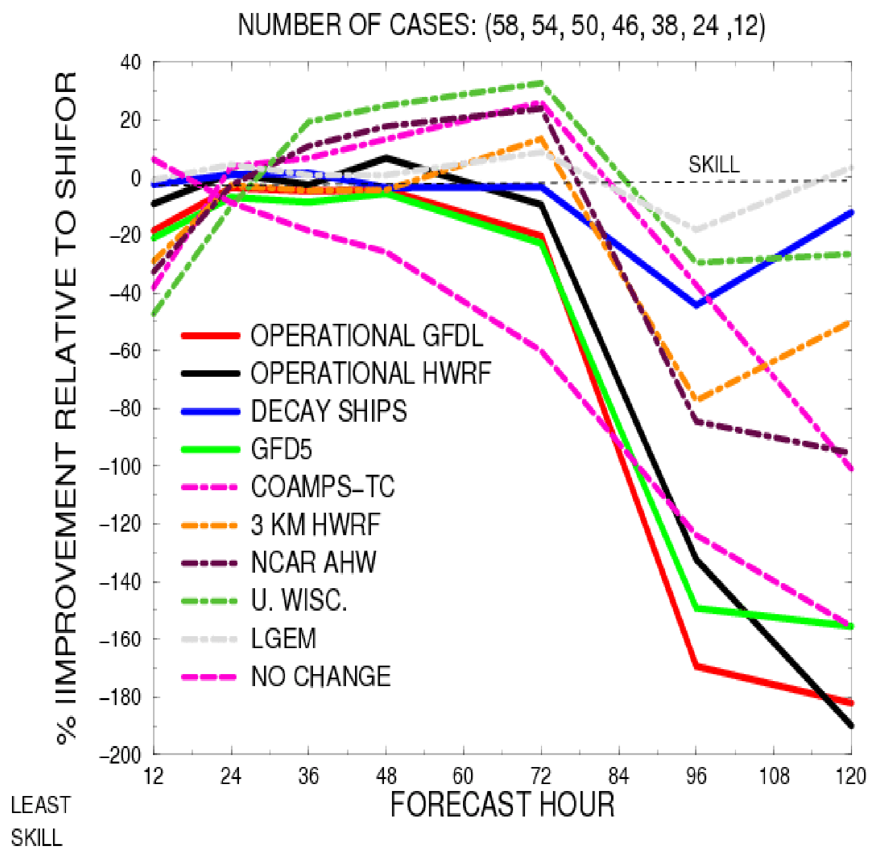
Operational HWRF showed some improved performance during the spin up (ref: later slide)

The 3 km HWRF had a reduced negative bias when compared to the operational HWRF or the GFDL models

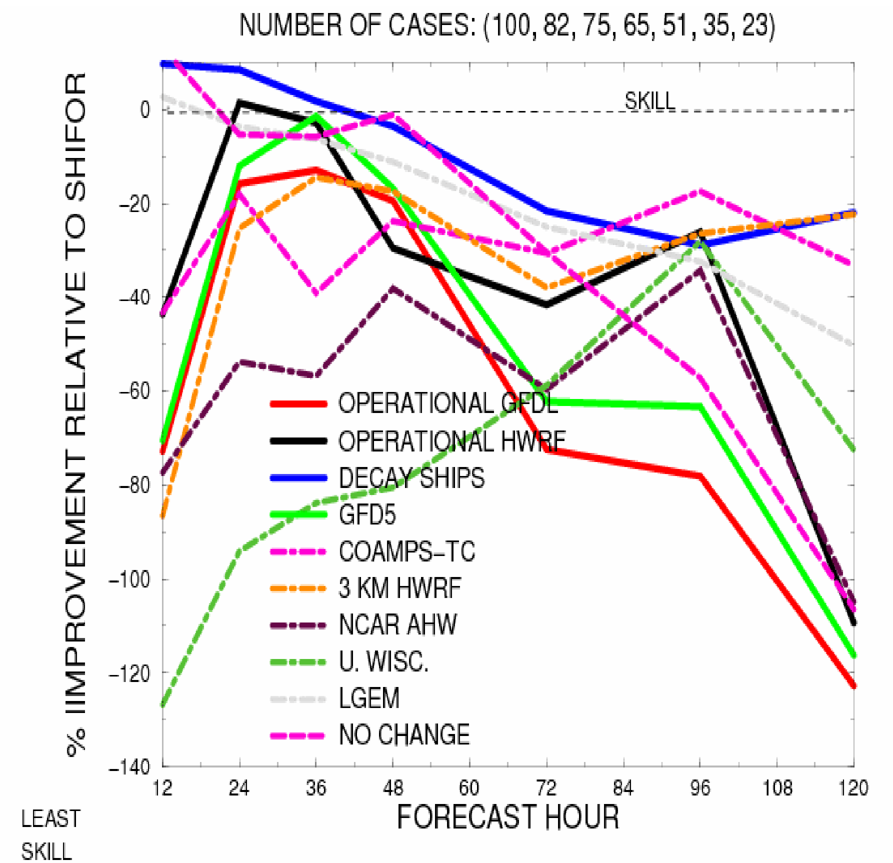
U.Wisc is the outlier and this is reflected in the intensity skills shown earlier

Model Strength and Weakness: Stratified Results

Initially Above Hurricane Strength



Initially Below Hurricane Strength

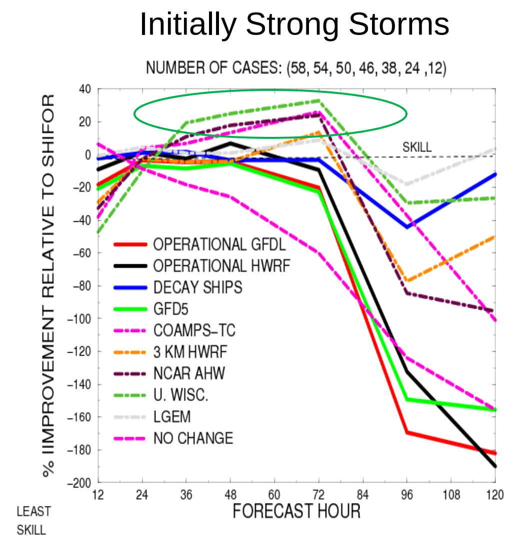


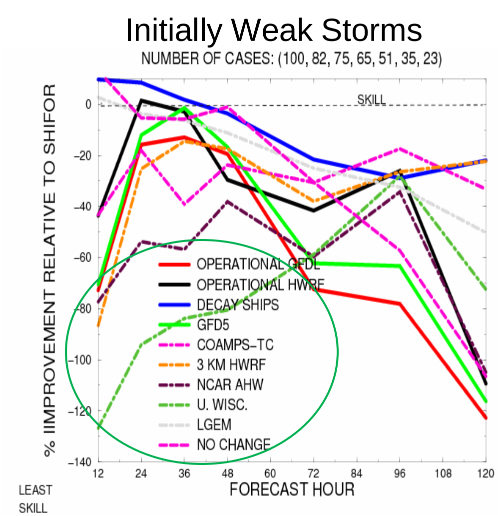
Skills for the 1.5 stream models improve on initially strong storms with NCAR-ARW showing much improved skill after stratification

All dynamical models show very poor skills for initially weak storms

2011 UW-NMS Highlights (& Lowlights)

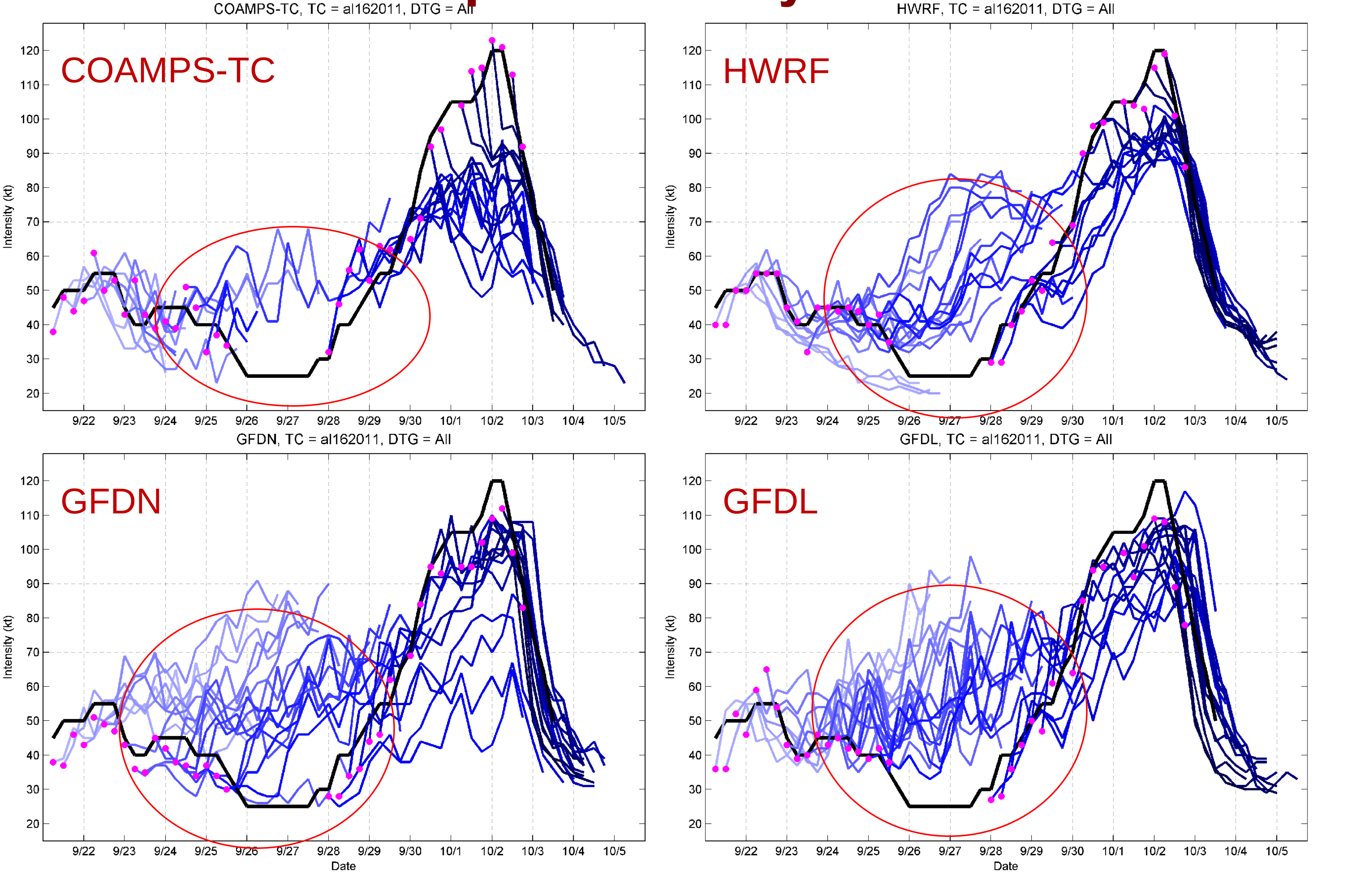
- Very good intensity performance for $\max(\text{wind}_{t=0}) \geq 64$kt
  - most skillful dynamical model after 30 hr (even after being the worst for $\tau < 24$ hr!)
- Dismal intensity performance for $\max(\text{wind}_{t=0}) < 64$ kt.
  - least skillful model for $\tau < 72$ hr, but better thereafter
- Bottom line: poor initialization / spin-up contaminating intensity forecasts in the short range.
- No surprise that structure simulation follows similar pattern (demonstrated in following slides).
- However, for reasons yet to be determined, the error growth after spin-up seems more highly damped than for most other models (tentative: needs further analysis; 2008-2010 retro cases will help clarify)





Growth of Initially Weak Cases

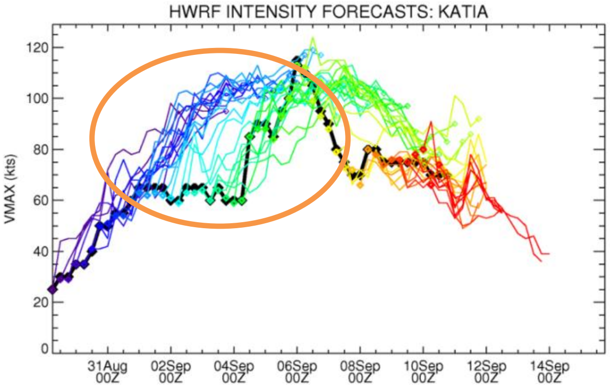
Ophelia Intensity Statistics



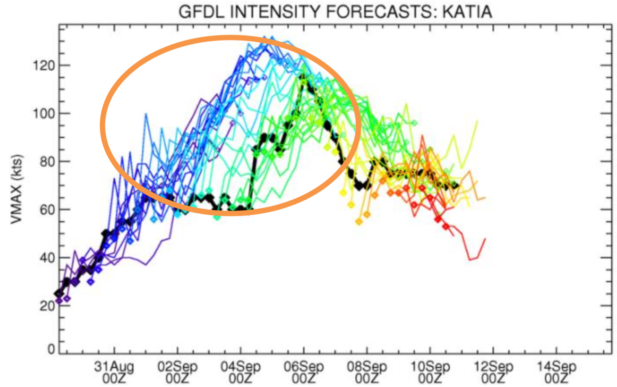
Ophelia is more a challenging problem: wrong place at the wrong time… No further analysis possible !!

Growth of Initially Weak Cases
Katia Track and Intensity Statistics

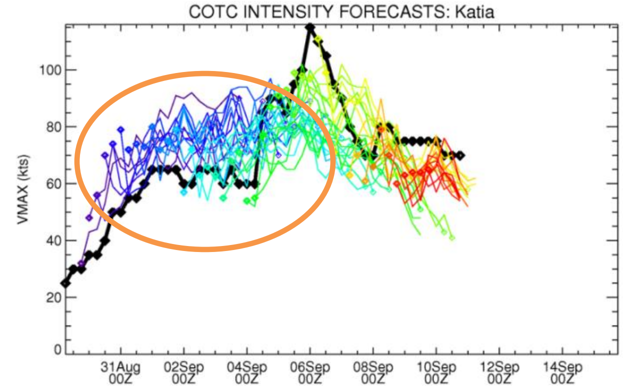
HWRF

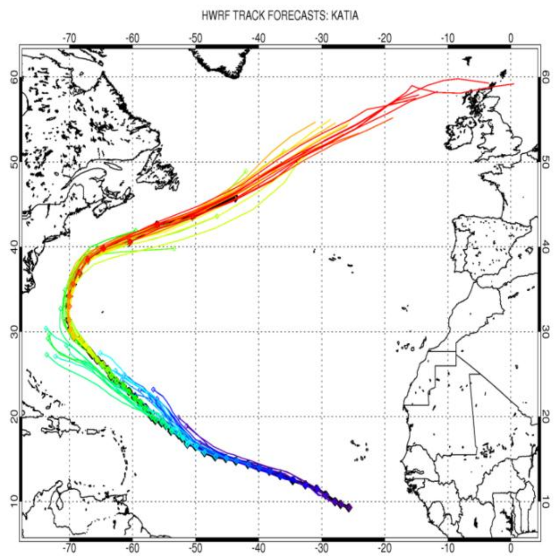


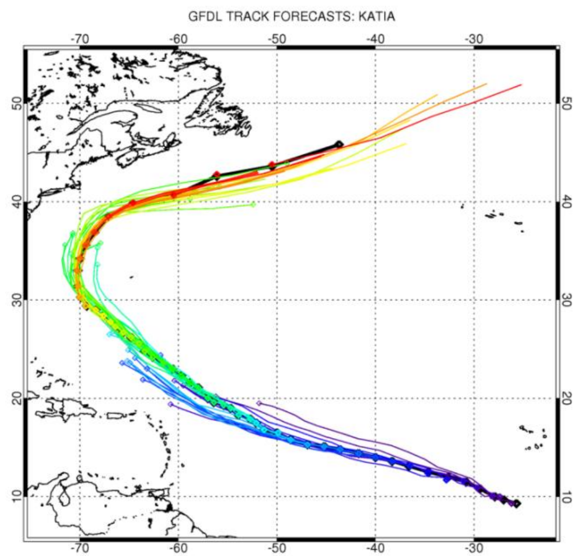
GFDL

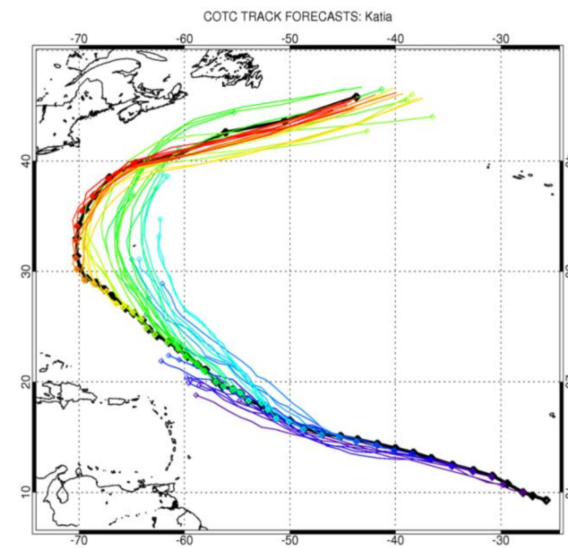


COTC



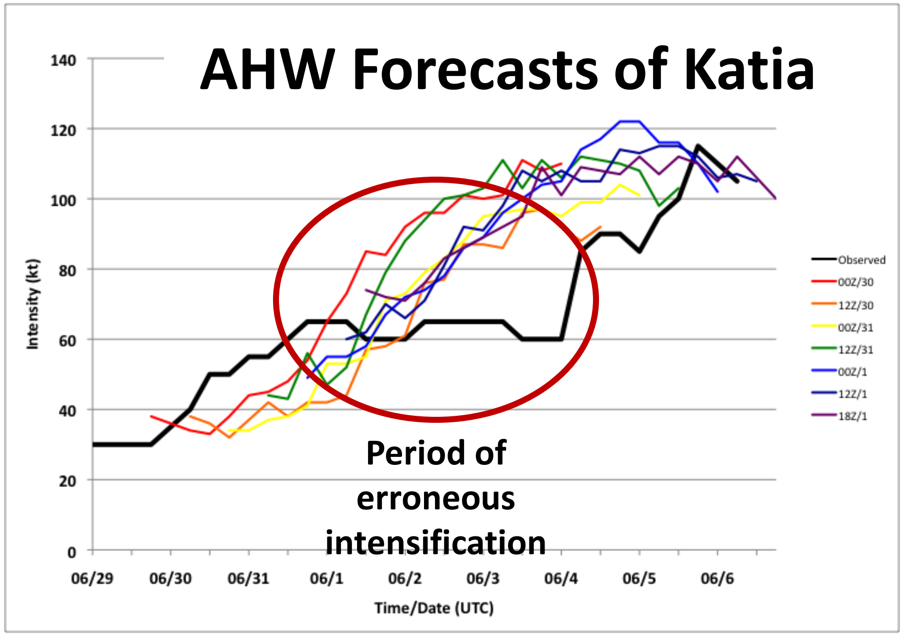


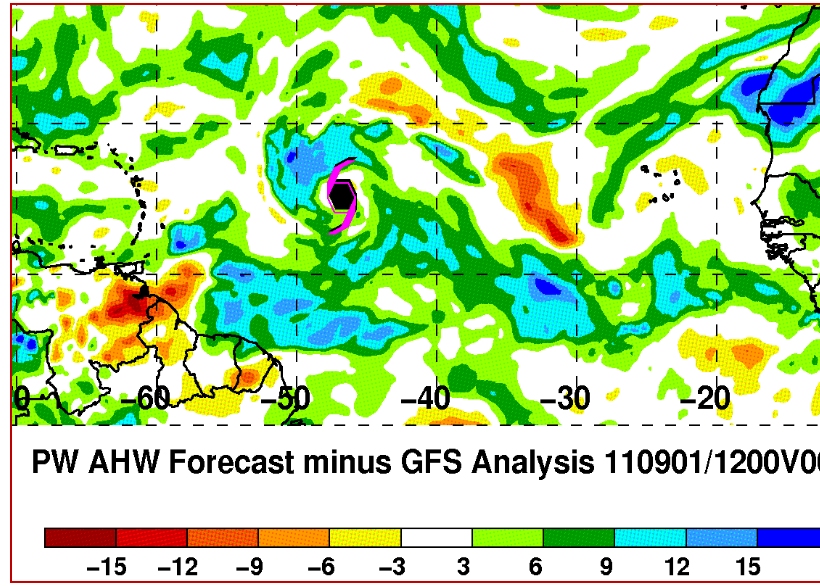




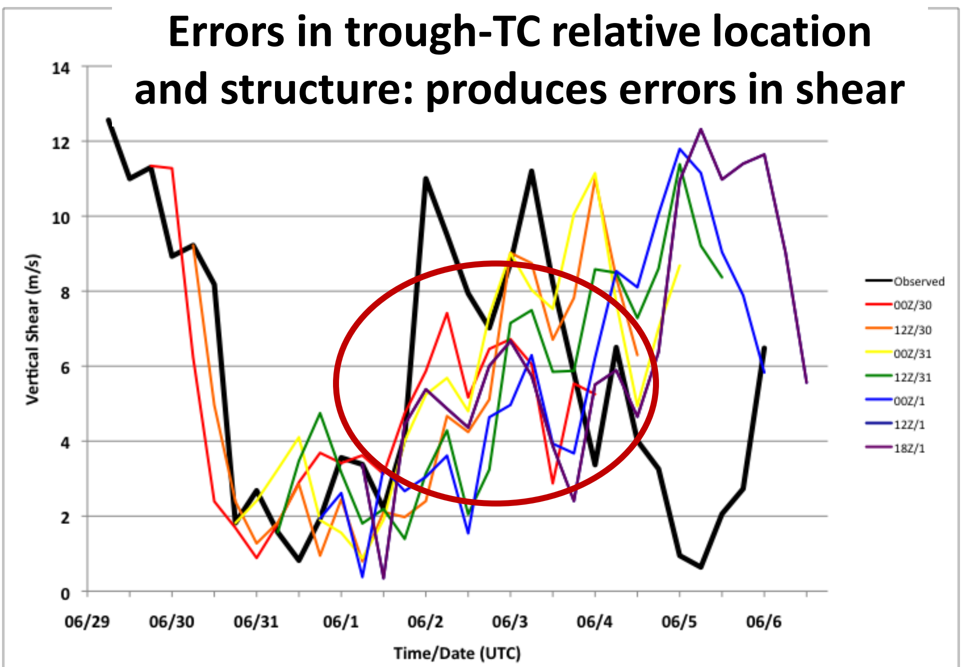
Is this driven by shear-vortex interactions or poor initialization of weak storms or both ?

Thanks to CIRA for the plots

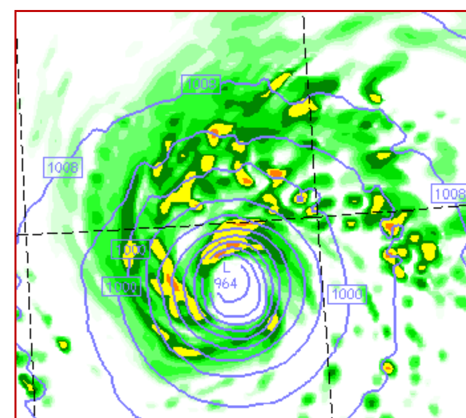




Why? Probable moist bias.



Result?
Too much
convection,
surrounds
core too
easily



Challenges Last Year: Spin Up Issues with HWRF
(EMC and AOML/HRD)

1. Vortex size correction

- Instead of matching only RMW but also matching outer radii such as ROCI or R34kt

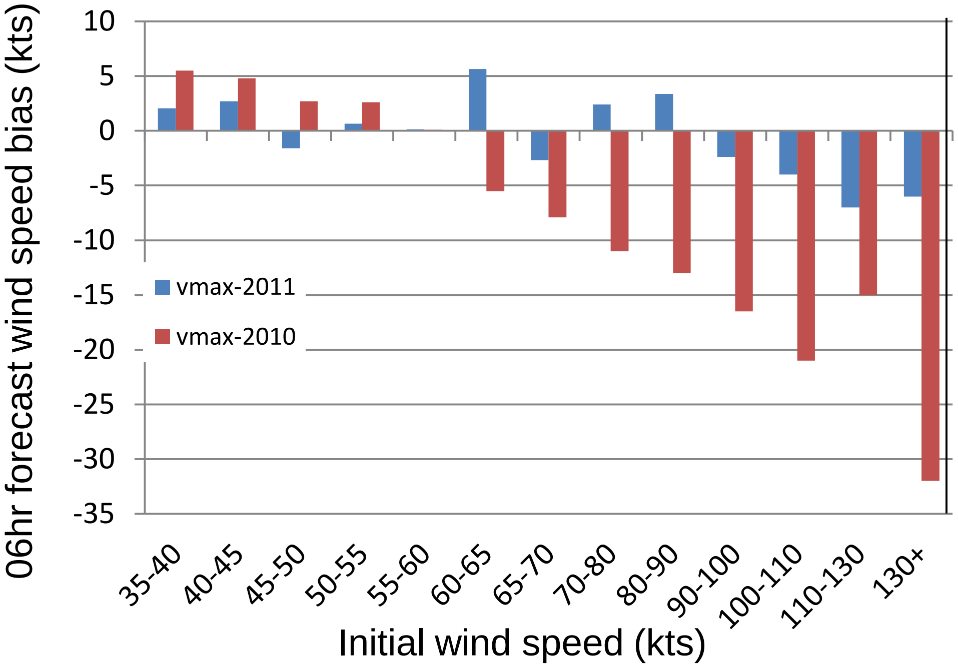
2. Less use of the composite storms for weak storms

- Preventing the rapid spin-up of weak storms

3. Matching the maximum 10m wind speed but not forcing the minimum SLP

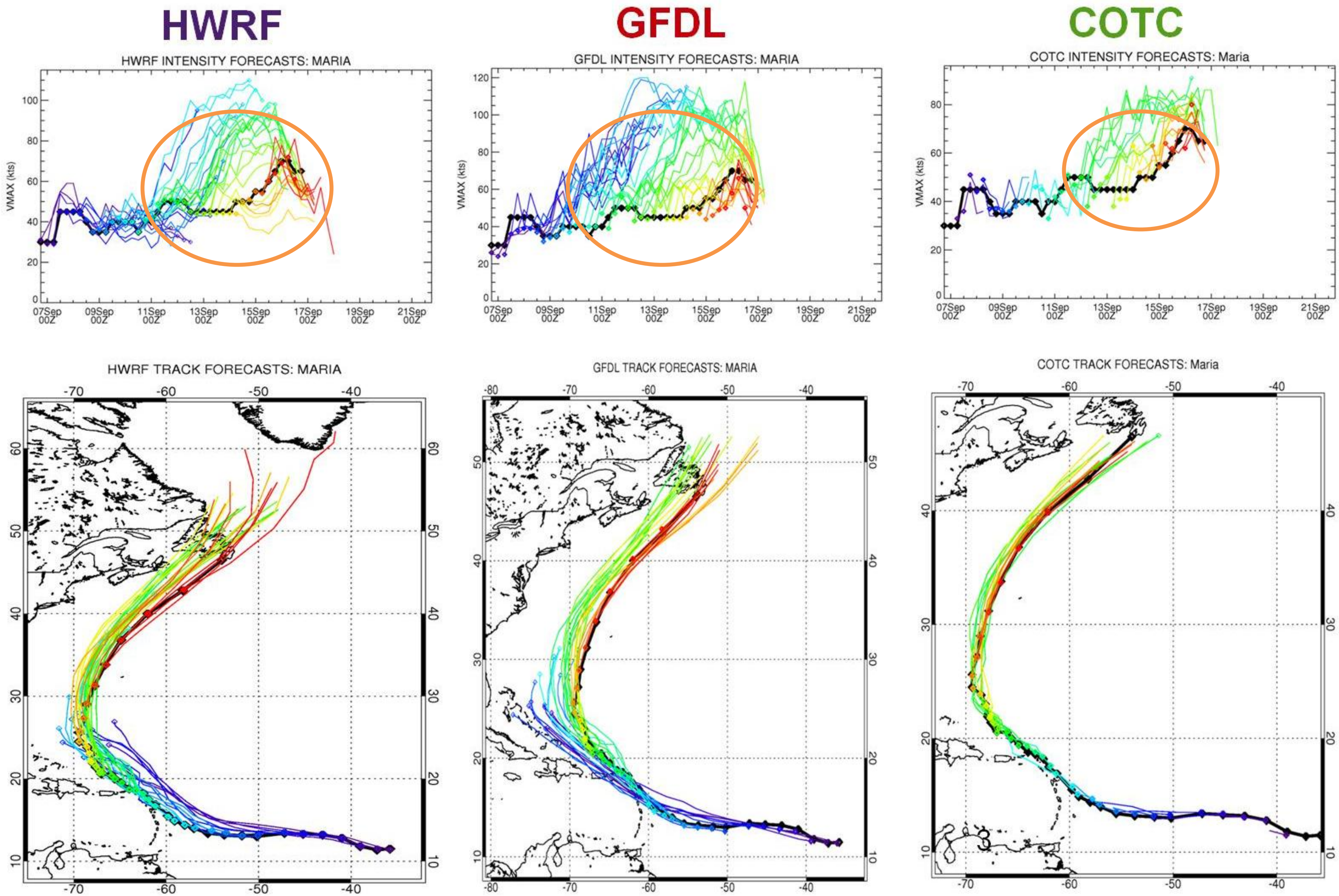
- With more balanced vortex, rapid spin-down of strong storm is much reduced

*** Modified initialization significantly improve the intensity skill of HWRF model (especially 0-48hr)**



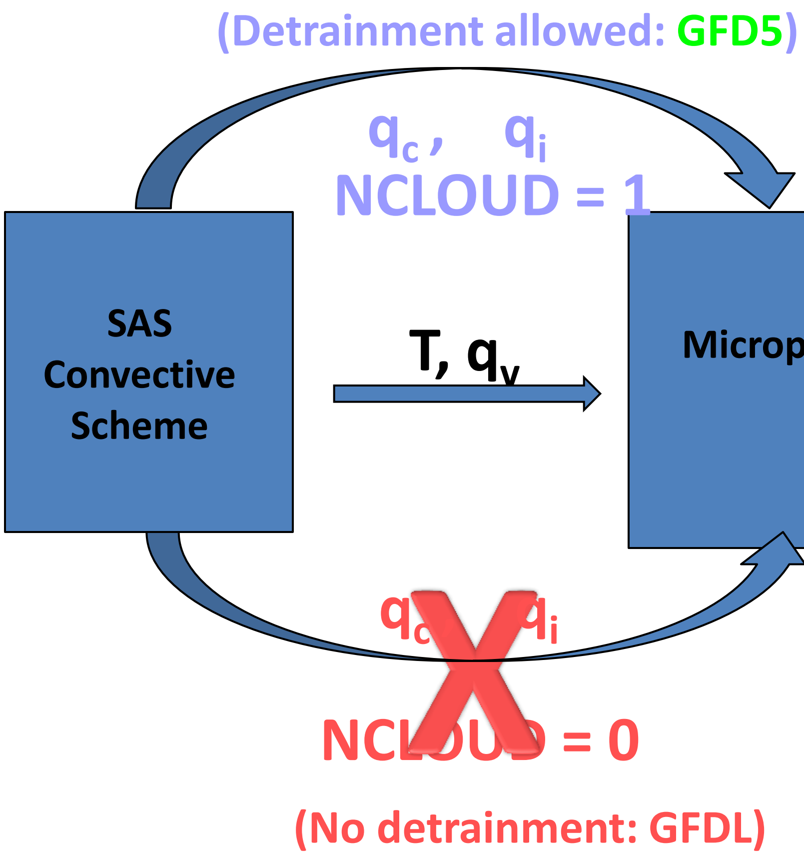
Spin-up problem for weak storms and spin down problems of strong storms are much improved in 2011 season

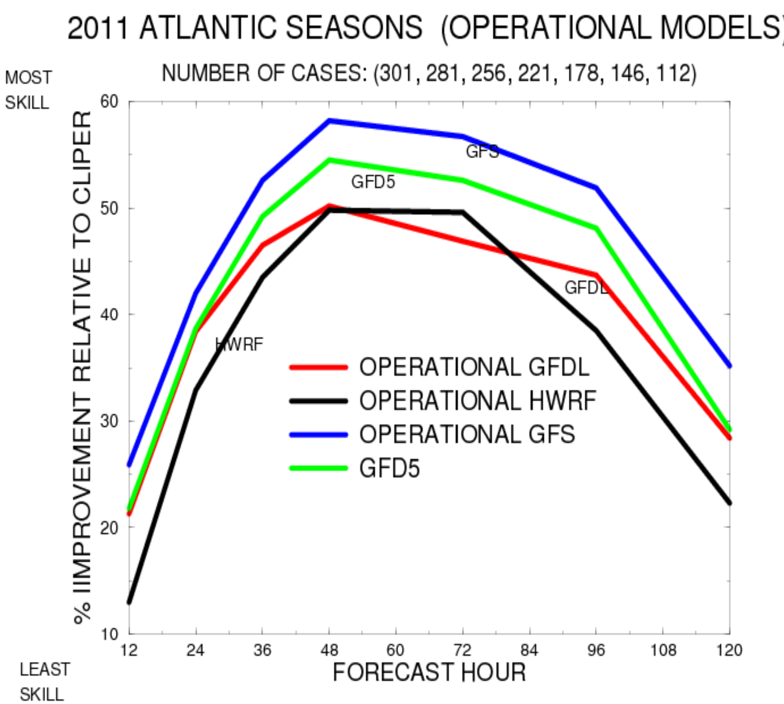
Challenges this Year: Weak and Sheared Storms



Thanks to CIRA for the plots

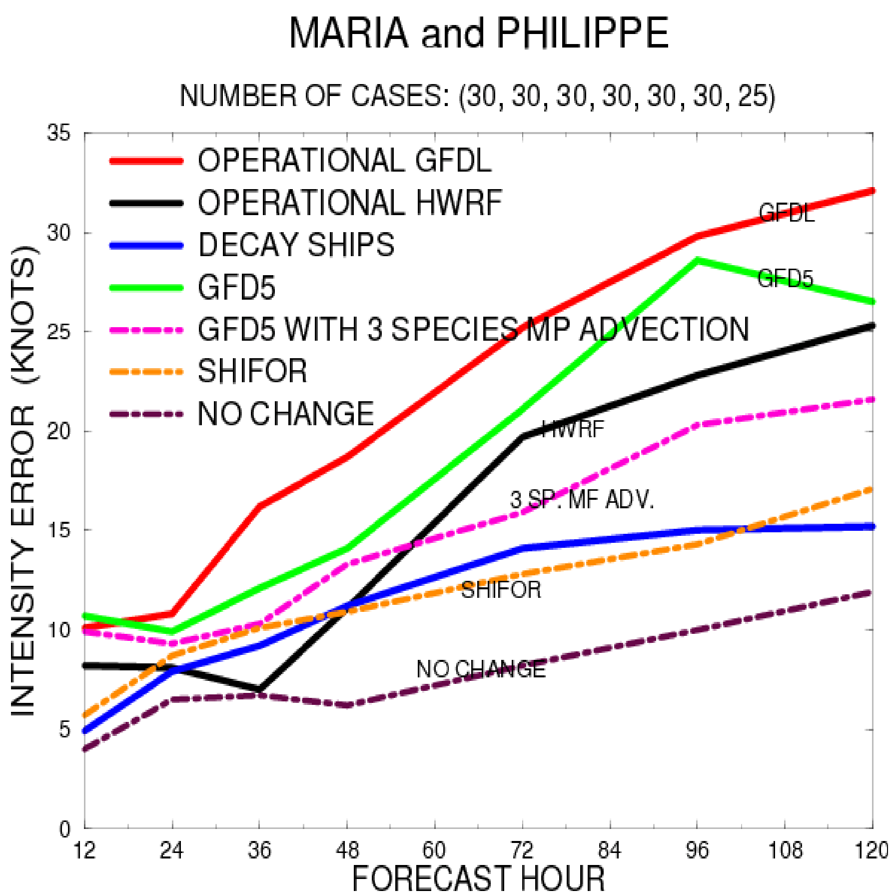
Physics Sensitivities: Importance of Microphysics and Microphysics-Cumulus interactions (GFDL)





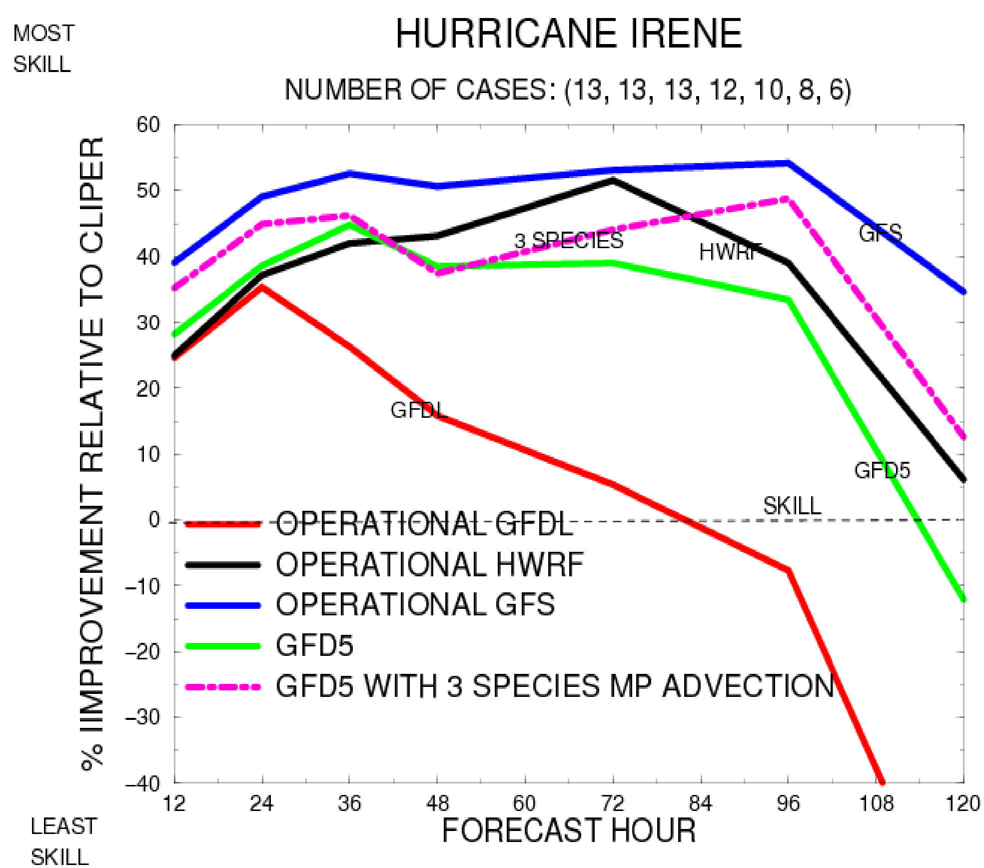
GFDL: Examples of Positive impact in track and intensity with micro-physics modification

NCLOUD= 1 reduced severe positive bias in highly sheared storms
Further improvement with individual advection of micro-physics species

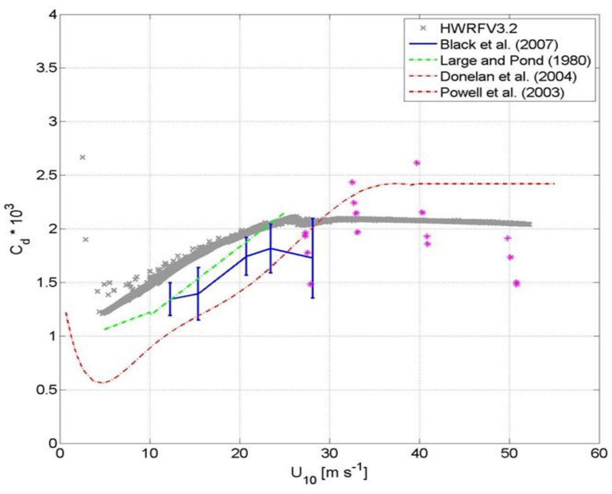


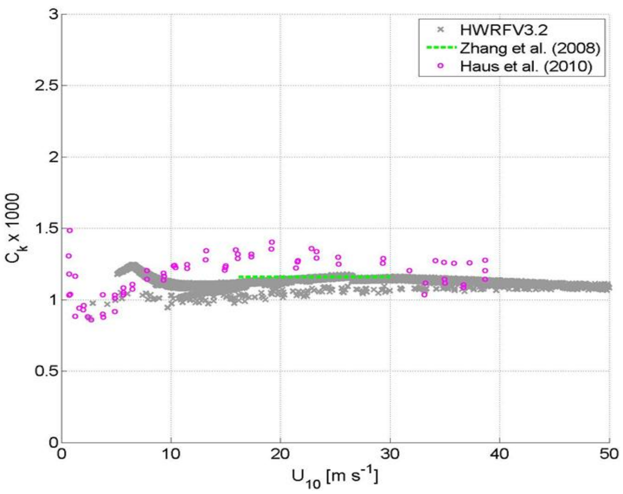
Large positive track improvement for Hurricane Irene

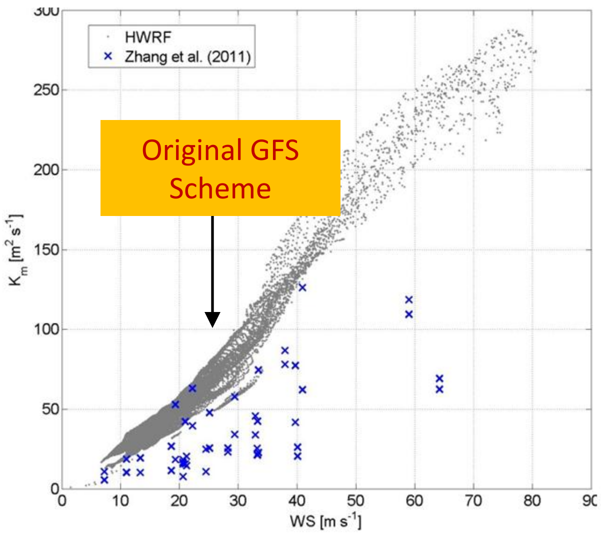
Example of Improved tracks

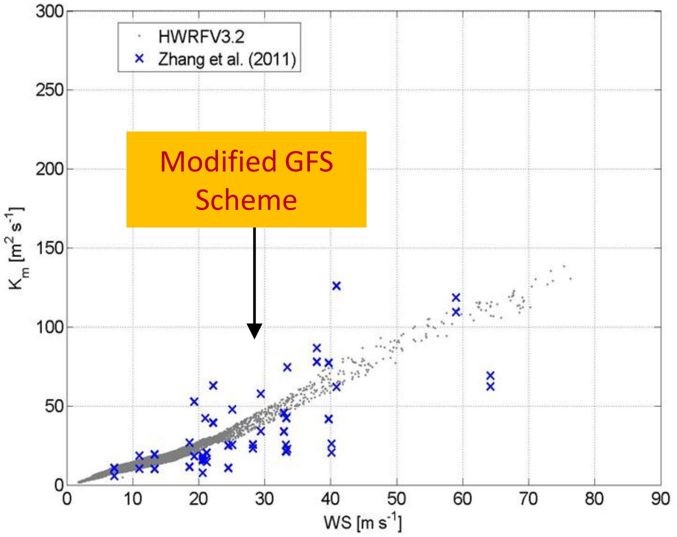


Physics Sensitivities with 3 km HWRF: High Resolution PBL Physics Consistent with Observations (AOML/EMC/PSD)



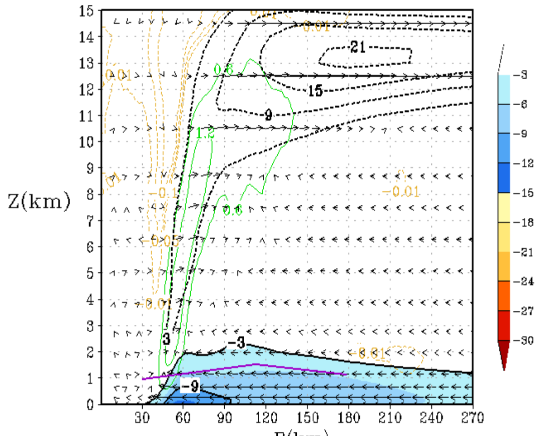




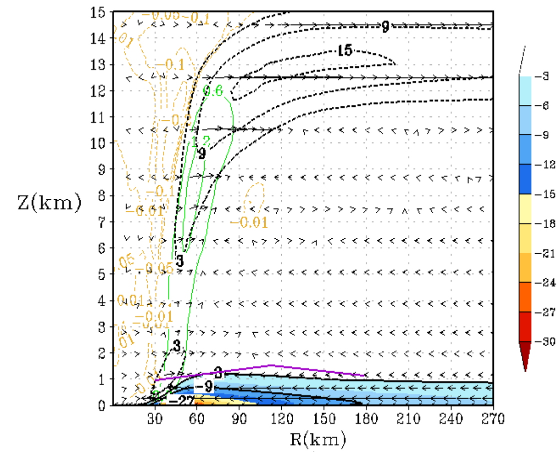


3 KM HWRF: Improved Structure Predictions

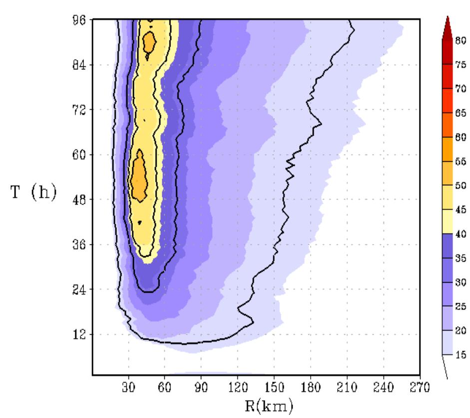
Original Formulation

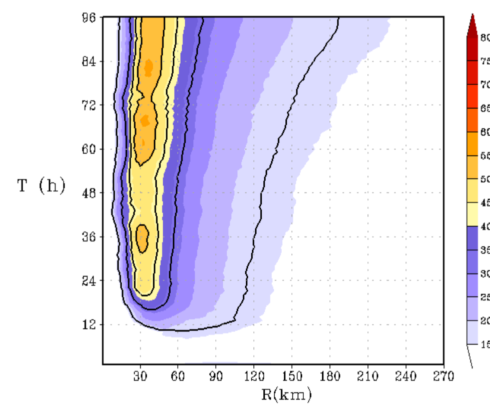


Latest Formulation



Azimuthally averaged secondary circulation: Radial Wind and W





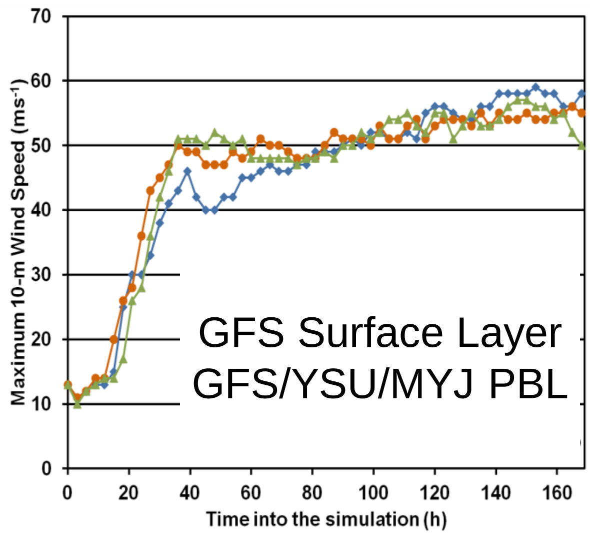
Hovemoller of 10-m wind speed

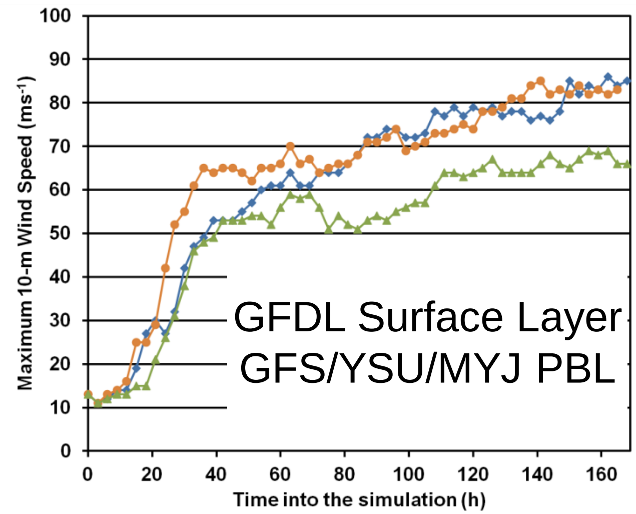
Towards an Improved PBL Package for the Operational 3-KM HWRF Model (PSD/HRD)

- ❑ Assess the performance of the GFS, MYJ and YSU BL mixing schemes that are coupled with the same surface layer scheme (either the current GFDL SFCLAY scheme or an alternative better scheme) (Stream 1.5 Task).

- ❑ Establish a better understanding of the resolved and subgrid physical processes connecting the surface fluxes and moisture flux above the BL; and identify aspects in the HWRF representations of these processes that require improvement (Stream 2 Task).

- ❑ Recommend an improved combination of the surface layer, the BL mixing and the subgrid convection schemes to couple with the operational microphysics scheme for better representing resolved and subgrid moisture flux under high winds (Stream 2 Task).





HWRF Support and Code Management

- Community Support
  - HWRF Tutorial April 2011
  - HWRF v3.3a release in August 2011(contains 2011 operational capability)
  - Ongoing user support and website maintenance
  - Draft online tutorial

- Code Management
  - New HWRF repository at DTC
  - Components linked to community repositories
  - Contains 2011 operational; Stream 1.5 being added
  - In use by DTC, EMC, and developers
  - Ability for DTC to support multiple developers
  - Developers have access to each others' code

2011 HFIP Demo
Lessons Learned and Science Challenges

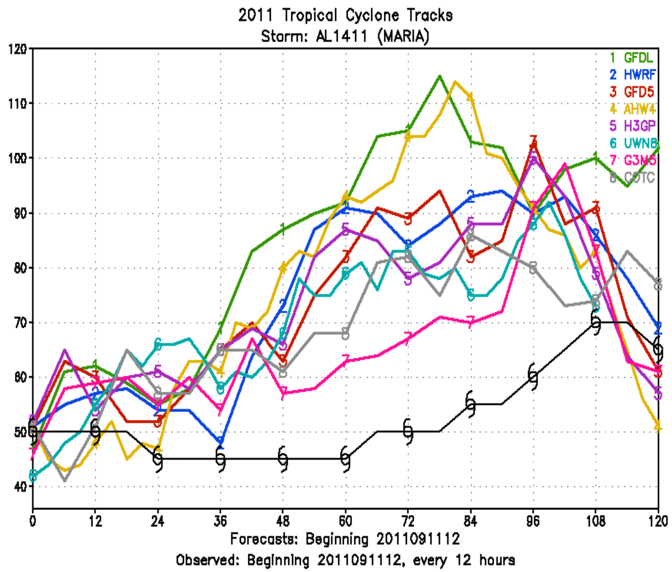
➢Lessons Learned

- Microphysics changes have marked impacts on track and intensity (GFDL/COAMPS).
- Advection of species (ice, rain and mix) shows positive impacts in GFDL model for sheared storms
- Model diffusion/PBL shows positive impacts on structure predictions
- Sea Spray had positive impact on structure (UWNMS)
- Physics interoperability is recommended (DTC/ESRL/AOML)
- Idealized case recommended for intercomparisons
- Inclusion of TPW observations improves tracks (COAMPS)

➢Challenges

- Shear vortex interactions (location and timings)
- Intensity is too insensitive to shear (microphysics/cumulus interactions important)
- Initially weak storms are challenging than strong ones
- Improved PBL and microphysics (intercomparison & diagnostics needed)
- Rapid intensification process
- Land surface interactions

Impact of advecting more microphysical species on TS. Maria (GFDL model)



Additional Material

2011 COAMPS-TC HFIP Demo

Lessons Learned and Science Challenges

➢Lessons Learned

- Overall COAMPS-TC intensity forecasts were promising (esp. Irene)
- Improvements to PBL, in-cloud vertical diffusion, radiation were important
- Large intensity sensitivity to: i) PBL, ii) microphysics, iii) vortex initialization
- Inclusion of TPW observations in NAVDAS improved track forecasts
- Promising results: COTC ensemble (10 member, 5 km) & coupled systems

➢Challenges

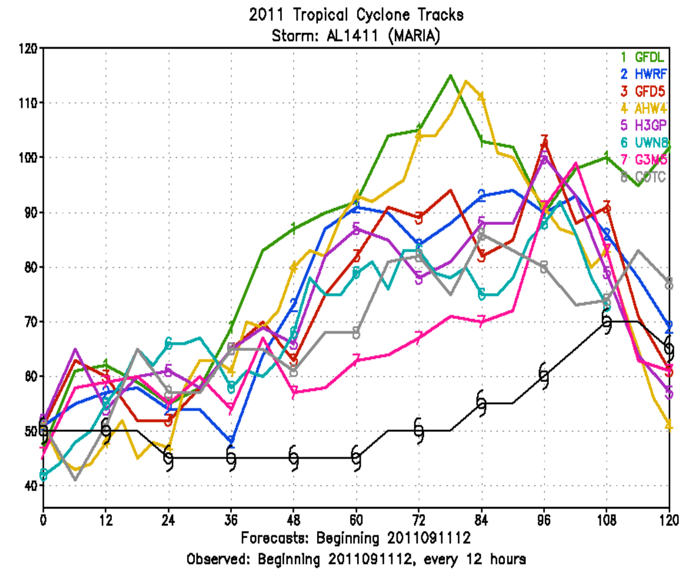
- Realistic (structure) and balanced initialization
- Rapid intensification (both timing and magnitude)
- Intensity is too insensitive to shear (could be a microphysics issue?)
- Weak storms are challenging than strong
- Improved PBL and microphysics (intercomparison & diagnostics needed)
- Interaction with land appears to be problematic (other models too)
- Storm radius of maximum winds is typically too large
- Right track bias (often early recurvature) (initialization or physics?)
- Nest tracker issues

2011 NOAA Models

Lessons Learned and Science Challenges

➢Lessons Learned

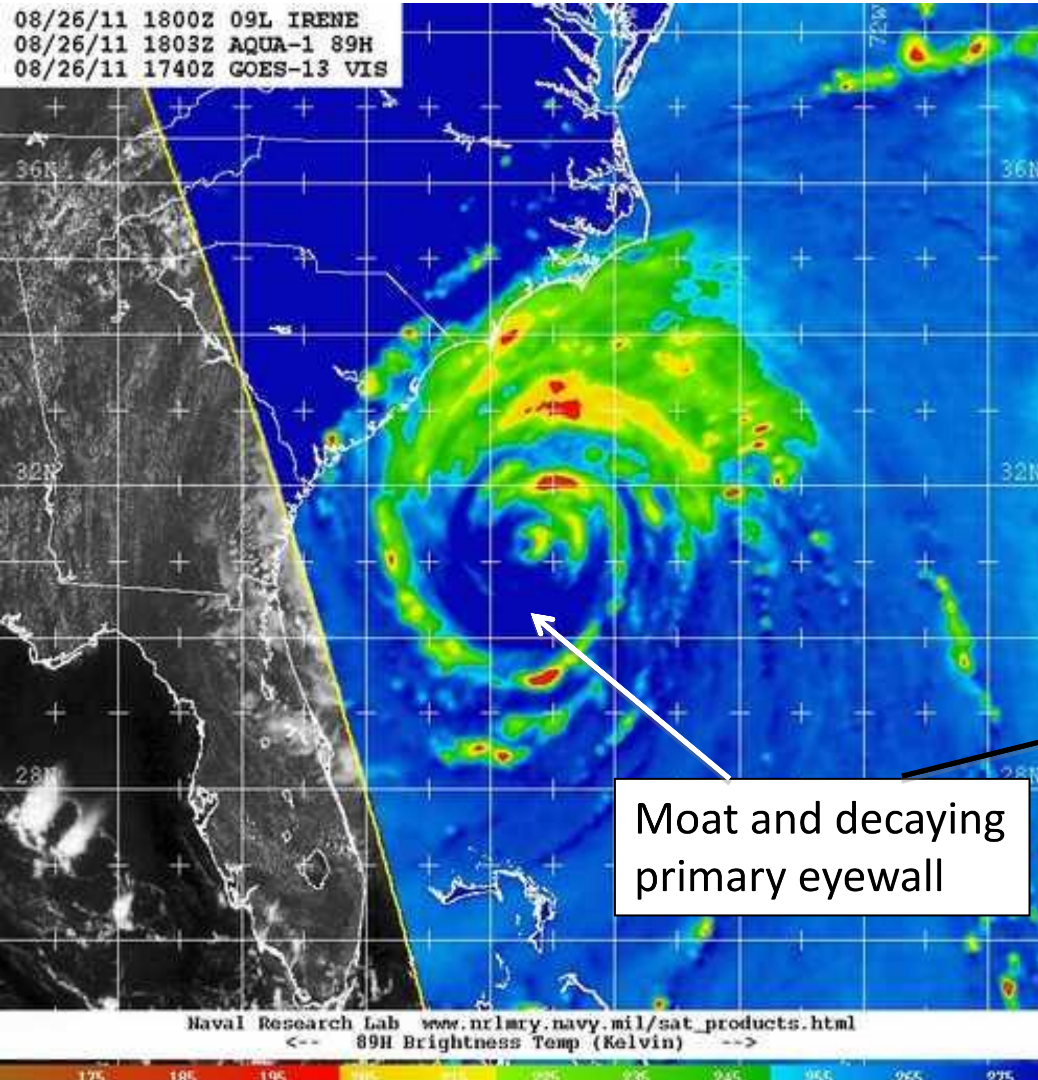
- 3 km HWRF track and intensity forecasts were promising (retro/2011)
- 3 km version shows marked improvements over GFDL and HWRF (retro/2011)
- Advection of species (ice,rain and mix) shows positive impacts in GFDL model for sheared storms
- Improved microphysics-cumulus response impacts tracks and intensity (GFDL)



➢Challenges

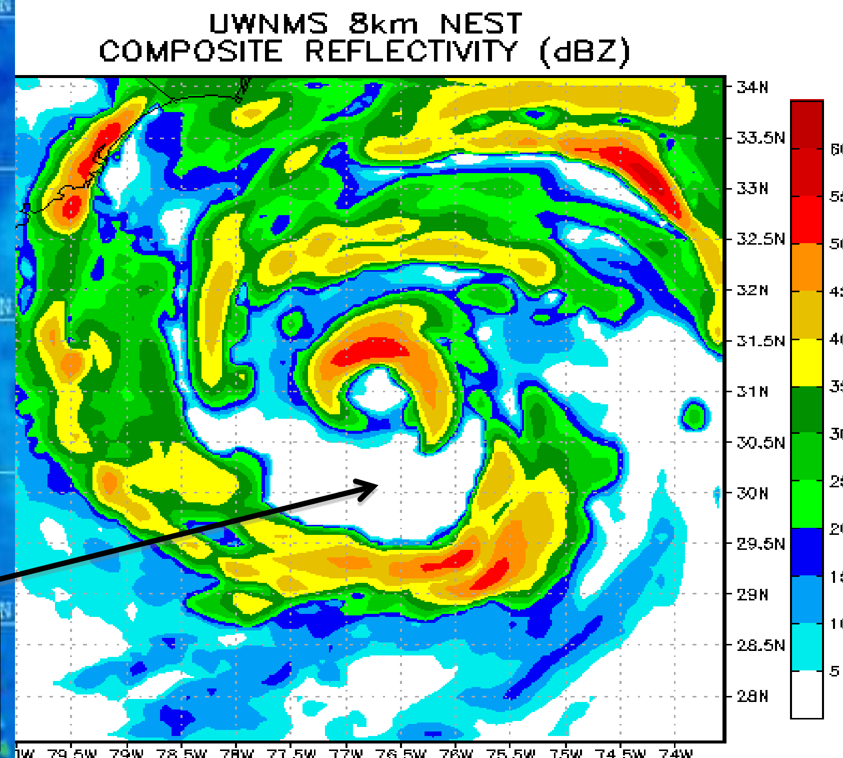
- Intensity is too insensitive to shear (microphysics/cumulus interactions important)
- Initially weak storms are challenging than strong ones
- Improved PBL and microphysics (intercomparison & diagnostics needed)
- Land surface interactions

Irene Structure (AMSR-E vs. UWNMS)



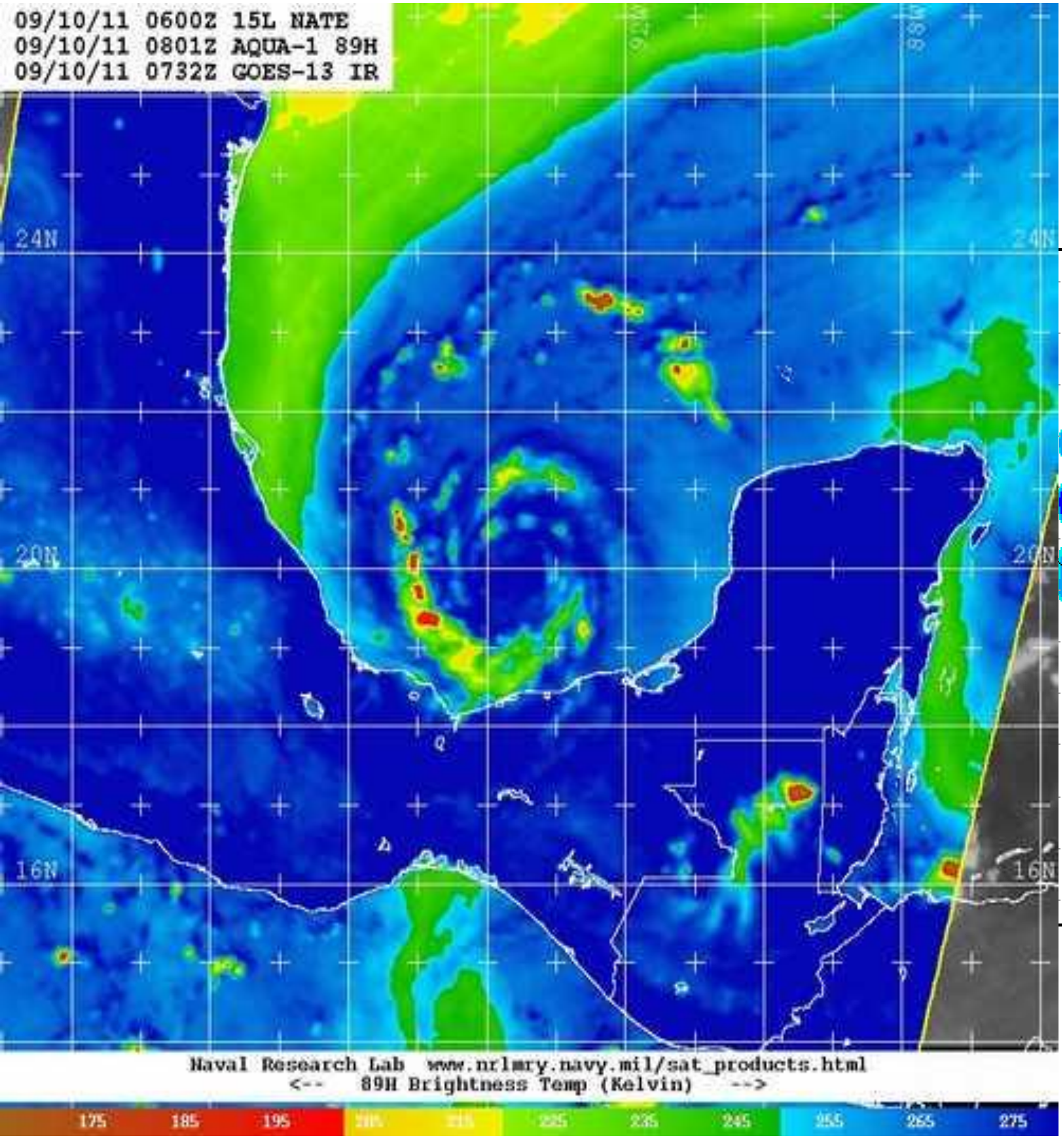
Moat and decaying primary eyewall

UWNMS 66-hr FCST VALID 08/26/11 18Z

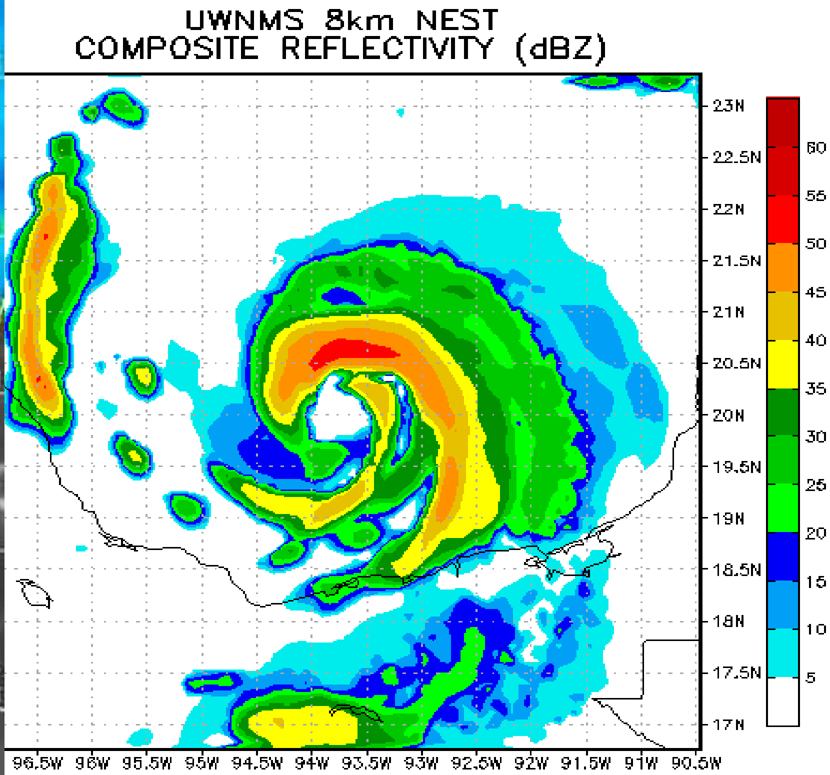


BT = 85kt, FCST = 86kt

Nate Structure (AMSR-E vs. UWNMS)



UWNMS 33-hr FCST VALID 09/10/11 09Z



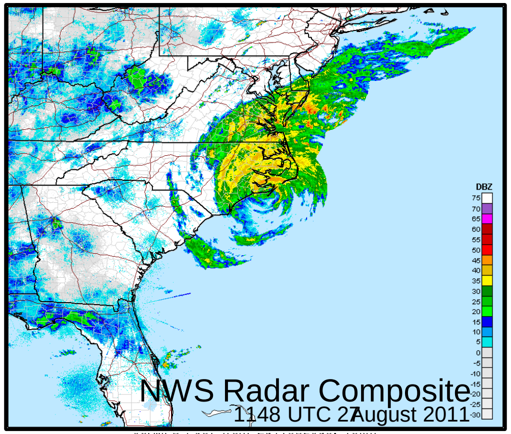
BT = 45kt, FCST = 90kt

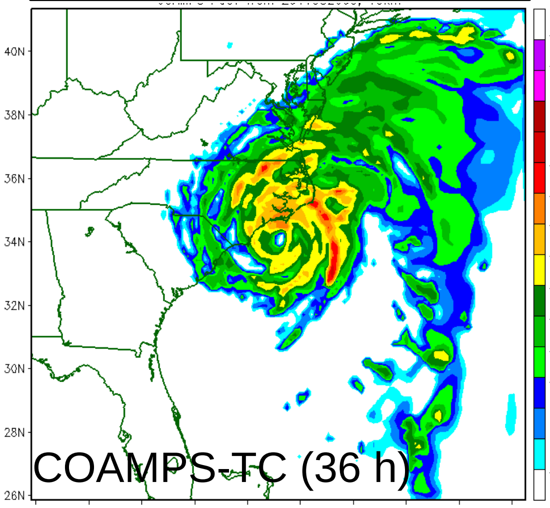
Unresolved Issues UW-NMS

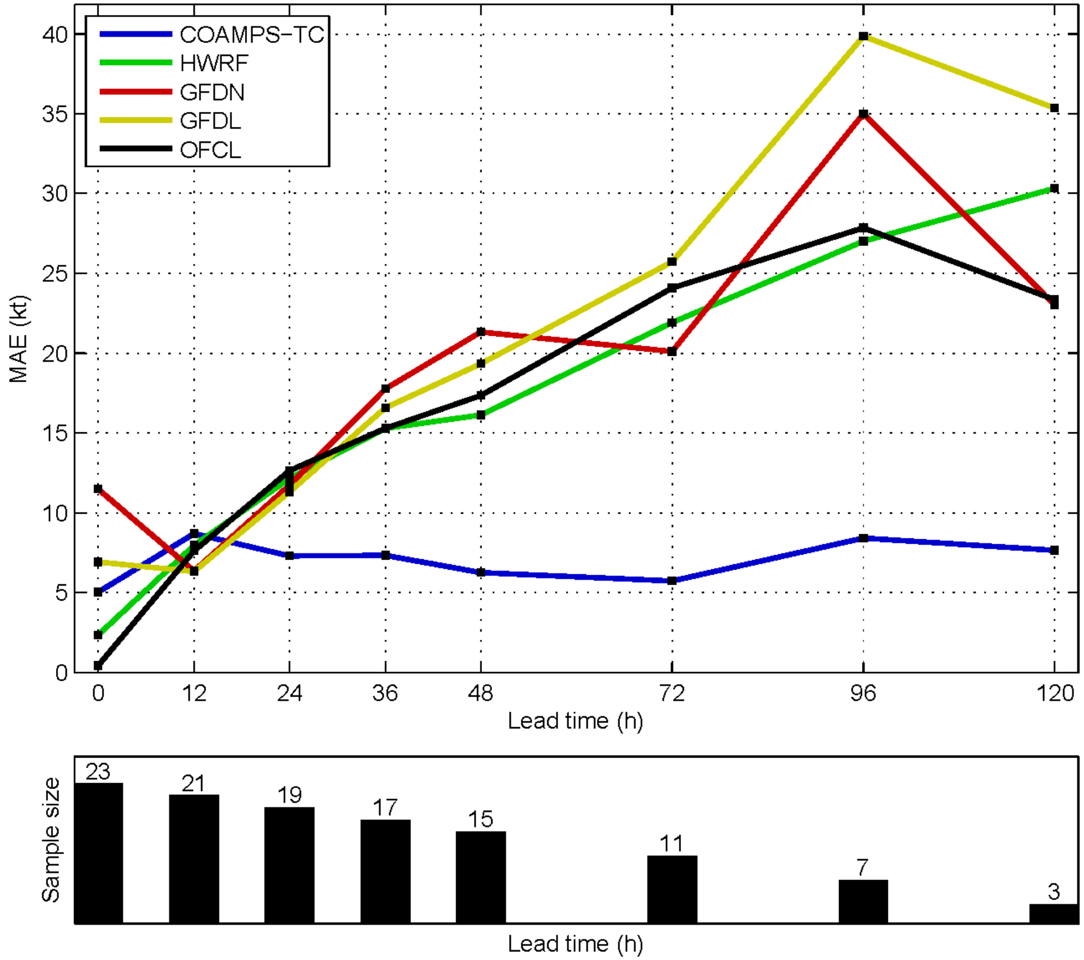
- Initialization / spin-up remains a challenge.
  - KC Bogus improves upon previous method, but will likely require cycling / relocation to produce acceptable short-range results.
  - DA on high spatiotemporal scales is, of course, the ultimate goal.
- Other groups have documented the importance of PBL and microphysics; we have noticed similar sensitivities.
- Inclusion of sea-spray (Andreas scheme) was beneficial in improving storm structure / evolution relative to HRH results. Further tuning may yield additional improvements.

COAMPS-TC Highlight

Real-Time Hurricane Irene Forecasts







- **Realistic precipitation shield and structure.**
- **COAMPS-TC did very well for Intensity during Aug-Sep, including for Irene.**

2011 COAMPS-TC HFIP Demo

Lessons Learned and Science Challenges

➢ Lessons Learned

- Overall COAMPS-TC intensity forecasts were promising (esp. Irene)
- Improvements to PBL, in-cloud vertical diffusion, radiation were important
- Large intensity sensitivity to: i) PBL, ii) microphysics, iii) vortex initialization
- Inclusion of TPW observations in NAVDAS improved track forecasts
- Promising results: COTC ensemble (10 member, 5 km) & coupled systems

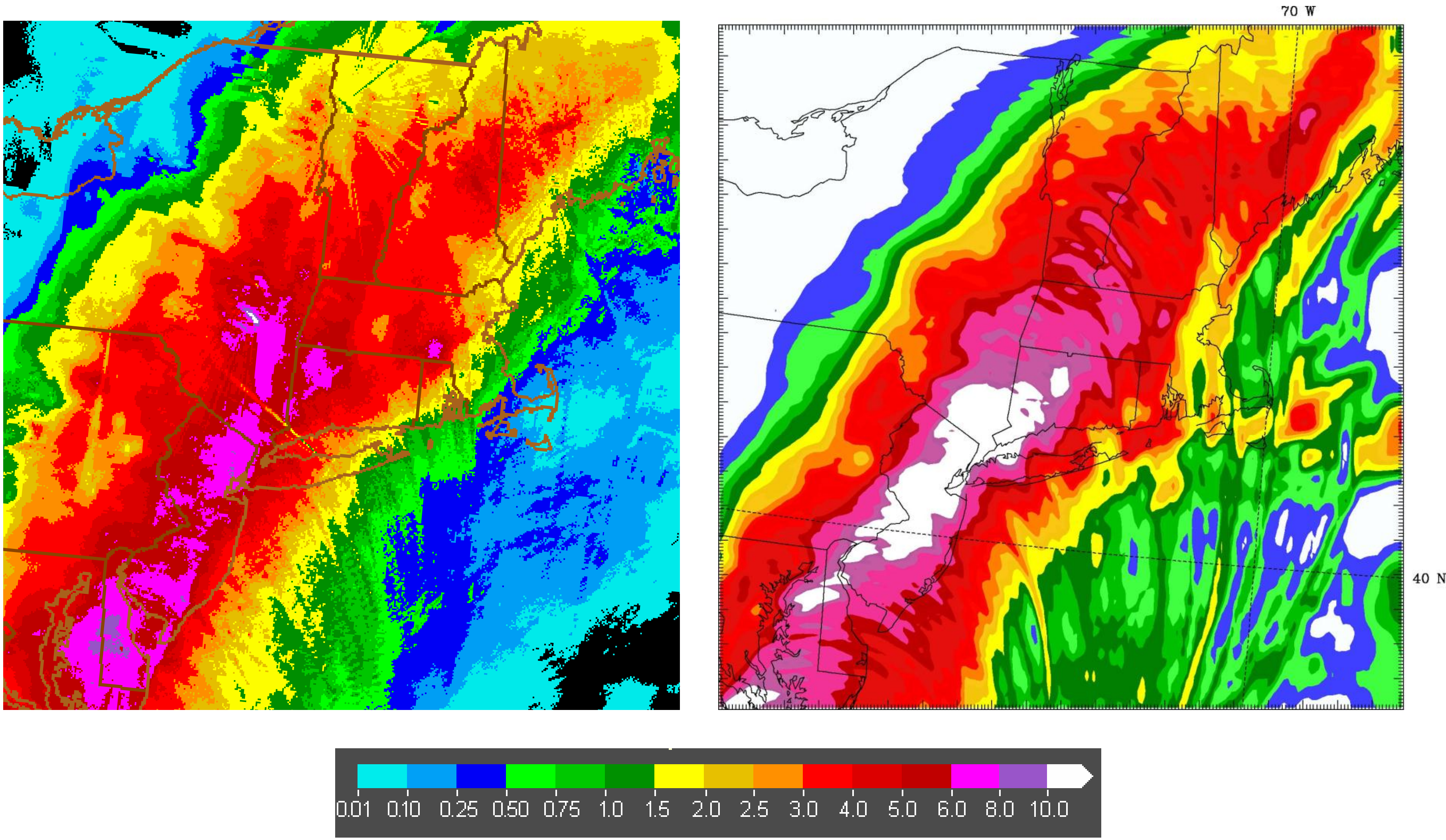
➢ Challenges

- Realistic (structure) and balanced initialization
- Rapid intensification (both timing and magnitude)
- Intensity is too insensitive to shear (could be a microphysics issue?)
- Weak storms are challenging than strong
- Improved PBL and microphysics (intercomparison & diagnostics needed)
- Interaction with land appears to be problematic (other models too)
- Storm radius of maximum winds is typically too large
- Right track bias (often early recurvature) (initialization or physics?)
- Nest tracker issues

Irene: Precipitation Forecasts

(from AHW initialized 18 UTC 26 August)

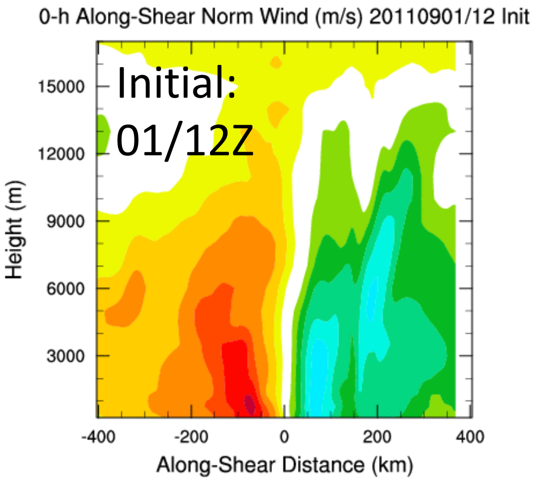
2-day Rainfall, Ending 2 PM EDT August 28



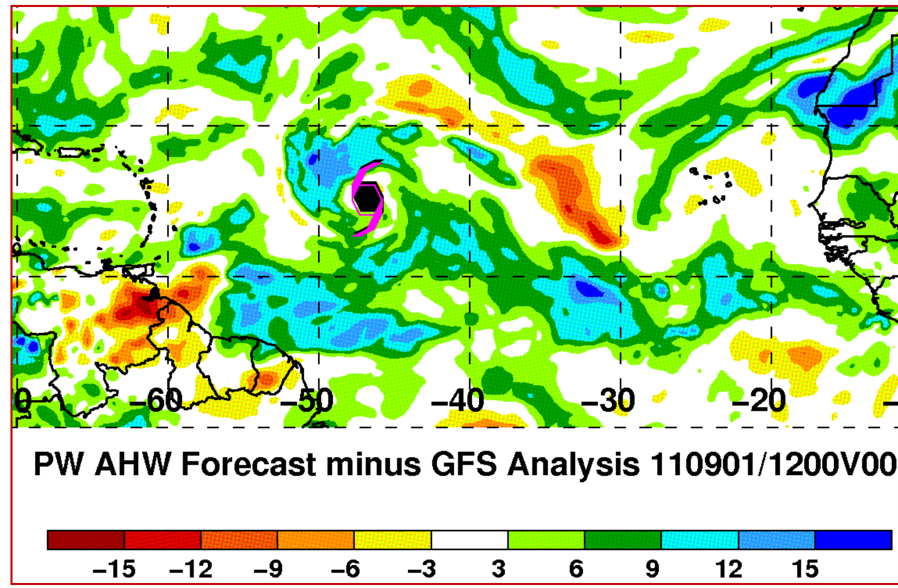
Inches

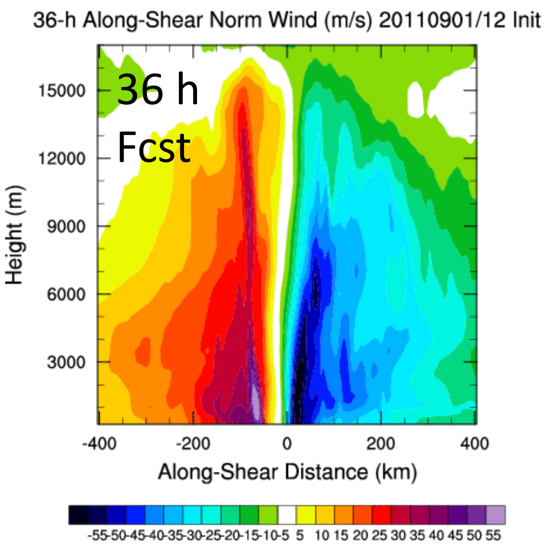
Is all the error due to synoptic-scale PV errors? No.
Even with reasonable initial shear, storm intensifies too much

Katia, initialized at 01/12Z, is clearly shallow and sheared, but quickly develops deep hurricane structure

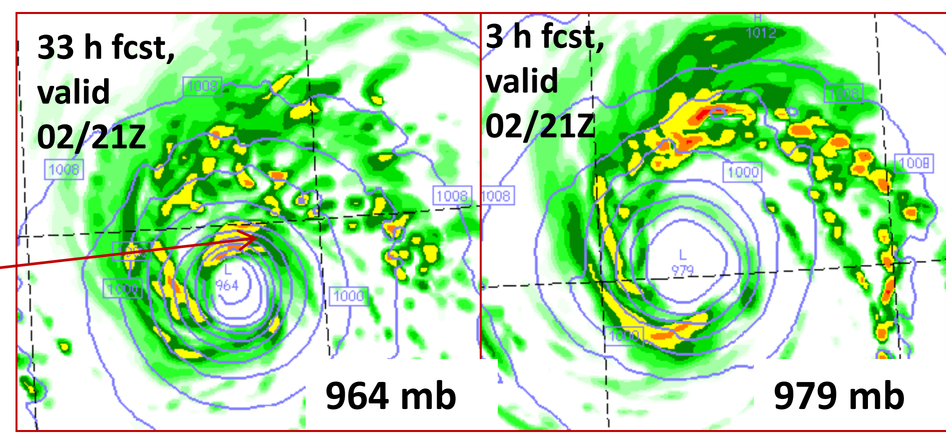


Why?
Probable moist bias.





Result?
Too much convection, surrounds core too easily

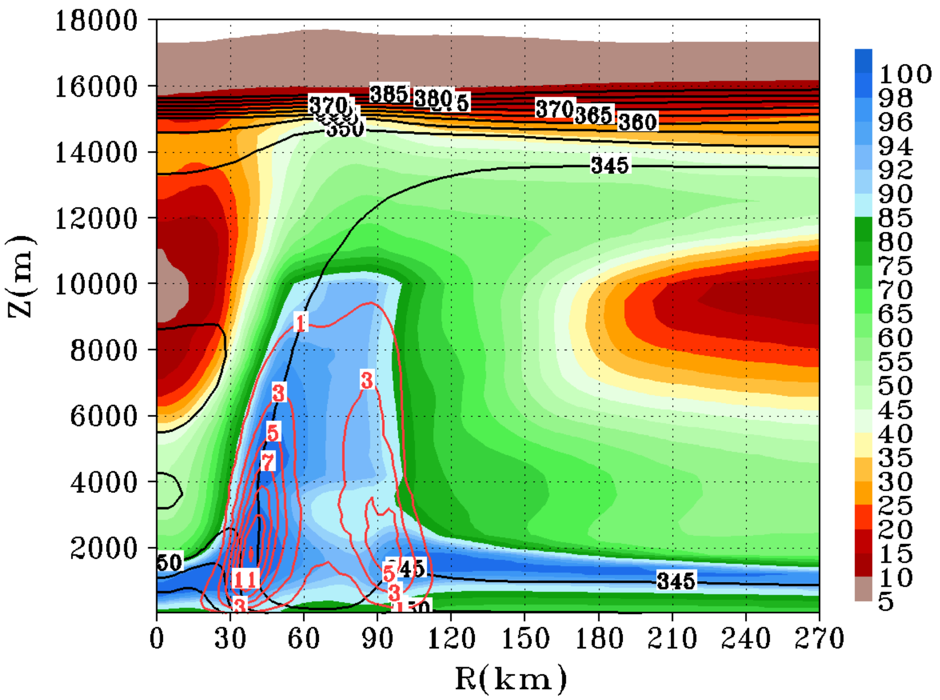


ARW Current Research and Testing

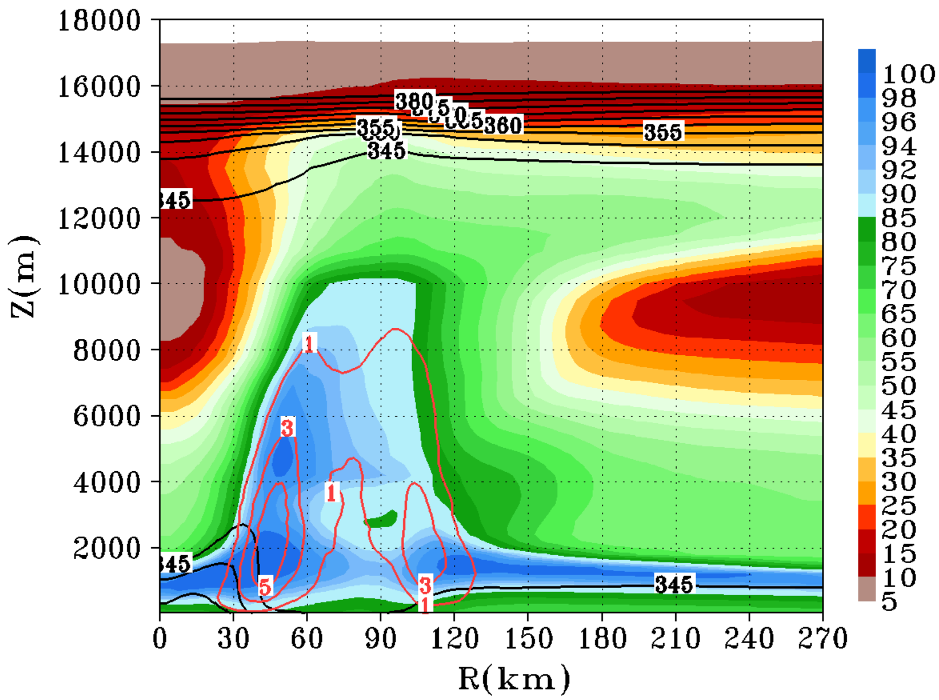
Generally Aimed at Improving Forecasts of TC Environment (improving track prediction and convection response)

- Surface flux formulation: increase drag at low wind speeds, account for cool-skin, warm layer and salinity
- Adjust shallow convection (Tiedtke): too much detrainment and moistening
- Examine K-F (deep) and Tiedtke (shallow) cumulus together
- Modify radiative forcing (ozone and aerosol climatology): affects temperature, winds, and TC tracks

Impact of Surface Fluxes on Convection in Eyewall via BL Mixing: Interaction between PBL and Cloud Physics



HWRF Control Experiment w/ Original GFDL Cd and Ck



HWRF Sensitivity Experiment w/ Current HWRF Cd and Ck

24-36 hourly azimuthal average RH (color shaded), theta_e (black contours), and vertical moisture flux (red contours)

Physics Interoperability and Diagnostics (DTC/EMC/AOML/PSD)

- Documented which schemes do/don’t with HWRF
- Increased interoperability for HWRF
  - Can run with any number of vertical levels
  - New SAS (coded by YSU)
  - RRTMG SW/LW
- Working on physics sensitivity studies with Regional Modeling Team
  - Idealized capability: being incorporated in community code
  - Cumulus: Starting to test KF, Grell, NSAS, Tiedke
  - Working with developers to address interoperability issues