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DTC Activities in Support of Transition of Research to the Operational Hurricane WRF model

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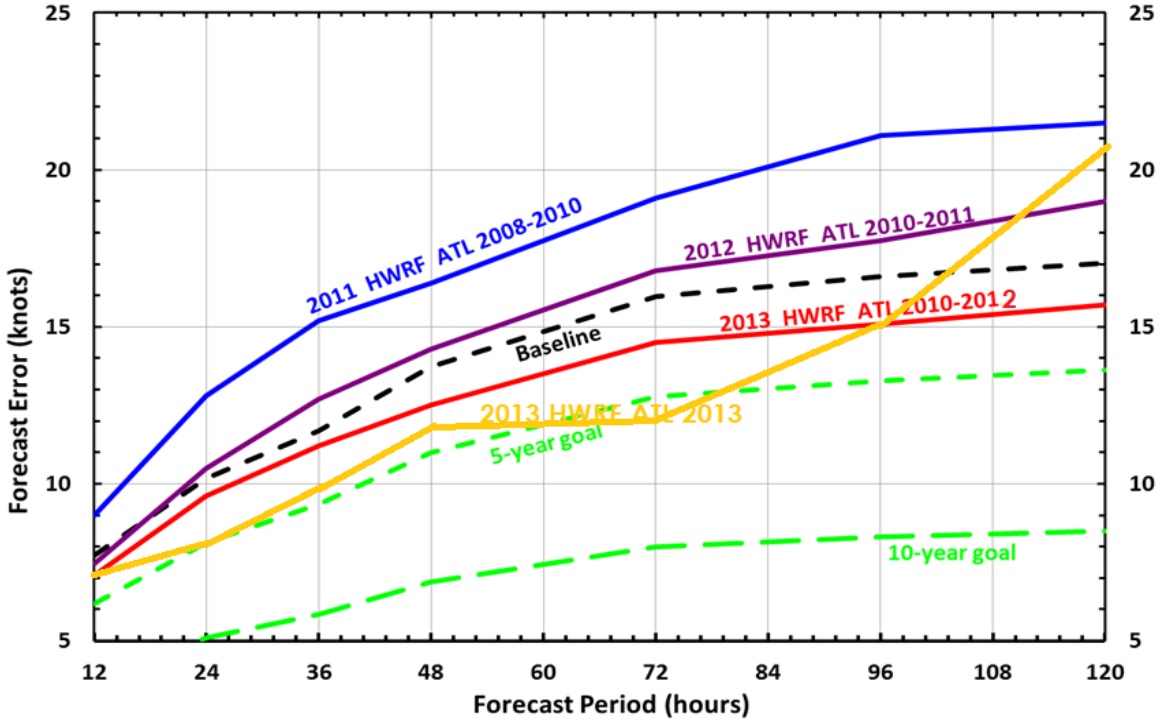
Hurricane WRF history

Operational goal:
Provide tropical cyclone track and intensity guidance to the National Hurricane Center
2007: initial operational implementation
2007-2013: yearly upgrades

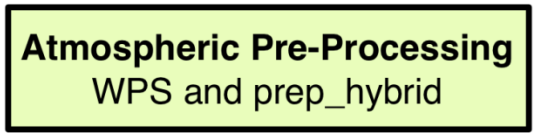


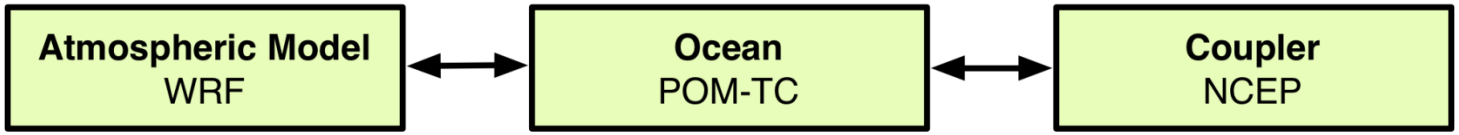
Intensity Errors (kt) in Atl

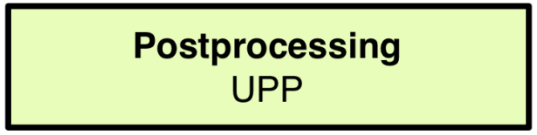
- Decrease yearly up to 96-h
- Approach 5-y goal of the Hurricane Forecast Improvement Project (HFIP)

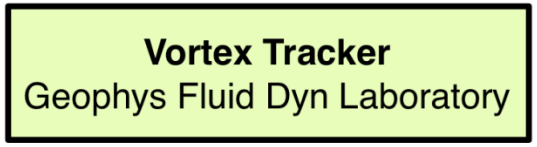
How does improvement happen and what is the role of the Developmental Testbed Center in the process?

About HWRF: components









HWRF is a complex modeling system

- Eight software components
- Running scripts
- Namelists
- Fixed files

Several HWRF components are used by wider community, in particular

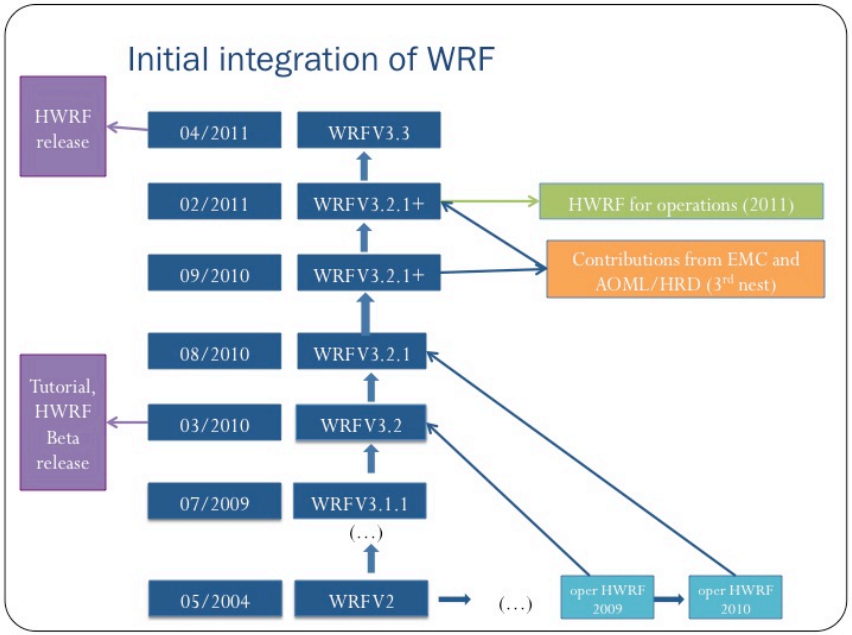
- WRF/WPS (AFWA, NCEP RAP, SREF etc., research)
- GSI data assimilation (GFS, NAM etc.)

Potentially makes developments available for HWR

HWRF code: divergence and unification of atmospheric component (WRF)

- 2007: HWRF initial operation
  - 2004: WRF code was obtained from community
  - 2004-2009: HWRF at EMC evolved and diverged from community
  - Operational HWRF could not benefit from HRD's HWRFX or community

WRF component integration



2009-2010: DTC/EMC integrated codes. Operations and community now use same source

2011-2014: HWRF code management maintains codes integrated, making available 3-nest configuration, physics (cu, microphysics, PBLs, and LSMs) and multiple moving nests (*basinscale)* for potential operational implementation

DTC Strategies to promote HWRF R2O

Code Management

- Create a framework for NCEP and the research community to collaborate and keep HWRF code unified

DTC Visitor Program – some approved projects involving HWRF

- *Development of an HWRF diagnostics module to evaluate intensity and structure using synthetic flight paths through tropical cyclones* (J. Vigh - NCAR)
- *Diagnosing tropical cyclone motion forecast errors in HWRF* (T. Galarneau - NCAR)
- *Improving HWRF track and intensity forecasts via model physics evaluation and tuning* (R. Fovell - UCLA)

User and developer support

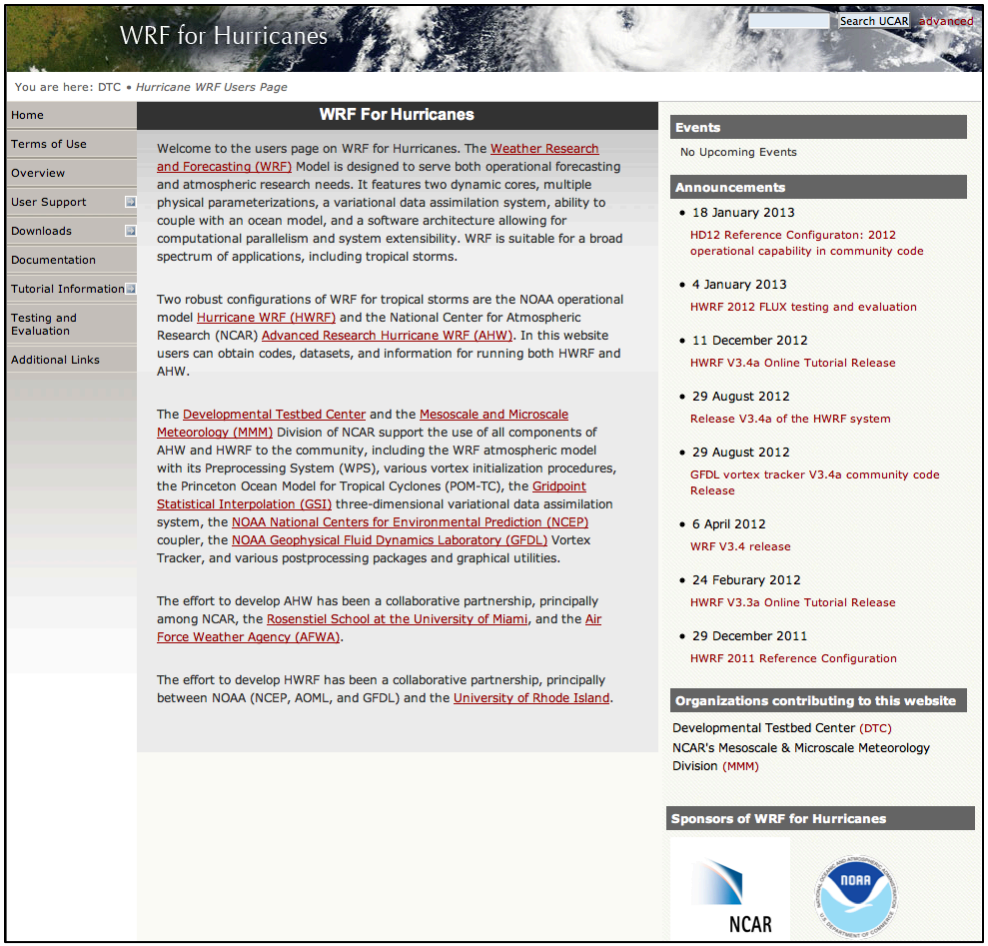
- Support the community in using an operational hurricane model

Testing and Evaluation

- Perform tests to assure integrity of community code and evaluate new developments for potential operational implementation

www.dtcenter.org/HurrWRF/users

Support to users and developers



700 registered users

Stable well-tested code downloads, documentation, helpdesk

Yearly releases: current HWRF v3.5a (2013 operational)

Tutorials in 2014

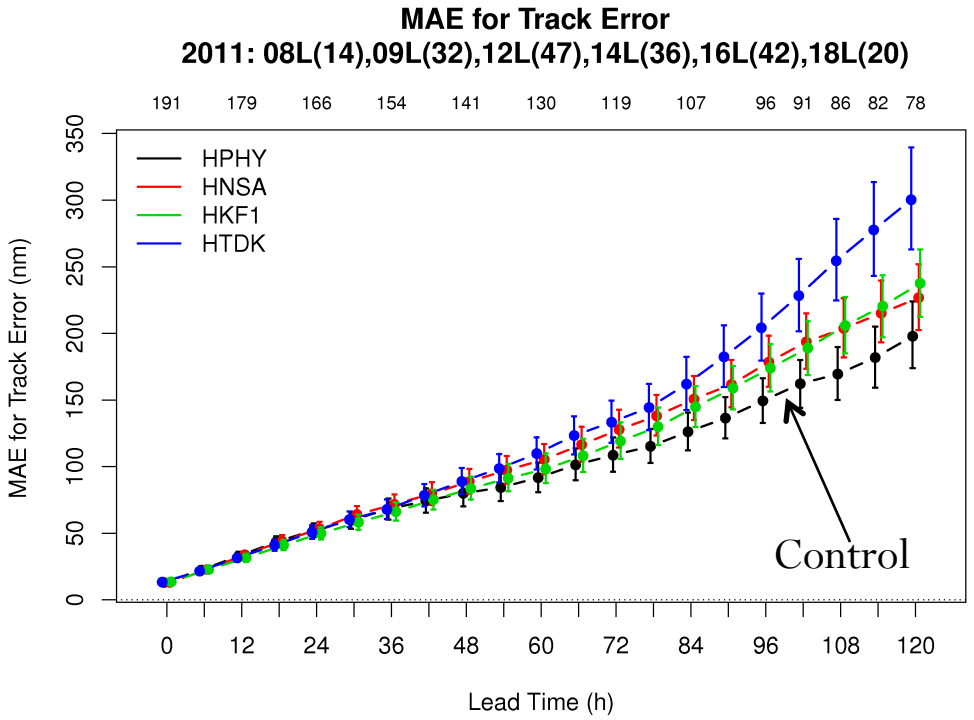
- College Park, MD (Jan)
- Taiwan (May)

Support to developers

- Direct access to code repository
- Use of experimental configurations
- Code integration to avoid divergence
- Collaboration among developers

HWRF T&E I: Cumulus Parameterizations

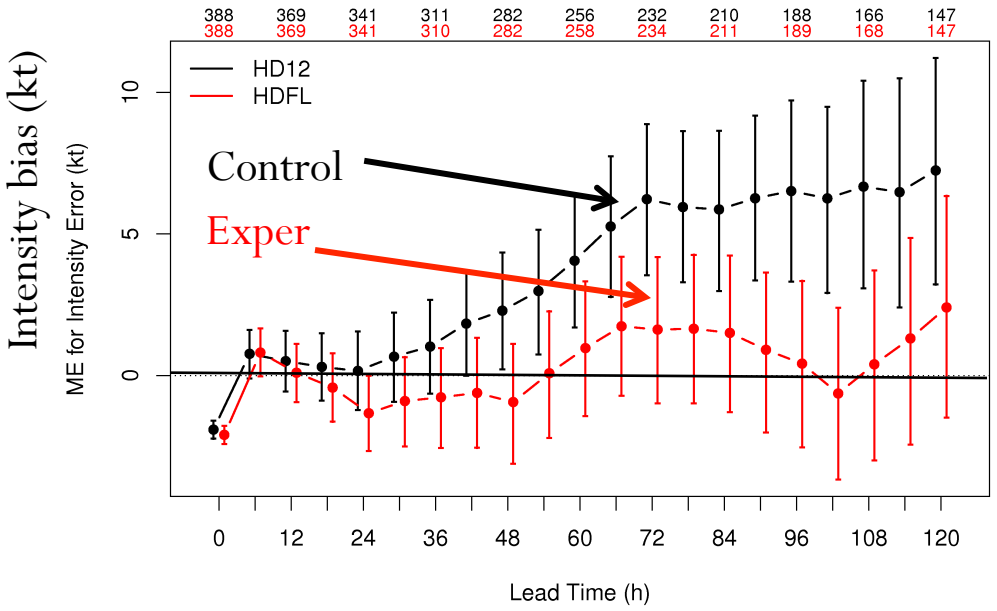
- **Operational Simplified Arakawa Schubert (SAS)**
- **New SAS implementation from YSU**
- **Kain Fritsch**
- **Tiedtke**



Test conducted in 2011 using several storms from 2011:
The alternate cumulus schemes did not perform better than the control configuration.

HWRF T&E II: Air-Sea fluxes

- Since 2007, air-sea fluxes in POM truncated because storms too large and intense inducing too much cooling
- With 2012 operational implementation of higher resolution (3 km) and changes in PBL physics, storm intensity/size improved
- DTC worked with URI, HRD, and EMC to test elimination of (unnecessary and partially unphysical) truncation of fluxes in POM-TC



Test conducted in 2012 using entire 2012 season:
Intensity bias in AL eliminated and flux reduction implemented in 2013 HWRF operations.

HWRF T&E III: Thompson/RRTMG

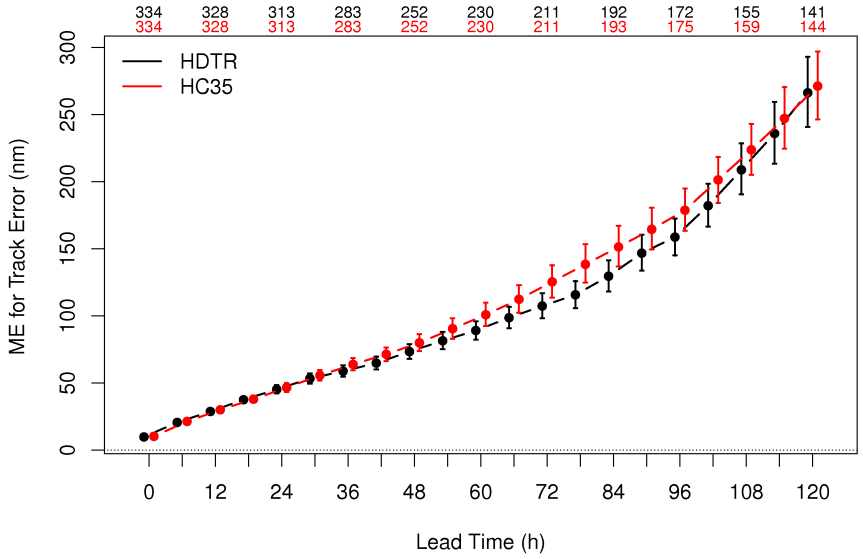
- Community involvement
  - NCAR/RAL visitor (A. Chakraborty, India CAOS) tested HWRF with Thompson mp for Hurricane Sandy and obtained track improvements
  - HFIP participant (R. Fovell, UCLA) diagnosed inconsistencies between Ferrier and GFDL radiation: clouds too transparent to radiation
- DTC worked in coupling Thompson mp and RRTMG radiation
  - Old RRTMG scheme received mixing ratio from Thompson scheme and used assumptions to determine number concentration and particle sizes
  - New RRTMG uses number concentration and particle sizes consistent with Thompson
  - Tested and presented by Thompson et al. at 2013 WRF Workshop
- DTC/EMC designed test plan and DTC conducted test for 2012 season

	Control HC35	Experiment HDTR
Microphysics	Ferrier	**Thompson**
SW/LW radiation	GFDL	**RRTMG**

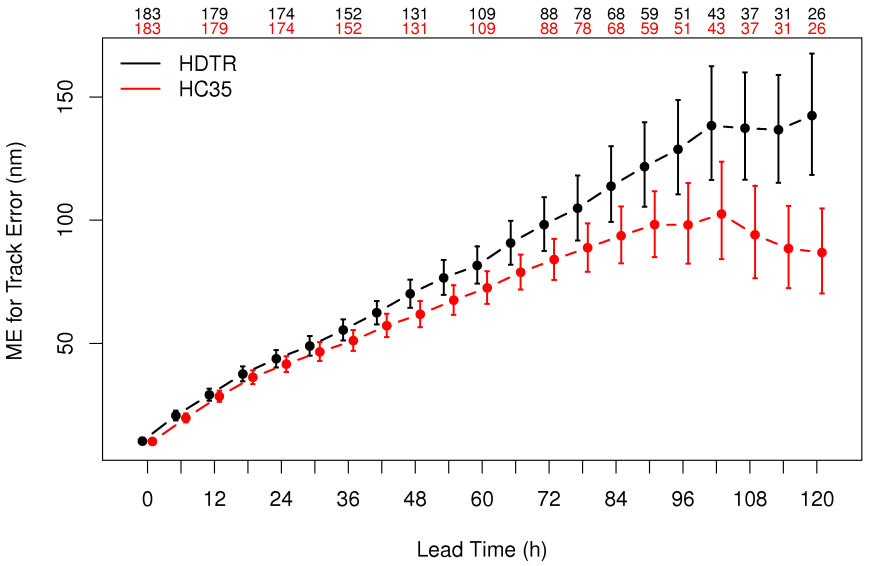
HDTR = Experiment
HC35 = Control

Track error

North Atlantic



Eastern North Pacific

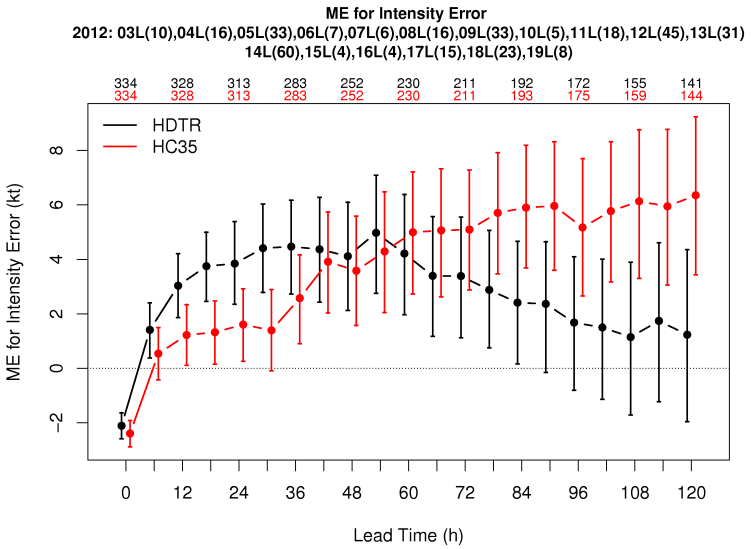


Experimental configuration improves track for AL but degrades for EP

HDTR = Experiment
HC35 = Control

Intensity bias

ATLANTIC



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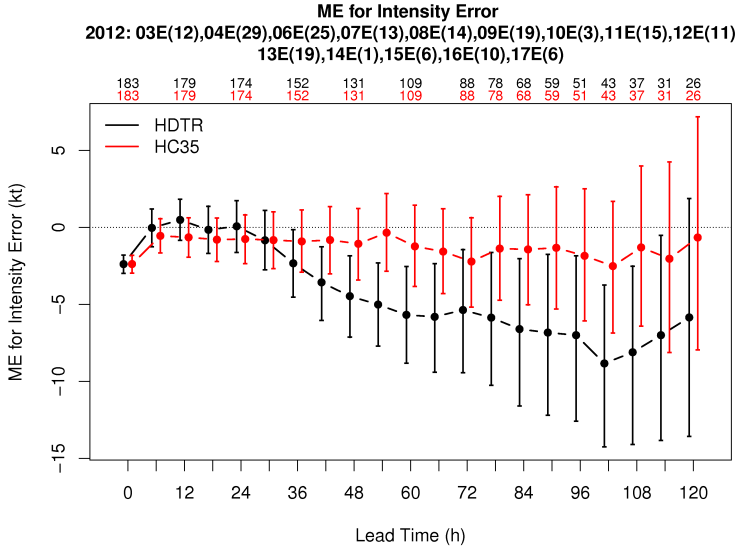
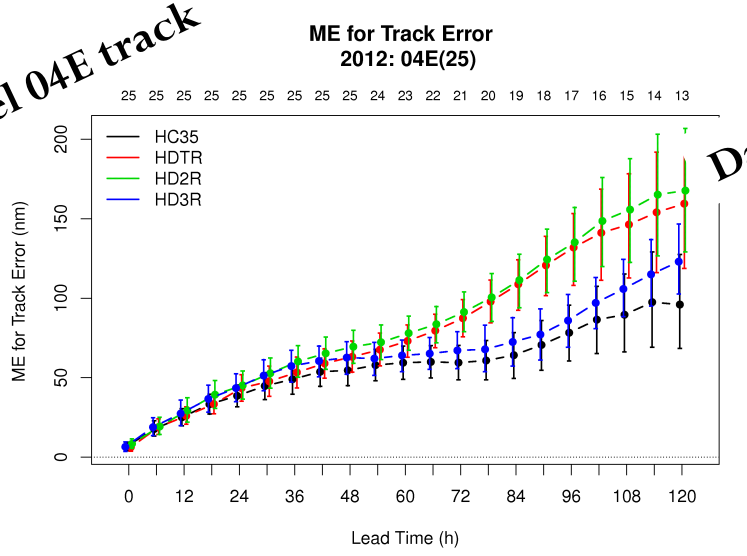


Experiment increases intensity for shorter lead times, decreases for longer lead times

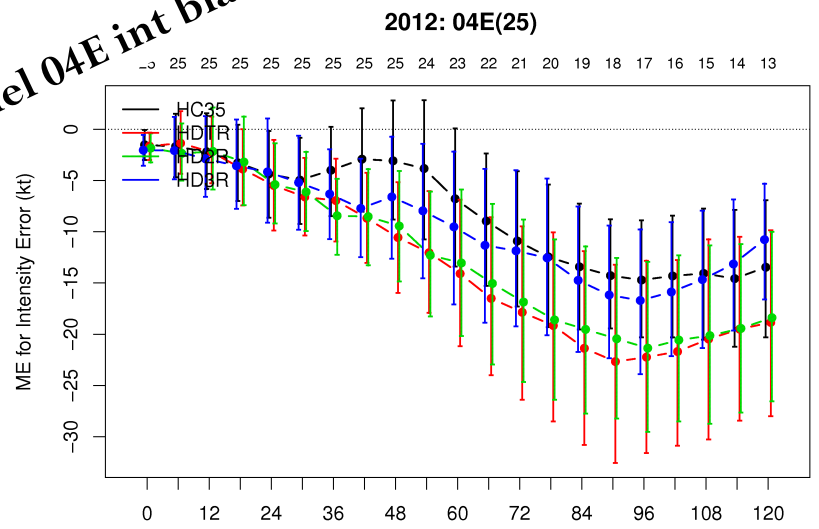
Further analysis

	HC35	HD3R	HD2R	HDTR
Microphysics	Ferrier	Ferrier	**Thompson**	**Thompson**
SW/LW rad	GFDL	**RRTMG**	**RRTMG**	**RRTMG**
Radiation dt	1 h	**15 min**	**15 min**	**4 h**

Daniel 04E track

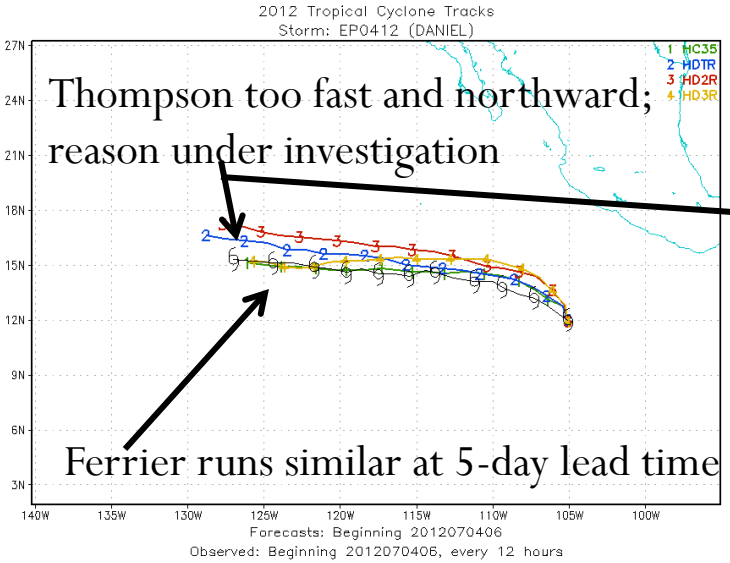


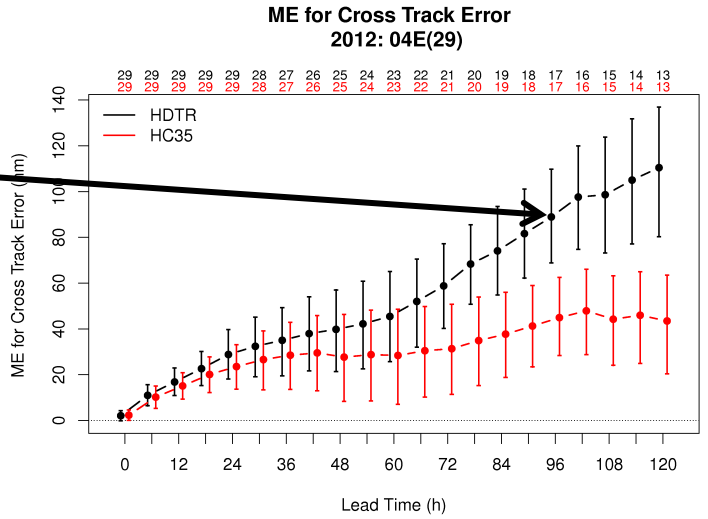
Daniel 04E int bias



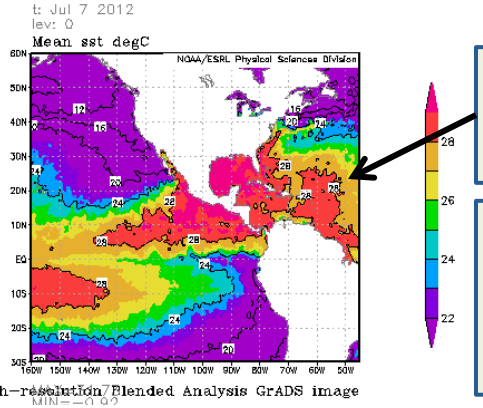
- Control gives the best track and intensity performance
- Changing radiation to RRTMG causes small degradation
- Changing mp to Thompson scheme leads to larger degradation

Case study: Daniel 04E



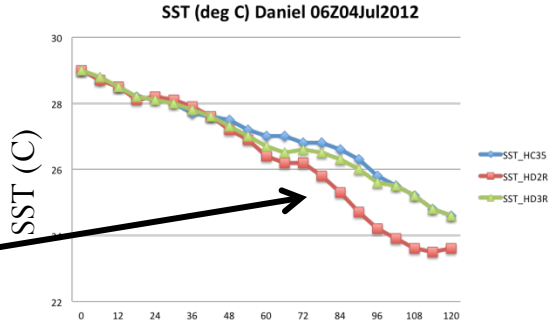


Bulk statistics for Daniel 04E and case study show that Thompson takes track to N



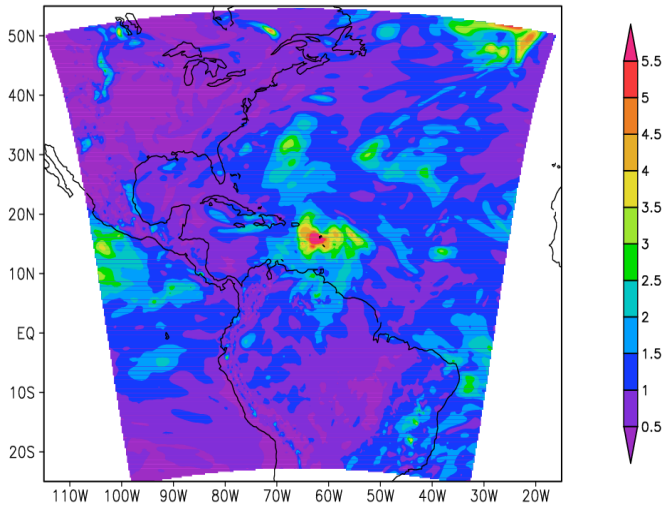
Storms are in area of strong SST gradient

Northern tracks leads to cool SST under storm and low bias

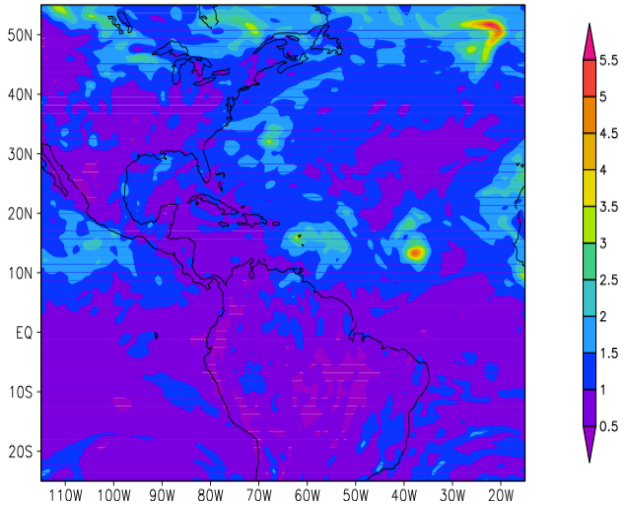


HWRF T&E IV: Initialization highlight

- HWRF uses GFS ensemble in hybrid ensemble-variational data assimilation
- However, GFS ensemble has limited spread in hurricane area
- DTC tested HWRF ensemble for DA



HWRF (20) ensemble spread



GFS (80) ensemble spread

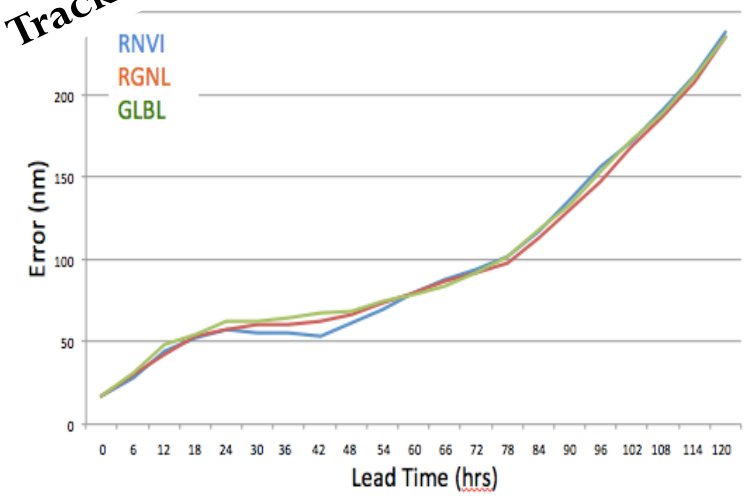
6-h forecast of 850 hPa winds

HWRF ensemble run by DTC using EMC 2013 HWRF experimental ensemble code: model physics perturbation with stochastic convective trigger

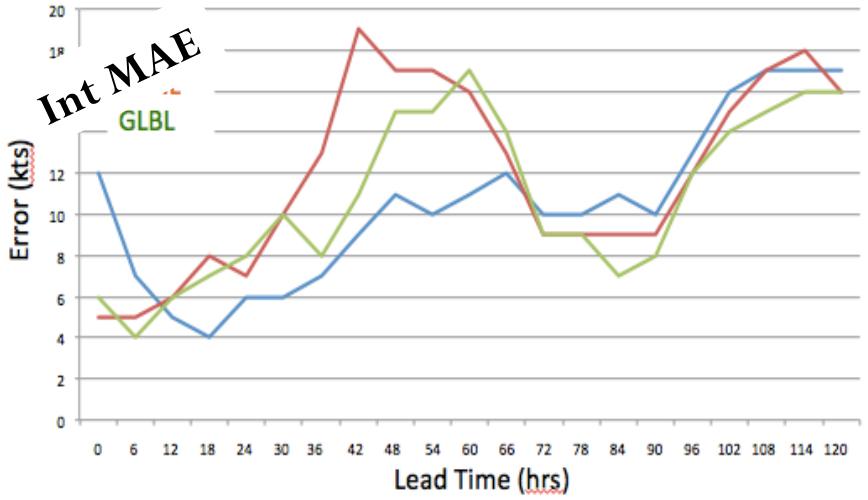
Forecast verification: Isaac 2012

	GLBL	RGNL	RNVI
Ensemble	GFS	**HWRF**	**HWRF**
Vortex init	YES	YES	**NO**

Track error



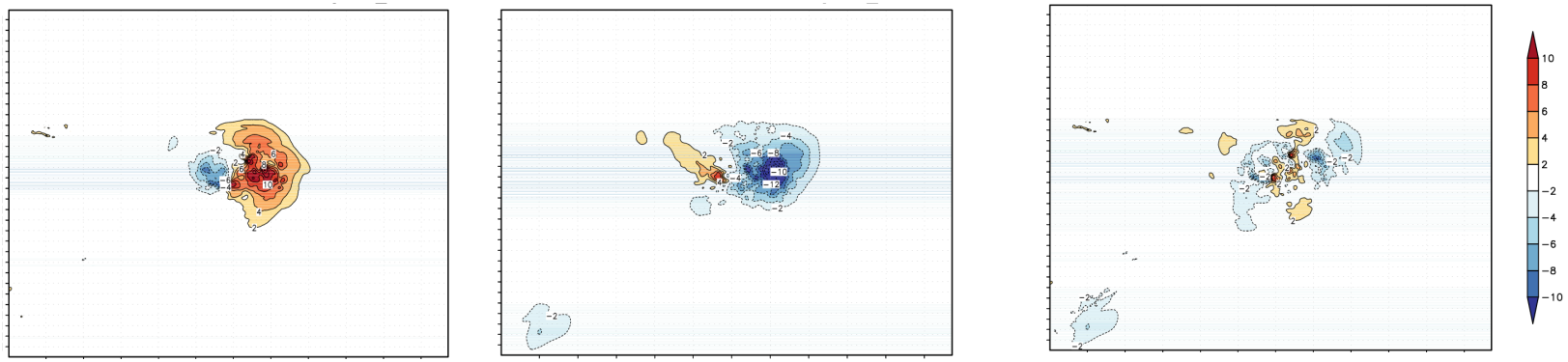
Int MAE



Tracks: No sensitivity
Intensity: increased errors for regional, but some improvement when vortex init is off

Impacts of vortex initialization vs DA

V (m/s) at level 11 – Isaac init 08/23/2012 00 UTC



Vortex init. increments

DA increments

Total adjustments through vor.init. and DA

Background → Vortex initialization → GSI-hybrid → HWRF

For this case, vortex initialization counter-acts with the DA increments in the inner domain.

RGNL, using tail Doppler radar data in GSI

What we do well and challenges

- **HWRF code management and user support are mature and work well**
  - Future migration of HWRF to the NEMS/NMM-B framework require community development and build up of expertise in DTC and academic community
- **Testing and evaluation has partial success**
  - Some test results implemented in operations (e.g., air-sea fluxes)
  - Testing improvements "off the shelf", without specific tuning for HWRF, has not always led to HWRF improvements.
  - Need to partner closely with EMC and community developers to adapt capabilities to HWRF
    - **New in 2014: Work jointly with HFIP PIs in new capabilities for HWRF**