6th NOAA Testbeds and Proving Grounds Workshop
April 15, 2014
Boulder, CO

Transition of Research to the Operational Hurricane WRF model: the Role of the Developmental Testbed Center

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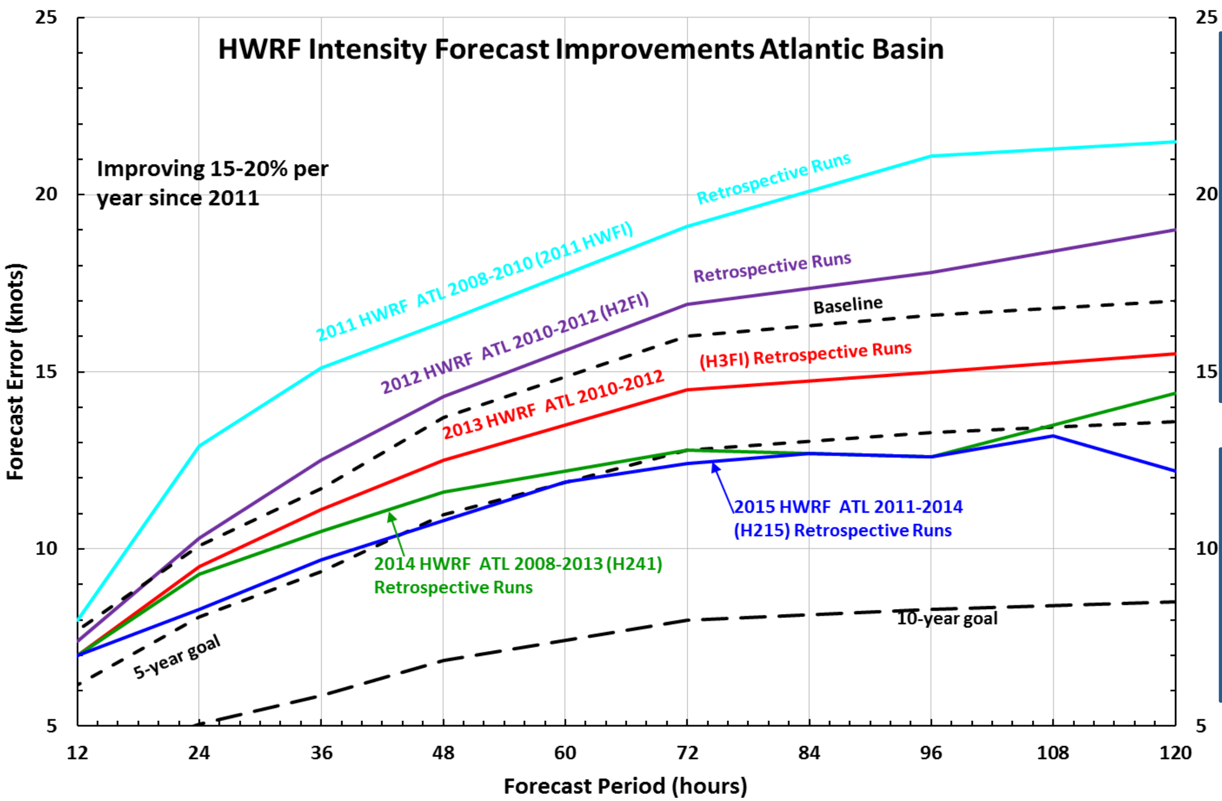
Acknowledgements: URI and at NOAA EMC, AOML/HRD, GFDL, and ESRL

Developmental Testbed Center

Hurricane WRF history

Numerical guidance to National Hurricane Center & Joint Typhoon Warning Center
2007: initial operational implementation
2007-2015: yearly upgrades



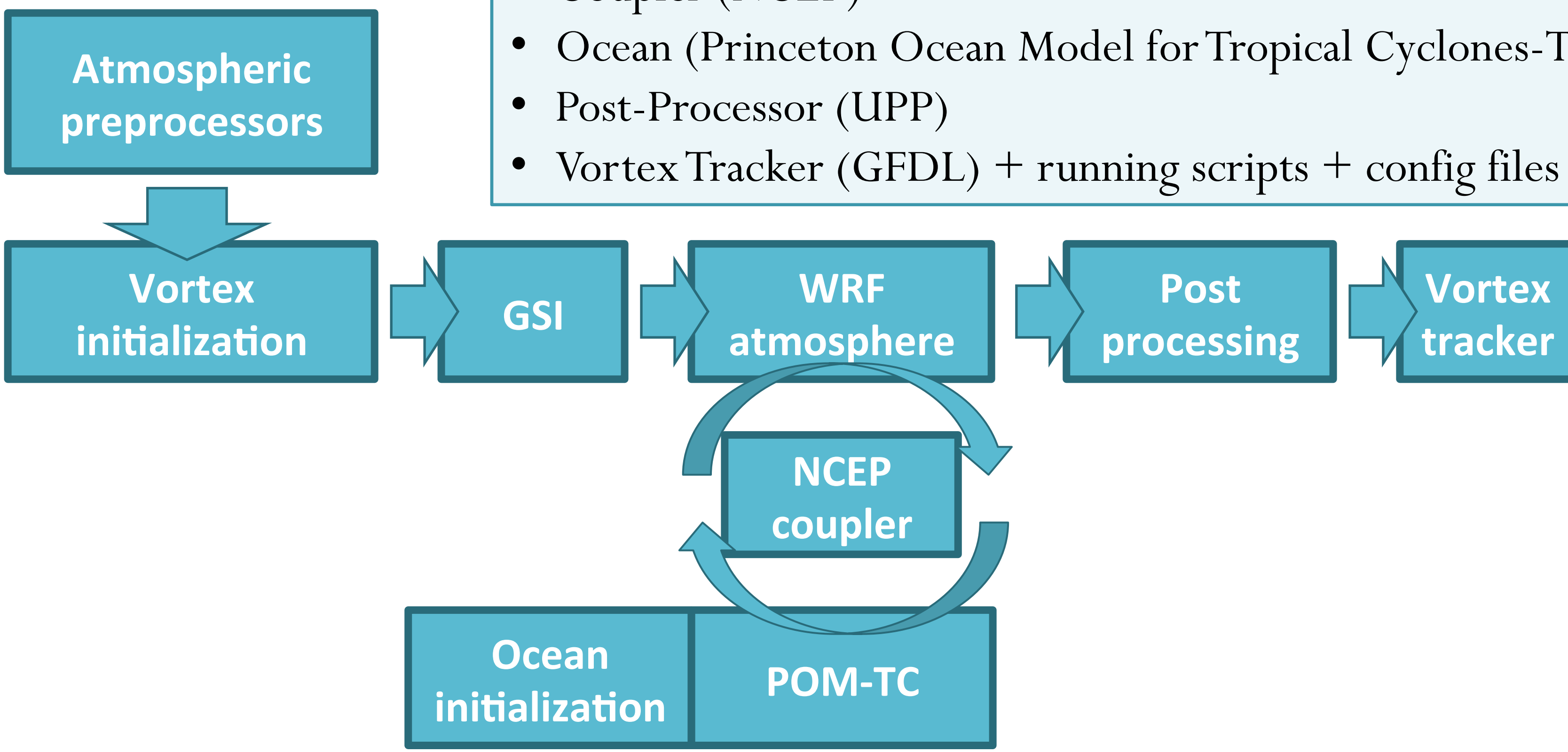
Intensity Errors (kt) in Atl

- Consistent yearly decrease
- Approach 5-y goal of the Hurricane Forecast Improvement Project (HFIP)

What is the role of the Developmental Testbed Center in the process of improving HWRF?

HWRF: a multi-component system with distributed development

- WRF-NMM model (NMM)
- Pre-Processors (WPS and prep_hybrid)
- Vortex initialization
- Data assimilation (Gridpoint Statistical Interpolation)
- Coupler (NCEP)
- Ocean (Princeton Ocean Model for Tropical Cyclones-TC)
- Post-Processor (UPP)
- Vortex Tracker (GFDL) + running scripts + config files



DTC Strategies to promote HWRF R2O

Code Management

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

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

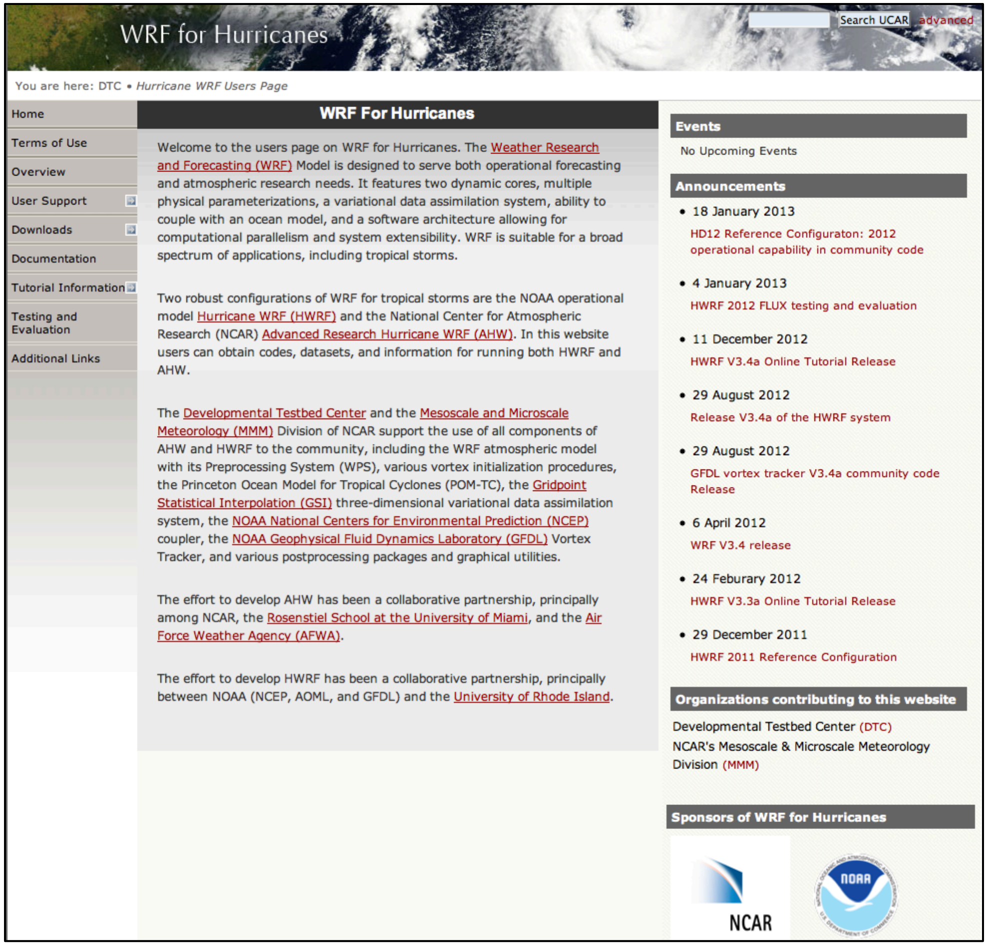
DTC Visitor Program – sample of funded projects involving HWRF

- S. Bao - CCU: - *Evaluation of two HWRF microphysics/radiation configurations with remote sensing*
- R. Yablonsky – URI: *Developing and supporting HWRF ocean coupling with advanced ocean physics and initialization options and new diagnostic tools for comprehensive model evaluation*
- T. Galarneau – NCAR: *Diagnosing tropical cyclone motion forecast errors in the 2014 HWRF Retrospective Test*
- R. Fovell – UCLA: *Improving HWRF track and intensity forecasts via model physics evaluation and tuning*

www.dtcenter.org/HurrWRF/users

www.dtcenter.org/HurrWRF/developers

Support to users and developers



800 registered users

Stable well-tested code downloads, documentation, helpdesk

Yearly releases: current HWRF v3.6a (2014 operational)

Tutorials in 2014

- College Park, MD
- Taiwan

Support to developers

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

DTC's role in HWRF physics development: connecting the pieces

2013

- Fovell (UCLA-HFIP award) diagnoses problems with longwave tendencies in HWRF's operational radiation parameterization (GFDL scheme)
- EMC/DTC tests RRTMG radiation parameterization – poor results

2014

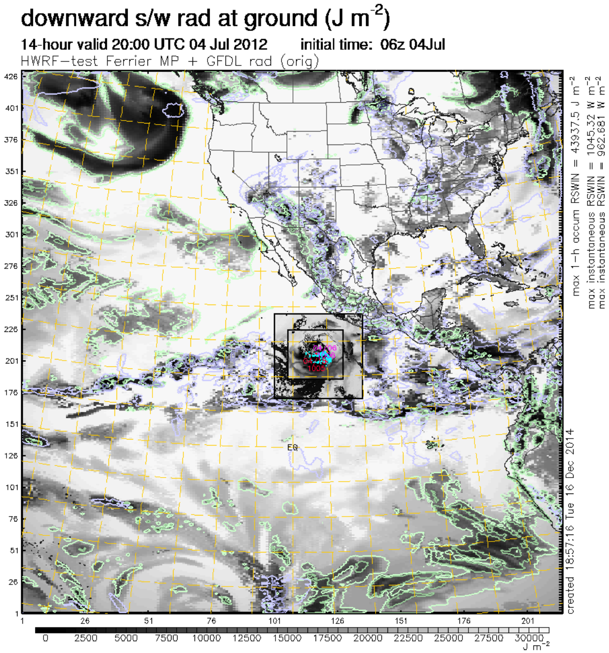
- DTC performs diagnostics, implements subgrid-scale cloudiness scheme to address lack of shortwave attenuation in RRTMG, and tests in several storms
- Fovell (UCLA-DTC visitor) suggests improvements to planetary boundary layer (PBL) physics that complement use of RRTMG radiation

2015

- RRTMG, partial cloudiness, and PBL changes delivered to EMC and included in 2015 operational HWRF

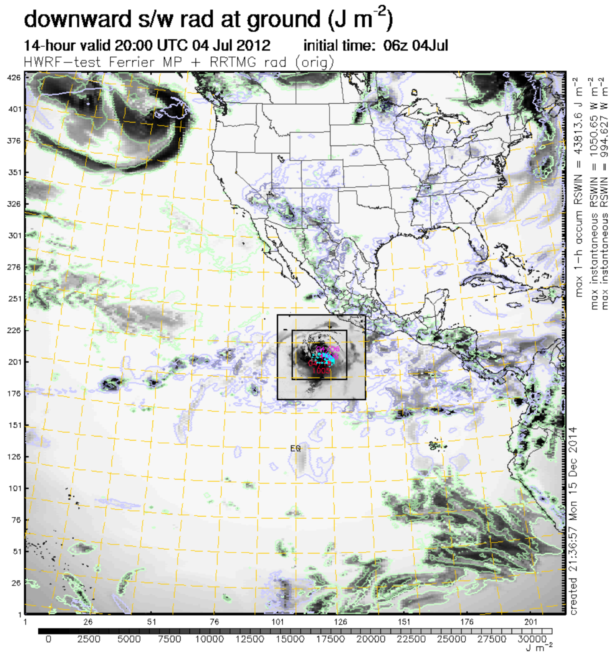
Addressing issues in RRTMG-cloud connection

Ferrier/GFDL radiation



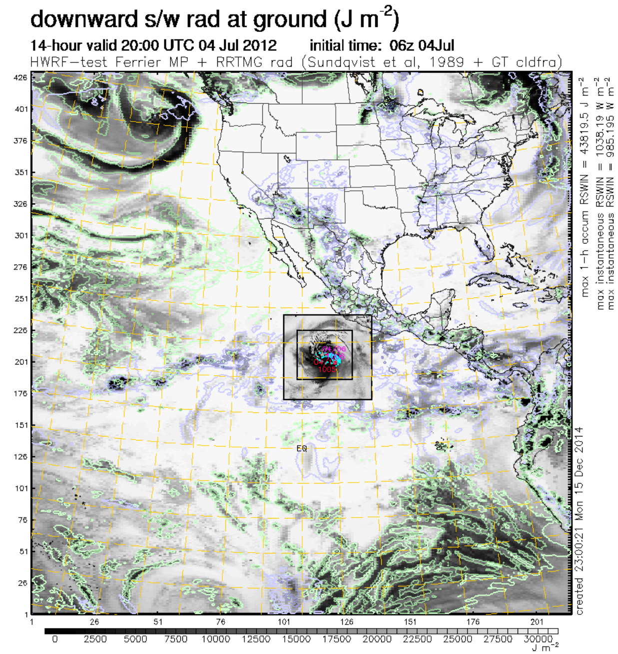
Control: Reasonable SW attenuation but documented problems in LW

Ferrier/RRTMG radiation



Excessive SW radiation reaching surface: SAS clouds transparent to RRTMG radiation and lack of stratus representation

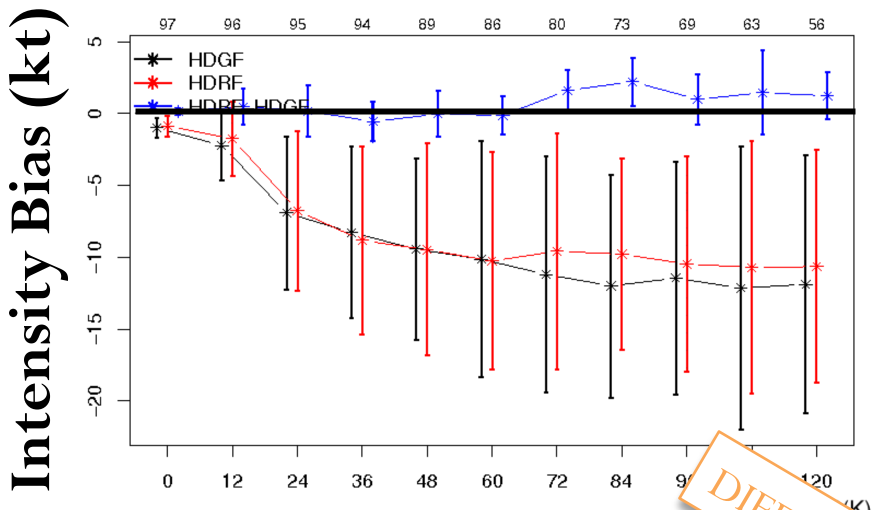
Ferrier/RRTMG/part cloud

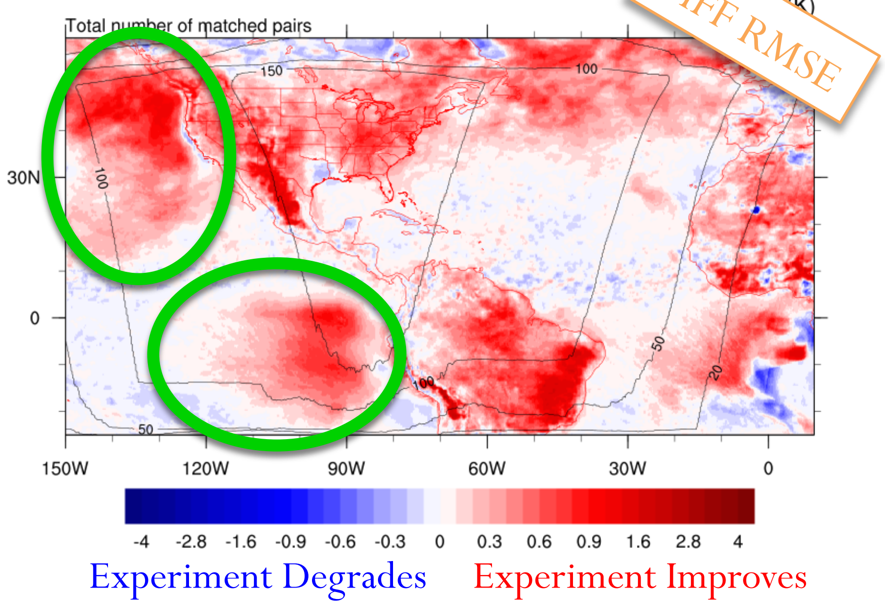


Reasonable SW attenuation with partial cloudiness scheme implemented by DTC

DTC Developmental Testbed Center

Impact of Experiment: RRTMG & Partial Cloudiness test





DTC tested 200 cases in Atl and East Pac

Intensity bias for East Pac reduced 3-5 day
HDGF = control
HDRF=innovation

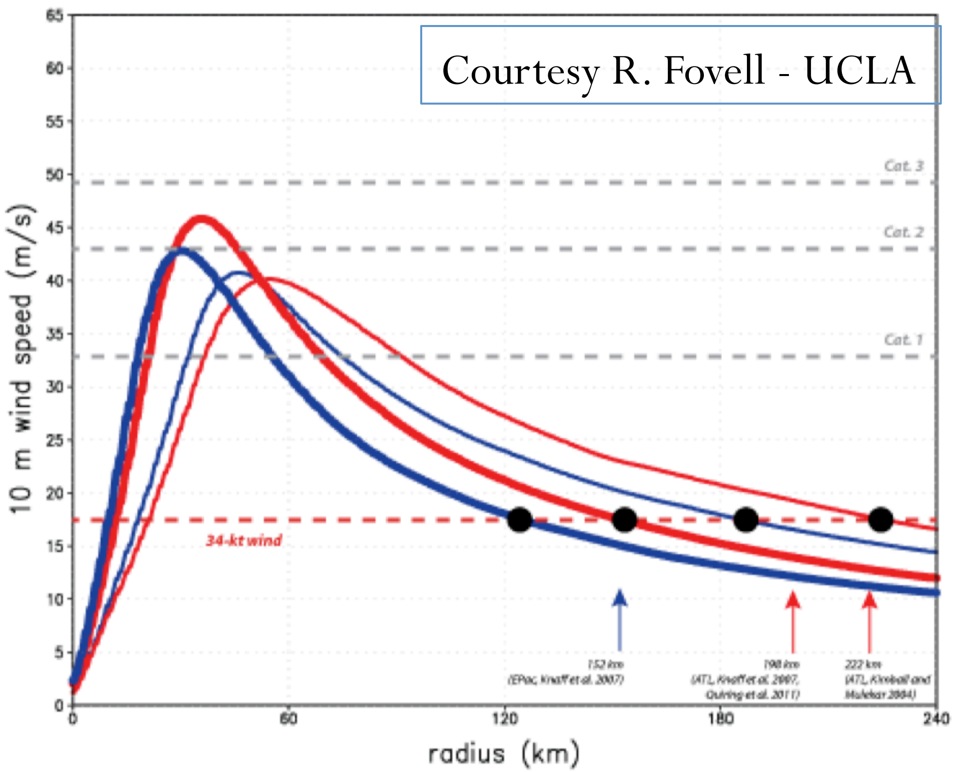
Large scale verification

In addition to verification of track/ intensity, DTC conducted large-scale verification against GFS analyses

Improvements seen in various fields - 1000-hPa T shown here

Included in 2015 operational HWRF

Assisting community with software system contributions – WRF model development



Thin blue: GFDL radiation & mix ↑
Thin red: RRTMG radiation & mix ↑
Thick blue: GFDL radiation & mix ↓
Thick red: RRTMG radiation & mix ↓

Both vertical mixing and cloud-radiation parameterization affect storm size, which influence motion

Rob Fovell UCLA contributed changes to the vertical mixing (PBL) to improve storm size and motion

Variable α parameter modulates eddy diffusion coefficient based on observations provided by AOML HRD

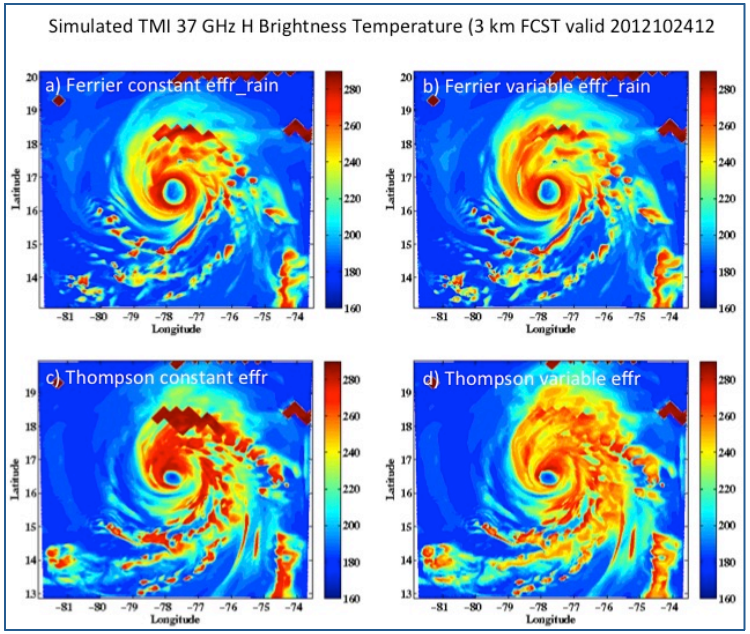
Included in 2015 operational HWRF

Assisting community with software system contributions – innovations in postprocessing

- J. Otkin's team at U. Wisconsin CIMSS (HFIP grant) have added innovations to UPP – the NCEP Unified Post Processor, used by all NCEP models
- DTC's role
  - Connect developers with UPP and CRTM developers at NCEP for planning
  - Assist U. Wisconsin with incorporating developments into HWRF code repository

- Added sensors for synthetic satellite images
  - GOES-13 and GOES-15 imagers, channels 2-5
  - (MSG) SEVIRI imager , channels 5-11
  - (F13-15) SSMI, channels 1,2,4,5,6,7
  - (F16-F20) SSMIS, channels 9,12,13,15,16,17,18
- Improved computation of hydrometeor effective radii
- User configuration files simplified

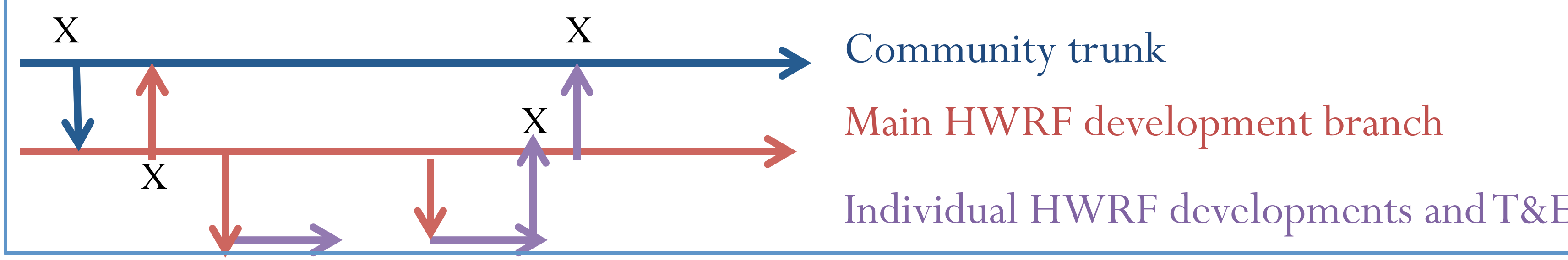
Included in 2015 operational HWRF



Courtesy J. Otkin – U. Wisconsin

HWRF IT infrastructure to support development

<u>HWRF Code Management</u>: repository (housed at DTC) is a single code base for all developers – allows NOAA to benefit from external collaborators



<u>HWRF scripts redeveloped by EMC and DTC in OO Python</u>

Workflow customization
- run_ocean = [yes, no]
- run_gsi = [yes, no]

Component customization
- Grid spacing and vert levels
- Physics suite

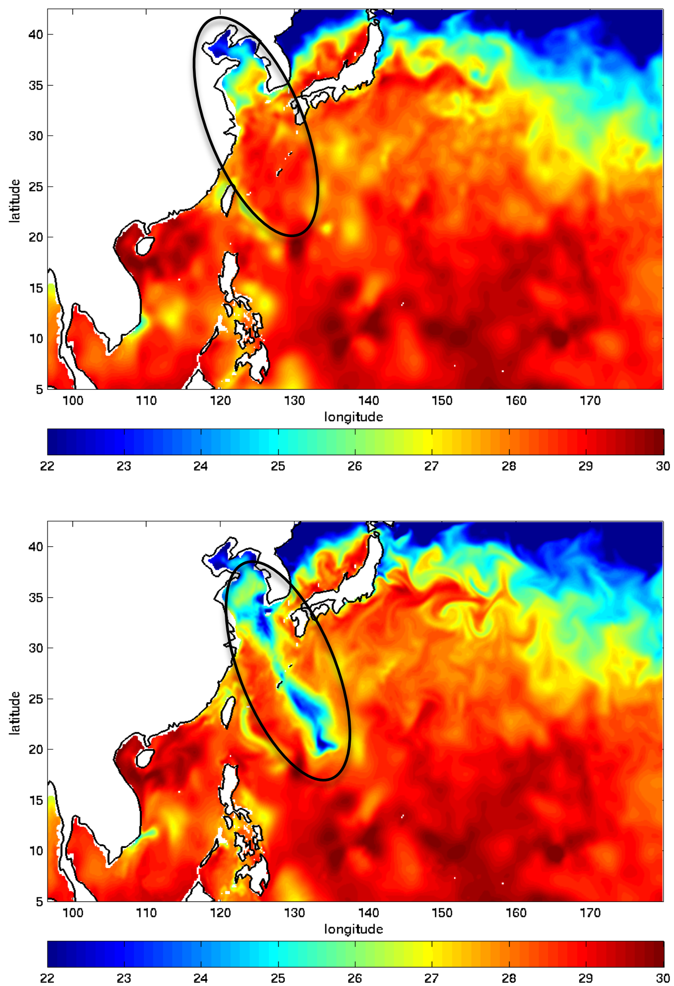
Input data customization
- Fetch from mass store or disk
- Use GFS v2012 or GFS v2015

Included in 2015 operational HWRF

Courtesy R. Yablonsky - URI

A flexible HWRF system for research

SST at t=0 (top) and t=5 days (bottom)



More research means more potential for R2O

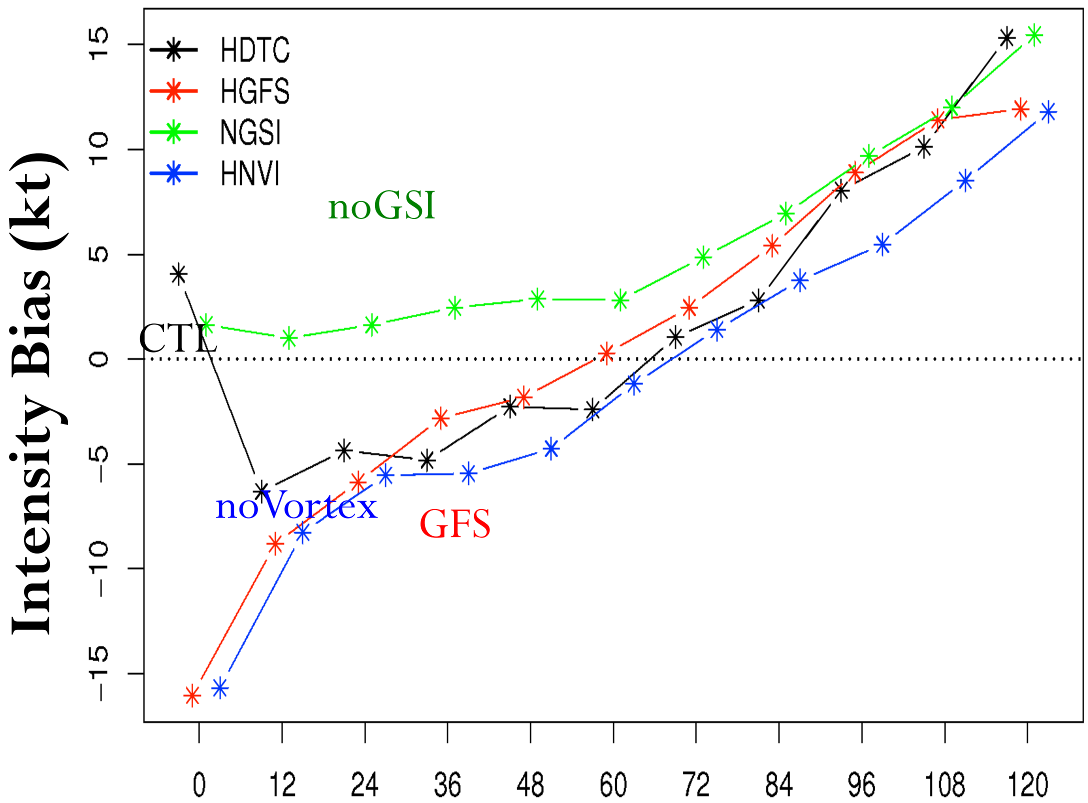
Example: HWRF ocean model (POM-TC)

Funding provided by the DTC Visitor Program enabled the transition of alternate ways of initializing the ocean. Shown here is a HWRF simulation of Supertyphoon Bolaven initialized from NCODA.

Large SST cooling only possible with an ocean model. Large potential to impact storm intensity

Now in HWRF trunk and available to all developers

In depth investigation at DTC – looking ahead to future contributions



HDTC: control as 2014 oper
(Uses DA and vortex init)
Spin down in first 6 hours. Why?

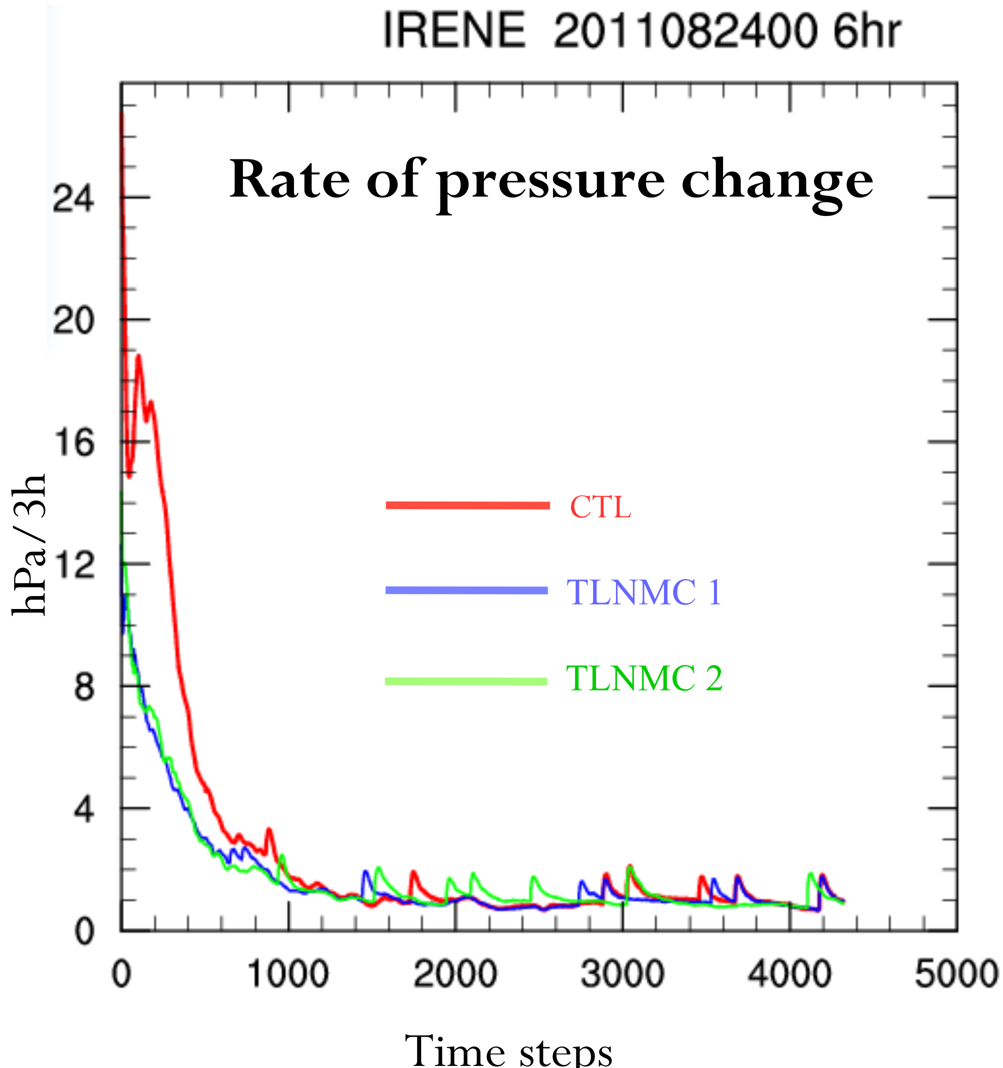
No DA, Yes vortex - NGSI
Improved bias

Yes DA, No vortex - HNVI
No spin down, but low bias

No DA, No vortex - HGFS
No spin down, but low bias

- Spin down only occurs when both DA and vortex initialization present
- Points to an imbalance introduced by DA, which is done after the vortex init

Improving balance in data assimilation



Control (CTL)

Large pressure fluctuations in beginning of simulation

TLNMC

Two options in **Tangent Linear Normal Mode Constraint** applied led to improvement in balance in initial fields

Ongoing additional tests show promising results

Summary: Kudos and challenges

- **Kudos**
  - HWRF code management and user support are mature and work well
  - Transition of new capabilities very successful in 2015
    - R2O of innovations developed and/or tested by DTC
      - RRTMG, partial clouds, Python scripts
    - R2O of community contributions through DTC : PBL and UPP changes
    - New research capabilities (ocean)
  - Also working on new capabilities for 1-3 years ahead
  - Effective partnership with HFIP – funding developers/DTC helps
- **Challenges**
  - Future migration of HWRF to the NEMS/NMM-B framework require community development and build up of expertise
  - Remaining effective in R2O for a very complex modeling system with limited resources at DTC