

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

Ligia Bernardet^{1*%}, V. Tallapragada², C. Holt^{1*%}, S. Trahan^{2&},

M. Biswas^{3%}, L. Carson^{3%}, H. Shao^{3%}, C. Zhou^{3%}

¹NOAA ESRL Global Systems Division, Boulder CO

²NOAA NCEP EMC, College Park, MD

³National Center for Atmospheric Research, Boulder, CO

*University of Colorado CIRES , Boulder CO

&I. M. Systems Group, Inc., Rockville, MD

%Developmental Testbed Center



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

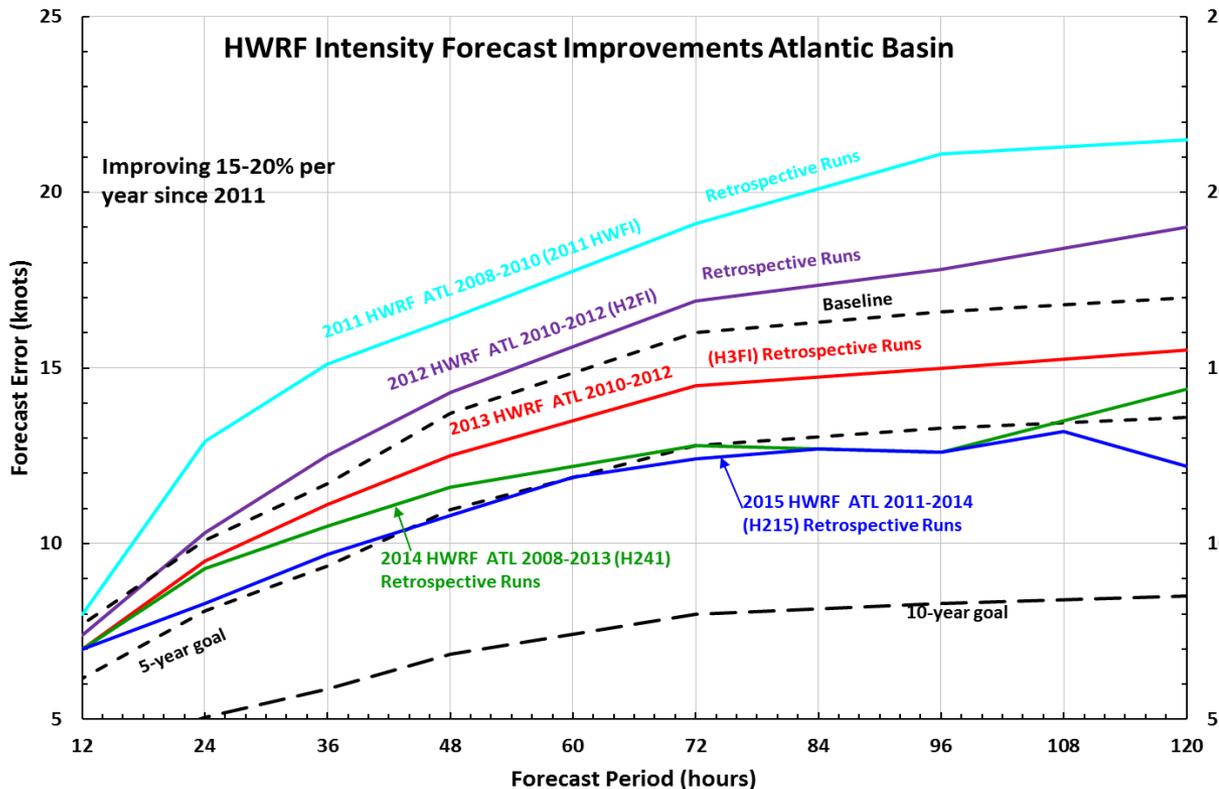
Developmental Testbed Center

Hurricane WRF history

Numerical guidance to National Hurricane Center & Joint Typhoon Warning Center

2007: initial operational implementation

2007-2015: yearly upgrades



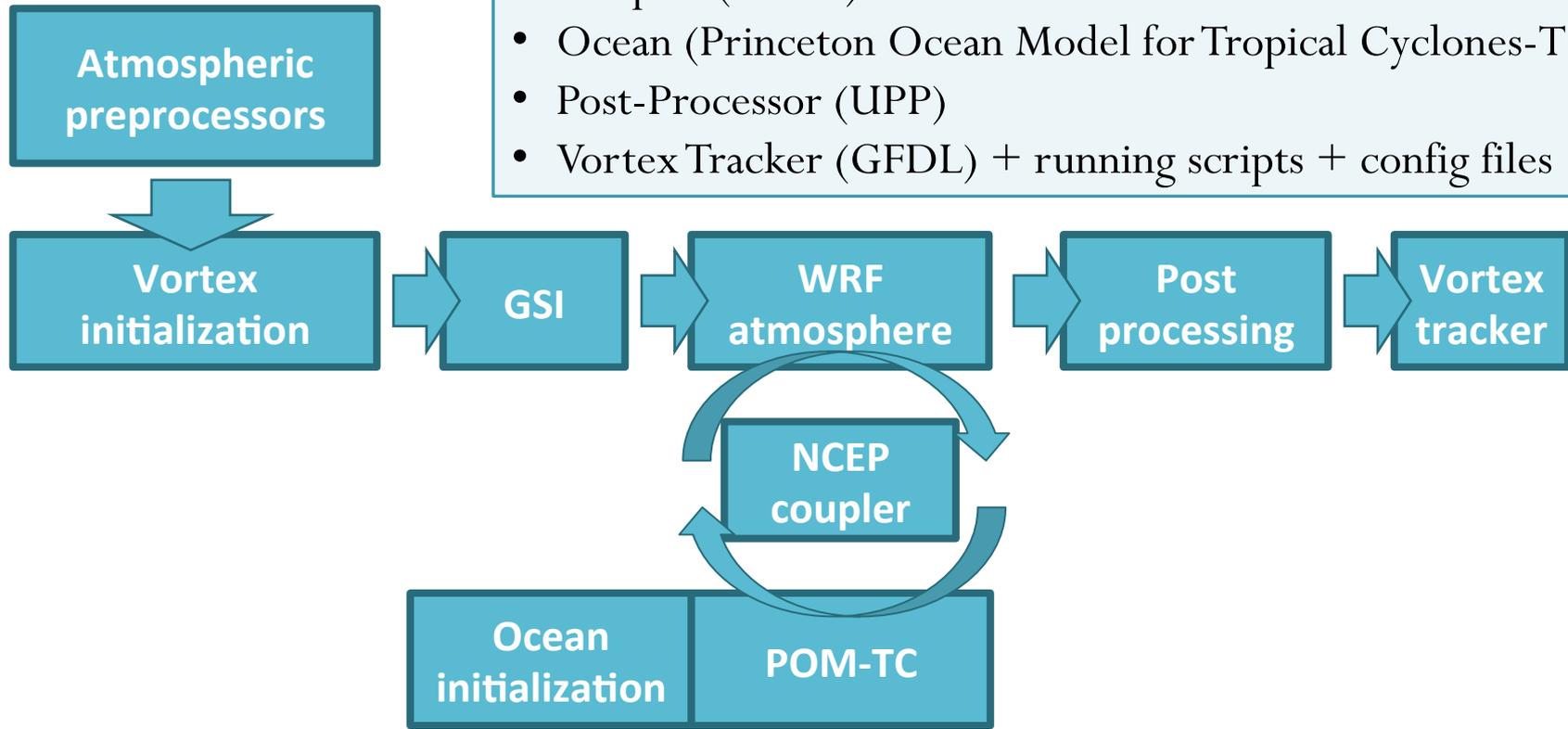
Intensity Errors (kt) in Atl

- 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 R20

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*

Support to users and developers

WRF for Hurricanes

You are here: DTC • Hurricane WRF Users Page

Home **WRF For Hurricanes**

Terms of Use

Overview

User Support

Downloads

Documentation

Tutorial Information

Testing and Evaluation

Additional Links

Welcome to the users page on WRF for Hurricanes. The [Weather Research and Forecasting \(WRF\)](#) Model is designed to serve both operational forecasting and atmospheric research needs. It features two dynamic cores, multiple physical parameterizations, a variational data assimilation system, ability to couple with an ocean model, and a software architecture allowing for computational parallelism and system extensibility. WRF is suitable for a broad spectrum of applications, including tropical storms.

Two robust configurations of WRF for tropical storms are the NOAA operational model [Hurricane WRF \(HWRF\)](#) and the National Center for Atmospheric Research (NCAR) [Advanced Research Hurricane WRF \(AHW\)](#). In this website users can obtain codes, datasets, and information for running both HWRF and AHW.

The [Developmental Testbed Center](#) and the [Mesoscale and Microscale Meteorology \(MMM\)](#) Division of NCAR support the use of all components of AHW and HWRF to the community, including the WRF atmospheric model with its Preprocessing System (WPS), various vortex initialization procedures, the Princeton Ocean Model for Tropical Cyclones (POM-TC), the [Gridpoint Statistical Interpolation \(GSI\)](#) three-dimensional variational data assimilation system, the [NOAA National Centers for Environmental Prediction \(NCEP\)](#) coupler, the [NOAA Geophysical Fluid Dynamics Laboratory \(GFDL\)](#) Vortex Tracker, and various postprocessing packages and graphical utilities.

The effort to develop AHW has been a collaborative partnership, principally among NCAR, the [Rosenstiel School at the University of Miami](#), and the [Air Force Weather Agency \(AFWA\)](#).

The effort to develop HWRF has been a collaborative partnership, principally between NOAA (NCEP, AOML, and GFDL) and the [University of Rhode Island](#).

Events

No Upcoming Events

Announcements

- 18 January 2013
[HD12 Reference Configuration: 2012 operational capability in community code](#)
- 4 January 2013
[HWRF 2012 FLUX testing and evaluation](#)
- 11 December 2012
[HWRF V3.4a Online Tutorial Release](#)
- 29 August 2012
[Release V3.4a of the HWRF system](#)
- 29 August 2012
[GFDL vortex tracker V3.4a community code Release](#)
- 6 April 2012
[WRF V3.4 release](#)
- 24 February 2012
[HWRF V3.3a Online Tutorial Release](#)
- 29 December 2011
[HWRF 2011 Reference Configuration](#)

Organizations contributing to this website

Developmental Testbed Center (DTC)
NCAR's Mesoscale & Microscale Meteorology Division (MMM)

Sponsors of WRF for Hurricanes

NCAR

NOAA

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

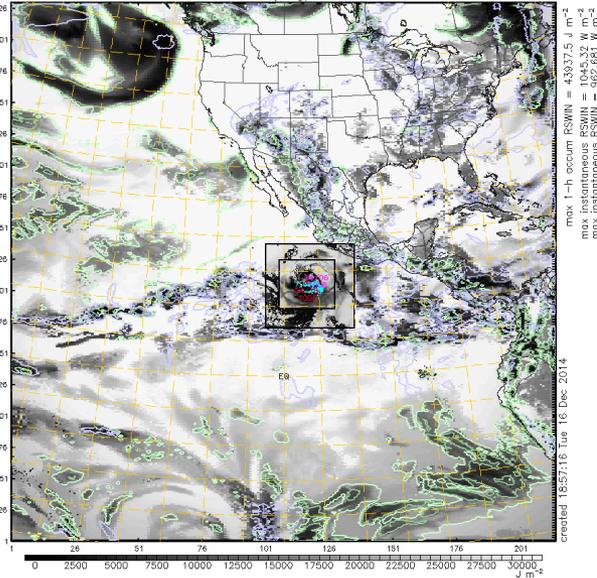
- RRTMG, partial cloudiness, and PBL changes delivered to EMC and included in 2015 operational HWRF

Addressing issues in RRTMG-cloud connection

Ferrier/GFDL radiation

downward s/w rad at ground ($J m^{-2}$)

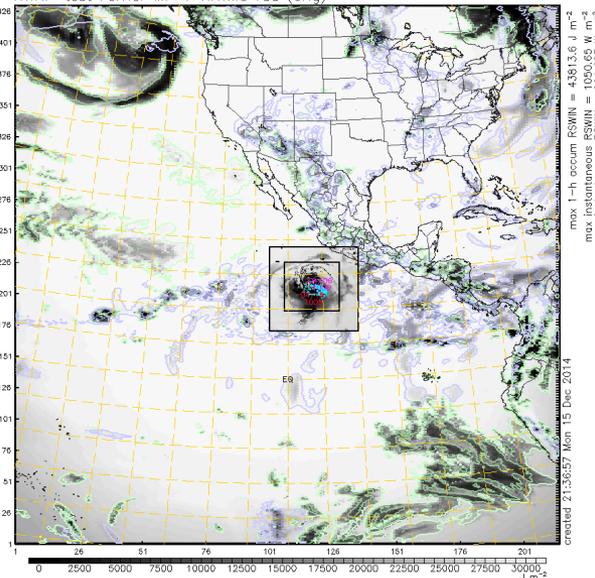
14-hour valid 20:00 UTC 04 Jul 2012 initial time: 06z 04Jul
HWRF-test Ferrier MP + GFDL rad (orig)



Ferrier/RRTMG radiation

downward s/w rad at ground ($J m^{-2}$)

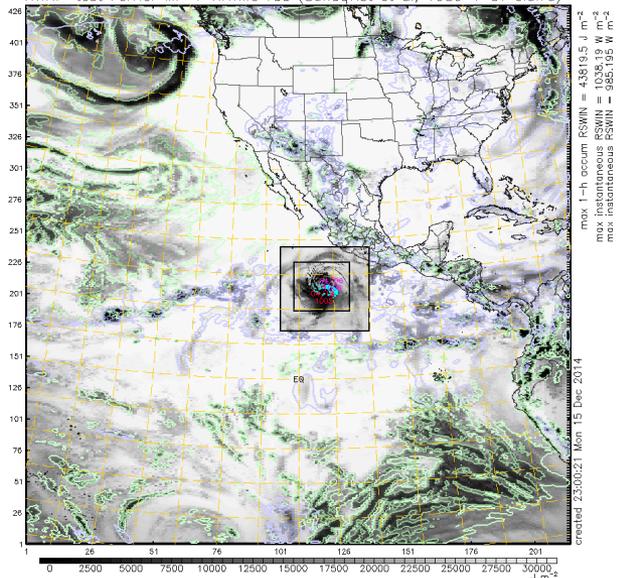
14-hour valid 20:00 UTC 04 Jul 2012 initial time: 06z 04Jul
HWRF-test Ferrier MP + RRTMG rad (orig)



Ferrier/RRTMG/part cloud

downward s/w rad at ground ($J m^{-2}$)

14-hour valid 20:00 UTC 04 Jul 2012 initial time: 06z 04Jul
HWRF-test Ferrier MP + RRTMG rad (Sundqvist et al, 1989 + GT cldfro)



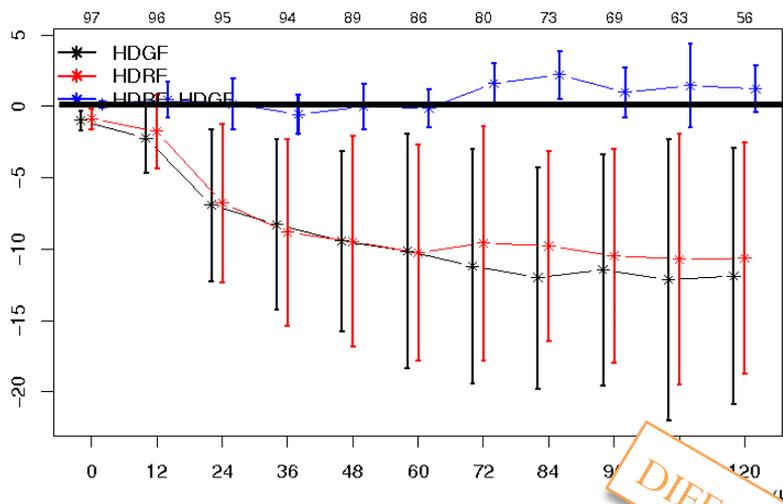
Control: Reasonable SW
attenuation but documented
problems in LW

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

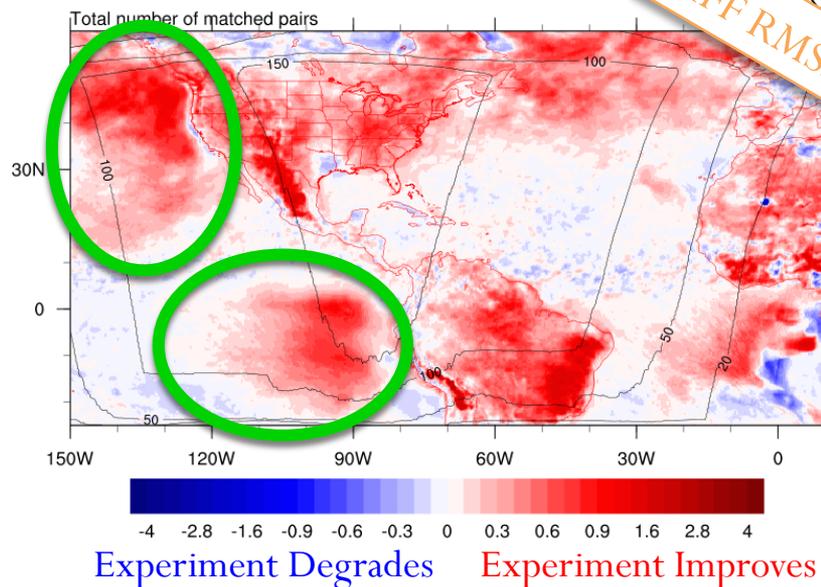
Reasonable SW attenuation
with partial cloudiness
scheme implemented by
DTC

Impact of Experiment: RRTMG & Partial Cloudiness test

Intensity Bias (kt)



DIFF RMSE



DTC tested 200 cases in Atl and East Pac

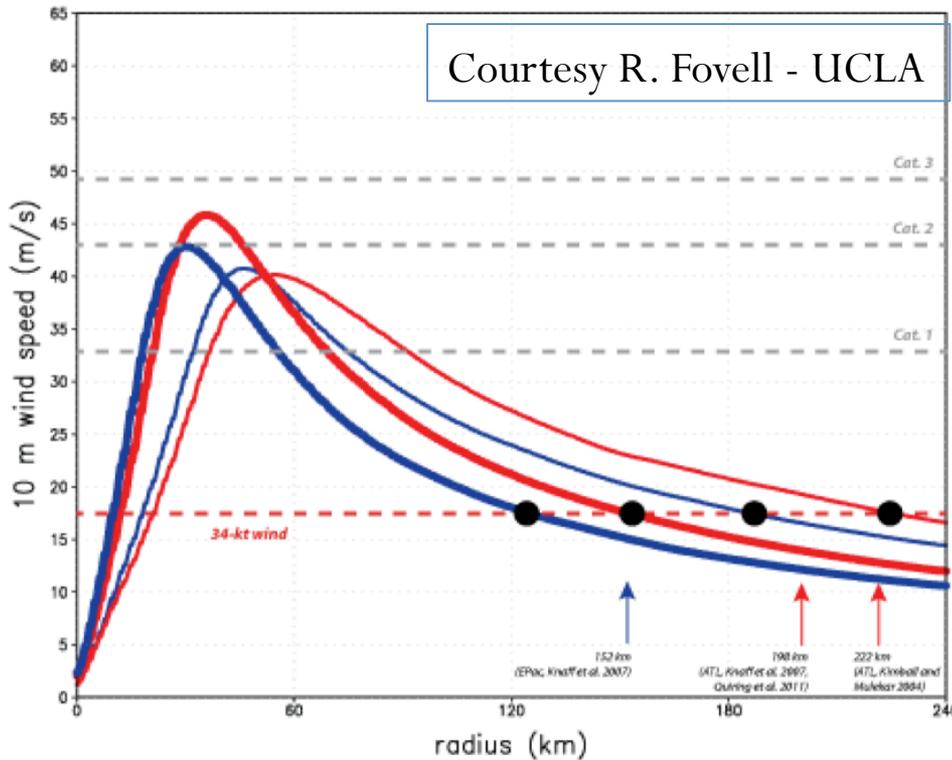
Intensity bias for East Pac reduced 3-5 day
HDGF = control
HDRF=innovation

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



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

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

Included in 2015 operational HWRF

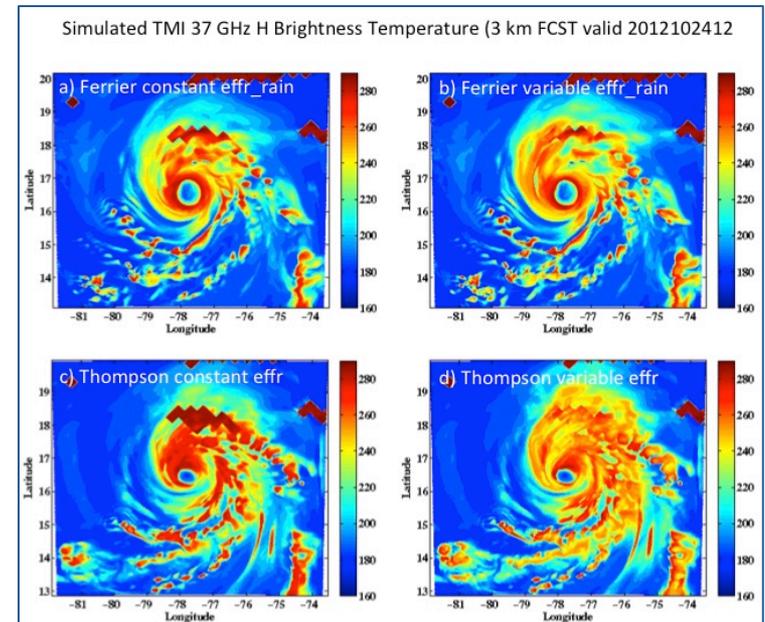


Assisting community with software system contributions – innovations in postprocessing

- 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

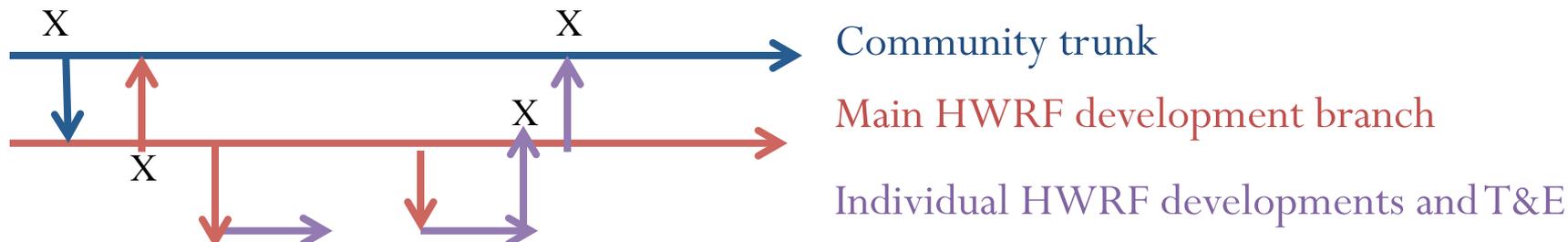
Included in 2015 operational HWRF



Courtesy J. Otkin – U. Wisconsin

HWRF IT infrastructure to support development

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



HWRF scripts redeveloped by EMC and DTC in OO Python

Workflow customization

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

Component customization

- Grid spacing and vert levels
- Physics suite

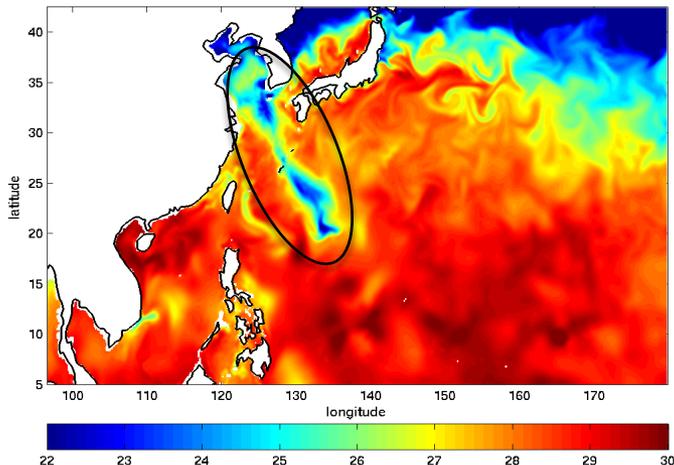
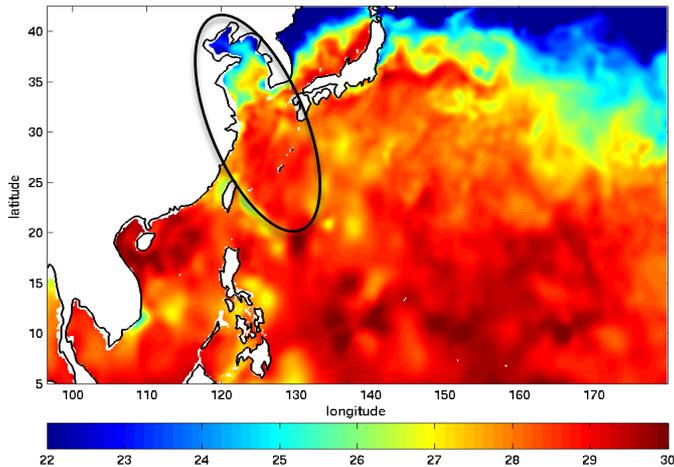
Input data customization

- Fetch from mass store or disk
- Use GFS v2012 or GFS v2015

Included in 2015 operational HWRF

A flexible HWRF system for research

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



More research means more potential for R2O

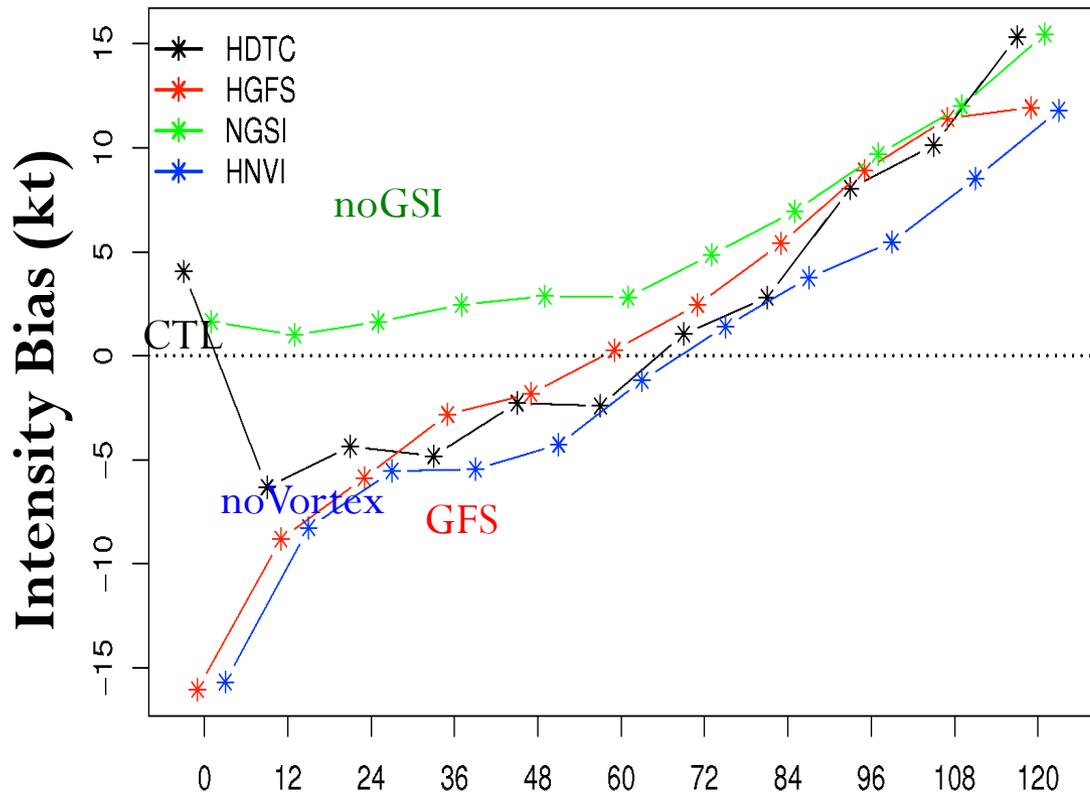
Example: HWRF ocean model (POM-TC)

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

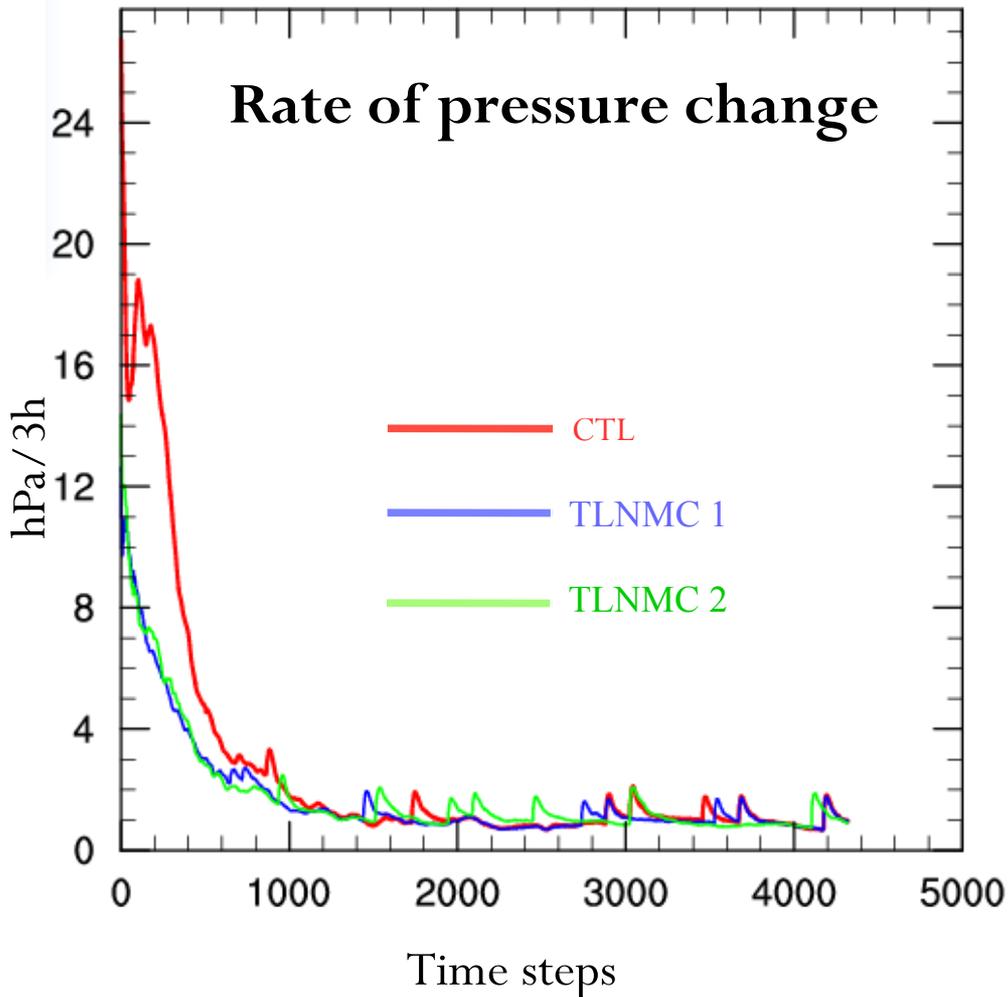
Yes DA, No vortex - HNVI
No spin down, but low bias

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

IRENE 2011082400 6hr



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