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

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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

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

Ferrier/RRTMG radiation
- Reasonable SW attenuation with partial cloudiness scheme implemented by DTC

Ferrier/RRTMG/part cloud
- Control: Reasonable SW attenuation but documented problems in LW
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

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 $\alpha$ parameter modulates eddy diffusion coefficient based on observations provided by AOML HRD.

Included in 2015 operational HWRF.

- Thin blue: GFDL radiation & mix
- Thin red: RRTMG radiation & mix
- Thick blue: GFDL radiation & mix
- Thick red: RRTMG radiation & mix

Courtesy R. Fovell - UCLA

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

Simulated TMI 37 GHz Brightness Temperature [3 km FCST valid 2012102412]

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

- Community trunk
- Main HWRF development branch
- Individual HWRF developments and T&E

**HWRF scripts redeveloped by EMC and DTC in OO Python**

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

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

**Component customization**
- Grid spacing and vert levels
- Physics suite

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

- 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

Graph:
- **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

- CTL
- noGSI
- GFS
- noVortex

Intensity Bias (kt)
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