Pre-implementation T&E of proposed upgrades for 2013 HWRF

Young C. Kwon, Vijay Tallapragada and HWRF team

HFIP telecon 04/10/2013
Features of Planned 2013 HWRF upgrades

**Infrastructure upgrades:**
- Upgrade the *nest tracking algorithm* based on NCEP tracker
- Re-design of *nest-parent interpolations* for improved treatment of nest boundaries
- **Increased frequency of physics calls** (from 180 sec. to 30 sec.) and **increased size of the third domain** (from 5°x5.5° to 6°x6.5°)

**Data Assimilation and Vortex Initialization upgrades:**
- Implement HWRF GSI V3.2 *one-way hybrid EnKF-3DVAR data assimilation* with GDAS forecasts as first guess and 80-member GFS EnKF forecasts for ensemble covariances, assimilation of all conventional data and provision to assimilate real-time inner-core TDR/ FL/SFMR/Dropsonde recon datasets
- **Improved storm size correction** in the vortex initialization, *modified filter domain* and use of GFS vortex when the storm is weaker than 16 m/s

**Physics upgrades:**
- **Modifications to GFS PBL** to allow the critical Richardson number vary with stability and wind speeds and *bug fix for GFDL radiation*
- *Implementation of Meso-SAS convection scheme and RRTM-G radiation scheme (withdrawn from 2013 implementation plans)*

**Ocean upgrades:**
- **Removal of flux truncation** from HWRF to POM
- *Trans-Atlantic/East Pacific 3D MPI-POM (withdrawn from 2013 implementation plans)*
## 2013 HWRF pre-implementation test plan

<table>
<thead>
<tr>
<th></th>
<th>Baseline (H130)</th>
<th>Physics upgrades</th>
<th>Combined (H213=H131)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Revised init/GSI, New nest parent interpolations, Radiation bug fix, Revised nest movement, Increased frequency of Physics calls</td>
<td>PBL(H131)</td>
<td>Meso-SAS (H132)</td>
</tr>
<tr>
<td><strong>Person</strong></td>
<td>Qingu, In-Hyuk Sam Trahan Mingjing, Young</td>
<td>Baseline + Variable Ric</td>
<td>Meso SAS</td>
</tr>
<tr>
<td><strong>Cases</strong></td>
<td>Whole 2011 and 2012 storms and some 2010 storms</td>
<td>Whole 2011 and 2012 storms and some 2010 storms</td>
<td>Whole 2011 and 2012 storms and some 2010 storms</td>
</tr>
</tbody>
</table>
## 2013 HWRF pre-implementation Test Plan

<table>
<thead>
<tr>
<th>EXP</th>
<th>Description</th>
<th>Comments</th>
<th>Platform/# of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-Baseline Experiments</strong></td>
<td></td>
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</tr>
<tr>
<td>TDRP</td>
<td>FY12 HWRF + One-Way Hybrid GSI</td>
<td>Run in real-time during 2012 hurricane season (Stream 2.0 Demo). Also included real-time TDR data for 19 cases.</td>
<td>CCS, All 2012 ATL and EP 821 cases</td>
</tr>
<tr>
<td>HDFL</td>
<td>FY12 HWRF + Flux truncation into POM</td>
<td>DTC performed these tests to evaluate the impact of 25% reduction of heat, momentum and radiative fluxes in the operational coupled HWRF-POM</td>
<td>Jet, All 2012 ATL and EP 821 cases</td>
</tr>
<tr>
<td>P160</td>
<td>FY12 HWRF + Initialization Changes</td>
<td>Improved size correction, modifications to filter domain and use GFS vortex when initial storm intensity less than 16 m/s</td>
<td>Jet, All 2012 ATL and EP 821 cases</td>
</tr>
<tr>
<td>HNPI</td>
<td>FY12 HWRF + New nest-parent interpolations</td>
<td>Revised nest-parent interpolations and improved treatment of variables at nest boundaries</td>
<td>Jet, All 2012 ATL and EP and 6 others from 2010-11; 988 cases</td>
</tr>
<tr>
<td>HNTT</td>
<td>HNPI + New nest movement algorithm</td>
<td>Improved nest tracking based on membrane MSLP and Tim’s tracker. Choice of 8 storms that had difficulty tracking the nest properly</td>
<td>Jet, 8 Selected storms 168 cases</td>
</tr>
<tr>
<td>HHPC</td>
<td>FY12 HWRF + High Frequency Physics Calls</td>
<td>Increased Physics calling frequency from 180 sec. to 30 sec. Third nest size increased by about 20% from 5.5x5 to 7x6.5</td>
<td>Jet, A few selected storms from 2012; 100 cases</td>
</tr>
<tr>
<td><strong>Baseline Experiment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H130</td>
<td>All modifications from pre-baseline experiments</td>
<td>2013 HWRF baseline is based on positive outcome from the pre-baseline experiments described above. Run on three different platforms.</td>
<td>Jet/Zeus/WCOSS, All 2010-2011-2012 ATL and EP 1870 cases each</td>
</tr>
<tr>
<td><strong>Physics Upgrades</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H131</td>
<td>H130 + PBL changes</td>
<td>HWRF PBL (GFS based scheme) is upgraded to include variable critical Richardson number for improved treatment of PBL height in all weather conditions.</td>
<td>Jet, All 2011-2012 and August - October 2010 ATL and EP 1870 cases</td>
</tr>
</tbody>
</table>
Revised Vortex Initialization Procedure: GDAS Forecast as first guess for environment, GFS Vortex (int. <16 m/s) or HWRF Vortex (int. >16 m/s)

**Vortex Initialization - Stage I - Only runs if previous HWRF available and st_int >= 16 m/s**
- hrf_hi5.exe (3 times) (previous HWRF with d01, d02, d03 files to binary)
- hrf_merge.real_4x, step12_3m.exe (merge workouts from d01, d02 and d03 onto 3K domain to produce data_4x_hrf and roughness)
- hrf_split.exe (separate data_4x onto environment and storm)
- hrf_per_c.t.exe (adjust the HWRF vortex)

**Stage I** is used to split the previous HWRF forecast onto storm and environment so that the vortex can be adjusted and relocated. This is not done when the storm is very weak as it is best to use the GFS vortex in that case.

**Stage II** is used to split the GDAS or GFS forecast to get the environment.

**Vortex Initialization - Stage II - Always runs**
- hrf_probe_4x.exe (4 times) (refine data_4x, d01, d02 and d03 onto 3K domain to produce data_4x_hrf and roughness)
- hrf_merge.real_4x, step12_3m.exe (merge from d01, d02 and d03 onto 3K domain to produce data_4x_gfs and roughness)
- hrf_split.exe (separate data_4x onto environment and storm)
- hrf_per_c.t.exe (adjust the HWRF vortex)

**Vortex Initialization - Stage III - Always runs**

**Cold, st_int < 30 m/s**
- if hrf_hi5.exe was already run to adjust the HWRF vortex in Stage I, so do not run it here
- hrf_per_c.t.exe (adjust the GFS vortex)
- hrf_per_c.t.exe
  - hrf_create.real_4x, step12_5m.exe (refine data_5m)
  - hrf_create.real_4x, step12_5m.exe (refine data_5m)
  - hrf_create.real_4x, step12_5m.exe (refine data_5m)
- hrf_per_c.t.exe (adjust the GFS vortex)

**Cold, st_int >= 30 m/s**
- hrf_hi5.exe (3 times) (previous HWRF with d01, d02, d03 files to binary)
- hrf_merge.real_4x, step12_5m.exe (merge from d01, d02 and d03 onto 3K domain to produce data_4x_gfs and roughness)
- hrf_split.exe (separate data_4x onto environment and storm)
- hrf_per_c.t.exe (adjust the HWRF vortex)

**Flow chart by Ligia Bernardet, DTC**
Assimilation of conventional prepbufr data in d01 with GDAS forecast as first guess

One-Way Hybrid Ensemble-Var GSI DA System for HWRF
Critical Richardson number function of Ro (Vickers and Mahrt, 2003)

Vickers and Mahrt (2003) showed that the critical Richardson number is not a constant but varies with case by case.

\[ R_{ic} = 0.16 \left( 10^{-7} U_{10}/fZ_0 \right) - 0.18 \]

The magnitude of \( R_{ic} \) modifies the depth of PBL and diffusivity, so the \( R_{ic} \) varying with conditions would fit both hurricane condition and environments.
Performance of H131 (proposed FY2013 HWRF configuration) compared to 2012 operational HWRF (H212)

2010-2012 seasons, ATL and EPAC
Atlantic Basin

2010-2012 Track Verification

~10% improvement
Track errors

H131: 2013 HWRF
H212: 2012 HWRF

Track FSP
**Intensity errors**

- >20% improvement

**Intensity FSP**

- 2010-2012 Atlantic Intensity/Structure Verification

**Mean 34-kt Radius Error**

**Intensity Bias**
Eastern-Pac Basin

2010-2012 Track Verification

HWRF FORECAST – TRACK ERROR (NM) STATISTICS
VERIFICATION FOR EPAC BASIN 2010–2012

HWRF FORECAST – TRACK FSP ERROR (%) STATISTICS
VERIFICATION FOR EPAC BASIN 2010–2012

~15% improvement

Track errors

Track FSP
HWRF FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS
VERIFICATION FOR EPAC BASIN 2010–2012

Intensity errors

~17% improvement

HWRF FORECAST – INTENSITY FSP ERROR (%) STATISTICS
VERIFICATION FOR EPAC BASIN 2010–2012

2010-2012 E-PAC Intensity/Structure Verification

Mean 34-kt Radius Error

HWRF FORECAST – BIAS ERROR (KT) STATISTICS
VERIFICATION FOR EPAC BASIN 2010–2012

Intensity Bias

HWRF FORECAST – AVERAGE 34KT RADIUS ERROR (NM) STATISTICS
VERIFICATION FOR EPAC BASIN 2010–2012
Thanks to James Franklin (NHC)

H131 interpolated
2010-12 Average Forecast Errors
Atlantic Basin - Intensity

Thanks to James Franklin (NHC)

H212 interpolated

H131 interpolated
**TRACK/Intensity Forecasts**

2010-2011 Seasons Retrospective Runs

H212/H3GP/H130 (27:9:3 km) -- Skill relative to HWRF (27:9 km)

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**SKILL of ABSOLUTE TRACK ERRORS (vs HWRF)**

**H130:** Major improvements over HWRF & H3GP +
Improved over H212
& better than AVN0 (GFS) For 2010-11

*From Stan Goldenberg (HRD/AOML)*
H131 vs. H212 P-W relationship

ATLANTIC

H131: AT basin 2010-2012

E-PAC

H131: EP basin 2010-2012

Red: Best Track

H212: AT basin 2010-2012

H212: EP basin 2010-2012
Summary

• Major upgrades for 2013 operational HWRF are implementation of one-way hybrid GSI; improved nest tracking and nest-parent interpolations; increased 3rd domain size; increased frequency of physics calls; improved vortex initialization; and improved PBL.

• Retrospective testing for 2010, 2011 and 2012 hurricane seasons with H131 indicated significant enhancements in model forecast skill for track, intensity and structure compared to the 2012 operational HWRF. For the Atlantic basin, there was about 10-15% improvement in track forecasts and about 20-25% improvement in intensity forecasts over the current operational HWRF configuration.

• Similar improvements were noted for the Eastern Pacific basin as well.

• Results also indicated improved storm size from H131 as measured in terms of radius error for various intensity thresholds.
NHC has reviewed the performance of the proposed HWRF implementation for 2013. The model has been extensively tested on a three-year sample of cases with very impressive results. **For Atlantic basin track, the HWRF is improved by ~5-15% and now appears competitive with the GFS. For intensity, the model reduces errors by ~15%, has demonstrated skill greater than that of the NHC official forecast and greater than that of the statistical models.** These are remarkable results and Rick has asked me to relay NHC's strong endorsement for implementation of the upgraded HWRF for the 2013 season.

Congratulations on a tremendous effort. NHC is eager to see the new model in operations as soon as possible.

-- James Franklin
**HWRF Team Plans for 2013 Hurricane Season**

- **Stream 1.0:**
  - Operational implementation of FY13 HWRF (H131) on WCOSS (parallel feed from NCO until WCOSS goes live in August)

- **Stream 1.5:**
  - 20-member HWRF ensembles using GEFS initial conditions and stochastic convective physics perturbations *(Zhan Zhang, pending evaluation by NHC/TCMT)*

- **Stream 2.0:**
  - FY13 HWRF with MYJ PBL, RRTMG, Meso-SAS and MPI-POM *(High-Resolution Physics Tiger Team)*
  - FY13 HWRF with aircraft recon and TDR DA *(Recon Data Impact Tiger Team)*
  - FY13 HWRF with higher model top, increased vertical levels and global-regional blended vertical coordinate *(Satellite DA Tiger Team)*
  - FY13 HWRF with HYCOM
  - FY13 HWRF with High-Resolution ECMWF IC/BC
  - FY13 HWRF for Western Pacific and Indian Ocean basins
## Satellite DA experiments for HFIP Stream 2.0 Demo

<table>
<thead>
<tr>
<th>Stream 2.0</th>
<th>Satellite data assimilated</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control</strong></td>
<td>None</td>
<td>FY13 HWRF Conventional data assimilated</td>
</tr>
<tr>
<td><strong>A</strong></td>
<td>AMSU-A and ATMS (O$_2$ channels) radiances GPS bending angle</td>
<td>Provide temperature information Jun. 1 – Nov. 1 2013</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td>A + MHS and ATMS (H$_2$O channels) radiances</td>
<td>Provide moisture information in the troposphere Jun. 1 – Nov. 1 2013</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>A + B + GOES Sounder, HIRS, AIRS &amp; IASI radiances</td>
<td>Provide temperature &amp; moisture constraint Jun. 1 – Nov. 1 2013</td>
</tr>
<tr>
<td><strong>D</strong></td>
<td>A + B + C + EUMETSAT IR/VIS cloud drift winds NESDIS IR/VIS cloud drift winds NESDIS imager water vapor winds</td>
<td>Provide wind (u &amp; v) information on various vertical levels, and geographical regions Jun. 1 – Nov. 1 2013</td>
</tr>
<tr>
<td><strong>E</strong></td>
<td>Best combination of satellite data determined from experiments A to D</td>
<td>Aug. 1 – Nov. 1 2013</td>
</tr>
</tbody>
</table>
Performance of H131 for Individual Hurricane Seasons
2010 Atlantic ~25% improvement

2010 E-Pac ~45% improvement

H212: 2012 Operational
H131: FY2013 Baseline

Track Errors

>20% improvement

~20% improvement

Track Errors

Intensity Errors
HWRF FORECAST – TRACK ERROR (NM) STATISTICS
VERIFICATION FOR NATL BASIN 2011

2011 Atlantic
comparable

~30% improvement

2011 E-Pac
~10% improvement

~18% improvement

HWRF FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS
VERIFICATION FOR NATL BASIN 2011

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HWRF FORECAST – TRACK ERROR (NM) STATISTICS
VERIFICATION FOR EPAC BASIN 2011

~30% improvement

~18% improvement

HWRF FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS
VERIFICATION FOR EPAC BASIN 2011
HWRF FORECAST – TRACK ERROR (NM) STATISTICS
VERIFICATION FOR NATL BASIN 2012

**2012 Atlantic**

Track Errors

**comparable**

Intensity Errors

~16% improvement

HWRF FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS
VERIFICATION FOR NATL BASIN 2012

**2012 E-Pac**

Track Errors

**comparable**

Intensity Errors

~30% improvement