Plans for Operational Hurricane Modeling in FY17

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Environmental Modeling Center
NOAA / NWS / NCEP
Outline

• Long term plans for HWRF

• Planned 2017 HWRF upgrades

• Preliminary test results

• Current and future plans

• Quad chart and resources
# HWRF Long-Term Plans

## Development, T&E and Implementation Plans for HWRF (supported by HFIP)

- **2016 Dec**: H217 configuration ready
- **2017 Jan-Feb**: H217 pre-implementation testing
- **2017 March**: EMC CCB and code hand-off
- **2017 May**: H217 Implementation

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>HWRF Operational Model Continues Followed by Ensembles</td>
</tr>
<tr>
<td>2017</td>
<td>GFDL —— HNMMB 10-member HWRF/HNMMB Ensembles</td>
</tr>
<tr>
<td>2018</td>
<td>Basin-Scale HWRF/NMMB———Tropical/Global NMMB Domain</td>
</tr>
<tr>
<td>2019</td>
<td>Hurricane Models take over Hurricane Wave Forecasts</td>
</tr>
<tr>
<td>2020</td>
<td></td>
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</tbody>
</table>
FY17 HWRF v11.0.0
Implementation plans
Scope of FY17 HWRF Upgrades

➢ System & Resolution Enhancements

- Framework upgrade to HWRFV3.8a
- T&E with new 2017 GFS IC/BC
- Consider storm’s meridional movement when determining parent domain center
- New Tracker (still waiting for changes from Tim)
- Code optimization (IBM analyst)
- Increase vertical resolution with 75 vertical levels and 10-hPa top, with adjusted domain sizes for d02 (256 x 472) and d03 (256 x 472) (H216: 288 x 576)
- More products: MAG and AWIPS2

-- Green: Included in Baseline
-- Blue: Included in Baseline (if ready)
-- Orange: Tested separately as an option
Summary of 2017 GFS changes

- NEMS superstructure and infrastructure (NEMSIO)
- Upgraded land parameterizations, higher resolution land surface climatologies (should improve near-surface fields and reduce patchiness)
- Fix to excessive cooling of 2m temperatures during sunset (00Z)
- Changes to cumulus convection parameterization that should help to *improve summertime precipitation forecasts*
- NSST’s that represent diurnal warming effects and sub-layer cooling
- Assimilation of additional data (some GPS data, AMVs, and some radiances), minor bug fixes mostly related to cloud water
- Rayleigh damping reduced by 50% in the upper stratosphere above 2 hPa
- GFS hurricane track and intensity forecasts are neutral with 2017 NEMS-GSM upgrade (based on 2014-2016 retrospectives)
Impact of Considering Storm’s Meridional Movement on Hurricane Matthew
Adjusted Domain Sizes for H217 with higher vertical resolution: Hurricane Joaquin (2015)

**H215**
- d02: 142 x 274
- d03: 265 x 472
- Levels: 61
- Top: 2 mbar

**H216**
- d02: 288 x 576
- d03: 288 x 576
- Levels: 61
- Top: 2 mbar

**B217L**
- d02: 256 x 472
- d03: 256 x 472
- Levels: 75
- Top: 10 mbar
Hurricane track and vertical resolution for Hurricane Joaquin (2015)

From B. Zhang et al. (2016), which shows that the track forecasts of Hurricane Joaquin (2015) were greatly improved by increasing the vertical resolution of HWRF.
Impact of Vertical Resolution/Distribution for Hurricane Matthew: Early results

A17B and C17L have the same domain sizes as FY2016 HWRF.
Impact of Vertical Resolution/Distribution for Hurricane Matthew: Early results
Scope of FY17 HWRF Upgrades

➢ Physics Advancements

- Bug fix for 10 meter wind (already in HWRFv3.8a)
  - Removing the residual impact of the bias correction for U10 (H216), using consistent algorithm when calculating U10 from the lowest model level at model initial time and when nests move

- Update F-A Microphysics (Sergio’s talk)
- Updates to PBL/EDMF (Sergio’s talk)
- Update scale-aware SAS scheme or G-F cumulus scheme (DTC)

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Impact of U10fix for Matthew

HWRF FORECAST — TRACK ERROR (NM) STATISTICS
VERIFICATION FOR NATL BASIN 14L2016

HWRF FORECAST — INTENSITY VMAX ERROR (KT) STATISTICS
VERIFICATION FOR NATL BASIN 14L2016

HWRF FORECAST — BIAS ERROR (KT) STATISTICS
VERIFICATION FOR NATL BASIN 14L2016
HWRF 2016, “Hybrid” PBL

K-profile + other term

**Mass Flux**
Because K-profile alone under-predicts growth of boundary layer

New in HWRF 2016, along with GFS changes since 2011

**Counter Gradient**
Because mass flux deteriorates wind field over tropical oceans

As in HWRF 2011

**K-profile**

**Other local Scheme**
(function of the Richardson number)

Strongly unstable (over continents)  Weakly unstable  Weakly stable  Very stable

\( z/l \)

-0.5  0  0.2
Ferrier-Aligo Microphysics Changes

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>High reflectivity bias in PBL clouds</td>
<td>Added a drizzle parameterization (allows larger number of droplets)</td>
</tr>
<tr>
<td>High reflectivity bias at anvil</td>
<td>Increased largest possible number concentration of snow</td>
</tr>
<tr>
<td>Lack of stratiform precipitation</td>
<td>Constant rain drop size during rain evaporation (reduces evaporation)</td>
</tr>
</tbody>
</table>

Old

New
Scope of FY17 HWRF Upgrades

➢ Initialization/Data Assimilation Improvements

- Improve vortex initialization (new composite storm vortex)
- GSI code upgrades; *new data sets for GSI (hourly shortwave, clear air water vapor and visible AMV’s, GH changes, G –IV TDR data)*
- Bug fixes (TDR DA)
  - Fully Cycled EnKF two-way hybrid DA when TDR data is available
  - Change in blending threshold (to 64 kt) (Jason’s talk)
- HDOBS data assimilation (Jason’s talk)

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Impact of New Composite Vortex

- New composite vortex according to H216
- Only adjust low level vortex intensity and structure for weak storms
GSI upgrades sensitivity test
EDOUARD 06L 2014
2016 HWRF Hybrid Data Assimilation System
Warm-start HWRF ensemble when TDR available

```
Global EnKF/Var hybrid system

Analysis member 1 member 2 ...... member 80
high res analysis

Forecast member 1 member 2 ...... member 80
high res forecast

Vortex initialization

HWRF ensemble forecast
member 1 member 2 ...... member 40

HWRF one-way hybrid system

Analysis outer, middle, inner

HWRF 3-9hr forecast

Conventional data
TDR data
HS3 dropsonde, Tcvital MSLP data

Satellite radiance data
Satellite derived wind
GPS RO banding angle

GSI hybrid Ens/Var DA d03
GSI hybrid Ens/Var DA d02
Outer domain analysis

Analysis outer, middle, inner

HWRF forecast

TDR available

TDR not available

EnKF member update

Recenet analysis

Analysis member 1 member 2 ...... member 80
high res analysis

Forecast member 1 member 2 ...... member 80
high res forecast

outer, middle, inner

HWRF forecast
```

HWRF 3-9hr forecast

```
GSI hybrid Ens/Var

Outer domain analysis

Analysis outer, middle, inner

HWRF forecast

```

TDR available

TDR not available

```
EnKF member update

Recenet analysis

Analysis member 1 member 2 ...... member 80
high res analysis

Forecast member 1 member 2 ...... member 80
high res forecast

outer, middle, inner

HWRF forecast
```
2017 HWRF Hybrid Data Assimilation System
Cycled HWRF EnKF Ensemble Hybrid when TDR available

TDR mission in the next ~24 hours

Conventional data:
- TDR data
- Satellite AMVs
- HS3 dropsonde
- Tc vital MSLP data
- HDOB

Satellite radiance data:
- GPS RO banding angle

Vortex
- initialization

Analysis outer, middle, inner

Forecast (3-9hr)

Vortex relocation
- member 1
- member 2
- ... member 40

EnKF
d02

Analysis
- member 1
- member 2
- ... member 40

Forecast
- member 1
- member 2
- ... member 40

Analysis
- member 1
- member 2
- ... member 40

GSI hybrid Ens/Var
- DA d03

GSI hybrid Ens/Var
- DA d02

WRF EnKF/Var hybrid system

GDAS
- 3-9hr forecast

GDAS/ENKF ensemble forecast
- mem 001
- mem 002
- ...

GFS analysis

GDAS/ENKF Analysis
- mem 001
- mem 002
- ...

Recenter
- Analysis
- EnKF d01 & d02

2017 HWRF Hybrid Data Assimilation System
Cycled HWRF EnKF Ensemble Hybrid when TDR available
2017 Data Assimilation Upgrades (ATL and EPAC)

Hybrid EnKF-GSI DA system: 2 way coupling

Advanced self-cycled HWRF EnKF-GSI Hybrid Data Assimilation System (HDAS)
Cycled HWRF ensemble hybrid DA
2016 AL storms with TDR data available
Impact of changes to Blending and HDOBS (2014 Storms)

- HB65: Increasing blending threshold results in better intensity forecasts
- HD65: Adding HDOBS significantly improves intensity
- No impact on track
Impact of changes to Blending and HDOBS (2014 & 2016 Storms)

- Expanded sample to include Matthew & Hermine
- Consistent results of significant intensity improvement peaking at 48 h
➢ Other upgrades in 2017....

- Use of NEMSIO (IC) and GRIB2 (LBC) files for inputs
- Reduce coupling time step from 9min to 6 min for both waves and ocean
- Increase vertical resolution from 24 to 40 levels for POM with reduced time step
- Modify WW3 frequency bins and time step with hourly wave products
- Revised early model interpolation method
- WW3 boundary conditions from global wave model
- RTOFS initialization for NATL (??)
- HYCOM/RTOFS for WPAC, NIO
- Graphics included in workflow

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## HWRF Upgrade Plan for 2017 Implementation

### Multi-season Pre-Implementation T&E

<table>
<thead>
<tr>
<th>Model upgrades</th>
<th>Physics and DA upgrades</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline (H17B)</strong></td>
<td>Data Assimilation changes (H17S)</td>
<td>Physics changes (H17P)</td>
</tr>
</tbody>
</table>

### Description

1. Framework upgrade to HWRFV3.8a; domain center; new tracker
2. New 2017 GFS upgrade
4. GSI upgrades, cycled EnKF

- 1. HDOBS
- 2. Blending threshold

Assess impact of physics changes

Baseline + DA changes + all physics changes + others

### Cases

- Only Aircraft DA cases for 2014-2016
- Priority cases (~500 cases in each basin)

- Three-season 2014-2016 retrospectives ~5000 simulations in all TC basins

### Platform

- WCOSS/Jet/Theia
- WCOSS/Jet/Theia
- WCOSS/Jet/Theia
- WCOSS Cray
HWRF: Current and Future Tasks

• Further improvements to hurricane physics
• Further improvements to vortex initialization and data assimilation
• Increase/change vertical resolution, nested domain sizes
• Replace operational Hurricane Wave model with HWRF system
• 5-10 Member Ensembles
• Three-way Atmosphere-Ocean-Wave coupling
• Basin-scale configurations
Q3FY17 Hurricane WRF V11.0.0
Project Status as of 10/19/16

Project Information and Highlights

Lead: Avichal Mehra, EMC and Steven Earle, NCO
Scope:
1. Improved air-sea-wave coupling for HWRF; replace operational Hurricane Wave model with HWRF system
2. Possible implementation of multi-storm configuration and/or single domain (basin-scale) configuration for improved multi-scale interactions and tropical cyclogenesis predictions;
3. Further improvements to hurricane physics (especially microphysics and air-sea-wave interactions)
4. Further improvements to vortex initialization; assimilate additional aircraft and satellite data
5. Increase vertical resolution in North West pacific, North Indian and Southern Hemisphere Ocean basins consistent with North Atlantic and Eastern North Pacific Basins;
6. Extend ocean coupling to Southern Hemisphere Ocean basins

Expected Benefits:
1. Improved track & intensity forecast skill in all basins
2. Improved products including AWIPS

Issues/Risks

Issues: Complex T&E due to dependency on NEMS/GSM and RTOFS upstream requirements

Risks: Implementation dates are dependent on completion of T&E
Mitigation: Conduct T&E as soon as (or along with) NEMS/GSM and RTOFS retrospective data are available.

Scheduling

<table>
<thead>
<tr>
<th>Milestone (NCEP)</th>
<th>Date</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify preliminary System Configuration</td>
<td>11/01/2016</td>
<td></td>
</tr>
<tr>
<td>Start preliminary evaluation</td>
<td>11/01/2016</td>
<td></td>
</tr>
<tr>
<td>Finalize System configuration</td>
<td>01/10/2017</td>
<td></td>
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<tr>
<td>Initial coordination with SPA team</td>
<td>01/10/2017</td>
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<tr>
<td>Freeze codes for real-time and retrospective runs</td>
<td>01/10/2017</td>
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<tr>
<td>Pre-CCB Briefing to EMC management</td>
<td>02/15/2017</td>
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<tr>
<td>Completion of full retrospective runs and external evaluation</td>
<td>02/15/2017</td>
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</tr>
<tr>
<td>EMC CCB/NCEP OD approval</td>
<td>02/28/2017</td>
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<tr>
<td>Deliver final code to NCO (including downstream codes)</td>
<td>02/28/2017</td>
<td></td>
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<tr>
<td>Technical Information Notice Issued</td>
<td>03/07/2017</td>
<td></td>
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<tr>
<td>Special event if applicable</td>
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<td></td>
</tr>
<tr>
<td>Complete 30-day evaluation and IT testing</td>
<td>05/15/2017</td>
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<tr>
<td>Final Management Briefing</td>
<td>05/22/2017</td>
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<tr>
<td>Operational Implementation</td>
<td>05/31/2017</td>
<td></td>
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</tbody>
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Resources

Human Resources: 3 FTE full time for 6 months.
Funding Sources: STI
Compute: Archive:

v1.0 09/14/07

Management Attention Required  Potential Management Attention Needed  On Target
**Targeted Resources for Hurricane Modeling**
(maximum per storm)

<table>
<thead>
<tr>
<th>Operational System</th>
<th>2016 (nodes)</th>
<th>2017 (nodes)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>HWRF</td>
<td>63</td>
<td>58</td>
<td>Optimization, with configuration changes</td>
</tr>
<tr>
<td>WW3-multi2</td>
<td>8</td>
<td>0</td>
<td>WW3 coupled to HWRF</td>
</tr>
<tr>
<td>GFDL</td>
<td>3</td>
<td>0</td>
<td>Discontinued</td>
</tr>
<tr>
<td>HNMMMB</td>
<td>0</td>
<td>26*</td>
<td>Uses much less resources than HWRF</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>74</strong></td>
<td><strong>84</strong></td>
<td>13.5% resource increase*</td>
</tr>
</tbody>
</table>

- Initial implementation is targeted for only 5 storms serving NHC areas of responsibility (ATL & EPAC)
After 22 years of glorious service, GFDL Hurricane model is planned to be retired!

Thank you Morris, Bob, Tim, Matt along with past research personnel at GFDL and their collaborators (NHC, HRD, EMC, FLEET, URI, others) for valuable operational guidance to NHC and JTWC and key contributions to the broader worldwide Tropical Storms research community!!