HFIP Joint HWRF/COAMPS-TC/GFDL Multi-Model Regional Ensemble System

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**GFDL:** Matthew Morin, Timothy Marchok, Morris Bender

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Outline

- Motivations and Goals;
- Introduction to Three-model High-resolution Regional Ensemble System;
- Verification Results from Retrospective experiments;
- Real Time Ensemble Forecast Products.
Motivations and Goals

➢ Increase number of ensemble members to take into account more uncertainties in:
  ▪ Large scale environment flows, IC/BC;
  ▪ Vortex intensity and structures at the model initial time;
  ▪ Model physics and dynamics.

➢ Provide improved and reliable real time storm track/intensity forecasts and probabilistic forecasts (real time tier1 products will be submitted to TCMT for verification);

➢ Develop more ensemble probabilistic forecast products based on multi-model ensembles.
• Synoptic perturbations:
  • Perturbation drawn from a static covariance
  • Perturb the boundaries
  • Use WRFVAR cv3

• Vortex scale perturbations:
  • Vortex position, max wind, and RMW.
  • Perturbation variance from:
    • Torn and Snyder 2012
    • Landsea and Franklin 2013
  • Max wind and RMW covariance derived from 2001-2013 best track data.
  • Variance’s and covariance’s depend on TC-vital max wind speed.
GP00: Control forecast (based on NCEP's 2014 implementation of the GFDL hurricane model)

GP01: Opposite vortex bogussing method of the ensemble control model (i.e., runs unbogussed when the control runs bogussed, and vice versa)

GP02: Increase NHC-observed Vmax 10%, 34-kt radii 25%, 50-kt radii 40%, ROCI 25%

GP03: Decrease NHC-observed Vmax 10%, 34-kt radii 25%, 50-kt radii 40%, ROCI 25%

GP04: Increase inner-core moisture by a max of 10%

GP05: Decrease inner-core moisture by a max of 10%

GP06: Increase SSTs by a max of 2°C within the initial extent of the TC

GP07: Decrease SSTs by a max of 2°C within the initial extent of the TC

GP08: Surface physics modification: GFDL 2011 operational formulation of CD & CH (surface drag and enthalpy exchange coefficients)

GP09: Surface physics modification: HWRF 2014 operational formulation of CH (surface enthalpy exchange coefficient)

GPMN: Ensemble mean computed at each lead time where the member availability is at least 4 members (40% threshold)
Use 2014 operational deterministic HWRF model except for
- Less vertical resolution: L43 vs. L61;
- Smaller Do2, Do3 domains, same as H213;
- No GSI due to lack of GDAS data;

IC/BC Perturbations (large scale): 20 member GEFS.

Model Physics Perturbations (vortex scale):
- Stochastic Convective Trigger in SAS: -50hPa to + 50hPa white noise;
- Stochastic boundary layer height perturbations in PBL scheme, -20% to +20%;
- Stochastic initial wind speed perturbations with zero mean and 7% standard deviation, Gaussian distribution.
## Retrospective Runs from HWRF/COAMPS-TC/GFDL Ensembles

<table>
<thead>
<tr>
<th>Models</th>
<th>Number of Cycles</th>
<th>Number of Storms</th>
</tr>
</thead>
<tbody>
<tr>
<td>HWRF</td>
<td>520 cycles, 2011-2013, AL and EP</td>
<td>54</td>
</tr>
<tr>
<td>COAMPS-TC</td>
<td>210 cycles, 2010-2013, AL</td>
<td>10</td>
</tr>
<tr>
<td>GFDL</td>
<td>716 cycles, 2011-2013, AL</td>
<td>43</td>
</tr>
</tbody>
</table>

### Homogeneous Samples:
(133 Cycles, 8 TC)

1. Irene, 2011/09L
2. Katia, 2011/12L
3. Ernesto, 2012/05L
4. Isaac, 2012/09L
5. Nadine, 2012/14L
6. Sandy, 2012/18L
7. Gabrielle, 2013/07L
8. Humberto, 2013/09L

Ensemble mean is computed when the forecasts available from 40% of the total ensemble members.
HWRF-EPS vs. HWRF-deterministic (2014 Real time)

HWRF FORECAST - TRACK ERROR (NM) STATISTICS
VERIFICATION 2014 Ensemble against HWRF ATL 2014

- AL-Track
- WP-Track

HWRF FORECAST - INTENSITY VMAX ERROR (KT) STATISTICS
VERIFICATION 2014 Ensemble against HWRF ATL 2014

- AL-Intensity
- WP-Intensity
Three Model Ensembles vs. Two-model Ensembles

Three-model ensemble is generally better than Two-model ensemble in terms of both track and intensity forecasts at all forecast hours.
Multi-Model Ensemble Verification
(Retrospective runs 2011-2013)
Combined ensemble track forecasts have:
1. lowest track forecast errors;
2. adequate ensemble track spread.
1. Even though HWRF ensemble spread has fast growth rate, it is much smaller than its forecast error because of zero spread at the initial time. This is corrected by adding intensity uncertainties at initial time now.  
2. Combined forecast errors are close to the combined ensemble spread.
Relationship between Forecast Error and Ensemble Spread (Track)

- **24h, sample size: 126**
- **48h, sample size: 120**
- **72h, sample size: 110**
- **96h, sample size: 96**
Relationship between Forecast Error and Ensemble Spread (Intensity)

- **24h, sample size: 126**
- **48h, sample size: 120**
- **72h, sample size: 110**
- **96h, sample size: 96**
Composite track forecasts for Humberto 09L, 2013
Composite intensity forecasts for Humberto 09L, 2013

MEMN

HWRF-EPS

COAMPS-TC EPS

GFDL-EPS
Composite track forecasts for Sandy 18L, 2012

HEMN

HWRF-EPS

COAMPS-TC EPS

GFDL EPS
Composite intensity forecasts for Sandy 18L, 2012

MEMN

HWRF-EPS

GFDL EPS

COAMPS-TC EPS
HWRF Ensemble Products
Can be extended to multi-model ensemble products.
Intensity Forecasts

Can be extended to multi-model ensemble products.
Track Probability Forecast based on HWRF-EPS and Deterministic HWRF Forecast Errors

Cristina 03E, 2014061300  
Rammasun 09W, 2014071512

Can be extended to multi-model ensemble products.

Credited to Sam Trahan
Wind Probability Forecasts based on HWRF-EPS at different Thresholds

V > 34kts

V > 50kts

Cristina 03E, 2014061300
Rainfall Probability Forecast based on HWRF-EPS at different Thresholds

Cristina 03E, 2014061300

Credited to Sam Trahan
Hourly Ensemble Max/Min Vertical Velocity (m/s)

Matmo 10W, 2014072212

Useful for tornado forecast guidance for landfalling storms

Credited to Sam Trahan
Hourly Ensemble Updraft Helicity ($m^2/s^2$)

Max 2–5km updraft Helicity ($m^2/s^2$) 2014072212 F001
Min=0 Max=42.6099

Matmo 10W, 2014072212

Useful for tornado forecast guidance for landfalling storms

Credited to Sam Trahan
Summary

- Combined HWRF/COAMPS-TC/GFDL ensemble system takes into account most of uncertainties that are important to model hurricane track/intensity forecasts;

- Combined ensemble system provided improved track/intensity forecasts, compared to the forecasts from each individual ensemble system;

- Combined ensemble system has adequate forecast error and ensemble spread relationship;

- More ensemble products can be developed based on the combined ensemble system.
COAMPS-TC
Slides provided separately
GFDL Ensemble Products
GFDL Ensemble Track Forecasts
Storm: ELEVEN11W  Valid: 07/28/2014 12 UTC

Adapted from ellipse plots on HFIP website;
Thanks to Jon Moskaitis for his MATLAB assistance

Mean track forecast position marked every 6 hrs
Ensemble track positions and ellipses color-coded for days 0, 1, 2, 3, 4, and 5.

GFDL Hurricane Dynamics Group
http://data1.gfdl.noaa.gov/hurricane/gfdl_ensemble/

Track Forecasts

Forecast initial time: 2014072812

Track forecast positions are labeled every 6 hrs (hover over points to see member ID and forecast hour)

Lat, Lon: 14.84937990914623, 149.12918038666248
Lat, Lon on click: 16.741721000434605, 147.35015831887722

Map zoom options:
1. Use mouse scroll wheel, 2. double left-click to zoom-in, double right-click to zoom-out, or 3. use "+/" slider control
Intensity Forecasts

GFDDL Ensemble Forecast for ELEVEN11W from 12Z28JUL2014

Max Wind (kt)

Forecast Hour (# of members present)

Vortex initialization used TCvitals: 25 kts; 1004 mb

Max Wind (kt)

Forecast Hour (% of members dissipated)

Missing members (out of 10) at t=0: None

GFDDL Hurricane Dynamics Group
Wind Probability Forecasts Based on GFDL-EPS
Rainfall Probability Forecast Based on GFDL-EPS

http://data1.gfdl.noaa.gov/hurricane/gfdl_ensemble/