Forecasts of Hurricanes using a suite of mesoscale models

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## Model Descriptions for Mesoscale Models for ensemble forecasts

<table>
<thead>
<tr>
<th>Models</th>
<th>Nesting Horizontal resolution (km)</th>
<th>Vertical levels</th>
<th>Cumulus Parameterization</th>
<th>Microphysics</th>
<th>PBL</th>
<th>Land Surface</th>
<th>Radiation</th>
<th>Initial and boundary conditions</th>
<th>Initialization</th>
</tr>
</thead>
<tbody>
<tr>
<td>HWRF-X HRD version of HWRF (H3HW)</td>
<td>2/9/3</td>
<td>42</td>
<td>Simplified Arakawa Schubert</td>
<td>Ferrier</td>
<td>GFS Non-Local scheme</td>
<td>GFDL Slab Model</td>
<td>GFDL scheme</td>
<td>GFS</td>
<td>HWRF</td>
</tr>
<tr>
<td>WRF ARW (NCAR) (AHW1)</td>
<td>2/12/4</td>
<td>36</td>
<td>New Kain Fritsch (12 km only)</td>
<td>WSM5</td>
<td>YSU</td>
<td>5-layer thermal diffusion soil model</td>
<td>RRTM (longwave) / Dudhia (shortwave)</td>
<td>GFS</td>
<td>EnKf method in a 6-hour cycling mode</td>
</tr>
<tr>
<td>COAMPS-TC (COTC)</td>
<td>3/45/15/5 (15/5 km following the storm)</td>
<td>40</td>
<td>Kain Fritsch on 45 km and 15 km</td>
<td>Explicit microphysics (5 class bulk scheme)</td>
<td>Navy 1.5 order closure</td>
<td>Force and restore slab land surface model</td>
<td>Harshvardardet et al. (1987)</td>
<td>NOGAPS</td>
<td>3D-Var data assimilation with synthetic observations</td>
</tr>
<tr>
<td>GFDL/GFD5 (parallel)</td>
<td>3/30/15/7.5</td>
<td>42</td>
<td>Arakawa Schubert</td>
<td>Ferrier</td>
<td>GFS Non-Local PBL</td>
<td>Slab Model</td>
<td>Schwarz-kopf-Fels scheme</td>
<td>GFS</td>
<td>GFDL synthetic bogus vortex</td>
</tr>
<tr>
<td>WRF ARW (ARFS) FSU</td>
<td>2/12/4</td>
<td>27</td>
<td>Kain-Fritsch (new Eta scheme)</td>
<td>WSM5</td>
<td>YSU</td>
<td>5-layer thermal diffusion soil model</td>
<td>RRTM (longwave) / Dudhia (shortwave)</td>
<td>GFS (initial and boundary condition)</td>
<td>GFS</td>
</tr>
</tbody>
</table>
Correlation Based Consensus (CBC)

- Observed increment values (Lat, Lon, Int) for each lead time
- Model increment forecasts (Lat, Lon, Int) for each lead time

**Correlation coefficients for each model for Lat, Lon, Int at each lead time**

**Training phase**
- 2010 storm cases (Total 149 cases)
- The storm to be forecasted is taken out to calculate the correlation coefficients

Normalize the coefficients using available member models for Lat, Lon, Int at each lead time

Utilize the above coefficients during the forecast phase and construct a new forecast
HFIP **Track** Performance Baseline (units are nautical miles)

<table>
<thead>
<tr>
<th>VT (h)</th>
<th>N</th>
<th>OFCL</th>
<th>OCD5</th>
<th>CONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>818</td>
<td>7.4</td>
<td>7.7</td>
<td>7.8</td>
</tr>
<tr>
<td>12</td>
<td>741</td>
<td>29.4</td>
<td>44.5</td>
<td>30.0</td>
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<tr>
<td>24</td>
<td>663</td>
<td>49.6</td>
<td>93.3</td>
<td>49.8</td>
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<td>36</td>
<td>586</td>
<td>69.9</td>
<td>150.9</td>
<td>69.5</td>
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<tr>
<td>48</td>
<td>518</td>
<td>91.2</td>
<td>212.2</td>
<td>89.6</td>
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<tr>
<td>72</td>
<td>411</td>
<td>135.0</td>
<td>317.2</td>
<td>132.0</td>
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<tr>
<td>96</td>
<td>313</td>
<td>173.0</td>
<td>396.5</td>
<td>175.2</td>
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<tr>
<td>120</td>
<td>247</td>
<td>218.6</td>
<td>473.0</td>
<td>221.9</td>
</tr>
</tbody>
</table>

HFIP **Intensity** Performance Baseline (Units are knots)

<table>
<thead>
<tr>
<th>VT (h)</th>
<th>N</th>
<th>OFCL</th>
<th>OCD5</th>
<th>CONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>820</td>
<td>1.9</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>12</td>
<td>745</td>
<td>7.2</td>
<td>8.3</td>
<td>7.7</td>
</tr>
<tr>
<td>24</td>
<td>667</td>
<td>10.4</td>
<td>11.5</td>
<td>10.1</td>
</tr>
<tr>
<td>36</td>
<td>590</td>
<td>12.6</td>
<td>14.2</td>
<td>11.7</td>
</tr>
<tr>
<td>48</td>
<td>522</td>
<td>14.6</td>
<td>16.1</td>
<td>13.7</td>
</tr>
<tr>
<td>72</td>
<td>415</td>
<td>17.0</td>
<td>17.8</td>
<td>16.0</td>
</tr>
<tr>
<td>96</td>
<td>316</td>
<td>17.5</td>
<td>19.3</td>
<td>16.6</td>
</tr>
<tr>
<td>120</td>
<td>250</td>
<td>19.0</td>
<td>19.3</td>
<td>17.0</td>
</tr>
</tbody>
</table>

The CONS Baseline is showed on the plots
Hurricane Danielle
20-31 August

Forecasts
Danielle (2010) Track Errors

Forecast Hours

Error (nm)

Danielle (2010) Intensity Errors

Forecast Hours

Error (kt)

Cases: 10, 9, 8, 7, 5, 3, 1
Hurricane Earl (2010)
(22 Aug-5 Sep)
Earl (2010) Track Errors

Earl (2010) Intensity Errors

Cases: 9, 9, 9, 9, 7, 5, 2
Hurricane Igor (2010)
(Sep 7-21)
CBC picks up outliers
Igor (2010) Track Errors

Cases: 11, 10, 9, 9, 8, 7, 5

Forecast Hours

Error (nm)

Igor (2010) Intensity Errors

Forecast Hours

Error (kt)
Hurricane Julia (2010)
(Sep 9-24)
Julia (2010) Track Errors

Cases: 18, 18, 18, 17, 16, 15, 11
Hurricane Otto
29 September – 10 October
Otto (2010) Track Errors


Cases: 4, 4, 4, 4, 2
Hurricane Richard
16 – 26 October
Richard (2010) Track Errors

Richard (2010) Intensity Errors

Cases: 9, 9, 8, 6, 1, 1, 1
2010 Track Skills

2010 Intensity Skills

Cases: 41, 39, 36, 33, 19, 13, 8
2010 Track Errors

2010 Intensity Errors

All statistics shown here are homogeneous comparisons of all member models.

Cases: 41, 39, 36, 33, 19, 13, 8
Track Error comparisons 2010 season

Intensity Error comparisons

ICON vs CBC

DSHP (Decay-SHIPS)
LGEM (Logistic Growth Equation Model)
HWFI (interpolated HWRF), and GHMI (adjusted GFDI)

ICON: Average of LGEM, HWFI, GHMI, and DSHP
The Correlation Based Consensus (CBC) is much more consistent in its forecast performance from one forecast to the next.

The maximum number of homogeneous cases for the 2010 named storm forecasts were 44, 39, 36, 33, 19, 13, 8 for hours 12, 24, 36, 48, 72, 96, 120. The number of forecasts at hour 120 were very few. In future real time it may be necessary to require that all modelers provide forecasts for all storms through hour 120. This may not be always possible since some storms in some forecasts weaken before 120 hours.

The track errors for CBC are around 75 nautical miles at hour 120 of forecast, and the intensity errors are around 17 knots at hour 120 of forecast. These track errors are around one third the value of the baseline. These intensity error is very close to that of the baseline.

The track and intensity forecast summaries for the 2010 season show that the normalized track forecasts, normalized with respect to CLIPER, and the intensity forecasts, normalized with respect to SHIFOR, show that the CBC carries the best forecast skills compared to all participating models. These percentage improvements (between hours 12 and 120) over CLIPER and SHIFOR for CBC, are around 30 to 85 percent for track and around 0 to 60 percent for the intensity.
- The correlation based consensus (CBC) consistently performed better than Guna (a mean of large scale model forecasts) and the GFS ensemble mean for hurricane tracks (through hour 120 of forecasts) for the 2010 season.

- The correlation based consensus (CBC), for intensity forecasts performed better than ICON.
SPECIAL THANKS TO BOB GALL and NAOMI SURGI FOR THE SUPPORT OF THIS WORK.

We also acknowledge the hurricane centers for providing their model forecasts.

The ARFS forecasts are run on TJET machine.
THANKS

QUESTIONS??