Real-Time, Ensemble-Based Probabilities of Tropical Cyclone Rapid Intensification

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Contributions from various Ensemble Modeling Groups, DTC and NHC Forecasters

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Overview

- Significant effort to develop ensemble dynamical and statistical models
- Most forecasters only use the mean, but is there is additional information in the ensemble distribution itself
- Focus of HFIP Ensemble Tiger Team is new ensemble-based operational products
- Real-time, ensemble-based RI probability of RI similar to SHIPS product
  - 30 kt 24 h\(^{-1}\), 55 kt 48 h\(^{-1}\), 65 kt 72 h\(^{-1}\)
### Intensity Change Probability

<table>
<thead>
<tr>
<th>Model</th>
<th>Type</th>
<th>Real-Time Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>HWRF (HWMN)</td>
<td>Dynamical (IC + Physics)</td>
<td>12 h</td>
</tr>
<tr>
<td>GFDL (GPMN)</td>
<td>Dynamical (IC + Physics)</td>
<td>6 h</td>
</tr>
<tr>
<td>COAMPS (COMN)</td>
<td>Dynamical (IC)</td>
<td>6 or 12 h</td>
</tr>
<tr>
<td>HWRF Analog (ANEN)</td>
<td>Statistical</td>
<td>6 h</td>
</tr>
<tr>
<td>SPICE (RISC)</td>
<td>Statistical</td>
<td>0 h</td>
</tr>
<tr>
<td>SHIPS (RIOD)</td>
<td>Statistical</td>
<td>0 h</td>
</tr>
</tbody>
</table>

- Probabilities derived for first four models via counting number of members where condition is satisfied
- Output in ATCF e-deck format
Verification

• Remainder of this talk is on verification of the ensemble probabilities from 2013-2015
  – large number of cases (over water only)
  – HWRF ensemble has smaller sample
• Both raw and interpolated versions of model output are produced
  – XXMN – Raw intensity changes
  – XXXI – 6 h interpolated intensity changes
  – XXX2 – 12 h interpolated intensity changes
  • Example: COMN, COMI, COM2
0-24 h RI Probability

24 hr RI Reliability Diagram
30kt Change Probability BDELT A >=30, 492 probs (46 non-zero), Basin: al, Model: COMI, Lead: 24

- Forecast probabilities too low
- Ideal forecast
- Forecast probabilities too high
00-24 h AL RI Reliability

- HWRF
- GFDL
- COAMPS
- HWRF Ana.
- SPICE
- SHIPS

Graph showing observed probability vs. forecast probability for different models.
00-24 h EP RI Reliability

![Graph showing reliability of 00-24 h EP RI forecasts for different models. The graph plots forecast probability against observed probability for HWRF, GFDL, COAMPS, HWRF Ana., SPICE, and SHIPS models. The x-axis represents forecast probability, and the y-axis represents observed probability. The lines for each model show their performance in relation to the perfect reliability line (45-degree line).]
00-48 h AL RI Reliability

![Graph showing observed probability versus forecast probability for different models: HWRF, GFDL, COAMPS, and HWRF Anal.](image)
Other Intensity Categories

- Difficult to validate RI probabilities because it is by definition a relatively rare event
- Do any ensemble prediction system have skill predicting other intensity changes?
  - $\delta \leq -30 \text{ kt } 24 \text{ h}^{-1}$ (rapid weakening)
  - $-30 \text{ kt } 24 \text{ h}^{-1} < \delta \leq -10 \text{ kt } 24 \text{ h}^{-1}$ (weakening)
  - $-10 \text{ kt } 24 \text{ h}^{-1} < \delta < 10 \text{ kt } 24 \text{ h}^{-1}$ (steady)
  - $10 \text{ kt } 24 \text{ h}^{-1} \leq \delta < 30 \text{ kt } 24 \text{ h}^{-1}$ (intensifying)
  - $\delta \geq 30 \text{ kt } 24 \text{ h}^{-1}$ (rapid intensification)
24 hr RI Reliability Diagram

0kt Change Probability BDELTA >=-10 and <10, 237 probs (215 non-zero), Basin: al, Model: COM2, Lead: 24
00-24 h Intensifying Reliability

- HWRF
- COAMPS
- S: AL
- D: EP
00-24 h Weakening Reliability

- HWRF
- COAMPS
- S: AL
- D: EP
Summary

• Ensemble-based probabilistic intensity change was provided to NHC in 2016
• Retrospective forecasts show varied skill at predicting RI
• More skill at predicting smaller amplitude intensity change categories
  – Evidence of over-confidence
• https://ral.ucar.edu/projects/hfip/d2016/ens RI/
Future Directions

• Increase reliability of forecast delivery
• Understanding what situations lead to over-confidence in the ensemble (i.e., near 100% probabilities)
• Multi-model probabilistic intensity changes (i.e., combination of HWRF, COAMPS-TC)