An Update on Verification of NHC Forecasts of Extratropical Transition

Jack Beven and Colleagues (with an assist from Jay Hobgood and Nick D’Allura)

NATIONAL HURRICANE CENTER

WHERE AMERICA’S CLIMATE AND WEATHER SERVICES BEGIN

ma AVHRR NCOL - 2011-08-28 15:09UTC
Outline

• Background
• Verification Methodology
• Results
• A Couple of Interesting Cases
Hurricane Lili (1996)

“Obviously we have little skill with Lili in forecasting extratropical transition” – Lixion Avila

<table>
<thead>
<tr>
<th>Fcst Time</th>
<th>Mean Error (hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 hr</td>
<td>39.43</td>
</tr>
<tr>
<td>24 hr</td>
<td>99.00</td>
</tr>
<tr>
<td>36 hr</td>
<td>27.00</td>
</tr>
<tr>
<td>48 hr</td>
<td>42.00</td>
</tr>
<tr>
<td>72 hr</td>
<td>24.00</td>
</tr>
</tbody>
</table>

In terms of timing, this is still the worst forecast ET event in the forecast verification data set.
ET Verification Principles

- Potential ET cases includes all cyclones where ET either occurred or was forecast.
- All cases includes all cyclones whether ET was forecast/occurred or not.
- Forecast ET was based on designation of “extratropical” in the forecast package.
- Actual ET was based on designation of “extratropical” in the best track.
- A tropical cyclone absorbed by a front without any subsequent ET positions was treated as dissipation, not transition.
- ET forecast later than actually occurred was assigned a negative timing error. ET forecast earlier than actually occurred was assigned a positive timing error.
ET Verification Metrics (I)

- Based on the 2x2 contingency table used by the NWS for severe local storms verification - was ET forecast (yes or no) and did it occur (yes or no)?
- www.sec.noaa.gov/forecast_verification/Glossary.html
- Probability of Detection (POD) – Percentage of the occurring ET events that were forecast - from 0 (totally wrong) to 1 (perfect)
- False Alarm Ratio (FAR) – Percentage of the forecast ET events that did not occur – scores range from 0 (no false alarms) to 1 (all false alarms)
- Critical Success Index (CSI) – Ratio of the number of forecast ET events to the total number of ET forecasts + the missed ET occurrences – scores range from 0 (totally wrong) to 1 (perfect)
### Verification Table for 2011

<table>
<thead>
<tr>
<th>ET Forecast</th>
<th>ET Observed</th>
<th>417 forecasts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>106 (successfully forecast ET)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>35 (false alarms)</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>15 (missed transitions)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>261 (successfully forecast non-ET)</td>
</tr>
</tbody>
</table>
ET Verification Metrics (II)

- **Percent Correct** – Percentage of forecasts that either correctly forecast ET or lack thereof

- **Event Bias** – ratio of the number of times ET was forecast to the number of times it was observed

- **Gilbert Skill Score** – Unbiased version of the CSI accounting for the number of forecasts that were correct by chance – scores range from -0.33 to 1.0 (best) with negative values indicating forecasts worse than chance

- **Heidke Skill Score** – Skill-corrected verification measure accounting for correct random forecasts – scores range from -1.0 (no correct forecasts) to 1.0 (no incorrect forecasts)

- **True Skill Statistic (Peirce Skill Score or Kuipers’ Performance Index)** – Verification measure accounting for unbiased random forecasts - 1.0 score reflects perfect forecasts, 0.0 score reflects random forecasts, and negative scores for worse than random forecasts
Over the past decade, NHC forecasts of ET have a clear negative bias – ET usually occurs earlier than NHC forecast at all forecast times.
5-Day Potential ET Cases Only

Critical Success Index
False Alarm Ratio
Probability of Detection
Event Bias
Linear (Critical Success Index)
Linear (Probability of Detection)
Linear (False Alarm Ratio)
Linear (Event Bias)
5-Day All Forecast Cases

Skill Score

Year
2001 (352)
2002 (324)
2003 (400)
2004 (426)
2005 (663)
2006 (255)
2007 (213)
2008 (389)
2009 (160)
2010 (435)
2011 (417)

% Correct
Gilbert
Heidke
True
Linear (% Correct)
Linear (Gilbert)
Linear (Heidke)
Linear (True)
3-Day Potential ET Cases Only

Positive biases (some quite large) existed for much of the 1990’s. Since then, the biases have become persistently negative – ET occurs before it is forecast.
3-Day Potential ET Cases Only

Skill Score vs. Year

- % Correct
- Gilbert
- Heidke
- True
- Linear (% Correct)
- Linear (Gilbert)
- Linear (Heidke)
- Linear (True)
Meteorological Issues

- Aborted transitions: Alberto 2000
- Slow or interrupted transitions: Gabrielle 2001, Maria 2005, Helene 2006
- Unclimatological transitions: Michelle 2001
- Unclimatological non-transitions: Humberto 2001, Juan 2003, Cindy 2011
- Unusual synoptic patterns: Lee 2011
ET Timing Issues in 2011

NHC forecasts of ET have a clear negative bias for every TC in 2011 that underwent ET – ET usually occurs earlier than NHC forecast. Why could this be happening?
NHC track forecasts have a slow bias near the northeastern U. S. This is likely contributing to the errors in ET timing.
EXCERPT FROM NHC DISCUSSION

THE TRACK GUIDANCE IS IN BETTER AGREEMENT TONIGHT AND EVEN THE STUBBORN GFDL WHICH PREVIOUSLY INSISTED ON BRINGING IRENE TOWARD FLORIDA HAS NOW SHIFTED EASTWARD AND HAS JOINED THE OTHER DYNAMICAL MODELS. THIS INCREASES THE CONFIDENCE IN THE TRACK FORECAST EVEN MORE.
EXCERPT FROM NHC DISCUSSION

THE MODEL GUIDANCE REMAINS IN EXCELLENT AGREEMENT FOR THE FIRST 2-3 DAYS. AFTER THAT TIME...THERE IS SOME QUESTION AS TO WHETHER OR NOT IRENE CONTINUES ON A NORTH-NORTHEAST HEADING OR TURNS BACK TOWARD THE NORTH AHEAD OF A MID-LATITUDE TROUGH APPROACHING THE GREAT LAKES REGION. THE GFDL AND HWRF MODELS REMAIN ALONG THE WEST SIDE OF THE GUIDANCE ENVELOPE AND SHOW A TRACK OVER OR VERY CLOSE TO THE MID-ATLANTIC COAST. THE UKMET AND NOGAPS ARE ALONG THE EASTERN SIDE AND KEEP THE CORE OF THE HURRICANE WELL OFFSHORE. GIVEN THE TYPICAL MODEL AND OFFICIAL TRACK ERRORS...BOTH SCENARIOS ARE VIABLE OPTIONS AT THIS TIME...AND USERS ARE ONCE AGAIN REMINDED NOT TO FOCUS ON SPECIFIC FORECAST POINTS THREE TO FIVE DAYS DOWNSTREAM.
TROPICAL DEPRESSION IKE DISCUSSION NUMBER 53
NWS TPC/NATIONAL HURRICANE CENTER MIAMI FL AL092008
500 AM EDT SUN SEP 14 2008

SURFACE OBSERVATIONS INDICATE THAT IKE WEAKENED TO A TROPICAL DEPRESSION DURING THE PAST Several HOURS...WITH 25 TO 30 KT WINDS AND HIGHER GUSTS OCCURRING WELL TO THE SOUTHEAST OF THE CENTER. THE SURFACE DATA SHOW A COLD FRONT IS APPROACHING IKE...WITH AN AREA OF 25-35 KT WINDS DEVELOPING BEHIND THE FRONT FROM SOUTHWESTERN MISSOURI ACROSS NORTHWESTERN ARKANSAS INTO EASTERN OKLAHOMA. THIS IS THE FIRST SIGN OF EXTRATROPICAL TRANSITION...AND IT IS EXPECTED THAT IKE WILL LOSE TROPICAL CHARACTERISTICS DURING THE NEXT 24 HOURS AS IT MERGES WITH THE FRONT. SOME RE-INTENSIFICATION IS EXPECTED AFTER EXTRATROPICAL TRANSITION IS COMPLETE...WITH IKE PRODUCING GALE-FORCE WINDS UNTIL IT MERGES WITH A LARGER LOW IN ABOUT 72 HR.

THE INITIAL MOTION IS NOW 045/26. IKE IS EXPECTED TO ACCELERATE TOWARD THE NORTHEAST DURING THE NEXT 24 HOURS...AND THEN CONTINUE RAPIDLY NORTHEASTWARD UNTIL THE SYSTEM MERGES WITH THE LARGER LOW AT VERY HIGH LATITUDE.

THIS IS THE LAST ADVISORY ON IKE FROM THE NATIONAL HURRICANE CENTER. FUTURE ADVISORIES WILL BE ISSUED BY THE HYDROMETEOROLOGICAL PREDICTION CENTER IN WASHINGTON DC.

FORECAST POSITIONS AND MAX WINDS

<table>
<thead>
<tr>
<th>Time</th>
<th>Position</th>
<th>Pressure</th>
<th>Max Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>INITIAL</td>
<td>14/0900Z 36.4N 92.5W</td>
<td>30 KT...INLAND</td>
<td></td>
</tr>
<tr>
<td>12HR VT</td>
<td>14/1800Z 40.4N 87.0W</td>
<td>30 KT...BECOMING EXTRATROPICAL</td>
<td></td>
</tr>
<tr>
<td>24HR VT</td>
<td>15/0600Z 45.6N 76.5W</td>
<td>35 KT...INLAND EXTRATROPICAL</td>
<td></td>
</tr>
<tr>
<td>36HR VT</td>
<td>15/1800Z 50.0N 65.3W</td>
<td>40 KT...EXTRATROPICAL</td>
<td></td>
</tr>
<tr>
<td>48HR VT</td>
<td>16/0600Z 55.0N 52.5W</td>
<td>40 KT...EXTRATROPICAL</td>
<td></td>
</tr>
<tr>
<td>72HR VT</td>
<td>17/0600Z...MERGED WITH LARGER LOW</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FORECASTER BEVEN
Ike (2008) and the Windstorm over Ohio

Jay Hobgood and Nick D’Allura
Ohio State University
May 12, 2010
Impacts from ET Ike

- Strong wind gusts from Missouri through the Ohio Valley into southern Ontario and Québec, primarily not associated with convection
- $2.3 billion in property damage in this area
- Millions of people without power for days to weeks
- 28 deaths from various causes

Source: Louisville NWSFO Photo: Mike Howard (from Jay’s presentation)
Highest Measured Wind Gusts (Official Observations)

75 m.p.h. – Port Columbus International, OH and Louisville, KY
74 m.p.h. – Cincinnati-Northern KY Airport and Airborne Airpark, Wilmington, OH
71 m.p.h. – Lorain, OH
69 m.p.h. – Bolton Field, OH and Beaver Falls, PA
68 m.p.h. – Dayton-Wright Brothers Airport, OH
63 m.p.h. – Don Scott Field, OH
60 m.p.h. – Dayton International Airport
59 m.p.h. – Wright-Patterson Air Force Base, OH

Many of the strong gusts were not associated with convection!
SSW 60 kt
SW 35 kt
Gravity waves?
Fig. 1. Actual section of microbarovariograph record for four different stations located around Lamont. Time runs from left to right covering more than 1 h. Maximum pressure variation is 350 μb.

Source: Gedzelman and Rilling (1978)
Possible Causes of Gravity Waves

1. Convection
2. Density impulses
3. Unbalanced jet streaks
4. Strong frontal systems
5. Topography
6. Vertical shear instability
Factors Contributing to High Winds

1. Ike made landfall as a large hurricane
2. Ike contained much higher winds just above the surface.
3. Limited rainfall did not produce downdrafts that would have mixed down the winds earlier (farther south)
4. Mechanical mixing possibly caused by gravity waves brought higher wind speeds down to the surface.
5. The wavelength of the gravity waves was 10-20 km.
6. The gravity waves may have resulted from a combination of vertical shear, frontal processes and convection.
7. An inversion near the 700 mb level may have helped to maintain the gravity waves.
Work Left to Do

1. Determine the location where the gravity waves originated.
2. Identify the precise cause of the gravity waves.
3. How much did Ike re-intensify, and how much of the winds were due to changes in vertical mixing? (JLB question)

Acknowledgements

- NWS Wilmington web site and storm summary
- NRL-Monterrey Tropical Cyclone Page and archived images of Ike
- NOAA National Data Buoy Center
- Nick D’Allura for analyzing some of the surface stations
Conclusions

• NHC forecasts of extratropical transition show skill according to the metrics of the 2-D contingency table verification.

• ET forecasts have shown a general increase in skill since 1991. This is likely due to better NWP models, as well as use of the Hart and Evans Cyclone Phase Space diagrams.

• The NHC forecasts currently have a persistent bias of being too late – transition often occurs before the time it is forecast. In the Irene (2011) case, this resulted from slow track forecasts.

• As shown by the Ike case, incorrect forecasts of meteorological parameters during and after ET can cause problems!