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ESTIMATION OF TROPICAL CYCLONE TRACK FORECAST UNCERTAINTY

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1. INTRODUCTION

Consensus tropical cyclone (TC) track forecast aids formed using TC track forecasts from regional and global numerical weather prediction models have become increasingly important in recent years as guidance to TC forecasters at both the National Hurricane Center (NHC) and the Joint Typhoon Warning Center (Goerss et al. 2004). Forecasters at NHC routinely utilize consensus forecast aids (e.g., GUNA) formed using the interpolated TC track forecasts from the GFDL model (GFDI; Kurihara et al. 1993, 1995, 1998) and the Global Forecast System (AVNI; Lord 1993) run at NCEP, the Navy Operational Global Atmospheric Prediction System (NGPI; Hogan and Rosmond 1991, Goerss and Jeffries 1994), and the UK Meteorological Office global model (UKMI; Cullen 1993, Heming et al. 1995). In this study a second consensus aid (CONU) is formed using the interpolated TC track forecasts from the GFDL model (GFNI; Rennick 1999) run at FNMOC along with those from the aforementioned models. The TC track forecast performance of CONU is compared with that of GUNA.

The purpose of this study is to determine to what extent the TC track forecast error of the consensus models, GUNA and CONU, can be predicted prior to the time when official forecasts must be issued. Predictors of consensus forecast error must be quantities that are available prior to the time when official forecasts must be issued. Consensus model spread is defined to be the average distance of the member forecasts from the consensus forecast. Forecast displacement is defined to be the difference between the initial and forecast latitudes (or longitudes). The possible predictors examined in this study are consensus model spread; initial and forecast TC intensity; initial and forecast displacement of TC location (latitude and longitude); TC speed of motion; and number of members available (for CONU).

2. RESULTS AND CONCLUSIONS

The interpolated versions of the aforementioned five high-quality TC track forecast models available to the forecasters at NHC were used in this study. GUNA is a consensus model routinely used by the forecasters at NHC that is computed when the track forecasts from all four models (GFDI, AVNI, NGPI, and UKMI) are available. CONU is a consensus model computed when track forecasts from at least two of the five models (GFDI, AVNI, NGPI, UKMI, and GFNI) are available. For the 2001-2003 Atlantic hurricane seasons, the TC track forecast errors for the individual models ranged from 68-81 nm at 24h,122-145 nm at 48h, 186-216 nm at 72h, 241-306 nm at 96h, and 312-385 nm at 120h. The respective errors for GUNA were 61 nm, 112 nm, 165 nm, 214 nm, and 271 nm. While the TC track forecast errors for CONU were virtually identical to those for GUNA, the forecast availability for CONU was found to be superior to that for GUNA. The forecast availability for GUNA was 72%, 68%, 65%, 53%, and 50% at 24 h, 48 h, 72h, 96h, and 120 h, respectively, while that for CONU was 91%, 91%, 90%, 86%, and 85%.

The correlations between consensus model TC track forecast error and each of the aforementioned predictors were determined for the 2001-2003 Atlantic hurricane seasons. For all forecast lengths, the consensus model spread was found to be related to consensus model TC track forecast error. The strongest correlation was found for 96-h and 120-h forecasts. For CONU, the correlation between spread and forecast error was 0.63 and 0.59 at 96h and 120h, respectively, while the correlations for shorter forecast lengths ranged from 0.27 to 0.39. Initial and forecast TC intensity were found to be consistently but, in general, less strongly related to track error with correlations ranging from 0.30 to 0.40. Other predictors were found to be reasonably well correlated with forecast error at certain forecast lengths. For example the correlation between longitude displacement and forecast error for CONU was 0.36 and 0.52 at 96h and 120h, respectively.

Using stepwise linear regression and the pool of predictors, regression models were found for each forecast length to predict the TC track forecast error of the consensus models. For CONU, the spread was found to be the leading predictor at 72h, 96h, and 120h, and the second leading predictor at 24h and 48h. The leading predictors at 24h and 48h were initial TC intensity and forecast TC intensity, respectively. Initial latitude and the forecast displacement of latitude and longitude were selected as predictors for four of the five forecast lengths. The number of available members was selected for three forecast lengths while the TC speed of motion was selected for two forecast lengths. Using these linear regression models, the percent variance of CONU TC track forecast error that could be explained for the 2001-2003 Atlantic seasons ranged from just under 20% at 24h and 48h to roughly 50% at 96h and 120h. Similar results were found for GUNA.

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For the 2001-2003 Atlantic hurricane seasons, circular areas with static radii based on NHC's official forecast error for the last ten years of 81 nm at 24h, 150 nm at 48h, 225 nm at 72h, 282 at 96h, and 374 nm at 120h drawn around the official forecasts contained the verifying TC position 67-71% of the time. For the same period, radii were computed by adding a constant varying with forecast length to the predicted TC forecast error derived using the linear regression models. The constants chosen were 15 nm at 24h, 30 m at 48h, 45 nm at 72h, 60 nm at 96h, and 75 nm at 120h. These predicted radii, which varied from 15-140 nm at 24 h, 30-250 nm at 48 h, 45-580 nm at 72 h, 60-1060 nm at 96 h, and 75-1200 nm at 120 h, were used to draw circular areas around each of the CONU forecast positions. These areas were found to contain the verifying TC position 73-76% of the time. Thus, based on the size of these circular areas, a forecaster can determine the confidence that can be placed upon the consensus forecasts and use that information in the process of producing the official forecast.

Finally, independent data testing was performed using a jackknifing technique. Predicted TC forecast errors were computed for each storm after removing that storm from the dependent data set. This process was repeated for all of the storms in the three year sample and radii were computed exactly as described above and used to draw circular areas around each of the CONU forecast positions. For 120h, these areas were found to contain the verifying TC position 71% of the time for the independent testing compared with 76% of the time for the dependent sample. These results were typical of those found at the other forecast lengths and indicate that one can expect only a small degradation in this predictive capability in practice.

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