

## SIXTH INTERNATIONAL WORKSHOP on TROPICAL CYCLONES

### Topic 0.1: **Track forecasts**

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#### **Abstract:**

This paper describes how operational tropical cyclone track forecasting is performed at various centers. The paper also includes track forecast verifications and discusses the issuance and verification of tropical cyclone warnings for the United States. The use of wind speed probabilities by RSMC Miami to better convey forecast uncertainties is introduced.

#### 0.1. **Track forecasts**

The tropical cyclone track forecast is a critical component of the warning system, as it serves as the basis for forecasting the areas threatened by damaging winds, storm surge, and rainfall. RSMC Miami has extended tropical cyclone track forecasts from 3 days out to 5 days, but demand for even longer lead times continues. As with other forecast problems, tropical cyclone prediction relies on a subjective mix of objective guidance with human interpretation and understanding, so that forecaster skill and experience are critical for success.

RSMC Miami track forecast errors defined as the distance between a forecast and the subsequently observed position of the storm center averaged 65, 91, 118, 171, 231, and 303 n mi for the 24, 36, 48, 72, 96, and 120 h forecasts, respectively, for the 5-yr period 2001-2005. Using a combination of climatology and persistence as a basis for comparison, track forecast skill exists at all time intervals through 5 days, with the skill increasing out to 36 h and then remaining relatively constant thereafter. The extended 5-day forecasts are currently as accurate as the three-day forecasts were 15 years ago, and forecast errors from 24-72 h are now roughly half of what they were in 1990. During the two very active Atlantic hurricane seasons of 2004 and 2005, RSMC Miami 12-72h track forecast accuracy was at or near record levels. Fig. 0.1.1 shows the long term average track forecast errors for the Atlantic basin.

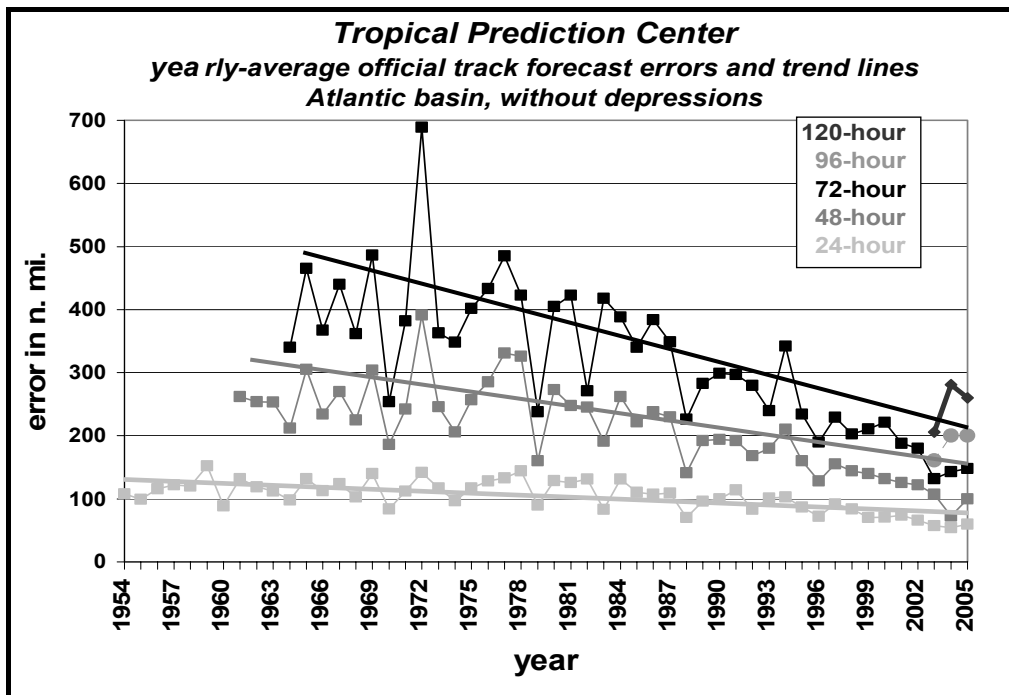


Fig. 0.1.1. Yearly official track forecast errors and trend lines for the Atlantic basin.

The track errors associated with the forecasts issued 24 through 120 hours before a U.S. landfall during the past five years averaged 36, 69, 142, 233, 300 n mi. Figure 0.1.2 shows the average track error for all storms and for those making landfall in the U.S.

The track errors for landfalling storms are slightly smaller for the 24 through 72 hours period. There is practically no difference for the 96 through 120-h periods.

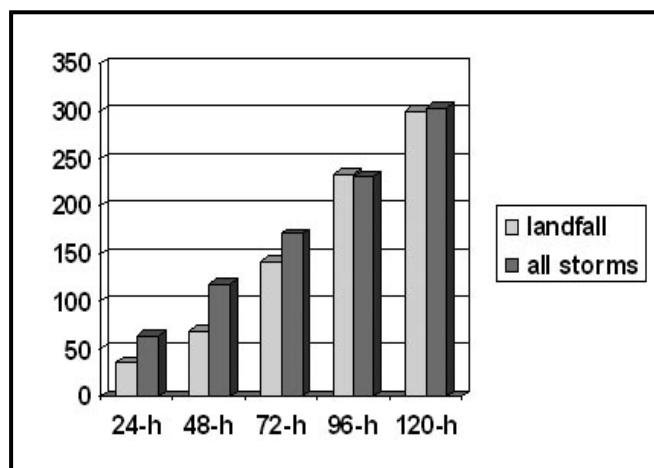


Fig 0.1.2. Average track errors for storms making landfall in the United States versus all storms.

The gradual reduction in track forecast errors with time is also evident in other basins. Fig. 0.1.3 shows that for the Australian region the 24-h errors have decreased from 225 km in the early eighties to near 150 km during the past couple of years with a record low of 120 km in 2004. The region issues track forecasts through 24 hours only.

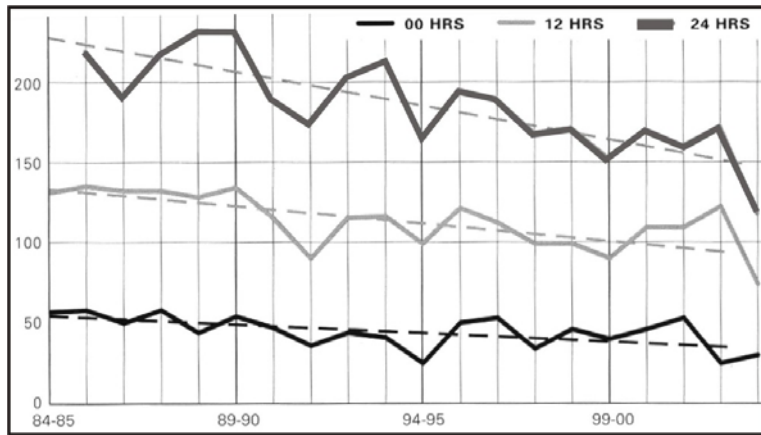


Fig. 0.1.3. Official average 0-h, 12-h and 24-h track forecast errors for the Australian region from 1984 through 2005.

RSMC La Reunion issues track forecast through 48 hours. Data displayed in Fig. 0.1.4 indicate that there has been no significant change in the 24 hours forecast during the past 20 years. However, a modest improvement has been accomplished at 48 hours. The errors have decreased from 375 km in the early nineties to about 300 km during the past 5 years.

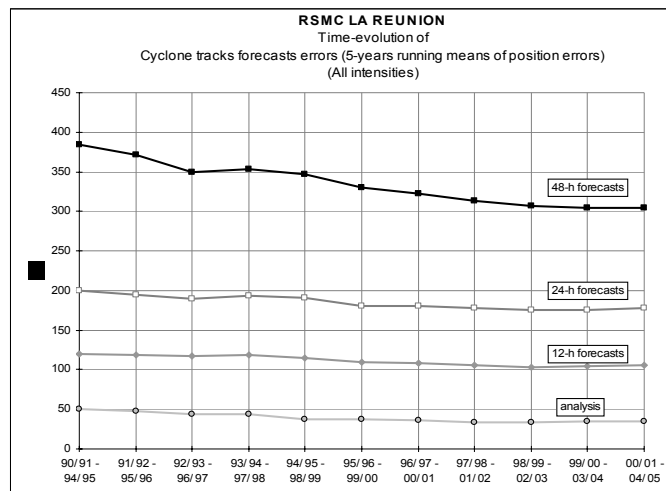


Fig. 0.1.4. RSMC La Reunion official average 0-h,12-h, 24-h and 48-h track forecast errors from 1990 through 2005.

The steady reduction in track error could be attributed to various factors, including the improved quantity and quality of observations from a suite of instruments ranging from satellites to dropsondes, the use of improved data assimilation methods (particularly for unconventional satellite observations).

Moreover there has been a significant advance in the resolution and physics of dynamical forecast models. Fig. 0.1.5 shows the gradual reduction in the 48-h track model errors.

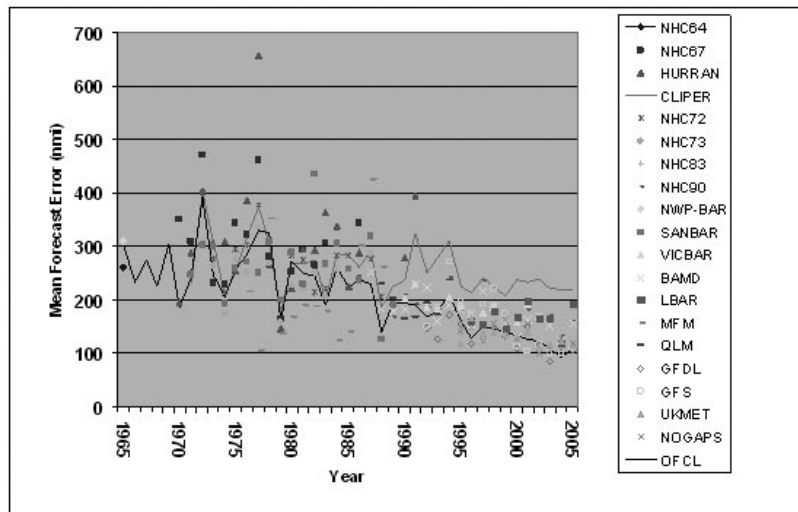


Fig. 0.1.5. 48-h track forecast errors from 1965 to 2005.

Despite the improvements in track forecast accuracy, forecast uncertainty requires the issuance of U.S. hurricane warnings for relatively large coastal areas. During the period 2000-2005, the average length of a hurricane warning in the United States was 275 n mi. This represents a decrease from the preceding decade, during which the average warning length was 395 n mi, and appears to represent a reversal of an earlier trend toward larger warning areas. Even so, only about one-quarter of an average hurricane warning area experiences hurricane conditions. Another important factor is the lead-time of hurricane warnings. This is defined as the time between the issuance of the warning and the time of experiencing hurricane force winds at a warned point.

The average lead-time of NHC hurricane warnings has increased from 19 hours in the seventies to near 34 hours for the period 2000-2005. See Figure 0.1.6.

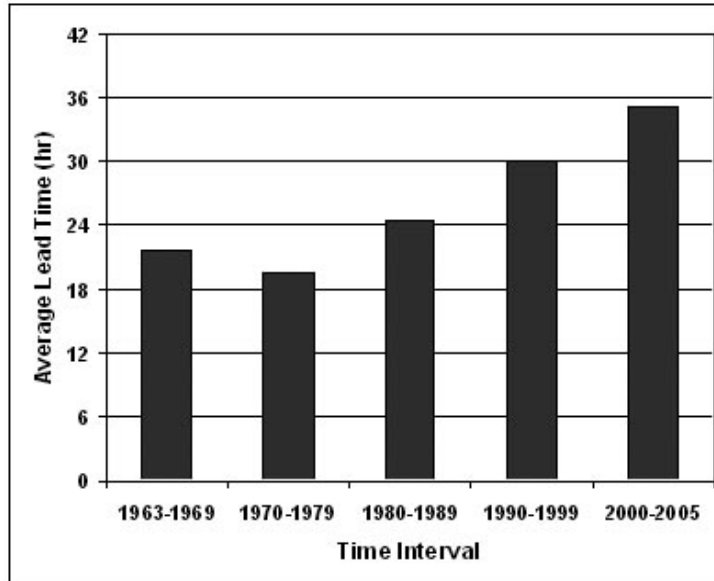


Fig. 0.1.6. Average lead-time of hurricane warnings for the United States.

Continued improvements in track forecast accuracy could be used to decrease the amount of “over-warning”. However, hurricane warnings must carefully balance the need to minimize the negative impacts of over-warning against the need to safeguard lives and property. The continual increase in coastal population and development without concurrent expansion of evacuation routes has resulted in increased evacuation clearance times. As a result, the NHC has put greater attention on translating forecast improvements into increasing the lead-time of warnings, instead of decreasing the warning area. Hurricane Katrina reminds us that in spite of all the progress that has been made in forecasting the path of tropical cyclones, the United States remains vulnerable to a large loss of life from storm surge.

RSMC Miami has been using a cone of uncertainty to display graphically the uncertainties of a track forecast as shown in Fig 0.1.7. This cone is constructed using the past forecast track errors.



Fig. 0.1.7. Cone of uncertainty associated with Hurricane Katrina, 2005.

RSMC Miami has also begun to use “wind speed probabilities” to better convey the uncertainty in forecast. This new product is about a **weather event** at any specific location and conveys chances of wind speeds of at least particular thresholds 34- and 50 -kt (tropical storm force) and 64 kt (hurricane force) and in fact, it accounts for combined uncertainty in track, intensity, and size. This method is based on a large set of plausible tracks and intensities (ensemble members) roughly centered around the current official forecast and determined by random sampling of historical track and intensity errors in official forecasts (since 2001). Fig 0.1.8 shows the wind speed probability associated with Hurricane Rita 2005.

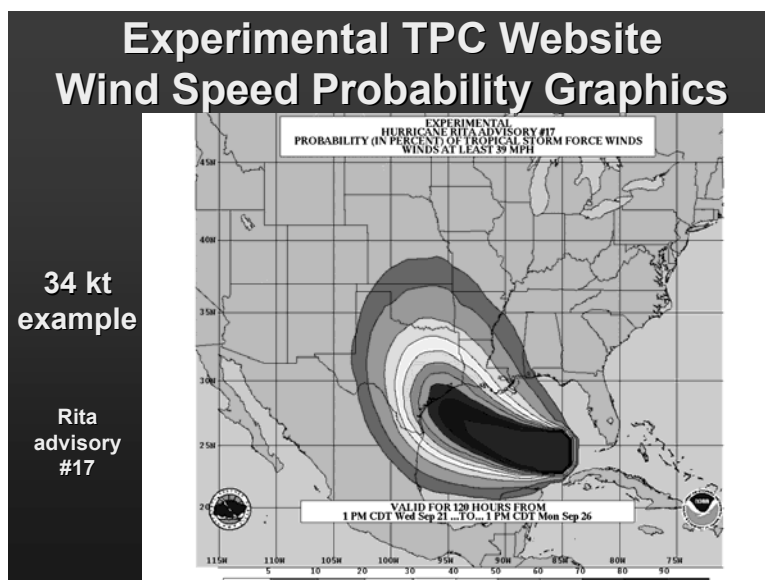


Fig. 0.1.8 Probability of 34-kt winds associated with Hurricane Rita, 2005.

### 0.1.1 Practical operational remarks

In making the track forecast, it is suggested to maintain continuity with previous forecast. It is better to have a modest response lag than to jerk the forecast back and forth. The official forecast rarely deviates from the guidance envelope and the guidance spread is in general reflected in the forecast confidence. For example, a large model spread as shown in Fig. 0.1.9 implies low confidence in the forecast. The opposite is not necessarily true. A multi-model consensus is a very powerful tool for producing accurate track forecast. However, it is important to examine the synoptic data and the model fields and do not focus in the predicted TC track in the model. This is also important in identifying a model outlier but this is very difficult.

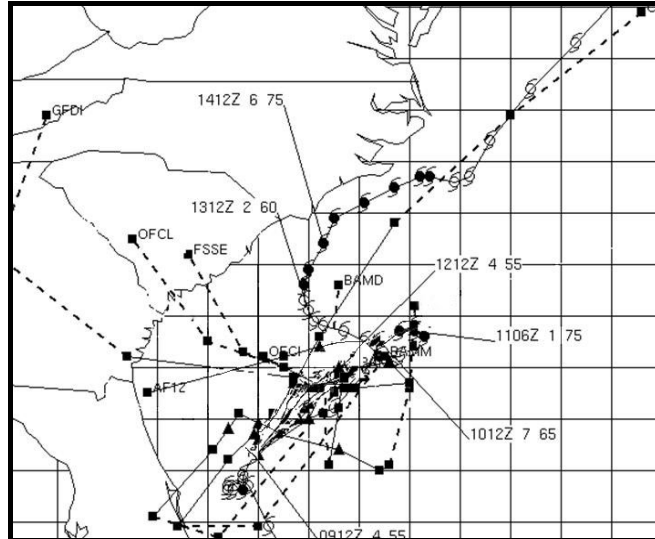


Fig. 0.1.9. Track guidance associated with Hurricane Ophelia at 1200 UTC 9 September. Note the large spread in the models implying low confidence in the forecast.

**Acknowledgments:**

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