13A.2

AN ANALYSIS OF ALONG- AND CROSS-TRACK FORECAST ERRORS AND ERROR BIASES FOR TCs IN THE ATLANTIC BASIN

Chris Fogarty* and Peter Bowyer

Canadian Hurricane Centre, Halifax, Nova Scotia, Canada

1. INTRODUCTION

It has often been suspected that track forecasting**2** errors for tropical cyclones (TCs) undergoing extratropical transition (ET) is greatest in the along-track sense of storm motion, compared to the cross-track sense. Storms which have undergone recurvature and are going through ET move in a direction governed by the deep-layer mean wind of the baroclinic mid-latitude "westerlies". The speed at which they move in that flow is often a significant forecasting challenge that impacts the lead time of weather warnings for these fast-moving storms. The objective of this simple study was to quantify track forecasting errors in terms of the along- and cross-track components of the storm's motion. Additionally, we wished to detect any forecast biases, and study the season-to-season variability of the track forecast errors.

2. METHODOLOGY

Best track data from 2000 to 2006 was used in this study as the observed (verifying) information. Forecasts from the Canadian Hurricane Center (CHC) and National Hurricane Center (NHC) were used for select storms in the above timeframe that underwent ET. Software was written to parse multiple forecasts from the issuing centers including the best track data so that computations could be carried out. The computations involved decomposing the track error into along- and cross-track components, as well as finding simple intensity error statistics. Various forecast lead times were considered – namely 12, 24, 36, 48, 72 and 120HR forecasts. A composite of 11 storm tracks used in the study is shown in Fig. 1 below.

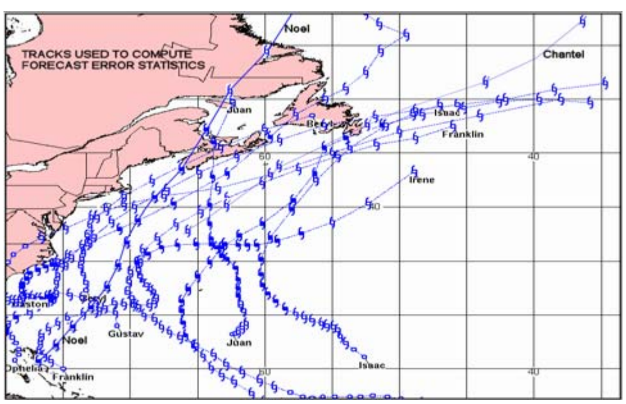


Fig. 1. Storm tracks used in the study.

* *Corresponding author address*: Chris Fogarty, Meteorological Service of Canada, 3rd Floor, 45 Alderney Drive, Dartmouth, NS, Canada B2Y 2N6; email: chris.fogarty (at) ec.gc.ca.

3. RESULTS

3.1 Selected Case Composite (ET)

Table 1 shows some mean along- and cross-track errors and error biases from the CHC for the 11-case sample from storms in the 2000-2006 period. It is apparent that the track error distribution becomes more elliptical at later forecast hours (i.e. later in the ET process).

Table 1. Mean CHC track error and error bias statistics for the 11-case composite. Units in nautical miles.

HR	MTPE	MCTPE-B	MATPE-B	MACTPE	MAATPE
12	43.6	-8.6	1.4	24.8	34.5
24	66.8	-16.7	-5.7	39.7	51.3
36	98.3	-16.7	-3.4	52.7	80.5
48	130.7	-15.0	-6.1	72.9	111.0
72	164.8	18.3	-22.9	75.4	142.7
120	224.7	14.3	-215.6	70.8	213.1

HR – Forecast hour
MTPE – Mean track position error
MCTPE-B – Mean cross-track position error bias
MATPE-B – Mean along-track position error bias
MACTPE – Mean absolute cross-track position error
MAATPE – Mean absolute along-track position error

A graphical representation of these results is shown in Fig. 2. The track shown is arbitrary, but generally representative of a typical storm evolution after recurvature.

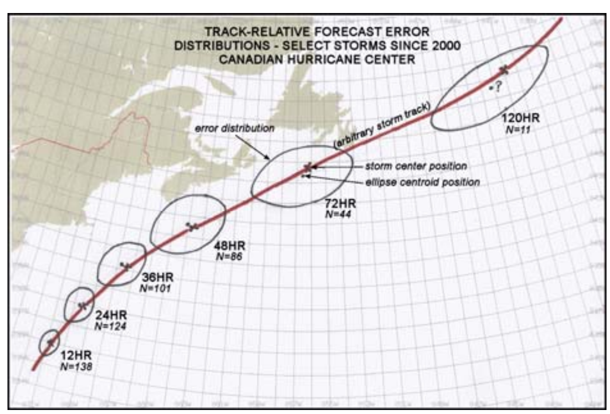


Fig. 2. Graphical presentation of the results. Sample size for each forecast lead time is shown (N).

3.2 *NHC Seasonal Track Error Statistics (non-ET)*

The second component of the study was to look at seasonal along- and cross-track error statistics for NHC's *official* forecasts for tropical-only stages of the storm lifecycle. Seven seasons were chosen from 2000 to 2006. The results are shown in Fig. 3 indicating that there still exists a tendency for there to be greater along-track errors compared to cross-track, although it is not as pronounced as the extratropically-transitioning storms. The mean absolute errors here compare well with NHC's track error information available at:
http://www.nhc.noaa.gov/verification/

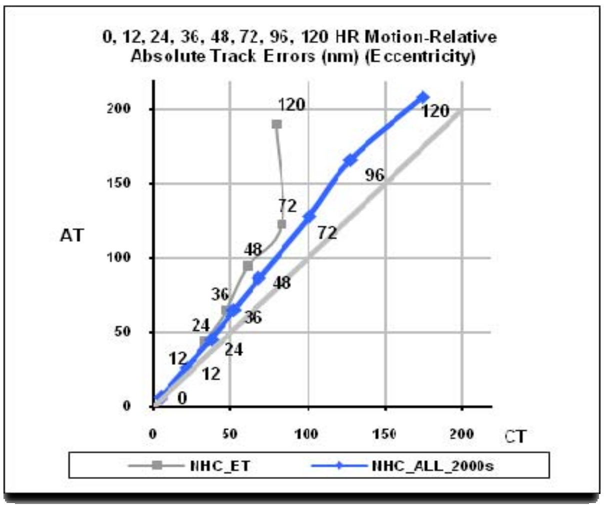


Fig. 3. Mean absolute along-track and cross-track errors from NHC official forecasts from 2000 to 2006 for tropical-only storms (blue) and ET events (grey boxed). A circular error distribution is represented by the straight diagonal line.

Where Fig. 3 gives an indication of the elliptical nature of the error distribution, Fig. 4 shows the NHC error *biases* for the various forecast lead times for all tropical-only phases of storms in the 2000 to 2006 period.

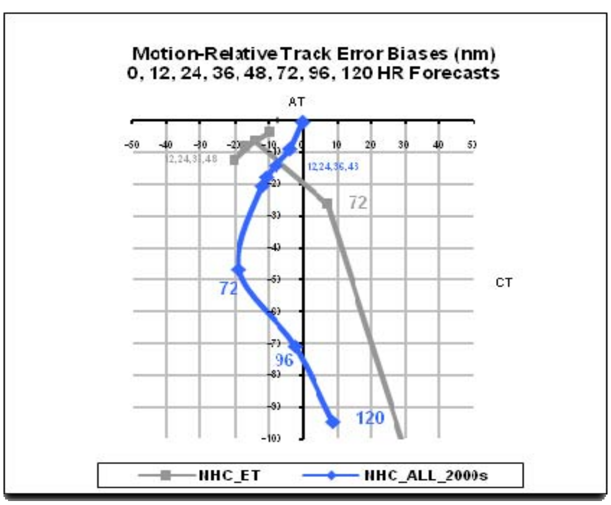
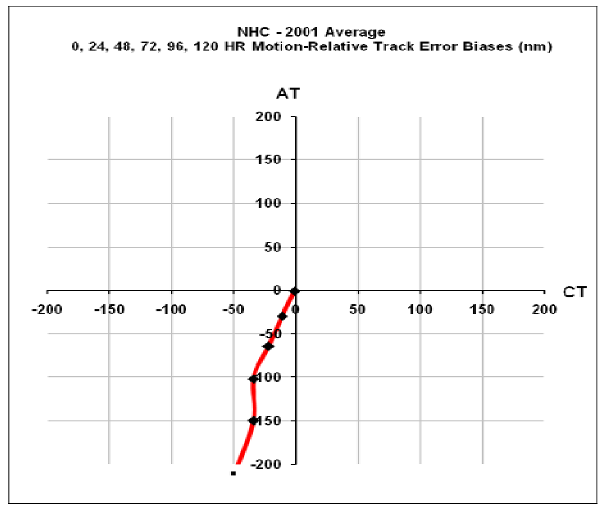
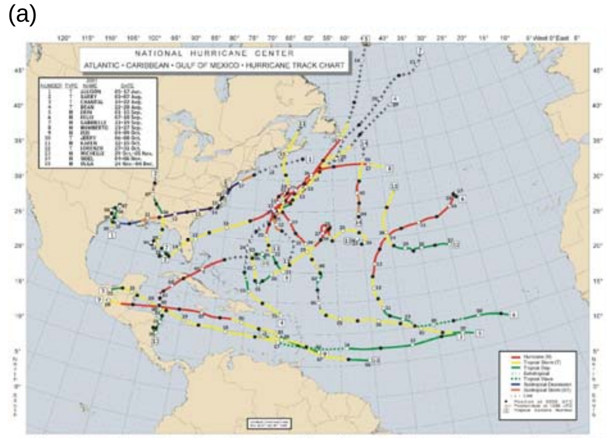


Fig. 4. Mean along-track and cross-track error *biases* from NHC official forecasts from 2000 to 2006 for tropical-only storms (blue) and ET events (grey boxed).

There is a negative along-track error tendency for both ET-only events and tropical-only events. The negative tendency becomes greater with forecast lead time, such that the 5-day bias is about -100 nm (e.g. a slow bias). There is also a negative cross-track bias, which is typically on the Caribbean or continental side of the storm track. The error biases are largely season-dependant. However, most of that seasonal variability occurs in the cross-track sense, while the along-track error biases are often negative when averaged over a season. A couple of examples are shown in Fig. 5 and Fig. 6.



(a)

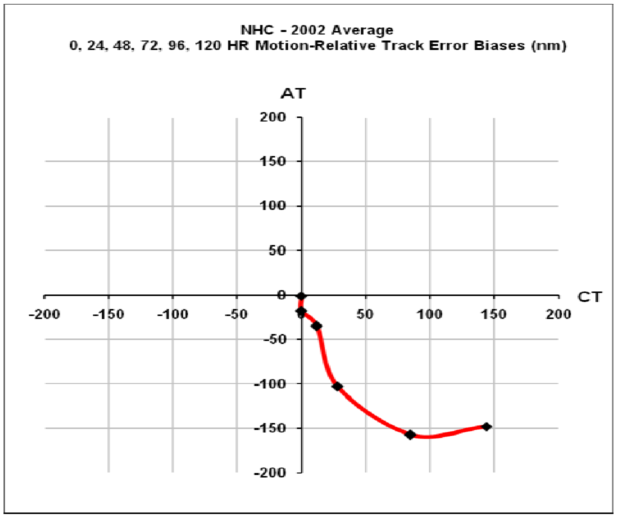


(b)

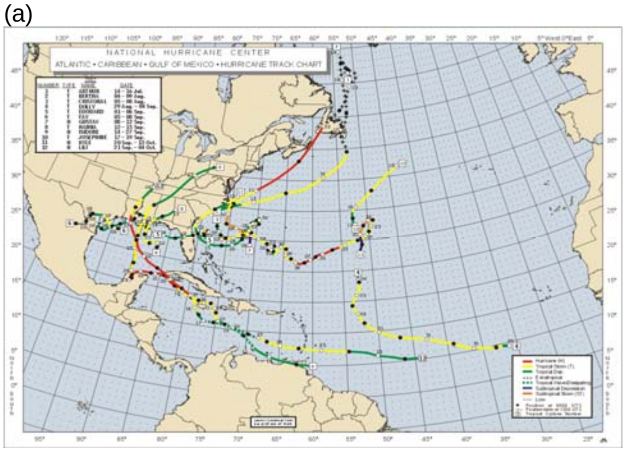
Fig. 5. (a) NHC season-averaged track error biases (tropical-only phase) for 2001. (b) Composite of all tropical cyclones in 2001 (taken from NHC website: http://www.nhc.noaa.gov)

Notice in Fig. 5 that there were rather pronounced biases to the left-of-track, and a slow tendency for all lead times. Also note that most storms were in the open Atlantic, where one would expect error and error biases to be quite large.

During the 2002 hurricane season, storms tracked closer to the continent with similar negative along-track biases as 2001, but with generally right-of-track biases overall compared to 2001 when the bias was left-of-track.



(a)



(b)

Fig. 6. Same as Fig. 5 except for 2002.

4. CONCLUSIONS AND APPLICATIONS

Recasting tropical cyclone forecast errors into motion-relative components is a more effective way to communicate error tendencies (e.g. along-track errors associated with storm arrival time and cross-track errors associated with errors in the storm's direction of motion). Compiling statistics from the CHC and NHC forecasting offices provides meteorologists with quantitative measures of their forecast performance – be it for a single storm, or for the overall season.

The results confirm (especially after recurvature and during ET) that the error distribution is most pronounced in the along-track sense, with an overall slow bias. In terms of atmospheric dynamics, this is not a surprise since the steering flow in the mid-latitudes is more defined than the deep tropics, while the speed at which a storm moves in the strong steering environment is more difficult to predict. The latter challenge likely relates to storm scale and flow interaction, but it is an important one to understand and predict, since the lead time for fast-moving ET-type storms is critical for preparation time.

The findings of this work and other similar work (Goerss 2006, 2008) can be used to refine track error cones in forecast storm track graphics which commonly assume a circular-type error distribution. Results here are also important tools for educating end-users of the nature of forecast uncertainties as they relate to storm nature (ET, tropical, etc) and motion.

5. REFERENCES

Goerss, J., 2006: Prediction of consensus tropical cyclone track forecast error. Submitted to *Mon Wea. Rev*.

Goerss, J., 2008: Prediction of Consensus TC Track Forecast Error and Correctors to Improve Consensus TC Track Forecasts. *Powerpoint presentation from the 62nd Interdepartmental Hurricane Conference*, *Charlseton, SC, March 3-7, 2008.* Talk available online at: http://www.ofcm.gov/ihc08/linking_file_ihc08.htm