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Estimating The Probability Of Rapid Intensification of Tropical Cyclones in the Atlantic and Eastern Pacific Basins

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1. Introduction

While there has been some improvement in operational tropical cyclone (TC) intensity forecasting skill in recent years, TC intensity forecasts remain considerably less skillful than that TC track forecasts (Simpson et al. 2003). More importantly, the capability of predicting rapid intensification (RI) remains inadequate as evidenced by the unexpected RI of several recent Atlantic (e.g., Keith (2002), and Lilly (2002)) and East Pacific (Kenna (2002)) hurricanes. This lack of skill has prompted the National Hurricane Center (NHC) to rank improving the capability to forecast episodes of rapid intensification (RI) as one of their highest forecast priorities (Rappaport, personal communication). Since current operational intensity prediction models have not yet demonstrated the ability to reliably predict RI events, Kaplan and DeMaria (2003) have developed a simple RI index that can be used to estimate the probability of RI for a 24-h period using output from the SHIPS model. The RI index has been provided in real-time to forecasters at the NHC for the past three Atlantic hurricane seasons as part of the Joint Hurricane Testbed (JHT). Although, the RI index has been designated for operational implementation by the NHC commencing with the 2004 hurricane season, it was originally developed for the Atlantic basin. Thus, an analogous index is being developed for the East Pacific basin. This paper will discuss the derivation of the East Pacific RI index and will compare its performance to the Atlantic version.

2. Data

The data employed in this study were obtained from the 1989-2002 SHIPS and NHC HURDAT databases. The former contains synoptic and storm-scale predictors evaluated every 12h for all tropical and subtropical cyclones in the Atlantic and Eastern Pacific basins. The SHIPS synoptic atmospheric predictors were evaluated using the t=0 h NCEP Aviation analysis fields while the synoptic oceanic predictors were evaluated using the most recent weekly Reynolds sea-surface temperature analysis. The storm-scale inner-core predictors were evaluated using GOES infrared imagery (Zehr 2000). The NHC HURDAT file, which contains TC positions and intensities every 6 h from 1886 to the present, was employed to evaluate the climatological and persistence predictors.

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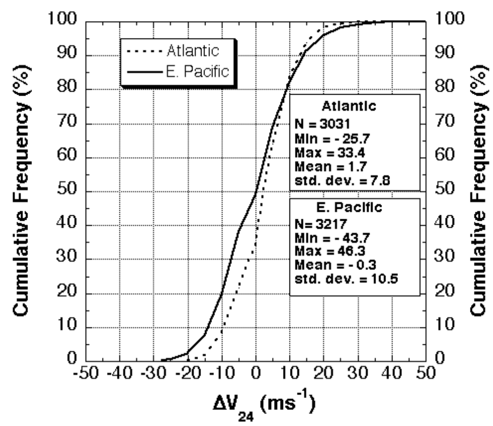

Fig. 1. The cumulative frequency distributions for the Atlantic and Eastern Pacific basins.

3. Results

Figure 1 shows the 24-h over-water intensity change (ΔV_{24}) distributions for tropical and subtropical cyclones that formed in the Atlantic and Eastern Pacific basins from 1989-2002. The distributions indicate Eastern Pacific cyclones exhibit a larger range of ΔV_{24} than do Atlantic cyclones. Specifically, the maximum (minimum) ΔV_{24} observed in the Eastern Pacific basin is 46 ms^{-1} (-44 ms^{-1}) while the maximum (minimum) intensity change observed in the Atlantic basin is only 33 ms^{-1} (-26 ms^{-1}). Following the methodology of Kaplan and DeMaria (2003), RI was defined as the 95th percentile of all ΔV_{24} values. This corresponds to a ΔV_{24} of ~16 ms^{-1} and ~19 ms^{-1} in the Atlantic and Eastern Pacific basins. However, for the purpose of this study we have defined RI as a ΔV_{24} of $\geq$15.4 ms-1 (30 kt) and $\geq$18 ms^{-1} (35 kt) for the Atlantic and Eastern Pacific basins, respectively. Thus, the actual percentage of systems undergoing RI in the Atlantic and Eastern Pacific basins is about 6%. Figure 2 shows the locations of the RI cases in both basins. Interestingly, the RI cases in the Atlantic basin occur over a much broader area than those in the Eastern Pacific basin. Specifically, the Atlantic RI cases are most prevalent in the western portions of the Atlantic, Caribbean, and Gulf of Mexico, while the Eastern Pacific RI cases tend to be clustered in a region off of the southwest Mexico coastline.

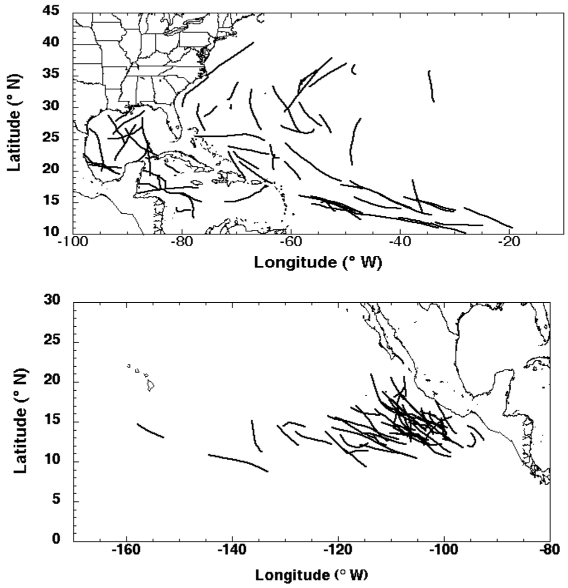

Fig. 2. The 24-h tracks of the Atlantic (top) and Eastern Pacific (bottom) RI cases.

An RI index was developed for the Eastern Pacific basin and an updated RI index was also developed for the Atlantic basin following methodology that was very similar to that described in Kaplan and DeMaria (2003). Briefly, the Eastern Pacific and Atlantic samples were divided into RI and non-RI cases and statistical significance tests were performed to identify the predictors for which statistically significant differences existed between the two samples at the 99.9% level. However, the 24-h average magnitudes of the synoptic predictors were compared rather than the t=0 magnitudes as was done previously (Kaplan and DeMaria 2003) since recent results indicate that employing 24-h average values yields superior RI probability estimate. Nevertheless, the t=0 h average magnitudes of the storm-scale GOES predictors were employed rather than the 24-h average values since there is no current technique for predicting such values as would be required if they were employed operationally. Thresholds for RI were then established for each of the predictors for which statistically significant differences were found between the RI and non-RI samples. These thresholds were equivalent to the mean values of the RI sample for each of the statistically significant predictors.

Sensitivity tests were performed to determine which sets of statistically significant predictors were used in the final versions of the RI indices. This was done objectively by choosing those predictors that yielded the highest Brier Skill Score for a homogeneous set of cases that comprised the dependent sample. The Brier Skill Score was evaluated for each version of the RI index by comparing the hindcasted RI probabilities to the climatological probability of RI (i.e.,6%) of the Atlantic and Eastern Pacific samples. The sensitivity tests showed that combining the five predictors that had been employed in the previous version of the Atlantic RI index (previous 12 h intensity change, 850-200 hPa vertical shear, sea-surface temperature, potential intensity, 850-700 hPa relative humidity) as well as two storm-scale inner-core predictors (infrared brightness temperature and std. dev. of the infrared brightness temperature) yielded the most skillful version of the RI index in both basins. Figure 3 shows the variation of the probability of RI as a function of the total number of RI thresholds (out of 7) satisfied. The behavior of both indices is similar with very low probabilities found when 0 thresholds are satisfied and fairly high probabilities observed when 6 or 7 of the thresholds are satisfied. However, the figure also shows that the percentage of RI cases that occur is rather small when all of the thresholds are satisfied. Interestingly, the Eastern Pacific version of the RI index was 23% more skillful than climatology, while the Atlantic version was only 16% more skillful. While the results in Fig. 3 are encouraging, the RI index is admittedly simple and future research efforts will focus on re-deriving it employing more sophisticated methods.

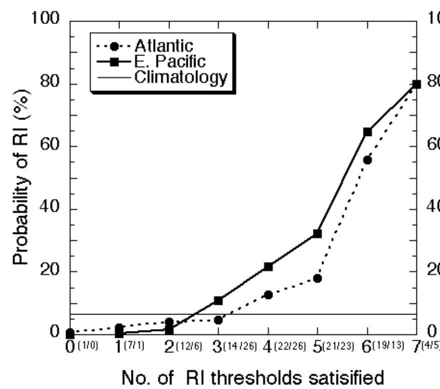

Fig. 3. The probability of RI as a function of the total number of RI thresholds satisfied (out of 7). The percentage of RI cases that were observed is also shown in parentheses along the x-axis. The Atlantic value is shown first followed by the E. Pacific value.

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