**Estimating the Probability of Rapid Intensification Utilizing the SHIPS Model Output**

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## 1. Year 1 (1 July 2001 – 1 July 2002)

### a. Accomplishments

The 1989-2000 SHIPS database was employed to obtain an updated rapid intensity (RI) index for the 2001 Atlantic Hurricane season. Computer code was also developed and added to the SHIPS code so that operational estimates of the probability of RI (defined here as a 24 h intensity increase of $\geq$15.4 $ms^{-1}$) could be obtained for each Atlantic basin SHIPS forecast. In late July, a handout that described the methodology that would be used to compute operational estimates of the probability of RI during the 2001 season was given to all hurricane specialists and was also made accessible via the worldwide web. From 2 August 2001 to 30 November 2001 estimates of the probability of RI, the climatological probability of RI, and the number of RI thresholds satisfied were computed for each 2001 Atlantic basin SHIPS forecast. These estimates were obtained after comparing the initial (t=0 h) magnitudes of various operational SHIPS predictors (e.g., persistence, sea-surface temperature, low-level relative humidity, potential intensity, and vertical shear) to the RI threshold values that had been determined previously during analysis of the 1989-2000 SHIPS database. This information was included on the SHIPS log file that was sent to NHC whenever an operational SHIPS run was made. Suggestions for changes to the format and content of the RI information that was printed on the log sheets were solicited from all of the NHC hurricanes specialists. Based upon these suggestions, an alternative RI format was proposed and then implemented by the PIs during the 2002 hurricane season.

A presentation was made at the NOAA hurricane conference held in December 2001 that summarized some of the preliminary results of the first year attempts to estimate the probability of RI. Also, the final verification of the 2001 probability of RI estimates was shown at the 25th Hurricane Conference (Kaplan and DeMaria 2002).

### b. Results

Fig. 1 shows the verification of the operational probability of RI estimates for the entire 2001 season. This verification was performed using all 6 hourly forecasts times

when a system remained over-water and tropical for the entire 24 h forecast period. The variation of the probability of RI as a function of the total number of RI thresholds satisfied is shown for the 1989-2000 dependent sample for comparison. The probability of RI estimates computed for the 2001 season were determined by dividing the number of occurrences of RI by the total number of forecasts for each of the specified number of RI thresholds. For example, there were 2 occasions when 5 of the RI thresholds were satisfied during the 2001 Hurricane seasons and RI occurred on 1 of these 2 occasions. Consequently, the probability of RI was 50 % when 5 of the RI thresholds were satisfied during the 2001 season. While the 2001 sample size was fairly small (especially when 4 or 5 thresholds were satisfied), the operational probability of RI estimates that were provided during the 2001 season were reasonably consistent with those that had been obtained previously for the 1989-2000 dependent sample. Moreover, the RI index was employed successfully during Hurricane Michelle by NHC hurricane specialists who correctly increased the forecasted wind speed above that which was provided by the objective guidance do ,in part, to the RI index which showed that all 5 of the RI thresholds were satisfied. These results suggest that the RI index has the potential to be a useful forecast tool.

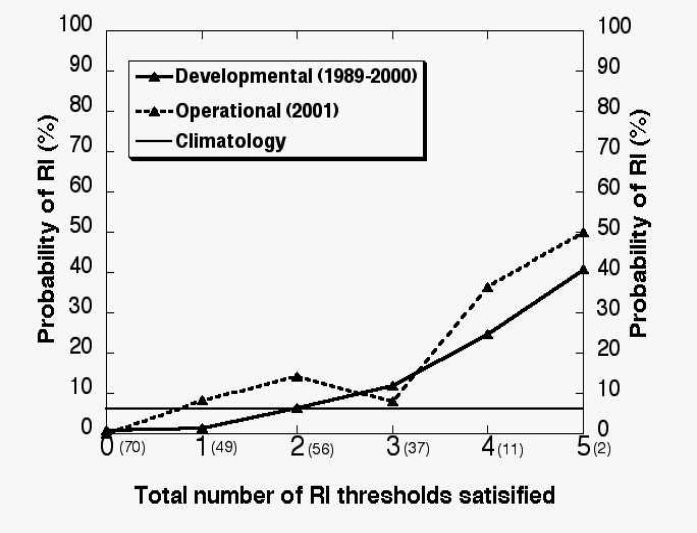


Fig. 1. The probability of RI as a function of the total number of RI thresholds satisfied (out of five) for the 1989-2000 Atlantic basin developmental sample. The 2001 operational probabilities are also shown with the number of cases presented in parentheses. The climatological probability of RI is also depicted.

**2. Year 2 (1 July 2002 – 1 July 2003)**

**a. Accomplishments**

An updated version of the RI index for the 2002 Atlantic hurricane season was developed. The methodology employed to derive the 2002 version of the RI index was similar to that used to develop the 2001 version with a few notable exceptions. First, the entire life cycle of all Atlantic tropical cyclones were employed when re-deriving the RI index. Previously, the wave and/or low pressure stage of a tropical cyclone were excluded from the developmental data sample. In addition, the 24-h average magnitudes of all five of the RI predictors save persistence (e.g., sea-surface temperature, low-level

relative humidity, potential intensity, and vertical shear) were employed to estimate the probability of RI instead of the t=0 h values that were used in the previous version. Lastly, the updated RI probabilities and thresholds were determined using all of the cases from the period 1989-2001 rather than the period 1989-2000. A detailed description of the above procedures was placed on the web, and a seminar/tutorial was given at TPC that provided an overview of the capabilities of the 2002 RI scheme. The 2002 version of the SHIPS RI index was implemented on July 16, 2002 and was provided in real-time to forecasters at the TPC for the remainder of the 2002 Hurricane season. Finally, a presentation was given at the 54th Interdepartmental Hurricane Conference that summarized the performance of the RI index for the 2002 Atlantic Hurricane Season (Kaplan and DeMaria 2003a).

### b. Results

Figure 2 shows the probability of RI estimates for the 1989-2001 developmental sample. The operational estimates for the 2002 season and the probability of RI estimates computed separately for each of the thirteen years that comprised the developmental sample are also provided. The figure shows that the RI index did not perform as well during the 2002 season as it had during the 2001 season. Inspection of the individual cases suggest that the degradation in performance might be due, in part, to the close proximity to land of several of the systems (Lilly, Isidore) for which the conditions were otherwise conducive to RI. Nevertheless, the 2002 results were generally within the range of possible performance of the RI index for any given year. The large yearly variability in performance is not that surprising since this version of the RI index does not include any predictors that provide a direct assessment of the degree of organization of a tropical cyclone's inner-core.

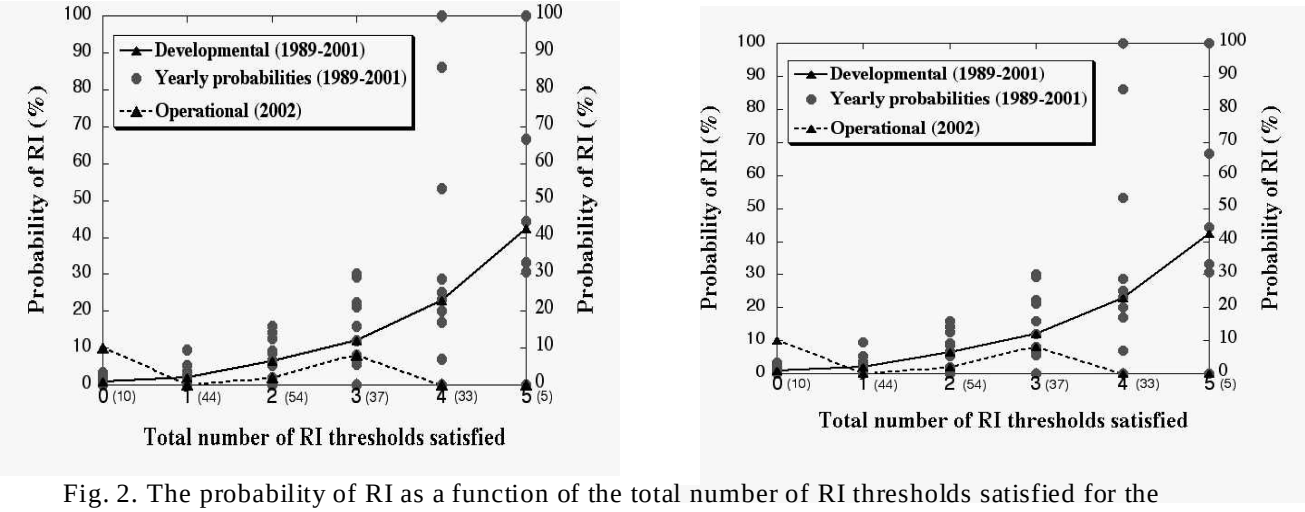


Fig. 2. The probability of RI as a function of the total number of RI thresholds satisfied for the 1989-2001 Atlantic basin developmental sample (solid line). The RI probabilities computed separately for each of the 13 years that comprised the developmental sample (filled circles) are also provided. The 2002 operational probabilities (dashed line) are also shown with the number of forecast cases for the 2002 season depicted in parentheses.

In an effort to improve the performance of the Atlantic RI index, GOES infrared data (Zehr 2000) and satellite-derived estimates of the observed ocean heat content (OHC)

(Mainelli et al. 2002) were tested as potential predictors of RI. The results of this analysis showed that combining two GOES predictors evaluated at t=0 h (standard deviation of the IR brightness temperature from 50-200 km and the percent area from 50-200 km with IR temperature colder than –50º C) with the five standard RI predictors discussed previously (see section 1) improved the overall performance of the RI index. Figure 3 shows that the false alarm ratio (number of non-RI cases divided by the number of RI cases) is reduced significantly by inclusion of the GOES predictors. To illustrate, for the case when $\geq$ 4 of 5 of the standard RI predictor thresholds are satisfied versus $\geq$ 6 of 7 of the GOES RI predictor thresholds are satisfied the false alarm ratio is reduced from 2.6 to 0.8, while the percentage of RI cases detected (percentage of the sample total of RI cases) using the GOES version (25%) is only slightly reduced from that obtained using the standard version (35%).

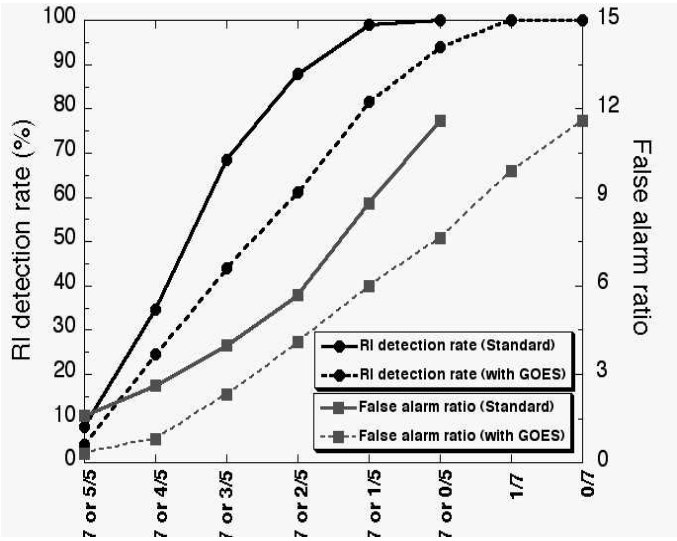


Fig. 3. The false alarm ratio (no. of non-RI cases/no. of RI cases) and the RI detection rate (percentage of RI cases relative to the sample total) for the standard and GOES versions of the Atlantic RI index. The false alarm ratio and RI detection rate are expressed as functions of the minimum number of RI thresholds satisfied out of the maximum possible total of five (standard) and seven (GOES) thresholds.

In contrast to the results obtained using the GOES data, sensitivity tests showed that inclusion of OHC did not improve the performance of the RI index. However, this does not mean that OHC is not a potentially useful predictor of RI, but merely that it did not yield improved probability of RI estimates using the current formulation of the RI index. Indeed, inspection of the distribution of OHC for the cases that underwent RI and those that did not (not shown) suggests that it may be useful for estimating the probability of RI for cases with high values of OHC. However, since RI was also observed for an appreciable fraction of cases with low OHC more research will be required to determine if it is possible to improve future versions of the RI index by utilizing OHC as a predictor.

Since the GOES version of the RI index was not completed in time to be run operationally during the 2002 Atlantic hurricanes season, it was re-run after the season

concluded to simulate its 2002 performance. Figure 4 indicates that the GOES version of the RI index had problems that were similar to those encountered when employing the standard version for the 2002 season (Fig. 2). Nevertheless, the 2002 performance of the GOES version of the RI index was generally within the range of the potential performance of the RI index for any given year.

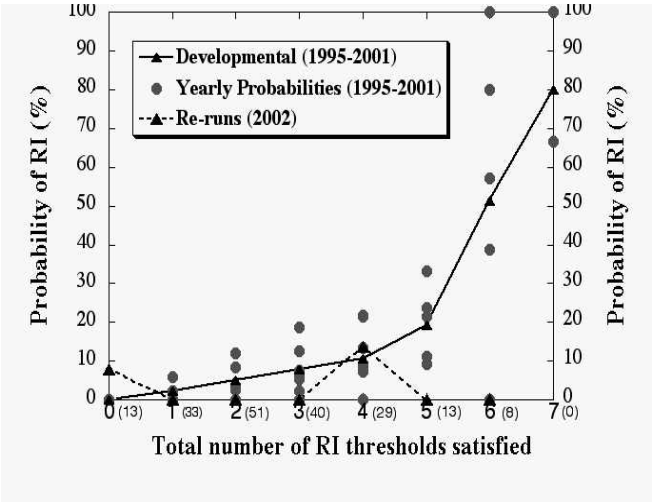


Fig. 4. The probability of RI as a function of the total number of RI thresholds satisfied (out of seven) for the GOES version of the RI index. The probabilities obtained by using the entire 1995 -2001 developmental sample (solid line) and those computed separately for each of the seven years that comprised the developmental sample (filled circles) are shown. The probabilities obtained by re-running the 2002 cases after the season concluded (dashed line) are also depicted with the number of cases shown in parentheses.

In preparation for the 2003 season, the standard (5 predictor) and GOES (7 predictor) versions of the RI index were updated using data from the 2002 Atlantic hurricane season. In addition, subtropical cases were also included when updating both versions of the RI index since this stage had been previously excluded from the developmental database. Although re-analysis data were used when deriving the 2003 version of SHIPS, the operational analyses were used when updating the RI index. This decision was made because the re-analysis low-level (850-700 mb) relative humidity data appear to have a low bias relative to the operational values, and sensitivity tests showed that this bias resulted in noisier probability of RI estimates.

The subroutines that are used to compute the 2003 versions of the RI index were updated and were installed in the operational version of SHIPS on 2 June 2003. Also, the RI code that was originally developed to run on a VAX operating system in FORTRAN 77 was cleaned up and documented. The code was then successfully compiled and run on the HRD HP11i operating system in FORTAN 90, and all of the computer code, data files, and instructions required to re-derive both versions of the RI index were provided to TPC. The PIs and supporting staff will continue to work with the TPC/JHT staff to facilitate a smooth transition of the RI code to the JHT. Finally, a manuscript that was partly devoted to the description of the RI index was submitted and accepted by Wea. and Forecasting. (Kaplan and DeMaria 2003b).

## 3. Future research

In the future, we plan to develop an RI index for the Eastern Pacific basin,which is analogous to the RI scheme that has been developed for the Atlantic basin. Also, we will explore the possibility of improving the RI index by employing more sophisticated statistical techniques (e.g., neural networks).

## 4. References


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