Joint Hurricane Testbed Final report

Project: Development of a Rapid Intensification Index for the Eastern Pacific Basin

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Date: August 1, 2005

1. First year accomplishments (July 1, 2003-May 1, 2004)

a. Derivation of the Eastern Pacific rapid intensification index

The software that was previously employed to derive a rapid intensification (RI) index for the Atlantic basin was modified so that it could be utilized to derive an RI index for the Eastern Pacific basin utilizing the SHIPS (DeMaria et al. 2005) and TPC/NHC best track databases. Following the methodology that was utilized for the Atlantic basin (Kaplan and DeMaria 2003), RI was defined as the 95th percentile of all of the over-water 24-h intensity changes for the tropical and sub-tropical cyclones that comprised the database. For the Eastern Pacific, this corresponded to a 24 h intensity change of ≥ 18 ms^{-1} (35 kt). In contrast, a 24-h intensity change of ≥ 15 ms^{-1} (30 kt) is used as the Atlantic basin RI threshold (Kaplan and DeMaria 2003).

Sensitivity tests were performed to determine which sets of predictors should be included in the final version of the Eastern Pacific RI index. This was done objectively by choosing the predictors that yielded probability of RI estimates that produced the highest Brier Skill Score (Wilks 1995) for a homogenous set of cases that comprised the developmental sample. The Brier Skill Score (Wilks 1995) was evaluated by comparing the probability of RI estimates of the various versions of the RI index to the climatological probability of RI (i.e. ~6%) to assess which method more accurately reflected whether or not RI occurred during any given 24-h period. These tests showed that combining the five predictors that were employed previously by Kaplan and DeMaria (2003) to obtain the standard version of the Atlantic RI index (i.e., previous 12-h intensity change, 850-700 hPa relative humidity, 850-200 hPa vertical shear, sea-surface temperature, potential intensity) and two inner-core GOES predictors (area-averaged infrared brightness temperature and the standard deviation of the GOES infrared brightness temperature) produced the most skillful version of the RI index for the Eastern Pacific basin. Both of the GOES predictors and the previous 12-h intensity change were evaluated at t=0 h, while the remaining four predictors were averaged for the 24 hour period commencing at t=0 h.

To allow for comparisons between both versions of the RI index, the Atlantic version was re-derived utilizing the Atlantic SHIPS database for the period 1989-2002. Interestingly, the predictors in the re-derived version of the Atlantic RI index were identical to those that were utilized in the recently developed Eastern Pacific version of the index save for a slight difference in the area over which the standard deviation of the brightness temperature was computed. Figure 1 shows a comparison of the skill of both versions of the RI index for the 1995-2002 developmental samples. Although some of the RI thresholds were determined using cases prior to 1995, the probabilities could only be computed for the period from 1995-2002 since the GOES data were unavailable prior to 1995. The probability of RI estimates shown are for the 24 h period that begins at t=0 h and ends at t=24 h. Thus, if RI was observed to have occurred but just not for that 24 h period (i.e. it took place for the 6-h period just prior to or after the period beginning at t=0) then it was assumed that RI did not occur for the purpose of computing the RI probabilities shown in the figure.

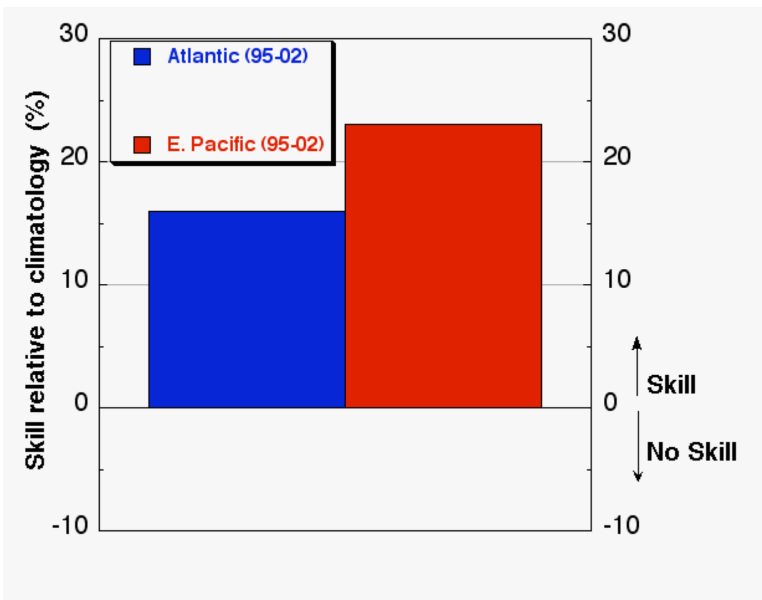

Fig. 1. The Brier skill relative to climatology for the Atlantic (blue) (N=1248) and E. Pacific (red) (N=1392) versions of the RI index for the 1995-2002 developmental samples.

b. Performance of the RI index for the 2003 Eastern Pacific hurricane season

Since derivation of the Eastern Pacific version of the RI index was not complete until after the 2003 hurricane season had ended, it was not possible to test the RI index in real-time. However, all of the operational data necessary to run the index was saved and the RI index was re-run for the entire season. Figure 2 shows the results of the re-run cases for the 2003 Eastern Pacific hurricane season and those obtained for the 2003 real-time GOES version of the Atlantic RI index. The figure shows that the RI index did not perform well for the Eastern Pacific re-runs. However, the Atlantic version did have some skill for the 2003 Hurricane season.

The disappointing performance of the EPAC RI index during the 2003 season may have been due, in part, to the use of inaccurate sea-surface temperature estimates by SHIPS. To illustrate, Gentemann et al. (2004) showed that employing the AMSR-E deduced sea-surface temperatures in place of those obtained from the Reynolds analysis yielded improvements of up to 8% (~6% at 24 h) in the magnitude of the EPAC SHIPS forecast errors. Gentemann et al. (2004) hypothesized that these improvements were due to the more accurate SSTs that were obtained using the AMSR-E measurements. Specifically, they cited the capability of AMSR-E to capture the lowered sea-surface temperatures that were produced in the cool wake regions of previous cyclones as the primary reason for the observed improvements. Since two of the seven predictors (i.e. sea-surface temperature and potential) that are used in the RI index are dependent on sea-surface temperature, the RI index was likely adversely affected by the inaccuracy of the Reynolds values. To test the sensitivity of the index to the use of different sea-surface temperature measurements, the RI index was re-run using the AMSR-E sea-surface temperatures instead of the Reynolds values. As can be seen in Fig. 3, the use of the AMSR-E values greatly improved the performance of the RI index, although the index still was not skillful relative to climatology.

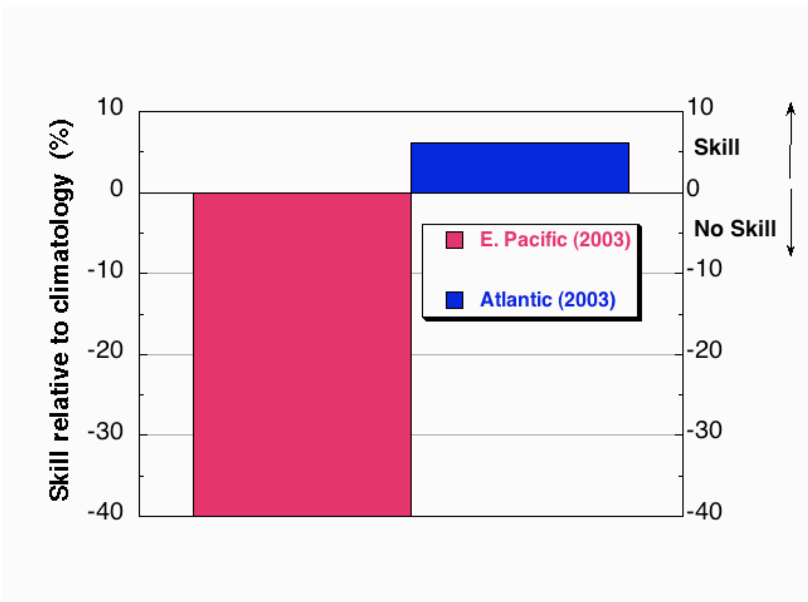

Fig. 2. The skill of the RI index for the 2003 E. Pacific re-runs (N=196) and for the real-time Atlantic basin forecasts (N=252)

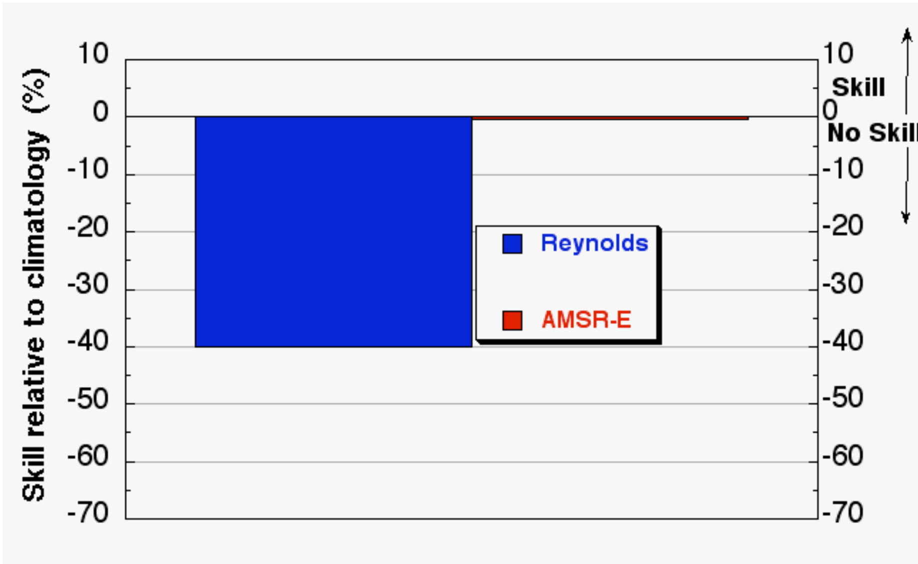

Fig. 3. The Brier skill scores of the Eastern Pacific version of the RI index for a homogeneous sample of the 2003 re-run cases (N=196). The results are shown for the version that used Reynolds sea-surface temperatures as well as for the version that used AMSR-E values.

c. Preparation of RI index for the 2004 hurricane season

In preparation for real-time (Eastern Pacific version) and operational (Atlantic version) testing during the 2004 hurricane season, both versions of the RI index were updated by including data from the 2003 hurricane season. Figure 4 shows the updated probabilities that were used for the 2004 season. The skill relative to climatology for the updated versions of the index decreased somewhat from those shown previously (Fig. 1) which reflects the difficulties encountered when employing the RI index during the 2003 hurricane season. It is worth noting that the E. Pacific version still outperformed the Atlantic version for the updated sample. The subroutine that was used to compute the RI index in the operational SHIPS model during previous hurricane seasons was modified so that it could be used to compute the probability of RI for both the Eastern Pacific and Atlantic basins.

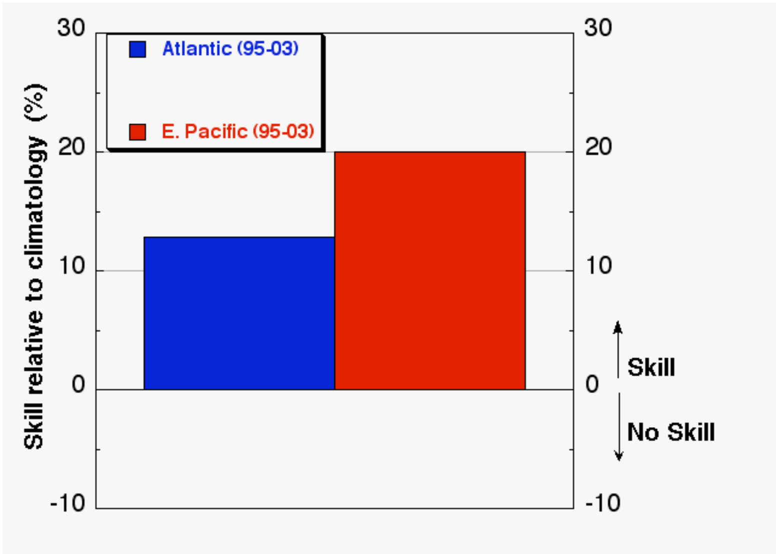

Fig. 4. The skill of the Atlantic (N=1733) and E. Pacific RI index for the 1995-2003 (N=1446) developmental samples.

2. Year 2 (May 1-2004 – July 31 2005)

a. Performance of RI index for the 2003 Hurricane season

The E. Pacific version of the SHIPS RI index was run in real-time every 6 h from 24 May to 30 November 2004. This version of the RI index compared the operational magnitudes of seven SHIPS predictors (previous 12-h intensity change, 850-700 hPa relative humidity, 850-200 hPa vertical shear, sea-surface temperature, potential intensity, and 100-300 km area-averaged GOES infrared brightness temperature and standard deviation of GOES infrared brightness temperature) to previously determined RI thresholds to estimate the probability of rapid intensification. These RI index probability of RI estimates were provided on the SHIPS log files that were printed out at TPC/NHC after the completion of each SHIPS forecast. Figure 5 shows that the real-time version of the E. Pacific RI index was skillful for the 2004 hurricane season. However, the Atlantic version that was operational for the 2004 hurricane season did not exhibit skill.

b. Development of a scaled RI index

A weakness of the aforementioned methodology for estimating the probability of RI is that these estimates are determined by comparing the magnitudes of each of the RI predictors to a single (fixed) RI threshold. Consequently, an RI predictor that barely meets an RI threshold (and thus is viewed as marginally conducive for RI) is given the same weight as one that is much more conducive to the likelihood that a system may undergo RI. To ameliorate this problem, the RI index was re-formulated so that the degree to which each RI predictor is viewed as being conducive to the occurrence of RI was used quantitatively when assessing the probability of RI by employing a scaling technique. The so "scaled" version of the RI index included all of the same predictors that were used in the "threshold" version that was run in real-time during the 2004 Hurricane season except that the percent are covered between 50-200 km by -30° C was used instead of the area-averaged brightness temperature from 100-300 km radius.

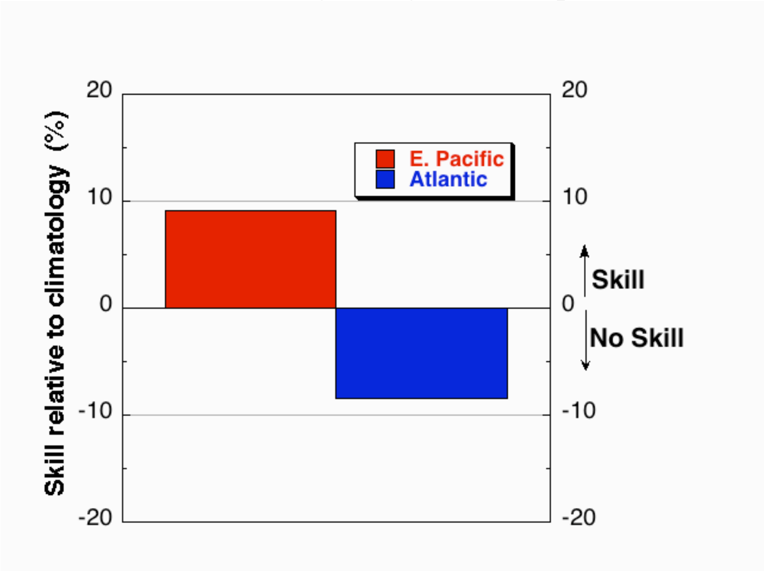

Fig. 5. The skill of the operational Atlantic (N=197) and real-time E. Pacific (N=332) version of the RI index for the 2004 hurricane season..

The basic scaling technique is similar to that employed by DeMaria et al. (2001) except that the individual predictors are summed in the current methodology rather than multiplied together like they were by DeMaria et al. (2001). The scaled index is given by:

$$\text{Scaled Index} = \sum_{\boldsymbol{i}=1}^{\boldsymbol{N}} \boldsymbol{S} \qquad (1)$$

where $\boldsymbol{N}$ is the total number of predictors and $\boldsymbol{S}$ is the scaled magnitude (from 0 to 1) of each predictor. In this formulation, $\boldsymbol{S}$ is 1 when the predictor is the most conducive for rapid intensification and 0 when it is the least conductive. For each predictor, $\boldsymbol{S}$ was evaluated using the range of values over which rapid intensification occurred in the developmental dataset. The value that was judged most conducive for RI and thus assigned a magnitude of 1 was the value for which the likelihood of RI was found to be highest as discussed in Kaplan and DeMaria (2003). To illustrate, Kaplan and DeMaria (2003) showed that RI was much more likely for higher sea-surface temperatures and the sea-surface temperatures of the E. Pacific RI cases ranged from 26.6 to 30.1 ° C. Thus, $\boldsymbol{S}$ was set to 1 if the sea-surface temperature was ≥ 30.1 °C and 0 if the sea-surface temperature was ≤ 26.6 °C. The scaled value would then increase linearly from 0 to 1 as the sea-surface temperature increased from 26.6 to 30.1° C. All of the 7 predictors used in the scaled RI index were computed in this manner except for the persistence predictor. For that predictor the magnitude of $\boldsymbol{S}$ was set to 1 if it had a magnitude equal to the average value of all of the RI cases, since sensitivity tests showed the scaled RI index was more skillful when this formulation was utilized. Furthermore, this predictor was set equal to 0 when its magnitude was equal to the maximum and minimum value at which RI was observed to have occurred.

Figure 6 shows a comparison of the skill of the threshold version of the RI index and the scaled version for both the Atlantic and E. Pacific basins for the 1995-2003 developmental database. It can be seen that the scaled version of the RI index had ~ 6 % more skill in absolute terms for the EPAC developmental sample. This represents a relative improvement of 30% when compared with that obtained for the threshold version of the RI index. In contrast, the scaled version was only slightly more skillful than the threshold version for the Atlantic basin sample. Since the scaled version of the RI index was not finalized until after the 2004 season was over, the index was tested by re-running all of the cases from the 2004 E. Pacific and Atlantic hurricane seasons using data that was collected and used by the SHIPS model in real-time. Figure 7 shows a comparison of the skill of the threshold and scaled versions of the RI index for the Atlantic and E. Pacific basins. It can be seen that the scaled version of the RI index was ~ 7 and 10% more skillful for the Atlantic and E. Pacific basins, respectively. While the E. Pacific scaled version of the RI index was ~15% more skillful than climatology the Atlantic version had essentially equal skill to climatology underscoring the greater difficulty that exists for that basin. Figure 8 shows an example of the performance of the scaled and threshold methods of the RI index for Hurricanes Charlie (Atlantic) and Howard (E. Pacific) during the 2004 hurricane season. The figure shows that the scaled version of the RI index generally performed better for both systems with higher probabilities over the time period for which RI occurred. Moreover, the RI index probabilities changed more gradually with time which should make them easier to use by forecasters.

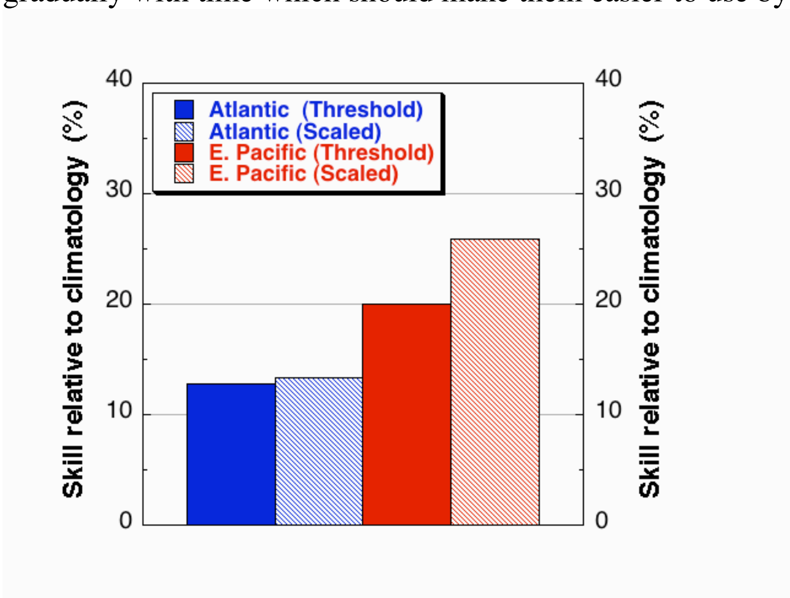

Fig. 6. A comparison of the skill of the threshold and standard versions of the RI index for the 1995-2003 database for the Atlantic (N=1733) and E. Pacific (N=1446) basins .

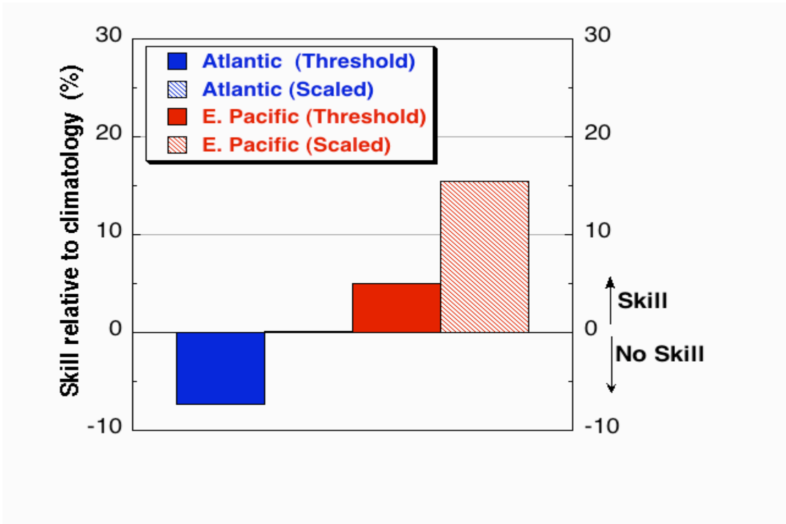

Fig. 7. The skill of the threshold and scaled versions of the RI index for the 2004 Atlantic (N=294) and E. Pacific (N=181) re-run cases.

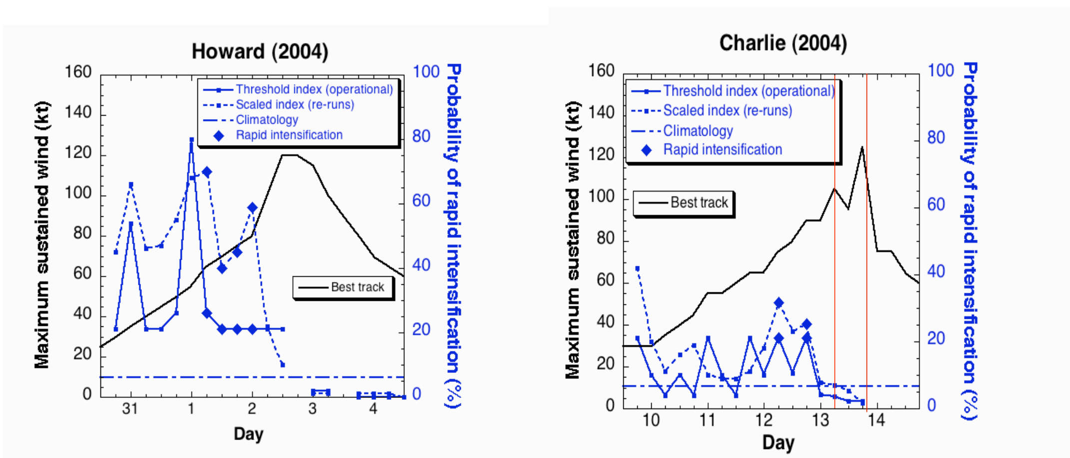

Fig. 8. Performance of the threshold and scaled versions of the RI index for Hurricanes Charlie (Atlantic) and Howard (E. Pacific) during the 2004 season. The threshold probability estimates are those obtained in real-time while the scaled values are based upon the independent 2004 re-runs. The time at which RI commenced for any given 24-h period is denoted by a diamond, and the time of each landfall is denoted by a vertical red line.

As noted previously, while the E. Pacific version of the scaled RI index was skillful for the 2004 hurricane season the Atlantic version was not. Thus, the 1989-2003 developmental dataset was employed to determine the accuracy and utility of employing additional 24-h intensity thresholds in real-time. This was accomplished by employing the same methodology that was used previously to derive the scaled RI index for the 30 kt (Atlantic) and 35 kt (E. Pacific) RI thresholds. Fig. 9 shows the performance of the RI index for the (20,25,30, and 35 kt) thresholds for the Atlantic and E. Pacific basin. The figure shows that skill of the scaled RI index increases as the intensity threshold magnitude decreases. The figure also shows that the scaled RI index is more skillful in the E. Pacific basin. Figure 10 shows the skill of the scaled RI index for each of the four intensity thresholds for the 2004 Atlantic and E. Pacific re-run forecasts. The figure shows that the performance of the RI index for the 2004 re-runs exhibited a similar pattern of skill to that obtained for the 1995-2003 developmental dataset, although the skill was generally lower for the re-run forecasts.

c. Preparation of RI index for 2005 Hurricane season

Based upon the aforementioned results and those presented by Kaplan and DeMaria (2005) at the Interdepartmental Hurricane Conference and at the National Hurricane Center in April 2005, the National Hurricane Center decided that the scaled version of the RI index that was based upon the 25 kt RI threshold should be employed in both the Atlantic and E. Pacific basins during the 2005 hurricane season. This threshold corresponds to roughly the 90th percentile of over-water intensity changes for both the E. Pacific and Atlantic basins. In preparation for the 2005 hurricane season, the scaled RI index was updated using the 1989-2004 SHIPS database. Additionally, code was written to compute the index in real-time as part of the operational SHIPS model runs. Due to problems accessing the GOES data on the new NCEP IBM and to a coding error in the main SHIPS program the new scaled RI index was not fully implemented in both the E. Pacific and Atlantic basins until July 7 of 2005.

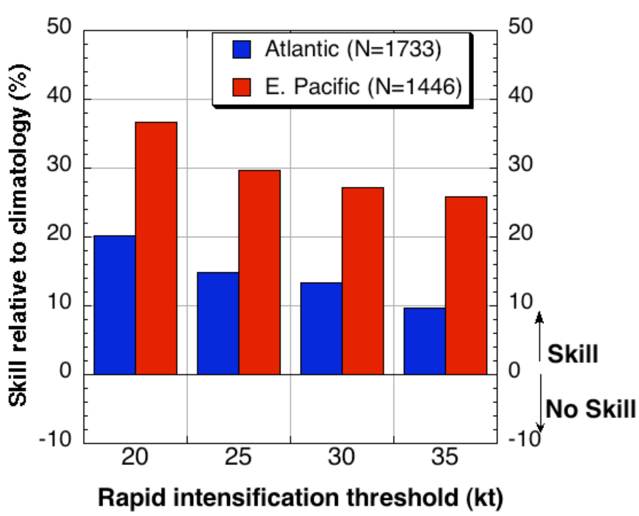

Fig. 9. Performance of the scaled RI index for the 20,25,30, and 35 kt thresholds for the 1995-2003 developmental dataset in the Atlantic and E. Pacific basins.

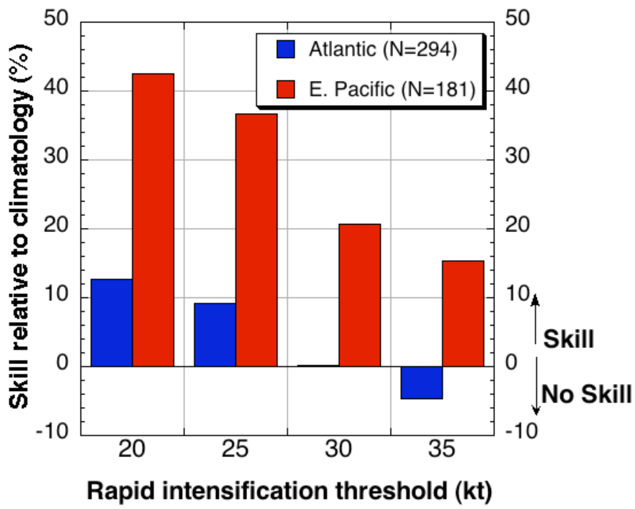

Fig. 10. Performance of the scaled RI index for the 20,25,30, and 35 kt thresholds for the 2004 Atlantic and E. Pacific re-run forecasts.

3. Future work

In the future, the feasibility of developing an index for estimating the probability of rapid weakening will be investigated. Also, a discriminant analysis technique will be employed to determine if it is possible to improve the skill of both the rapid intensification and weakening indices utilizing a more sophisticated statistical method.

4. References.

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