Improvements to the SHIPS Rapid Intensification Index: A Year-2 JHT Project Update

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Background and Motivation

Predicting episodes of tropical cyclone (TC) rapid intensification (RI) remains one of NHC's top forecast priorities.

To aid in the forecasting of RI, a statistically-based rapid intensification index (RII) that uses large-scale predictors from the SHIPS model has been developed and is currently used operationally by the NHC (Kaplan and DeMaria 2003, Kaplan et al. 2010, Kaplan et al. 2011) .

Current JHT Project Goals

Although the current operational RII is generally skillful, its skill is still rather limited (particularly in the Atlantic basin). Thus, our current project seeks to improve the forecasting utility of the operational RII by performing the following tasks:

- **Develop new versions of RII for forecast lead-times out to 48-h using multi-model ensemble-based approach**
- **Incorporate new multi-lead time ensemble-based probabilistic RII in recently developed deterministic rapid intensity guidance model**
- **Derive new microwave-based version of RII**

Multi lead-time ensemble-based RII

- New multi-lead time ensemble based versions of RII were developed for 12-h, 24-h, 36-h and 48-h lead times for both the Atlantic and E. Pacific basins.
- The ensemble-based RII is the average (consensus) of the SHIPS, Bayesian, and Logistic versions (Rozoff and Kossin 2011).
- Multi-lead time ensemble-based RII was first run in real-time starting ~Aug 1, 2012 at CIRA in Colorado with forecasts made available to forecasters via a website.
- Forecasts for cases prior to Aug 1 were also obtained using real-time data at the time that the new version was first run at CIRA.

New multi-lead time ensemble-based RII

Emilia (2012)

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                  * EAST PACIFIC RII PARALLEL RUNS FOR JHT/PG *
                  * GOES AVAILABLE,       OHC AVAILABLE       *
                  *  EP05        EP052012  07/08/12  00 UTC   *

              CURRENT MAX WIND (KT):   35. LAT, LON:   10.5  -102.5

++++++++ SECTION 1, 2012 OPERATIONAL RII WITH ++++++++
                  TPW, IRPC, CFLUX ENHANCEMENTS

      ** 2012 E. PACIFIC RI INDEX EP052012 EP05       07/08/12  00 UTC **
           ( 30 KT OR MORE MAX WIND INCREASE IN NEXT 24 HR)

 12 HR PERSISTENCE (KT):  10.0 Range:-22.0 to  38.5 Scaled/Wgted Val:  0.5/  1.1
 POT = MPI-VMAX (KT)   : 121.6 Range: 40.3 to 144.5 Scaled/Wgted Val:  0.8/  1.2
 850-200 MB SHEAR (KT) :   2.5 Range: 18.7 to   1.4 Scaled/Wgted Val:  0.9/  1.5
 HEAT CONTENT (KJ/cm2) :  39.2 Range:  0.0 to  73.7 Scaled/Wgted Val:  0.5/  0.8
 STD DEV OF IR BR TEMP :   8.2 Range: 38.9 to   2.4 Scaled/Wgted Val:  0.8/  1.2
 MAXIMUM WIND (KT)     :  35.0 Range: 22.5 to 132.0 Scaled/Wgted Val:  0.3/  0.4
 D200 (10**7s-1)       :  66.6 Range:-11.0 to 135.3 Scaled/Wgted Val:  0.5/  0.6
 BL DRY-AIR FLUX (w/m2):  68.6 Range:638.0 to -19.8 Scaled/Wgted Val:  0.9/  0.0
 % AREA WITH TPW <45 mm:   0.0 Range: 82.1 to   0.0 Scaled/Wgted Val:  1.0/ -0.4
 2nd PC OF IR BR TEMP  :  -0.3 Range:  2.1 to  -1.7 Scaled/Wgted Val:  0.6/ -0.1

 Prob of RI for 25 kt RI threshold=    70% is   5.6 times the sample mean(12.5%)
 Prob of RI for 30 kt RI threshold=    58% is   7.0 times the sample mean( 8.3%)
 Prob of RI for 35 kt RI threshold=    37% is   6.2 times the sample mean( 5.7%)
 Prob of RI for 40 kt RI threshold=    36% is  10.6 times the sample mean( 4.0%)


++++++++ SECTION 2, RII WITH LIGHTNING DATA ++++++++
                  FOR GOES-R PROVING GROUND

Prob of RW, Avg IC, RI=  0%    65%   35%    no lightning, experimental algorithm
Prob of RW, Avg IC, RI=  0%    61%   39%  with lightning, experimental algorithm

Rapid Weakening       (RW) = -20 kt or less max wind change in 24 hr
Rapid Intensification (RI) = +30 kt or more max wind change in 24 hr

Recent Lightning Density History (Strikes/km2-year)
Date/Time  vmax(kt)  Inner core (0-100 km)  Rainband (200-300 km)
12 0708 00    35       0.0                    12.0
12 0707 18    30       0.0                    61.0

Sample mean:         33.0                     9.0

 Note: Inner core lighting < sample mean favors RI
       Rainband lighting   > sample mean favors RI
       Converse for RW


++++++++ SECTION 3, RII WITH MULTIPLE TIMES ++++++++
                  AND CONSENSUS FOR JHT

 ** 2012 E. Pacific EXPERIMENTAL  RI INDEX EP052012 EP05       07/08/12  00 UTC **

 Prob RI for 20kt/ 12hr RI threshold=  23% is   3.7 times sample mean ( 6.2%)
 Prob RI for 25kt/ 24hr RI threshold=  70% is   5.6 times sample mean (12.5%)
 Prob RI for 30kt/ 24hr RI threshold=  58% is   7.0 times sample mean ( 8.3%)
 Prob RI for 35kt/ 24hr RI threshold=  37% is   6.2 times sample mean ( 5.7%)
 Prob RI for 40kt/ 24hr RI threshold=  36% is  10.6 times sample mean ( 4.0%)
 Prob RI for 45kt/ 36hr RI threshold=  55% is   9.4 times sample mean ( 5.9%)
 Prob RI for 55kt/ 48hr RI threshold=  70% is  12.7 times sample mean ( 5.5%)

 Matrix of RI probabilities
 ---------------------------------------------------------------------------
  RI (kt / h)  | 20/12 | 25/24 | 30/24 | 35/24 | 40/24 | 45/36 | 55/48
 ---------------------------------------------------------------------------
    SHIPS-RII:    22.7%   70.3%   57.9%   37.2%   36.2%   55.3%   69.7%
     Logistic:    53.7%   88.6%   81.0%   70.0%   68.8%   80.3%   61.7%
     Bayesian:    16.5%   65.0%   54.2%   38.7%   14.1%   22.3%   16.5%
    Consensus:    31.0%   74.6%   64.4%   48.6%   39.7%   52.7%   49.3%
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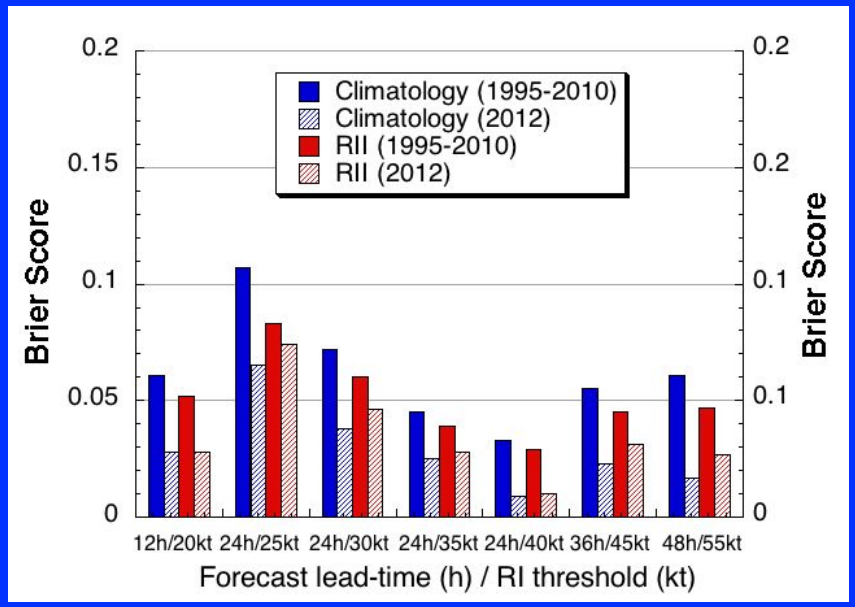
Brier Score (BS) of the 2012 Atlantic RII "Real-time" and 1995-2010 cross-validated RI forecasts as well as those of climatology (top panel). The probability of RI for each of these time periods is also shown (bottom panel).

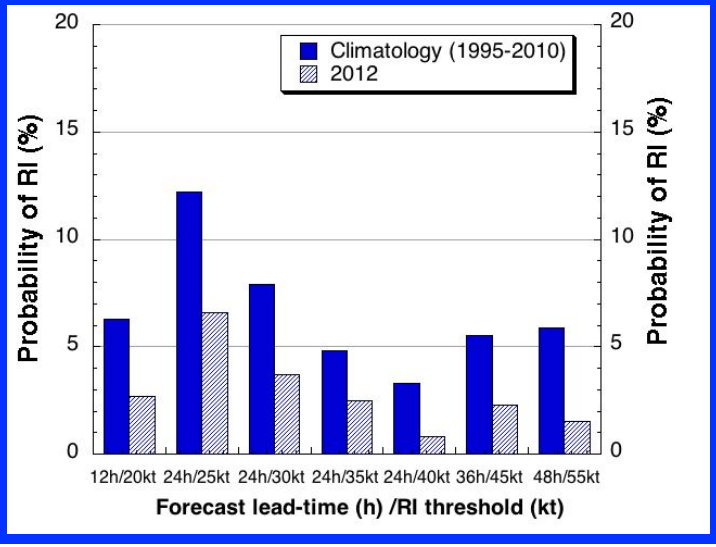
$$BS = 1/n \sum_{k=1}^{n} (y_k - o_k)^2$$

where y_k is the forecasted probability of RI from the RII and

$o_k = 0$ if no RI occurs and
$o_k = 1$ if RI does occur

$0 \leq BS \leq 1$
(where 0 denotes perfect skill)





Skill of the 2012 Atlantic multi-lead time "Real–time RII forecasts

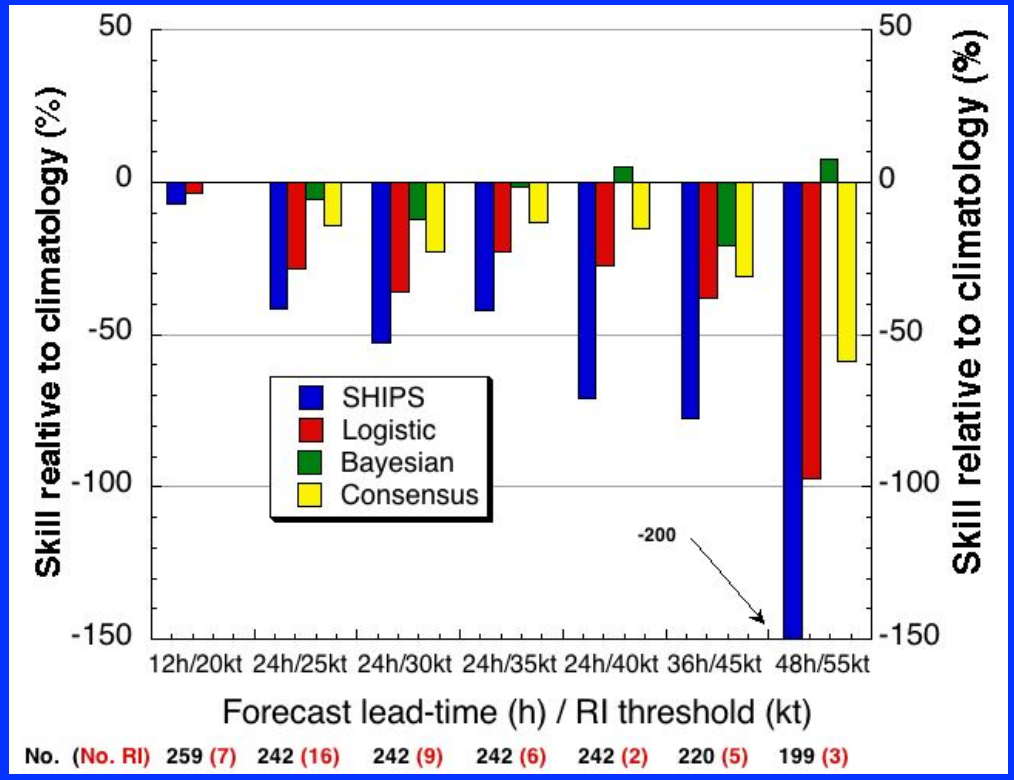
Verification rules: All 24-h over-water RII forecasts for tropical and subtropical systems (including unnamed depressions) were verified using most recent NHC best track data.

Results are shown for the SHIPS (Kaplan et al. 2011) , Bayesian, Logistic, and ensemble based versions of the RII (Rozoff and Kossin 2011).

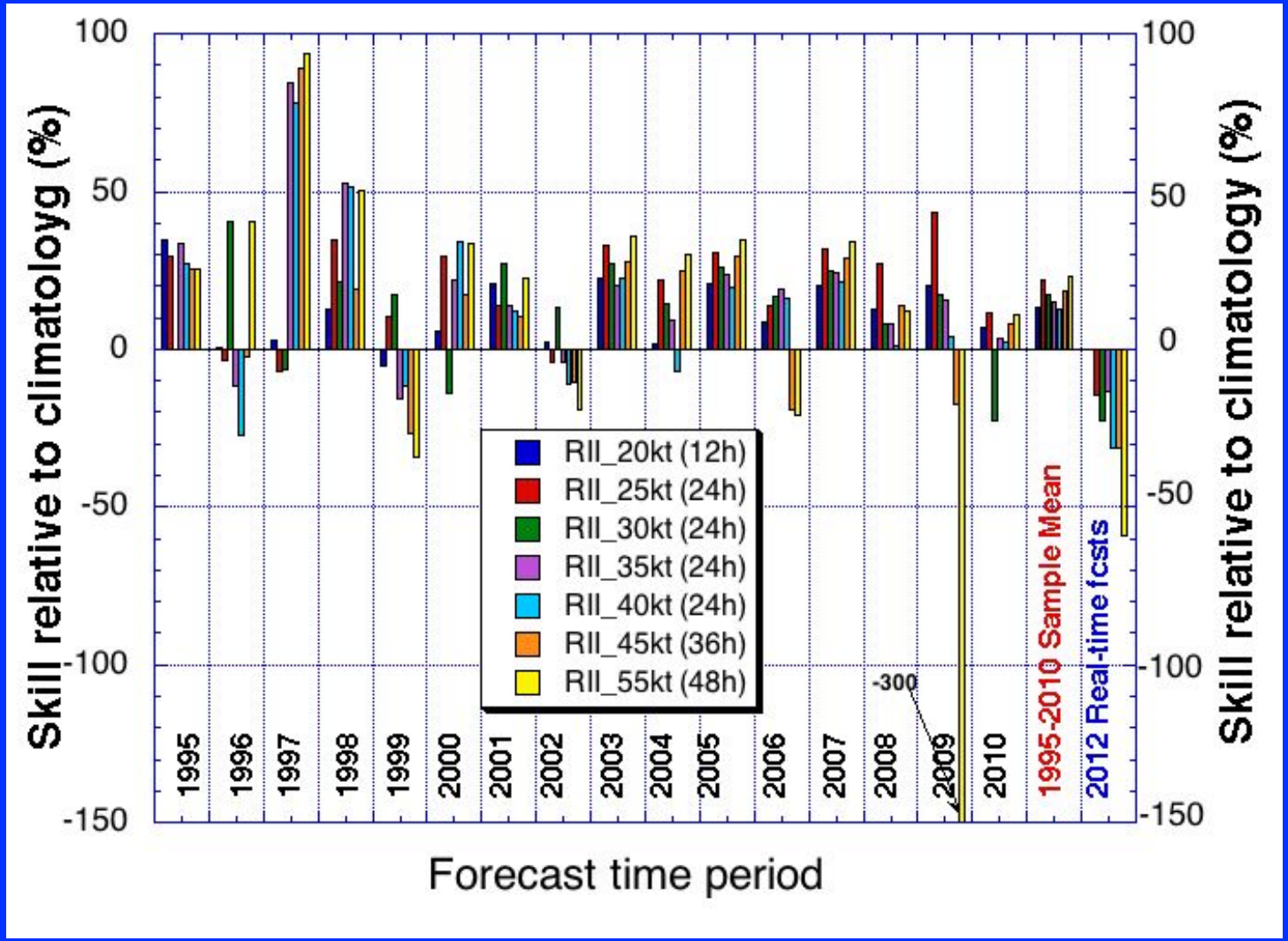
Skill = (1. – BSM/BSREF)*100

where BSM=Brier score of the RII forecasts and BSREF is the Brier score of the climatological forecasts.

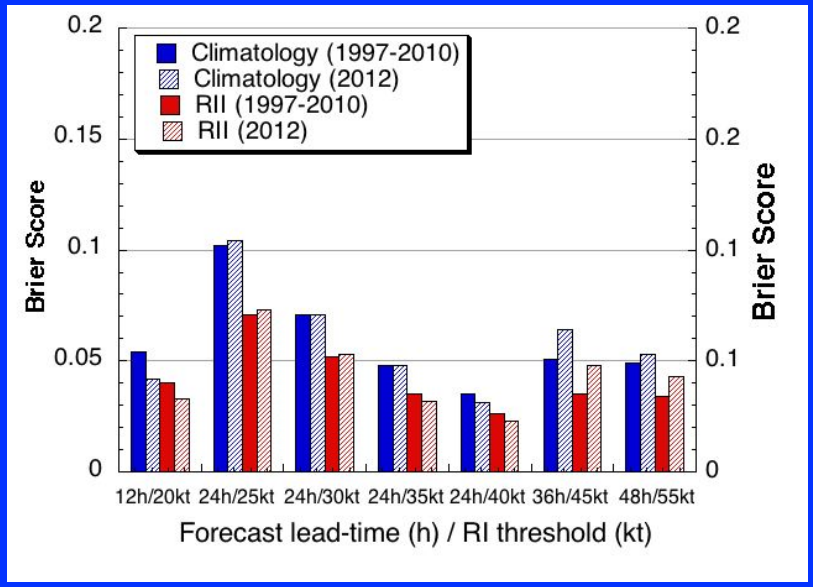
-∞<Skill<100
(so perfect skill is 100%)

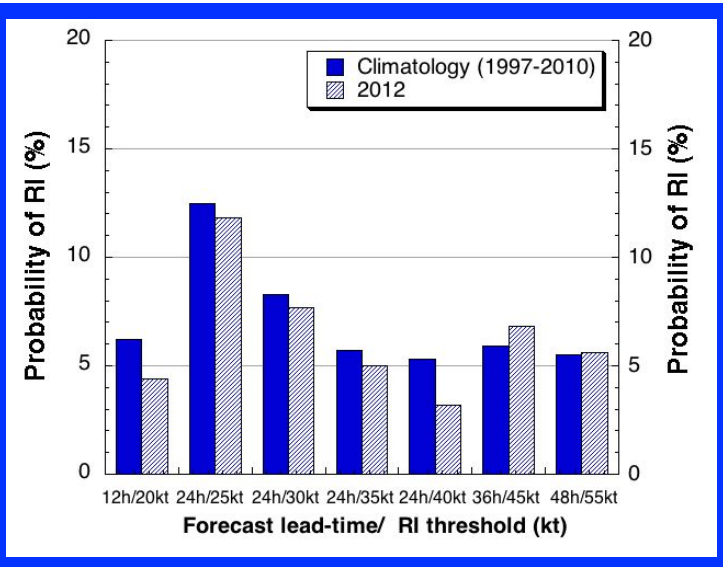


Temporal variability in skill of the cross-validated Atlantic basin multi-lead time ensemble-based RII. The 2012 real-time skill of the ensemble-based RII is also provided.

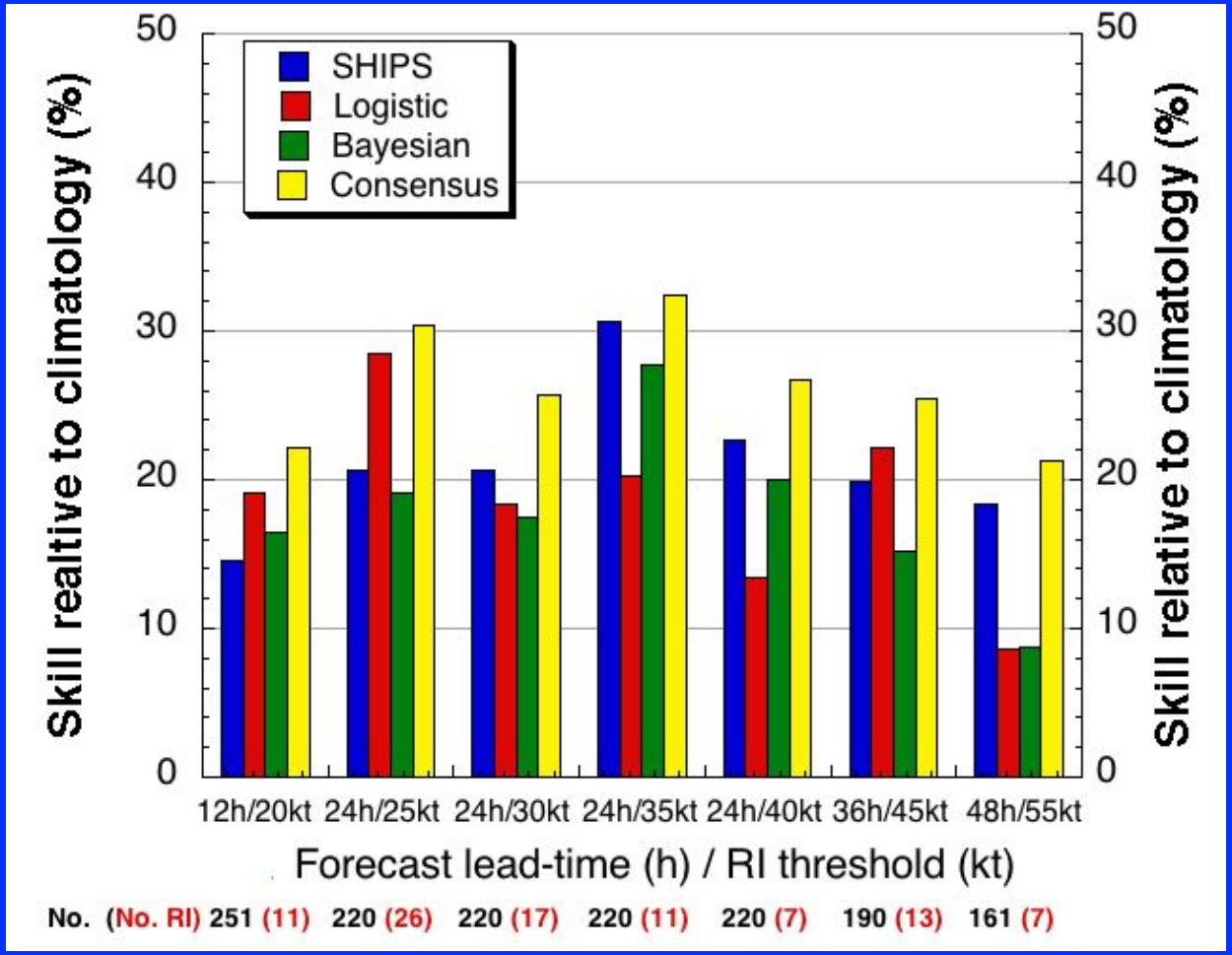


Brier Score (BS) of the 2012 E. Pacific RII "Real-time" and 1997-2010 cross-validated RI forecasts as well as those of climatology (top panel). The probability of RI for each of these time periods is also shown (bottom panel).

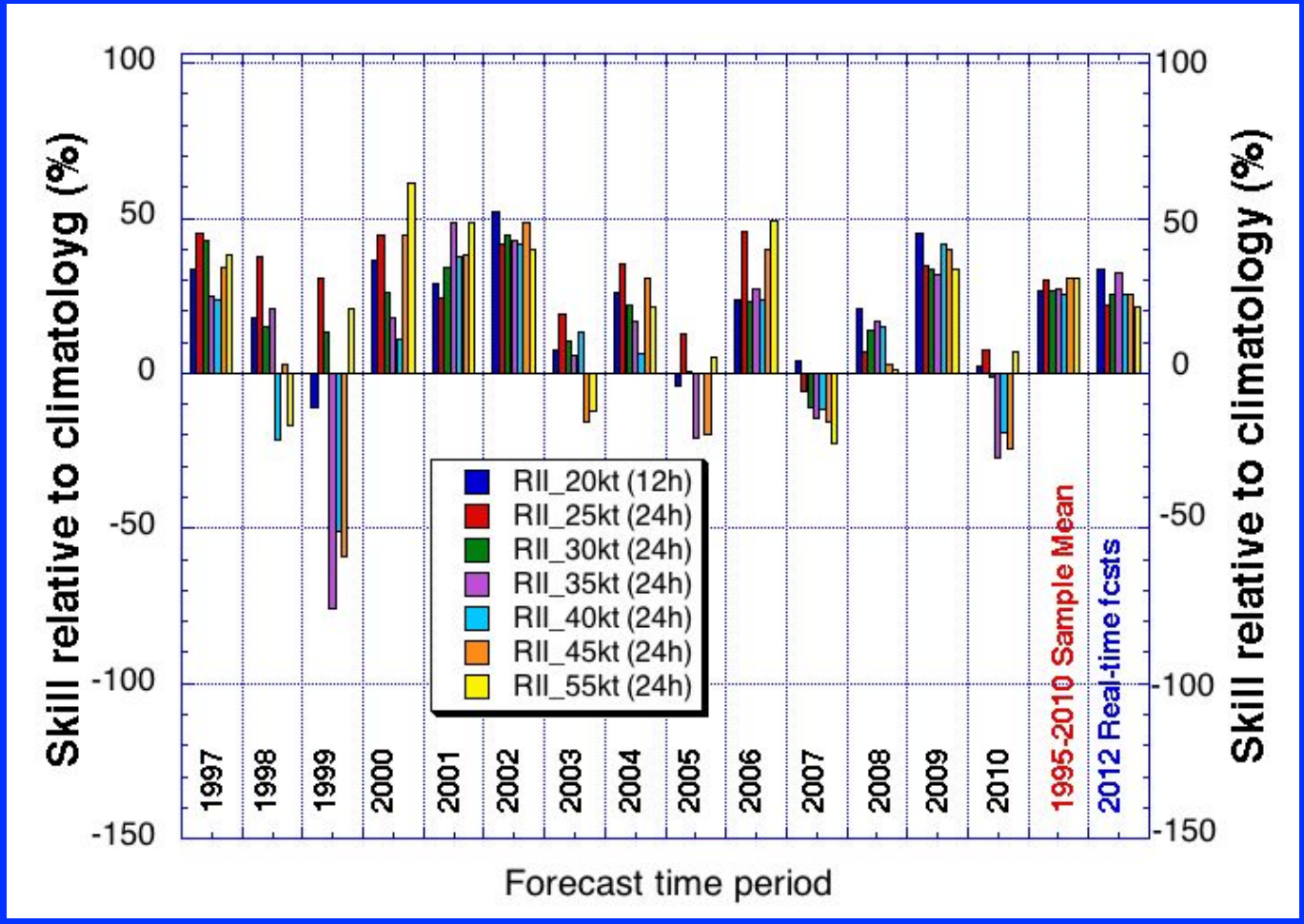




Skill of the 2012 E. Pacific multi-lead time "Real–time RII forecasts



Temporal variability in skill of the cross-validated E. Pacific basin multi-lead time ensemble-based RII. The 2012 real-time skill of the ensemble-based RII is also provided.



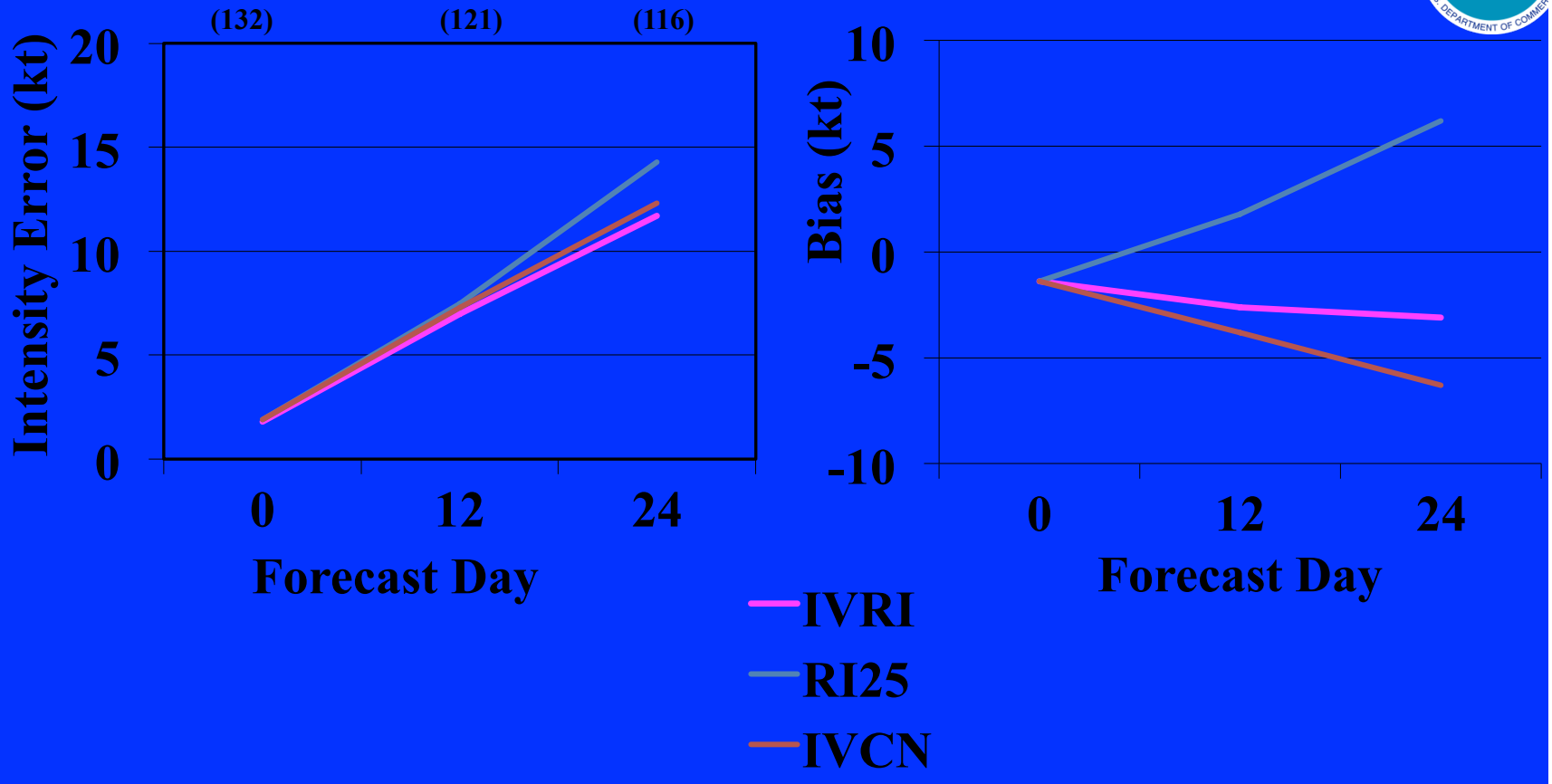
Deterministic RI Aid

- **Uses probabilistic RII forecast probabilities**
- **Assigns intensification rate when RII forecasted probability > 40%**
- **Can be displayed directly on ATCF**
- **Reduces bias and mean error if included in IVCN**

Reference

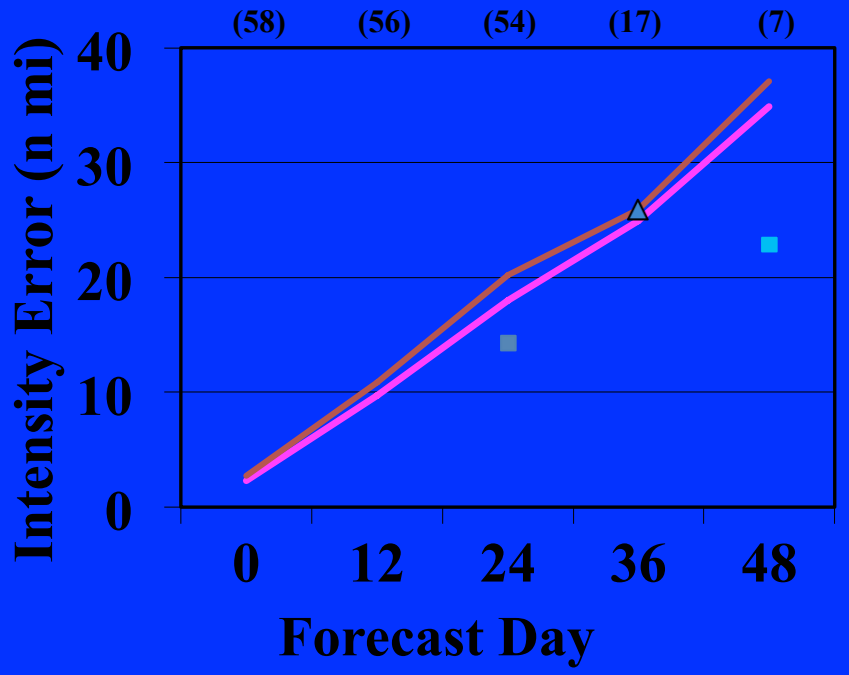
Sampson, C. R., J. Kaplan, J. A. Knaff, M. DeMaria, C. A. Sisko, 2011: A deterministic rapid intensification aid, **Wea. Forecasting, 26**, 579-585.

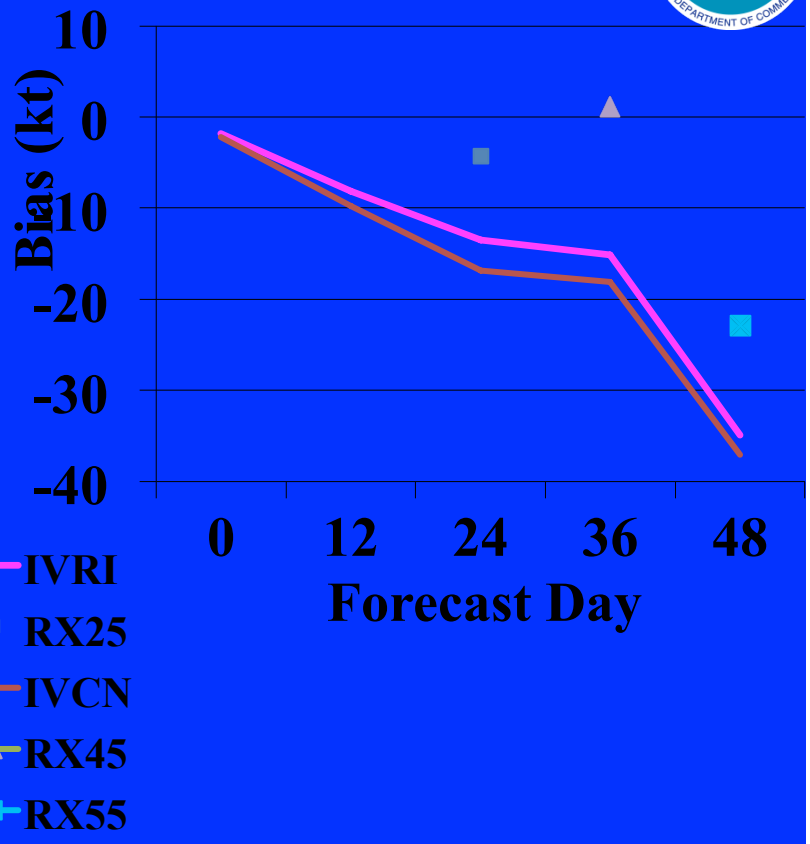
Deterministic RI and modified consensus verification for the combined independent 2011 and 2012 Atlantic and E. Pacific samples



IVCN is the operational NHC intensity consensus, RI25 is a deterministic RI aid derived from RI probabilities, and IVRI is a consensus that includes the IVCN members and operational deterministic RI aids (RI25, RI30, RI35, RI40). IVRI shows **significantly improved** skill and bias over IVCN in this **independent sample**.

Deterministic RII forecast verification of the ensemble-based RII forecasts for the dependent 2008-2010 Atlantic and E. Pacific samples





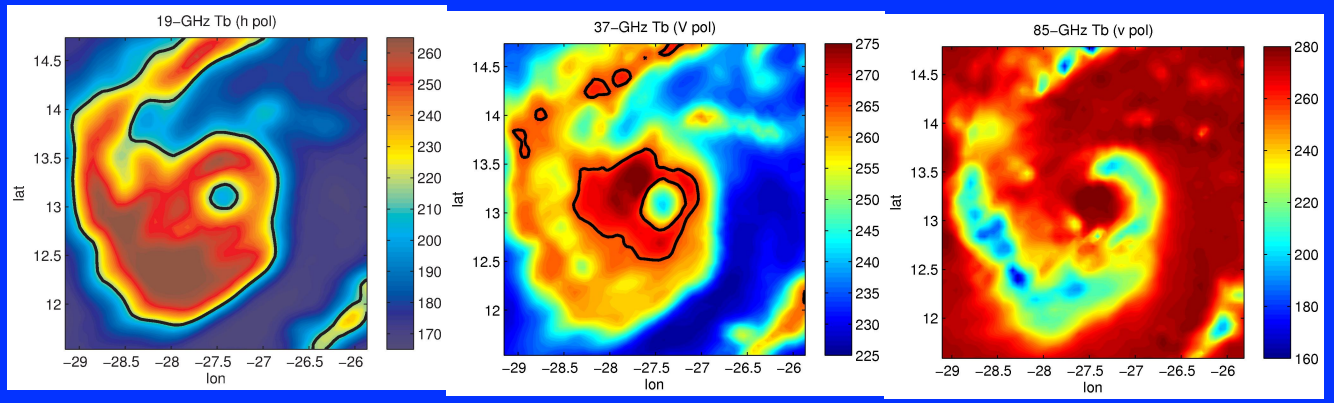
IVRI
RX25
IVCN
RX45
RX55

RX25 is a deterministic RI aid derived from then ensemble RI probabilities, and IVRI is a consensus that includes IVCN members and deterministic RI aids from the ensemble. IVRI shows improved skill and bias over IVCN, and RX25 outperforms both in this **dependent sample.**

Microwave Imagery-enhanced models

- **Developmental data:**
  - SHIPS developmental dataset (DeMaria et al. 2005)
  - SSM/I, WindSat, TMI, and AMSR-E from 1998 – 2008. Frequencies used: 19, 37, and 85-GHz

Example from TMI/Danielle (2004) – each channel provides different information.



19 (H) GHz
Mostly warm rain
Lowest resolution

37 (V) GHz
Some warm rain + ice
Intermediate resolution

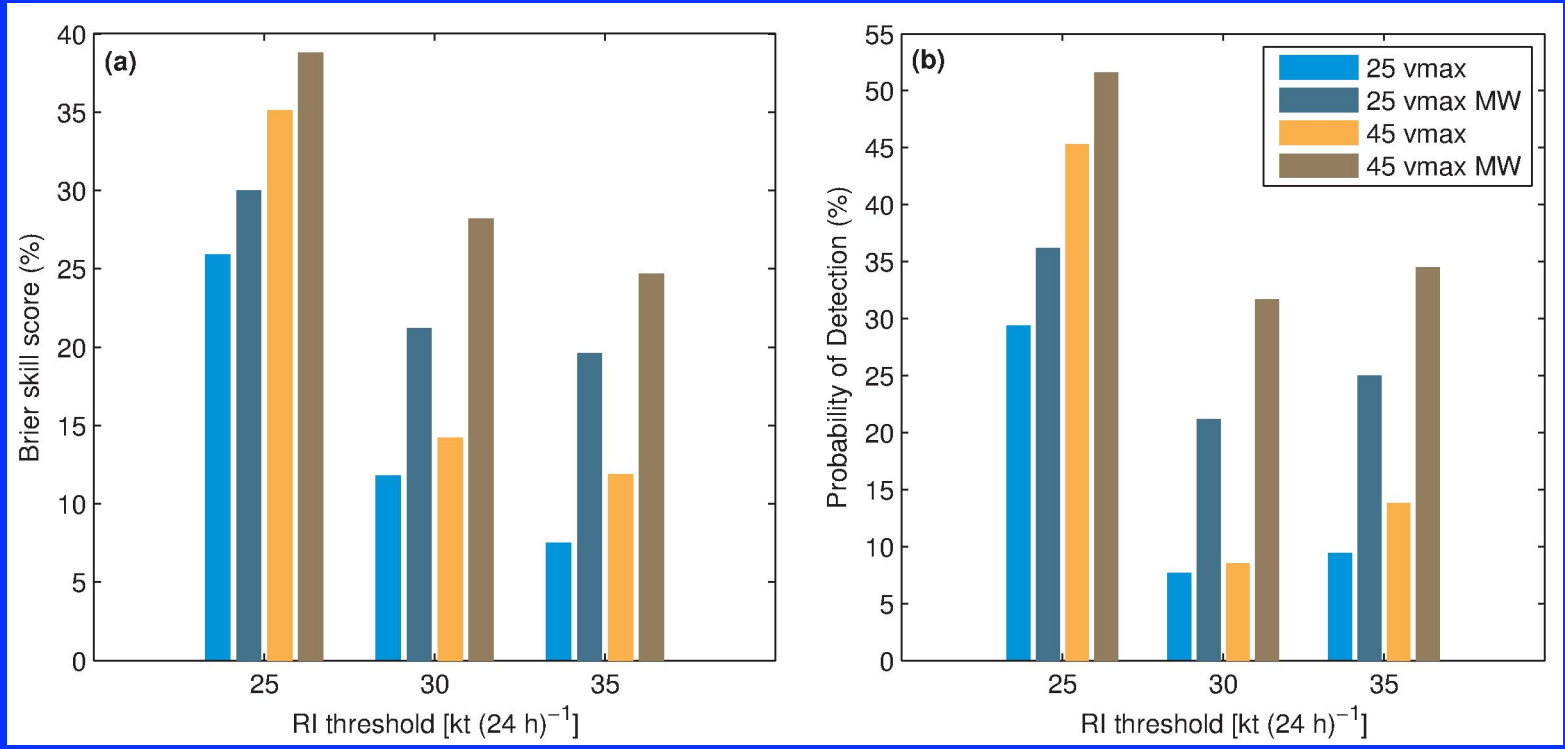
85 (V) GHz
Ice scattering
Highest resolution

Microwave Imagery-enhanced models

- **Baseline model:**
  - logistic regression model from Rozoff and Kossin (2011)
- **Enhanced model:**
  - Baseline model + additional MI-based predictors.
    - These predictors describe aspects of the precipitation structure such as eye and eyewall brightness temperatures, the degree of structural symmetry and the radial extent of precipitation.

MI-based Predictors for RI (35 kt/24 h)	RI ave
19.4-GHz average $T_{b,v}$ (r = 100 – 300 km)	higher
19.4-GHz minimum eye $T_{b,v}$	higher
19.4-GHz average ring $T_{b,h}$	higher
37.0-GHz radius of maximum $T_{b,h}$	lower
37.0-GHz average $T_{b,v}$ (r = 0 – 100 km)	higher

Contributions of Microwave Imagery to the Logistic Regression Model



The skill impact of adding MI-based predictors to the logistic regression model (results shown for versions of the model without MI (light blue, orange) and with MI (dark blue, brown). (a) Brier skill score (with respect to climatology) and (b) probability of detection (based on a 50%-decision rule). Results are shown for storms having at least 25 kt and 45-kt current intensity. (Results for the Atlantic, 1998-2008.)

* Results here use TRMM-TMI, AMSR-E, SSM/I, and WindSat. SSMI/S has recently been added (Feb. 2013).

Summary

- **A new multi-lead time ensemble-based RII was developed and tested in the Atlantic and E. Pacific basins in real-time during the 2012 season.**

- **Verification of the 2012 RII forecasts showed that the multi-lead time ensemble-based Atlantic forecasts were not skillful at any lead-time relative to climatology while the E. Pacific forecasts were skillful at all lead times.**

- **The lack of skill of the 2012 Atlantic RII forecasts was likely due in part to both the anomalously low rate of RI events in that basin in 2012, as the 2012 forecast errors were less than those of the long-term cross-validated sample mean, as well as the expected year to year variability in skill of RI forecasts.**

- **An evaluation of the independent deterministic intensity forecasts for the combined 2011-2012 Atlantic and E. Pacific basin sample showed that these forecast exhibited significant skill relative to IVCN in terms of error and bias. Skill was also found relative to IVCN when the multi-lead time ensemble-based RII was employed to make intensity forecasts for the 2008-2010 dependent sample.**

- **The microwave-based RII model is currently being re-derived with updated datasets, including data from 2009-2011 and now all SSMI/S data. Results, including testing of the 2012 season, should also be available within the next few months.**

Future Work

- **Continue to perform real-times tests of the new ensemble-based multi-lead time RII during the upcoming 2013 Atlantic and E. Pacific Hurricane seasons.**

- **Also, test recently developed ensemble-based version of the RII aid in the Atlantic and E. Pacific basins during the upcoming 2013 Hurricane season.**

- **Finally, complete re-derivation of microwave-based RII and perform real-time testing during the upcoming 2013 Hurricane Season in both the Atlantic and Eastern Pacific basins**