Multi Lead-time Statistical Rapid Intensification Guidance

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Background and Motivation

- **Predicting episodes of tropical cyclone (TC) rapid intensification (RI) remains one of NHC's top forecasting priorities.**
  - **To aid in forecasting RI, a statistically-based rapid intensification index (RII) was developed for the Atlantic and E. Pacific basins (Kaplan and DeMaria 2003, Kaplan et al. 2010, Kaplan et al. 2011) .**
  - **The SHIPS-RII employs environmental and a few inner-core GOES predictors to estimate the probability of RI from t=0 to t=24 h utilizing linear discriminant analysis. The SHIPS-RII is currently used operationally by the NHC.**

Recently Completed JHT Project Goals

- **Improve the forecasting utility of existing operational SHIPS-RII by:**
  - **Developing new multi-lead time (12-h, 24-h, 36-h, and 48-h) ensemble-based RI models that employ the SHIPS-RII and recently developed Bayesian and Logistic regression RI models (Rozoff and Kossin 2011).**
  - **Utilized new multi-lead time ensemble RI models in recently developed deterministic rapid intensity aid guidance (Sampson et al. 2011).**
  - **Deriving new microwave- based versions of the RII (See talk by Rozoff et al.).**

Multi Lead-time Ensemble RII

- New multi-lead time ensemble versions of RII were derived using 1995-2012 SHIPS developmental data at lead times of 12-h, 24-h, 36-h and 48-h for both the Atlantic and E. Pacific basins.
- The ensemble RII is the average of SHIPS, Bayesian, and Logistic versions of the RI model (Rozoff and Kossin 2011) .
- Multi-lead time ensemble RII was run in real-time at CIRA in Colorado (with forecasts made available to NHC forecasters via a website) from ~August 1 to Nov 30 of the 2013 Hurricane Season.

New multi-lead time ensemble-based RII →

Humberto (2013)

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                  *   ATLANTIC RII PARALLEL RUNS FOR JHT/PG   *
                  * GOES AVAILABLE,       OHC AVAILABLE       *
                  * AL09        AL092013  09/10/13  18 UTC    *

              CURRENT MAX WIND (KT):   60. LAT, LON:   14.7   -27.9

++++++++ SECTION 1, 2013 OPERATIONAL RII WITH ++++++++
                  TPW, IRPC, CFLUX ENHANCEMENTS

** 2013 ATLANTIC  RI INDEX AL092013 AL09       09/10/13  18 UTC **
         ( 30 KT OR MORE MAX WIND INCREASE IN NEXT 24 HR)

12 HR PERSISTENCE (KT):   5.0 Range:-49.5 to  33.0 Scaled/Wgted Val:  0.7/  1.9
850-200 MB SHEAR (KT) :   7.9 Range: 28.8 to   2.9 Scaled/Wgted Val:  0.8/  1.1
STD DEV OF IR BR TEMP :  15.4 Range: 37.5 to   2.9 Scaled/Wgted Val:  0.6/  0.8
2nd PC OF IR BR TEMP  :  -0.6 Range:  2.4 to  -3.1 Scaled/Wgted Val:  0.5/  0.8
HEAT CONTENT (KJ/cm2) :   4.0 Range:  0.0 to 155.1 Scaled/Wgted Val:  0.0/  0.0
MAXIMUM WIND (kt)     :  60.0 Range: 22.5 to 121.0 Scaled/Wgted Val:  1.0/  0.4
POT = MPI-VMAX (KT)   :  55.6 Range: 28.4 to 139.1 Scaled/Wgted Val:  0.2/  0.2
D200 (10**7s-1)       :  70.8 Range:-23.1 to 181.5 Scaled/Wgted Val:  0.5/  0.3
% AREA WITH TPW <45 mm:   0.0 Range:100.0 to   0.0 Scaled/Wgted Val:  1.0/  0.4
BL DRY-AIR FLUX (w/m2): 157.4 Range:960.3 to -67.2 Scaled/Wgted Val:  0.8/  0.0

Prob of RI for 25 kt RI threshold=    27% is   2.2 times the sample mean(11.9%)
Prob of RI for 30 kt RI threshold=    16% is   2.2 times the sample mean( 7.6%)
Prob of RI for 35 kt RI threshold=    15% is   3.2 times the sample mean( 4.5%)
Prob of RI for 40 kt RI threshold=     0% is   0.0 times the sample mean( 3.0%)


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

AL09       Initial vmax, lat, lon:    60.   14.7   -27.9 Date/time:   13 0910 18

Probability Rapid Intensification=   12%    no lightning, experimental algorithm
Probability Rapid Intensification=   14%  with lightning, experimental algorithm

Rapid Intensification (RI) = +30 kt or more max wind change in 24 hr

Predictor Name      Normalized Value   Prob Contribtuion
Climatology              0.0               5.5
SST Potential           -0.8              -2.8
850-200 hPa Shear       -0.8               1.5
200 hPa Divergence       1.0              -0.1
Persistence              0.3               1.3
GOES IR Cold Pixels      0.7               2.2
GOES IR asymmetry       -0.4               0.7
Ocean Heat Content      -1.3               0.4
850-700 hPa RH           1.6               2.2
GFS Vortex Tendency      0.8               2.0
Near Core Lightning     -0.9               2.7
Outer Lightning         -0.5              -1.3

Recent Lightning Density History (Strikes/km2-year)
Date/Time  vmax(kt)  Near Core (0-200 km)  Outer Region (200-400 km)
13 0910 18     60          0.0                      1.8
13 0910 12     55          0.0                      0.8
13 0910 06     55          0.0                      0.0
13 0910 00     50         15.0                      0.0
13 0909 18     45          4.0                      0.4
13 0909 12     40          4.0                      4.0
13 0909 06     35          2.0                      1.6
13 0909 00     30         17.0                      7.2
13 0908 18     25          3.0                      3.9

Weighted sample mean:   15.1                       8.3

 Note: Near core lightning < sample mean favors RI
       Outer      lightning > sample mean favors RI

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

** 2013 ATLANTIC EXPERIMENTAL  RI INDEX AL092013 AL09       09/10/13  18 UTC **

Prob RI for 20kt/ 12hr RI threshold=    8% is   1.4 times sample mean ( 5.8%)
Prob RI for 25kt/ 24hr RI threshold=   27% is   2.2 times sample mean (11.9%)
Prob RI for 30kt/ 24hr RI threshold=   16% is   2.2 times sample mean ( 7.6%)
Prob RI for 35kt/ 24hr RI threshold=   15% is   3.2 times sample mean ( 4.5%)
Prob RI for 40kt/ 24hr RI threshold=    0% is   0.0 times sample mean ( 3.0%)
Prob RI for 45kt/ 36hr RI threshold=    0% is   0.0 times sample mean ( 5.1%)
Prob RI for 55kt/ 48hr RI threshold=    0% is   0.0 times sample mean ( 5.3%)

Matrix of RI probabilities
-------------------------------------------------------------------------------
 RI (kt / h)  | 20/12 | 25/24 | 30/24 | 35/24 | 40/24 | 45/36 | 55/48
-------------------------------------------------------------------------------
   SHIPS-RII:    8.0%   26.6%   16.4%   14.6%    0.0%    0.0%    0.0%
    Logistic:    8.3%   33.7%   18.9%    7.3%    0.0%    8.5%    2.8%
     Bayesian:   7.7%   32.8%    9.3%    1.5%    0.6%    4.0%    0.7%
   Consensus:    8.0%   31.1%   14.9%    7.8%    0.2%    4.1%    1.2%
```

Ensemble RII Verification Methodology

- Multi-lead time independent versions of the RI models were derived for each year between 2004 and 2013 by first removing all cases from each individual year and then re-deriving the models using cases from the remaining 9 year sample.

- Ensemble RII re-run forecasts were then performed using the operational GFS forecast fields and operational NHC storm information archived for the period 2004-2013 using the independent models that were derived for the 10 year sample.

- All over-water tropical and subtropical forecast cases from 2004-2013 were verified using a Brier skill score (see Kaplan et al. 2010):

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

where y_k is the forecasted RI probability ($0.0 \leq y_k \leq 1.0$) from the RI model for each case

and

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

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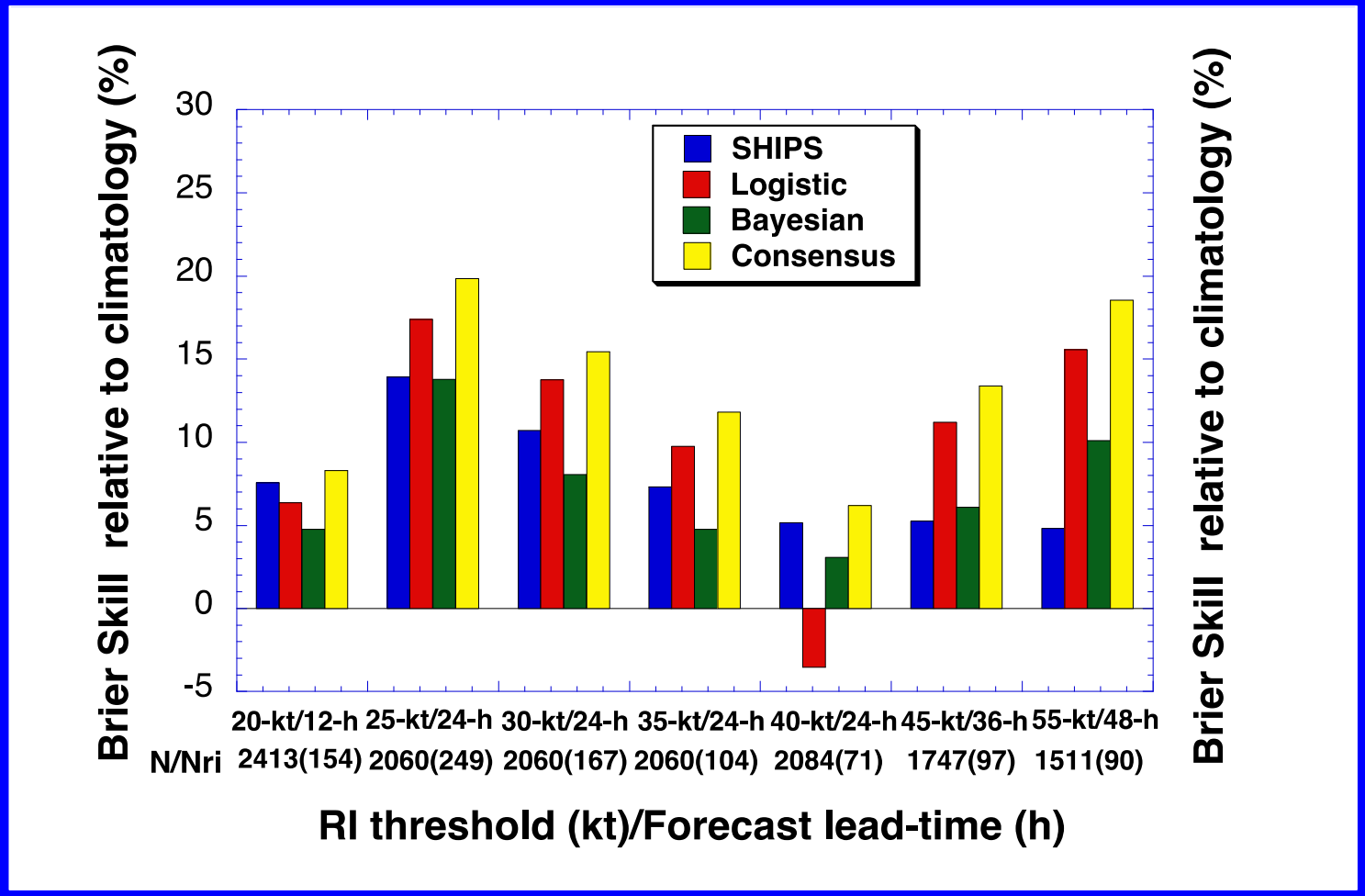
Brier Skill Score = (1. – BSM/BSCLIM)*100

where **BSM** and **BSCLIM** are the Brier Scores (**BS in yellow box**) of the RI model and climatological forecasts, respectively .

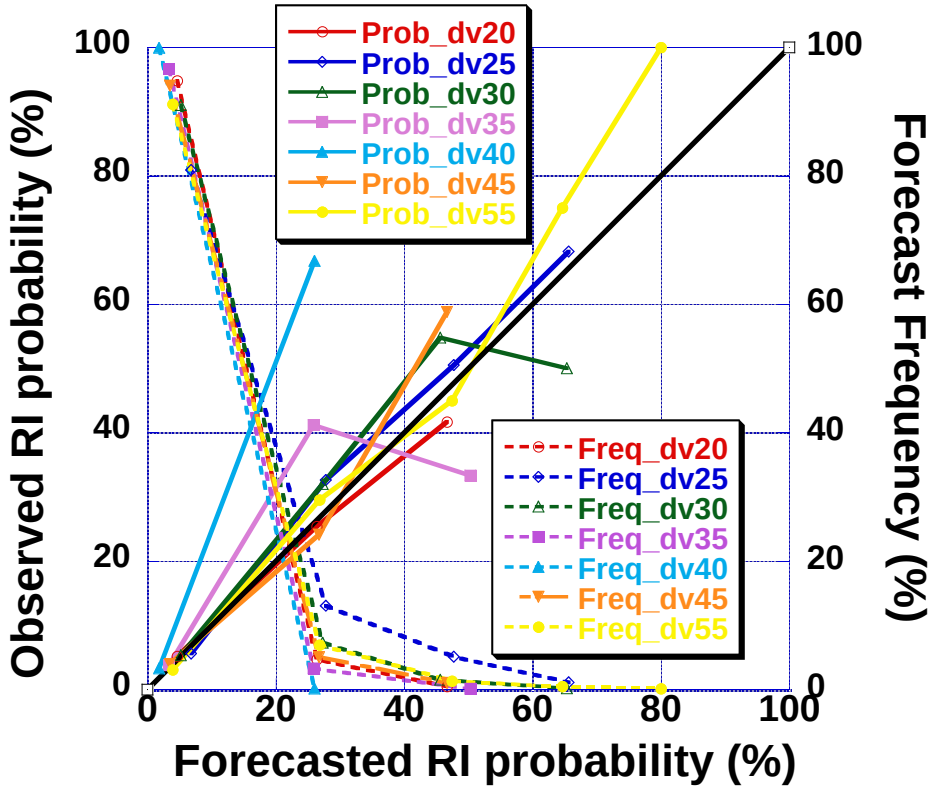
$-\infty < Skill < 100$

(so perfect skill is 100%)

Skill of the Atlantic Basin 2004-2013 Independent Re-run RI Model Forecasts

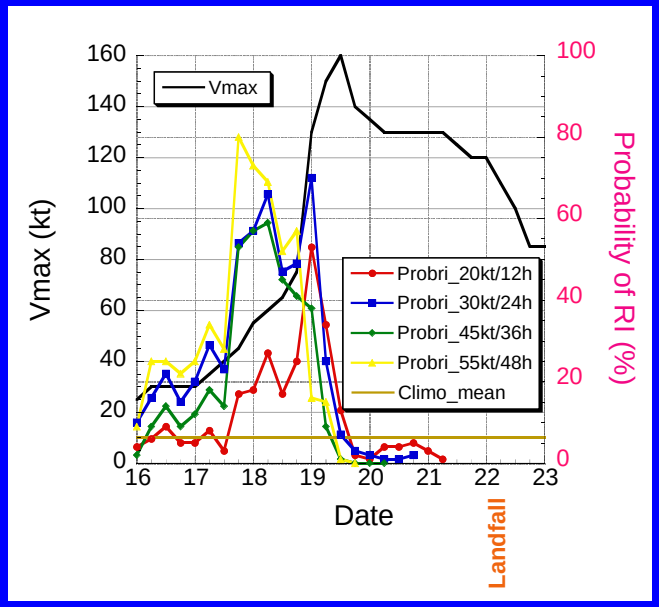


Reliability Diagram for 2004-2013 Atlantic Independent Re-run Ensemble RI Model Forecasts

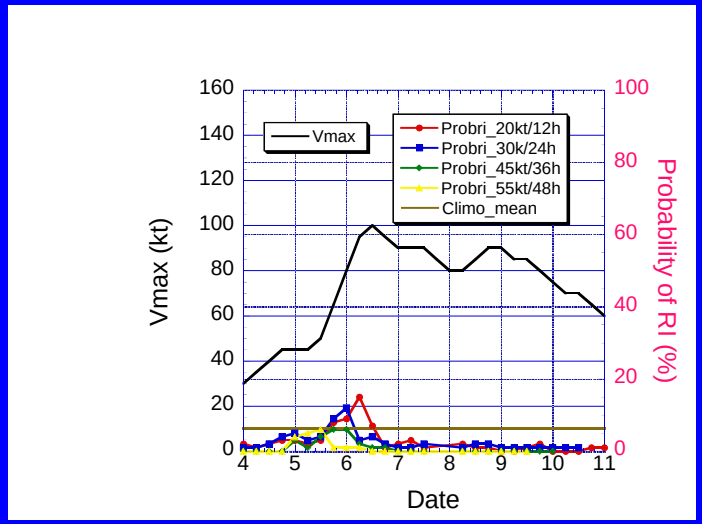


Samples of Atlantic Basin Ensemble Re-Run RI Model Performance

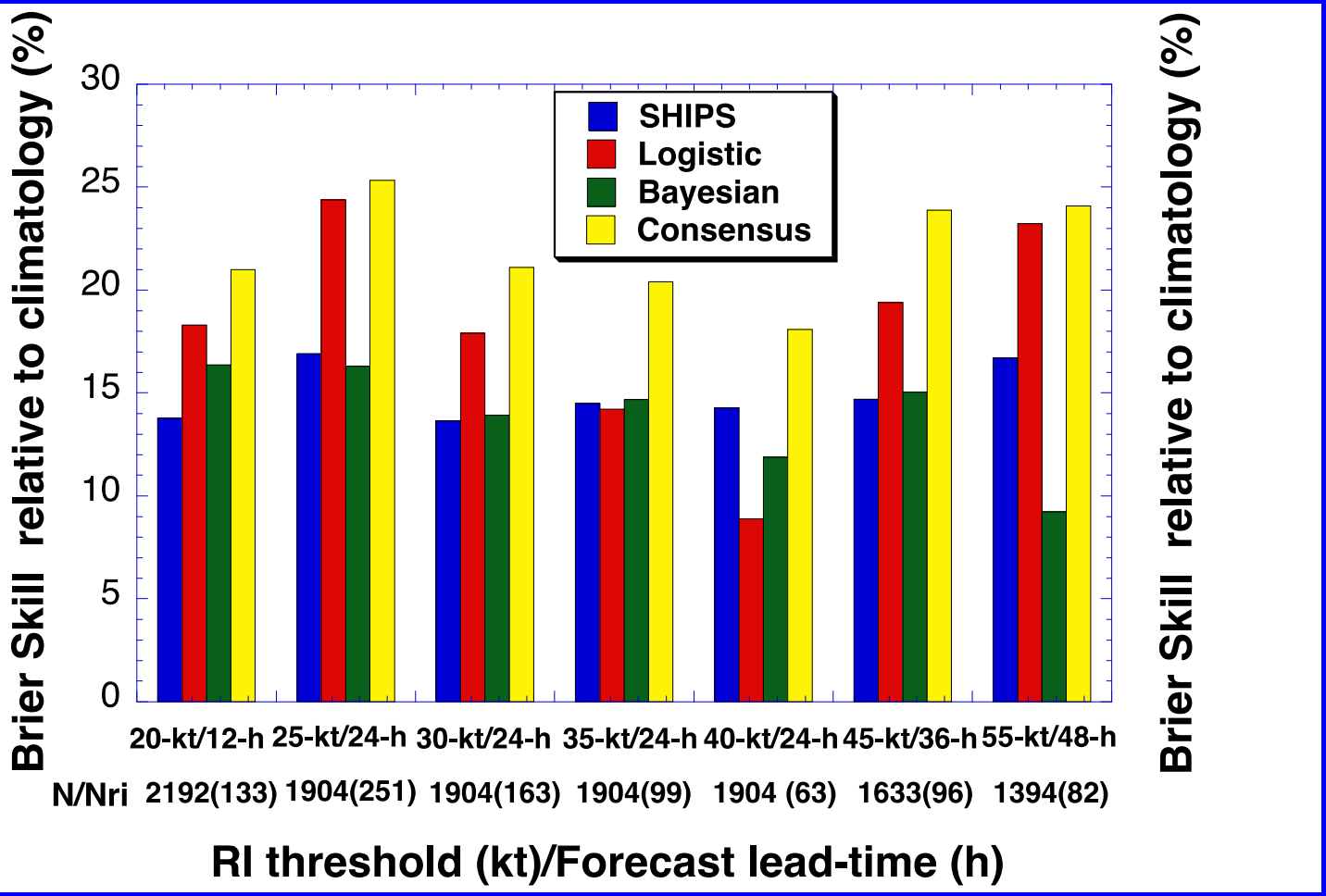
Wilma (2005)



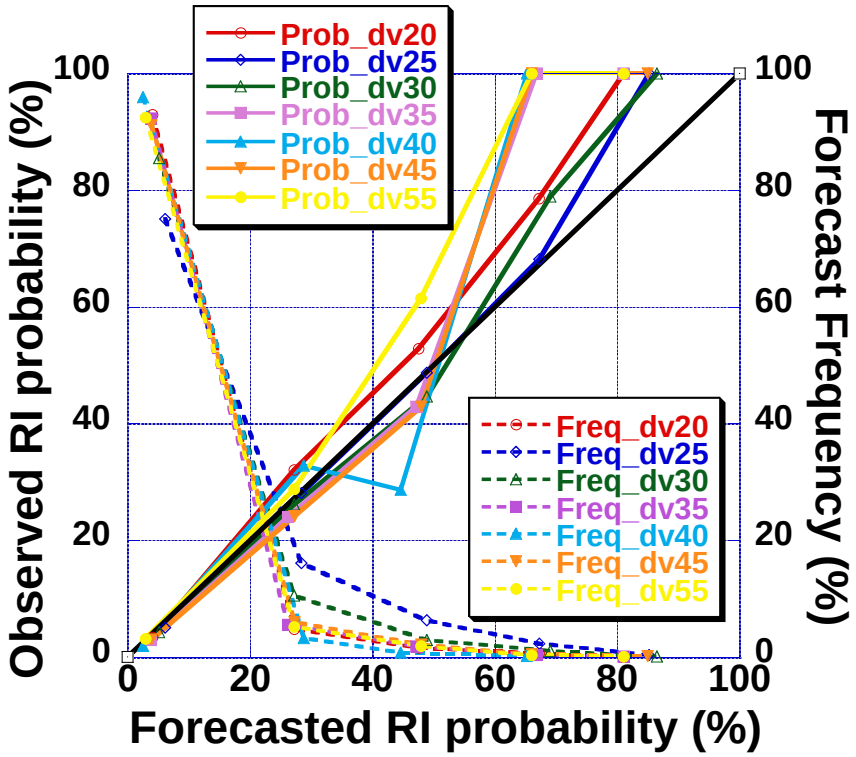
Michael (2012)



Skill of the E. Pacific basin 2004-2013 Independent RI model Re-run Forecasts

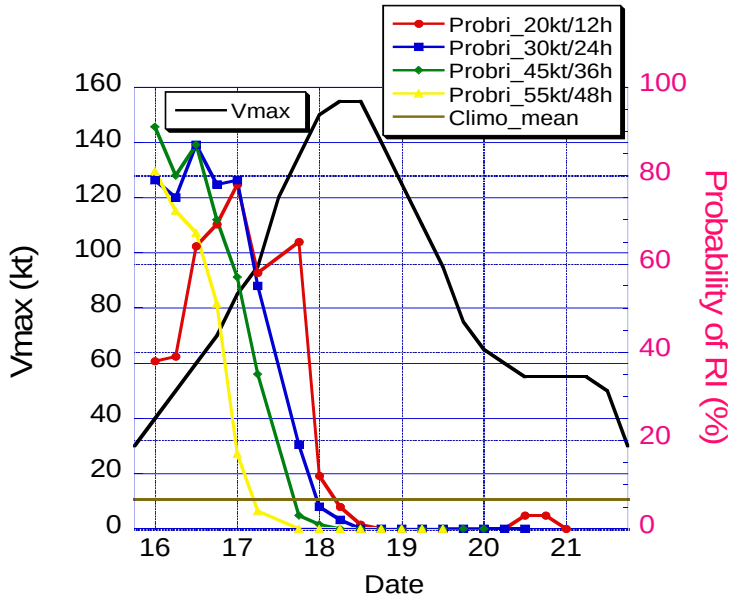


Reliability Diagram for 2004-2013 E. Pacific Independent Ensemble RI Model Re-run Forecasts

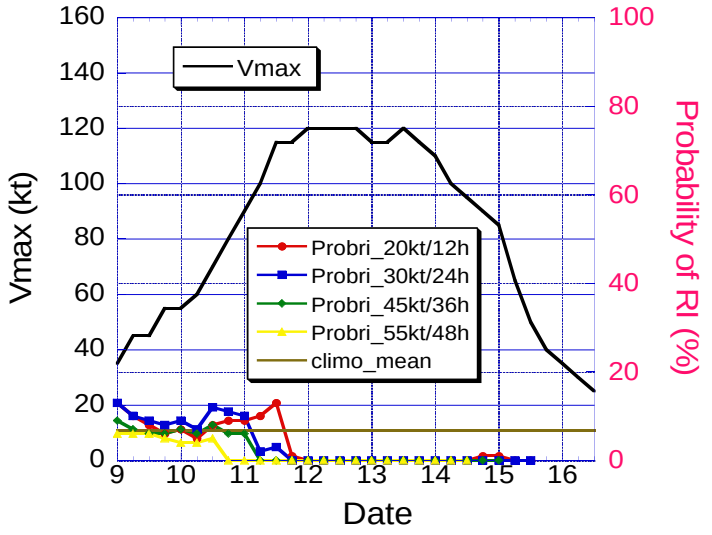


Samples of E. Pacific Basin Ensemble Re-Run RI Model Performance

Rick (2009)



Flossie (2007)

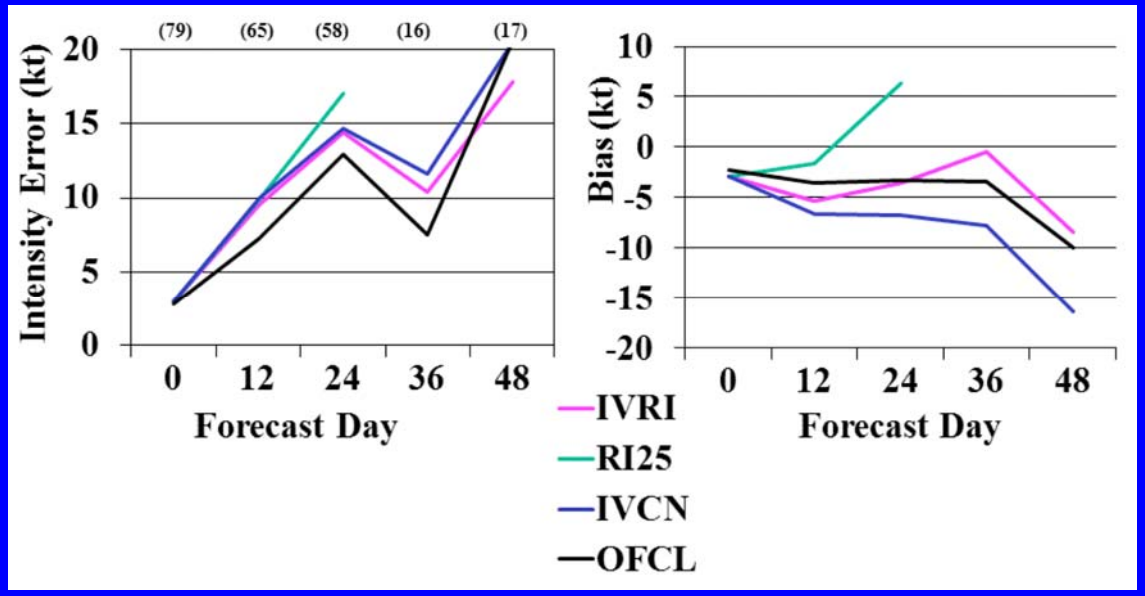


Deterministic RI Aid

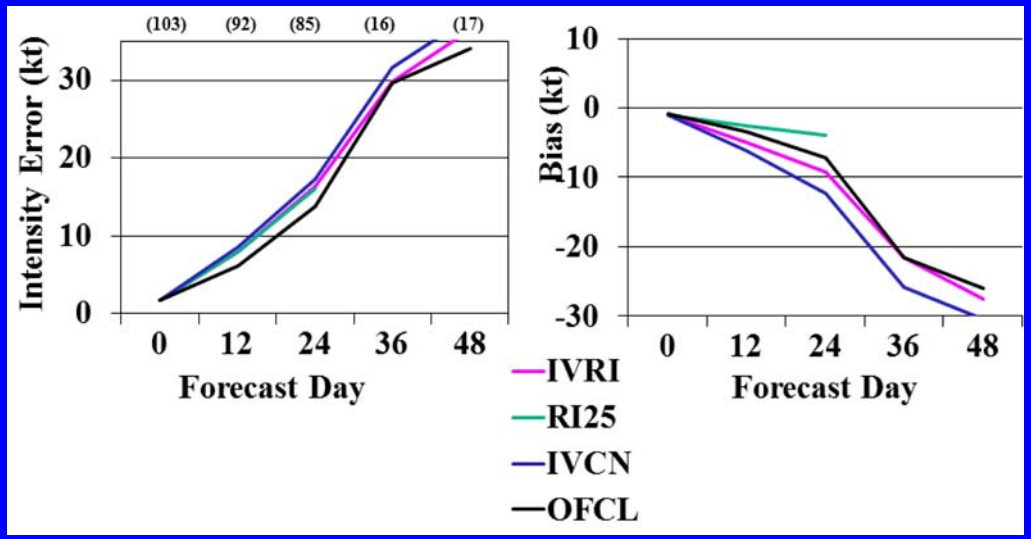
- **Background**
  - **Rapid intensity aid derived to provide deterministic RI intensity forecasts by combining IVCN model (e.g., HWRF,LGEM) and probabilistic 24-h SHIPS-RII forecasts (Sampson et al. 2011).**
  - **Revised versions of RI Aid have been developed to employ new multi-lead time ensemble RII guidance for Atlantic and E. Pacific basins.**
- **Methodology**
  - **RI aid assigns intensification rate when ensemble RI forecasted probability > 40% for a given RI threshold.**
  - **Assigned intensification rate added to existing IVCN model forecasts (HWRF,GFDL,SHIPS,LGEM) to obtain new deterministic RI aid intensity forecast (IVRI) at 12-48 h.**
  - **IVRI compared to IVCN and NHC Official (OFCL) forecasts for homogeneous independent 2008-2013 sample.**

2008-2013 Independent Rapid Aid Verification

Atlantic basin



E. Pacific basin



Summary

- **Improved multi-lead time ensemble-based RI models for estimating probability of RI at 12-h,24-h, 36-h and 48-h lead times were developed and tested in Atlantic and E. Pacific basins in real-time during 2013 Hurricane season.**

- **Verification of 2004-2013 independent RI re-run forecasts showed that multi-lead time forecasts of individual RI models (SHIPS, Bayesian, Logistic regression) were generally skillful at each lead-time in both basins with ensemble-based version proving to be the most skillful overall.**

- **New versions of the deterministic rapid intensity aid (IVRI) that employ both probabilistic RI guidance and operational intensity model consensus (IVCN) were developed using ensemble-based multi-lead RI models for the Atlantic and E. Pacific basins.**

- **An evaluation of the new multi-lead time IVRI forecasts conducted for the independent 2008-2013 RI re-run sample demonstrated that, on average, the IVRI forecasts exhibited lower means absolute errors and smaller biases than did IVCN in both the Atlantic and E. Pacific basins.**

Future Work

- **Run new multi-lead time RI, microwave-based RI, and IVRI guidance in real-time during the upcoming 2014 Atlantic and E. Pacific Hurricane seasons (as desired).**

- **Work on combing experimental lighting and current operational versions of SHIPS-RI models.**

- **Explore potential for improving RI model forecasts by including NHC-derived real-time tropical cyclone structural information.**