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.).
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.
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):

\[ BS = \frac{1}{n} \sum_{k=1}^{n} (y_k - o_k)^2 \]

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
**Ensemble RII Verification Methodology**

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

  \[
  BS = \frac{1}{n} \sum_{k=1}^{n} (y_k - o_k)^2
  \]

  where \( y_k \) is the forecasted RI probability \((0 \leq y_k \leq 1)\) from the RI model for each case and

  \( o_k = 0 \) if no RI occurs and

  \( o_k = 1 \) if RI does occur

  \[ Brier \ Skill \ Score = (1. - BSM/BSCLIM) \times 100 \]

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

  \(-\infty < \text{Skill} < 100\)

  (so perfect skill is 100\%)
Skill of the Atlantic Basin 2004-2013 Independent Re-run RI Model Forecasts

Brier Skill relative to climatology (%) vs. RI threshold (kt)/Forecast lead-time (h)

- SHIPS
- Logistic
- Bayesian
- Consensus

RI thresholds:
- 20-kts/12-h 24,13 (54)
- 25-kts/24-h 20,60 (249)
- 30-kts/24-h 20,60 (167)
- 35-kts/24-h 20,60 (104)
- 40-kts/24-h 20,84 (71)
- 45-kts/36-h 17,47 (97)
- 55-kts/48-h 15,11 (90)
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

![Diagram showing Brier Skill relative to climatology for different RI thresholds and forecast lead times.](image)

RI threshold (kt)/Forecast lead-time (h)

Brier Skill relative to climatology (%)
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.