Australian Government
Bureau of Meteorology

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

# Ensemble Tropical Rainfall Potential (eTRaP) forecasts

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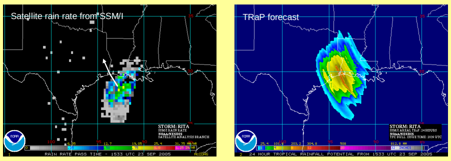
## 1. Strategy

- ***Extension of satellite-based TRaP methodology***
- ***"Poor man's ensemble" of TRaP forecasts***
- ***Produces deterministic and probabilistic QPFs***

***Background: Tropical Rainfall Potential (TRaP)***

NOAA/NESDIS produces operational areal Tropical Rainfall Potential (TRaP) forecasts of rainfall for landfalling tropical cyclones. TRaP forecasts are essentially 24 h extrapolation forecasts of satellite rain rates derived from passive microwave observations from polar orbiting satellites. Sensors include the Advanced Microwave Sounder Unit (AMSU), Special Sensor Microwave Imager (SSM/I), and Tropical Rainfall Monitoring Mission (TRMM) Microwave Imager.




TRaP rainfall accumulations are predicted every 6h out to 24h following three basic assumptions: (a) the satellite rain rate estimates are accurate, (b) the forecasts of cyclone track are accurate, and (c) the rain rates over a 24 h period can be approximated as steady state following the cyclone path. Errors in these assumptions lead to errors in TRaP rainfall predictions.

eTRaP combines TRaP forecasts from multiple scans and multiple sensors. The variability within the ensemble reflects the uncertainty in predicted rainfall resulting from uncertainties in satellite-estimated rain rate and rain system evolution. Averaging the ensemble members reduces the random error in the deterministic forecast.

## 2. How is eTRaP generated?

For a given accumulation and lead time:

1. Select all available 6h TRaP segments within the period of interest. These include TRaPs based on the latest microwave scan and earlier scans.

2. Assign each TRaP segment a weight according to the latency of the forecast and the relative accuracy of sensor in determining rain rates:

$$w_i = w_{forecast} \times w_{sensor}$$

where
$$w_{forecast} = \begin{cases} 1.0 & \text{0 - 6h old} \\ 0.7 & \text{6 - 12h old} \\ 0.4 & \text{12 - 18h old} \\ 0.1 & \text{18 - 24h old} \end{cases} \qquad w_{sensor} = \begin{cases} 1.3 & \text{AMSU} \\ 1.0 & \text{TRMM} \\ 0.7 & \text{SSM/I} \end{cases}$$

3. Using all permutations of 6h segments, combine TRaP forecasts to make ensemble members with the desired accumulation. The weight associated with each ensemble member is the sum of the weights of its 6h segments.

4. Generate deterministic forecasts as the weighted ensemble mean and weighted probability-matched ensemble mean*.

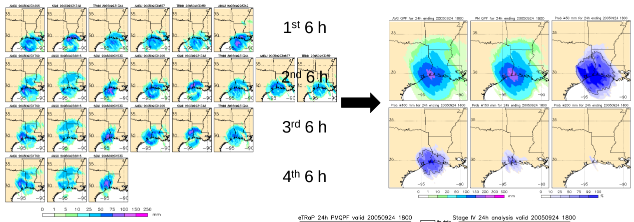
* The probability-matched mean has the same relative spatial distribution of rain as the ensemble mean, but the intensity distribution is transformed using probability (histogram) matching to have the same intensity distribution as the full ensemble. The purpose of this transformation is to remove some of the excess light rain caused by the averaging process, and to restore the heavy rain accumulations that may have been lost during averaging.

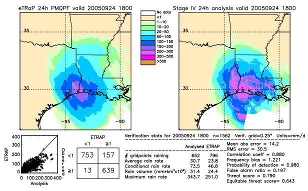
5. Generate probabilistic forecasts using weighted polling.

**Table 1. Atlantic storms for which eTRaP forecast performance was evaluated.**

| Storm | Period verified |
|---|---|
| Tropical Storm Bonnie | 12 August 2004 00 UTC – 13 August 2004 12 UTC |
| Hurricane Charley | 13 August 2004 00 UTC – 15 August 2004 00 UTC |
| Hurricane Frances | 4 September 2004 12 UTC – 8 September 2004 12 UTC |
| Hurricane Ivan | 15 September 2004 00 UTC – 17 September 2004 12 UTC |
| Tropical Storm Arlene | 11 June 2005 00 UTC – 12 June 2005 12 UTC |
| Hurricane Cindy | 5 July 2005 00 UTC – 7 July 2005 00 UTC |
| Hurricane Katrina | 25 August 2005 12 UTC – 27 August 2005 00 UTC, |
| | 28 August 2005 12 UTC – 30 August 2005 12 UTC |
| Hurricane Rita | 23 September 2005 12 UTC – 25 September 2005 12 UTC |

## 3. Example: Landfall of Hurricane Rita, 0600 UTC 24 September 2005



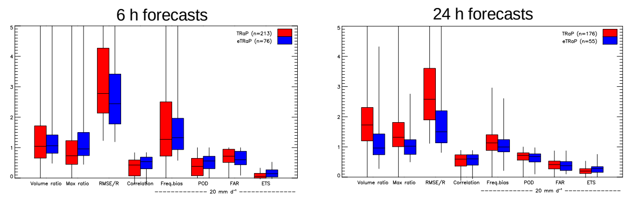




Compared to single-scan TRaP the eTRaP deterministic forecasts are smoother, less prone to extreme values, and tend to match the observations slightly better.

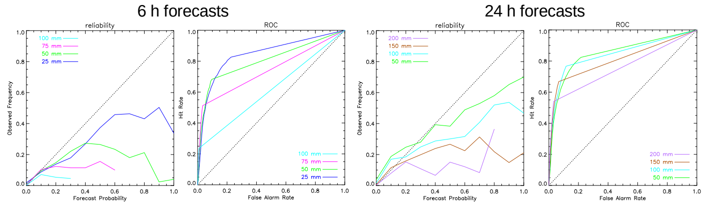
## 4. Performance of eTRaP for eight storms during the 2004 and 2005 Atlantic hurricane seasons.

eTRaP forecasts were evaluated for the eight Atlantic storms listed in Table 1. The verification data were Stage IV radar-rain gauge analysis over a 10°lat/lon domain centered on the best track position.

***Deterministic forecasts***




***Probabilistic forecasts***




## 5. Conclusions and future work

Ensemble TRaP (eTRAP) forecasts give more accurate rainfall predictions than single-scan TRaPs, with less bias, lower RMS errors, more realistic maxima, and more accurate delineation of heavy rain areas.

In addition, the probabilistic forecasts of heavy rain probability made possible by this strategy provides valuable information to emergency managers and other decision makers. The eTRaP heavy rain probabilities were too high (overconfident); calibration of probabilistic QPFs will increase their reliability.

Much remains to be done to further test and optimize the eTRaP methodology. In the future we will test the inclusion of IR-based TRaPs made using the Hydro-Estimator algorithm. Addition of independent rain forecasts from NWP models and climatology (R-CLIPER) may also add skill to the ensemble approach.

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