Quarterly Report ending 31 December 2001

Development of a Tropical Cyclone Rainfall Climatology and Persistence (R-CLIPER) Model

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During the first quarter a tropical cyclone (TC) rain CLIPER (R-CLIPER) model based upon 53 years of U.S. rain gauge data was completed at CIRA (DeMaria and Tuleya, 2001). This project is funded by the Insurance Friends of the National Hurricane Center. The gauge data set includes 125 U.S. landfalling storms from 1948 to 2000. There were about 1,000,000 hourly rain gauge reports within 500 km of the storm center. Only storms that were hurricanes at landfall are included (46 storms). There were about 560,000 hourly gauge reports within 500 km of the storm center for these cases. The gauge data was stratified into 50 10-km wide annuli surrounding the storm center and mean rainfall rates were computed for each annuli (Fig. 1). In order to handle storms after they made landfall an inland-decay model was developed using the rain gauge data set by stratifying the results by time after landfall (Fig. 2). The rainfall climatology was reduced to a linear fit of the mean rainfall rates by radius (r) and time (t) after landfall defined as:

$$R(r,t) = (ae^{-\alpha t}+b)e^{-(r-r_m)/r_e} \quad (1)$$

where parameters a and α are defined from the fit to the gauge data in time and b by the fit to the gauge data by radius, where r_m is the radius of maximum rainfall (which is at the origin) and r_e is 500 km. This approach results in a circularly symmetric rain distribution that can be combined with the forecast track to produce a swath of rain along the forecast track before and after landfall. The climatology was combined with the operational track forecasts through the automated tropical cyclone forecast (ATCF) system used at TPC/NHC to compute an integrated rain distribution for each forecast interval to produce the R-CLIPER (Fig. 3).

The gauge-based R-CLIPER model was implemented at NHC in September 2001 with the help of Michelle Mainelli (TPC) as part of that project. Michelle wrote a program to plot the rainfall totals in N-AWIPS. However, because the hourly gage data is sparse, particularly within 100 km of the storm center, it is difficult to obtain a large enough sample to stratify the data by storm intensity.

To overcome this limitation the R-CLIPER was expanded to include a global satellite-based TC rainfall climatology based on rain estimates from the NASA Tropical Rain Measurement Mission (TRMM) satellite; in particular the microwave imager (TMI). This climatology was developed at HRD under a NASA TRMM contract (Lonfat et al 2000). To date, this climatology includes global TMI rain estimates in 245 storms from December 1997 to December 2000, yielding 2121 events, where 64% of the events were tropical storms, 26% were category 1-2 hurricanes, and 10% were category 3 or higher. The climatology provides a mean rain rate and the rain rate probability distribution in a storm-centered coordinate system composed of 50 10-km wide annuli in four quadrants. The results are stratified as a function of storm intensity (Fig. 4) which shows that the mean rain rate increases by a factor of 4 (3 in day^{-1} for tropical storms versus 12 in day^{-1} for category 3 and higher TCs) within 50 km of the storm center with increasing intensity. Figure 4 also indicates that the radius of maximum rainfall (r_m) also decreased with increasing intensity (i.e., from 55 km for tropical storms, to 45 km for category 1-2 hurricanes, and to 28 km for category 3-5 hurricanes).

A comparison of the satellite-based to the gauge-based climatology for all hurricanes and tropical storms depicted in Fig. 1 denotes a surprising similarity between the two mean rainfall rate curves with radius and intensity. The major difference is the high variability of the mean rainfall rate at radii<100 km in the gauge climatology, particularly for tropical storms, which is caused by the low number of points in those annuli. There is also a lack of a minimum in the mean rainfall rate at small radii for the gauge-based climatology. Despite these slight differences, this comparison gives a good indication of the veracity of both climatologies.

The satellite-based R-CLIPER uses the TMI rain climatology partitioned by storm intensity developed by Lonfat et al (2000) to provide the storm-centered mean rain rate distribution out to 500 km radius (r_e) from the storm center as a function of radius:

$$
\begin{aligned}
R(r) &= (R_0) + (R_m - R_0)(r/r_m) \qquad && r<r_m \\
&= R_m \exp(-(r-r_m)/r_e) && r>r_m \qquad (2)
\end{aligned}
$$

where parameters R_0, and R_m, are the mean rainfall rates at r_e and r_m, respectively. The climatology was combined with the operational track forecasts through the ATCF in the same manner as the gauge-based climatology to compute an integrated rain distribution for each forecast interval to produce the R-CLIPER. This version of the R-CLIPER model was presented at the NOAA Hurricane Conference in December 2001[1].

An important use of the R-CLIPER is to provide a benchmark for the evaluation of other more-general QPF techniques. To evaluate the R-CLIPER forecasts it will be run on a number of past storms to provide some statistics on model performance and to develop different data products useful to the hurricane specialists. At the NOAA Hurricane Conference we met with representatives of the NWS Hydrometeorological Prediction Center (HPC) and TPC/NHC to select suitable cases to test R-CLIPER. These discussions resulted in the selection of five storms: Andrew (1992), Fran (1996), Danny (1997), Floyd (1999), and Allison (2001). They recommended that we compare R-CLIPER forecasts with 6-h areal average rainfall amounts on a 1°X1° grid, which is what HPC uses. They have this type of information going back 10-12 years and will make it available for us. Comparisons with storm total rain gauge data will also be

[1] ftp://ftp.aoml.noaa.gov/hrd/pub/marks/NHC2001_slides.pdf

performed. A University of Miami undergraduate (Gretchen Kappler) will work with Frank Marks on these evaluations over the next few months to insure the R-CLIPER is operational by the start of the 2002 Hurricane Season. Results from these tests will be presented at the Interdepartmental Hurricane Conference in March and the 25th Conference on Hurricanes and Tropical Meteorology in May.

References:

DeMaria, M. D., and R. Tuleya, 2001:Evaluation of quantitative precipitation forecasts from the GFDL hurricane model. Reprints *Symposium on Precipitation Extremes: Predictions, Impacts, and Responses*, AMS, Albuquerque, NM, 340-343.

Lonfat, M., F. D. Marks, S. Chen, 2000: Study of the rain distribution in tropical cyclones using TRMM/TMI. Preprints *24th Conference on Hurricanes and Tropical Meteorology*, AMS, Ft. Lauderdale, FL, 480-481.

Figures

Climatological Rainfall Rates from TRMM and Rain Gauges for Hurricanes and Tropical Storms

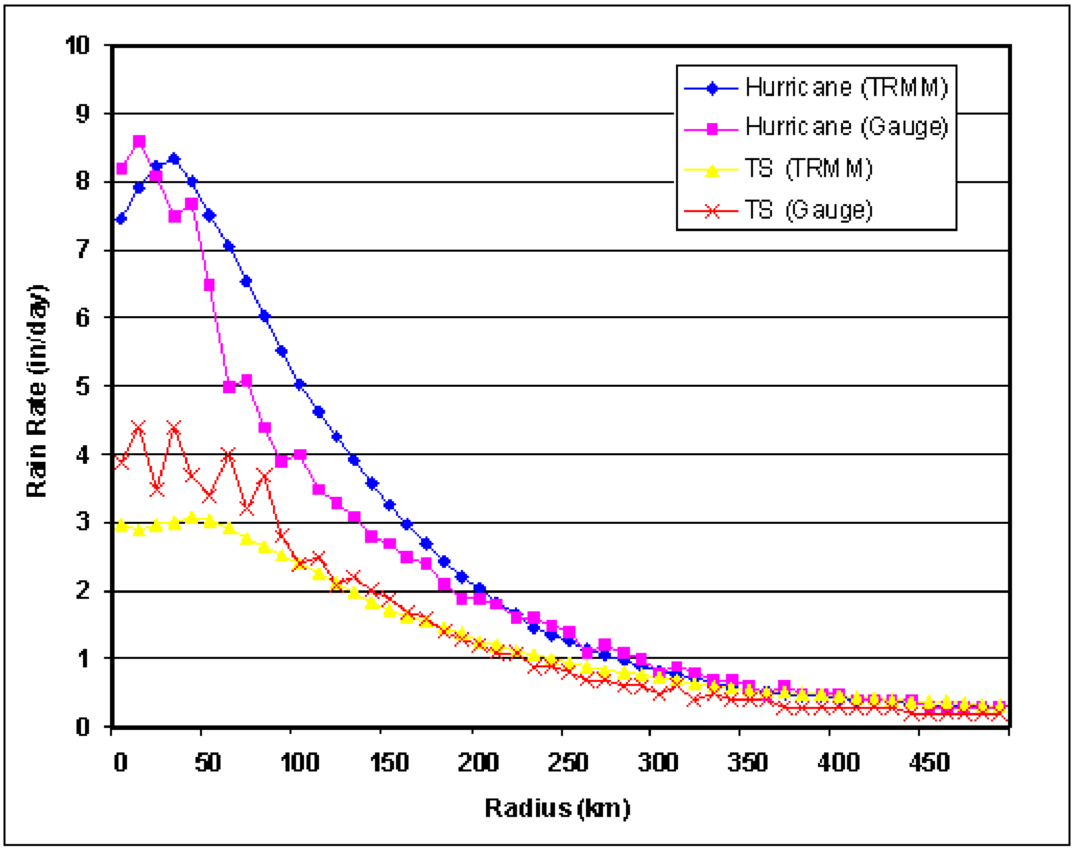

Fig. 1. Gauge-based TC rainfall climatology (in day^{-1}) from 1948-2000 and TRMM TMI-based TC rain climatology (in day^{-1}) from December 1997-2000. Comparisons are made for tropical storms and hurricanes.

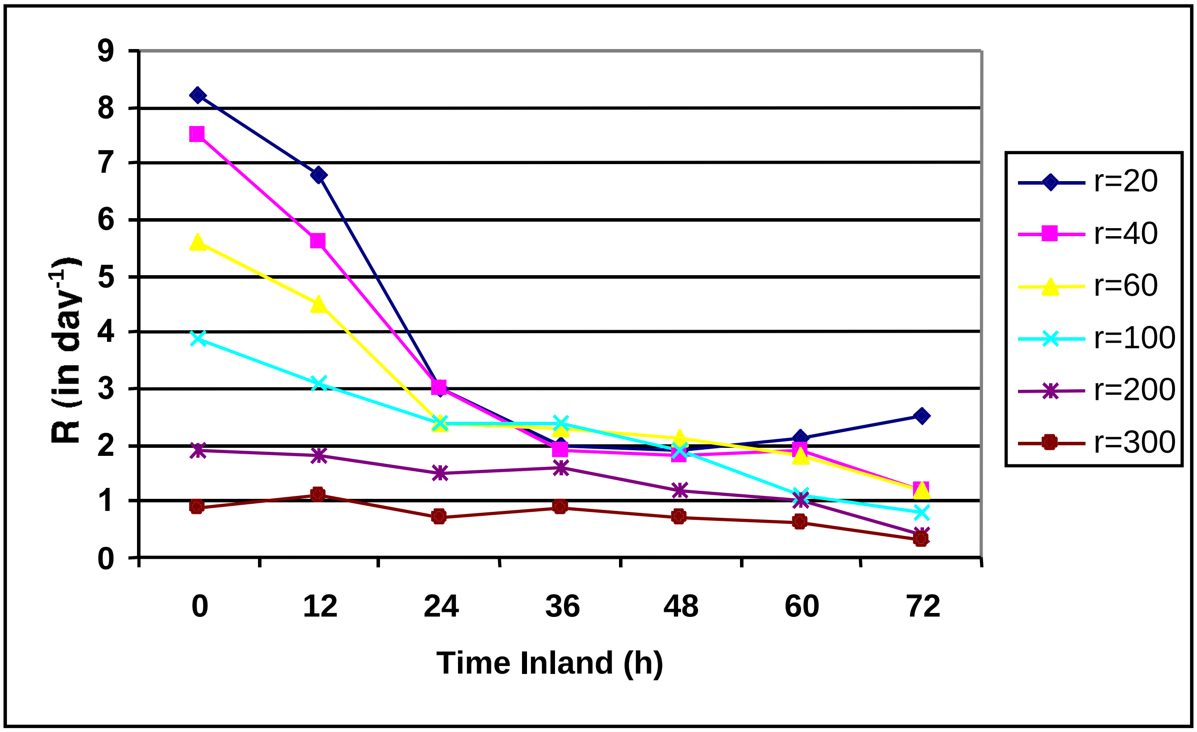

Fig. 2. Comparison of gauge-based rainfall climatology (in day^{-1}) for time inland (h) at different radii from the storm center (r).

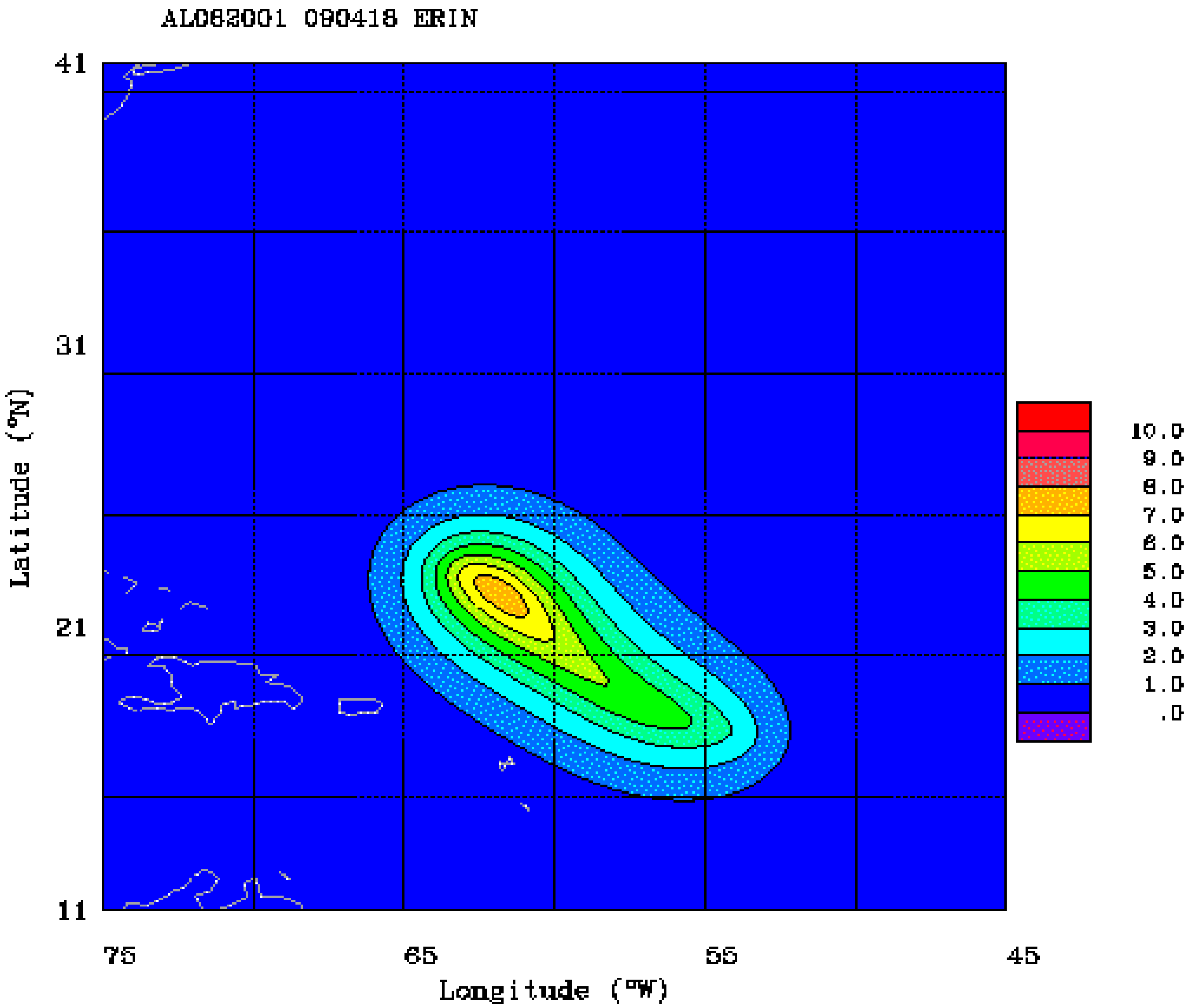

Fig. 3. Rainfall rate (in day^{-1}) forecast from gauge-based R-CLIPER accumulated along 72 h NHC track forecast for Erin (4 Sept. 2001 18 UTC).

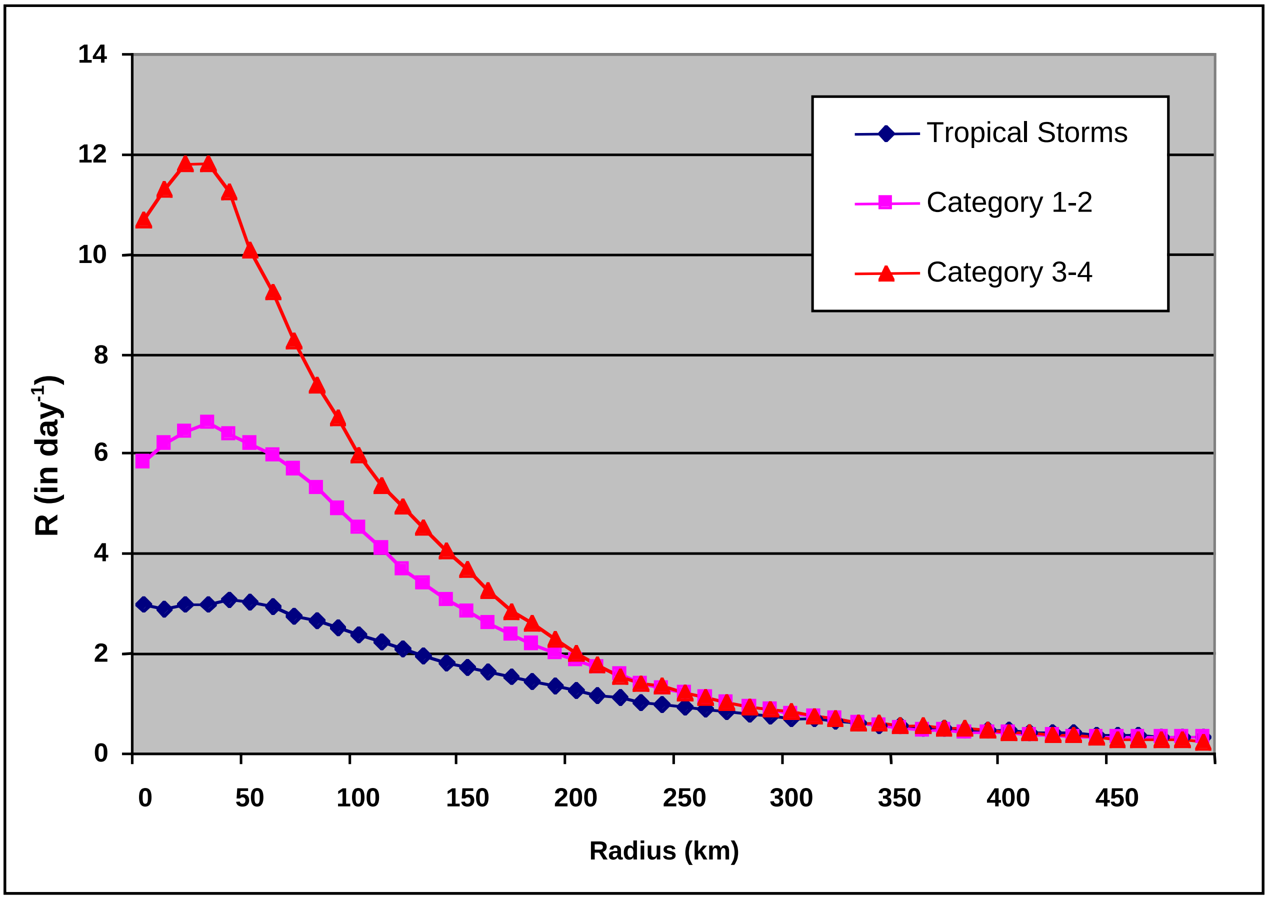

Fig. 4. TMI-based rainfall climatology (in day^{-1}) for tropical storms, Category 1-2, and Category 3-5 hurricanes.