Quarterly Report ending 30 June 2002

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

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Activities in the third quarter were divided into three areas:

(1) continued evaluation of the tropical cyclone (TC) rain climatology and persistence (R-CLIPER) model on the five storms selected through discussion with members of TPC/NHC and HPC;
(2) presentations of our results at the AMS 25th Conference on Hurricanes and Tropical Meteorology and at the COMAP Course ; and
(3) a visit to the Hydrological Prediction Center (HPC) to give a seminar on our results and to get access to gauge and other data sets to help with our evaluation.

We also started evaluating six storms in 1998-1999 that effected the U.S. with heavy rainfall.

(1) Using the R-CLIPER running at HRD modified to run on 6-h best track positions for the five cases listed in Table 1 and illustrated in Figs. 1 and 2, we found that the R-CLIPER underestimated the storm total rainfall by nearly a factor of two, as compared to the available gauge data. We refined these estimates for all five cases through the addition of climatological gauge rain totals from Hurricanes Andrew and Fran. Figure 3 shows the cumulative distribution function (CDF) of all of the storm total rain estimates over the U.S. from the available gauges (top) and the R-CLIPER (bottom). The number of gauges varied from case to case, but they covered the region effected by the storm. The R-CLIPER estimates (R_C) represent the area covered by the swath shown in Fig. 2 that was over the U.S. Assuming that the gauge estimates (R_G) are representative of the areal rain distribution covered by the R-CLIPER, we compared the CDF for the gauge estimates and R-CLIPER using the probability-matching method (PMM, e.g. Calheiros and Zawadski, 1987; Rosenfeld et al 1993). The PMM finds the set of pairs of R_G, and R_C at which the cumulative probabilities of the two are equal. The assumption is that the area covered by that cumulative probability rain amount is equivalent for both the gauges and the R-CLIPER (a big assumption considering how representative each gauge is of the large area covered by the R-

CLIPER, especially for small R_G).

Figure 4 shows the PMM gauge and R-CLIPER storm total rain estimates for all five cases (individual cases were run as well). The comparison shows the factor of two estimate applies at all amounts, with slightly worse underestimates at R_G<2 inches. At R_G>2 inches the underestimation is almost exactly a factor of two. This result, while a bit discouraging, indicates a rather robust relationship between the R-CLIPER and the gauge storm total estimates. *For this season, the hurricane specialists should be able to use the present R-CLIPER rain forecasts by doubling the estimates.*

More work is needed, however, to understand why the R-CLIPER underestimates the gauge amounts by a factor of two. First, we checked the algorithm developed by Mark DeMaria from the TMI climatology of the mean rain amount in each annulus to derive the rain estimates for each storm category. The algorithm slightly underestimated the rain estimates because it assigned the values derived for the three intensity ranges defined by Lonfat et al (2000) to the middle of each intensity range. The storm intensity statistics from Lonfat et al suggest that the rain estimates are more representative of the lower edge of each intensity range. We altered the algorithm to reflect this difference and reran the comparisons with only a slight change (the results presented in Figs. 2-4 use the new version of the algorithm). Second, as suggested in the last quarterly report, we are also beginning to look into using other measures of the rain PDF for the next generation R-CLIPER to improve this underestimate. The current version of the model will remain in use for this hurricane season at TPC while we continue our evaluation of the products (see attached email from Mark DeMaria for details on the current version).

(2) The R-CLIPER model was presented at the 25th Conference on Hurricanes and Tropical Meteorology in May 2002 (Marks et al 2002) and at the COMAP NWS training course in Boulder, CO in early June. Both presentations are available on my anonymous ftp site: ftp://ftp.aoml.noaa.gov/hrd/pub/marks/R-CLIPER.ppt and ftp://ftp.aoml.noaa.gov/hrd/pub/marks/tropical_met_class/Shuyi_lecture.ppt, respectively)

(3) Frank Marks also visited HPC in late May, giving a seminar on the R-CLIPER, and to get access to the 6-h rain products for comparison to the R-CLIPER 6-h rain totals. During my seminar I showed the results from the 5 selected case studies in Figs. 1 and 2, plus 6 cases from 1999-2000 shown in Fig. 5. An interesting observation that came out of our discussion is how sensitive the storm total rain distribution is to changes in storm track direction. All cases presented in Figs. 2 and 5 have large increases in storm total rain amounts when the track direction changes. This result is caused by two effects: (1) when the storm turns to a new direction it usually slows down increasing the duration of the rain; and (2) there is a increase on the inside of the turn due to the increased duration caused by the shape of the track. These two effects occur whether there is other influences present or not, and they may explain increases in storm total rainfall we have seen from the gauge data when there is no apparent cause, such as topographic lifting or a frontal zone. *Hence, as a rule of thumb, forecasters should look for local increases in storm total rain when the track is predicted to turn.*

Discussions with folks at HPC indicated that the 6-h rain data archive available at HPC only goes back to 2000. So we will focus on storms after that data for our comparisons with their archive data sets. While these data give the best estimate of the 6-h rain amounts on a regular grid, these cases are limited to only tropical storms at this time.

During my seminar and visit to HPC we discussed what aspect of the rain distribution the forecaster needs to predict in order to determine what type of products the R-CLIPER should produce for them. We decided to share copies of the algorithm that runs on the best track and the operational model to test new ideas and products.

We also discussed the problem with the operational R-CLIPER's dependence on the ATCF forecast for a storm track identified last quarter. Currently, the ATCF contains no track forecast information after the storm makes landfall, when TPC/NHC stops producing them. HPC continues to follow the storm's remnants, however, no track forecast is produced from which to run the R-CLIPER. HPC will look into using their internally generated center for the R-CLIPER using a version of the operational algorithm that resides on the NWS IBM machine.

References:

Calheiros, R. V., and I. Zawadski, 1987: Reflectivity-rain rate relationships for radar hydrology in Brazil. *J. Climate and Appl. Meteor.*, **26**, 118-132.

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

Marks, F. D., G. Kappler, M. DeMaria, 2002: Development of a Tropical Cyclone Rainfall Climatology and Persistence (R-CLIPER) Model. Reprints of the 25th *Conference on Hurricanes and Tropical Meteorology*, AMS, San Diego, CA. (ftp://ftp.aoml.noaa.gov/hrd/pub/marks/7D2_Marks.pdf)

Rosenfeld, D., D. B. Wolff, and D. Atlas, 1993: General probability relations between radar reflectivity and rain rate. *J. Appl. Meteor.*, **32**, 50-72.

Attachment:

Subject: R-CLIPER on the IBM
Date: Friday, July 19, 2002 4:30 PM
From: DeMaria, Mark <DeMaria@cira.colostate.edu>
To: Frank Marks <Frank.Marks@noaa.gov>
Cc: <Michelle.M.Mainelli@noaa.gov>, <chris.a.sisko@noaa.gov>, <Jiann-Gwo.Jiing@noaa.gov>, <Stacy.R.Stewart@noaa.gov>, <Christopher.A.Burr@noaa.gov>, <Edward.N.Rappaport@noaa.gov>, <gross@nhc.noaa.gov>

Frank:

I installed the most recent version of the r-cliper model on the IBM (with your new TRMM coefficients) today. For future work, I separated out the rain rate subroutine (rrcal.f), so that this could be replaced if you come up with something new. Chris Sisko knows where the code is on the IBM, and can make future modifications. The one thing I did not do was turn on the TRMM rain rate (the operational code still uses the rain rate based from the rain gauge climatology). I felt that it is up to TPC to decide if they want to make that change. My feeling is that the TRMM version is better, since it includes the variation in rain rate with storm intensity. If TPC agrees to go ahead with the TRMM version, all Chris S. would have to do is change the flag (the igauge parameter) in the rrcal.f routine on the IBM, and then recompile the code using the make file as follows:

(In the /tpcprd/atcf_unix/prgms/rcliper directory, type "make" followed by "make movex". The first step compiles the code. The second step copies the new executable to the directory where Jim Gross keeps all of the executables for the NHC guidance models).

Also, while I was at TPC a few weeks ago, Michelle got the program to display the results in N-AWIPS to work (the get_rcliper script, which works in a similar manner to the get_ships script). Thus, if there is a storm near land and the forecasters wanted to see the graphical output, they would have to type get_rcliper on the same workstation that they use to run get_ships.

I don't plan to do too much else with the r-cliper model, although I am coordinating with a graduate student at NCSU who is looking into developing a topography adjustment based upon the rain gauge climatology.

Mark

Table 1.

Storm	R-CLIPER maximum rainfall (in)	Location of R-CLIPER maximum rain	Gauge Maximum rainfall (in)	Location of gauge maximum rain
Andrew 1992	7.7 5.0	Louisiana coast Florida coast	11.9 7.8	Hammond, LA Broward, FL
Fran 1996	4.8	Carolina coast	14.2	Luray, VA
Danny 1997	15.9	Alabama coast	27.0	Theodore, AL
Floyd 1999	8.3 4.1	Bahamas Carolina coast	11.9 14.5	Clinton, NC Williamsburg, VA
Allison 2001	8.6	SE Texas	36.9	Houston, TX

Figures

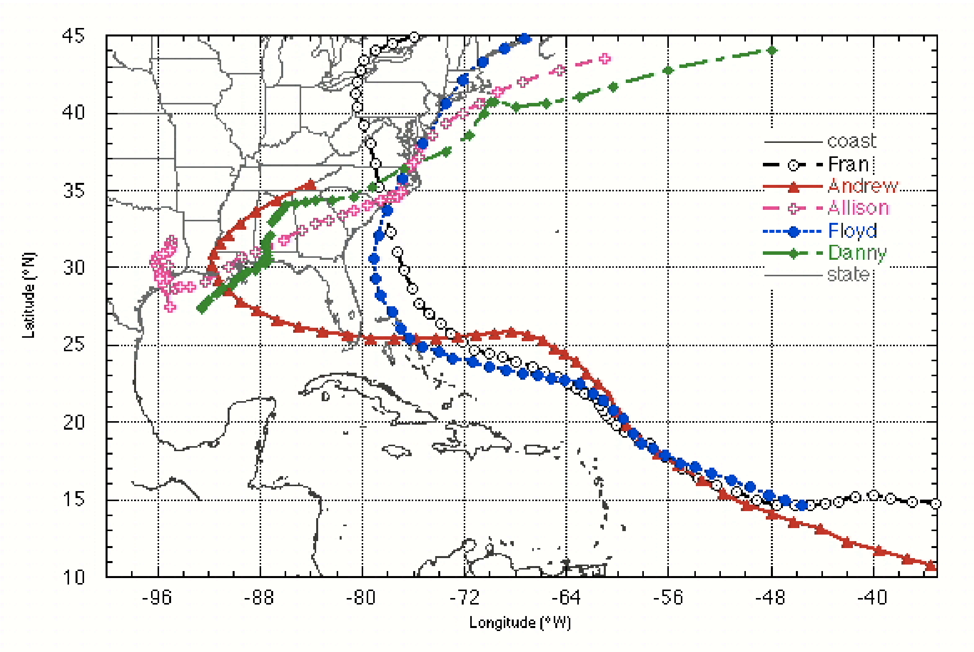

Fig. 1. Best track for the five cases used for the R-CLIPER validation.

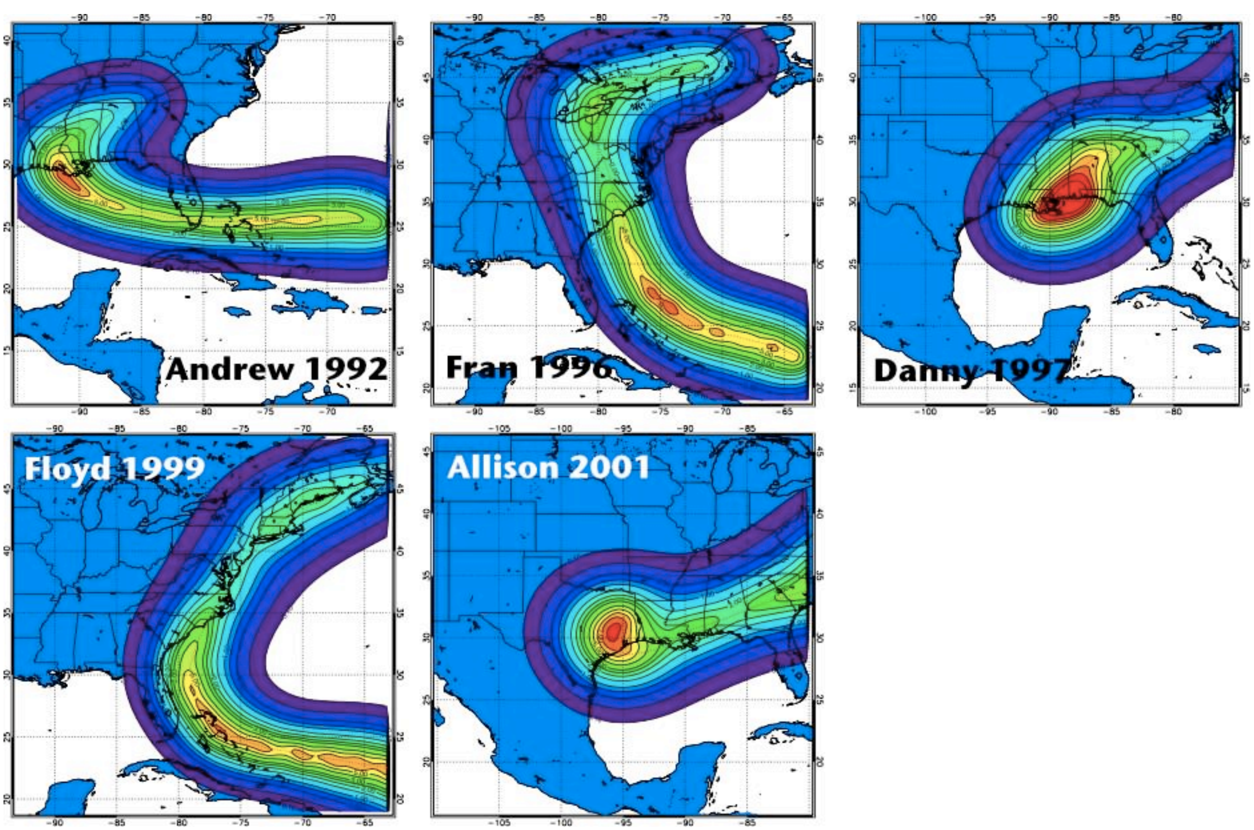

Fig. 2. Storm-total rainfall (inches) for the five cases in Fig. 1. Rainfall totals are denoted by color shading and contours, whereas the storm best-track (6 h) is denoted by a red dotted line.

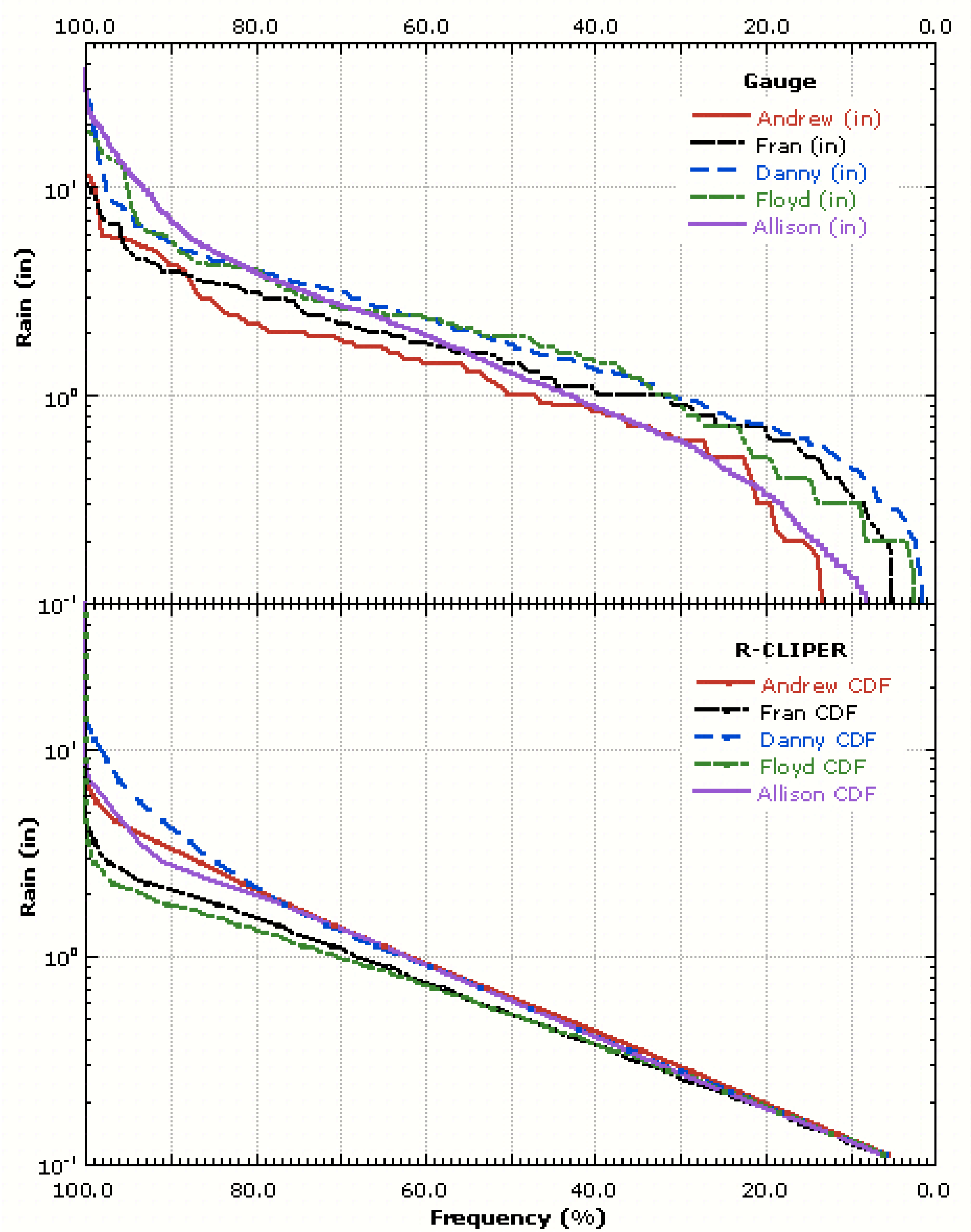

Fig. 3. Cumulative probability distributions of gauge and R-CLIPER storm-total rainfall (inches) for the five cases.

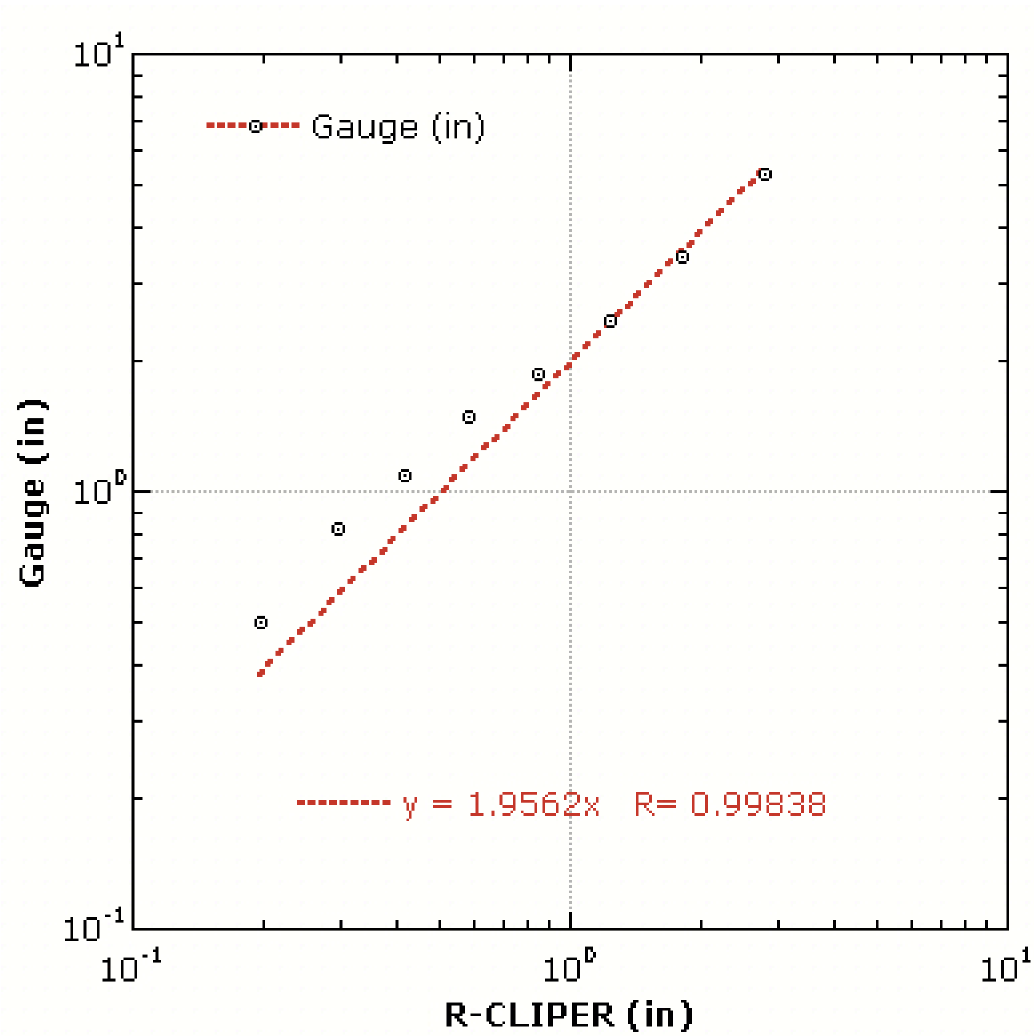

Fig. 4. Probability-matched storm total rain estimates from gauges and R-CLIPER for all five cases in Fig. 1. Each point represents the probability-matched value at 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90% from left to right, respectively. A least-square fit to the probability-matched values is denoted by the red dashed line.

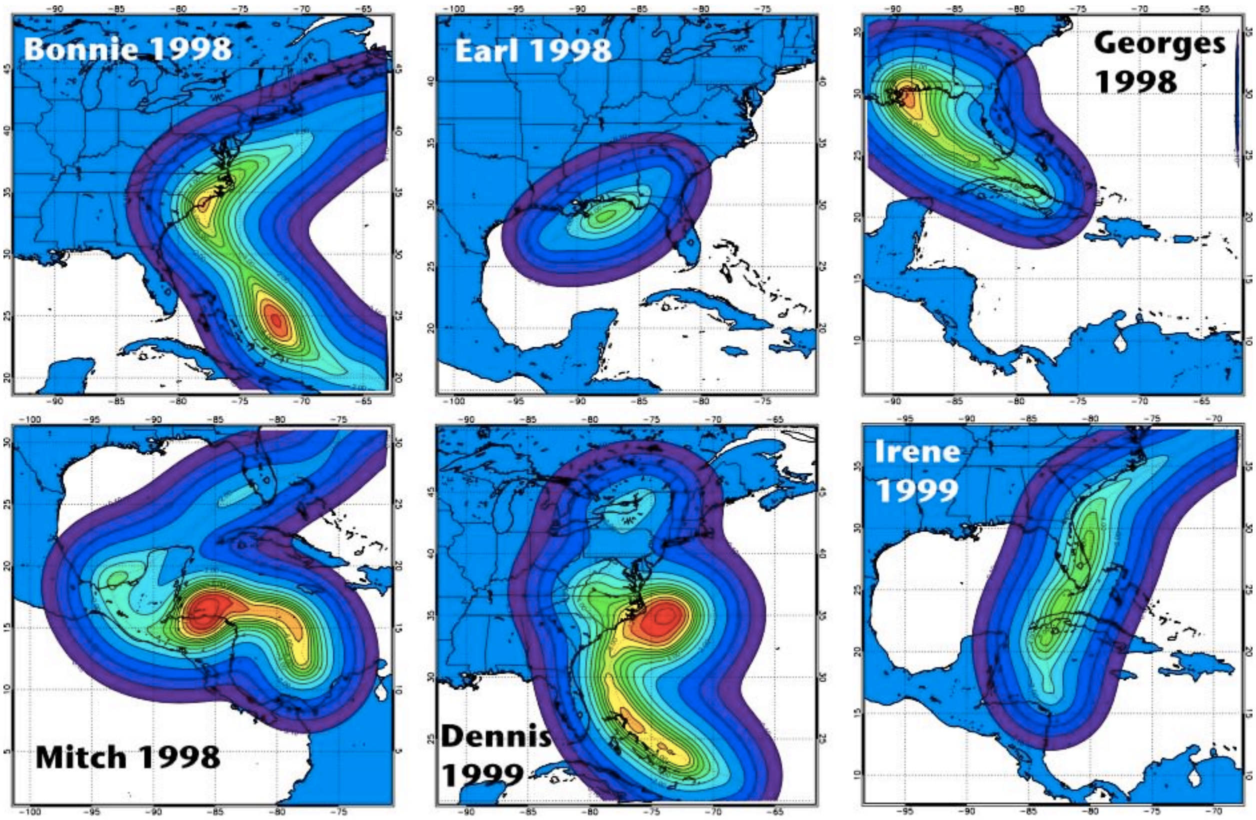

Fig. 5. Storm-total rainfall (inches) for six cases effecting the U.S. in 1998-1999 not included in the first sample. Rainfall totals are denoted by color shading and contours, whereas the storm best-track (6 h) is denoted by a red dotted line.