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

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TPC/NHC Needs

A tropical cyclone (TC) drops copious amounts of precipitation daily. Over the oceans the rainfall is not a serious concern to society, but once a TC makes landfall, and even several hundred miles inland after the hurricane force winds have ceased, it can produce a serious threat to society from urban and inland flooding. Indeed, in the last 30 years the majority of deaths related to TCs have been attributed to flooding (Rappaport 2000). Improved quantitative precipitation forecasts (QPF) in TCs are one of the primary goals of the U. S. Weather Research Program (USWRP) effort on TC landfall (Marks and Shay, 1999). The varied nature of precipitation makes the QPF topic very complex. Although much of the significant precipitation occurs in conjunction with convective clouds, stratiform clouds also account for significant precipitation accumulations over extended intervals. While all of these mechanisms are active in TCs, the vortex structure acts to dynamically constrain the smaller scale circulations that often confound QPF.

Objectives

Estimates of rainfall based on radar and other remote sensors offer promising avenues for improvement. At the same time numerical models, both operational and research, have been improved, running on faster computers at higher resolution, and with improved model physics.

However, there is little previous work validating the model QPF performance in TCs. Partly it is because of the lack of accurate observations of the rain distribution and evolution in TCs. A major stumbling block to improving QPF in TCs is a lack of a comprehensive climatology of TC precipitation, i.e., a description of the distribution of rain in space and time. Few precipitation climatologies exist for TCs in the United States, and other TC basins have similarly limited climatologies. However, remote sensors such as the WSR-88D and those on the NASA Tropical Rain Measurement Mission (TRMM) satellite; in particular the microwave imager (TMI) and the active precipitation radar (PR), are providing a first cut at a credible TC rain climatology (Marks et al 2000, Lonfat et al 2000). To date this climatology includes TMI rain estimates in 245 storms from December 1997 to December 200, 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 have also been examined as a function of storm intensity. The results to date suggest that the mean rain rate increases by a factor of 4 (3.0 mm h^{-1} for tropical storms versus 12.5 mm h^{-1} for category 3 and higher TCs) within 50 km of the storm center with increasing intensity. This storm-centered climatology is precisely what is needed for a simple rainfall climatology and persistence (CLIPER) model, which can be used to validate numerical models and other QPF methods.

A TC rain CLIPER (R-CLIPER) model based upon U.S. rain gage data is already completed at CIRA (funded by the Insurance Friends of the National Hurricane Center). The gage-based R-CLIPER model is already being implemented at NHC as part of that project. However, hourly gage data is necessary to determine the storm-relative rainfall rate. Because the hourly gage data is sparse, it is difficult to obtain a large enough sample to stratify the data by storm intensity. In the proposed JHT project, the satellite based rainfall rate estimates will be used to generalize the rain-gage R-CLIPER by expanding the available TC rain database significantly and making the rainfall rate a function of storm intensity. As a first cut at a satellite based R-CLIPER we propose to use 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 from the storm center. The climatology needs to be 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. It should also be possible to determine a wave number 1 azimuthal dependence of the rainfall rate using the information in the four quadrants (in a storm-relative coordinate system) in addition to radial dependence determined from the satellite and rain gage data. As part of the first year's effort we also plan to run the R-CLIPER model on a number of past storms to provide some statistics on model performance and to develop different data products useful to the hurricane specialists.

An important use of the R-CLIPER is to provide a benchmark for the evaluation of other more-general QPF techniques. For example, does the NCEP/GFDL hurricane model provide more accurate predictions than the R-CLIPER? In the second year of the project, verification methods will be developed to allow this type of comparison. The ground truth for the verifications can be obtained from the rainfall analyses used by the Hydrometeorological Prediction Center (HPC) for verification of their operational QPF forecasts. We will also need to evaluate the R-CLIPER forecasts for historical storms in the ATCF archive using available rain gauge data and other operational rain estimates (e.g., TRaP).

Selected references:

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.

Marks, F. D., L. K. Shay, and PDT-5, 1998: Landfalling Tropical Cyclones: Forecast Problems and Associated Research Opportunities. *Bull. Amer. Meteor. Soc.*, **79**, 305-323.

Marks, F.D., L. Selevan, and J. F. Gamache, 2000: WSR-88D derived rainfall distributions in Hurricane Danny (1997). Preprints *24th Conference on Hurricanes and Tropical Meteorology*, AMS, Ft. Lauderdale, FL, 298-299.

Rappaport, E.N, 2000: Loss of Life in the United States Associated with Recent Atlantic Tropical Cyclones. *Bull. Amer. Meteor. Soc.*, **81,** 2065–2074.

Timeline and Schedule

Responsible Party	Date	Activity
	1 October 2001	Start date
CIRA/HRD	30 November 2001	R-CLIPER code running off ATCF with TRMM climatology (output product is a 72-h swath of maximum storm total rainfall)
HRD/CIRA	3-7 December 2001	R-CLIPER presentation at the NOAA Hurricane Conference, meet with HPC representative to select verification cases
HRD/TPC/HPC/CIRA	31 December 2001	Identify the first verification case (candidates: Fran 1996; Josephine 1996; Danny 1997; Earl 1998; Floyd 1999; Allison 2001) – verification data sets selected (e.g., 72-h storm totals, 24 h totals at selected gauge sites)
TPC/HPC/HRD	28 February 2002	Select additional products beyond 72-h storm total and 24 h total (candidates: distribution of maximum rain within 0-1°, 1-2°, and 2-3° of storm center)
TPC/HPCHRD/CIRA	31 March 2002	Complete 1st verification data set, select 2nd verification case
HRD/CIRA	May 2002	Present R-CLIPER and results for 1st verification case at AMS Conference on Hurricanes and Tropical Meteorology
TPC/HPC/HRD/CIRA	15 May 2002	Implement 1st generation of R-CLIPER products for ATL/EPAC hurricane season
TPC/HPC/HRD/CIRA	15 May-30 November 2002	Monitor R-CLIPER product during 2002 ATL/EPAC hurricane season
TPC/HPC/HRD/CIRA	30 September 2002	Complete 2nd verification case, select 3rd verification case

Reporting Procedure:

Responsible Party	Date	Activity
	1 October 2001	Start date
HRD/CIRA	31 December 2001	1st quarterly report due
HRD/CIRA	31 March 2002	2nd quarterly report due
HRD/CIRA	30 June 2002	3rd quarterly report due
HRD/CIRA	30 September 2002	Final report due