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PRECIPITATION AND LANDMASS INTERACTION DURING HURRICANE GEORGES (1998) LANDFALL AT PUERTO RICO

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1. INTRODUCTION

Quantitative precipitation forecasting (QPF) and intensity change of tropical cyclones (TCs) are perhaps the most challenging and important forecasting problems currently faced by operational centers. The factors that affect the highly variable distribution of precipitation and the modulations of TC intensity at landfall are not well understood. One of these factors is TC landfall on complex terrain and associated orographic effects, an issue in many regions where TC impacts are felt. The objective of this study is to examine the development and distribution of precipitation and storm intensity change during Hurricane Georges (1998) at landfall at Puerto Rico using an explicit numerical model simulation in conjunction with observational data. Few numerical studies have examined the effects of terrain on TCs. Bender et. al. (1987) conducted an idealized study using the Geophysical Fluid Dynamics Laboratory (GFDL) hurricane model at 1/6° resolution that examined the effect of island terrain on TCs. Although they concentrated primarily on the TC track, they also found a weakening of the storm in all cases, and briefly mentioned precipitation in one case but drew no conclusions. Researchers in China and Taiwan have carried out some research in this area due to frequent landfalls of TCs on the mountainous terrain of those regions.

2. METHODOLOGY

Hurricane Georges made landfall on the southeast coast of Puerto Rico at 2200 UTC 21 September 1998. The interaction of Georges with the island terrain was accompanied by heavy and often localized precipitation as well as a weakening of the storm. Observation of Georges as it traversed the Carribean was intensive, particularly while in the vicinity of Puerto Rico. A wealth of aircraft flight level data, dropsondes, land-based and airborne radar, as well as ocean and surface measurements were collected. This abundant observational data will be utilized to verify model simulated precipitation and storm structure and as a complement to the model output in elucidating the physical processes at work. In this study, the PSU/NCAR MM5 is employed with a unique storm following coordinate and high resolution (5 km) inner nest. This will provide the detailed representation of landmass topography as well as storm structure necessary to investigate the island's effect on storm precipitation and intensity. Initial and boundary conditions are provided by NCEP atmospheric and SST analyses for the full integration from 0000 UTC 19 September to 0000 UTC 27 September. No convective parameterization is used on the 5-km mesh during its activation from model integration hours 24 to 120.

3. RESULTS

To allow subsequent investigation of the physical processes underlying the precipitation distribution and intensity change associated with Georges' interaction with complex terrain, the first phase of this study involves verification of the simulated Georges versus observations. Fig. 1 compares the model simulated positions with the Best Track. Agreement is excellent in the cross-track direction throughout the entire 192 hour simulation, with errors less than 100 km; however in the along track direction the model is somewhat slow, arriving near Puerto Rico about 12 hours after the observed storm. This error arises in large part from the 0000 UTC 19 September NCEP analysis which is used to provide the simulated storm's initial position. The NCEP analysis at this time places Georges approximately 600 km to the east of

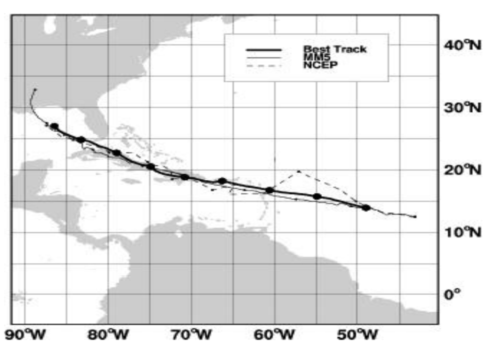

Fig. 1 Hurricane Geroges tracks from MM5 simulation (thin solid), NCEP analysis (dashed), and the Best Track (thick solid).

the corresponding Best Track position. In addition, the simulated storm center passes about 50 km to the south of the island. Despite these variations of the model simulated track from the observed Best Track, interaction with Puerto Rico is strong and we feel that

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the conclusions drawn from an analysis of landmass effects are valid.

The model simulated instantaneous rainrate at 1000 UTC 22 September (82 hours into the model integration), when the simulated Georges is located in a position near the southeast coast of Puerto Rico, is shown in Fig. 2a. A distinct minimum in rainfall is seen in the NW quadrant on the landward side of the eyewall. In contrast, the maximum rainfall rate occurs in the SE quadrant of the eyewall, furthest from the influence of land. When compared with a NOAA/HRD radar composite from 1845-1915 UTC 21 September (when Georges was in a similar position with respect to the island of Puerto Rico, Fig. 2b), the similarity is evident. The location of simulated minimum and maximum precipitation rates agrees very well with the observed reflectivities. Both images show a SSW-NNE oriented elliptical eyewall with a small tail to the SW. Banding features are also in similar positions and a majority of stratiform precipitation is found to the east and southeast in both plots. Comparison of the evolution of simulated rain rate with a HRD radar composite loop constructed from the time period while Georges was in the vicinity of Puerto Rico shows the same degree of consistency.

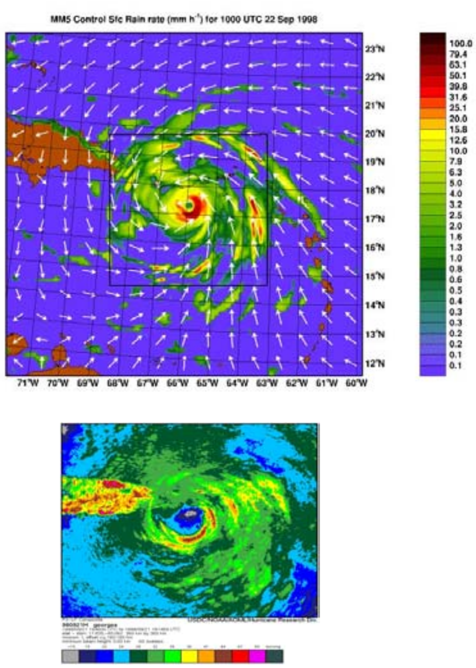

Fig. 2 (a) MM5 simulated rainrate and (b) NOAA/HRD airborne radar Reflectivity composite for Hurricane Georges.

The model simulated storm intensity is stronger than that observed, by approximately 20-30 hPa during the time period of interest (72h-96h); beyond this time the intensity is well simulated. Also, the lack of landfall at Puerto Rico may prevent weakening to some degree. The advection of dry air into the TC circulation from the high terrain of the island landmass was implicated in the weakening of each of the simulated storms in the study of Bender et. al. (1987). On the other hand, they found little evidence of disruption of the TC circulation, a process which they also considered as a possible factor behind the filling of the storm. In our simulation, there is no evidence of either process occurring as the simulated Georges tracks to the south of Puerto Rico, and no weakening occurs. Interestingly, when the simulated Georges makes landfall at Hispaniola later in the model integration, simultaneously a marked ingestion of dry air and disruption of the storm circulation is accompanied by a weakening of the storm.

4. SUMMARY

It appears from preliminary results that this simulation of Hurricane Georges (1998) verifies satisfactorily with observations. Further verification studies are in progress. We believe that this simulation can provide valid and meaningful insight into the development of the observed precipitation distribution and relevant processes. In addition, we hope that some aspects of the intensity change associated with landmass interaction can also be investigated. Plans for future work involve quantitative analysis of storm precipitation and hydrometeor distributions, as well as storm structure as it pertains to the factors that affect the simulated intensity.

5. ACKNOWLEDGEMENT

This research is supported by the NSF/USWRP research grant ATM 9908944.

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