A Comparison of the Observed and MM5 Modeled Hurricane Georges (1998)

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Introduction

Quantitative precipitation forecasts (QPF) and forecasting intensity change in tropical cyclones (TCs) is one of the most difficult problems in the operational meteorology centers. The two main objectives of this study is to investigate the topographic effects on Hurricane Georges’ (1998) intensity change, storm structure, and rainfall distribution at landfall; in addition, to understand the physical processes of how the environmental condition impacts the storm intensity change prior to landfall. Few numerical studies have examined the effects of terrain on TCs using an explicit numerical model simulation in conjunction with observational data. Bender et al. (1987) conducted an idealized study using the Geophysical Fluid Dynamics Laboratory (GFDL) hurricane model at 1/6° resolution that examined the effects of island terrain on TCs. Although they concentrated primarily on TC track, they also found a weakening of the storm in all cases, and briefly mentioned precipitation in one case but drew no conclusions. These objectives can be reached by analyzing the numerical simulation of Hurricane Georges and discuss where the modeled storm and observed storm are in good agreement and where they depart and the possible reasons of their departure.

Methodology

Hurricane Georges made landfall in several Caribbean islands throughout its continuous northwest track through the Caribbean. The interaction of Georges with the island terrain was accompanied by heavy precipitation and weakening of the storm. A wealth of
aircraft flight level data, dropsondes, land-based and airborne radar, as well as ocean and surface measurements were collected throughout Hurricane Georges track. In this study the PSU/NCAR MM5 is used with a unique storm following coordinate and 5km inner nest. Initial and boundary conditions are from the NCEP for the full integration from 0000 UTC 19th September 1998 until 0000 UTC 27th September 1998. An analysis is made of this simulation in comparison to the NHC preliminary report.

**Results**

We will first examine and compare the model simulated track and the best track data from the NHC. Error occurs in timing and formation from the initialization point from NCEP at 0000 UTC 19th September 1998. After this point the MM5 simulated track is in excellent agreement in the cross section throughout the entire simulation within 100km of the best track, predominantly to the south in the Caribbean and to the west in the Gulf of Mexico. The greatest error in the MM5 was timing, through initialization the storm was 3 days and 12 hours late. At the time the modeled storm was at its closest position to Puerto Rico the modeled storm was 12 hours late, at landfall in Hispaniola the modeled storm was on target with the observed, and when the modeled storm crashed into the Gulf Coast it was 36 hours early. The forward speed of the modeled simulated hurricane was too fast. Below is a figure of the observed, best track, of Hurricane Georges as well as the MM5 and NCEP projected tracks.
The next comparison between the observed and MM5 simulated Georges was the intensity of the tropical cyclone. The MM5 model run had some difficulty forming a strong tropical cyclone after NCEP initialization. The observed Georges became a powerful hurricane by 0000 UTC September 20th 1998; however, six to twelve hours later significant weakening occurred. The observed Georges strengthened to a Category 4 storm before greatly weakening to a Category 2 storm without the influence of land. It is not fully understood why this weakening occurred but an analysis is made discussing weakening due to vertical shear or dry air intrusion. The MM5 model did not depict the same magnitude of weakening as observed. However, one must keep in mind the model storm was significantly weaker, 46hPa weaker, at this time period than the observed so the weakening profiles of these storms would not appear the same. Below there are two sets of figures comparing the MM5 simulated storm with the observed Hurricane Georges at 0000-0300 UTC September 20, 1998. This is the period of the maximum intensity of the observed storm before the significant weakening.
The NHC Preliminary Report discusses that northerly vertical wind shear was likely the cause of the weakening of Hurricane Georges over the warm Caribbean Sea. In light of the NHC analysis, we observed the MM5 modeled winds during the 0600-1200 UTC time period on September 20th 1998. Observing wind patterns at the surface, 850mb, 700mb, 500mb, and 200mb every hour in the time period, no vertical wind shear was observed in the MM5 model. The circulation patterns appeared fairly symmetric with no evidence to declare weakening due to wind shear from the model output.
A second hypothesis for the weakening is dry air intrusion. When dry air is ingested it distorts the saturation of air in a hurricane, the high cloud tops of the thunderstorms decay, cloud top temperatures warm, convection dies, and the hurricane weakens. Using the MM5 during the same time period we observed plots of specific humidity at the surface, 850mb, 500mb and 200mb. Differences of 4 g/kg close to the inner eye wall were observed in the 850mb at 0600 UTC September 20. The highest specific humidity variables are observed to the north and behind the center of the storm. The lowest moisture values were on the outskirts of the storm and near the center. Similar results were observed at the same levels through 1000 UTC September 20th. At 1200 UTC, the specific humidity contours filled in, and the highest values were observed near the center decreasing outward from the center of the storm. This provides an interesting case, by analyzing this data, we observed dry air getting entrained into the storm’s circulation weakening the model’s storm. At the end of the time period of the weakening, the storm’s specific humidity values became more prevalent for strengthening and that is exactly what occurred. This evidence was supported by model simulations of the relative humidity and mixing ratio variables. In both loops drier air is ingested into the storm during this six to twelve hour time period. Further investigation is suggested using a higher resolution of the PSU/NCAR MM5 model simulation with a larger domain. The model had depicted the correct qualities; however, due to the large intensity difference, comparisons are difficult to make.
The rest of the model simulation faired very well with the observed Georges. The observed Georges strengthened briefly after making landfall in Puerto Rico, before weakening over Hispaniola. The MM5 projected Georges to continue strengthening after remaining stable near Puerto Rico and crashed into Hispaniola much stronger than observed. Intensity and track profiles were in much agreement and weakening stages over the mountainous islands of Hispaniola and Cuba appeared similar. The MM5 projected Georges to survive through the islands and the observed storm did. The observed Georges strengthened again when reaching the Gulf of Mexico into a Category 2 hurricane, the MM5 strengthening was a bit slower but it did strengthen; however, due to the model’s faster velocity the storm made landfall in Mississippi 36 hours before the observed Georges. Once again, timing was a distinct error, and further analysis must be given to understand the conditions over the complex terrain. The figure below shows the modeled and observed storm after landfall in the Florida Keys.
Future Research

This case is an interesting and informative one, it is suggested that the MM5 model run be put into high resolution and re-analyzed, this will assist in completing the analysis and perhaps a conclusion can be drawn on the weakening of Hurricane Georges from a category 4 to a category 2 storm without the influence of land in the Caribbean Sea. Doppler analysis compared with vertical cross sections from the MM5 will improve theories on the hurricane’s behavior over the complex Caribbean terrain.