P1.72 CLIMATOLOGY OF HEAVY RAINFALL ASSOCIATED WITH TROPICAL CYCLONES AFFECTING THE CENTRAL APPALACHIANS

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1. INTRODUCTION

The National Weather Service (NWS) Weather Forecast Offices (WFOs) have the responsibility for issuing flood or flash flood warnings for the protection of life and property across their County Warning Areas (CWAs). During the summer and early fall months, a fraction of heavy rain events requiring these warnings are associated with land-falling tropical cyclones. Since tropical cyclones can deliver catastrophic amounts of rain, an examination of data detailing the patterns and effects of past storms is critical to understanding the impact of these systems. The purpose of this study is to establish a database of tropical cyclone tracks and associated rainfall affecting the Central Appalachians, and to determine which factors are the most influential in producing substantial rainfall. This tropical rainfall climatology will be an important operational and training reference for forecasters in the Central Appalachian region, and will supplement current references which focus on track climatology (Hudgins 2000). Results of this study will allow forecasters to better assess the potential rainfall impact of future tropical cyclones on the Central Appalachians, in order to issue more accurate and timely flood and flash flood watches and warnings.

2. DATA AND METHODOLOGY

Tropical storm tracks and rainfall data from 1950-2003 were gathered using data archives from NOAA's NWS Tropical Prediction Center (TPC), Unisys, and the National Climatic Data Center (NCDC). Additional weather parameters were provided by the NWS Daily Weather Map Series and the Plymouth State University meteorology web site. All the data were compiled and incorporated into a graphical database using Global Tracks hurricane software (Jincs Solutions 2004).

The topography of the Central Appalachians is characterized by a rapid increase in elevation from southeast to northwest, starting from less than 300m in the Piedmont, to mountainous terrain of 1,000-1,500m in the higher elevations of the Blue Ridge, and Appalachian mountains of western VA, southeastern WV, and northwestern NC (Fig. 1.).

The climatological analysis consists of studying 28 land-falling tropical cyclones that tracked within 500 km of NWS WFO Blacksburg (RNK) from 1950-2003 (Fig. 2). The 500 km radius includes tracks of all cyclones that had a major flooding impact during this period of time on what we are defining as the *Central* Appalachians, the mountains of Virginia and West Virginia, as well as extreme northwest NC. It is important to point out that not all of these events resulted in flooding rains, (a couple only produced 25-50mm maximum rainfall). The 28 events were then examined more closely in order to discriminate between Atlantic and Gulf Coast land-falling tropical cyclone tracks, and to determine the relative importance of a number of factors such as the orientation of the track to the Appalachian ridges, speed of movement, degree of upslope, intensity at landfall, and several others.

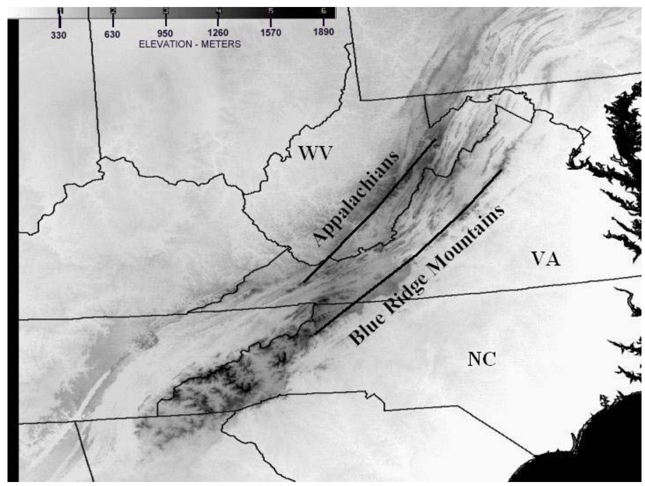

Figure 1. Map depicting the terrain of the Blue Ridge and Appalachian mountains across VA, NC and WV.

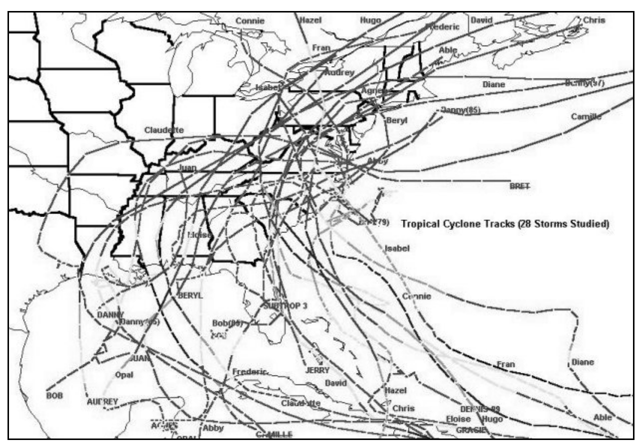

Figure 2. Tropical cyclone tracks (28) studied during the period 1950-2003.

3. RAINFALL DISTRIBUTION

Rainfall distributions showed a wide variation in totals ranging from 250-350mm (and even higher single maximum reports in a few events) to some with only 25-50mm maximum rainfall amounts. This variability was at least partially dependent upon where systems came inland and how they eventually tracked in relation to the

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Central Appalachians. The tropical cyclone tracks were divided into two categories: Atlantic and Gulf Coast land falls. Each category was then sub-divided based on cyclone track relative to topography.

3.1 Gulf Coast Landfalls

Rainfall distribution with Gulf Coast land-falling storms was divided into four track categories: remaining west of the Appalachians, along the spine of the Appalachians, moving across the mountains from the west, and those paralleling east or southeast of the Blue Ridge. Maximum rainfall associated with storms tracking west of the mountains (the category with the most cases) was relatively low compared to other categories (<125mm maximum, with one exception), and tended to focus heavy rainfall (>100mm) mainly across northwest NC, but also along other parts of the Blue Ridge. Systems tracking near the spine of the Appalachians produced the most widespread heavy rainfall (large swaths of >100mm) among all Gulf Coast land-falling storms. Storms moving across the Appalachians from the west were limited to just a few events with generally low rainfall, with one extreme exception that had catastrophic results (Camille in 1969), with an east-west swath of over 150mm across the Appalachians and a maximum along the Blue Ridge of west-central VA of over 600mm! There were also only two tropical cyclones from the Gulf that paralleled the Appalachians well to the east, and these resulted in large swaths of 100-200mm rain falling along and well east of the Blue Ridge.

3.2 Atlantic Coast Landfalls

Rainfall characteristics of Atlantic Coast land-falling storms were divided into three categories, including those making landfall south of Charleston, SC (just below where Fig. 1 cuts off on the coast) and then moving generally parallel to the Appalachians, those that made landfall north of Charleston, SC ,and those that moved directly inland from the east. Most common were storms making landfall south of Charleston and then tracking parallel to the mountains. These tended to produce the most expansive areas of heavy rain, and with maximums of 75 to 230mm along the east to southeast facing portions of the Blue Ridge from northwest NC into west-central VA. Systems moving inland across the Carolinas (north of Charleston) and then either parallel or crossing the mountains brought the heaviest maximum rainfall (150-300mm) to the north-central Blue Ridge escarpment of VA of all Atlantic Coast land-falling storms. Two tropical cyclones tracking inland from the east, more perpendicular to the ridges, produced two different rainfall distributions and overall amounts, which seemed to be largely dependent on speed of movement, but both showed terrain enhanced maxima along the Blue Ridge in VA.

4. FACTORS INFLUENCING HEAVY RAINFALL

Upslope flow (both intensity and duration) associated with tropical cyclones appeared to be the most important factor in determining the distribution of maximum rainfall. This was especially true with low-level flow from the southeast since this is the most favorable upslope orientation for the Blue Ridge (where the highest rainfall totals were most often observed). Speed of movement and overall strength/intensity (within the 500km radius) appeared to be very important in determining overall extreme amounts, due to duration of tropical moisture in any one location as well as duration of enhanced upslope flow. Specifically storms that moved through the Appalachian region at speeds of 10 m/s or greater tended to produce maximum rainfall of 75mm or less. The few exceptions to this were influenced by particularly strong upslope or interaction with a boundary, such as Camille. Slow moving storms (average speeds of 5 m/s or less) generally resulted in rainfall amounts of at least 150mm. Several other factors examined in this study, including deep layer shear (Cline 2002), and intensity at landfall, were found to influence heavy rainfall distribution and amounts, but in less obvious ways.

5. CONCLUSION

Tropical cyclones that move inland and affect the Central Appalachians often produce heavy to excessive rainfall of 150-250mm or occasionally much higher. The topography of the Blue Ridge and Appalachians plays an important role in focusing the heaviest rainfall in highly favored upslope regions. Several other factors including speed of storm movement, track, and inland intensity (wind speeds) also contributed to location and amount of rainfall. On average, the stronger tropical cyclones that affected the Appalachians were those making landfall on the southeast U.S. coast, particularly systems that moved inland across the Carolinas. The database established as a result of this study will serve forecasters as a baseline in assessing the potential effects of future tropical cyclones and their rainfall impact.

6. ACKNOWLEDGEMENTS

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