

Chapter 1. Introduction

1.1 Introduction

Heavy rainfall events and their associated flooding have made tremendous impacts on human society in terms of property damage and loss of human life. Not only does the flooding cause death and property damage, it can also transport polluted water into freshwater supplies or fragile ecosystems, as occurred with Hurricane Floyd in North Carolina in 1999 (Barnes, 2001). Also, flooding can occur well downstream of the initial target area as rivers and streams transport rainwater downstream.

While heavy rainfall is possible anywhere, some areas are more susceptible or vulnerable than other areas. Mountainous regions (European Alps, U. S. Rockies and Appalachians, Taiwan's Central Mountain Range, etc.) are prone to heavy rainfall development and flooding due to terrain or orographic effects. Airflow can impinge upon the mountain slopes, leading to upslope flow and sustained ascent and precipitation development over long periods of time. Often these regions are headwaters for rivers, which can lead to further flooding downstream of the initial impacted area. Lin et al. (2001) synthesized some common mesoscale and synoptic conditions conducive to orographic rainfall development by studying past U. S. and European cases: 1) a conditionally or potentially unstable flow impinging on the mountains, 2) a very moist low-level jet, 3) steep mountain slope, and 4) a quasi-stationary synoptic system to slow the convection over the threatened area.

Other regions that are prone to heavy rainfall are those areas affected by landfalling tropical systems.

These areas include the Gulf and East Coasts of the U. S., and the eastern Asian coast (from India to China, including Taiwan, Japan, and the Philippines). Also regions downstream (in terms of atmospheric flow) of these coastal areas are at risk because of the extratropical transition of the tropical storms and interaction with extratropical systems. The transition and interaction can further aid in development of heavy rainfall well downstream of the storm center. Notable U. S. cases include Hurricane Hazel (1954) (Palmén, 1958; Anthes, 1990), Agnes (1972) (Bosart and Dean, 1991, Dimego and Bosart 1982a, 1982b) and most recently Hurricane Floyd in 1999 (Bosart and Atallah, 2000; Atallah, 2000; Kong, 2000; Atallah and Bosart, 2003; Colle, 2003).

1.2 Purpose of Research

The research presented here will focus on numerical simulations of the two types of heavy rainfall scenarios noted above: a landfalling hurricane and an orographic rainfall event. The hurricane to be studied will be Hurricane Floyd (1999) as it made landfall in eastern North Carolina on 16 September 1999 (Fig. 1.1a). The orographic rainfall event will be an event in the northern Italian Alps, Intensive Observation Period 2B (IOP-2B) from the Mesoscale Alpine Programme (MAP) in September 1999 (Fig. 1.1b).

Hurricane Floyd is of interest because the heavy rainfall developed north of the storm center along a baroclinic zone just inland of the eastern U. S. coast (see Fig. 1.1a). This baroclinic zone appeared to have developed as the warmer easterly flow north of the hurricane's center became juxtaposed with cooler northeasterly flow from the northeast U. S. This zone was collocated with a surface confluence/convergence zone. There also appeared to be evidence from observations that a wedge of cool air formed over central and western

North Carolina, enhancing the baroclinic zone. In addition to the low-level features, a mesoscale jet developed over North Carolina, with the entrance region's ageostrophic transverse circulation coupled with the hurricane outflow's ageostrophic transverse circulation. This coupling appeared to take place over the low-level confluence and baroclinic zone, possibly enhancing the vertical motion. The MAP case represents a case of a pre-trough warm southerly flow into the Lago Maggiore region of Italy (see Fig. 1.2b). This southerly flow impinged upon the Alps, leading to upslope flow and triggered precipitation development as an upper-level jet entered the region. The upper-level jet's ageostrophic circulation may have been coupled to the low-level convergence formed by southerly flow converging with easterly flow from eastern Italy.

Another element of this research will be to explore any link between Floyd and MAP IOP-2B as Floyd propagated off the North American coast and merged with an extratropical cyclone associated with IOP-2B over the North Atlantic, approximately 48-72 hours in advance of IOP-2B. Given the scarcity of data over the North Atlantic, numerical simulations will be able to show any relationship between the two events.

The purpose of this research is to understand the common dynamical processes that cause extreme rainfall events, specifically how upper-level features become coupled with low-level features to facilitate rainfall production. Based on observations from both Floyd and IOP-2B, it is hypothesized that thermally direct ageostrophic circulations of upper-level jets become coupled to circulations associated with a low-level jet (as in the case of IOP-2B) or the thermally indirect ageostrophic transverse circulation of a second upper-level jet (as in the case of Floyd). It is further hypothesized that these circulations become coupled over a

low-level or surface confluence/convergence zone, enhancing the vertical motion already associated with the confluence zone.

In addition to testing the stated hypothesis, the proposed research will attempt to specifically answer the following questions:

1. What was the environment conducive to the heavy rainfall of Hurricane Floyd and what was the effect of the cool air damming on the development of the coastal baroclinic zone.
2. How important is the intensity of Hurricane Floyd in the development of the heavy rainfall, specifically in the development of the low-level confluence zone and upper-level jets associated with Floyd?
3. For MAP IOP-2B, did the Atlas Mountains funnel hot dry desert air toward Italy as seen in previous cases (Tripoli et. al, 2000) and how did this affect the low-level conditions near the Alps?
4. How did the Alps affect the development of the low-level confluence zone near the Lago Maggiore region during IOP-2B?
5. What link if any, is there between Hurricane Floyd's extratropical transition and the synoptic environment associated with MAP IOP-2B?

To answer these questions, sensitivity tests with numerical simulations using the NCAR/PSU MM5 (Version 3) model will be utilized. Discussions of Hurricane Floyd and MAP IOP-2B will follow in Chapters 2 and 3 respectively. Chapter 4 will focus on the extratropical transition of Floyd and its link with MAP IOP-2B. Chapter 5 will discuss commonalities between Floyd and MAP IOP-2B.

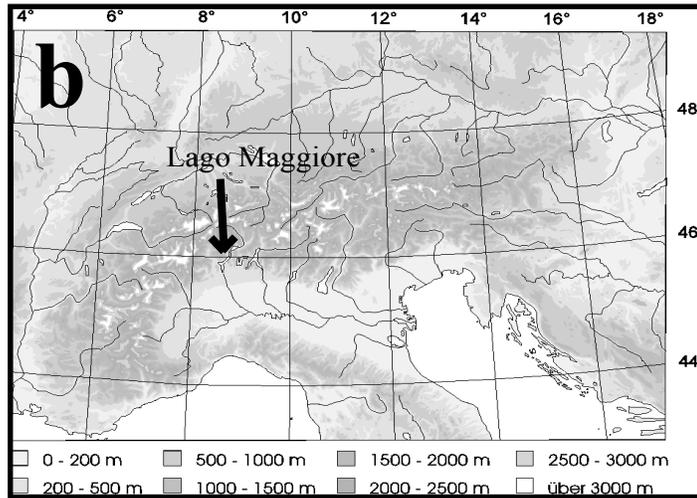


Figure 1.1. a) Terrain of the eastern U.S. and approximate track of Hurricane Floyd and b) location of Lago Maggiore and terrain of the Italian Alps.