# Chapter 64

# A Geospatial Analysis of Convective Rainfall Regions within Tropical Cyclones after Landfall

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## ABSTRACT

*In this article, the author utilizes a GIS to spatially analyze radar reflectivity returns during the 24 hours following 43 tropical cyclone (TC) landfalls. The positions of convective rainfall regions and their areal extent are then examined according to storm intensity, motion, vertical wind shear, time until extratropical transition, time after landfall, and distance from the coastline. As forward velocity increases in conjunction with an extratropical transition, these regions move outward, shift from the right side to the front of the TC, and grow in size. A similar radial shift, but with a decrease in areal extent, occurs as TCs weaken. Further quantification of the shapes of these regions could yield a more spatially accurate assessment of where TCs may produce high rainfall totals.*

## INTRODUCTION

Tropical cyclones (TCs) can produce high rainfall totals that lead to flooding both near the coastline where fast winds and storm surges are also of concern, and hundreds of kilometers away from the location of landfall (Rappaport, 2000). For example, more than 150 lives were lost from fresh water flooding as Hurricane Camille (1969) produced record rainfall totals nearing 700 mm in Virginia. Several days earlier, most deaths that occurred during the landfall of Hurricane Camille resulted from the high storm surge (Schwarz, 1970). Recently, the original rainfall climatology and persistence (R-CLIPER) statistical model developed to verify rainfall predictions for TCs

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(Marchok, Rogers, & Tuleya, 2007) has been upgraded to include the effects of vertical wind shear and topography as these characteristics have been shown to cause asymmetries in TC rain fields (Lonfat, Rogers, Marchok, & Marks, 2007). However, as recently as 2007, the American Meteorological Society stated that rainfall predictions for landfalling TCs are still in need of improvement (AMS, 2007).

Although stratiform clouds can cover ten times more area within a TC than convective clouds (Jorgensen, 1984), the higher rainfall rates produced by convective clouds can produce flooding rainfall in a relatively short amount of time (Geerts et al., 2000; Elsberry, 2002). Even though Hurricane Floyd (1999) was moving at a relatively fast forward velocity of 9 m $s^{-1}$ during landfall, the high rain rates produced by convective processes caused more than 500 mm of rain to accumulate (Lawrence et al., 2001; Atallah & Bosart, 2003). Thus, identifying the conditions under which convective clouds cover a large area within a TC's rain fields, and where these areas of convection will exist relative to the circulation center of a TC is an important task.

This study employs geospatial research techniques to examine convective rainfall regions that exist during the 24-hour period after TCs make landfall. Specifically, three research goals are pursued: 1) determine where regions of heavy rainfall exist in relation to the circulation center of the TC under different conditions, 2) determine the areal extent, or size, of these rainfall regions, and 3) determine the conditions under which the largest areas of heavy rainfall tend to form. To achieve these research goals, radar reflectivity returns are analyzed within a GIS to locate the heavy rainfall regions and to calculate the spatial properties of these regions as they relate to six factors. These factors are a) storm intensity, b) vertical wind shear, c) storm motion, d) whether or not a TC becomes extratropical, e) the time elapsed after landfall, and f) the distance that the storm and its convection are located relative to the coastline. In addition to achieving these research goals, this study analyzes a large number of TCs in a GIS framework.

## BACKGROUND

Willoughby, Marks, and Feinberg (1984) describe the regions of convection that develop in both the core of a hurricane (within 100 km of the circulation center), and in the outer rainbands that can extend more than 360 km from the circulation center of the storm. Convection is enhanced by increased surface friction along the coastline during landfall (Tuleya, 1994; Frank & Ritchie, 1999), and fast tangential winds can advect moisture counterclockwise into the left front quadrant in the core of a hurricane (Parrish, Burpee, Marks, & Grebe, 1982). Konrad, Meaux, and Meaux (2002) found that intense TCs have increased rainfall near the core of the storm. On the other hand, tropical depressions have very little organized convection in their core (Frank & Ritchie, 1999). These findings suggest that storm intensity could exhibit a strong relationship with both the location of convection relative to the circulation center of the storm and the size of the area covered by convective rainfall.

A recent modeling study by Kimball (2008) found that rainfall spreads outwards from the circulation center as a TC tracks inland, and shifts from a maximum on the right side of the storm to the front of the storm in a counterclockwise direction. Observational studies of individual TCs have demonstrated that convection within TCs may increase or decrease in spatial extent after landfall (e.g., Bluestein & Hazen, 1989; Atallah & Bosart, 2003; Medlin, Kimball, & Blackwell, 2007; Matyas, 2008). Time elapsed after landfall may demonstrate an association with these trends in the location and areal extent of TC convection. However, the influence of the atmosphere, internal storm dynamics, and the earth's surface may exhibit an even stronger association with the

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