The Spatial Patterns of Rainfall Produced by Hurricane Irene (2011) and Other Tropical Cyclones with Similar Tracks

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Introduction

Hurricane Irene (2011) produced heavy rainfall in the U.S. and more than 20 people died from fresh water flooding (Avila and Cangialosi 2011). Many tropical cyclones (TCs) tracking northward over the northeastern U.S. have produced heavy rainfall that caused flooding (e.g., Atallah and Bosart 2003; Atallah et al. 2007; Hart and Evans 2001; Konrad and Perry 2010). When passing through this region, TCs are typically undergoing extratropical transition (ET) (Hart and Evans 2001). Interaction with strong westerlies associated with a middle latitude trough causes an increase in storm forward motion, vertical wind shear, and vorticity, and the environment surrounding the TC becomes baroclinic. The isentropic uplift of the moist tropical air mass ahead of the storm center enhances precipitation (Atallah et al. 2007; Jones et al. 2003; Sinclair 2004). Interaction with topography such as that which occurs near the Appalachian Mountains can also enhance precipitation (Haggard et al. 1973; Sturdevant-Rees et al. 2001). In less than 24 hours, 200-300 mm of rain can fall from these systems (Jones et al. 2003). Thus, understanding the rainfall patterns that they produce is important when considering how to reduce damage to property and loss of lives. This study utilizes a Geographic Information System (GIS) to explore the spatial patterns of rainfall produced by Irene (2001) and TCs taking similar tracks.

Data and Methods

- Analysis tool: ArcGIS 10.0
- TC tracks 1851 - 2011 (HURDAT)
- Buffer Irene's U.S. track by 200 km; use to clip other TC tracks
- Rainfall : NCEP–CPC Unified Precip. Dataset (1948-2011, 0.25° x 0.25°)
- Study region: 1460 grid cells over land within the U.S. (from 35° N north to Canadian border, and 82° W east to Atlantic coastline)
- Use Sum function to calculate storm-total rainfall for each TC
- Use Near function to calculate distance of each cell from storm track
- Extract top 10% of rainfall values from each storm for further analysis
- Calculate Spearman's Rank correlation coefficients for rainfall amount, latitude, longitude, and distance from track
- Use Cell Statistics to determine maximum rainfall received at each grid cell from any storm

Research Questions

- Which TCs have taken tracks similar to that of Irene (2011)?
- Which of these TCs produced rainfall distributions similar to that of Irene?
- How similar are the spatial patterns of rainfall among these storms?
- What is the maximum storm-total rainfall received at each location in the study region and which TC produced it?

Results

- 25 TCs have taken tracks similar to Irene (2011) since 1850, 11 since 1948 (Fig. 1)
- Irene produced more than 300 mm of rainfall in multiple locations and 10 states had at least one location receiving one of the top 10% highest rainfall totals (Fig. 2)
- Rainfall totals over 250 mm occurred from 2 – 220 km away from the track of Irene although the median distance for the top 10% was 79 km (Table 1)
- More of Irene's high rainfall totals left of track occurred near landfall and no significant correlation with distance to track was found (Table 2)
- When considering rainfall totals and the locations of high rainfall totals relative to storm track (Table 1), through producing more rain, Floyd (1999) was most similar to Irene
- Spearman's rank correlation coefficients illustrate that not all TCs undergoing ET produce the same spatial patterns of rainfall (Table 2)
- Floyd produced the highest rainfall over 24% of the study region (Fig. 3) while Irene (2011) produced the highest rainfall over 12% of the study region
- 14% of the study region, including 10 states, has received at least 200 mm of rainfall from a TC since 1948 (Fig. 4)

Conclusions

- Irene (2011) produced the second highest rainfall totals of the 12 TCs and high rainfall totals occurred at multiple distances from storm track
- Floyd (1999) produced the most similar spatial distribution of high rainfall to that of Irene
- Not all TCs had the same patterns of rainfall – while many produced their highest rainfall close to the storm track, others featured rain fields that expanded or contracted
- Floyd (1999) produced the highest rainfall overall, and the highest rainfall over 24% of the study region.

Future Work

- Examine storm-total rainfall for all TCs since 1948 to quantify spatial patterns and examine contribution to rainfall climatology
- Preliminary results for Irene (2011)
  - Contributed more than 50% of August 2011 rainfall in most grid cells located within 200 km of storm track
  - In 2011, one location in New York experienced its wettest August since 1948
- Additional analyses for Irene (2011) through Stage IV data

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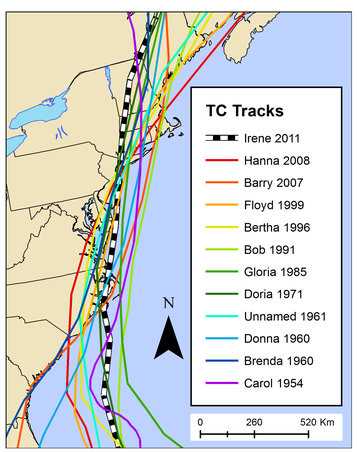

FIG. 1. Tracks of tropical cyclones occurring post-1948 passing nearest to the track of Hurricane Irene (2011).

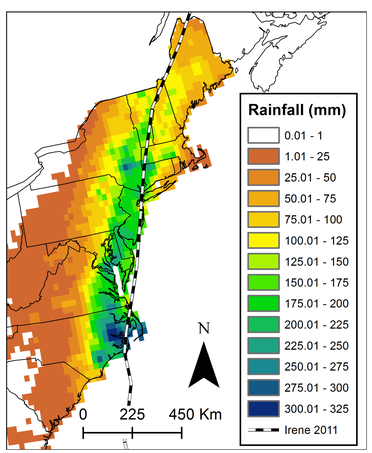

FIG. 2 Storm total rainfall for Hurricane Irene 2011.

TC	Median Rainfall (mm)	Rain Range (mm)	Max. Rain (mm)	Medn Dist. Track (km)	Max. Dist. Trk. (km)
I2011	208	142	324	79	163
H2008	117	87	187	80	152
B2007	65	48	106	132	939
F1999	251	360	548	89	173
B1996	102	99	190	59	180
B1991	137	108	211	95	215
G1985	151	101	223	144	228
D1971	132	125	225	67	701
U1961	37	49	78	115	844
D1960	153	59	198	103	236
B1960	118	108	197	50	128
C1954	87	99	176	102	366

Table 1: Statistics for storm total rainfall and distance to track for top 10% of rainfall totals left of track.

TC	Rain vs. Dist.	Rain vs. Long.	Rain vs. Lat.	Dist. vs. Lat.
I2011	-0.063	-0.373**	-0.506**	-0.154
H2008	0.072	0.048	0.052	0.098
B2007	-0.246**	0.383**	0.382**	-0.217**
F1999	-0.408**	-0.537**	-0.681**	0.293**
B1996	-0.190*	-0.172*	-0.192*	0.257**
B1991	-0.352**	0.089	-0.115	-0.040
G1985	0.133	-0.313**	-0.216**	0.420**
D1971	-0.324**	0.028	-0.078	0.000
U1961	0.234**	0.423**	0.493**	0.569**
D1960	-0.061	0.056	-0.001	0.098
B1960	-0.068	-0.521**	-0.622**	-0.230**
C1954	-0.255**	-0.288**	-0.417**	0.037

Table 2. Spearman's Rank correlation coefficients for top 10% rainfall totals each storm comparing rainfall amount, distance from the storm track, longitude, and latitude.

** significant at α = 0.01; * significant at α = 0.05

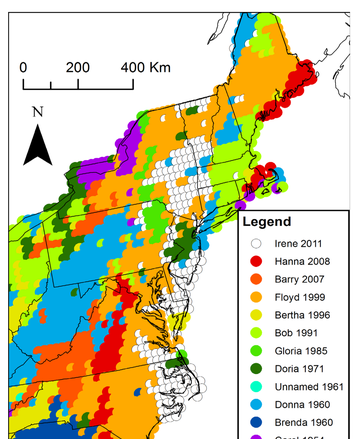

FIG 3. Tropical cyclone producing maximum storm total rainfall for each grid cell.

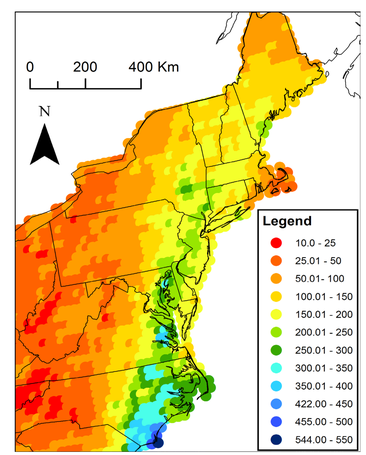

FIG. 4 Maximum storm total rainfall (mm) produced by a tropical cyclone included in the current study.