The Impact of Tropical Systems on WFO RLX

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Table of Contents

The County Warning Area (CWA)

The Weather Forecast Office (WFO) in Charleston, West Virginia is responsible for forty-nine counties within four different states—Kentucky, Ohio, Virginia, and West Virginia. Figure 1 (right) shows the distribution of those counties within the four states.

In WFO Charleston (RLX), there is a variety of terrain types and a large change in elevation—an approximately 2,800 ft. difference—from the western to eastern sides of the CWA. If the area were divided in three equal parts, the western third would mainly be characterized by rolling hills and elevations less than 1,000 ft. The eastern third would contain the Appalachian Mountains with elevations exceeding 2,000 ft. and, in some areas, reaching approximately 4,000 ft. above sea level. The remaining central third varies greatly as it transitions from the lowlands to the mountains.

Figure 1. RLX area of responsibility

General Information

Over two thousand tropical systems have been recorded in the North Atlantic Basin since the 1850s, and out of those, only about one percent have made it far enough inland to affect RLX. Compared to many of the southern coastal states, this may seem like an insignificant amount; however, these systems can bring potentially hazardous impacts such as high winds, heavy rains that may cause flooding, and an occasional tornado or two within our borders.

According to the National Hurricane Center (NHC), hurricane season spans from June 1 through November 30 with the greatest activity usually between August and October. In a typical hurricane season, eleven systems are named with five to six of the eleven becoming hurricanes, and one to two of those hurricanes becoming major hurricanes. NHC classifies tropical cyclones based on wind speeds (Table 1).

Table 1. Tropical Cyclone Classification

Classification	Sustained Winds	Description
Tropical Depression	≤ 38 mph	
Tropical Storm	39-73 mph	
Hurricane:		
Category 1	74-95 mph	Very dangerous winds will produce some damage
Category 2	96-110 mph	Extremely dangerous winds will cause extensive damage
Category 3*	111-129 mph	Devastating damage will occur
Category 4*	130-156 mph	Catastrophic damage will occur
Category 5*	≥ 157 mph	Catastrophic damage will occur

*Major hurricane

Unlike the majority of natural hazards, tropical systems tend to have a fairly long lead time and may often be tracked across the open water for some time before they reach land. That being said, uncertainties still remain with respect to landfall location, intensity, and duration.

Tropical Systems in RLX

Historical hurricane track data shows a total of twenty-nine tropical systems have passed within the vicinity of RLX, but only sixteen were verified through storm data to have significant impacts on the CWA.

At this point, there is a significant issue to note—the historical hurricane data extends all the way back to 1851 whereas the storm data used to show where impacts occurred only reaches 1950; therefore, events prior to 1950 were extremely difficult to verify. For the purposes of this study, only the sixteen storms (shown in Table 2) with verified impacts were evaluated to show what, where, and when impacts occurred within RLX.

Table 2. Tropical systems with verified impacts in RLX

	Year	Name	RLX Maximum Category	Lifetime Maximum Category
1	1969	Camille	Tropical Depression	Hurricane: Category 5
2	1975	Eloise	Extratropical	Hurricane: Category 3
3	1979	Frederic	Tropical Storm	Hurricane: Category 4
4	1992	Andrew	Tropical Depression	Hurricane: Category 4
5	1995	Erin	Tropical Depression	Hurricane: Category 2
6	1995	Opal	Extratropical	Hurricane: Category 4
7	1996	Fran	Tropical Depression	Hurricane: Category 3
8	1999	Dennis	Tropical Depression	Hurricane: Category 2
9	2002	Isidore	Tropical Depression	Hurricane: Category 3
10	2003	Isabel	Tropical Storm	Hurricane: Category 5
11	2004	Frances	Tropical Depression	Hurricane: Category 4
12	2004	Ivan	Tropical Depression	Hurricane: Category 5
13	2012	Sandy	Extratropical	Hurricane: Category 3
14	2015	Bill	Tropical Depression	Tropical Storm
15	2017	Cindy	Tropical Depression	Tropical Storm
16	2018	Florence	Tropical Depression	Hurricane: Category 4

None of these systems maintained full hurricane strength, but several affected the area as tropical storms or tropical depressions. For the most part, the impacts were indirectly related to the tropical systems and were usually strongest when combined with fronts, or other low-pressure systems.

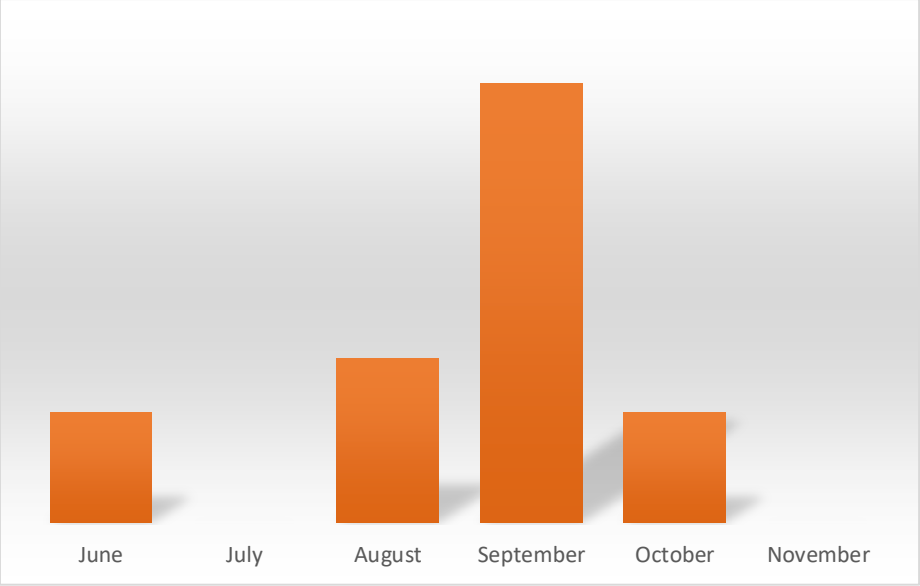

Figure 2. Tropical System Distribution by Month

Figure 2 shows how the storms in this study are distributed by month. As expected, the majority of storms that impacted RLX occurred in September, which is usually the peak month of hurricane season.

All Impacts

When all impacts—rain, flooding, wind, tornadoes, and snow—were taken into account, impacts from tropical systems occurred more often near and west of the Ohio river and within the mountains. Figure 3 (right) represents the frequency of these impacts by county. The brighter orange colors show the counties that were affected more frequently while the green colors are counties affected less frequently by tropical systems.

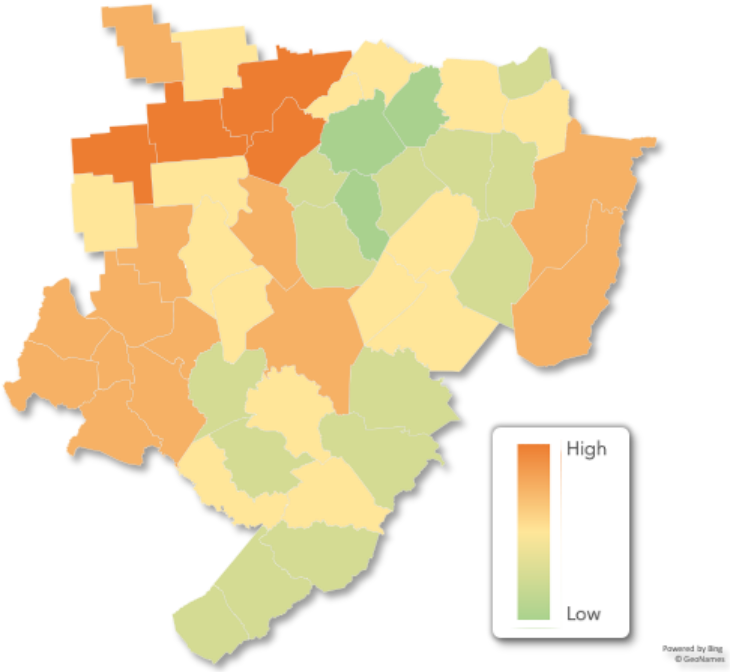

Figure 3. Frequency of all impacts by county

Impact: Rain and Flooding

By far, rain was the most common impact in the RLX area of responsibility and fell most often west of the Ohio River—mainly within the Ohio and Kentucky counties (as seen in Figure 4). On the right, Figure 5 shows both a heat map of where highest rainfall amounts occurred on average as well as the average rainfall measured at the RLX Cooperative Observer (COOP) sites. While there were a couple of hot spots for high rainfall in Athens, OH and Putnam/Kanawha Counties in WV, no clear pattern to high rainfall is evident.

Flooding tended to be highly dependent on how wet or dry the soil had been prior to the event. Some storms that produced several inches of rain did not result in flooding due to extremely dry or drought conditions, whereas other events that produced less rainfall over previously saturated areas did result in either flooding or flash flooding.

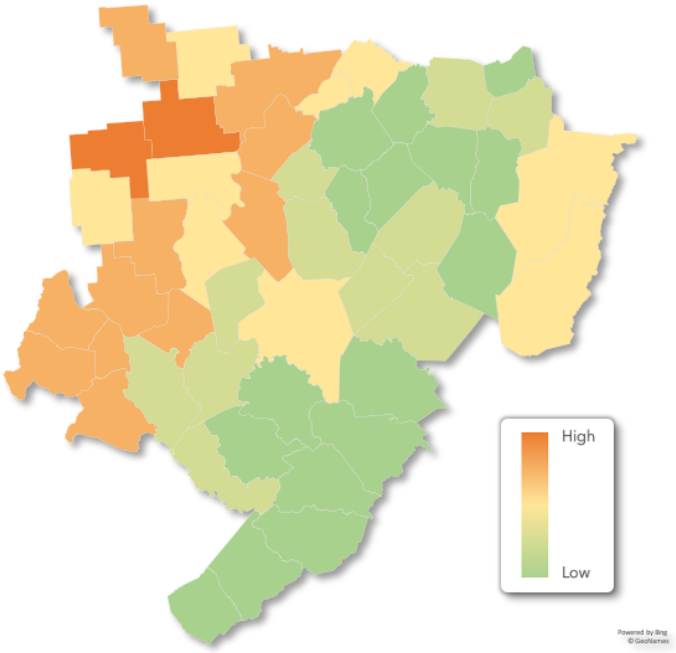

Figure 4. Frequency of rain and flooding impacts in RLX

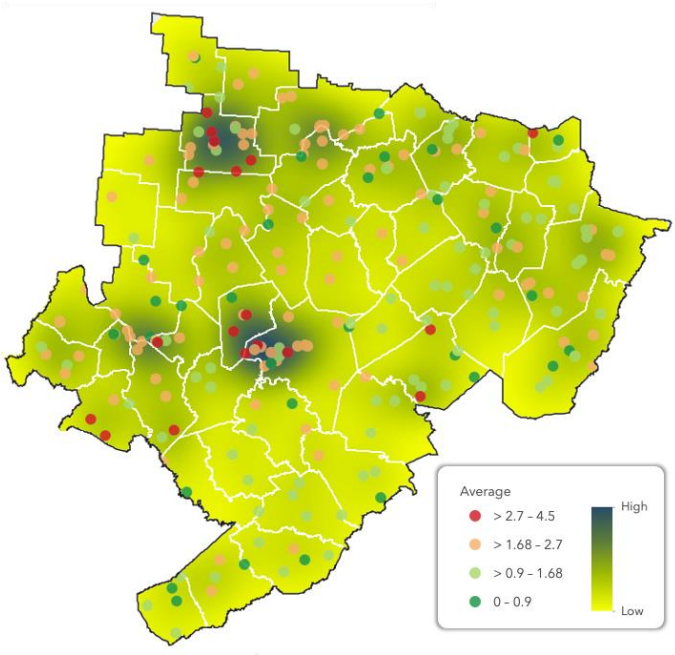

Figure 5. Average rainfall from tropical systems at COOP sites

Impact: Wind

Wind reports were much harder to come by than rainfall. As shown in Figure 6, many counties have no data (grey counties). With the lack of data, it was hard to draw any conclusions about susceptibility to wind.

For the most part, the documented wind reports for these storms were weaker than what is typical during a severe thunderstorm (less than 58 mph).

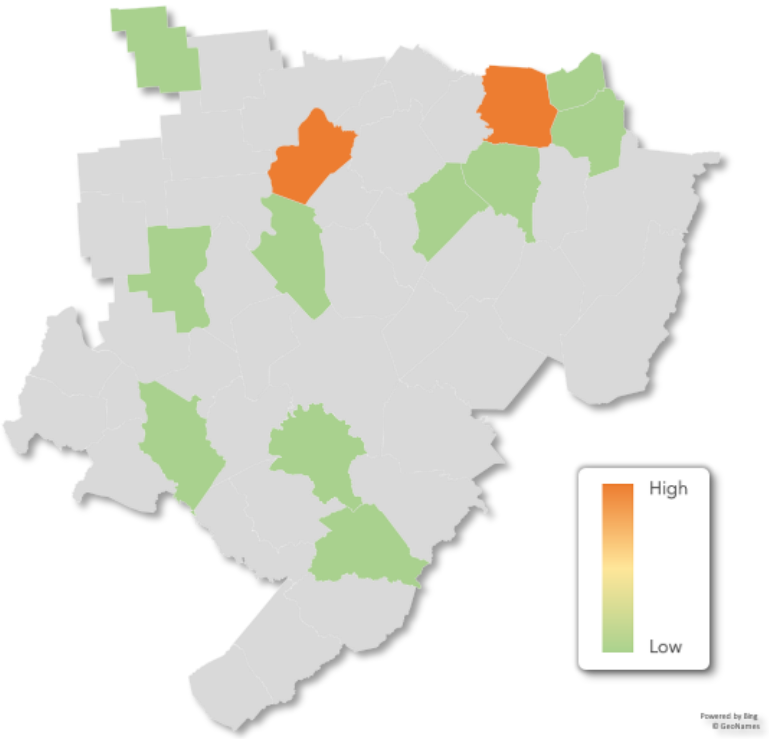

Figure 6. Frequency of wind impacts in RLX

Impact: Tornadoes

Out of all sixteen systems studied, only two brought tornadoes to the RLX area. These were Tropical Storms Bill (2015) and Cindy (2017).

The EF-0 tornado associated with the remnants of Bill occurred in Washington County, OH and had estimated wind gusts of up to 85 mph and caused mainly tree damage, though some outbuildings and one home also sustained some damage.

While only one tornado occurred within the CWA (in Harrison Co., WV), multiple tornadoes both in West Virginia and nearby states are attributed to the passage of remnants of Cindy. The EF-1 near Maken, WV was specifically cited for causing approximately $300,000 worth of damage.

The two figures below show the locations where the tornadoes that occurred.

Figure 6

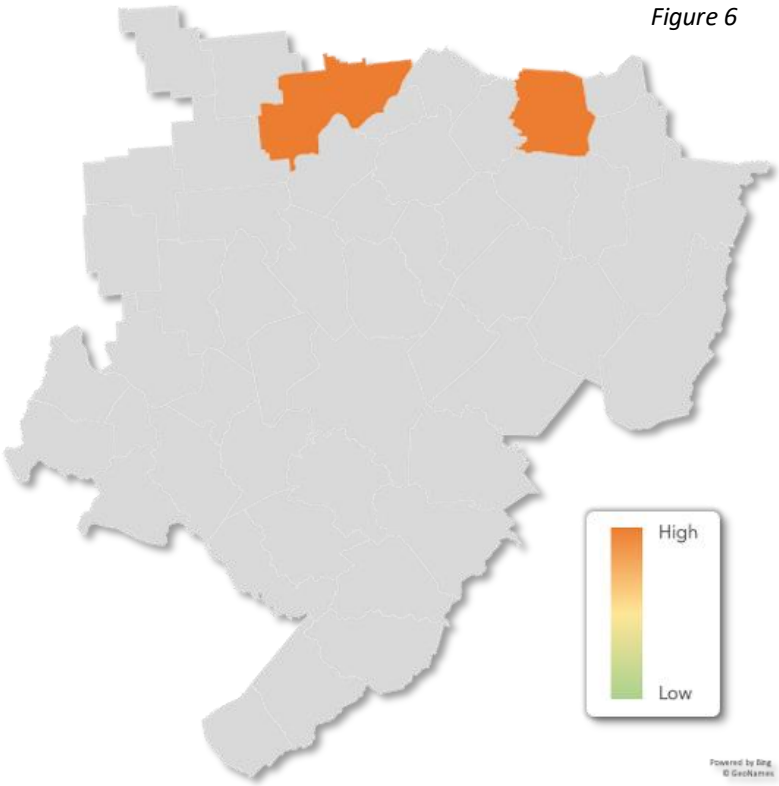

Figure 7. Frequency of tornado impacts in RLX

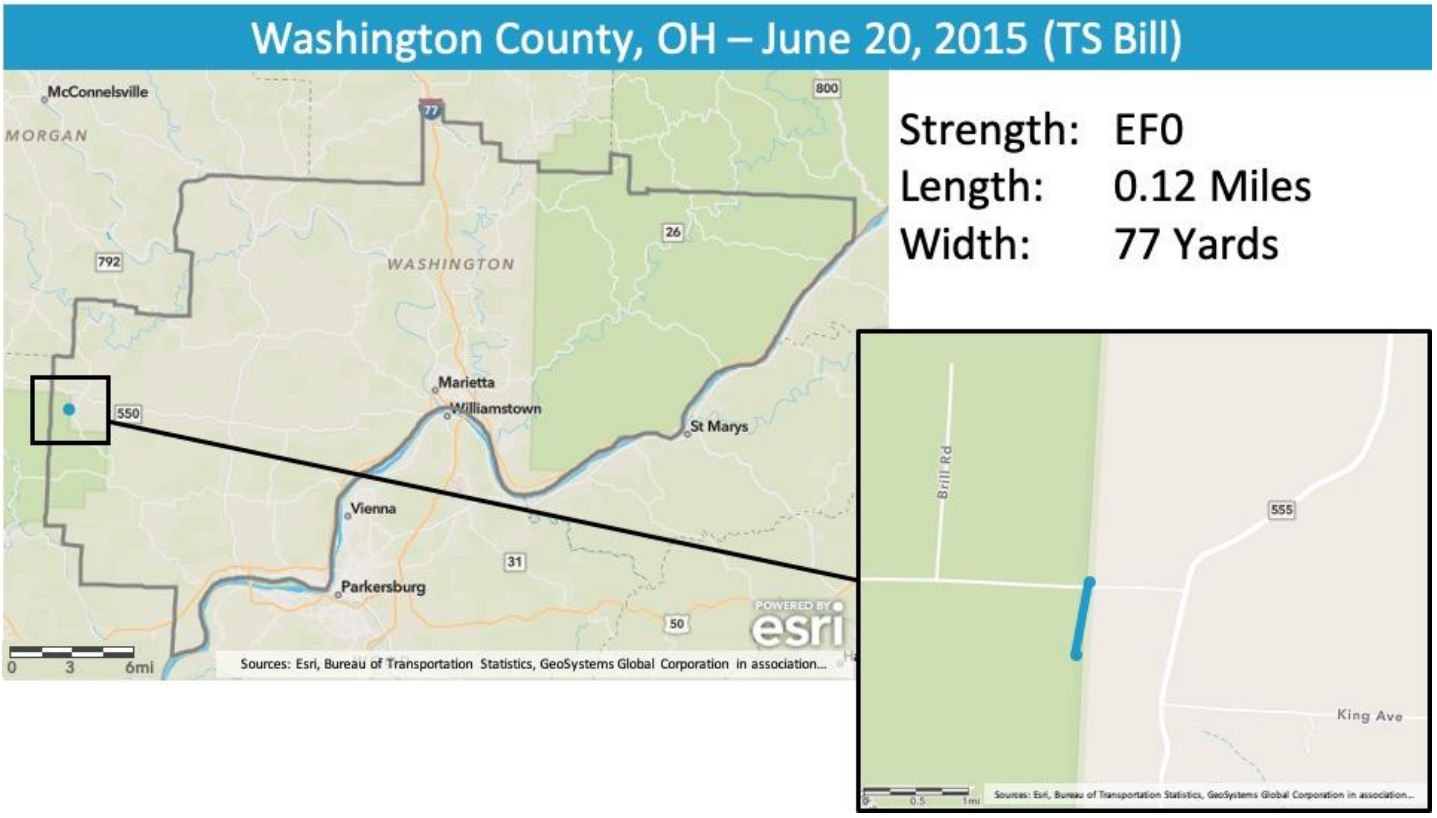

Figure 8. Location and path of the EF-0 tornado that occurred in the remnants of Tropical Storm Bill

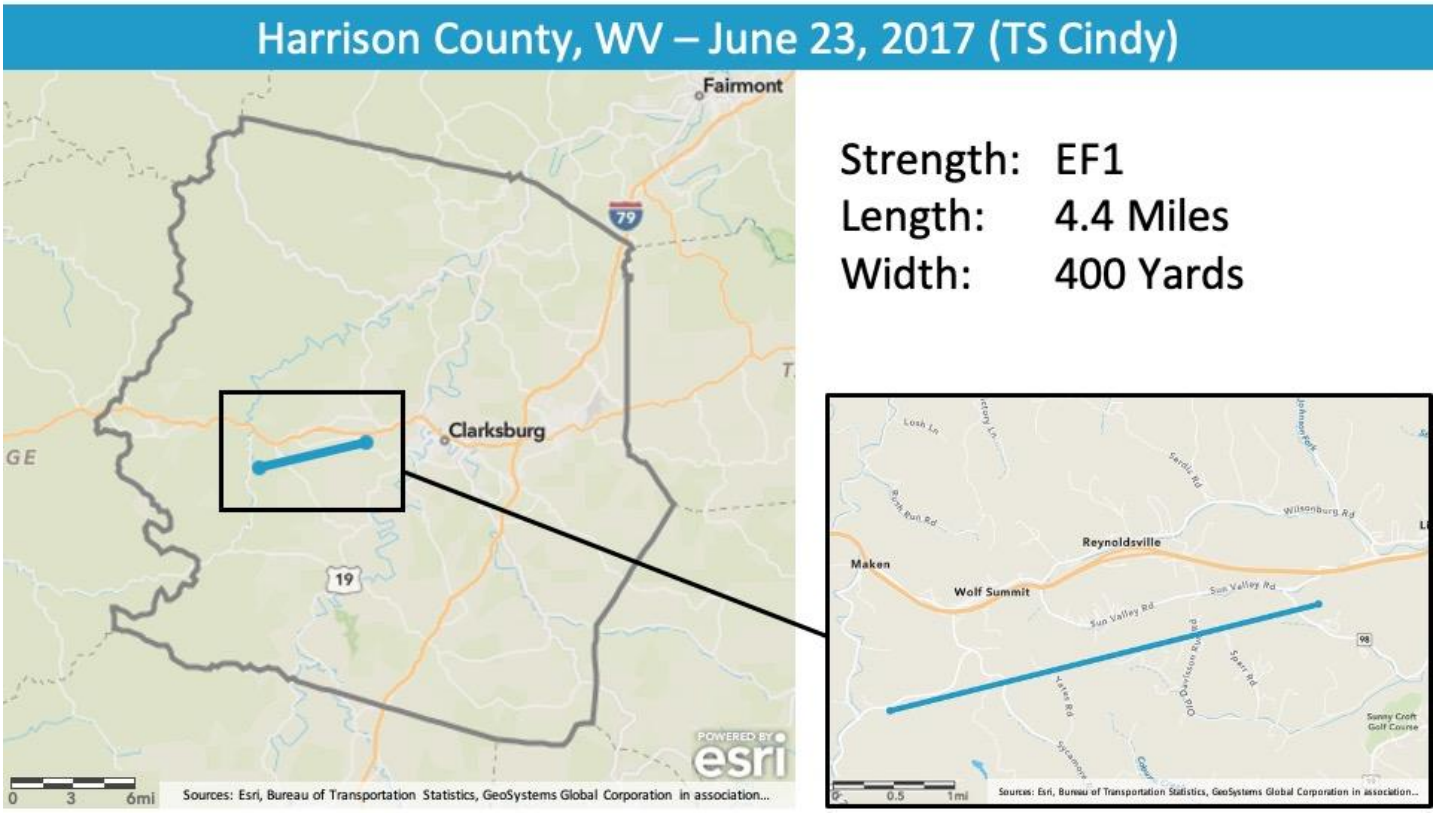

Figure 9. Location and path of the EF-1 tornado that occurred in the remnants of Tropical Storm Cindy

Impact: Snow

Snow is not a typical impact associated with tropical systems; however, it did occur in 2012 with the remnants of Hurricane Sandy.

Sandy was a late season hurricane whose remnants did not reach the RLX area until late in the month of October. In this case, the remnants merged with a trough in the polar jet which eventually led to heavy snowfall.

In the mountains, snow amounts were highest with some reports of over forty inches in the highest elevations. Snow reports of one to three feet were common in the mountain counties with amounts lessening to only a couple of inches to the west.

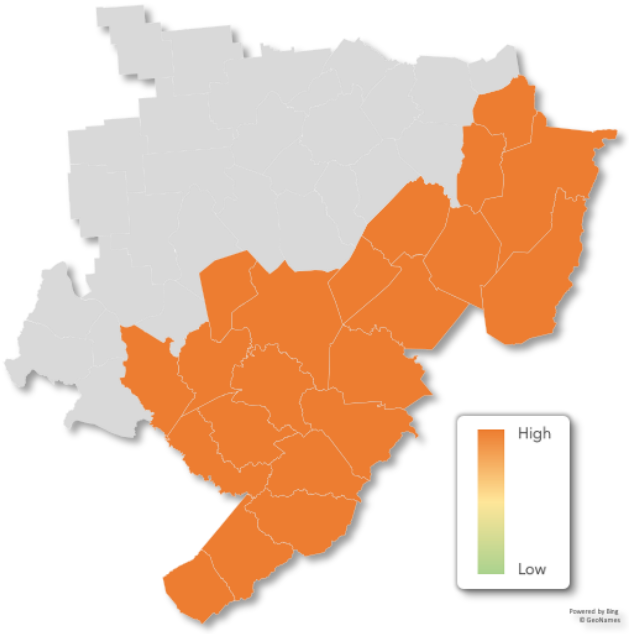

Figure 10. Frequency of snowfall impacts in RLX

Methodology

First, the historical hurricane track database was reviewed to see which systems had moved in the vicinity of RLX. Then, the NHC's Tropical Cyclone Reports for each storm was read to gain a better understanding of the formation and movement of each storm. The post-event rainfall maps created by WPC were also taken into account to help determine where rain and/or flooding could have been an issue. From there, storm data was used to determine where flooding, wind, and tornados had occurred during these storms. COOP data was also used to show the amount of rainfall and snow that accumulated during the events.

Summary

This project was intended to answer the following questions:

- How is RLX impacted by tropical systems?
  - The main impacts are usually indirectly related to the systems and often occur as the remnants move through or in the vicinity of the CWA.
- What types of impacts occur here?
  - Heavy rainfall, flooding, high wind, tornadoes, and even heavy snow have been a result of past systems.
- Which impacts are most common?
  - Rain and flooding
- Where do these impacts occur? Are certain areas or counties more susceptible to impacts than others?
  - Impacts have happened across the entire CWA, though they do occur most often west of the Ohio River and along the RLX mountain counties in WV.