P.083 SEVERE WEATHER EVENTS DETECTED BY PUERTO RICO'S TROPINET DUAL-POLARIZED DOPPLER X-BAND RADARS NETWORK

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1. INTRODUCTION

In order to improve nowcasting (warning) operations, new technologies that provide products to conduct research activities on precipitation and land surface processes of potentially hazardous weather are necessary. The need for improving weather radar coverage of the lower atmosphere is necessary to allow monitoring of precipitation and winds at low altitudes to positively impact forecast of flooding. This is especially true for regions with complex terrains, as well as urban and coastal areas. The Puerto Rico's west coast is a combination of all these conditions, where the coast and a range of mountains meet along with urban, making the warning for these areas very challenging and difficult. In addition, the TJUA NEXRAD located at Cayey is approximately 100 km from the west coast, has limitations observing the lower atmosphere in this area due to the complex topography and earth curvature. For this, University of Puerto Rico at Mayaguez sponsored by NSF-MRI developed network of X-band dual-polarized Doppler radars that focus in the observation of the lower atmosphere. The network consists of 3 radars that are strategically located along the west coast and can monitor the lower atmosphere of the west coast with high spatial (150m) and temporal resolution (1 minute), making the west region of Puerto Rico the most densely sampled lower atmosphere in the tropics. These radars have a 40 km maximum range, and their footprints overlap over urban, coastal and mountainous regions (Galvez et. al., 2013).

The UPRM radar infrastructure is already in place, and is currently run by faculty and graduate students. Recently several case studies where funnel clouds, waterspouts, and hail were reported in the west coast. The UPRM radars were able to observe these funnel clouds and waterspouts using it's Doppler capabilities. Moreover, hail detection was possible using polarimetric products (such as ZDR for HDR calculations) at low altitudes; very important for hail detection and algorithm development/improvements in the Tropics. These observations were invisible to the NEXRAD, as the comparison data depicted, and the higher resolution provided more detail in their structural development. These preliminary cases were a strong proof that improvement in Puerto Rico's West coast's nowcasting (warning) operation of NWS can be achieved using the short-range high-resolution radars from the UPRM.

Figure 1: TropiNet X-band Weather Radar Network located in western Puerto Rico's coast.

2. BACKGROUND AND METHODOLOGY

Hail events are fairly rare in the Tropics *compared* to higher altitudes. But with the deployment of the TropiNet Dual-polarized Doppler weather radar, now is easier to detect, especially in western Puerto Rico where it is located. Frisby (1964 and 1966) and Frisby and Sansom (1967) made the most complete survey of hail in the tropics by dividing it into zones. They gathered data for many years from the literature and through extensive correspondence with individuals and

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meteorological services. She found that in Zone 1, where Puerto Rico was located, hail principally falls in Spring, when there was the transition right before Summer; but specifically February through May. This was consistent with correspondence with the NWS, who provided a list of 5 likely hail events in the west in a period of 4 months during 2012, but in 2013 four events were clearly identified in a period of 3 days in just the month of September. The advantage of now having dual polarization data in high resolution and given the events frequency in western Puerto Rico we expect enough events to conduct an experiment analyzing the vertical structure of the storm using radar volume scans additional to the ones available.

To examine hail development, reflectivity values higher than 55dBZ will be monitored and the '*hail signal*', known as HDR in dB as defined by Aydin et al.1986, will be calculated using the following relation:

$$HDR = Z_h - f(Z_{DR}) \qquad [1]$$

The $f(Z_{DR})$ depicts the rain-hail boundary line as shown in Figure 2. This relation is a function of frequency and region.

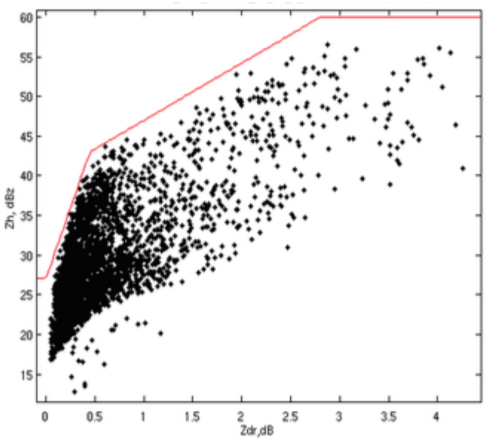

Figure 2: Rain-Hail boundary line simulated by (Tolstoy et al. 2011).

Several relations have been found (Bringi and Chandrasekar 2001) for $f(Z_{DR})$ but none have been found for the tropics at X-band. Sue et al. 2010 described $f(Z_{DR})$ for X-band in a temperate zone (also in Ma 2010, Ma et al. 2010). Another relation using X-band radar data and/or disdrometer data, have been found for sub-tropical coastal environment (equation 2) (Tolstoy et al. 2011).

$$f(Z_{DR}) = \begin{cases} 27 & Z_{DR} \le 0dB \\ 27 + 35.56Z_{DR} & 0 < Z_{DR} \le 0.45dB \\ 39.74 + 7.23Z_{DR} & 0.45 < Z_{DR} \le 2.8dB \\ 60 & Z_{DR} > 2.8dB \end{cases} \qquad [2]$$

This latter relationship was used to calculate HDR. The intention is to identify hail regions using the dual-polarized data form the TropiNet further on than using Z_{DR} in an inspecting way. This relation in equation 2 was selected as it was found for the closest region to the tropical zone. Because of this, for the purpose of this research, only HDR≥10dB will be considered a '*hail signal*'.

3. DATASET

Data from the TropiNet Radar Network will be used. For the cases presented data from the Cornelia node will only be used.

Three convective cases are presented. The *first case* corresponds to a severe weather event approaching the west over the mountainous region of Aguada, Puerto Rico. This event on September 12th, 2014 was around 18:48 UTC. The *second case* was a funnel cloud detected over the Mayaguez road PR-2, which where the main transit on the west. This case was on September 9, 2014 around 18:24 UTC. The *third case* presented was a waterspout detected at the Mayaguez offshore. This was on September 9, 2014 around 18:48 UTC.

Reflectivity, Z_H has been corrected for attenuation using the differential phase approach. Z_{DR} has been corrected as well.

4. RESULTS

In this section the results for the hail detection and rotation activities like waterspout and funnel cloud will be presented.

4.1 Hail detection

On September 12, 2015 a system was approaching the west through Moca approaching Aguada mountainous region. At around 19:48 UTC, observers informed the NWS of hail activity in the area. Our radars indicated high reflectivity values up to 55dBZ at this time, suggesting hail presence (Figure 3).

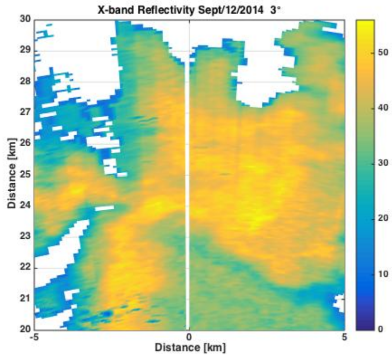

Figure 3: Reflectivity PPI scan at 3 degrees elevation on Sept 12, 2014 at 18:48 UTC.

Using the algorithms described in the previous session, the HDR signal was calculated and it agreed with what the public observed in situ. HDR results showed values as high as 25dB in some areas (Figure 4). In Figure 5 a zoomed area of 4km by 4km was selected. This area in particular has high activity of hail precipitation. The data presented was filtered for values of HDR≥10dB. This threshold was established to make sure of hail presence given that the relation used is for a sub-tropical coastal zone.

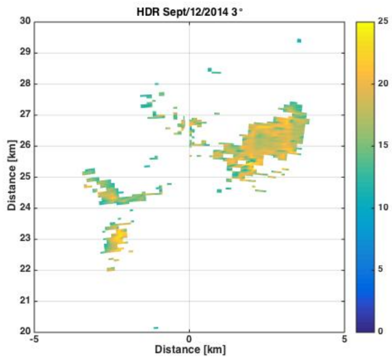

Figure 4: HDR result at 3 degrees elevation on Sept 12, 2014 at 18:48 UTC.

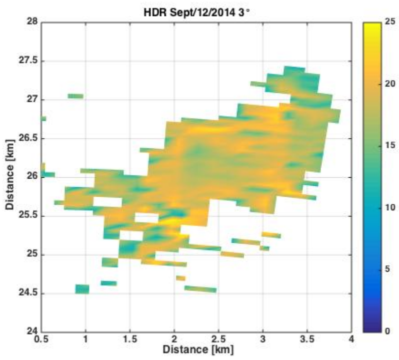

Figure 5: Hail signal for Figure 4 area zoomed in for the same case.

A contour of the 'hail signal' shown in Figure 4 over the reflectivity PPI (Figure 3) is shown in Figure 6. These show specific areas of high HDR at the top right and bottom left of the plot. Both areas are approximately 1.5km by 1.5km each.

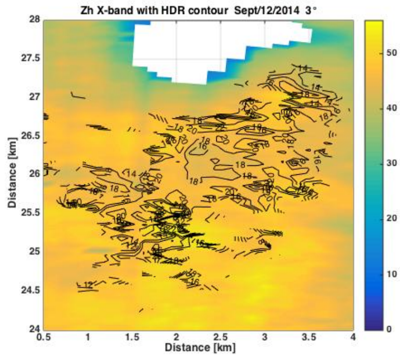

Figure 6: HDR contours over reflectivity Z_H for the case presented.

4.2 *Circulation detection*

4.2.1 Funnel Cloud Case

On September 9th, 2014 at 18:24 UTC, a funnel cloud was observed over the PR-2 road (Figure 7). This is the main road crossing PR's west area from North to South. The TropiNet Cornelia Node was able to detect its formation and dissipation. A clear hook of this funnel cloud can be observed with the reflectivity PPI in Figure 8. Doppler velocity measurements can be seen in Figure 9, which clearly show the rotation.

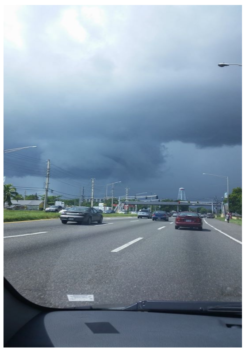

Figure 7: Picture of funnel Cloud over PR-2 road at Mayaguez, PR on September 9th, 2014 at 18:24 UTC.

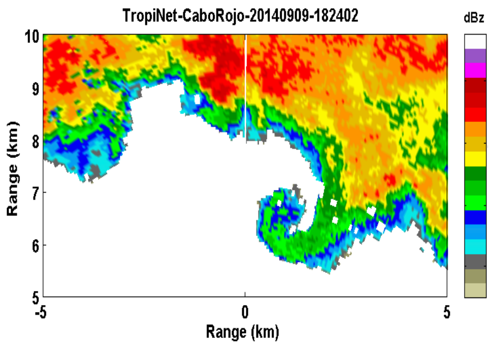

Figure 8: Reflectivity PPI scan at 3 degrees in elevation for the funnel cloud case on September 9th, 2014 at 18:24 UTC.

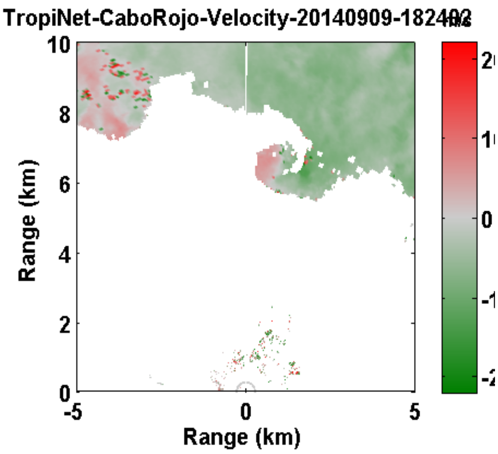

Figure 9: Doppler velocity values for the PPI scan presented in Figure 8. A waterspout was detected.

4.2.2 Waterspout case

Later on that same day, on September 12th, 2014 at 18:48 UTC, a waterspout was detected by the same TropiNet Cornelia Node. This was located a few kilometers offshore of Mayaguez.

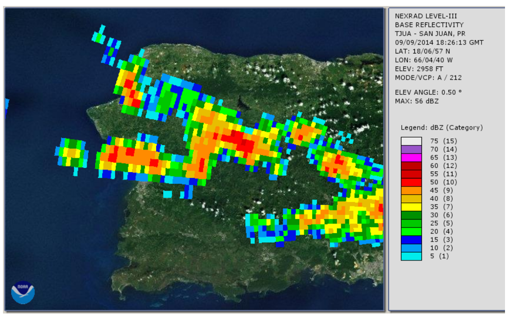

Figure 10: Reflectivity PPI scan from NEXRAD. Waterspout is not detected.

Figure10 shows NEXRAD's radar reflectivity at the moment, that when compared to the TropiNet's reflectivity below in the atmosphere and better resolution (Figure 11), the waterspout can't be distinguished. This is a clear example of the importance of sensing PR's west coast lower troposphere. NEXRAD's blindness in this area makes it difficult to issue any warning to the population, especially fishermen in the area.

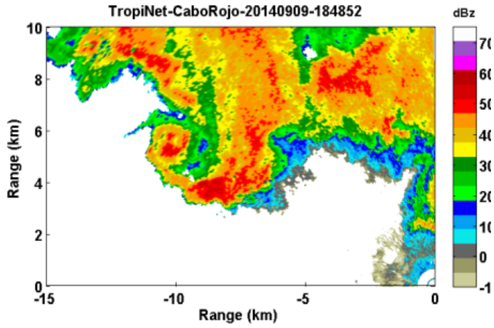

Figure 11: Reflectivity PPI scan at 3 degrees in elevation for the waterspout case on September 9, 2014 at 18:48 UTC.

Figure 12 shows the Doppler velocity values. When monitored the formation and dissipation of this waterspout was tracked it was noted that it was part of the same system passing through that afternoon, but not the funnel cloud presented in the previous section that made its way to the water. Even when it appeared around he same 6km north the radar both of them the time-lapse showed there was no rotation activity in between for around 15 minutes.

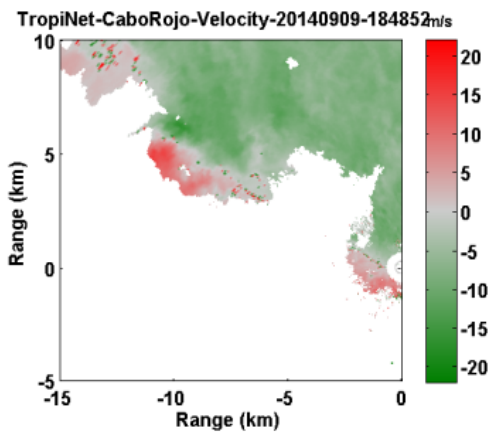

Figure 12: Doppler velocity values for the PPI scan presented in Figure 11. A funnel cloud was detected.

5. CONCLUSIONS

Given that for the Puerto Rico tropical zone an HDR relation has not been yet been found, a sub-tropical coastal relation for $f(Z_{DR})$ was used. A threshold of HDR≥10dB was established to identify the '*hail signal*'. With this in place, HDR zones up to 25dB were detected. These values coincided with eyewitnesses in the Aguada area.

In the other hand Doppler velocities from the dual–polarized TropiNet radar at the Cornelia Node, provided information to detect two important severe events. One waterspout at the Mayaguez offshore and a funnel cloud over Mayaguez's PR-2 road. Both were witnessed and reported to the NWS.

The detection of these events in the west coast of Puerto Rico represents a milestone, since these events were totally undetected for the NWS's NEXRAD's radar and it was the first time that a dual-polarized weather radar detected severe events like this in Puerto Rico. These results will aid the research community to study this kind of events in the tropics with the use of the new established TropiNet X-band weather radar network.

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6. REFERENCES

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