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 operations of the lower atmosphere is necessary to allow monitoring and detecting hazardous weather, such as hail, which has potential to develop in 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 along the east and west coast must along with urban, making the weather for these areas very challenging and difficult. In addition, the TJA NEKO located at Ceiba is approximately 100 km from the west coast, has limitations obtaining the lower atmosphere in the area due to the complex landscapes and earth curvature. For this, University of Puerto Rico at Mayaguez approved by NSF-MRI developed network of X-band dual-polarized Doppler radars that focus in the observability of the lower atmospheres. 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 (750m) and temporal resolution (1 min), 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.

The UPWM radar infrastructure is already in place, and is currently run by faculty and graduate students. Recently several cases studies where funnel clouds, waterspouts, and hail were reported in the west coast. The UPWM radars were able to observe these funnel clouds and waterspouts using its Doppler capabilities. Moreover, hail detection was possible using polarimetric products (such as $Q_p$ for HRR calculations) at low altitudes, very important for hail detection and algorithm development/improvements in the tropics. These observations were matched to the NEXRAD, as the comparison data expected, and the higher resolution provided more detail in the structural development. These preliminary results were a strong indication improvement of these dual-polarized Doppler radars operation of NEXRAD can be achieved using the short-range high-resolution radars from the UPWM.

2. Background and Methods

Hail events are fairly rare in the tropics compared to higher altitudes. But with the deployment of the Tropihail Dual-polarized Doppler weather radar, now is easier to detect, especially in western Puerto Rico where it is located. Friday (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 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 correspondence with individuals and meteorological services. This latter relationship was used to calculate HDR. The relation is to identify hail regions using the dual-polarized Doppler radars, now is easier to detect, especially in western Puerto Rico where it is located.

Several relations have been found (Koppen and Chandrasekar 2001) for $Z_{dr}$ but none have been found for the zone at 3-Band. Guo et al. (2010) described HDR 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 (Tolstoy et al. 2011).

This relation in equation 2 was selected as it was found for the closest relation to the tropical zone. Because of this, for the purpose of this research, only HDR from $Z_{dr}$ will be considered a ‘hail signal’.

$\text{HDR}=Z_{dr}^{\frac{27}{7.23}}\times \left( 1 + \frac{0.45}{Z_{dr} - 0.45} \right)$

$\text{HDR}=Z_{dr}^{\frac{0.45}{2.8}}$ for X-band in a temperate zone (also in Tolstoy et al. 2011).

$\text{HDR}=Z_{dr}^{\frac{27}{35.56}}\times \left( 1 + \frac{0.45}{Z_{dr} - 0.45} \right)$

$\text{HDR}=Z_{dr}^{\frac{27}{39.74}}$ for X-band in a temperate zone (also in Tolstoy et al. 2011).

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

$\text{HDR}=Z_{dr}^{\frac{27}{7.23}}\times \left( 1 + \frac{0.45}{Z_{dr} - 0.45} \right)$

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Figure 1: Tropihail X-Band Weather Radar Network located in western Puerto Rico’s coast.

Figure 2: Rain-Hail boundary line as shown in Figure 2. This relation is a function of frequency and region.

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

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

3. RESULTS

CASE 1: HAIL EVENT OVER AGUADA, PR

Sept 12th, 2014 at 18:48 UTC

Figure 5: Area zoomed in for the same case.

Figure 6: HDR contours over reflectivity $Z_{dr}$ for the case presented.

CASE 2: FUNNEL CLOUD OVER PR-2 ROAD, MAYAGUEZ, PR

Sept 9th, 2014 at 18:24 UTC

Figure 7: Reflectivity PPI scan at 3 degrees in elevation for the waterspout case on September 9th, 2014 at 18:24 UTC.

Figure 8: Doppler velocity values for the PPI scan presented in Figure 6. A waterspout was detected.

CASE 3: WATERSPOUT IN MAYAGUEZ, PR

Sept 9th, 2014 at 18:48 UTC

Figure 9: Reflectivity PPI scan from NEXRAD. Waterspout is not detected.

Figure 10: Reflectivity PPI scan at 3 degrees in elevation for the waterspout case on September 9th, 2014 at 18:48 UTC.

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

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

4. Conclusions

Given that for the Puerto Rico tropical zone an HDR method has not been yet been found, a sub-tropical coastal relation for $\text{HDR}=\text{Z}_{\text{dr}}^{\frac{27}{7.23}}\times \left( 1 + \frac{0.45}{\text{Z}_{\text{dr}} - 0.45} \right)$ was used to identify the ‘hail signal’. With this in place HDR values up to 55dBZ were detected. These values coincided with eyewitness accounts in the Aguada area. In the other hand Doppler velocities from the dual-polarized Tropihail radar at the Cornelia Piedras 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 NW). The detection of these events in the west coast of Puerto Rico represents a milestone, since these events were locally undelected 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 add research community to study the kind of events in the tropics with the use of the new established Tropihail X-band weather radar network.

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