Meteorological Investigation of a Possible Undocumented Tornado in Puerto Rico on 17 June 2012

Marco A. Monrouzeau

Department of Earth, Atmospheric and Planetary Sciences

PURDUE UNIVERSITY

Department of Earth, Atmospheric, and Planetary Sciences

1. This study centers around a storm video the first author took in 2012

Tornadic events are rare occurrences in Puerto Rico, but they do occasionally happen. This case study explores a potentially undocumented tornado captured on video (Fig. 1) on a Father's Day Sunday in 2012 near the municipalities of Dorado and Toa Baja. The video itself is low quality but there are signs that point toward there being a rear flank downdraft, clear slot, rain-free base, mesocyclone,and extended funnel cloud, all which are common attributes of a tornado . Our working hypothesis was that the event captured in video was indeed a tornado, but to confirm this we first needed to reject the null hypothesis that both the atmospheric environment and storm were not supportive of tornado development.

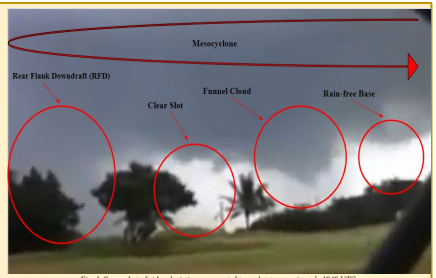

Fig. 1. Screenshot of video depicting a suspected tornado at approximately 1949 UTC.

2. Hook echo is detected coinciding with the funnel in the video

We examined Doppler radar signatures near the time of the event. Using radar reflectivity, we noticed the development of a brief hook echo embedded in a storm cell located near the Toa Baja and Dorado municipalities (Fig 2). This hook echo is approximately concurrent with the suspected funnel cloud or tornado captured in the video. To determine if rotation was present at the time, radial velocity was examined. The radial velocity (Fig 3) indicated a weak low level rotation storm, which could point to the development of a weak mesocyclone. Additionally, an analysis of specific atmospheric conditions from that day was done to determine if they were conducive for a tornadic event. We evaluated observations collected by a radiosonde the morning before the event, since it was more representative of the pre-convective environment. Using the University of Wyoming website's weather archive, weather balloon data for 17 June 2012 at 1200 UTC was picked to make a skew-T, log p diagram, and hodograph (Fig. 4) and compute several stability indices: lifted index (LI), K-Index (KI), totals total (TT), severe weather threat Index (SWEAT), convective available potential energy (CAPE), convective inhibition (CIN), storm relative helicity (SR HEL), and energy helicity index (EHI) (Peppler 1988).

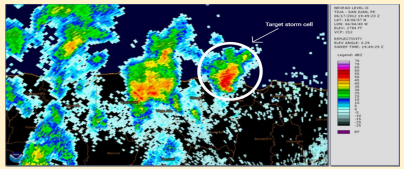

Fig. 2. Radar reflectivity (in dBZ) at 1949 UTC from TJUA, generated by Weather and Climate ToolKit, depicting storm cell of interest.

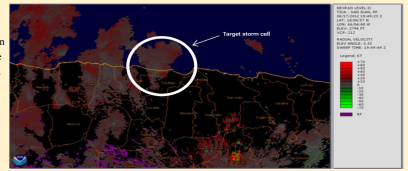

Fig. 3. As in Fig. 2, but showing radial velocity (in kt).

3. Results point toward a slight chance of supercell development

- The calculated LI for the 0000z sounding was -5.91 deg C, corresponding to an unstable atmosphere. This value falls within the strong potential for severe weather criteria, which made sense because strong thunderstorms developed and were observed around the island.
- The KI and TT values calculated, 34.10 deg C and 49.60 deg C respectively, both point toward the potential severe convective thunderstorms. Both the KI and TT were good predictors of the thunderstorms and heavy rainfall that occurred throughout the afternoon of that day.
- The SWEAT index evaluates the probability of a severe weather event (e.i. winds >58 kts, hail >1 inch in diameter, or tornado). The obtained value was 230.42 corresponds to a slight to moderate potential for a severe weather event. This seems to be a viable value given that most of the thunderstorms that developed that day did not fulfill the severe weather criteria, with a possible exception of the suspect thunderstorm.
- Given that LI, KI, and TT point toward very unstable atmospheric conditions, a high CAPE value is to be expected. The calculated CAPE yielded a value of 2467.6 Jkg^{-1}, hence providing more evidence of large levels of instability. This indicates a large reservoir of energy for the development of strong thunderstorms across Puerto Rico.
- To compute EHI, both CAPE and SRH were considered, yielding a value of 1.74 $Jm^2\ kg^{-1}s^{-2}$. This value falls above the lowest criteria for which supercells are likely, meaning that there was a slight probability of supercells developing on that day.

Based on these calculations, we expected a non-zero probable chance of development for supercells and tornadoes.

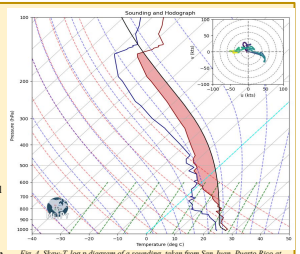

Fig. 4. Skew-T, log p diagram of a sounding taken from San Juan, Puerto Rico at 1200 UTC on 17 June 2012, including temperature (deg C; dark red solid line), dew point (deg C; dark blue solid line), and surface parcel trajectory (deg C; black solid line). The region shaded pink (blue) corresponds to CAPE (CIN). Dashed red, blue, and green lines correspond to dry adiabats, moist adiabats, and water vapor mixing ratio lines, respectively. Inset: Hodograph from the same sounding (in kts), color shading (indigo to yellow) corresponds to increasing height (0.2 km MSL to 12.6 km MSL). Dashed gray rings are drawn every 20 kts. Area shaded between the moist adiabat and the environmental temperature curves shows CAPE. Red (blue) shaded area between the parcel trajectory and the environmental temperature curve graphically depicts CAPE (CIN).

4. The Doppler radar's location limits detection of lower level rotation near the site of the suspect storm

Looking at radar imagery the appearance of a thunderstorm going briefly supercellular is supported by the hook echo observed at 1949 UTC in Fig. 2, which overlaps with the funnel shaped cloud caught in the video and shown in Fig 1. A common rule of thumb" for storm spotters is that a funnel cloud that extends more than 50% of the distance from the cloud base to the ground should be reported as a tornado. From the funnel's appearance (Fig. 1), this criterion is satisfied. Because SRH tends to decrease as surface friction decreases, the source of rotation for this "supercellular" thunderstorm is unknown. But, it could be speculated that changes in wind direction induced by the dryline, drier air flowing down the Cordillera Central "colliding" with moist warm air flowing in land from the ocean waters, could be substantial factors in supplying rotation. This mechanism, though, can not be confirmed. Additionally, the Doppler radar in Puerto Rico, located in Cayey, is at an altitude of nearly 1,700 ft (0.5 km) (Fig. 5), so the radar beam fails to capture activity at lower levels. In context of this storm, the Doppler radar could be detecting weak rotation over 1 - 2 km above ground level, making it difficult to decipher lower level rotation (<1 km). Although the EHI suggests a slight to marginal likelihood of supercell development, given the confounding variables and the Doppler radar's limitations, the results are inconclusive. Further research will continue in collaboration with the NWS in Puerto Rico in the summer of 2023.

Fig.5. Topographical map of Puerto Rico showing elevation meters, and the location of the Cordillera Central. Circled is the location of the Doppler Radar at an elevation of approximately 0.5 km.

(https://media.springernature.com/original/springer-static/image/chp%2E10.1007%2F978-3-319-57168-9_14/MediaObjects/426562_1_En_14_Fig2_HTML.gif)

Acknowledgements:

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QR code to video footage:.

References:

Peppler , R. A., 1988: A REVIEW OF STATIC STABILITY INDICES AND RELATED THERMODYNAMIC PARAMETERS . https://www.isws.illinois.edu/pubdoc/MP/ISWSMP-104.pdf (Accessed 24 February 2023)