THE EFFECT OF WIND SHEAR ON THUNDERSTORMS LIGHTNING ACTIVITY: A CASE STUDY IN THE AMAZON BASIN

POSTER2-78

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1. INTRODUCTION

Traditionally severe storms are classified by material damage criteria, with the occurrence of either: hail(>2.5 cm), strong wind gusts (> 93km/h) or a tornado, according to U.S. National Weather Service(NWS). However, as discussed by Doswell (2001, p. 13), these thresholds are somewhat arbitrary and have no physical reasoning for explaining the severity of thunderstorms; he suggests that updraft intensity is the key parameter for describing severity of storm cells.

Direct vertical velocity measurements are difficult to obtain, therefore different methodologies have been used to infer updraft intensity, like lightning stroke rate(Cecil et al. 2005; Zipser et al. 2006) ,because stronger updrafts enhance the formation of graupel and hail (rimming and accretion of super-cooled water on ice particles), that in turn increases the charge separation mechanism (Takahashi 1978).

Other studies(Weisman and Klemp 1982; Weisman and Rotunno 2004) show the existence of a correlation between vertical wind shear and updraft intensity on the thunderstorm life cycle. On radar measurements, vertical wind shear is identified by the cloud tilting observed on radar reflectivity cores. Thus, vertical wind shear could be estimated from the tilting angle that a vertical precipitating radar echo presents (Byers and Battan 1949).

In the Amazon basin, severe thunderstorms (>180 lightning strokes/min, according to Anselmo (2015)) have been observed despite the fact the is in the tropics where barotropic instability predominates and wind shear is not so strong as observed in the extra-tropics and mid-latitudes.

Considering this puzzle, this study proposes to understand how lightning activity responds to the vertical wind shear to further develop a relationship between updraft intensity and lightning flash rates.

To investigate such relationship, this study will focus on a multi-cell thunderstorm case observed on September 8th, 2014 in the vicinity of Manaus, Amazonas, Brazil during the CHUVA project, where radar and lightning measurements are available,

2. DATA AND METHODS

For this study, we used SIPAM (Amazon Protection System) volumetric radar measurements from Manaus single polarization S-Band Doppler weather radar and LINET 3D lightning network deployed in the Amazon basin during August-September of 2014 as part of the CHUVA-Manaus field campaign (Machado et al., 2014; Vilela, 2017).

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2.1 Manaus S-Band Radar

SIPAM operates a S-Band Doppler Radar at Manaus, a metropolis at the heart of the Amazon rainforest, as visible in Figure 1. The radar has an antenna beam width of 2º,and it configured with a gate resolution of 500 m to scan 17-elevation every 12 min (Vilela 2017). For this study, only the first 150 km range is used to avoid propagation effects and geometry.

Figure 1 Manaus S-Band Radar location (yellow marker) and range (red circle). Source: Google Earth®

The volumetric data were converted to 19-level 3D-CAPPI with 2 km x 2 km x 1 km resolution (from 2 km up to 20 km height levels). Then, an individual thunderstorm 3D cell was identified by a threshold of 45 dBZ reflectivity (iso-surfaces). Moreover, the identified cells were visually tracked in time. For each cell the following statistics were calculated: mean height, echotop, total volume and volume above 5 km height (~0 ºC isotherm) and vertical tilting angle, which was calculated by 3D-linear regression (Guo et al. 2017, sec. 2).

2.2 LINET Dataset

During the field campaign, a network of 8 VLF/LF LINET antennas was installed around Manaus. LINET, uses the Time-of-Arrival (TOA) method to detect and locate Intra-Cloud (IC) and Cloud-to-Ground (CG) strokes with 150 m accuracy (Betz et al. 2009).

Three-minutes lightning strikes were co-located with identified radar storm cells defined by a 20-dBZ threshold in order to determine the entire thunderstorm extension. So, for each thunderstorm, we computed the stroke rate. Then, computed lightning rates were assigned to the convective cores (45-dBZ cells) embedded within the respective 20-dBZ cell. For multiple convective cores, the same lightning rate computed for the 20-dBZ rain cell is applied to all 45 dBZ cores.

3. PRELIMINARY RESULTS AND DISCUSSION

As a first result, 3D convective cores defined by 45 dBZ have been tracked using 3D CAPPI with 2 km x 2 km horizontal and 1 km vertical resolution for a squall line observed on September 8th, between 18:00 UTC and 21:36 UTC, Figure 2.

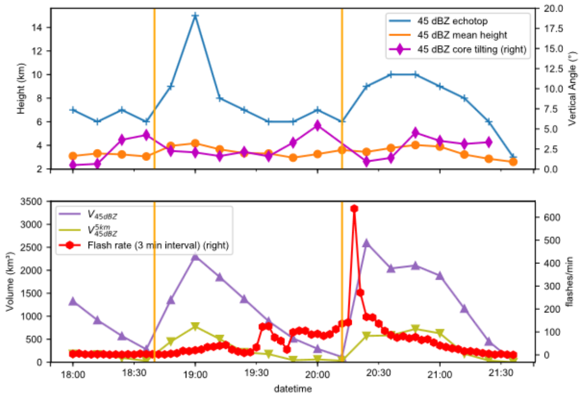

Figure 2 Time series of 45 dBZ cores statistics': echotop, mean height, vertical tilting angle (above), total volume, volume above 5 km level and 3-min mean flash rate (below)

Figure 2 shows the time series of the mean echo top, vertical tilting angle (shear), total (45 dbZ) rain volume and the volume above the height of 5 km and observed total lightning rate. It is important to state that three distinct convective cores were tracked since the main precipitation cell merges or dies, and those transitions are indicated by the vertical lines.

Overall, the first core was already decaying, presenting an echotop that oscillated between 6 km and 7 km, mean echo height of 3 km and low lightning rate (6 strokes/min) for the entire squall line (20 dBZ). The cell tilting was approximately 0° initially and after 18:24 it slightly increased to about 4°. The second core was still developing until 19:00, peaking at 2500 km³ total volume, around 750 km³ as mixed phase volume, an echotop above 14 km, and a mean height of 4 km indicating deep convection. However, the tilting angle and the lightning rate were low until 19:30, with values near 2.5° and 40 strokes/min, respectively. After 19:30, the echo top height falls to around 6 km (3 km mean) and then slightly increases to 7km from 19:48 to 20:00, followed by a tilting angle increase of approximately 5.5° and lightning rate reaching more than 100 strokes/min as it crosses Solimões river. To illustrate the vertical structure of this thunderstorm, Figure 3 shows the storm evolution at 20:00 and a vertical cross-section along the red line. This thunderstorm shows a broad and intense precipitation volume that extends more than 10 km height with reflectivity greater than 40 dBZ. Finally, the third core presented a maximum lightning rate of more than 600 strokes/min that was followed by a sudden increase on the echotop around 9 km, total volume of ~2500 km³ and ~500 km³ in the mixed phase. The tilting angle increased from 1° in the maximum activity to 4.5° in the decaying stage.

A possible explanation for this sudden lightning activity would be the interaction between gust fronts from this core with one from another nearby core (later the two merged) and the fluvial breeze circulation of the Solimões river that is oriented almost perpendicular to prevailing wind direction and storm motion besides been considerably wide (~1km), as pointed out by Vilela (2017).

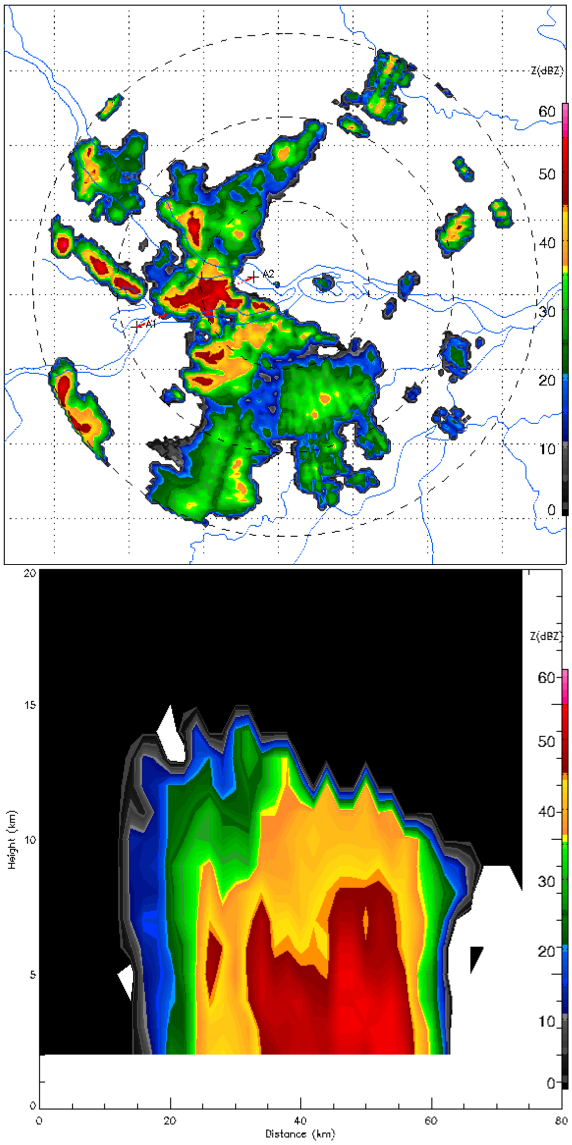

Figure 3 20:00 UTC MAXCAPPI with 50 km range circles(above) with vertical cross-section between poinst A1 and A2 (below).

4. SUMMARY

The 08-Sep-2014 storm case over Manaus can be classified as severe as it presented a maximum lightning rate of 767 strokes per minute, roughly a 4-fold compared to the regional threshold of 180 flashes per minute defined by Anselmo (2015).

All the three (45 dBZ) convective cores were deep and extended above 5 km height, with a considerable volume above this level, indicating a well-developed mixed phase cloud with large concentration of super-cooled water droplets that in the presence of graupel and hail lead to the invigoration of the storm electrification (Takahashi 1978), also observed by Vilela (2017).

The overall estimated vertical tilting was small with a maximum of 5.5 º, in accordance with predominant ambient of low shear. There was an increase in tilting when the convective core merged with another one and when they both crossed the Solimões river, raising the hypothesis that a complex interaction between storms gust fronts and the fluvial breeze might influence the establishment of vertical shear.

ACKNOWLEDGMENTS

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APPENDIX

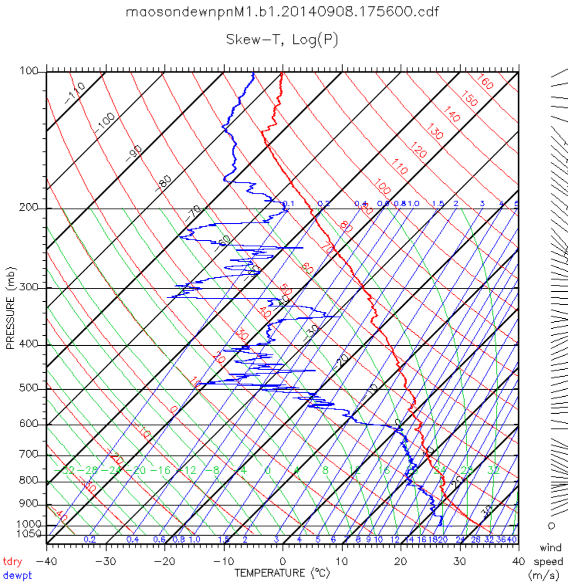

Figure 4 Skew-T 08-Sep-2014 17:56 UTC from Manacapuru Site (Manaus). Source: Atmospheric Radiation Measurement (ARM), U.S. Department of Energy,http://dx.doi.org/10.5439/1150270.