CHARACTERIZATION OF STORM PROPERTIES DURING THE TROCCIBRAS EXPERIMENT

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1. INTRODUCTION

The field experiment TroCCiBras (Tropical Convection and Cirrus Brazil) was conducted during the period of 22 January to 11 March 2004 in the central area of the State of São Paulo (Figure 1), with the objective to study the contribution of lightning-generated NOx (LNOX) from tropical convective storms to the already existing background NOx in the upper troposphere and lower stratosphere (UTLS). This was done in collaboration with scientists from two projects funded by the European Community, viz., TROCCINOX (Tropical Convection, Cirrus and Nitrogen Oxides Experiment) and HIBISCUS (a project on "Impact of tropical convection on the upper troposphere and lower stratosphere"). An overview of these three projects, the instrumentation and methods deployed, as well as some preliminary results have been presented by Held *et al.* (2004a). By combining and coordinating the available resources, it was possible to gather data, which not only characterize the storms, but also the atmosphere in which they occur. A variety of sensors, including two S-band Doppler weather radars, an elastic backscattering Lidar for aerosol profiling, up to 6 daily radiosonde ascents, two aircraft equipped for meteorological and chemical measurements, as well as a Lightning Detection Network, were deployed (Held *et al.,* 2004a, 2004b). Thus, a unique database for the State of São Paulo could be built up.

Until recently, the nowcasting capabilities of the IPMet radars were very limited once there was no objective procedure for the detection of severe storms and extrapolation of their evolution and movement. Through an on-going collaboration between the Meteorological Research Institute (IPMet) and the National Center for Atmospheric Research (NCAR), a specialized software package, TITAN (Thunderstorm Identification, Tracking, Analysis and Nowcasting; Dixon and Wiener, 1993) was made available to IPMet researchers. Generous assistance with the implementation of several specialized program routines was rendered by NCAR, in order to facilitate the input of raw data from IPMet's radars.

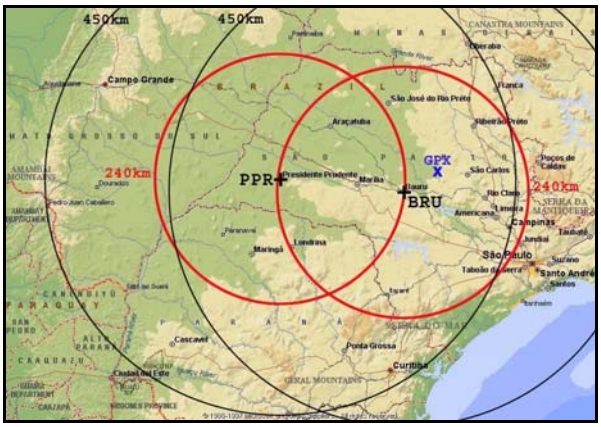

Figure 1. TroCCiBras Experiment Area, with IPMet´s Radar Network (BRU = Bauru; PPR = Presidente Prudente), showing 240 and 450 km range rings. GPX = Base for TROCCINOX research aircraft.

In this paper, only the characteristics of rainstorms monitored by the Bauru S-band Doppler radar in the central State of São Paulo (240 km range around Bauru) are being evaluated to determine the large-scale organization of these storms, their frequency of occurrences and spatial distribution, as well as their history of size and intensity.

2. DATA AND METHODOLOGY

The radar data, collected during the TroCCiBras Experiment, viz. from 22 January to 11 March 2004, was considered for the statistical analysis of the storm properties to characterize the convective activity during this period. In total, 27 days were included in the sample.

The S-band Doppler radar, from which the data was used in this study, is located in Bauru (Lat: 22°21'28" S, Lon: 49°01'36" W, 624 m amsl; Figure 1). It has a 2° beam width and a range of 450 km for surveillance and 240 km when operated in volume-scan mode, with a resolution of 1 km radially and 1° in azimuth, recording reflectivities and radial velocities. The radar data utilized for the analysis were collected in an automated operational mode, viz. 11 PPI scans

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from 0.3° to 35°, recorded every 7.5 or 15 minutes within the 240 km range.

TITAN, in its archive mode, was deployed as the objective storm-tracking tool. The TITAN track properties form the basis for this study. The program routine **Tracks2Ascii** extracts the radar data for each storm track for the specified time period, if a radar echo exceeds the reflectivity threshold of 35 dBZ and volume threshold of 50 km^3 for at least two volume scans (15 minutes). For all storms that meet the criteria, their properties, such as height, volume, area, intensity, velocity and direction, were determined.

3. CHARACTERISTICS OF STORM ECHOES OBSERVED DURING TROCCIBRAS

3.1 Horizontal Dimension of Radar Echoes

The relative frequency distribution of the radar echo areas (Figure 2) is a classification according to the horizontal scale of the storms observed by the Bauru Doppler radar during the period of the TroCCiBras Experiment in the mid-summer of 2004. It can be seen that the majority of storms, occurring during that period, was entirely convective in nature, with areas $\leq 10^2$ km^2 and only about 24% of the observed echoes accounted for larger ones, ranging from 10^2 – 10^3 km^2, most probably growing by merging processes. The presence of larger echoes, ranging from 10^3–10^4 km^2 in area, accounted for only 0.1% of the 27 days of analysis. The frequency distribution for the average storm volumes, as seen in Figure 3, confirms the predominance of small, isolated storm types.

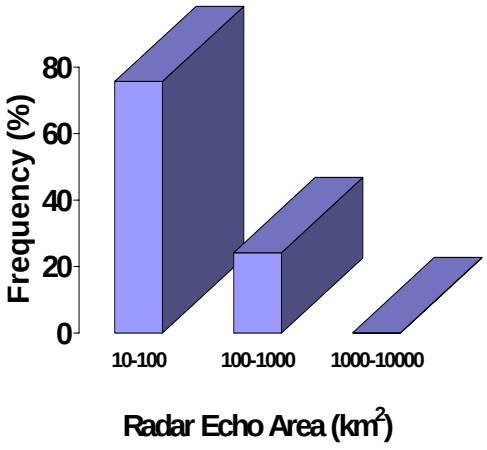

Figure 2. Frequency of storm area sizes observed during the TroCCiBras Experiment (≥35 dBZ, 50 km^3).

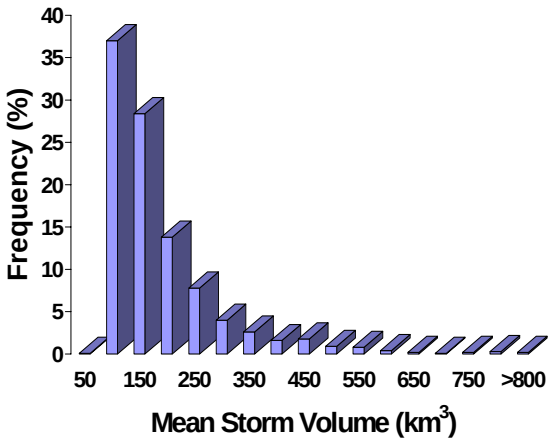

Figure 3. Frequency of storm volumes observed during the TroCCiBras Experiment.

Chaudry *et al.* (1996) have presented a statistical study of convective rainfall observed with the Bauru C-band radar, which preceded the S-band Doppler radar at IPMet, considering two uninterrupted rainy periods from October 1981 to March 1982 and October 1984 to March 1985, that had been selected at random from the Bauru radar records for their study. These areas were chosen as representative of the region of maximum monthly rainfall and a region with the maximum number of rain occurrences per month. In their study they have also established the average movement of the convective entities. The motion of the cells in terms of a frequency distribution of cell velocities has shown that the majority of them have speeds between 25 and 45 $km.h^{-1}$ and a lifetime of between 20 and 40 minutes.

It was found, that the majority of storm echoes during the analysis period of the current study was from D and C scales, using the classification by Houze and Chen (1977), which means they were predominantly from cumulus convection, but not exclusively, and also some from mesoscale scales.

3.2 Height of Storm Echoes

Echo height is a good indicator of storm development and severity. A frequency distribution of maximum heights of the 35 dBZ contour of the cells is presented in Figure 4. The mean value of maximum echo height was 7.1± 1.6 km amsl and about 64% of the observed storms have reached heights of between 6 and 8 km amsl, dropping off drastically towards the higher values, with only about 8% of the observed storms reaching heights between 12 and 15 km amsl. It should be noted here, that for case studies of severe storms, the term “echo top” usually refers to the maximum

height of the 15 or 10 dBZ contour, while in this case the 35 dBZ threshold was chosen to delineate the top of the echo cores.

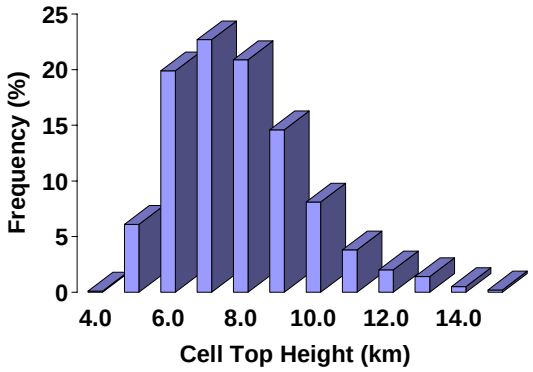

Figure 4. Frequency of occurrence of the maximum cell height (35 dBZ), for the storms observed during the TroCCiBras Experiment.

Another parameter that was calculated was the VIL Density, which is a measure of the Vertically Integrated Liquid water content normalized by the height of the echo top (Amburn and Wolf, 1997). The distribution of such a parameter had been previously determined, based on ten years of observations for the month of February, using the Bauru radar data (Gomes, 2002; Gomes and Held, 2004). The results were stratified according to storm severity. For the ten years, the VIL Density values obtained were:

- VIL_Dens <1.8 g/m^3 for non-severe storms;
- 1.8 < VIL_Dens ≤ 2.3 g/m^3 for severe storms;
- 2.3 < VIL_Dens ≤ 3.3 g/m^3 for extreme severe weather (confirmed by damage reports).

The predominant values for VIL Density for the duration of the 2004 experiment were between 0.4 and 0.8 g/m^3 (70%), which would fall into the non-severe type category of storms (Figure 5). VIL Densities of >1.8 g/m^3 occurred with very low frequencies (5%), indicating that the experimental period in 2004 was relatively dry. This is actually confirmed by the total of rain measured during February (162.3 mm) in Bauru (IPMet), which was about 20% below the climatological mean and distributed over only 13 days. On 5 days ≥10 mm were recorded, with the highest amount of rain (35.0 mm) having fallen on 07 February 2004.

In the context of this parameter it should also be added that during February 2004 at least one event, occurring on 27 February, could be classified as severe event, which was responsible for the destruction of several transmission towers from a Power Utility Company in the north-west of the State of São Paulo (300 km north-west of the BAU radar, thus outside the range of this study).

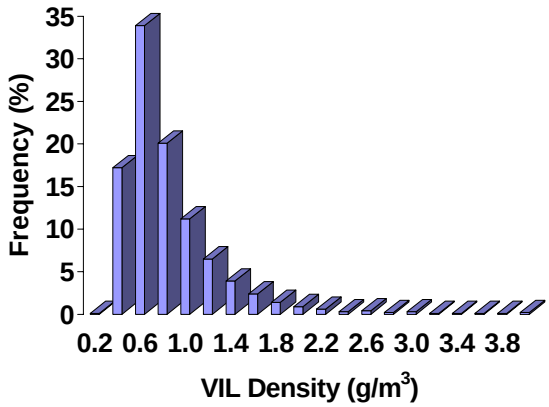

Figure 5. Frequency distribution of VIL Density observed during the TroCCiBras Experiment.

3.3 Duration of Storm Echoes

Each radar echo was identified and tracked by TITAN throughout its lifetime, based on the threshold selected for the identification of convective storms. Similar to the area, volume, and echo height characteristics, this method also yielded the frequency distribution of the echo storm duration for the study period. Figure 6 shows, that the majority of storms, which occurred during this period, was of short duration, viz., predominantly less than 2 hours (68%) and associated with echoes from the D scale (Houze and Cheng, 1977) or isolated type of convective storms.

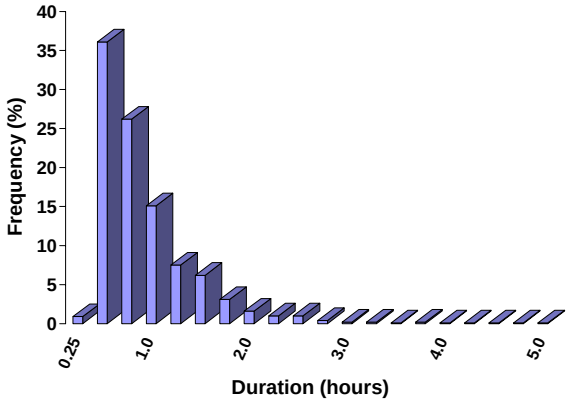

Figure 6. Frequency distribution of the duration of storm echoes observed during the TroCCiBras Experiment.

3.4 Storm Velocity and Direction of Movement

The frequency distribution of storm velocity and preferential direction of storm movement was also determined for the study period. The results are summarized in Figures 7 and 8.

These results highlight, that during the TroCCiBras Experiment, the average velocity of

73% of the observed storms varied from 5 to 20 km.h^{-1}, while the remaining 27% had speeds of between 25 and 70 km.h^{-1}. The overall average speed of cell displacement was 15 km.h^{-1}. The preferential direction of movement was from north-north-west and north-west.

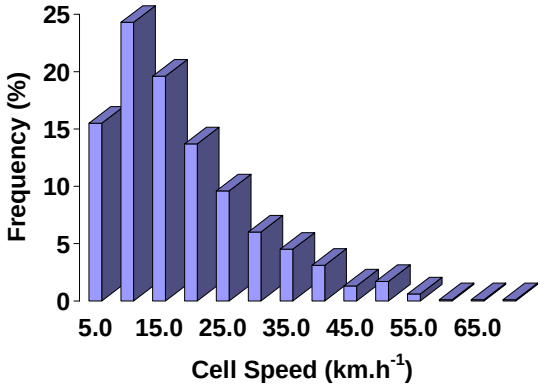

Figure 7. Frequency distribution of the cell speeds during the TroCCiBras Experiment.

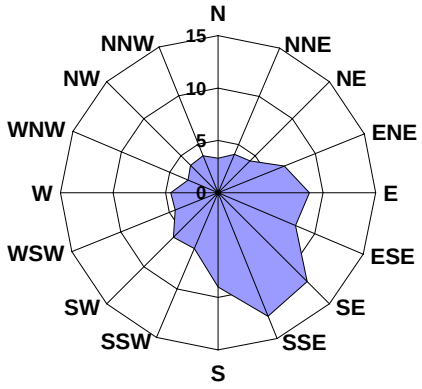

Figure 8. Frequency distribution of the direction of movement of storm echoes observed during the TroCCiBras Experiment.

Gandú (1984) has presented a statistical study of radar echoes for the eastern parts of the State of São Paulo using an S-band radar to describe the rainfall regime associated with large-scale circulation. He found, that storm cells in this region have a preferential movement from west to east with an average speed of 25 km.h^{-1}.

More recently, Held *et al.* (2005a, b) have confirmed, that severe storm events, including those spawning tornadoes, are characterized by cell speeds of >50 km.h^{-1}, amongst other typical features. Due to the relatively rare occurrence of severe storms, no preferential direction of cell movement could, as yet, be determined.

4. CONCLUSIONS

The deployment of the TITAN software, made available by the National Center for Atmospheric Research (NCAR), allowed for the first time to quantify all properties for the observed storms in the central area of the State of São Paulo.

Preliminary analysis has shown, that during the period of the TroCCiBras Experiment (22 January to 11 March 2004), a large percentage of the storms was small, with a mean volume of less than 500 km^3 and a duration of less than 2 hours, indicating a predominantly isolated convective activity, typical for the summer season in the central State of São Paulo. The 20% below normal rainfall was also confirmed by conventional rain measurements at IPMet. The VIL Density parameter has indicated the predominance of non-severe storms, although at least one severe event was reported during February 2004, but outside the range of this study. The mean maximum cell height was 7.1 $\pm$ 1.6 km amsl, for all storms identified by using a threshold of 35 dBZ, with some tops reaching up to 15 km height during the period. The distribution of storm velocities and preferential movement was mostly from north-north-west and north-west, with velocities ranging from 5 to 70 km.h^{-1} and an average speed of 15 km.h^{-1}.

This study will be continued, by considering other threshold settings and their impact on the regional storm statistics, as well as incorporating thermodynamic characteristics and radiosonde ascents made frequently during the TroCCiBras Experiment. Furthermore, other parameters, which have not yet been considered, such as the axis ratio of storm area, as well as the precipitation produced in association with the type of large-scale organization of the observed storms, will also be investigated. Thereafter, a complete climatological study for 10 years will be pursued, using observations from both Bauru and Presidente Prudente radars.

5. ACKNOWLEDGEMENTS

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