# SIGNATURES OF SEVERE THUNDERSTORMS FOR NOWCASTING IN THE STATE OF SÃO PAULO, BRAZIL

Gerhard Held[1], Ana Maria Gomes[1], Kleber P Naccarato[2] and Osmar Pinto Jr[2]

[1] Instituto de Pesquisas Meteorológicas, Universidade Estadual Paulista, Bauru, S.P., Brazil
gerhard@ipmet.unesp.br; ana@ipmet.unesp.br
[2] Grupo de Eletricidade Atmosférica, Instituto de Pesquisas Espaciais, São José dos Campos, S.P, Brazil
kleberp@dge.inpe.br; osmar@dge.inpe.br

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## I. INTRODUCTION

The Instituto de Pesquisas Meteorológicas (IPMet) of the Universidade Estadual Paulista has observed the three-dimensional structure of severe thunderstorms, including the radial velocities inside and near these storms, since 1992 and 1994, respectively, using two S-band Doppler radars in Bauru and Presidente Prudente, in the central and western part of the State of São Paulo (Figure 1). Criteria for the early detection of severe wind and hailstorms have been sought and are already, at least in part, incorporated in the real-time monitoring and alert system. However, research into the relationship between radar echoes and lightning discharges only commenced in 2004. Findings from two storm days with three confirmed tornadoes and two supercell storms within radar range are presented, using NCAR's (National Center for Atmospheric Research) TITAN (Thunderstorm Identification Tracking Analysis and Nowcasting; Dixon and Wiener, 1993) Software, which had been implemented at IPMet and adapted for local requirements in 2005/2006.

The ultimate goal of this study is to derive characteristic signatures, which could aid the nowcaster to identify severe weather and disseminate early warnings to Civil Defense Organizations, the electricity sector and the public.

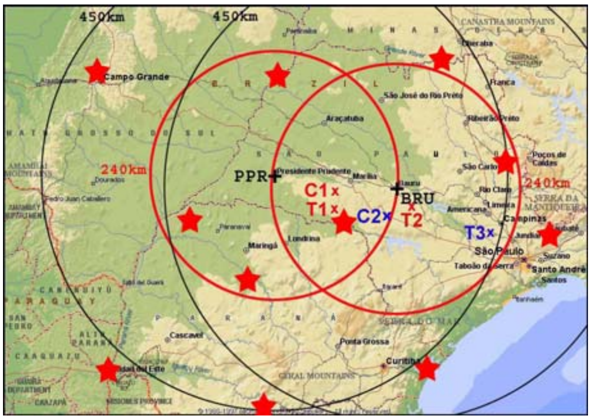


**FIG. 1:** IPMet's Radar Network (BRU = Bauru; PPR = Presidente Prudente), showing 240 and 450 km range rings. The areas where the tornadoes occurred are marked T1 (Palmital), T2 (Lençois) and T3 (Indaiatuba). C1 and C2 are severe storm cells moving on parallel tracks of T1 and T3, respectively. Lightning sensors are marked in red.

## II. METHOD

IPMet's radars have a range of 450km for surveillance, but when operated in volume-scan mode every 7.5 minutes it is limited to 240km, with a resolution of 1km radially and 1° in azimuth, recording reflectivities and radial velocities. In this study, the reflectivity threshold was set at 10 dBZ. The Brazilian Lightning Detection Network currently comprises 24 sensors in total (some are outside the area shown in Figure 1), with a detection efficiency of 80-90 % (CG = Cloud-Ground strokes only) and a location accuracy of 0.5-2.0 km (Pinto Jr., 2003).

TITAN produces a variety of important parameters for a chosen reflectivity and volume threshold throughout the lifetime of storms, such as Area, Volume, Precipitation Flux, VIL (Vertically Integrated Liquid water content), Maximum Reflectivity, Hail Metrics, speeds and direction of propagation, etc, per volume scan. It also has the facility to collocate flashes with the radar echoes, including a separation into positive and negative strokes.

## III. OBSERVATIONS AND RESULTS

Until recently, tornadoes were believed to be rather rare and exceptional events in Brazil, and very few radar observations had been available. The only Doppler radar observations of a tornado occurring in the State of São Paulo before 2004 were reported in Gomes *et al.* (2000). However, during May 2004 and 2005, three confirmed tornado-spawning storms and a supercell storm were observed in the State of São Paulo by IPMet's S-band Doppler radars. Since they occurred during the southern hemisphere autumn, the cells were not amongst the most intense in terms of radar reflectivity (50-60 dBZ) and their echo tops rarely exceeded 12 km, but they exhibited extremely strong radial velocities and rotational shear (up to $-5.0 \times 10^{-2} s^{-1}$), which initiated a cyclonic vortex in the center of the cells, spawning the tornadoes. One of the severe cells (C1) was classified as a supercell storm, based on its long life cycle of more than 8.5 hours (Figure 2). It had almost identical characteristics as its tornadic partner cell (T1), except for a Weak-Echo-Region.

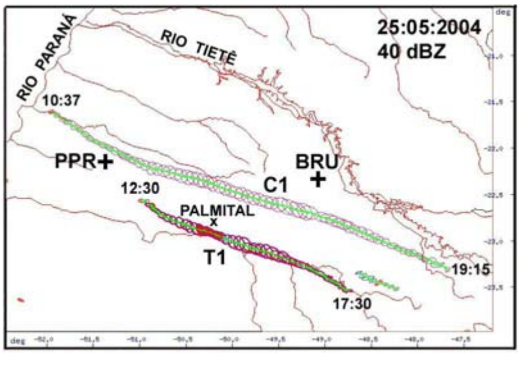


**FIG. 2:** Composite radar image, showing the tracks of 40 dBZ centroids of supercell C1 and tornadic cell T1 (Palmital) on 25 May 2004. Times of first and last detection in local time (LT). Not all simultaneous tracks are shown. Red centroids indicate the confirmed tornado touch-down.

Conventional Doppler radar observations had already identified cell motion of >50 km.h$^{-1}$, VIL (Vertical Integrated Liquid water), Weak Echo Regions, hook echoes (Markowski, 2002) and strong rotational shear as good indicators of possible severe storms in Southeast Brazil, including tornadoes (Held *et al.*, 2005). However, TITAN yields the temporal history of many severe storm indicators along all cell tracks, providing valuable signatures for Nowcasting. When subjected to TITAN analysis, the supercell revealed much greater severity parameters (VIL=70.6 kg.m$^{-2}$, MAX-Z=≥60 dBZ, VOL = 500 to >1000km$^3$ sustained for four hours; Figure 3), than the tornadic cells, but no reports of damage or the formation of another tornado were received. The temporal evolution of VIL values shows a rapid decrease close to the time of the observed destructive winds at ground level (e.g., tornado touch-down; T3, Figure 4), but the highest values of VIL were not necessarily observed close to the time of the tornado touch-down.

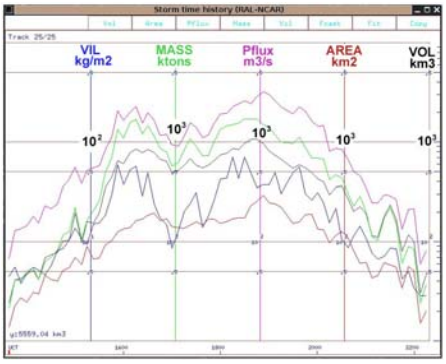


**FIG. 3:** 25 May 2004: Storm Time History of supercell C1 from 10:45 – 19:15 LT.

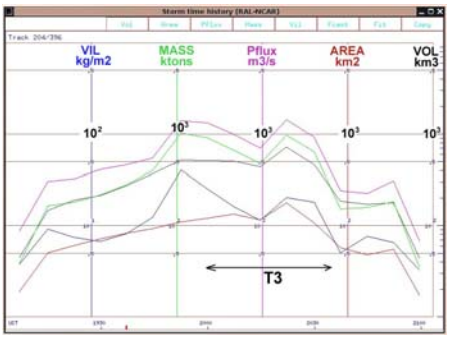


**FIG. 4:** 24 May 2005: Storm Time History of tornadic cell T3 during the second half of its life time (16:08 - 18:00 LT).

Analysis of lightning records, superimposed on radar images indicated a preferential location of CGs around or ahead of the core of tornadic cells, while in the supercells the CGs were observed within and around the core and with greater frequency. Lightning activity almost ceased shortly before the touch-down of the tornadoes (Figure 5), which is in agreement with observations of tornadoes and supercell storms in Oklahoma (Rison *et al.*, 2005). No significant differences of lightning parameters (peak current, multiplicity, polarity) were found for the tornadic and non-tornadic cells. However, flash polarity seems to be a good discriminator between mature convective cells and stratiform rain regions, with the latter producing only few and mostly positive flashes, while even slowly decaying convective cells may still generate large numbers of flashes, but an increasing portion is positive.

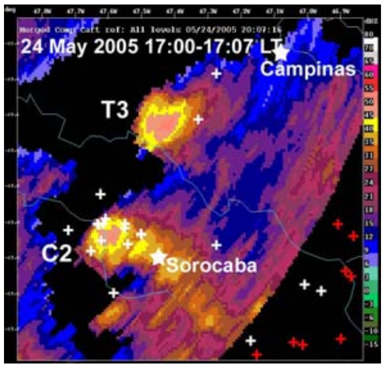


**FIG. 5:** 24 May 2005: Position of CG strokes (+ negative; + positive) relative to the echo core of storm T3 during the tornado activity, as well as for supercell C2, during a 7.5 min interval.

## IV. CONCLUSION

TITAN radar products are already operationally available to IPMet's meteorologists in real time, but mechanisms and algorithms still need to be developed for an automatic alert system. If high-resolution lightning data were also available in real time, they could be integrated into the radar images, yielding a powerful Nowcasting system, with vast benefits, not only for Civil Defense Authorities and the public, but for the agricultural and electricity sectors.

## V. ACKNOWLEDGMENTS

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