# P15R.15 YES, WE DO HAVE TORNADOES IN SAO PAULO, BRAZIL. FROM MESOSCALE MODELS TO THE RADAR REFLECTIVITY POINT OF VIEW

Wando Celso Maugeri Amorim* , C.A. Morales, R.I. Albrecht and R.M. Rosa
University of Sao Paulo - SP - Brazil

## 1. INTRODUCTION

Two meaningful events in the State of Sao Paulo have captured our attention early in the nineties. On September 30 of 1991, a severe thunderstorm at the Itu county area killed 15 people besides almost 200 injuries as shown by Massambani et al. (1992). Though no death has taken place, the least violent storm that was formed over the Sao Paulo Metropolitan Area (SPMA) in 26 of April of the same year, also caused similar destruction according to Silva Dias and Grammelsbacher (1991).

The similarities between both cases are not restricted to the violence, in spite of geographically different regions. People reports point to the presence of funnel clouds. Meantime, some of the destruction patterns point to the existence of another phenomenon of equal violence, the microburst. Then in both cases, the same question was not answered: had the tornado taken place or were they treating as cases of microbursts?

Besides the fact of the tornadoes are of difficult forecasting and detection, even where they happen more frequently as in the tornado alley in the USA, for the Brazilian cases only geopotential analyses, soundings and rudimentary radar data were available. Then, in those situations, even with strong signs, the presence of tornadoes could not be confirmed.

Video recorders taped more than ten years later, new cases. These events were registered, but were the available tools nowadays in the State of Sao Paulo able at least to detect the phenomena?

This is the main question of this work, which intends to analyze the synoptical and mesoscale situation besides the reflectivity radar data of both cases in search of signs that could confirm the presence of the tornadoes. Finally, we present a short discussion on the possible investments that might be done for the upgrades on forecasting and detecting them.

## 2. THE TORNADOES

On December 10 of 2000, about the noon, a tornado of small intensity (F0) was registered in the eastern zone of the city of Sao Paulo. Besides his weak intensity, it was of very short duration, just pulling out some tiles. It did not cause any death, even registering few minor injuries. On May 24 of 2005, at 5:30 p.m., a possible F3 tornado was fully recorded in Indaiatuba City. It touched the ground at the industrial park in that city which is around 90-km northwest of the Sao Paulo City. The figure 1 shows the pictures from those tornadoes.

*Corresponding author address: Wando Amorim, University of Sao Paulo, Rua do Matão, 1226, Cidade Universitária, Sao Paulo SP, Brazil, CEP 05508-090
e-mail: amorim@model.iag.usp.br

While the first one almost did not even take the funnel shape, according to several moments of the second tornado video it was possible to notice the presence of multiple-vortex pattern. Their damage signatures also were different. While the first one just pulled out some tiles and knocked down some small bushes, the second one lifted cars from the ground.

## 3. THEIR ENVIRONMENTS

Using the CPTEC (Center for Weather Forecast and Climatic Studies) global model, synoptical and mesoscale analysis were extracted, using the 12 GMT analyses for both cases.

On December 10th of 2000, the trough line that was previously over the Santa Catarina State, suddenly moved to the northern coast of the Sao Paulo State. The low-pressure system was presenting signs of occlusion with a 985 hPa center (45S35W), moving to northeast. In a few hours the winds changed from south to southeast, perpendiculars to the coast. In the north of the state, the winds were blowing from north and northwest due to the high pressure system of the Brazil northeast region, also known as “Atlantic high”. The opposite winds converged over the SPMA.

While in the first case the affected area was just behind the frontal system, on May 24th of 2005, the State of Sao Paulo was just ahead the cold front, with southward winds. Those winds were resultant from the predominant Atlantic high pressure system with a 1025 hPa center (35S25W). Besides being on the pre-frontal area, a depression line can be seen in the northwest portion of the Atlantic high. For the initial overview, this depression also known as a “little trough” inside the high is an indicator of possible storms coming. The figure 2 shows the South America sea level pressure and the wind at 850 hPa at 12 GMT for both cases.

Two important aspects collaborating so that these events were differentiated in terms of environment of the thunderstorms are the topography and the location of two regions. Located near the Atlantic Ocean, the city of Sao Paulo (black x) is enclosed by mountains and valleys, while the city of Indaiatuba (white x) is among a plain region, which is also more favorable to the tornado formation as shown in the figure 3.

Some of convective indicators were evaluated in order to compare those events. Two of the most useful parameters are the vorticity advection in middle levels and the dew point surface combined to the low level mixing ratio. They analyze respectively the vertical rising or descending movements and the availability of moisture in the environment of the storm as shown in the figure 4.

It is very clear that the atmosphere in the second event is more unstable. The negative vorticity advection just over the Indaiatuba City area suggests instability for strong updraft initiation, while in the first case the unstable areas are north of the SPMA which is under weaker vertical flows. Simultaneously, in the second event, the dew point temperature at the surface is 2 degrees higher than in the first one. This difference combined to the mixing ratio at 1000 hPa (7g/kg in the first case against 19 g/kg in the second one) shows the largest support for the thunderstorms life cycle over the Indaiatuba City.

One of the most used parameter determining thunderstorms is the convective available potential energy (CAPE), expressed in J/kg as shown in the figure 5. The CAPE indicates how much severe the storm might be if it was not inhibited by other factors just like the subsidence in the predominant large scale for example. The calculated CAPE for the first tornado was 1004 J/kg while in the second tornado it was 1597 J/kg.

Differently from Indaiatuba, where the significant phenomenon during the storm was only the tornado, in the Sao Paulo City case, there was register of wind gusts. Those might have been caused by microbursts that can be better understood if we look at the analyses of moisture divergence in the 700 hPa level.

In an environment of storms, with the reasonably dry atmosphere in that level, the process of evaporative cooling produces a downward current, also known as entrainment. The figure 6 shows the moisture divergence field at 700 hPa for both environments. Those fields show one of the clearest differences between the tornado environments. The atmosphere in that level was drier in the first case in Sao Paulo favoring the formation of penetrative downdrafts (Amorim et al. 1997).

## 4. THE RADAR REFLECTIVITY

The Salesopolis radar from the Hydraulic Technological Center Foundation (FCTH) has 3 different settings: 0.5km x 0.5km up to 60-km range, 1.0km x 1.0km from 60-km to 120-km range and finally 2.0km x 2.0km from 120-km to 240-km range. Its geographical coordinates and main characteristics are shown in the table 1 below.

Table 1: Salesopolis radar characteristics.

| Characteristics | Radar |
|---|---|
| Latitude ( º ) | -23 36 00 |
| Longitude ( º ) | -45 58 20 |
| Altitude (m) | 925 |
| Beam width ( º ) | 2.1 |
| Antenna diameter (m) | 3.6 |
| Antenna elevations | 20 |
| Scanning cycle (minutes) | 5 |

A 3D box was built over the State of Sao Paulo (Amorim and Morales, 2005), herein named 3D-PPT, where the reflectivity data was processed. This grid has the following vertical resolution:

- 0.5 km spacing from 1.5 km up to 7.0 km height;
- 1.0 km spacing from 7.0 up to 20.0 km height.
- The horizontal resolution is 2km x 2km.

Comparisons using the reflectivity factor from both tornado cases to another examples of severe storms without the presence of tornadoes are presented in the figure 7. Using the methodology purposed by Machado et al. (1998) to classify the convective storms, it is clear that the storm life cycle as function of the maximum size and the growing rate are so different that they could be explored and used as decisive parameters for a tornado warning system. In the tornado cases (7a and 7b), besides life cycles shorter than for the non-tornadic storms (7c), they best fit to smaller cells. Using the same analyses, the tornadic storms growing rate are practically twice than the non tornadic storms.

## 5. SUMMARY

The available tools are not appropriate for studying tornadoes in Brazil. Even the Doppler radars, which are already running, do not have accuracy enough because of their characteristics as the beam-width.

On the other hand the Sao Paulo State Research Agency (FAPESP) is investing in its new large project for an integrated hydrometeorological system named SIHESP. This system will install remote surface weather stations all over the state. It will also count on a mobile X-band Doppler radar. This will be a very important step in the severe storm research for the Sao Paulo State

## 6. ACKNOWLEDGEMENTS

This work would not be possible without the support from the Sao Paulo State Research Agency (FAPESP). We are also grateful to the Department of Atmospheric Sciences from the Institute for Astronomy, Geophysics and Atmospheric Sciences from the University of Sao Paulo as well as all the researchers who have contributed for this project. Our special acknowledgements to the FCTH by the data for this research.

## 7. REFERENCES

Amorim, W.C.M. and C. A. Morales, 2005, Storm-tracking and thunderstorms nowcasting for Sao Paulo State, Brazil, *32nd Conference on Radar Meteorology (CDROM)*, Albuquerque, NM.

Amorim, W.C.M., O. Massambani, I. Zawadzki, 1997: An Evaluation of the Predicted Pulse-Type Thunderstorm Gusts using Horizontal Divergence Field from Doppler Radar Data, *28th Conference On Radar Meteorology*, Austin, TX, USA, 378-379.

Massambani, O., L. M. V. Carvalho, M. A. Vasquez, 1992, Tornado ou microburst? Um diagnóstico por radar do caso de Itu, *VII Congresso Brasileiro de Meteorologia*, pp. 763-768.

Silva Dias, M.A.F. da, E.A. Grammelsbacher, 1991: A possível ocorrência de tornado em Sao Paulo no dia 26 de abril de 1991: Um estudo de caso., *Brazilian Meteorology Magazine*, **6**, 513-522.

Toledo, L.A.M., W. B. Rossow, R. L. Guedes, A. W. Walker, 1998, Life Cycle of Mesoscale Convective Systems over the Americas, *Monthly Weather Review*, 126, pp. 1630-1654.

**8. FIGURES**


Figure 1. The Sao Paulo F0 tornado (left) and the Indaiatuba F3 multiple-vortex tornado (right).

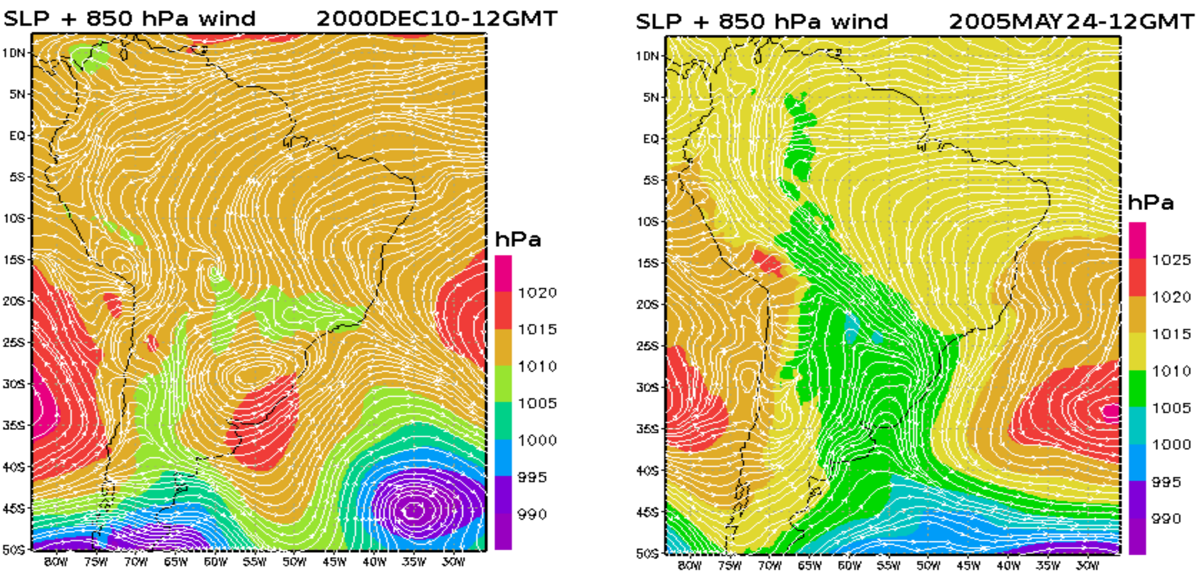


Figure 2. Sea level pressure and the wind at 850 hPa, 2000 case (left) and 2005 case (right).

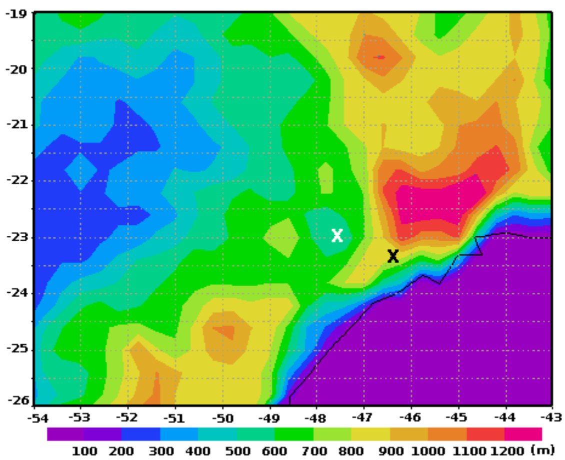


Figure 3. Topography of the Sao Paulo State.

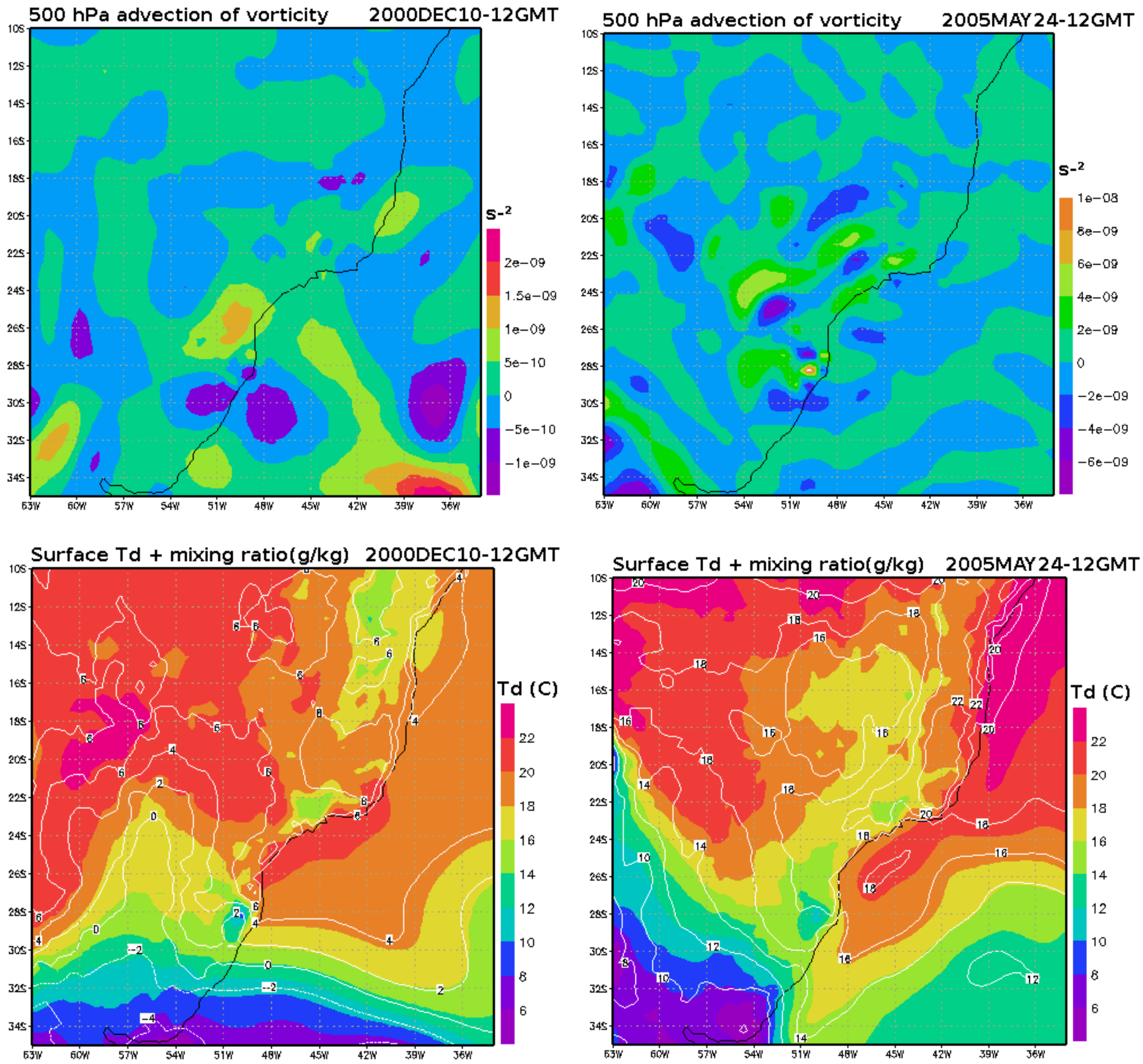


Figure 4. Advection of vorticity at 500 hPa (above) and the dew point temperature ate the surface combined to the mixing ratio at 1000 hPa level (below), 2000 case (left) and 2005 case (right).

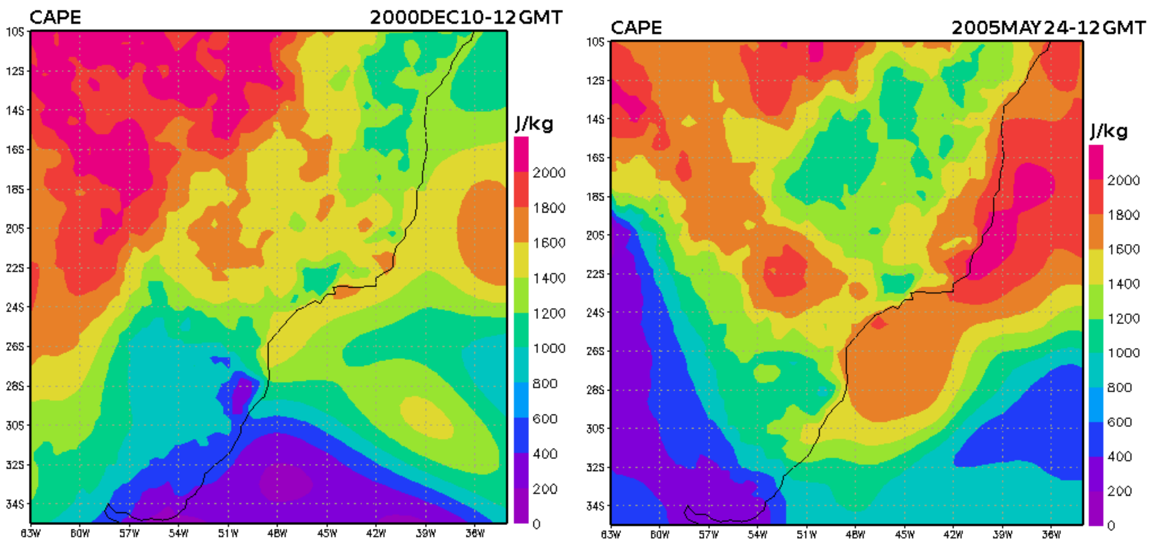


Figure 5. Severe storm chances indicated by the CAPE, 50% higher for the 2005 event (right) than for 2000 event (left).

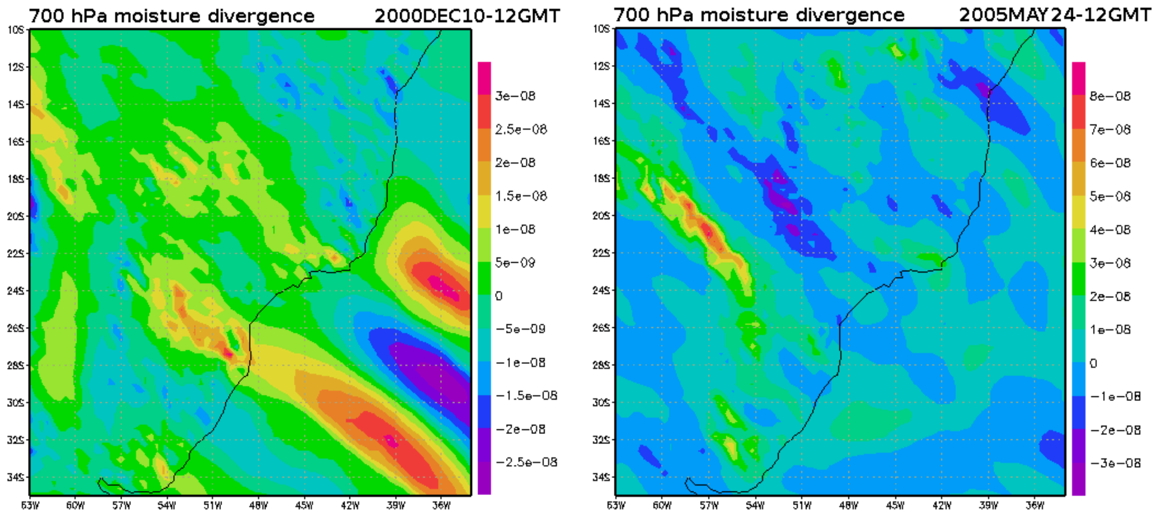


Figure 6. Moisture divergence at 700 hPa level for cases, Sao Paulo (left) and Indaiatuba (right).

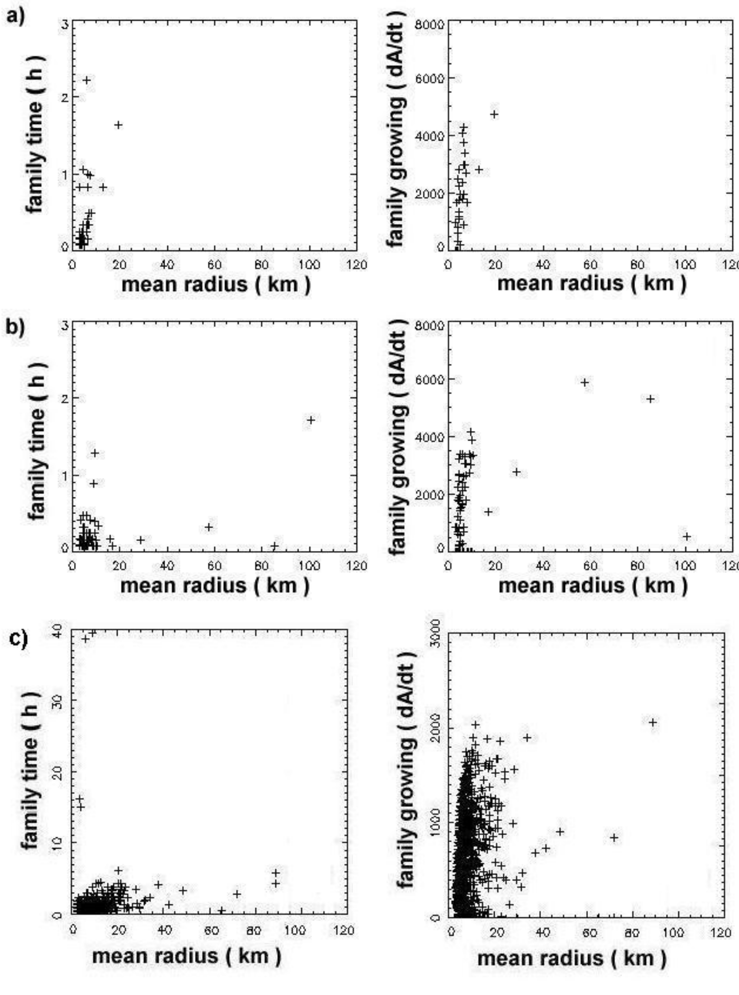


Figure 7. Families of convective cells time duration and growing in function of their mean radius. The 7a) indicates the tornado case of 2000, 7b) for the tornado case of 2005 and the 7c) for non tornadic storm cases of 2003.