FORECASTING SEVERE WEATHER OCCURRENCES IN THE STATE OF SÃO PAULO, BRAZIL, USING THE MESO-ETA MODEL

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I. INTRODUCTION

Severe storms in Southeast Brazil frequently cause enormous damage to agriculture, urban areas, industries, as well as loss of many lives, due to strong winds (relatively frequent microbursts and occasional tornadoes), hailstones, intense lightning and flash floods, resulting in many millions of US Dollar damage annually. Efforts had been concentrated on identifying specific signatures during severe storm events (Gomes *et al*., 2000, Held *et al*., 2001, 2005), which could be used as indicators of storm severity, as well as to develop algorithms for short-term predictions. However, it is of equal importance to develop an effective alert system for the occurrence of such severe events, ranging from a couple of days (based on model outputs) to 30 min to three hours ahead (nowcasting, using radar information).

The Meteorological Research Institute (IPMet) of the São Paulo State University (UNESP), based in Bauru, operates two S-band Doppler radars for continuous precipitation monitoring (Figure 1), which provide an ideal tool for testing the model capabilities in terms of the accuracy of predicted parameters, as well as the most reliable time range. Both radars have a 2° beam width and a range of 450 km for surveillance (0.3° PPI every 30 min), but when operated in volume-scan mode every 7.5 or 15 minutes it is limited to 240 km, with a resolution of 1 km radially and 1° in azimuth, recording reflectivities and radial velocities.

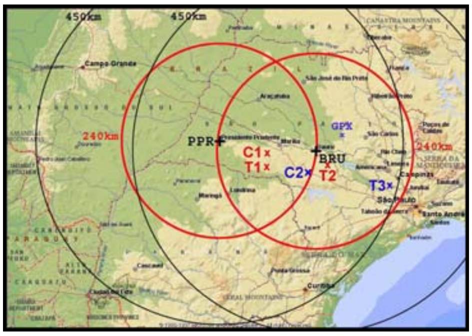

FIG. 1: IPMet's Radar Network (BRU = Bauru; PPR = Presidente Prudente), showing 240 and 450 km range rings. The areas where the tornadoes and the supercell storms occurred are marked as T1, T2 & C1 (25/05/2004) and T3 & C2 (24/05/2005).

II. METHOD

The operational Eta model (Black, 1994) is run by CPTEC (Center for Weather Forecast and Climatic Studies) twice daily (00 & 12 UTC) for the South American continent and initiated with the NCEP analysis (resolution T126L28; ca 100x100 km). On the boundaries it is updated with the CPTEC Global Model forecasts. The output has a resolution of 40x40 km, for every 6 hours up to 168 hours ahead. The Meso Eta model (Staudenmaier, 1996), running in non-hydrostatic mode, is also initialized with the NCEP analysis, but the boundary conditions are updated with the CPTEC Eta operational model (resolution 40x40 km). Its domain is 1300x840 km and can be centered over any point. Output resolution and intervals are variable (up to 96 h).

IPMet, in collaboration with CPTEC, runs the Meso-Eta model, centered over the Bauru radar, twice daily with a temporal resolution of 3 hours up to 48 hours (due to computer limitations) and a grid spacing of 10x10 km, in a non-operational research mode (Held and Gomes, 2003). A powerful server has been purchased recently and some of the output routines have been upgraded. Thus, both case studies will be re-run on the new machine, with a grid resolution of 12x12km, an improved topography (increased from 4 to 10 levels) and up to 60 hours forecasting period. Another new feature introduced now, is that the instability parameters and vertical profiles (Skew T – Log P) are being calculated from the first level above the height of the grid point, instead of starting at 1000 hPa, irrespective of the ground elevation.

III. SYNOPTIC SITUATION

Several storms, associated with areas of strong convective activity created by the passage of a baroclinic system with strong convective instability and vertical wind shear, had been observed by the radars on 25 May 2004 and 24 May 2005, respectively. Since both cases occurred during the southern hemisphere autumn, these cells were not amongst the most intense in terms of radar reflectivity (50-60 dBZ) and their echo tops rarely exceeded 12 km.

It is noteworthy, that on 24 May 2005, widespread pre-frontal rainfalls occurred over the southern parts of the State of São Paulo. Embedded nuclei of extremely intense precipitation were accompanied by strong winds, and at least one of the cells spawned a multiple-vortex tornado with F3 intensity on the Fujita scale, so far the most intense tornado observed in the region. More detailed descriptions of the synoptic situations and the damage caused by the tornadoes on both days can be found in Held *et al.* (2004 and 2005).

IV. MODEL RESULTS FOR 24 MAY 2005

Although the analysis of the model runs will be presented for both tornado days, viz. 25 May 2004 and 24 May 2005, due to space constraints, only some selected outputs from the 2005 case study are included in this abstract.

The model, initialized on 23 May 2005, 00UT, already predicted the incoming baroclinic system for the afternoon of 24 May 2005 (12:00, 15:00, 18:00 LT) quite accurately in various fields of variables, viz., CAPE, divergence and airflow at 300 hPa, K-index, humidity convergence at 850 hPa and also Omega (uplifting motion) above 850 hPa. It is especially noteworthy, that the region around Indaiatuba, where the severe tornado would occur

(T3 in Figure 1), was already indicated for the development of severe storms in most of the predictants (e.g., CAPE at 18:00 around 1200 $J.kg^{-1}$, with a nearby maximum of ≤1800 $J.kg^{-1}$), but especially the 300 hPa divergence and the 850 hPa humidity convergence fields, as well as the Omega at 500 and 300 hPa.

Since no radiosonde data are available from Bauru for this day and the nearest stations are São Paulo, Curitiba and Campo Grande, vertical "radiosonde" profiles were derived from the model for Bauru, Indaituba (T3) and Iaras (C2) from runs initiated up to 48 h ahead of the severe storms.

The 42-hour forecast profile for Bauru 12 UT (09:00 LT) agrees reasonably well with the one generated by the "analysis" data for the same time, indicating a good forecast. In order to verify the vertical profiles generated by the Meso-Eta model for Indaiatuba, the 36-hour predicted sounding (09:00 LT), was compared with the actual radiosounding from São Paulo at 09:00 LT (12UT), which is only about 85 km south-east from where the tornado occurred. Both temperature and the wind direction profiles agree remarkably well, including a marked wind shear at around 800 hPa.

Figure 2 shows the sounding predicted for 15:00 LT at Indaiatuba, about two hours before the tornado was observed (17:00 – 17:35; Held *et al*., 2006) with an anticipated CAPE of 2199 $J.kg^{-1}$. In contrast, the prediction for Bauru, based on the same model run, was only 896 $J.kg^{-1}$, and no severe storms occurred there.

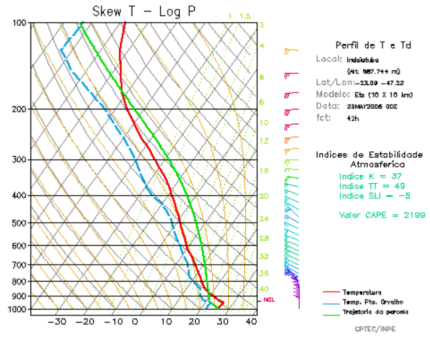

FIG. 2: Vertical sounding profile generated by the Meso-Eta model for Indaiatuba, 24 May 2005; 42-h forecast for 15:00 LT, initiated on 23 May 2005, 00UT.

CAPE values on mid-summer days with average-type convective activity in the State of São Paulo are in the range of 1000-2000 $J.kg^{-1}$. Considering that 24 May is already in the middle of autumn, with generally less energy being available for convection, then certainly predicted values of CAPE >2000 $J.kg^{-1}$ must be considered as a reasonable warning signal for extreme events.

Accumulated radar rainfall in 3-hourly intervals was calculated for ≥1 mm from composite radar images (PPR + BRU), using the Marshall-Palmer Z-R relationship. The model predicted very well from 09:00 LT (when the system entered into the radar range of PPR) until 03:00 the next day. Thereafter, the model did not move the rain areas fast enough towards north-east, thus underestimating the rainfall in the north-east of the State and overestimating it in the western parts. Figure 3 shows 3-hourly accumulated rainfall as observed by the radars for the period 15:00 to 18:00 LT and the 45-hour prediction of the Meso-Eta model for the same period, using the same scales for rainfall.

V. CONCLUSION

The objective of this study was to determine the capability of meteorological models to predict the possible occurrence of severe weather events in a specific region up to two days ahead, thus considerably extending the nowcasting scale, which ranges from 30 min to 3 hours and is mostly based on radar observations. This is extremely important for issuing general warnings to the public in the State of São Paulo. The severe storms observed on 25 May 2004 and 24 May 2005 by the Bauru radar provided an ideal opportunity to test the forecasting ability of the Meso-Eta Model, which appears to perform best with most predictants, including accumulated radar rainfall, for periods of around 48 hours ahead.

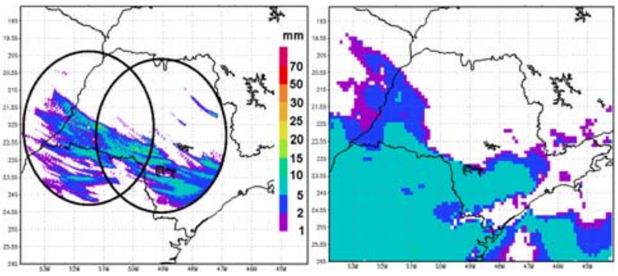

FIG. 3: Three-hourly accumulated rainfall on 24 May 2005 for the period 15:00–18:00 LT (intensive storm activity). *Left:* Radar observations (radar ranges 240 km); *Right:* 45-hour Meso-Eta forecast.

VI. ACKNOWLEDGMENTS

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