Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, INPE, p. 2085-2088.

AN ANALYSIS OF THE SYNOPTIC FORCINGS OF THE 28 APRIL 2001 SEVERE STORM GENERATING A TORNADO AT RESISTENCIA

Marcela M. Torres Brizuela*(1), Matilde Nicolini(1), Bibiana Cerne(1) and Norma Possia(1).
(1) Centro de Investigaciones del Mar y la Atmósfera (CONICET-UBA) - Departamento de Ciencias de la Atmósfera (FCEyN-UBA), Argentina
* brizuela@at.fcen.uba.ar

1. INTRODUCTION

A thunderstorm generating a tornado F2 (Fujita scale), developed during the afternoon (≈19:30 UTC) of 28 April 2001 over the area of Resistencia (27°27' S, 59°03' W), Province of Chaco, Argentina. On this day strong damages occurred in the area around Resistencia city, but also strong winds were detected at Corrientes city located in the other side of the Paraná river.

In order to identify the synoptic-scale forcings of this strong convective event a detailed analysis of the atmospheric patterns is addressed in this paper. The recognition of the synoptic forcings give support to the methodology used to initiate the ascent in a convective model that simulates the evolution and structure of this particular tornadic event (Torres Brizuela and Nicolini, 2006).

2. DATA AND METHODOLOGY

The synoptic analysis is done using the operative analysis fields of the Global Data Assimilation System (GDAS) from the National Oceanic and Atmospheric Administration/ National Center of Enviromental Prediction (NOAA/NCEP). These fields have an horizontal resolution of 1°, 26 vertical levels and every 6 hours. Upper-air observations, satellite images and the hourly surface data at Resistencia and Corrientes airports (Argentina National Weather Service) are used to identify the convective area and to characterize the thermodynamic structure, the potential source of convection and the severe winds at the surface.

3. RESULTS OF THE SYNOPTIC ANALYSIS

The radiosounding launched at Resistencia at 12 UTC presented a moderate CAPE (2246 J kg^{-1}) with a mid-level dry layer and a slight anti-clockwise curved hodograph favoring supercellular type convective growth (Figure 1). On this particular date (28 April 2001), the maximum surface wind at Resistencia attained 25 ms^{-1} while at Corrientes 18 ms^{-1} was reported with a time lag of 15 minutes.

Before the tornado outbreak, cold cloud top temperatures in the infrared satellite images displayed a narrow frontal band with a broken structure, similar to a "rope cloud" (see Fig. 2). Close to the time of the tornado event and near Resistencia, the satellite images exhibited a small area with colder temperatures indicating deep convection (see Fig. 2).

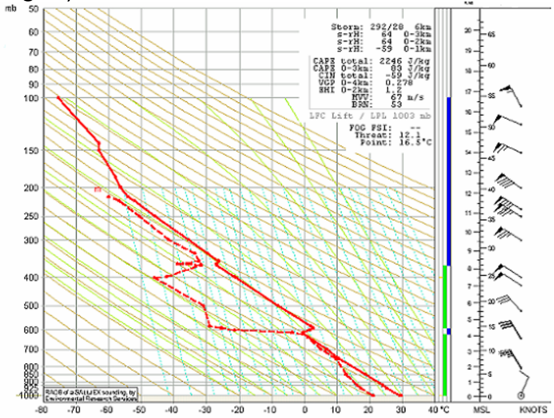

Figure 1: Radiosounding at Resistencia, 12UTC

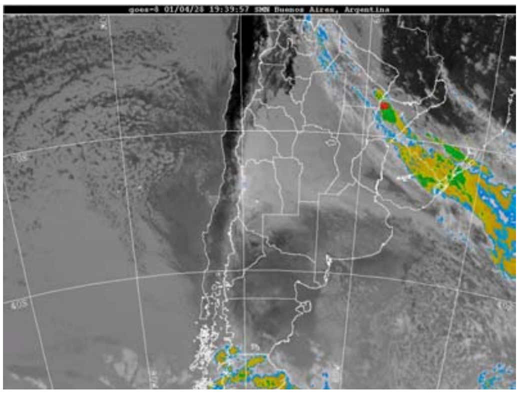

Figure 2: GOES Infrared satellite image, 19:39 UTC.

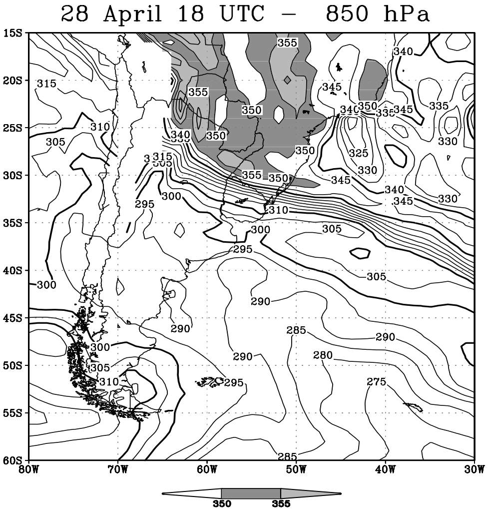

Figure 3: Θ_{ae} field at 850 hPa level (K, shaded area exceeds 350 K)

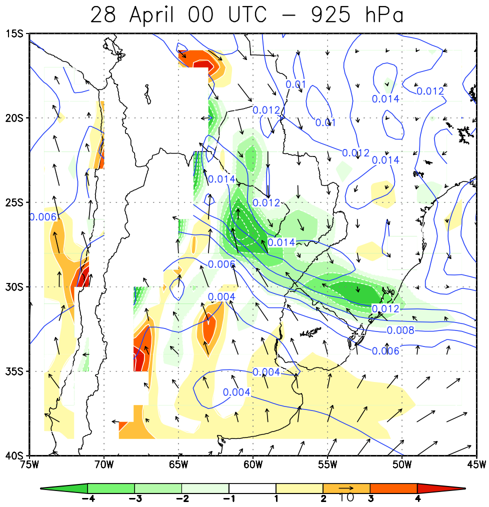

Figure 4: Divergence flux field at 925 hPa (x10^5 s-^{1}, shaded), water vapor ratio (g g^{-1}, blue lines) and superimposed the wind vectors.

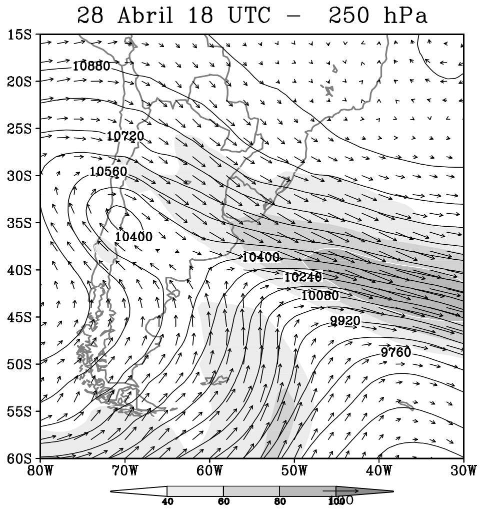

Figure 5: Geopotential height field at 250 hPa (mgp, black lines), wind vectors, and isotachs shaded for speeds exceeding 40 m s^{-1}.

Since 00UTC to 18UTC (28 April 2001) GDAS fields exhibit a cold frontal zone with a very slow displacement and oriented in the NW-SE direction, approaching the region nearby Resistencia at 18 UTC.). It is worth to mention that since 00UTC till 12 UTC the wind speed field and the location of the maximum fulfill the Chaco jet events (CJE) criteria (Salio et al., 2002). At this time, the Θ_{ae} field at 850 hPa level shows an intense warming effect to the north of Resistencia (Θ_{ae}>355 K). These values of Θ_{ae} are similar to those obtained in Salio et al. (2002) for the CJE composite for this variable. A strong horizontal gradient in Θ_{ae} delimits the frontal zone (Figure 3). Beneath this level (925 hPa), the presence of this cold front is also evidenced by an across the front cyclonic shear (Figure 4) and in the tight gradient in the water vapor ratio field which in the area surrounding Resistencia maximizes with values greater than 14 g kg^{-1}. This maximum is in concert and colocated with the convergence field along an elongated maximum (- 3x10^{-5} s^{-1}, Fig. 4). A maximum wind in the upper levels is located at 250 hPa (Figure 5) leaving Resistencia in the anticyclonic side at the entrance of an upper tropospheric jet stream. The convergence field at low levels coupled with the divergence associated with the upper jet stream provides the dynamical forcing for the convective development in the area. The anti-clockwise curved hodograph with high values of shear favors a supercellular mode on the left flank of the initial direction of motion of a simulated convective storm that reproduces this severe event (Torres Brizuela and Nicolini, 2006). Since 00UTC to 18 UTC the wind field exhibited an anti-clockwise turning (strong northerlies at 12 UTC at 925 hPa backing to weaker northwesterlies, as the frontal zone became close to Resistencia).

water vapor continuity equation (1)

$$\frac{\partial q}{\partial t} = \underbrace{-\nabla .(qV_H)}_{1} - \underbrace{\frac{\partial (q\omega)}{\partial p}}_{2}$$

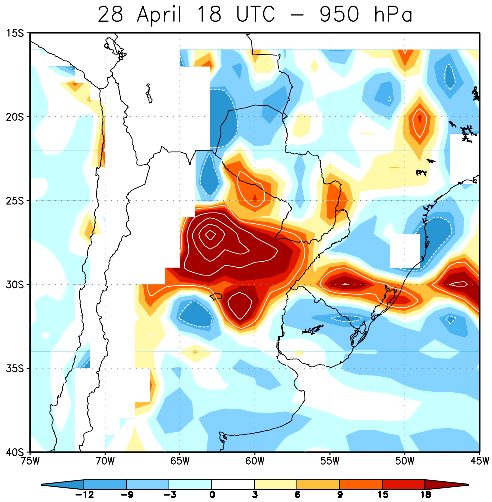

Figure 6a: Contribution to the water vapor mixing ratio tendency at 950 hPa, given by the first term **(1)** in the water vapor continuity equation (x10^8 g g^{-1}, shaded).

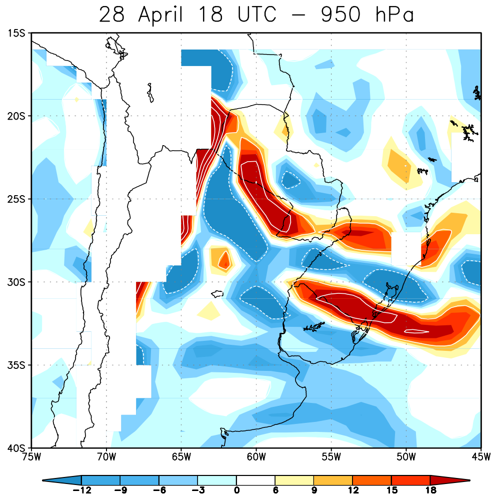
28 April 18 UTC – 950 hPa

Figure 6b: Contribution to the water vapor mixing ratio tendency at 950 hPa, given by the second term **(2)** in the water vapor continuity equation (x10^8 g g^{-1}, shaded).

In order to explore the processes that could precondition the environment, building up a gradual destabilization in the surrounding area of Resistencia, it is interesting to analize the advections of temperature and water vapor in a level near the surface (950 hPa). The different terms in the water vapor continuity equation are diagnosed with the assumption that neither evaporation nor precipitation was present in the area at 18 UTC. Both terms of this equation contribute in the same positive sense in the area, but the horizontal moisture flux convergence overwhelms in one order of magnitude the vertical component (compare Fig. 6a with 6b). In terms of temperature advection at low-levels within the area, this process is more apparent at 700hPa, with a rough compensation between horizontal and vertical terms in the thermodynamic equation assuming no diabatic effects at 18 UTC. A gradual cooling related to the baroclinic zone opposes to the low-level destabilization.

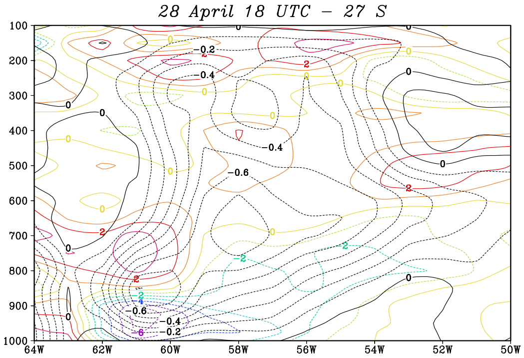
28 April 18 UTC – 27 S

Figure 7: Vertical slice at 27°S of ω (Pa s^{-1}, black lines) and superimpossed the divergence field (x10^5 s^{-1}, color lines)

At 18UTC, forced lifting nearby Resistencia is illustrated in the vertical cross section at 27ºS in the negative ω field, consistent with the already mentioned coupled upper divergence at 400 hPa (2x10^{-5} s^{-1}) and lower convergence (Figure 7).

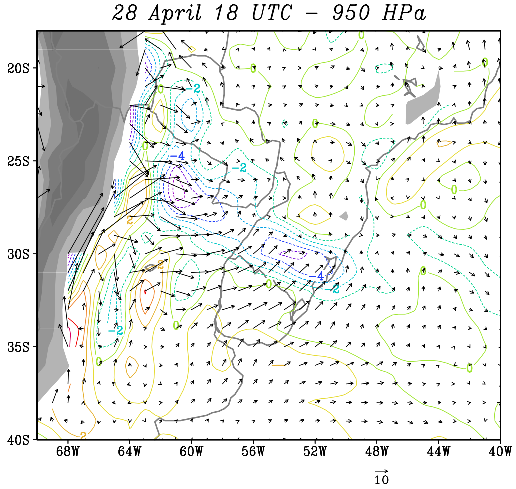
28 April 18 UTC – 950 HPa

Figure 8a: Divergence of the ageostrophic wind field (x10^5 s^{-1}, color lines) and superimposed the ageostrophic wind vectors at 950 hPa level.

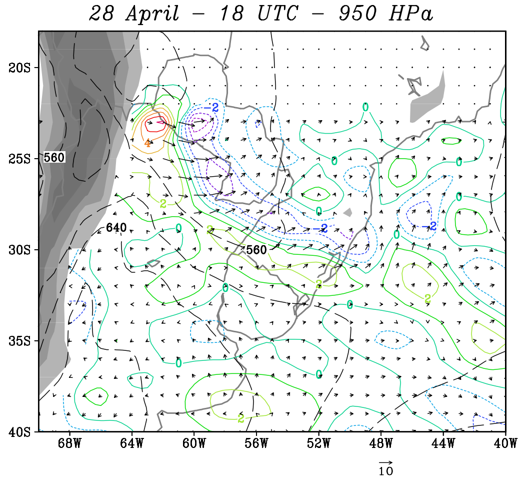
28 April – 18 UTC – 950 HPa

Figure 8b: Divergence of the isallobaric wind field (x10^5 s^{-1}, color lines) and superimposed the isallobaric wind vectors at 950 hPa level.

The ageostrophic wind and its different components: isallobaric, deformation and rotational, are analyzed to understand their contribution to the diagnosed divergence field. The ageostrophic wind, at low levels (950 hPa) exhibits at 18UTC a divergence pattern well matched with the frontal boundary (Figure 8a). A comparison of the patterns of the three components shows that the isallobaric component is the strongest and its convergence pattern is positioned northward respect to the total convergence main axis (Figure 8b). The other terms that contribute to the ageostrophic wind (deformation and rotational) counteract the effect of the isallobaric component at their leading edge forcing the convergence southward, whereas to the rear of it they act adding to the convergence of the main pattern. Therefore, convergence in the area of Resistencia is largely explained by the convergence of the isallobaric wind.

The ageostrophic components have been also analyzed at higher levels (400 hPa, not shown). The wind vectors for the different components present smaller magnitudes than at low-levels, despite the clear presence of divergence at the longitude of Resistencia (see Figure 7).

Another dynamic factor that has contributed to the relative vertical vorticity concentration to generate the tornado is related to the increasing synoptic scale vertical vorticity during the day of the event. The hypothesis is that this enhanced vertical vorticity contributed by the cyclonic shear to the west of the low-level jet as it progressed toward the east (forced by the cold air incursion), finally becomes located in the Resistencia area where the presence of convergence have concentrated the relative vertical vorticity by stretching, just in time for the occurrence of the tornadogenesis in a convective scale (Torres Brizuela and Nicolini, 2006).

Acknowledgments This work was partially supported by: ANPCyT grant PICT 2003 N° 07-14420, the University of Buenos Aires grants: UBACYT X266 and X264, and by the grant IAI CRN-055.

First author was finantially supported with a posdoc fellowship under the IAI CRN-055 grant.

The authors thanks the National Weather Service to provide the radiosounding data.

REFERENCES

Moral, A. E., B. Cerne, N. Possia and J.C. Ramos, 2002: Un tornado en Resistencia. |A tornado at Resistencia| *Investigaciones y Ensayos Geográficos*, **1**, 95-108.

Salio, P. V., M. Nicolini y C. Saulo, 2002: Chaco low level jet characterization during the austral summer season by ERA reanalysis. J. Geophys. Res. - Atmosphere. Vol 107, D. 24. 10.1019/2001JD001315.

Torres Brizuela, M. M and M. Nicolini, 2006: Numerical simulation of a convective storm generating a tornado. 8th International Conference on Southern Hemisphere Meteorology and Oceanography (8ICSHMO).