

TROPICAL-MID LATITUDE EXCHANGE OF AIR MASSES IN SOUTH AMERICA. PART II: DIAGNOSTIC OF THREE CASES STUDY OF EXTREME WEATHER SITUATIONS

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Abstract

Through of the three case studies, the effects and causes of the exchange of air masses between tropics and extratropics, were analyzed on some detail. The November 29, 1996 case showed that the Chaco Low favored the entrance of tropical air to higher latitudes, helping to increment the atmospheric instability which was later released by the passage of a frontal system. The June 30, 1996 event indicated that the freezing conditions in southern and southeastern Brazil were associated with the advance of a cold core anticyclone that moved rapidly to the north forced by a baroclinic wave of large amplitude and helped by the channeling effect of the Andes. Finally, incursions of frontal systems that reach subtropical latitudes in summer increment the convergence (divergence) in the lower (upper) levels on the region where SACZ is located. That was the case related to the storms and flooding in Ouro Preto, Brazil at the beginning of 1997.

Introduction

Transient incursions of mid latitude/tropical air to the east of the Andes Mountains into and tropical/mid latitudes are a distinctive feature of the synoptic climatology over South America (Seluchi and Marengo, 1998). With regards to this exchange of air masses between the tropics and mid-latitudes, the channeling effect of the mountains is particularly evident during winter, allowing the penetration of the cold air to reach very low latitudes. In summer time, the incursion of tropical air into mid latitudes seem to be linked to the presence of the *Chaco Low* (Lichtenstein 1989), located approximately at 25°S and 65°W, and the subtropical Atlantic high. The intensification of the Chaco Low usually leads to warm episodes over southern Brazil, Uruguay and central and northern Argentina, and to the occurrence of convective events. The *South Atlantic Convergence Zone (SACZ)* is another feature of the summer time circulation in South America, and an indicator of the moisture transport from Amazonia to higher latitudes. This represents to some degree the characteristics of a stationary frontal zone oriented from Northwest to Southeast, with wind following the same direction. The SACZ is responsible for strong thunderstorms and floods, which can paralyze cities and kill people.

This paper presents three case studies of extreme weather events in both summer and winter, which are typical examples of strong exchange of air masses between tropics and extratropics. Two examples of convective events during summer and one example of a winter time polar outbreak are described with some detail. In order to analyze these meteorological situations, the NCEP reanalyzes for 17 vertical levels and 6 hours temporal resolution is used as well GOES infra red satellite images.

1. *The storm of northern-central Argentina of November 1996.*

On November 29th, 1996, successive storms organized as squall lines affected the central provinces of Argentina producing intense rains, wind gusts, flooding, cuts on the energy service, etc. in several cities. The GOES image for the 03 UTC of November 29 (Fig. 1) shows an impressive center of strong convective activity, with the two centers of highest intensity with a NW-SE orientation (the brightest parts of the satellite image). These systems are located immediately to the north of a frontal zone that can be distinguished by the low clouds observed in the southern part of the continent and the southeastern Pacific. Orographic clouds over the Andes (approximately between 32-38°S) and scatter convective clouds can also be observed over the eastern side of this cordillera. The convective activity over the Amazon basin and the SACZ is weak or moderate. The main convective center moved to the northeast as a squall line, reaching eastern Bolivia, Paraguay and the Southern Brazil 36-48 hours later. The associated frontal zone also moved to the northeast weakening and was later assimilated by the SACZ.

Fig. 2 shows the near surface weather conditions at the 00 UTC for November 28, i. e. 24 hours before the beginning of the organized convection shown on Fig. 1. A strong and more southward displaced Chaco Low is observed, as a consequence of a cyclonic perturbation coming from the southern Pacific (at approximately 45°S and 80°W). Between the Chaco Low and the subtropical Atlantic anticyclone a band with intense northerly flow with maximum speeds of approximately 24 m/s is observed near 34°S which transport tropical air toward higher latitudes. Something worth to mention is the presence of strong winds from the west on the eastern side of the Andes, consequently a type of Fohn effect locally known as "Zonda Wind". The 500 hPa field (Fig. 3) shows the trough associated with the frontal system and the vigorous ridge that contributes to the anticyclonic circulation over the Atlantic Ocean. The vertical velocity field (not shown) indicates that at this time subsidence prevailed east of 65°W inhibiting the formation of storms. Isolated centers of ascending air are consistent with the presence of spread convection. From the 950 hPa level flow and the 24 hours variation of the specific humidity (shaded in Fig. 2) it is apparent that the persistence of the northerly wind generates an increase in the moisture content in the lower troposphere, which helps to enhance the instability. Fig. 4 shows a cross-section of the meridional component of the winds and the changes in the potential equivalent temperature (shaded) during the last 24 hours along 35°S at the same time as Fig. 2. A maximum of northerly wind can be observed at the 950 hPa level, east of 65°W and reaching speeds over 20 m/s. Berri and Inzunza's (1993) results suggest that this configuration correspond to a typical pattern of a LLJ. The shaded areas in Fig. 4 show the increase of equivalent potential temperature 24 hours before the beginning of the storms, which displays an increment of convective instability due to the injection of warm and humid air in the lower troposphere. Generalized convection started at 00 UTC of November 29, when the ascending motion associated to the frontal system and its midlevel trough released the instability accumulated during the previous days.

The November 29 1996 case is a typical example of how the incursion of humid and warm air masses from subtropical latitudes generated by the intensification of the Chaco Low resulted in an instabilization of the atmosphere at middle latitudes. The intensity and persistence of the streams of warm air in the lower troposphere usually drive the formation or intensification of convective phenomena.

2. *The weather events that led to floods in Ouro Preto*

At the beginning of 1997, a series of Mesoscale Convective Complexes (MCCs) embedded along the SACZ affected the neighborhood of the historical city of Ouro Preto

(21.2°S, 44.5°W), considered by UNESCO as Cultural landmark because its unique colonial barroque architecture. Intense precipitation extended during several days (1-4 January 1997) with daily totals larger than 200 mm, and a total accumulation larger than 500 mm in most of the State of Minas Gerais, where Ouro Preto is located. The excessive rain produced landslides that destroyed some of the XVII and XVIII century buildings downtown.

The satellite image (Fig. 5) of the 00 UTC for January 2 1997 (when intense precipitation started) show several MCC's located along the 20°S line, while skies are clear south of 25°S. It also can be observed that there is abundant cloudiness over the Amazon basin, depicting an anticyclonic circulation possibly linked to the Bolivian High. Several authors (Nogués-Paegle and Mo,1997; Garreaud and Wallace, 1998) suggest that the intensity of convection near the SACZ is regulated by extratropical baroclinic activity. In particular when a frontal system or some other cyclonic perturbation can reach subtropical latitudes, the additional vertical motion that they generate can intensify convection along the SACZ. The evidence presented here illustrates this mechanism, considered responsible for the weather conditions associated with storms and flooding in Ouro Preto. Fig. 6 shows the geopotential height and wind fields at 1000 and 950 hPa, respectively. A convergence zone in the extreme eastern portion of the map can be detected extending in the NW-SE direction south of 20°S, which merges with a low-pressure center located in an area with more convective activity. At the same time, a transient anticyclone located to the south contributes to transport maritime air into the continent. The frontal characteristics of the convergence zone are detected by: (a) the progressive northward movement of this convergence zone from previous days, (b) the cyclonic curvature of the flux that displays an inverted trough, and (c) the contrast in the thermal advection along the convergence zone, detected by the wind direction on both sides of it. On the other hand, variations in geopotential height and temperature, generated by the movement of the convergence zone between January 1 and 2 (Fig. 7) show a pattern typical of a frontal zone, with a decrease in temperature and increase in geopotential height to the south of the baroclinic zone. Shaded areas in fig. 6 reveal that the northward movement towards the north of this largely baroclinic zone generated an increment of local convergence at lower levels and an increase in the divergence on the higher troposphere (Fig. not included). This contributes to an intensification of the intensity of vertical motions, and consequently to an activation of deep convection along the SACZ.

3. Cold surges in southern Brazil on June 30 1996

The occurrence of freezing events in tropical and subtropical areas of South America is not a very frequent phenomenon. However, sometimes the channeling effect of the Andes combines with the presence intense southerly flow in the middle troposphere, leading to a quick advance of polar air towards lower latitudes. In the days leading up to June 30, an intense cyclone with a mostly meridional track was detected at approximately 55°S. In Fig. 8 the synoptic situation of June 27 is characterized by the intrusion of an intense cold core anticyclone to the south of a frontal system that extends in a NW-SE direction south of 10°S, delineated approximately by the 90 gpm contour. It is important to note that due to the presence of the Andes, the anticyclone turns to the South to cross over areas relatively lower in altitude, and then moves to the north due to the channeling effect of the Andes (see contours of 210 and 240 gpm). This effect helps the enhancement of the anticyclonic curvature and then intensifies the system. The 500-hPa geopotential (Fig. 8 shaded) shows a wave of great amplitude that contributes to the meridional displacement of the surface anticyclone.

In summary, the surface anticyclone and the associated polar air mass are forced to move towards the north due to the orography and to the presence of strong southern flow in the middle and upper-troposphere (Marengo et al. 1997). Fig 9 exhibits the surface weather situation 24 hours later, where the rapid northward movement of the anticyclone is observed. It is interesting to point out that the center of this system follows a rather northward path, immediately to the east of the Andes. This makes that the southern flow responsible for the sudden decreases in air temperature (shaded areas in Fig. 9) extends mainly between 65 and 40°W, i. e. over the same region where the climatological maxima of northerly winds take place. From Fig. 9, the largest drops in air temperature are located over the central and eastern side of the continent, while in the area near the lee-side practically there are no changes in temperature. The frost took place on early morning of June 30, when the cold core anticyclone reached its northernmost position. The cooling was due to a combined effect of cold advection observed from previous days and radiative cooling at nighttime, favored by the clear skies.

In general, all frontal systems and anticyclones that move on the lee side of the Andes follow a northward track due to its channeling effect. However, the occurrence of freezing conditions in the subtropical regions is usually linked to other factors such as the intensity, speed and track of the synoptic systems in both lower and upper levels (Seluchi and Nery, 1992; Marengo et al., 1997).

Acknowledgments: This research was supported by the (CNPq), the IAI and the CEC.

References

- Berri G. J., J. Inzunza B. 1993: The Effect of the Low-Level Jet on the Poleward Water Vapour Transport in the Central Region of South America. *Atmos. Environ.* **27A**, No.3, 335-341.
- Garreaud, R., Wallace, J. M., 1998: Summertime incursions of Mid-Latitude air into subtropical and tropical South America. In press. *Mon Wea Rev.*
- Lichtenstein E.R., 1989: Some influences of the Andes Cordillera on the synoptic scale circulation. *III Int. Conf. on S. H. Met. and Oc.*, AMS, Bs A, Argentina. 146-148.
- Marengo J., A. Cornejo., P. Satyamurty, C. Nobre, W. Sea: 1997a: Cold waves in tropical and extratropical South America. The strong event of June 1994, *M W R.* **125**, 2759-2786.
- Nogués-Paegle J. and K. Mo, 1997: Alternating Wet and Dry Conditions Over South America during Summer. *Mon. Wea. Rev.* **125**, 279-291
- Seluchi, M.E., Nery, J. T., 1992: Condiciones meteorológicas asociadas a la ocurrencia de heladas en la región de Maringá, *Revista Brasileira de Meteorología*, **7(1)**, 523-534.
- Seluchi M.E., Marengo, J.A., 1998: Tropical-Mid Latitude Exchange of Air Masses during Summer and Winter in South America: Climatic aspects and extreme events. Submitted to *Mon, Wea. Rev.*

Figure Captions

Figure 1: GOES IR image at 3:00 UTC of November 29, 1996. (Source INPE/DSA).

Figure 2: (a) 1000 hPa geopotential height (gpm), 950 hPa wind (m/s) and tendency of the specific humidity (g/Kg) for the next 24 hours, at 00 UTC for November 28 1996.

Figure 3: 500 hPa geopotential height (gpm) and 500 hPa temp (°C), 00 UTC Nov 28

Figure 4: Cross section of the meridional component of the wind (each 5m/s) at 35°S, 00 UTC for November 29 1996. Shaded areas represent increment of equivalent potential temperature (°K, plotted at 2°K intervals) for the next 24 hours. Dark rectangle represents the Andes shape

Figure 5: GOES IR satellite image at 00:00 UTC for January 2, 1997. (Source INPE/DSA).

Figure 6: 1000 hPa geopotential height (gpm) and 950 hPa wind (m/s) at the 00:00 UTC for January 2, 1997. Shading represents increments in the low-level convergence between 00:00 UTC of January 1 and 2, 1997.

Figure 7: Variations in 1000 hPa geopotential height (lines, m) and temperature (shaded, interval each 2°C) (shaded, interval of 2°C) between the 00:00 UTC of January 1 and 2, 1997.

Figure 8: 1000 hPa geopotential height (gpm) and 950 wind (m/s), at the 12:00 UTC for June 27 1996. Shaded represents 500 hPa geopotential height (gpm) at the same time.

Figure 9: 1000 hPa geopotential height (gpm) and 950 hPa wind (m/s), at 12:00 UTC June 28. Shading represents the decrease of temperature (each 2°C) with respect to 24 hours before.

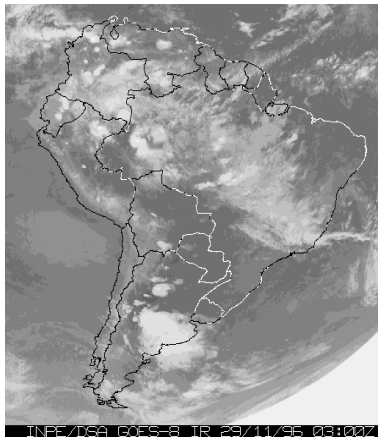


Fig. 1

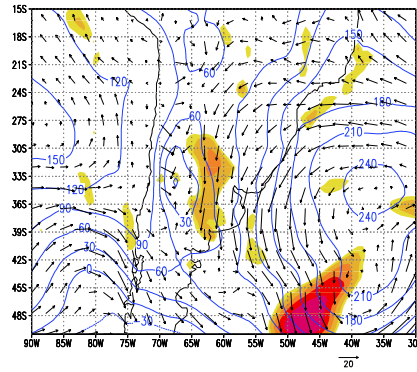


Fig.2

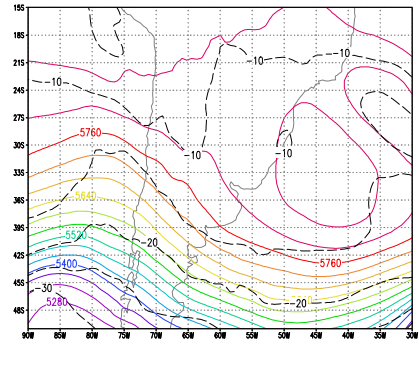


Fig. 3

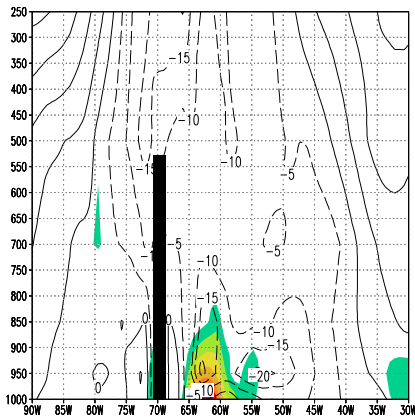


Fig. 4

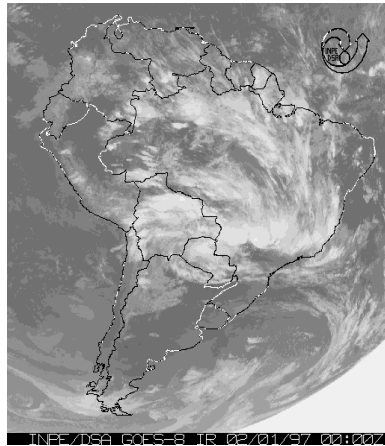


Fig. 5

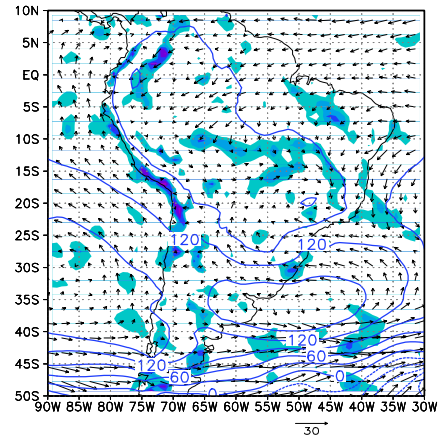


Fig. 6

