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SYNOPTIC AND THERMODYNAMIC ANALYSIS OF AN EXTREME HEAT WAVE OVER SUBTROPICAL SOUTH AMERICA.

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1. INTRODUCTION

During the last week of January of 2003 an intense and extensive heat wave occurred over most of the subtropical South America, affecting central and western Argentina, Uruguay, Paraguay, Southern Bolivia and Southern Brazil. In particular, the highest maximum temperature since record exists (44°C at 20:15 UTC on January 30, 2003) was reported at the Mendoza Airport (located approximately at 33°S near the Andean foothills). Moreover, the maximum temperature on January 30 was observed at San Juan station, about 150 km to the north of Mendoza, with a value of 45.4°C around 20:00 UTC. Figure 1 shows the temperature evolution (solid red line) at San Juan station from January 23 to February 1.

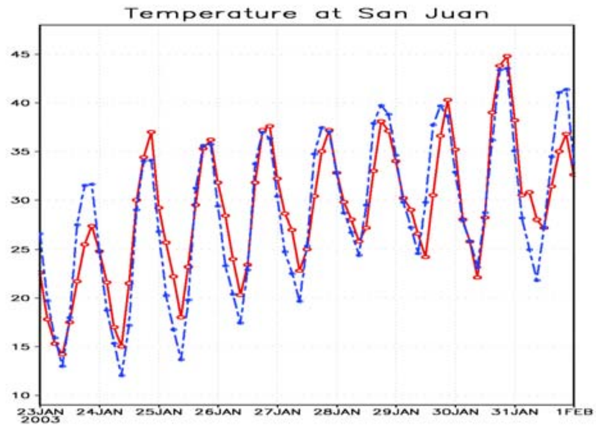

Figure 1: Observed temperature at San Juan Station (solid red line) and simulated temperature evolution (dashed blue line)

The studied period took place during the South American Low-Level Jet Experiment (SALLJEX) and a fly mission by the NOAA P3 plane was performed during the demise phase of the episode, on February 1st 2003.

Heat waves may cause severe impact on the population health, augment dramatically the fire risk, provoke agricultural damage (crop loss) and hydrological disasters (ice melt, landslides and floods near the Andes foothills) as well a critical increase of electricity demand.

The goal of this work is to analyze the prevailing meteorological conditions during the last week of January 2003 from a synoptic, dynamic and thermodynamic point of view in order to establish the physical processes that contributed to the heat wave.

2. DATA AND METHODOLOGY

Surface data and aerological soundings have been complemented to NCEP/NCAR reanalysis to overview the synoptic evolution. Physical mechanisms causing the heat wave were investigated through numerical simulations performed with the Eta/CPTEC regional model. Model domain and numerical settings are similar to those adopted for operational forecast at CPTEC (Seluchi and Chou 2001). Numerical simulation extended from 0000 UTC January 23 through 0000 UTC February 1. NCEP/NCAR reanalyses were used as boundary lateral conditions and simulated fields were plotted every three hours.

To quantify the influence of different physical processes to the temperature increase the thermodynamic equation was evaluated directly from model outputs. Temperature tendencies were obtained and recorded at each model time-step (96 s.) and then plotted at 3-hour intervals to avoid numerical residuals. Further details of this methodology can be found in Seluchi et al (2003).

The vertical (omega) velocity was also diagnosed through the quasi-geostrophic omega equation (Bluestein, 1993)

3. RESULTS

During the last week of January 2003, the atmospheric circulation over subtropical latitudes was dominated by a rather barotropic pattern. The main baroclinic zone was located further south, between 35°S and 40°S, fostering the development of the Nonwestern Argentinean Low and, consequently, the warm and humid advection from the north. The synoptic-scale pattern was inmersed in a large-scale wedge that provoked sustained subsidence over most of subtropical South America and contributed to keep the sky clear during the whole considered period.

Dynamic and thermodynamic analysis showed that the moderate but persistent warming was principally restricted to the middle-lower troposphere (below 700 hPa). For this reason the thermodynamic analysis was limited to the layer 700/950 hPa. As illustrated in Figure 1 the temperature increase was persistent during the whole week with two relative maxima between January

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24-25th and during January 30.th Dashed blue line in Figure 1 also exhibits the temperature evolution as simulated by the Eta/CPTEC model. The similarity between both curves, especially from January 25 to January 30, gives confidence to our analysis.

Figure 2 shows the temperature tendencies (derived from Eta/CPTEC numerical simulations) vertically integrated in the layer 700/950 hPa associated with each term of the thermodynamic equation. Temperature tendencies were computed during the period 23-30 of January 2003. Panels in Figure 2 represent the individual contribution of the horizontal temperature advection (panel a), the static stability term (adiabatic cooling/warming due to ascent/descent, panel b) and the diabatic forcing (including radiative transfer in the atmosphere and surface heat fluxes, panel c). Temperature changes resulting from moist processes as cooling/warming due to condensation/convection and diffusive terms are also included in panel c but these two later processes had an insignificant effect. Panel d represents the sum of all the terms included in the thermodynamic equation. This pattern is similar to those obtained subtracting the simulated temperature fields for the same period.

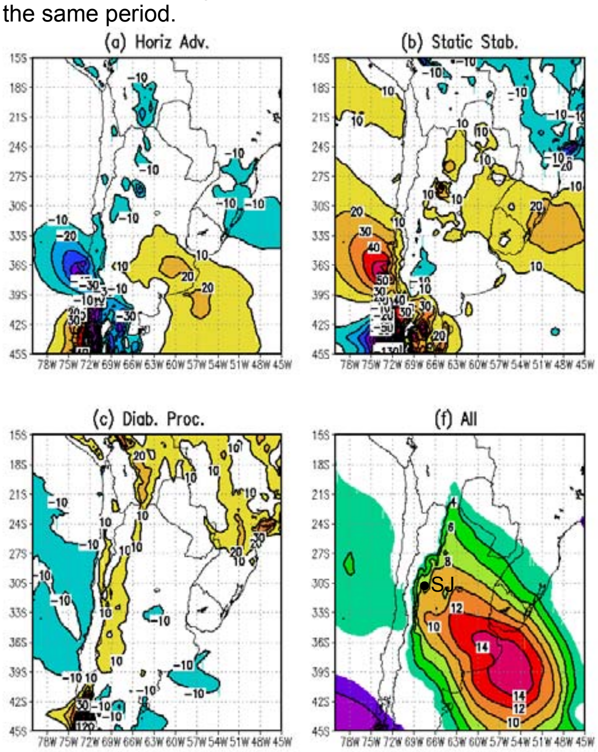

Figure 2: Temperature tendencies extracted from the terms of the thermodynamic equation (°C) accumulated from January 23 to January 30. The approximated location of San Juan City is indicated

The close inspection to the terms of the thermodynamic equation allows concluding that the heat wave was the consequence of a combination of different factors. Warm horizontal advection was a very important effect to the south of 33°S and to the east of 65°W, as the result of sustained northerly winds related to the development of the Nonwestern Argentinean Low and the presence above mentioned of the baroclinic region located around 35-40°S. Note that cold horizontal advection prevails near the Andean foothills. Slight to moderate larger-scale adiabatic warming by subsidence dominated over most of the subtropical latitudes. This latter effect exhibits a relative maximum near Andean slopes (were the cities of Mendoza and San Juan are located). Aerological soundings, equivalent potential temperature vertical sections and Froude numbers allow concluding that this warming is linked to the orographic forced subsidence, locally know as Zonda wind that blew during January 30 th. This fact is consistent with the temperature rise observed at San Juan (Fig. 1) during that day. Even thought the Zonda wind did not reach the surface (high Zonda), it contributed to significantly increase the heating rate near the 850 hPa level. According to Norte (1988) The Zonda wind is not a frequent summer feature.

Surface heat fluxes were also important to close the thermal balance (Fig 2c). Moderate warming was due to sensible heating from the surface, especially close to the eastern Andean slopes, where semi desert environment prevails. Surface heat fluxes were enhanced by the persistent absence of cloudiness as a consequence of the upper large-scale ridge that lasted during the last week of January.

The quasigeostrophic analysis indicated that the persistent large-scale subsidence occurred as the result of the cold advection over the Andean slopes and over Southern Brazil and, principally, due to the vorticity change (from cyclonic to anticyclonic) with height. This effect was particularly evident over central and western Argentina, where the midlevel large-scale ridge superimposed the Nonwestern Argentinean Low.

4. References:

Bluestein H. B., 1993: Synoptic-dynamic meteorology in midlatitudes, Volume II: Observations and theory of weather systems. Oxford University Press, 953 pp.

Norte F. A., 1988: Características del viento Zonda en la Región de Cuyo. PhD Dissertation. [Available at Programa Regional del Meteorología, CRICYT, (5500) Mendoza, Argentina].

Seluchi M. E, A. C Saulo, M Nicolini and P Satyamurty, 2003: The Northwestern Argentinean Low: a study of two typical events. Mon Wea Rev, 131, 2361-2378.

Seluchi, M. E., and S.Ch Chou, 2001: Evaluation of two Eta Model versions for weather forecast over South America, Geofís. Int., 40, 219-237

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