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PREVIOUS CONDITIONS ASSOCIATED WITH A DEVELOPMENT OF A MESOSCALE CONVECTIVE SYSTEM UNDER A SOUTH AMERICAN LOW-LEVEL JET EVENT: A CASE STUDY

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1. INTRODUCTION

A significant number of mesoscale convective systems (MCS) over subtropical latitudes that cover important extensions, develop in concert with the presence of a particular subset of the South American Low Level Jet (SALLJ) that penetrates into subtropical latitudes (generally called Chaco Jet Events, CJE). Favorable atmospheric conditions for convection at these latitudes, in the synoptic scale, are mainly dominated by the presence of a frontal zone close to northern Patagonia, a baroclinic wave train with a trough immediately to the west of the Andes at midlevels; low-level circulation that is characterized by a strong deceleration of the wind over northern Argentina; and the presence of a very unstable air mass all over Southeastern South America (SESA). Velasco and Fritsch (1987) and Nieto Ferreira et al. (2003) recognized the presence of the SALLJ in events of mesoscale convective complexes over SESA and Torres (2003) found a high percentage (around 80%) of occurrence of CJEs during the development of heavy precipitating subtropical MCS.

Despite the consensus that there is a close relationship between the SALLJ and the development and maintenance of the MCSs, it is still necessary to advance in the knowledge of the role of the low level jet (LLJ) in the generation of the conditions that support subtropical convection over South America. One of the objectives of SALLJEX experiment was to study this relationship (Vera et al. 2006). Intensive observational periods during this experiment allowed an exceptional temporal and horizontal coverage over subtropical areas and therefore to progress in the knowledge of this relationship.

The objective of the present work is to study the prestorm environment prior to the development of a group of subtropical MCSs during a SALLJ event. The evolution of the kinematics and thermodynamic structure of the atmosphere is studied in order to understand the gradual building of optimal conditions for the formation of organized convection during an intensive observation period.

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2. DATA AND METHODOLOGY

The work is centered on the study of a situation that occurs on 5 – 7 February 2003 during SALLJEX. This event is characterized by the presence of a group of MCSs and a SALLJ that penetrates up to subtropical latitudes. The period of study is included in a long intensive observation period during which, soundings were launched every 6 hours at some stations, and pibal observations were obtained every 3 hours in the whole SALLJEX network, allowing a better temporal resolution of the event.

The large-scale environment is described using operational analyses (Global Data Assimilation System, GDAS) with 1 degree horizontal resolution and 6-hours temporal resolution. Enriched analyses are used in order to describe the environment prior to the MCS development. These analyses were generated ingesting all available SALLJEX data (surface and upper air observations) following a downscaling methodology, using the Regional Atmospheric Modeling System (RAMS). Rams model was applied to obtain analysis every three hours, with a horizontal resolution of 80 km covering mostly South America and an enhanced domain with 20 km resolution for the SESA region. A more detailed description can be found in Garcia Skabar and Nicolini (2006, in this same Conference). SALLJEX daily accumulated precipitation data is used in order to verify the performance of the model during the studied period.

IR satellite images with high temporal and horizontal resolution are used to detect subtropical convection during the studied period (more information about this data set can be obtained in Janowiak et al. 2001). A clusterization and tracking technique called Forecasting and Tracking of Active Cloud Clusters (ForTraCC) is employed to determine the life cycle of the systems. A convective system is defined as an area of at least 150 pixels (2,400 km^2) enclosed by a temperature threshold. The threshold used in this paper is 218 K, in accordance with Machado et al. (1998) as representative of the presence of deep convection. The position and evolution in time of each cluster are determined through a tracking algorithm to decide their continuity based on a maximum areal overlap on each successive image (Machado and Laurent, 2004). The program detects when the system initiates from spontaneous generation and when it merges with another system or splits during its life cycle.

3. RESULTS

3.1 Large-scale environment characterization

The large-scale environment during Feb 5 is characterized by the presence of a warm and moist air mass northward 30°S. Equivalent potential temperatures (θe) higher than 350K are observed within the 1200 m height layer above sea level at 18Z (not shown). Toward the south, this air mass presents a weakly defined and stationary frontal zone over northern Patagonia. During the whole day, it is evident the presence of a northerly LLJ close to the Andes with maximum wind intensity positioned near Mariscal Estigarribia (22°S-60°W), showing its deceleration area over northern Argentina. The LLJ is present during the whole studied period, showing SALLJ conditions that reach 25°S principally in nocturnal hours. The Northwestern Argentinean Low (NAL) is located immediately east of the slope of the Andes and centered at 24°S. This depression presents a typical diurnal cycle evolution with its maximum intensity during afternoon hours. At 500 hPa, a trough from the Pacific Ocean moves into southern Argentina at the end of this day.

The NAL, during Feb 6, deepens and intensifies reaching values lower than 992 hPa at the surface. Another important feature is the meridional extension of the low pressure area due to the presence of both, a low over Paraguay (Chaco low) and the NAL, which covers an area between 18 and 34°S. The frontal zone, over northern Patagonia, intensifies and shifts northward generating a strong contrast between the subtropical and polar air masses. At the beginning of this day, the northerly flow still presents a LLJ profile and develops close to the slope of the Andes, and widens eastward during the following hours. Circulation in the upper troposphere shows the presence of the leading side of the trough and its associated northwest-southeast oriented jet streak over southern Argentina at 42°S. During the afternoon of the present day deep convection starts to develop over central Argentina. The aim of the present paper is to understand the relationship between those systems and their associated environment, which is described in the following sections. A composite of MCS under SALLJ events shows the upper level divergence associated with the left sector at the entrance of a jet streak positioned over the area where convection develops (Salio et al. 2006). In this case and in contrast with that finding, large scale divergence is further south from this position.

Feb 7 is principally characterized by a strong gradient in θe and by a northward advance of the frontal zone up to 34°S, but close to mountain areas the southerly current penetrates up to 30°S. It is also important to remark that MCSs reach their maximum extent and decay during this day. Another difference respect to subtropical MCS composites is in the northward advance of the baroclinic zone. In this case, the frontal zone remains stationary during the whole studied period close to 30-35°S.

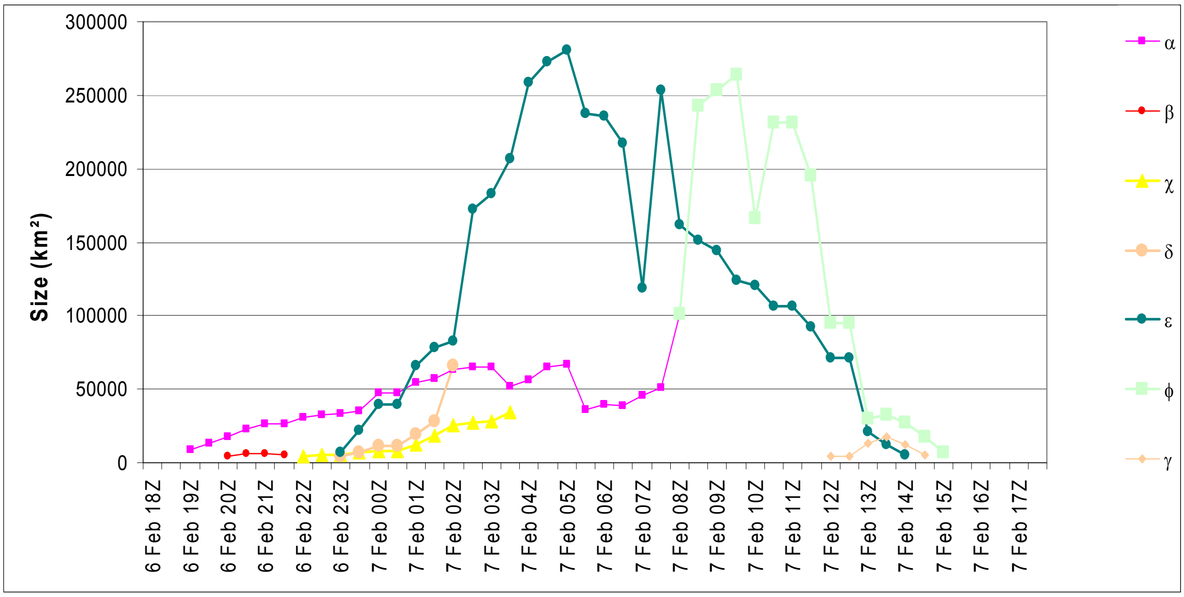

Figure 1: Temporal size (km^2) evolution of convective cells that play an important role during Feb 6 and 7 detected by ForTraCC.

3.2 Evolution of mesoscale convective systems during the period Feb 5 to 7, 2003.

During nocturnal hours of Feb 5, prefrontal MCSs develop over central and northwestern Argentina and move eastward during their life cycle. Those systems produce a stabilization in the low troposphere, principally evident in a slight decrease in CAPE. Feb 6 is characterized by the absence of subtropical convection, until 18Z, in the area between the Andes and 55°W, in spite of the persistence of SALLJ conditions. These findings can also be verified with the accumulated precipitation observed during SALLJEX, that evidences the presence of intense values during Feb 5 and the absence of precipitation on Feb 6 over central Argentina (Fig. 3).

A new isolated convective cell develops at 32°S-64°W at 18Z (β, Fig. 1 and 2), this system dissipates at 22Z. Another region with convective activity starts in northern Uruguay (α) and remains stationary in the area. The principal system (ε) starts over the east slope of the Andes at 23Z, and grows up while moving eastward. This system merges with two cells located in central Argentina (δ and χ) before it reaches the maximum extent of 280.000 km^2 at 5Z on Feb 7. System ε starts to decay, until 7Z when it merges with the MCS located in northern Uruguay (α) attaining an area of 253.000 km^2. From this moment the MCS diminishes its size, first of all, because it undergoes a split in two systems (ε and ϕ). Their dissipation occur at 13Z when their size is lower than 50.000 km^2, and finally these systems disappear before 18Z. New isolated developments grow up mainly in northern Argentina (close to 25°S) still in the prefrontal environment.

RAMS model underestimates the precipitation values on Feb 5, but the precipitation behavior on Feb 6 and 7 is well captured by the model.

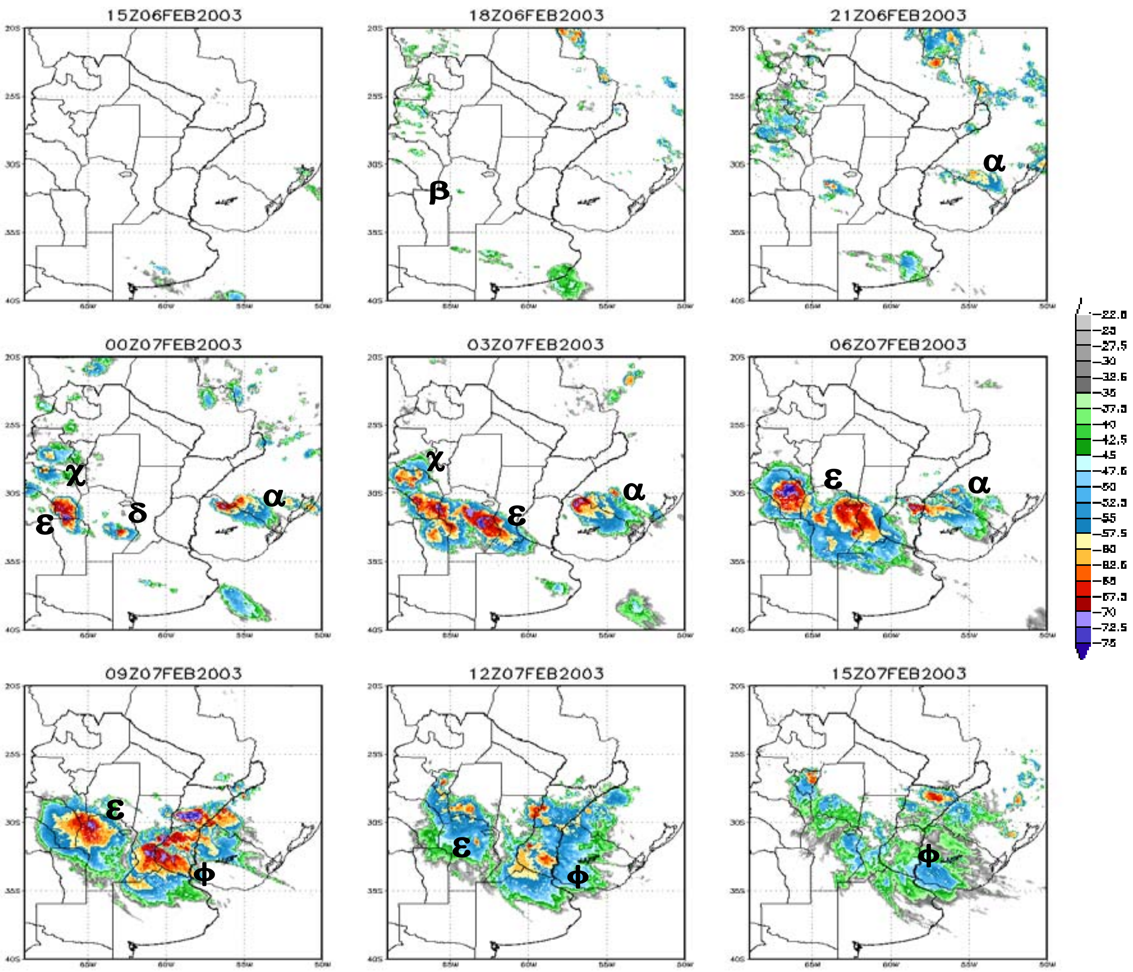

Figure 2: IR Brightness Temperature every 3 hours. Systems identified by ForTraCC are labeled with same name as in Fig. 1.

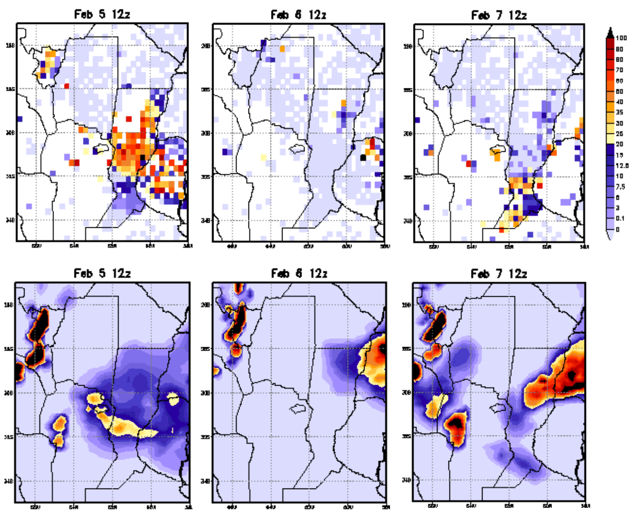

Figure 3: Daily accumulated precipitation observed during SALLJEX (upper panels) and modeled by RAMS (lower panels) during Feb 5 to Feb 7, 2003.

3.3 Environmental conditions associated with the mesoscale convective systems.

The subtropical area is dominated by a northerly flow that advects moist and high temperature air on Feb. 5. As mentioned before, the convection develops in the central area of Argentina and moves towards the northeast of this country. Due to this movement, the northerly flux retreated up to 27°S in low levels and a stabilization of the atmosphere is evident. At the end of Feb 5, during radiative heating hours, an upslope component of the wind is recognized over the NAL area. This component persists up to 3Z on Feb 6, when it starts to gyre anticlockwise until 9Z when it remains from the north.

This northerly flow is present over the northern region of SESA during the whole day showing a LLJ profile. A cross section at 25°S (Fig 4) evidences the behavior of this flow before and during the MCSs development. Between 15Z and 21Z, the LLJ presents its maximum intensity at the top of a mixed boundary layer (close to 1500m). It is important to remark, the vertical extension of the northerly flux up to 5000m and the clear anticlockwise gyre with height related to warm advection. During nocturnal hours, the LLJ core descends to 1000m and accelerates. On the core of the LLJ, it is detectable, in the ageostrophic component of the wind (not shown), the presence of a possible inertial oscillation with a maximum intensity during nocturnal hours and a decrease during daytime. The ageostrophic wind also has an important component, from the north, directed toward the MCS at the moment of maximum development of the systems (Feb 7, at 9 and 12Z), that can be related with an acceleration due to the warming in low and mid levels, generated by the latent heat release during the formation and expansion of the MCSs (Nicolini et al. 1993).

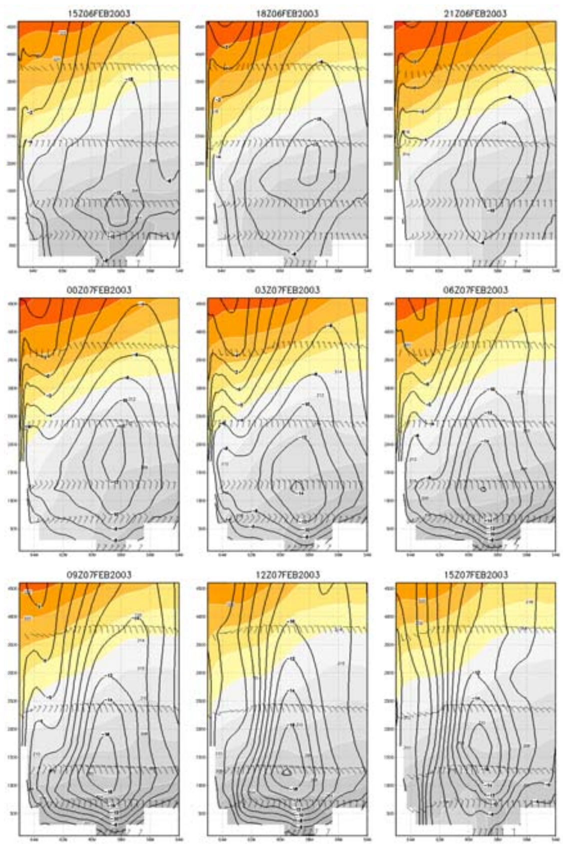

Figure 4: Vertical cross section of potential temperature (thin contour with shading, in K), wind barbs and meridional component of the wind (black contour, in m s^{-1}) at 25°S. All panels cover a longitudinal range from 65°W to 54°W, and are 3 hours apart.

The presence of the LLJ during the whole day (Feb 6) generates unstable conditions through moist and warm advection (Fig. 5). Moist advection at low levels is principally concentrated around the area centered at 32°S-64°W. This is evident during the whole day before the development of the MCSs and effects an increase in water vapor mixing ratio larger than 2 gr kg^{-1} every 6 hours (between 9 and 18Z). This favors a noticeable increase in the humidity between 15 and 18Z, which stays, with a slight increase, in the following hours of the day, reaching values higher than 18 gr kg^{-1} at 1200m (not shown). These maximum values of mixing vapor ratio are present on the cyclonic side of the LLJ exit, this increase could be partially explained by an orographic blocking effect, given by the convergence of the northerly flux on the mountain and by the moist advection that is present before and during the development of the MCSs. On the other side, there is also a warm advection in the area, but the magnitude of the contribution to θe is not as important as moisture advection. This supports an increase in θe values (Fig. 5) before the development of the MCSs which it is also favored by the radiative heating from the ground due to the clear sky during the afternoon of

Feb 6. This is clearly evident in the vertical cross section of θe at 15 and 18Z, close to the maximum of moisture advection (Fig. 7), where an increase in surface values leads to an increment in the convective instability in a deep layer between surface and 3000 m. Another important parameter for the description of the available instability is CAPE, extreme values of 4000 J kg^{-1} are found at 30°S and 63°W at 18Z. Observational value at Chamical (30°S-66°W) at the same time, is still higher (close to 4500 J kg^{-1}) than the one represented by the model.

The combination of all processes, described before, preconditions an optimal environment to the formation of convection, maximizing convective instability and moisture availability. The triggering of this convection is generated by the presence of many factors: a mesoscale process associated with an up-slope component of the wind during the afternoon; the convergence area of the LLJ, and a large scale mechanism associated with the presence of the frontal zone at 33°S. During their life cycle, MCSs present a northeastward movement, further north of the position of the frontal zone, following areas of maximum convective instability and convergence at low levels.

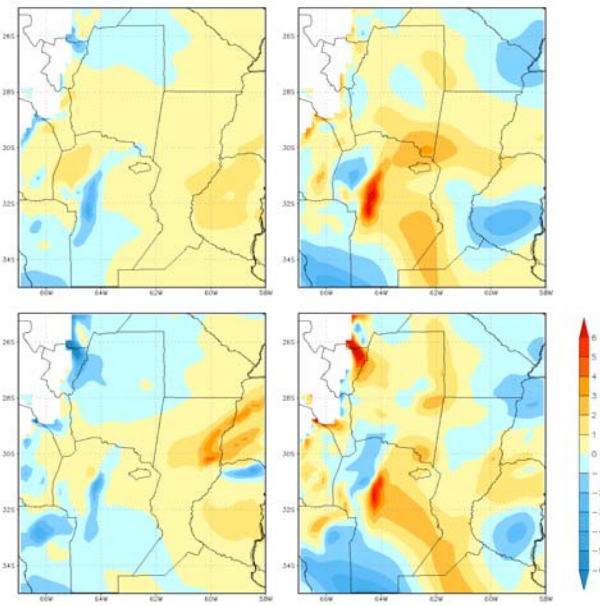

Figure 5: Horizontal advection of temperature (left column, in K) and vapor mixing ratio (right column, in gr kg^{-1}) every 6 hours at 2000 m. Upper row shows values for Feb 6 at 15Z and lower row at 18Z.

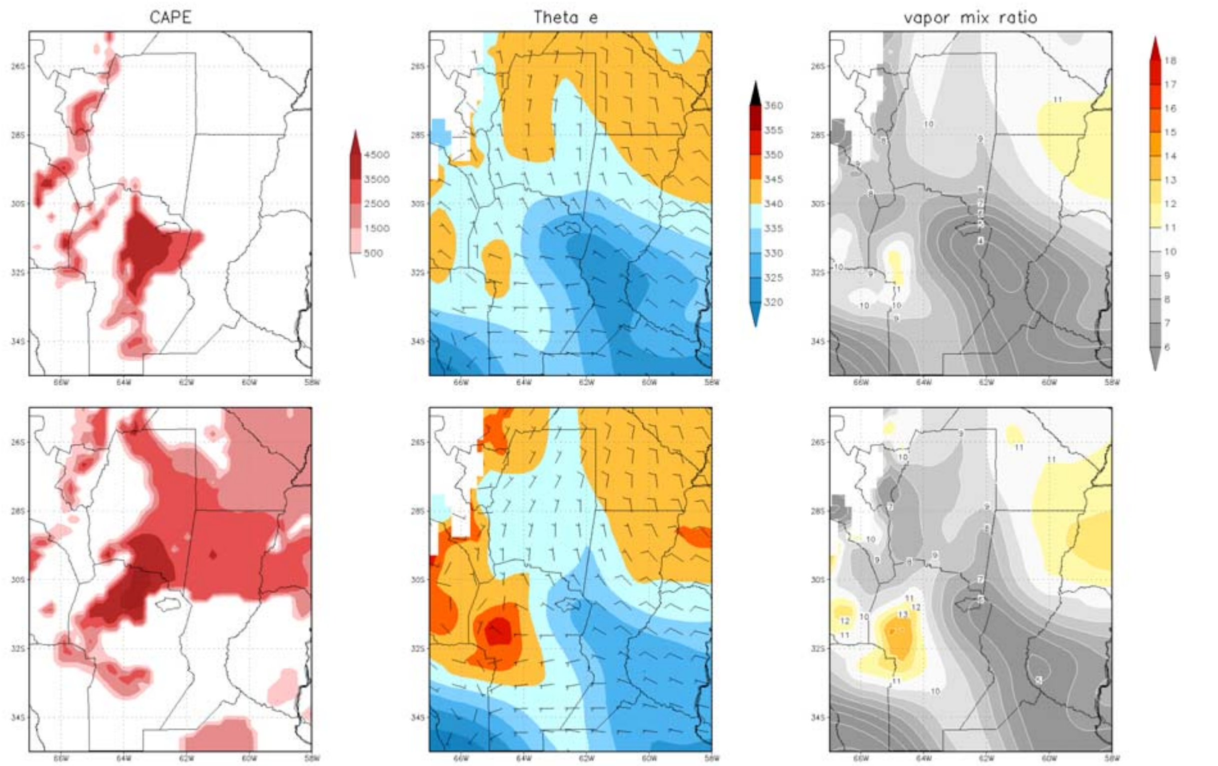

Figure 6: CAPE (left column, in Joule kg^{-1}), equivalent potential temperature at 1200m (central column, in K) and vapor mixing ratio at 2000 m (right column, in gr kg^{-1}). Upper row shows values for Feb 6 at 15Z and lower row at 18Z

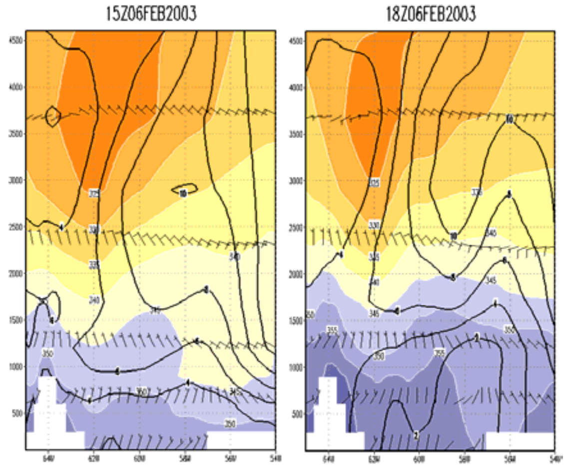

Figure 7: Vertical cross section of equivalent potential temperature (thin contour with shading, in K), wind barbs and meridional component of the wind (black contour, in m s^{-1}) at 30°S. All panels cover a longitudinal range from 65°W to 54°W.

A number of questions remain to be answered regarding the interaction between the SALLJ and MCSs. Mountains control the development, maintenance and decay of SALLJ, and it is still unknown how this interaction evolves. Future work has to be made in order to understand how the LLJ reorganizes after the dissipation of the convection, specially during SALLJ events that last several days and denote multiple periods of convection.

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