Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, INPE, p. 1163-1170.

DIFFERENCES BETWEEN SALLJ AND NO SALLJ EVENTS AND THEIR IMPACT ON THE DEVELOPMENT OF MESOSCALE CONVECTIVE SYSTEMS OVER SUBTROPICAL SOUTH AMERICA

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1. INTRODUCTION

Prior studies have shown that a low-level jet is a recurrent characteristic of the environment during the initiation and mature stage of mesoscale convective systems (MCSs) in the Great Plains of the United States. The South American low-level jet (SALLJ) has an analogous role, advecting heat and moisture from the Amazon basin southward into the central plains of southeastern South America (SESA), generating ideal environmental conditions for convection initiation and growth into MCSs. These systems are characterized by their large size and intensity, by accounting for 60 per cent of the precipitation (Mota 2003) and, in some instances, by generating severe phenomena in the area (Velasco and Fritsch 1987; Silva Dias 1999). Nicolini et al. (2002) compiled the environmental conditions in a sample of 27 heavily precipitating MCSs over SESA, and found a high correlation between these events and the occurrence of a SALLJ events extending south and penetrating into northern Argentina (81 per cent of the 27 cases studied). High frequency of MCSs is evident in the subtropical area under conditions SALLJ, but during situations without SALLJ the presence of organized convection is still significant in this region.

The purposes of this research are to characterize the subtropical MCS sample and to describe the environment associated with the presence of subtropical MCS under SALLJ or No SALLJ conditions. Differences between the evolution of the variables that describe the environment associated with subtropical MCS during both synoptic situations are studied in order to advance in the knowledge of the conditions that precede the MCS development.

2. METHODOLOGY

IR satellite images with high temporal and horizontal resolution are used to detect large subtropical MCSs from September 1, 2000 to May 31, 2003 (http://lake.nascom.nasa.gov/, Janowiak et al. 2001), over the area between 10ºS-40ºS and 40ºW- 75ºW. A definition of long lived MCS similar to that used by Cotton et al. (1989) and by Nicolini et al. (2002) is applied. The initiation stage of the systems is defined when the area enclosed by the 218 ºK isotherm exceeds 50,000 km² (3,125 pixels). The mature stage is attained when the above area reaches its maximum extent, whereas the dissipation stage is defined when the enclosed area again crosses the 50,000 km² threshold. A clusterization and tracking technique called Forecasting and Tracking of Active Cloud Clusters (ForTraCC) were employed to determine the life-cycle of the systems. One cluster is defined as a contiguous region that verified the considered temperature threshold. The position and the evolution of each cluster in time 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. This objective tracking was performed over the whole period of available images and over the window covering tropical and subtropical regions in South America.

The environment associated with the systems is described using operational analyses (GDAS - Global Data Assimilation System) with one-degree horizontal and 6-hour temporal resolution. SALLJ and No SALLJ days are detected using GDAS, considering a criterion similar to Bonner (1968) and Salio et al (2002) is used to identify these events. During the period studied, SALLJ events were diagnosed by GDAS in 35 per cent of the days (285 cases). The remaining days are called No SALLJ events, which cover an extensive variety of synoptic situations, representing 65 per cent of the three seasons studied.

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3. RESULTS

3.1 Geographical distribution and Characteristics of the MCSs.

During the 3-year period 645 MCSs (excluding winter season) were detected satisfying the MCS criterion. These systems are distributed during the seasons studied as follows: 286 in summer, 202 in spring and 157 in the fall. Systems which achieve their maximum extent north of 23ºS were considered as tropical, and the remainder as subtropical. Subtropical systems represent 33.2 per cent of the sample, the tropical systems 66.8 per cent.

Fig. 1 allows an analysis of seasonal and diurnal variations in the number and geographical location of tropical and subtropical MCSs at mature stage, under SALLJ or No SALLJ conditions. For the tropical area, the higher occurrence of MCSs is evident during summer, whereas in fall MCSs in this region diminish in frequency to increase again in spring. This evidence highlights the tropical cycle of convection associated with the advance and retreat of the intertropical convergence zone. These systems basically attain their maximum development during day time, showing their highest frequency during the No SALLJ days throughout the three seasons.

As for the observed subtropical MCSs, they develop with greater frequency during SALLJ events in spring and summer (80.6 per cent and 67 per cent respectively); whereas in fall MCSs do not show a clear correlation with SALLJ (48 per cent). Subtropical MCSs show a preference for a nocturnal phase at a maturity stage over Argentina which contrasts with a day time tendency over Uruguay.

It is worth emphasizing that the systems in the whole region, reached their maximum development east of 65ºW. This is not to say that there is no convection west of this meridian, but systems that develop over the slope of the Andes tend to be either smaller over their whole life cycle, or their maximum extent is attained after passing eastward of 65°W.

A total number of **140** subtropical MCSs develop during 117 SALLJ events (285 SALLJ days during the whole studied season), whilst **74** subtropical MCSs develop during 64 No SALLJ events (534 No SALLJ days during the whole studied season). These results drive to the important consideration that at least one large subtropical MCS developed in 41 per cent of the SALLJ events in all season. In contrast, during

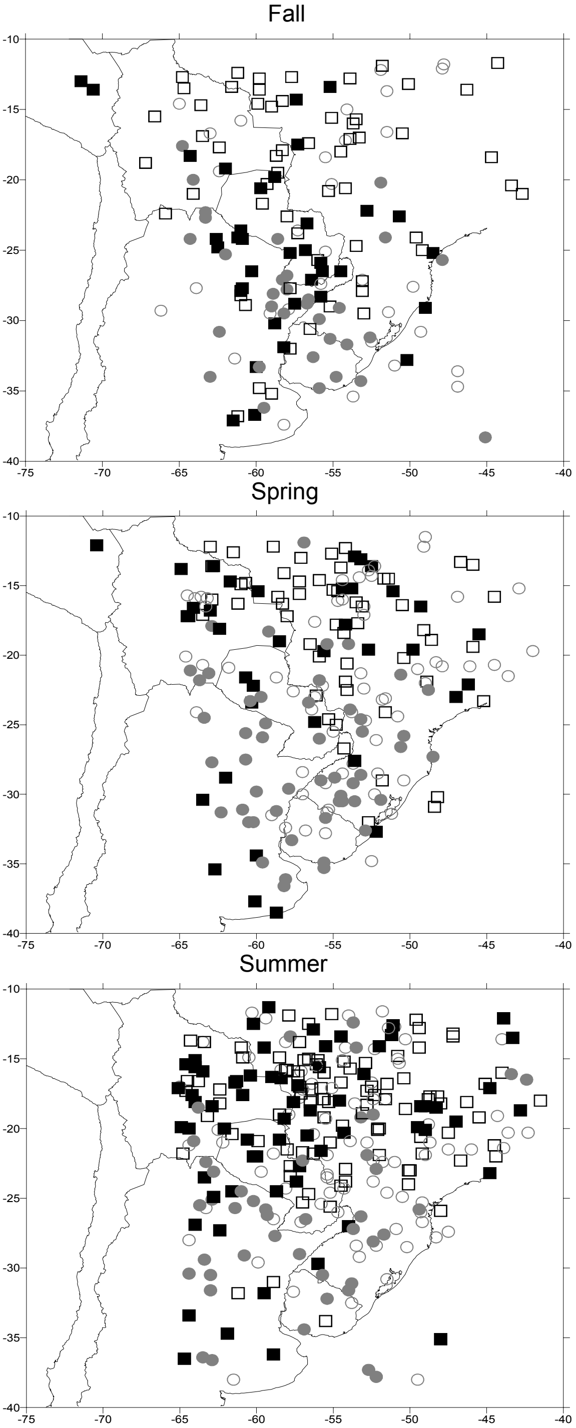
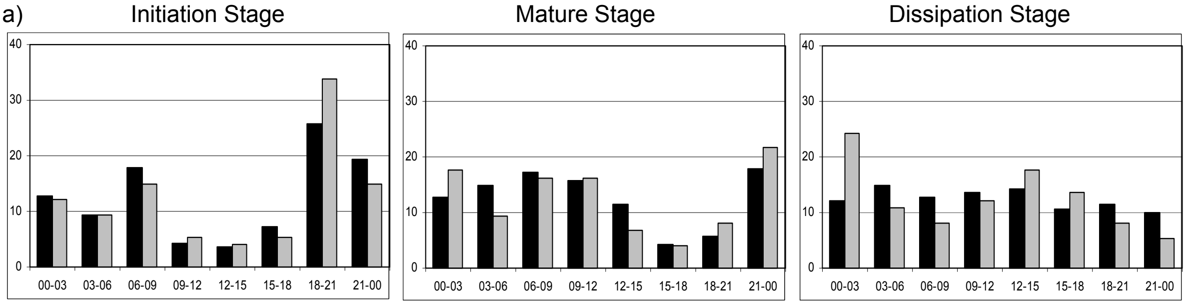


Figure 1: MCS centroids at the time of maximum extent during fall, spring and summer. The MCSs indicated with a circle correspond to the systems which occurred during a day of SALLJ, whereas the squares indicate a No SALLJ day. The open symbols indicate the systems that reached maximum extent during the day (between 1230 UTC and 00 UTC) whilst the full symbols show the systems that attained maximum extent at night (between 0030 UTC and 12 UTC).

NOSALLJ events this percentage dropped to 12 per cent.

In order to analyze the behavior of subtropical MCS during these different synoptic conditions, histograms of frequency of time of occurrence of the initiation, mature and dissipation stage are shown in Fig. 2a. Also size and lifetime of the MCSs are shown in Fig. 2b and c.

Subtropical systems show a maximum frequency of initiation between 18 and 00 UTC which extends toward the nocturnal hours with a minimum before noon (Fig. 2a). The maximum extent occurs over a wide range of hours, 60 per cent are nocturnal, although no single strong peak dominates the sample. It is interesting that the minimum is observed near local noon (1500 -1700 UTC). Dissipation can take place at any time of the day. No remarkable difference in the life cycle is observed between the MCS sample during SALLJ events (MCS-SALLJ) and during No SALLJ events (MCS-NOSALLJ).



b) Size

c) Lifetime

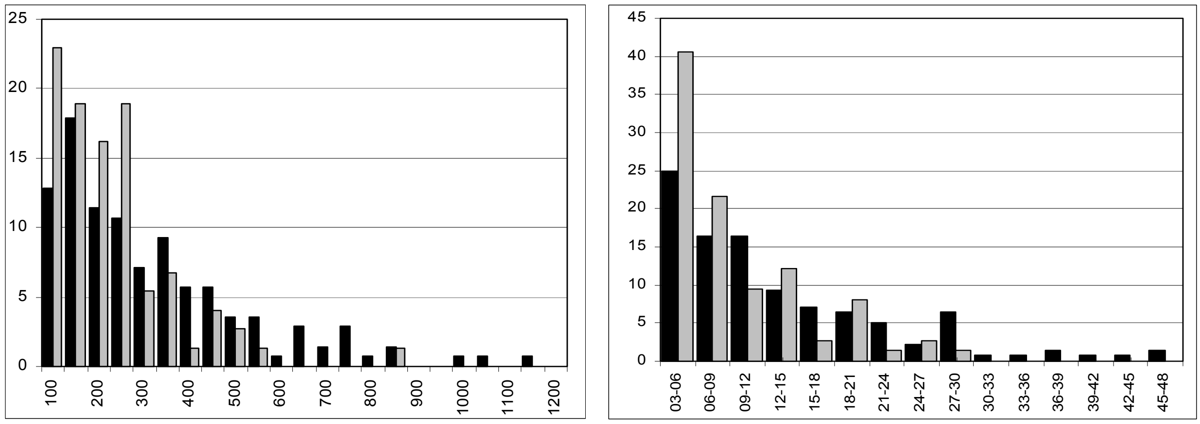


Figure 2: Frequency distributions in percent of a) initiation (left column), mature (center column) and dissipation stage (right column), time is expressed in UTC; b) MCS size (10^3 km^2) and c) Lifetime (hours) for SALLJ (black) and No SALLJ (light grey) samples.

MCSs-SALLJ attain a longer duration and wider size than MCSs-NOSALLJ with an extreme value of 1.2 10^6 km^2. MCSs-SALLJ have a broad distribution of their life cycle stages, implying that the forcing from the low level jet is more important than that from the diurnal cycle of heating, which, on the contrary, is more important for tropical MCSs (not shown). MCSs-NOSALLJ present a length of life shorter than 30 hours, but 60% even shorter than 6 hours evidencing, like in tropical systems, the important role of the radiative diurnal cycle.

3.2 Frequency of Convection during MCS-SALLJ and MCS-NOSALLJ events.

Convection frequency represented by an IR brightness temperature below 218 ºK was calculated over the whole domain and the evolution of its geographical distribution is displayed in Fig. 3 and 4 during the 3-day period centered on MCS-SALLJ day and MCS-NOSALLJ every 6 hours.

During MCS-SALLJ evolution, the presence of a zone with weak convection frequency is located in central Argentina on day -1 at 00 UTC. This maximum intensifies and spreads during the next 12 hours, covering Uruguay and the entire center of Argentina, with an apparent decline at 18 UTC. The contrast between figures at 18 UTC corresponding to day -1 and the 00 UTC corresponding to the MCS-SALLJ day is significant. A number of developments, not present in day -1, occur over the entire slope of the Andes and all over SESA. The frequency of convection intensifies at 06UTC and the concentration of its maximum at 12 UTC is the main difference respect to six hours before. This nocturnal extreme subsides toward the afternoon (18 UTC), showing a displacement north of 25ºS and toward Uruguay. On day +1 there is a clear weakening of the systems in subtropical areas and an intensification in tropical latitudes.

The evolution of the convection frequency during MCS-NOSALLJ events presents a different pattern respect to the cases when SALLJ is present, especially during the day 0. The evolution shows the presence of scattered convection the day -1 over SESA. Similar to MCS-SALLJ days, it is possible to detect a weakening at 18 UTC and an intensification all over SESA at 00 UTC on the following day. During nocturnal hours, there is no concentration of the developments, they are present over Argentina and Paraguay, and the frequency values are lower than 15%, whilst the extreme during MCS-SALLJ condition is 35%. The extremes tend to shift toward the northeast during the afternoon of MCS-NOSALLJ day.

MCS-SALLJ

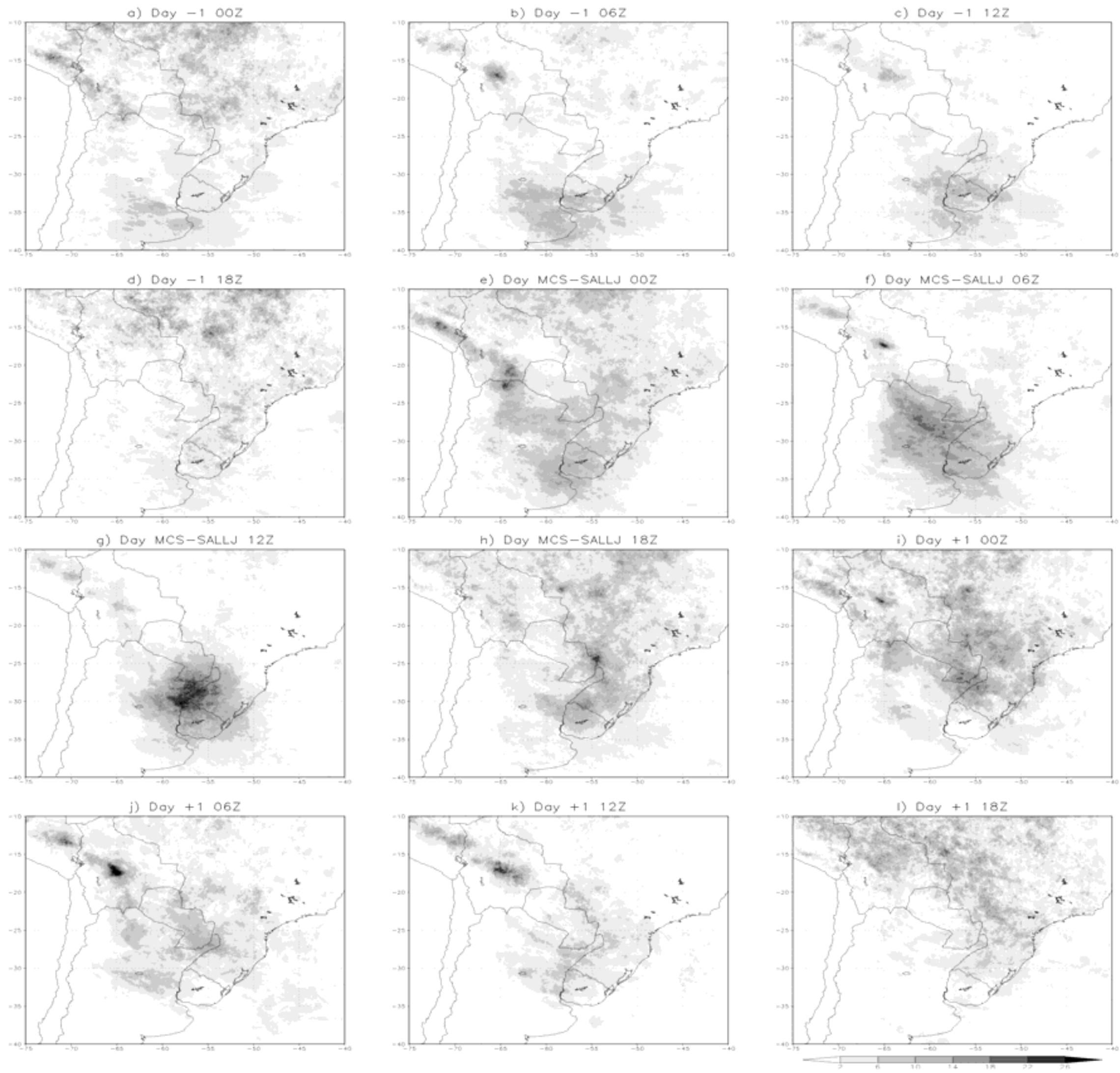


Figure 3: Geographical distribution of the frequency of convection represented by an IR brightness temperature below 218ºK for MCS-SALLJ events every 6 hours.

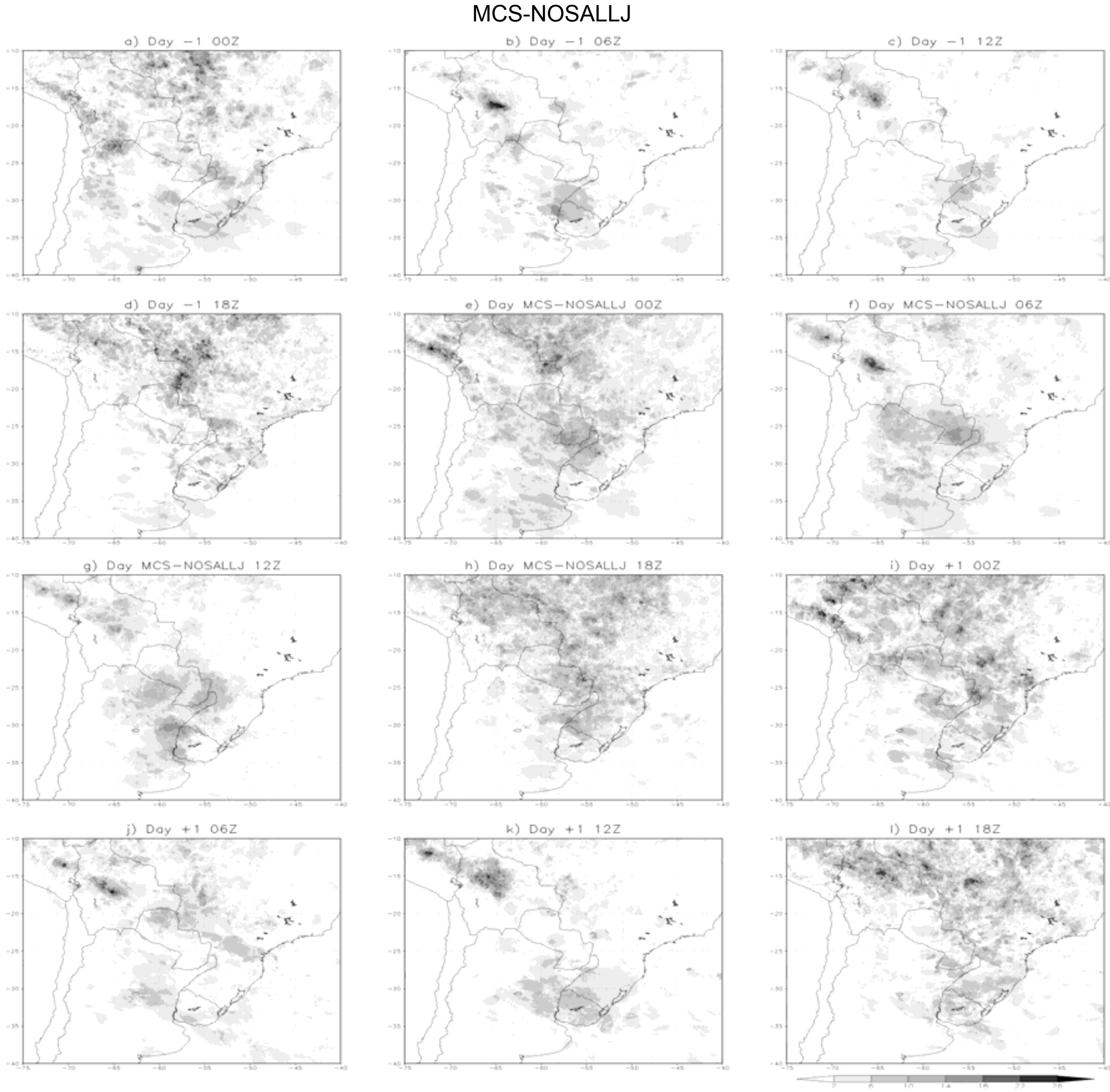


Figure 4: idem Figure 3 for MCS-NOSALLJ.

3.3 Large scale environment during MCS-SALLJ and MCS-NOSALLJ events.

The environment associated with the large long-lived subtropical MCSs exhibits a northerly flux during the previous day, and persisting during the whole life cycle of the system (Fig. 5). The entire SESA region is under the influence of the deceleration of the moisture flux and, therefore, of the associated convergence on day -1 and the day of MCSs occurrence. The principal difference between the two studied samples is the magnitude of the flux. While MCS-SALLJ events present a moisture flux with extreme values higher than 500 kg m^{-1} s^{-1}, during MCS-NOSALLJ the moisture flux is 50% smaller than this value.

Essential large scale features present on MCS-SALLJ event are: low level convergence generated by an anomalous all day long strong low level jet prior to the development of the system, overlapped by high level divergence associated with the anticyclonic flank of the entrance of an upper-level jet streak. This convergence structure provides the dynamical forcing for convection in an increasing convective unstable atmosphere driven by an intense and persistent horizontal advection of heat and moisture at low levels. These processes act during at least one diurnal cycle, enabling gradual building of optimal conditions for the formation of the largest organized convection in the subtropical area. The northeastward displacement and later dissipation of subtropical convection are affected by a northward advance of the southern boundary of high equivalent potential temperature air represented by a baroclinic zone, which is related to horizontal cold advection and divergence of moisture flux at low levels, both contributing to the stabilisation of the atmosphere.

Most of the ingredients present during MCS-SALLJ conditions are also evident during MCS-NOSALLJ (Fig. 6) but with less intensity. In those cases, the formation of convection is supported by the presence of a warmer and deeper convective unstable atmosphere in the subtropical area. θe values are higher than 355ºK close to the surface before the development of the systems. This composite does not show the evidence of a strong synoptic wave moving to the east, but the jet streak pattern is also evident (not shown).

All these elements support the existence of larger and longer systems during SALLJ events. But both composites reveal the vital role of the northerly flux as a moisture and heat conveyor efficient to generate dynamic and thermodynamic scenarios that promote subtropical convection.

MCS-SALLJ

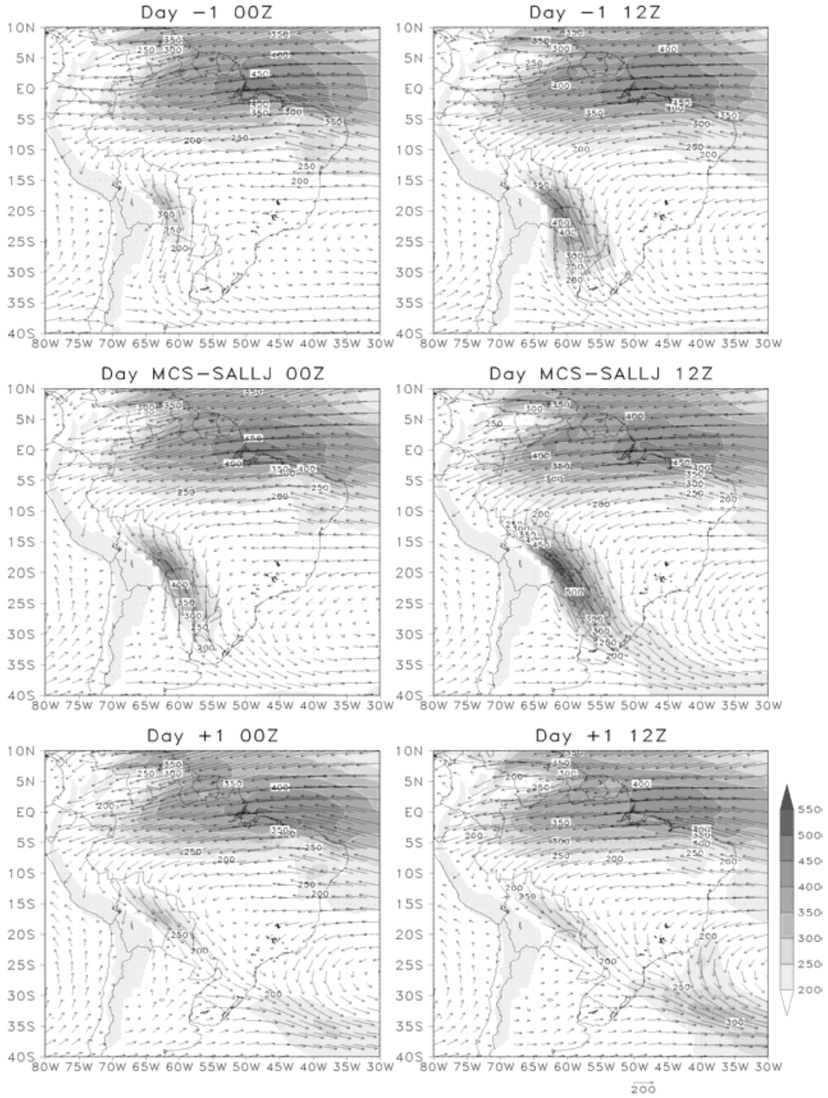


Figure 5: Vertically integrated moisture flux (vectors) and their absolute value (shaded) in kg m^{-1} s^{-1} for the MCS-SALLJ events. Values greater than 100 kg m^{-1} s^{-1} are shaded.

MCS-NOSALLJ

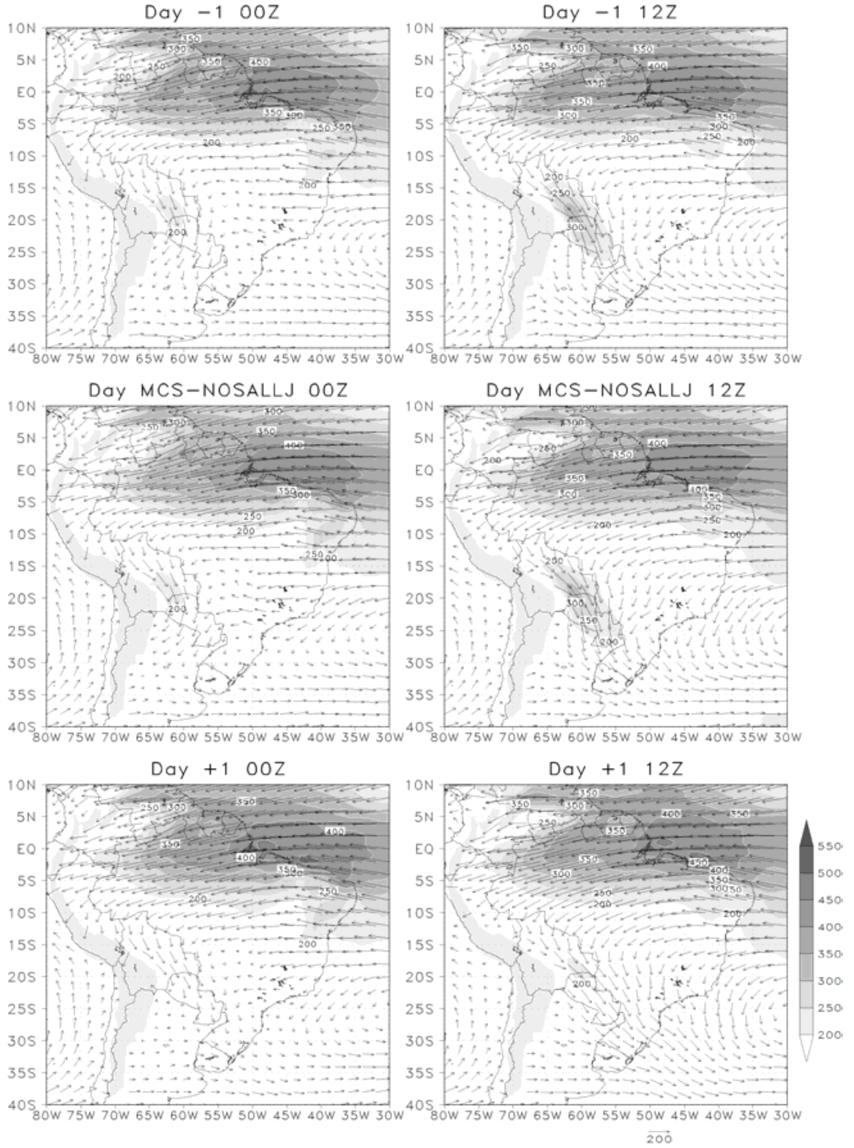


Figure 6: idem Figure 5 for the MCS-NOSALLJ events.

ACKNOWLEDGMENTS

This research is supported by UBA grant X266, ANPCyT grant Nº PICT 07 – 14420, NASA NAG5-9717, NOAA PID-2207021, NA03OAR4310096 and the collaborative program IAI-CRN 55.

REFERENCES

Bonner, W., 1968: Climatology of the low level jet. *Mon. Wea. Rev.*, 94, 167–178.

Cotton, W. R. , M. S. Lin, R. L. McAnelly and C. J. Tremback, 1989: A composite model of mesoscale convective complexes. *Mon. Wea. Rev.*, **117**, 4, 765–783.

Janowiak, J., R. Joyce, and Y. Yarosh, 2001: A real time global half hourly pixel resolution infrared dataset and its applications. *B. Am. Met. Soc.*, **82**, 2, 205–217.

Machado, L. A. T. and H. Laurent, 2004: The convective system area expansion over Amazonia and its relationships with convective system life duration and high-level wind divergence. *Mon. Wea. Rev.*, **132**, 714 - 725.

Mota, G.V., 2003: Characteristics of rainfall and precipitation features defined by the Tropical Rainfall Measuring Mission over South America. *Ph.D. Dissertation, University of Utah*, 215 pp.

Nicolini, M., C. Saulo, J. C. Torres, and P. Salio, 2002: Strong South American low level jet events characterization during warm season and implications for enhanced precipitation. *Meteorologica*, *Special Issue on South American Monsoon System*, **27**, 1 and 2, 59-69.

Salio, P., M. Nicolini and A.C. Saulo, 2002: Chaco Low level Jet Events Characterization During the Austral Summer Season by ERA Reanalysis. *J. Geophys. Res.,* **107** (D24), 4816, doi: 10.1019/2001JD001315.

Velasco, I. y J.M. Fritsch, 1987: Mesoscale convective complexes in the Americas. *J. Geophys. Res.*, **92**, 9591-9613.

Silva Dias, M.A.F., 1999: Storms in Brazil. In: Hazards and Disasters Series, Storms Volume II, R. Pielke Sr. , R. Pielke Jr., Eds., Routledge. pp.207-219.