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UPPER-LEVEL CUT-OFF LOWS IN SOUTHERN SOUTH AMERICA: PRELIMINARY RESULTS

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INTRODUCTION

There are numerous papers dealing with cut-off low systems (COLs) in the Northern Hemisphere, focused on case studies or climatologies. However, the methodologies used to select the cut-off events differ among themselves (Bell and Bosart, 1989, Kentarchos and Davies, 1998, among others). Recently, Nieto et al. (2005) made the first multidecadal climatology of cut-off systems in the Northern Hemisphere, based on 41 years (1958-98) of NCEP-NCAR (National Center for Environmental Prediction - National Center for Atmospheric Research) reanalysis. They proposed an objective method to select the COL events, taking into account the three main physical features of the conceptual model of cut-off lows: 200 hPa geopotential minimum, cut-off circulation, thickness ridge in front of the low. This paper validated some well-known results such as the existence of three preferential areas of COL occurrence, with greatest frequencies in the European area and during summer, and mostly lasting from 2 to 3 days.

There are few studies of COLs in the Southern Hemisphere. Pizzarro and Montecinos (2000, hereafter PM) characterized the cut-off cyclones off the subtropical coast of Chile during the period 1979-1996 using the daily 1200 UTC NCEP-NCAR reanalysis at 500 hPa and studied the impact of these systems on the rainfall regime in subtropical Chile. They found COL occurrence had significant interannual variability ranging from 2 to 15 events, being the austral spring the most frequent season. The 85% of cases was characterized by a deep 500-hPa trough with an intense NW-SE ridge upstream (located between 25ºS and 40ºS) and a 1000 hPa anticyclone in phase with the mid-tropospheric ridge.

The main objective of this paper is to perform a statistical analysis of the spatial and seasonal distribution of cut-off low systems over southern South America.

2. DATA AND METHODOLOGY

In the present study, the six-hourly NCEP-NCAR reanalyses (Kalnay et al., 1996) with a 2.5º by 2.5º horizontal resolution and 17 vertical pressure levels were used to perform a climatology of cut-off lows for a ten-year period from 1979 to 1988. The selected domain extends from 100ºW to 20ºW and from 15ºS to 50ºS. COL events were selected as follows:

1) an objective method to determine minima in the 250 hPa geopotential fields. We used the 250 hPa geopotential height instead of 200 hPa proposed by Nieto et al. (2005) –among others- to guarantee that the system is in the troposphere. A grid point is considered a minimum if its geopotential height is at least 20 mgp lower than the eight surrounding grid points, for at least eight time steps (2 days)

2) for all the cases selected in the previous step, a subjective analysis was performed imposing a cut-off circulation (the split of the jet stream) and a cold core, at lower or middle levels examining the 1000/500 hPa and 500/250 hPa thickness respectively.

Although COLs are mainly upper and/or mid-tropospheric features, they sometimes extend towards the low troposphere where a closed cyclonic circulation can be observed. Events without low-level cyclonic circulation were called NLC.

3. RESULTS

In the 10 year period studied 171 events occurred in southern South American. Figure 1 shows the distribution of events during this period and it is evident that COL events showed interannual variability as in the Northern Hemisphere, being 1979 the year with the greatest number of cases. Only 25% of the events correspond to cases with cyclonic circulation in lower levels. These are most frequent to the south of 40ºS.

In order to analyze a possible distinct behavior over different parts of the region under study, we assigned the events to three particular areas depending on where the COL reached its greatest depth: Pacific, continental or Atlantic area. Figure 2 shows the annual distribution of COL events over these particular areas. There were 75 events over the Pacific area, 51 events over the Atlantic Ocean and 44 over continental area. There is also an important interannual variability in the number of events in all the regions. A particular year was 1980, with no events over the Pacific Ocean and the Atlantic showing its maximum frequency. The greatest frequency in the Pacific took place in 1987, with 14 events.

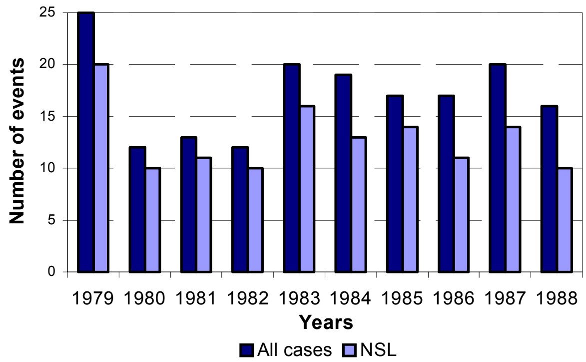

Figure 1: Annual distribution of the number of cutoff low events, for all cases and without surface cyclonic vorticity associated

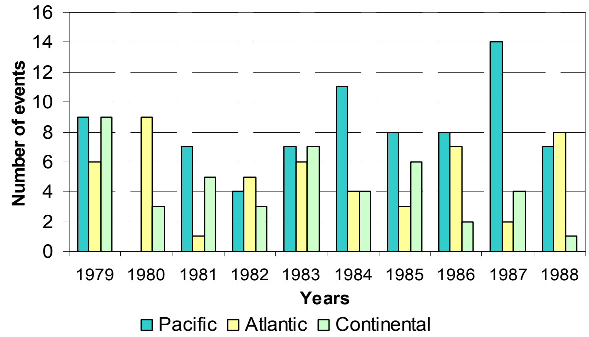

Figure 2: Annual distribution of the number of cutoff low events for the three areas considered.

The monthly distribution of COL events is shown in Figure 3. A slightly different behavior stands out when all the cases or only NLC cases are considered. Considering all the events, austral fall (March, April, May) has the maximum frequency of events (31.2% of the cases), followed by winter (June, July, August) with 24.7% and spring (September, October, November) and summer (December, January, February) with almost the same number of events (22.3% and 21.8% respectively). However, if only NLC cases are considered, the austral fall is still the most frequent season, followed by spring, summer and winter.

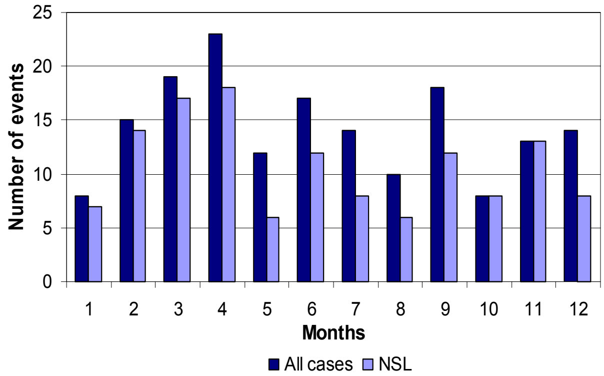

Figure 3: Monthly distribution of the number of cutoff low events for all cases and without surface cyclonic vorticity associated

The seasonal distribution of COLs was different in the three analyzed areas (not shown). Winter and autumn showed the maximum frequency over the continental area and autumn remained the most frequent season over the Atlantic and Pacific oceans.

Figure 4 shows the spatial distribution of all COL events over southern South America, at the time of their maximum depth. The continental area had maximum COL frequency over southeastern Brazil, while an almost homogeneous distribution was observed in the Atlantic region. There is a preferential region of occurrence between 68º-80ºW and 30º-45ºS. The study of PM also pointed this area as having frequent COL events. Spring (not shown) is the season with more events off the subtropical coast of Chile (as shown by PM), followed by autumn which also presents several cases along 70ºW. Another interesting feature is related to the geographic distribution of continental COL events, with the highest frequency in autumn and winter as mentioned in the previous section. Almost all the cases took place over subtropical South America.

Almost all the events (90%) of the cut-off low in southern South America lasted from 2 to 3 days over the oceanic areas and there were few cases lasting longer (not shown). The longest event lasted 7 days. Longer events tend to appear over continental areas and are related with cases around 20ºS.

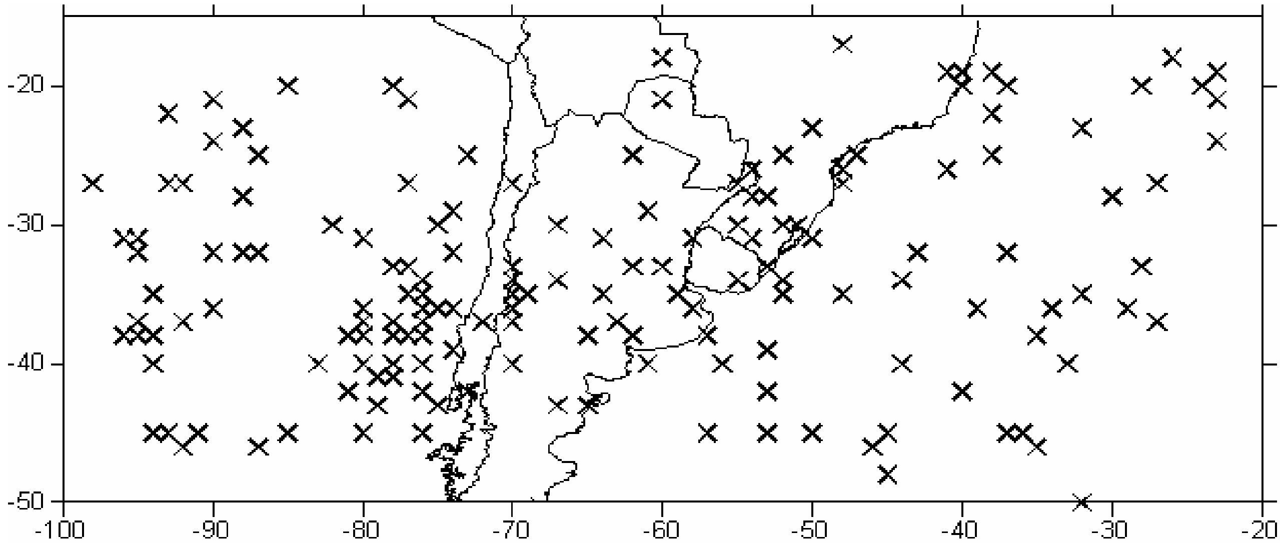

Figure 4: Spatial distribution of cut-off low events at time of maximum depth

4. Summary

The period 1979-1988 was used in this study to perform a statistical analysis of the spatial and seasonal distribution of the cut-off low system detected at the 250 hPa geopotential height level based on the NCEP-NCAR reanalysis. Analyses were restricted to the southern South America region between 15ºS - 50ºS and 100ºW – 20ºW.

Our statistical analyses reveal that cut-off have preferential regions of occurrence, being more frequent over the Pacific Ocean with 44% of the cases followed by the Atlantic Ocean with 30% and 26% over the continental area. The geographic distribution showed that cut-off lows developed more frequently in a region between 30º-45ºS and 68º-80ºW. Examining the geographic seasonal distribution of COL events we found that austral spring (SON) and autumn (MAM) had the highest frequency of events over this region. In particular, spring had more cases off the coast of Chile while autumn presented more continental cases.

The seasonal analysis over the entire domain revealed that fall is the preferential season (31.2%) followed by winter (24.7%), spring (22.3%) and summer (21.8%). This result differs from those obtained for the Northern Hemisphere (Kentarchos and Davies, 1998; Nieto et al. 2005) where summer seems to be the preferential season of cut-off low occurrence linked to the weakened jet streams and the warming of continental regions. The different large-scale circulation patterns around the northern and southern Hemisphere lead us to think seasonal occurrence of cut-off lows was different. Considering only the COL events that extended to lower levels, autumn remained the most frequent season but now followed by spring, summer and winter.

The duration of COL events in southern South America is similar to that in the northern Hemisphere. Nearly 90% of the cases lasted 2 or 3 days though continental events tend to be longer.

Also evident is the interseasonal and interannual variability in the different areas. Further studies must be conducted to investigate the physical and/or thermodynamic forcing responsible of these variabilities.

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