RAINFALL ASSOCIATED WITH MESOSCALE CONVECTIVE SYSTEMS WHICH AFFECTED RIO GRANDE DO SUL STATE IN JULY, AUGUST AND SEPTEMBER OF 2006

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I. INTRODUCTION

According to the Brazilian civil defence, more than forty sixth alerts related to meteorological events were reported in 2006 in Rio Grande do Sul state (RS), reaching around six thousand inhabitants, which has become frequent in the whole area in recent decades. In order of preventing socio-economic and environmental losses, such as crop failures due to the occurrence of severe weather events (hail, torrent, windstorm, flooding, etc.), it is necessary to make further studies of the rainfall regime, with a mission to contribute to a better dimensioning hydraulic structures, as well as favouring agricultural crops.

Some of the weather systems charge of rainfall in the tropics, including several locations in mid-latitudes, is known as Mesoscale Convective Systems (MCS). According to Houze (1993), the MCS are composed of a cluster of convective clouds owning different forms.

Under this light, this study aimed to identify the occurrence of MCS which affected RS in the period from July to September of 2006 (JAS-2006), using the application ForTraCC (Active Forecasting and Tracking of Cloud Cluster) developed by Vila et al. (2008), and analyze the precipitation associated with these events.

II. PRESENTATION OF RESEARCH

For the selection of MCS were used the raw data from the GOES12 (Geostationary Operational Environmental Satellite) in channel 4 (thermal infrared), within spatial resolution of 4 km by 4 km and time resolution of ½ hour, of JAS period from 2004 to 2008, provided by the Satellite Division and Environmental Systems, Center for Weather Forecasting and Climate Studies, National Institute for Space Research (DSA / CPTEC / INPE), which served as a database in ForTraCC technique. In addition, JAS data from 2004 to 2008 were used to obtain the average behaviour of the MCS in these five years, as well as the data from JAS 2006 were used to identify the MCS which affected RS in 2006.

Thereafter, daily rainfall amounts (P_d), on JAS period from 1977 to 2006 belonging to 12 meteorological stations in RS, of 8th DISME / INMET database (8th Meteorological Department of National Meteorological Institute) were used. The 12 weather stations were chosen for being well distributed, since they represent a full range of data to different regions (regions with different climatic characteristics) of RS state (Figure 1). Thus, JAS P_d data from 1977 to 2006 were used to get the normal conditions for this period, as well as JAS P_d data of 2006 were used to identify the precipitation associated with the SCM which affected RS in this quarter.

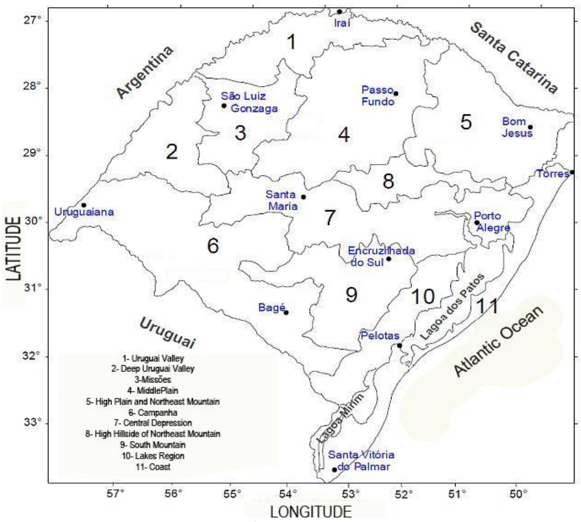


FIG. 1: Spatial distribution of weather stations used in this article.

The ForTraCC application was used in the diagnostic mode for the MCS's selection. This application is an identification and tracking method of MCS, which provides the MCS's physical and morphological characteristics identified during its life cycle. It is noteworthy that each of MCS (or family) detected by ForTraCC has its life cycle described by the group of characteristics displayed by it at any time, which corresponds to a member of MCS (or family). The process of identification of the MCS ForTraCC uses raw images of the GOES satellite and is based on thresholds of size and brightness temperature on the cloud tops (T_{ir}), where the size threshold used to detect a MCS was 150 pixels, to ensure that the same system could to be identified in an after image.

Simultaneously, for detecting MCS was used in ForTraCC the T_{ir} thresholds of 235 K to identify MCS, and 210 K to identify the convective cells immersed in MCS. According to studies by Carvalho and Jones (2001), Laurent et al. (2002), Machado and Laurent (2004) and Vila (2004), Tir's thresholds used in this selection seem acceptable to detect clouds associated with convection in different regions of South America, thus allowing the detection of both MCS and the convective cells immersed in it. Lately, were also used the threshold of 250 K for the early detection of SCM.

Once obtained the characteristics throughout the life cycle of all MCS identified by ForTraCC, were only considered in this study those which: i) maintained its center of mass throughout their life cycle below 20 º S ii) presented the life cycle of at least 6 hours (although considering systems with long life cycle, has not made any classification of the same in MCS, as MCC (Mesoscale Convective

Complexes) or SL (squall line), iii) had spontaneous initiation and natural dissipation, both at the time of initiation and in dissipation, there was no other merger or separation of the SCM MCS identified. (Using this condition ensures that the initial growth of selected SCM is associated with its own internal dynamics, as Machado and Laurent (2004). Despite this, it permitted the existence of mergers and separations during the life cycle of a given SCM, since otherwise the data set to examine would be limited.) and iv) affected the region covering the RS. It is noteworthy, it was determined that an MCS had affected RS when at least one member of the SCM analysis, presented latitude and longitude that is located within the grid covering the RS, between the latitudes of 27 º to 34 º S and longitudes 58 to 49 W.

According to INMET, the daily total rainfall for each weather station corresponds to the accumulated surface of the last 24 hours, collected at 12:00 UTC. Therefore, the rainfall associated with each detected MCS was determined as follows: whether the MCS began before 12:00 UTC on the day of detection, the rainfall associated with this was collected that day. If the MCS began after 12:00 UTC on the day of detection, the rainfall associated with this was collected the next day. The observed rainfall in the days following the detection of the event was only considered if the dissipation of MCS occurred after 12:00 UTC on any of the following days.

III. RESULTS AND CONCLUSIONS

Can be noticed in Table 1, which shows the daily total rainfall accumulated (P_{DA}) for 12 weather stations, which in 2006, the JAS P_{DA} average (310.8 mm) was lower than the JAS period from 1977 to 2006 (391.8 mm), that is, in 2006 had JAS rainfall negative anomaly. One rationale for the registration of volume below the normal precipitation in JAS 2006, is linked to El Niño Modoki (Ashok et al. 2007; Wang and Hendon, 2007, Weng et al., 2007), which causes drought in southern Brazil, since they were observed in this quarter, positive Sea Surface Temperature anomalies located in the central Pacific Ocean (Climanálise, 2006, Jamstec, 2010), which is indicative of this phenomenon.

Similarly, in Table 1 should be noted that the average P_{DA} associated with SCM that affected RS was 157.6 mm, which corresponded to 50.9% of the average JAS P_{DA} in 2006.

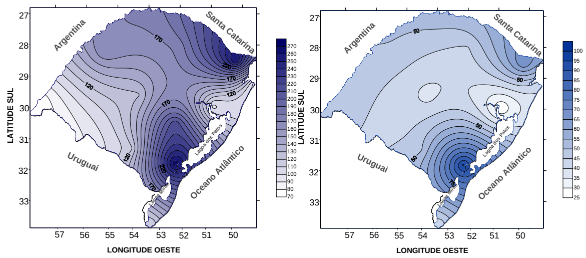
When analyzed the spatial distribution of PDA associated with MCS that affected RS in JAS of 2006 (Figure 2a) it was noted that the entire RS was reached through precipitation associated with MCS, but the western and the north coast regions had the lowest recorded occurrence of precipitation associated with the SCM that affected this quarter RS. On the other hand, the contribution of the precipitation associated with the MCS that affected RS rainfall total in JAS of 2006 (Figure 2b) was higher in the southeast, coinciding with the area with the highest rainfall in the months of study.

Comparing the features of MCS which affected RS in JAS of 2006 with those detected in the period of 2004 to 2008 (Table 2) it shows that JAS's MCS detected in 2006 occurred in the lowest number (33.09% less MCS), however had a higher average life cycle (lasting on average one hour and a half longer) and larger average size (SCM 15.12% higher) than those detected in the period of 2004 to 2008.

Weather Stations	JAS 1977-2006 (mm)	JAS 2006 (mm)	JAS SCM (mm)	Contribution (%)
Bagé (BG)	362,7	240,4	117	48,6
Bom Jesus (BJ)	439,7	373,1	260,7	69,9
Encruzilhada do Sul (ES)	433,6	403,4	217,2	53,9
Irai (I)	411,8	326,7	174,1	53,3
Passo Fundo (PF)	470,4	392,8	174,4	44,4
Pelotas (PEL)	367,9	277,8	266,4	95,9
Porto Alegre (POA)	397,4	377,9	96,7	25,5
Santa Maria (SM)	435,9	335,5	128,9	38,4
Santa Vitória do Palmar (SVP)	343,8	266,9	115,6	43,3
São Luiz Gonzaga (SLG)	427,4	345	168,7	48,9
Torres (T)	375,9	234,4	96,3	41,1
Uruguaiana (U)	235,9	156	75	48,1
Mean	**391,88**	**310,8**	**157,6**	**50,9**

TABLE 1: Total daily rainfall accumulated for 12 weather stations in RS belonging to 8th DISME/ INMET: period of JAS from 1977 to 2006, JAS of 2006, associated with the MCS that affected RS in JAS of 2006 and the contribution of MCS's precipitation associated that had affected RS in the total precipitation for JAS of 2006.

One explanation for this occurrence may be related to the fact that this quarter of 2006, the Sea Surface Temperature (SST) indicated the persistence of El Niño Modoki moderate intensity on the Equatorial Pacific. It is known that El Niño Modoki has similar impacts to the cold phase of ENSO in RS, for this reason, in this quarter had occurrence of drought in RS, mainly in the west and northwest of the state, which could be resulted in lower incidence of MCS. On the other hand, the high number of System Front (SF) on the study area encourages interaction between these systems (SF) and convection and thus the formation of MCS in larger and longer in this year period (Siqueira and Machado, 2004).



a) b)

FIG. 2 Distribution: (a) of the total daily accumulated rainfall associated with the MCS which affected RS in JAS of 2006(mm) and (b) the contribution of total daily accumulated rainfall associated with the MCS which affected daily total of RS accumulated rainfall in JAS, 2006 (%).

Period	nº SCM/year	Mean Life Cycle (h)	Mean Size (pixel)
JAS/2004-2008	28.4	13.52	20.790,62
JAS/2006	19 (-33,09%)	15.08 (+1.56h)	23.934 (+15,12%)

TABLE 2: Quantity, mean life cycle and mean size of MCS in JAS which affected RS in the period of 2004 to 2008 and 2006.

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