



Time participation of the continental tropical mass in the west part of Brazil's south center

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ABSTRACT. This study aimed at qualifying and quantifying the time spatialization of the continental Tropical mass participation in the state of weather in the west part of Brazil's South Center, from 2002 to 2010, with special focus on 2003 and 2008, years of El Niño and La Niña, considering that, beyond sparse studies, the region is close to this system's center of action. As the origin of this air mass is continental, during its period of performance, days present low relative humidity, intense heating and lack of rain. In South Brazil, the performance is more intense in the hottest months, and on the west part of the West Center region there are no studies. For this reason, it were chosen for this study the cities of Campo Mourão, in the State of Paraná, South of Brazil, and Cáceres, in the Sate of Mato Grosso, west part of Brazil's West Center. By analyzing the synoptic maps and satellite images, the participation of this system in a daily scale was quantified. The system showed itself more active for the region of Campo Mourão in the hottest months and for Cáceres during the winter.

Keywords: geographical climatology, state of weather, air masses.

A participação temporal da massa tropical continental na faixa oeste do centro sul do Brasil

RESUMO. O objetivo do estudo foi quantificar e qualificar a espacialização temporal da participação da massa Tropical continental no Estado do tempo no oeste do Centro-Sul do Brasil na série 2002 a 2010, com enfoque especial para 2003 e 2008, anos de El Niño e de La Ninã, considerando que além dos esparsos estudos, a região encontra-se próxima do centro de ação desse sistema. Como a origem dessa massa de ar é continental, durante o período de atuação, os dias apresentam baixa umidade relativa, intenso aquecimento e pouca chuva. No Sul do Brasil, a atuação é mais intensa nos meses mais quentes e no oeste da região Centro-Oeste do Brasil não se tem estudo, por essa razão, elegeram-se para esse estudo as cidades de Campo Mourão no Paraná, Sul do Brasil, e Cáceres no Mato Grosso, oeste do Centro-Oeste do Brasil. Por meio da análise das cartas sinóticas e das imagens de satélite, quantificou-se a participação desse sistema na escala diária. O sistema se mostrou mais ativo para a região de Campo Mourão nos meses mais quentes, e para Cáceres, no inverno.

Palavras-chave: climatologia geográfica, estado do tempo, massas de ar.

Introduction

Atmospheric dynamics in the west part of Brazil's South Center was surveyed from the atmospheric systems that operate in this region. Historic series from 2002 to 2010 were evaluated, focusing on two locations: Campo Mourão, in the State of Paraná, and Cáceres, in the State of Mato Grosso. For each location air masses were quantified by analyzing the synoptic maps from Brazil's Navy (PÉDELABORDE, 1970), and satellite images in the infrared channel.

The continental tropical mass is a low pressure system, with its origin center in the region of Chaco plain in Paraguay, in a zone of low lands with intense heating and extremely low humidity (MONTEIRO,

1968; ZAVATTINI, 2009). For such reasons, it is a hot air mass with low humidity. In Brazil it operates in the West Center, mainly in the west part of South and South-East regions. With the aging of the Atlantic Polar mass and its zonal displacement towards the interior of the Atlantic, the continental Tropical mass enlarges from its origin center and generates sunny days, high temperature and lack of rain. Episodes of rain are the consequence of high surface heating, that generates sparse and located convective systems: 'This low pressure is called Chaco low, continental low' (MONTEIRO, 1968). According to the same author, the longest frequency of cTm performance in the South region, mainly in the States of Santa Catarina and Rio Grande do Sul, occurs in January and

February. The short droughts, frequent during these two months in the South of Brazil, are the consequence of its domain in weather conditions (HERRMANN, 2001).

The atmospheric dynamics of Brazil's South Center began to be effectively studied and known from Serra and Ratisbonna (1942; 1945), Schröder (1956), Serra (1971a; 1971b; 1972), Monteiro (1968 and 1971), Nimer (1972), Titarelli (1972), Tarifa (1972), Conti (1975), Zavattini (2009), Sant'Anna Neto (1999) and Borsato (2008), among others. Most of these authors, in their studies, looked upon only one State of the Federation, only one sub-region and, in most of the cases, considering the difficulties of approaching a large series, they studied relatively short episodes or periods of time. For this reason, it was not possible for them to build a detailed characterization of the air masses' dynamics for the studied regions.

In this work, the dynamics of the atmospheric systems that operated in Brazil's South Center during the historic series from 2002 to 2010 were contemplated, quantifying the participation of each system from two locations. The results originated a huge volume of information and histograms. In this paper are presented the results from 2003, because it was a year of El Niño, and 2008, year of La Niña, both phenomena that cause anomalies in Brazil's weather, as well as in many regions of the globe.

The goal was to quantify, qualify and analyze the time spatialization of the continental Tropical mass participation in the state of weather for this region. The quantification was obtained by observing the chronological time this system operated in the region, in the daily scale and extending to the seasons of the year. The spatialization was made by comparing the time between the percentage participation in Campo Mourão and Cáceres. It was also considered the state of weather provided by this system, through atmospheric pressure, temperature and precipitations registered in the operation period.

The results confirmed wide operation during the summer for the south part of the studied area, and revealed that the participation for the region of Cáceres is wider for the colder season.

Material and methods

In Geographic Climatology, it is adopted the dynamic conception of weather proposed by Sorre (1951), and adjusted to the 'Rhythmic Analysis', developed by Monteiro (1971), in which the author suggests that daily variation of the weather

elements, associated to the synoptic circulation, could be used to reveal the genesis of weather phenomena.

Atmospheric systems were quantified from the reading and interpretation of the synoptic maps from Brazil's Navy, which is a methodology proposed by Pédelaborde (1970), and by the techniques developed by Borsato (2008). The satellite images in the infrared channel were used as a support to identify the actuating system.

The considered atmospheric systems were the ones that actuated in Brazil's South Center, that are: Frontal System (FS), continental Tropical mass (cTm), Atlantic Tropical mass (aTm), Atlantic Polar mass (aPm), and continental Equatorial mass (cEm) (VIANELLO, 2000; VAREJÃO-SILVA, 2000; BISCARO, 2007).

For the record of the atmospheric systems, tables were constructed in Excel® worksheets. Numerical values (24) were attributed for the days in which a single system operated in the region, and sometimes (12) for each, when the region was under confluence of two or more systems, or different values considering the participation time. The monthly and seasonal values were considered in percentage, and these, for their turn, were inserted in histograms and cartograms.

The atmospheric pressures read in Brazil's Navy synoptic maps were considered as low pressure when values were lower than 1013hPa, and as a high pressure when beyond this value (VAREJÃO-SILVA, 2000). For this research, actuation of the continental Tropical mass was considered only under conditions of low pressure. It was also considered the configuration of the cyclonic cell on the region of origin, Chaco low. Thus, the participations of this system in the state of the weather were obtained for the two locations.

Results and discussion

Brazil's South Center region does not present the characteristics of actuating centers generating surface. All the air masses that operate in this region go forward from their operation centers, by expansion or migration. Going forward, they impose their characteristics, while the invaded area is partially influenced, depending on the conditions imposed by the season of the year – as it is also a characteristic of the migrating air masses to acquire the corresponding characteristics to the areas where they move through and to impose their own characteristics.

The oceans, the deserts, the large icy areas and forests are *a priori* potentially propitious areas for the formation of air masses, in face to the uniformity they present. When one of these areas is under the

action of a vast anticyclone, all the requirements for the genesis of an air mass are fulfilled (VAREJÃO-SILVA, 2000, p. 369).

The atmospheric dynamics of a region is a consequence of general atmospheric circulation, local geophysical conditions, and regional extra phenomena such as El Niño and Southern Oscillation, among others.

The city of Campo Mourão is located in Paraná's Occidental Center, close to the line of the tropic of Capricorn, at -24.05 degrees latitude, and -52.37 degrees longitude. Cáceres is located in the board of Amazon, in the North-West limit of Brazil's South Center. The geographic coordinates of Cáceres's climatic station are -16.05 degrees latitude and -57.68 degrees longitude (Figure 1). This geographic position favors the low pressure and continental systems operation, mainly the cEm, although the cTm also operates frequently.

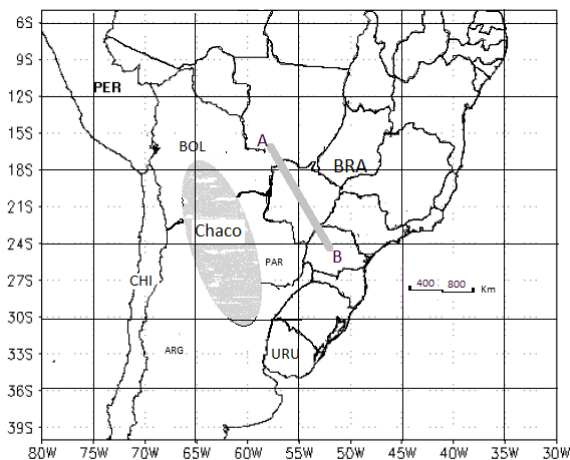


Figure 1. The studied area is shown by the segment A – B, in which A = location of Cáceres, in the State of Mato Grosso, and B = location of Campo Mourão, in the State of Paraná. It also shows the approximate location of Chaco Low. The symbols correspond to the countries of South America: ARG is Argentina, BRA is Brazil, BOL is Bolivia, CHI is Chile, PAR is Paraguay, PER is Peru and URU is Uruguay. Organized by the authors.

Air masses are large portions of atmospheric air with their own characteristics, with reasonable homogeneity in their thermodynamic properties, mainly regarding temperature and humidity. These properties are acquired in the regions where they are originated (OLIVEIRA et al, 2001).

According to Nimer (1979), the continental Tropical mass presents low humidity, and it is more persistent in the hottest months that extend from the end of spring to the beginning of autumn. He also considers:

[...]. Its region of origin is the thin hot, arid and low zone located at east of the Andes and south of the Tropic. It derives from the frontolysis in the Pacific Polar Front, from where cyclones move southwest, occluding after transposing the Andes, where it suffers the effects of the adiabatic dissection. This fact, linked to the great isolation of the summer solstice, may contribute to the temperature elevation and the mass dryness. Thus, the Chaco low becomes the source for the cTm (NIMER, 1979, p. 11).

The continental Tropical mass is a semi-temporary and cyclonic system, that is, it re-appears, in most cases, with the aging of the aPm. As the aPm goes east, the anticyclonic winds of this system, circumventing the center of high pressure located at the Atlantic coast, runs a long continental area, assimilating these characteristics and getting hot in function of the region's low latitude.

According to Seluchi and Marengo (2000), the stagnation of a hot and dry air mass above the central portion of the South-American continent is related to the presence of the Chaco low, located approximately at -25 degrees latitude and -65 degrees longitude, generated by the heating of the atmosphere above the continent.

Monteiro (1968) have argued that the atmospheric conditions, considered by some researchers as the configuration of the continental Tropical mass itself, are in fact the aged Polar mass.

The Continental Tropical Mass (cT), of a less conspicuous occurrence, has a complementary participation. Its individualization is more restrict to the summer when the Chaco Low, dynamized by the Atlantic Polar Front, superimposes a bag of cold air (in the superior circulation). Thus the hot and dry air of the continent's central low, with superior subsidence given by the import of cold air, presents a divergent movement, which is one of the basic conditions for the individualization of the air mass. Nevertheless, frequently, during the other seasons of the year, it is possible to note, in the Brazilian synoptic maps, references to the cT. Many times, this signaling refers to an aged polar mass, highly modified, that, within the continent, became much hotter and drier. It is more prudent, in such cases, to refer to an 'Aged Polar' modified in pseudo cT. Located within the corridor of the continent central lows, where equatorial and polar masses circulate, the operation of this air mass on Meridional Brazil, is a function of those (MONTEIRO, 1968, p. 122).

In this work, the years of 2003 and 2008 were investigated in detail. The 2003 year was marked by the phenomenon El Niño, and 2008 by La Niña.

The National Oceanic and Atmospheric Administration (NOAA) surveys the superficial

temperatures of the tropical Pacific waters. According to NOAA data (NOAA, 2013), temperatures below average were verified in the period that extends from May 2002 to February 2003. The CPTEC-INPE (Centro de Previsão do Tempo e Estudos Climáticos do Instituto Nacional de Pesquisas Espaciais) considered 2003 as a year of 'moderate' El Niño (CPTEC-INPE, 2012a) and 2008 as a year of 'strong' La Niña (CPTEC-INPE, 2012b).

The most known anomalies, and with a higher impact, are the ones related to rain inter-annual variability. According to Cunha (1999), rain anomalies are related to El Niño (waters of the hot Tropical Pacific and the negative Index of South Oscillation). La Niña reaches the same regions in the same periods of the year (or with a small discrepancy), however in an opposing way, that is, in those regions with excessive rains in years of El Niño, rain may be scarce in La Niña years.

It is admissible that there are about twenty regions in the Earth whose weather is affected by the ENSO phases. In Brazil, the north sector of the Northeast Region, the east part of the Amazon Region (in the tropical band) and the South Region are the most affected by this anomaly (CUNHA, 1999).

In Geographic Climatology these phenomena raise interests, the phenomenon consequences on the state of weather are evaluated and the most evident concern is related to precipitation, temperature and, finally, the systems' dynamics. The studies of Kousky and Cavalcanti (1984); Nery et al. (1997); Rao and Hada (1990); Grimm et al. (1998); Cunha (1999); Capel Molina (1999); Quadro (1999); Nery et al. (2000); Ferreira et al. (2004) show that the rainfall highs and its distribution are the main focus.

The first finding of this research refers to time spatialization. In Campo Mourão, the participation increases in the hottest months. In Cáceres, the amplification occurs in the colder months. This variation of space and time is related to the seasonal displacement, following the zonal movement of general circulation, as well as all the large atmospheric general circulation cells displace towards north or south, following the apparent movement of the Sun.

In 2003, the cTm action for Campo Mourão was 21,4% for summer, 8,7% for autumn, 5,9% for winter and 36,0% for spring. In Cáceres, the participation was 4,4% for summer, 49,8% for autumn, 42,5% for winter and 28,7% for spring. Figures 2 and 3 show the participation of the

systems that actuated in Campo Mourão and Cáceres in 2003. Comparing the two graphics, it is possible to visualize the participation increase in the hottest months for Campo Mourão and the contrary for Cáceres.

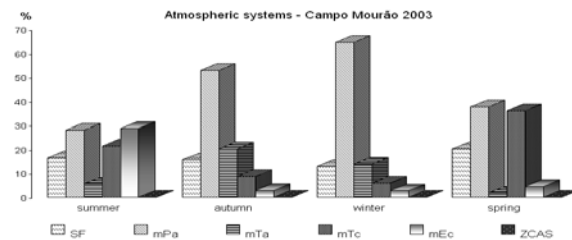


Figure 2. Atmospheric systems that actuated in Campo Mourão, Paraná state, in 2003. Organized by the authors.

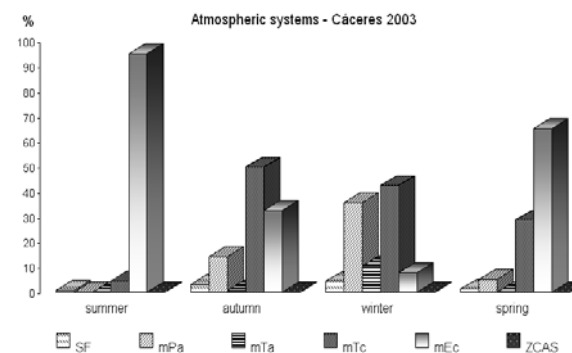


Figure 3. Atmospheric systems that actuated in Cáceres, Mato Grosso state, in 2003. Organized by the authors.

The year of 2008 was of La Niña, and the participation of the atmospheric systems for Campo Mourão and Cáceres kept the same dynamics verified in 2003, that is, for Campo Mourão, cTm is more active in the hottest months, and for Cáceres, in the colder ones. The cTm operation percentages were also similar to those registered in 2003.

In 2008, the cTm participation in Campo Mourão was 22,0% in summer, 12,7% in autumn, 11,2% in winter and 22,0% in Spring. In Cáceres, the participation was 4,9% in summer, 36,2% in autumn, 56,7% in winter and 35,6% in spring. Figures 4 and 5 show that the cTm operation for 2008 was similar to that one verified for 2003. The difference was smaller than the inter-annual one for the 2002 – 2010 series.

It was verified that for 2003, the cTm participation was 17,0% in Campo Mourão and 33,4% in Cáceres. For 2008, the annual participation was 18,0% in Campo Mourão and 31,3% in Cáceres. These results show that the participation time was inferior to the inter-annual one, thus it is possible to consider that El Niño and La Niña may have not

influenced the participation time of this system in both locations.

The analysis and quantification of this atmospheric system participation revealed some observations already made by other researchers.

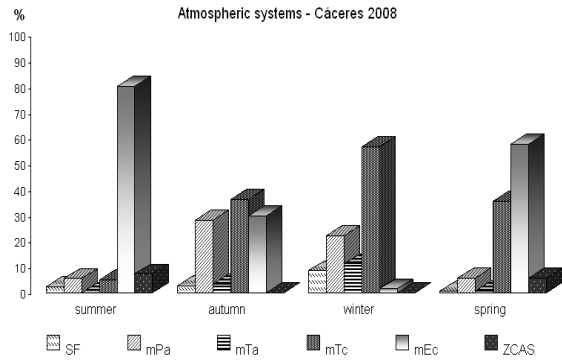


Figure 4. Atmospheric systems that actuated in Cáceres, Mato Grosso state, in 2008. Organized by the authors.

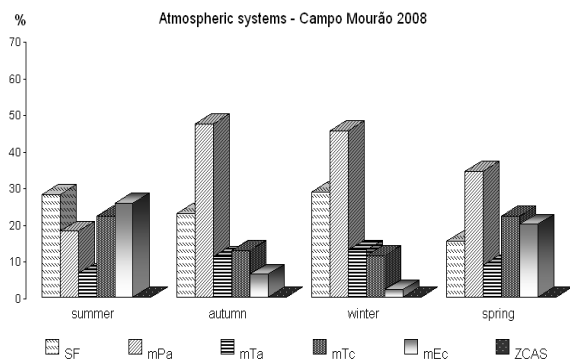


Figure 5. Atmospheric systems that actuated in Campo Mourão, Paraná state, in 2008. Organized by the authors.

With the aTm modification, mainly in its west border, the cTm amplifies and dominates the state of weather from Bolivia and the west of Mato Grosso (PADILHA, 2008). The participation of this system shows how longer is the actuation time for the region of Cáceres (Figure 6).

The quantification of cTm chronological participation oscillated through the years, apart from ENSO. The comparative study of these two years may mask the results, considering that other interactions may have more expressive consequences on the cTm participation.

It should also be considered that the study contemplated only the participation time, and not the intensity. Each amplification and retreat of the system on the studied area presents a different intensity, and this may be investigated from weather elements, such as atmospheric pressure and temperature.

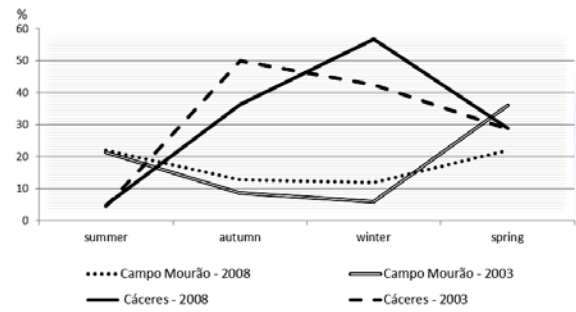


Figure 6. cTm participation in summer, autumn, winter and spring in the cities of Campo Mourão and Cáceres. Organized by the authors.

The study has compared monthly the atmospheric systems participation in both locations. As it is not possible to present them entirely, June 2008 was chosen, considering it is the month in which the cTm participation in Campo Mourão was reduced, and in Cáceres it was amplified. Figure 7 shows the participation in annual percentage for the series 2002 to 2010 for Campo Mourão and Cáceres.

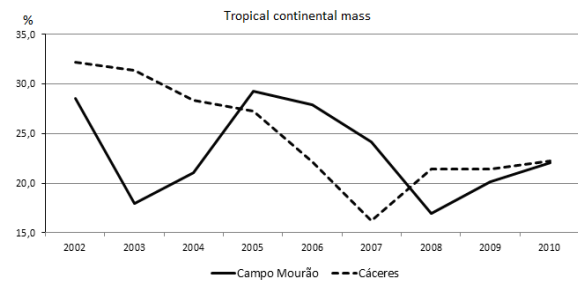


Figure 7. Participation of the continental Tropical mass for Campo Mourão and Cáceres, in the series 2002 to 2010. Organized by the authors.

In June 2008, cTm operated in 10,0% of the chronological time for Campo Mourão. For Cáceres, the participation was 37,8% (Tables 1 and 2).

Table 1 shows that the cTm is configured after the aPm participation. This configuration was considered by Monteiro (1971) as an aged polar mass. In the analysis of the maps, it was verified that, with the aPm displacement towards west, the intense heating of Chaco low consequently favors the configuration of a cyclonic cell, whose pressure oscillates before 1013,2h Pa.

The region of Cáceres, cTm was also configured after the aPm displacement, although in the month available in Table 2, it was configured only after aTm domain in a single circumstance. Along the studied series, cTm was onfigured for the region of Cáceres, mainly after the aTm crest advance until the region.

Table 1. Results obtained by the reading of the synoptic maps of Brazil's Navy and the images of Goes satellite, infrared channel, in June 2008, for the Location of Campo Mourão. Atmospheric pressure (read in the map), the actuating system and atmospheric precipitation were observed. The participation of the continental Tropical mass was 10.0%.

Date	atmospheric pressure	FS	aPm	aTm	cTm	cEm	atmospheric systems	P(mm)
01/06/2008	1020		12		12		aPm/cEm	0
02/06/2008	1025		24				aPm	0
03/06/2008	1022	12	12				aPm/cTm	0
04/06/2008	1018	8	16				FS/aPm	0
05/06/2008	1017			24			aTm	0
06/06/2008	1017	12			12		FS/cTm	0
07/06/2008	1020	12			12		FS/cTm	0.4
08/06/2008	1018		12	12			aPm/aTm	0
09/06/2008	1016	12		12			FS/aTm	0
10/06/2008	1020	12	12				FS/aPm	1.5
11/06/2008	1021		24				aPm	0
12/06/2008	1018		12		12		aPm/cTm	0.5
13/06/2008	1020		24				aPm	10
14/06/2008	1014	24					FS	0
15/06/2008	1013	12	12				FS/aPm	0
16/06/2008	1025		24				aPm	0
17/06/2008	1022		24				aPm	0
18/06/2008	1020		12		12		aPm/cTm	0
19/06/2008	1016			12	12		aTm/cTm	0
20/06/2008	1014	24					FS	0
21/06/2008	1015	12	12				FS/aPm	12.5
22/06/2008	1018		24				aPm	0
23/06/2008	1022		24				aPm	0
24/06/2008	1024		24				aPm	0
25/06/2008	1022		24				aPm	0.5
26/06/2008	1020		24				aPm	0
27/06/2008	1020		12			12	aPm/cEm	0.8
28/06/2008	1020	24					FS	9.9
29/06/2008	1024	8	16				FS/aPm	6.8
30/06/2008	1020		24				aPm	0
//	1019,4	23.9%	56.1%	8.3%	10.0%	1.7%	//	42.9 mm

Table 2. Results obtained by the reading of the synoptic maps of Brazil's Navy and the images of Goes satellite in June 2008 for the Location of Campo Mourão. Atmospheric pressure (read in the map), the actuating system and atmospheric precipitation were observed. The participation of the continental Tropical mass was 37,8%.

Date	atmospheric pressure	FS	aPm	aTm	cTm	cEm	atmospheric systems	P(mm)
01/06/2008	1024		24				aPm	0
02/06/2008	1022		24				aPm	0
03/06/2008	1020		24				aPm	0
04/06/2008	1012				24		cTm	0
05/06/2008	1016				24		cTm	0
06/06/2008	1016				24		cTm	0
07/06/2008	1016			12	12		aTm/cTm	0
08/06/2008	1016			24			aTm	0
09/06/2008	1016			24			aTm	0
10/06/2008	1019		12	12			aPm/aTm	0
11/06/2008	1016		12		12		aPm/cTm	0
12/06/2008	1013				24		cTm	0
13/06/2008	1016				24		cTm	0
14/06/2008	1014	4			20		FS/cTm	0
15/06/2008	1016	5	19				FS/aPm	0
16/06/2008	1024		24				aPm	0
17/06/2008	1017		24				aPm	0
18/06/2008	1012				24		cTm	0
19/06/2008	1012				24		cTm	0
20/06/2008	1012				24		cTm	0
21/06/2008	1020	4	20				FS/aPm	0
22/06/2008	1020		24				aPm	0
23/06/2008	1021		24				aPm	0
24/06/2008	1020		24				aPm	0
25/06/2008	1020		24				aPm	0
26/06/2008	1016		12		12		aPm/cTm	0
27/06/2008	1020		12		12		aPm/cTm	0
28/06/2008	1016	12			12		FS/cTm	0
29/06/2008	1020		24				aPm	0
30/06/2008	1020		24				aPm	0
//	1017,4	3.5%	48.8%	10.0%	37.8%	0.00%	//	0.0 mm

Conclusion

The first consideration is that the region still lacks researches in Geographic Climatology. Studies that discuss the systems participation for this region were not found. Atmospheric dynamics is best known and studied by Meteorologists, and not by Geographers.

The second consideration is the confirmation of the great participation of this atmospheric system in the South of Brazil in summer, considering that Campo Mourão is located in this region. The contrary was verified for Cáceres, that is, a great participation in winter months.

During the actuating period of this system, the state of the weather is characterized by low cloudiness and high temperatures, usually above average. When the invasion occurs with the fast displacement of the Atlantic Polar mass towards east, temperature increases rapidly, mainly for the region of Campo Mourão, where, during the aPm operation, temperatures oscillate below the standard deviation.

Rain episodes during the cTm operation are rare, however more frequent in summer, period in which relative humidity is higher.

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