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Climatologia e eventos extremos de precipitação no estado de Minas Gerais

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R E S U M O

O Estado de Minas Gerais apresenta um ciclo anual de precipitação bem definido, com verões chuvosos e invernos secos. Entretanto, os totais de precipitação variam espacialmente sobre o Estado e podem ocorrer também eventos extremos de precipitação. Dessa forma, o objetivo do presente trabalho é apresentar a climatologia de precipitação nas diferentes mesorregiões de Minas Gerais e realizar um estudo sobre os eventos extremos chuvosos com dados diários de precipitação em 48 cidades. Para tanto, são utilizados dados do período de 1975 a 2015 das estações meteorológicas do Instituto Nacional de Meteorologia (INMET). A climatologia mostrou que as cidades localizadas nas regiões mais ao sul do Estado possuem os maiores valores médios mensais de precipitação. Com relação aos eventos extremos chuvosos, no período de outubro a março há tendência positiva de ocorrência de extremos em 43 estações meteorológicas das 48 analisadas.

Palavras-Chave: Precipitação, Climatologia de precipitação, Eventos extremos, Minas Gerais,

Climatology and extreme rainfall events in the state of Minas Gerais

A B S T R A C T

Minas Gerais State presents a well-defined annual precipitation cycle, with rainy summers and dry winters. However, the precipitation totals vary spatially over the State and extreme precipitation events can also occur. Thus, the purpose of this work is to present the precipitation climatology in the different subdomains of Minas Gerais and to carry out a study of rainfall extreme events with daily precipitation data measured in 48 meteorological stations. For this reason, data from National Institute of Meteorology (INMET) for the period 1975-2015 were used. The climatology showed that the cities located in the southern regions of the State have the highest average values of monthly precipitation. Regarding the extreme rainfall events, in the period from October to March there is a positive trend occurrence of extremes in 43 stations out of48.

Keywords: Precipitation, Climatology of precipitation, Extreme Events, Minas Gerais.

Introduction

Extreme drought events are characterized by the absence of precipitation for several consecutive days, while extreme rainfall events are defined by intense precipitation in a short period of time and/or non-stop occurrence by consecutive days. The Intergovernmental Panel on Climate Change (IPCC, 2012) mentions that extreme events can be identified using percentile statistics.

Previous studies (Alexander et al., 2006; Donat et al., 2013) indicated an increase in the frequency of extreme rainfall events over the south-eastern region of South America between 1960 and 2000. Dufek and Ambrizzi (2008) emphasize the relevance of studies on these events, due to the economic and ecological damages.

The occurrence of extreme rainfall events is often related with synoptic scale systems (Maddox et al., 1979; Carvalho et al., 2002; Nielsen et al., 2016), convective systems (Tavares et al., 2012) and with the orographic influence (Lima et al., 2010). In South America, the configuration of the Andes mountains favors the channeling of the low level jet (LLJ) to the South and Southeast of Brazil; which is often related to the occurrence of extreme rainfall events on these regions (Liebmann et al., 2004; Reboita et al., 2010). During the austral summer, on the Brazil's Southeast, Lima et al. (2010) associated 53% and 47% of the intense rainfall events due to the passage of cold fronts and the occurrence of the South Atlantic Convergence Zone (SACZ), respectively.

Regarding Minas Gerais (MG) State, higher precipitation rates are recorded in summer and lower during the winter. Silva and Reboita (2013) point out that the southern, western and central areas

of MG present the highest annual averages of precipitation (between 1200 and 1600 mm), while the northern and eastern areas have the lowest rates (800 - 1100 mm and 1000 - 1200 mm mm, respectively). Silva (2013) analyzed daily extreme rainfall events in MG. It was found a significant spatial variability of the extremes, revealing trends of increase and reduction of these events distributed by the State.

The increase trends of frequency and intensity of extreme rainfall events over mid-latitudes and tropical regions (IPCC, 2014) motivates the development of this study, which aims to update the knowledge of the annual precipitation cycle and the frequency of extreme rainfall events in MG.

Materials and Methods

Study Area

The State of MG has an area of 588,384.30 km² and is located in the southeast of Brazil, between latitudes 14°13'58" and 22°54'00" South and longitudes 39°51'32" and 51°'35'35" West (Figure 1). It is the second most populous state in the country with almost 20 million inhabitants (IBGE, 2014). Figure 1 shows the division of the state mesoregions according to the division of the Brazilian Institute of Statistical Geography (IBGE). Regarding the climate conditions, Reboita et al. (2015) showed that the state has a tropical climate with dry winter (Aw) according to the Köppen-Geiger classification. However, in the south and in the Espinhaço and Mantiqueira mountains moist temperate climate with dry winter and warm summer (Cwa) and moist temperate climate with dry winter and temperate summer (Cwb) predominate.

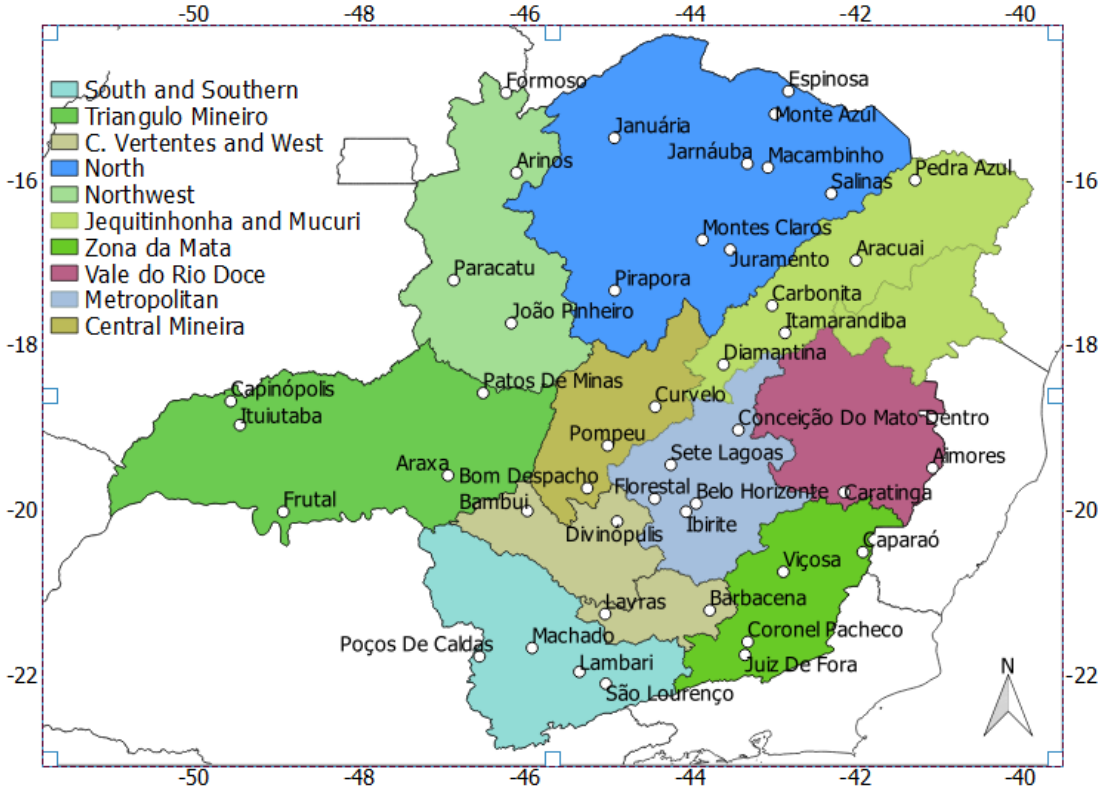

Figure 1. INMET conventional weather stations regarding its location in the State of Minas Gerais (left) and location of the State in Brazil (right).

Data

This paper used daily precipitation data between 1975 and 2015 obtained from the Weather Database for Teaching and Research (BDMEP) of the National Institute of Meteorology (INMET) from 48 conventional weather stations (Figure 1).

First, the number of missing data in each time series was checked. This information is shown in Figure 2. It is important to note that the correspondence between the number shown on the horizontal axis of Figure 2 and the respective cities can be found in columns 1 and 6 of Table 1. Weather station 37 (Juramento) was the station which presented the largest number of missing data, while stations 13 and 27 (Frutal and Curvelo) shown smaller numbers of missing data in the time series. Next, outliers in the time series were evaluated. Values above 150 mm/day were highlighted. Then, first it was checked whether

there were similar values in nearby stations. In the affirmative case, the value was maintained, otherwise the value was discarded from the time series.

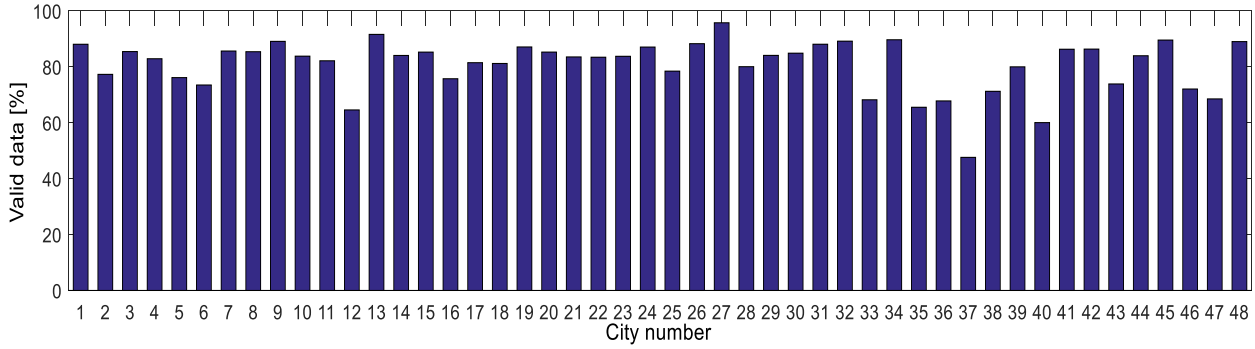

Figure 2. Percentage of data in each time series. The correspondence between the numbers and the name of the cities is shown in columns 1 and 5 of Table 1.

Table 1. 95% percentile value for identification of extreme events during the dry season (April to September) and rainy season (October to March) for each city (columns 1 and 6). It is also indicated the region in which each city is located, indicated by numbers (columns 5 and 10), where 1 is South and Southwest of MG, 2 Campo das Vertentes, 3 West of MG, 4 Zona da Mata, 5 Metropolitan Area of Belo Horizonte, 6 Central 7 Triângulo Mineiro and Alto Paranaíba, 8 Northwest of MG, 9 Norte de MG, 10 Jequitinhonha and 11 Vale do Rio Doce.

N°	City	Rainy	Dry	Region	N°	City	Rainy	Dry	Region
1	São Lourenço	45mm	36mm	1	25	Pompeu	45mm	43mm	6
2	Lambari	49mm	38mm	1	26	Conceição M. D.	53mm	32mm	5
3	Juiz de Fora	49mm	29mm	4	27	Curvelo	49mm	29mm	6
4	P. de Caldas	45mm	33mm	1	28	Capinópolis	51mm	41mm	7
5	Machado	46mm	35mm	1	29	Patos de Minas	46mm	35mm	7
6	Coronel P.	55mm	28mm	4	30	Diamantina	50mm	31mm	10
7	Lavras	46mm	32mm	2	31	João Pinheiro	51mm	35mm	8
8	Barbacena	46mm	29mm	2	32	Itamarandiba	48mm	26mm	10
9	S. S. Paraiso	53 mm	40mm	1	33	Carbonita	49mm	30mm	10
10	Viçosa	49mm	29mm	4	34	Pirapora	50mm	38mm	9
11	Caparaó	45mm	28mm	4	35	Paracatu	50mm	34mm	8
12	Divinópolis	50mm	31mm	3	36	Araçuaí	44mm	28mm	10
13	Frutal	36mm	33mm	7	37	Juramento	47mm	33mm	9
14	Ibirité	52mm	32mm	5	38	Montes Claros	50mm	31mm	9
15	Bambuí	49mm	35mm	3	39	Unaí	50 mm	40mm	8
16	B. Horizonte	55mm	32mm	5	40	Salinas	46mm	31mm	9
17	Ituiutaba	53mm	40mm	7	41	Pedra Azul	53mm	23mm	10
18	Florestal	53mm	28mm	5	42	Arinos	49mm	38mm	8
19	Caratinga	50mm	29mm	11	43	Mocambinho	48mm	34mm	9
20	Uberaba	47 mm	41mm	7	44	Janaúba	46mm	41mm	9
21	B. Despacho	50mm	31mm	5	45	Januária	50mm	31mm	9
22	Araxá	46mm	34mm	7	46	Monte Azul	44mm	34mm	9
23	Aimorés	52mm	18mm	11	47	Espinosa	48mm	36mm	9
24	Sete Lagoas	52mm	33mm	5	48	Formoso	47mm	47mm	8

After excluding the outliers, precipitation data was plotted by year (Figure 3) in which is evident periods with missing data and the distribution patterns of precipitation values. Some cities have data for less than 40 years.

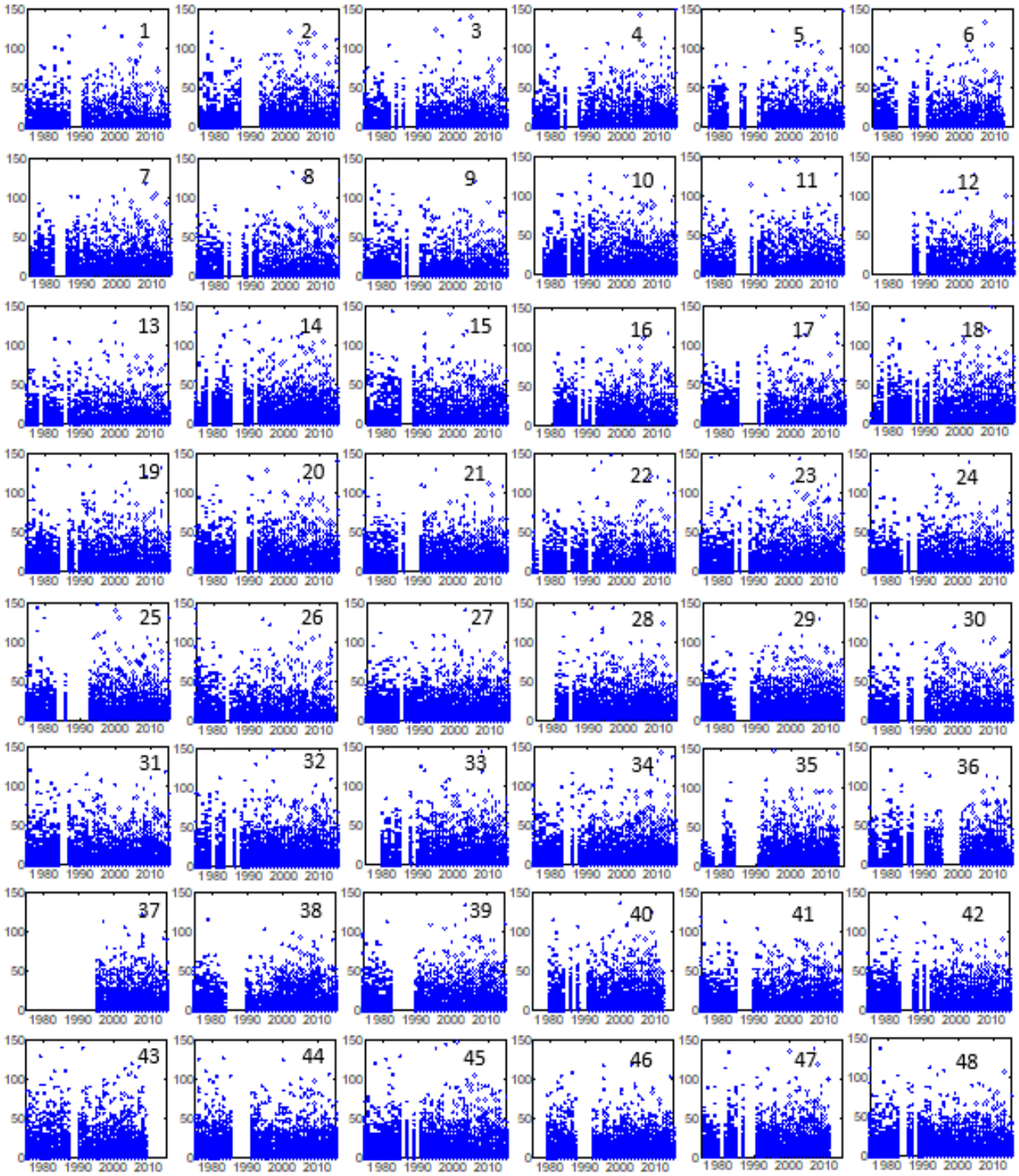

Figure 3. Daily precipitation (mm) time series for all cities from 1975 to 2015. The correspondence between the numbers in the upper left-hand corner of the figures and those cities are shown in Table 1.

Analysis

Rainfall Climatology: For each mesoregion shown in Figure 1, the monthly rainfall climatology was calculated from 1975 to 2015. Since the data had a daily frequency, first, the monthly accumulated rainfall rates were computed and then calculated the monthly climatological average, clustering stations located in the same region. The months that presented missing daily data did not have the monthly total computed and were not considered in the study.

Extreme rainfall events: daily data were separated into dry season (April to September) and rainy season (October to March). For these, extreme precipitation values were identified through the

percentile statistics. The data were placed in ascending order without regarding non-rainy days. Then the precipitation value corresponding to the 95% percentile in the data series were identified. The value is considered a threshold in the detection of extreme events. Daily precipitation totals higher than the threshold were considered as extreme rainfall events. The 95% percentile is also used by Shrestha (2014).

For each period (dry/rainy) and time series, the number of extreme rainfall events per month and per year was calculated, the results were organized by cities and these were numbered according to latitude (station number, table 1).

Trend analysis was conducted for the number of extreme rainfall events per year. It was also verified whether or not the trend was significant through the Mann-Kendall hypothesis test (MK, Mann 1945, Kendall 1975). The test is based on the statistical evaluation of the variable of interest. The trend is monotonic upward when the results show a positive trend over time, the opposite should occur for a negative trend. In both cases the trend may or may not be significant. In this study, the significance value of 0.05 was considered. The significant trend is indicated in Figure 6 with the letter S and not significant with the letters NS.

Results and discussions

Rainfall Climatology

Rainfall climatology in the different MG regions is shown in Figure 4. Highest rainfall rates occur in the Southern, Triângulo Mineiro, Zona da Mata, Campo das Verentes, West and Metropolitan Area of Belo Horizonte. The North, Jequitinhonha and Mucuri have lowest monthly rainfall totals. Central, Northwest and Vale do Rio Doce regions show intermediate values with highest rainfall rates registered in December. The results are similar to those presented by Teixeira and Satyamurty (2011) where stations were grouped with similar rainfall patterns into three groups: (a) Stations located to the north of the state of MG; (b) South Region of Zona da Mata extending from Triângulo Mineiro and part of the Northwest; (c) part of the Metropolitan Area, Vale do Rio Doce and Central. In addition, Figure 4 shows that summer months have the highest values while winter have lowest agreeing with Silva and Reboita (2013).

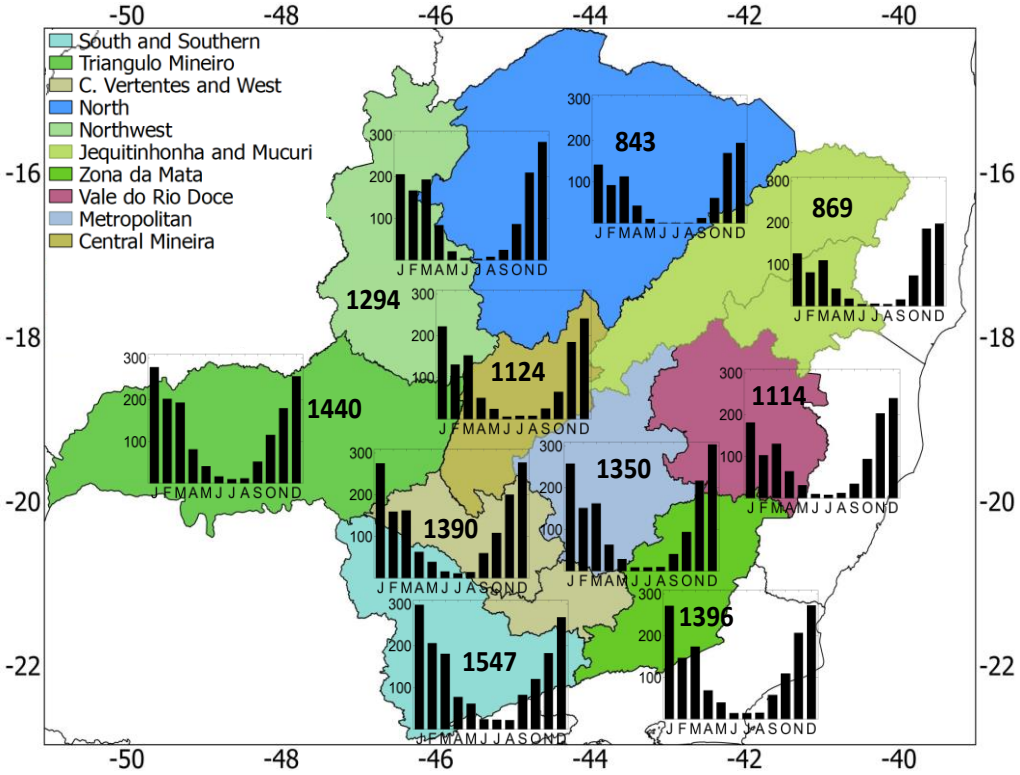

Figure 4. Rainfall climatology in millimeters (bars) and annual values (in numbers) by region in the State of Minas Gerais from 1975 to 2015.

Extreme rainfall events

The 95% percentile showed values between 36 and 55 mm as thresholds of extreme rainfall events for the wet season and values between 18 and 47 mm as thresholds for dry season (Table 1). In winter, thresholds for extreme rainfall events are lower. Figure 5 shows the monthly average number of extreme rainfall events indicating greater occurrence of extreme events during the wet season. More than half (25 of the 48) meteorological

stations shows highest number of extreme rainfall events in the month of December, followed by the month of January (16 cases, Figure 5).

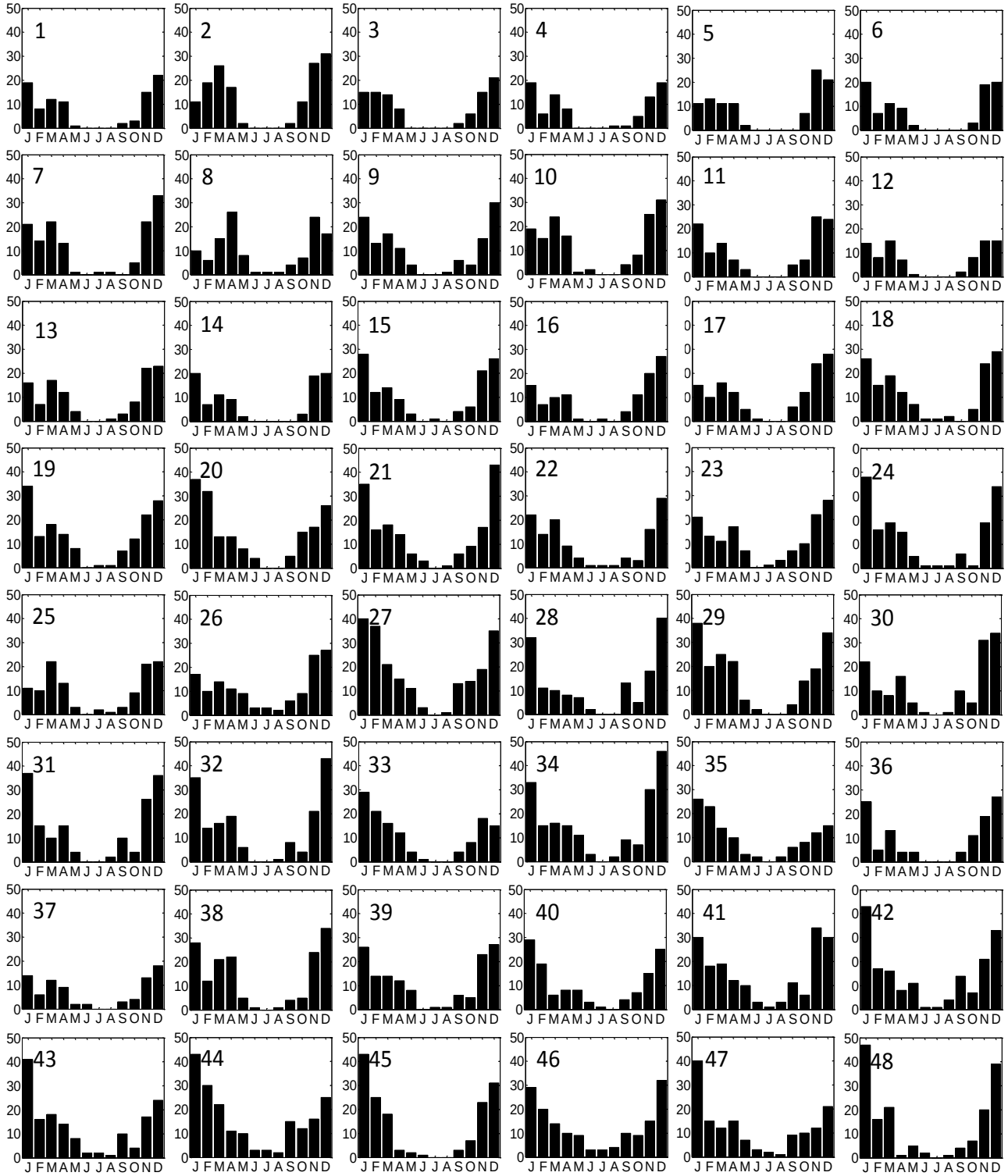

Figura 5. Número de eventos extremos mensal para cada cidade em todo o período de estudo.

Figure 6 shows annual frequency number of extreme rainfall events during dry season (black) and wet season (blue); the signal indicates whether the trend is positive (+) or negative (-) and the letters S and NS indicate whether the trend is significant or not significant, respectively. For the wet season, of the 48 cities, 43 shown a positive trend. In 20 of them the trend was significant. Only 5 cities presented a negative trend, although not significant. For dry season, 23 cities reveal a

negative trend; however, only one (Lambari) with significance. Of the stations with positive trends 5 were significant.

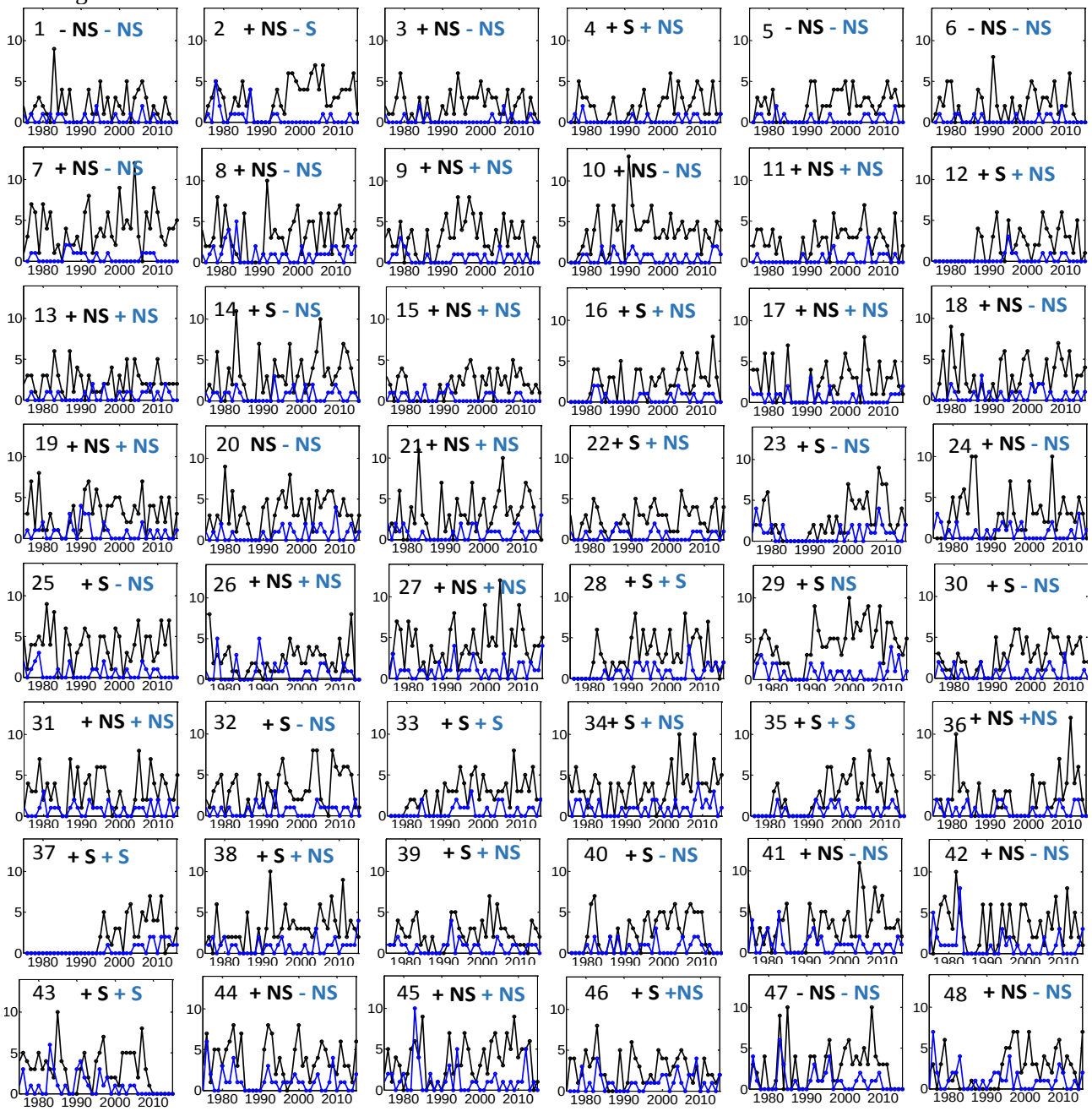

Figure 6. Annual frequency of extreme rainfall events for each city. The blue line correspondes to dry season and the black line wet season. NS and S correspond to non significant and significant trends respectively.

The northern region of the state presented the highest number of cities with a significant positive trend in extremes rainfall events, especially in the rainy season. These results agree with Costa et al. (2015); the authors verified a significant positive trend of extremes occurrence for the Northeast region of Brazil and part of the northern region of MG.

Conclusion

This study evaluated the rainfall climatology in the State of Minas Gerais, Brazil, and the number of extreme rainfall events during dry and wet season between 1975 and 2015. Monthly precipitation shows higher values for the south and southwestern regions and smaller for the northern part of the state.

It was also possible to verify the number of extreme rainfall events per month and per year in which it was concluded that some cities, such as Belo Horizonte, and most of the cities in the northern part of the State presented a significant positive trend in the frequency of extremes. For the southern cities of MG, only in the city of São Lourenço there was a significant trend in the number of occurrence of extremes (negative in the dry season). For other cities, there was no significant positive or negative trend. The positive trends shown in this paper may be an indicative of the effect of climate change.

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