ISSN: 2447-3359

REVISTA DE GEOCIÊNCIAS DO NORDESTE

Northeast Geosciences Journal

v. 8, nº 1 (2022)

https://doi.org/10.21680/2447-3359.2022v8n1ID22006

Spacio-temporal behavior of precipitation in the potengi-rn river hydrographic basin.

Comportamento espaço-temporal da precipitação na bacia hidrográfica do rio potengi-rn.

Julie Andrade Souza[1]; Rodrigo de Freitas Amorim[2];

[1] Federal University of Rio Grande do Norte (UFRN), Natal / RN, Brazil. Email: julie_andrade_souza@hotmail.com
ORCID: https://orcid.org/0000-0001-9532-147**X**

[2] Federal University of Rio Grande do Norte (UFRN), Natal / RN, Brazil. Email: rodrigofba@gmail.com
ORCID: https://orcid.org/0000-0001-8282-6903

Abstract: Rainfall is the most important variable considered in order to understand the dynamics of surface structure in landscapes and its consequences on several human activities. The quantitative analysis of data allow us to spacialize volumes of rainfall, relate them to the main climatic mechanisms acting on an area and estimate the recurrence time of extreme events. In order to reach the goals, the methodology was based on the use of statistic tools of spatialization in pure data (Kriging) and the use of the Gumbel method to calculate the times of recurrence of maximum rainfall in the basin. The results demonstrate that there is a significant time-space variation of rainfall in different areas. Concerning the maximum events, it was possible to confirm that, in a 10-year recurrence gap, all the four cities presented values over 100 mm in 24 hours. We concluded that the climatic events of high magnitude rainfall and low recurrence are frequent in decade time-scale, being bound to the regional climatic dynamics and to the global control constraints.

Keywords: Spatialization; Variation; Precipitation.

Resumo: A precipitação é a variável mais importante quando se pretende compreender a dinâmica da estrutura superficial da paisagem e as consequências nas diversas atividades humanas. As análises quantitativas dos dados permitem espacializar os volumes de chuva, relacioná-los aos principais mecanismos climáticos que atuam na área e estimar os tempos de retorno de eventos extremos. Para atingir os objetivos, a metodologia compreende o uso de ferramentas estatísticas de espacialização de dados (krigagem) e a utilização do método de Gumbel para calcular os tempos de retorno de precipitações máximas na bacia. Os resultados demonstram que há uma significativa variação espaço-temporal da chuva nos diferentes compartimentos. Com relação aos eventos máximos, foi possível verificar que no intervalo de retorno de 10 anos, todos os quatro municípios apresentam valores de acima de 100 mm em 24h. Pode-se concluir que os fenômenos climatológicos de precipitação com alta magnitude e baixa recorrência são frequentes em uma escala de tempo de décadas, estando, esses, vinculados à dinâmica climática regional e aos condicionantes de controle global.

Palavras-chave: Espacialização; Variação; Precipitação.

Received: 03/08/2020; I accept: 29/09/2020; Published: 04/03/2022.

1. Introduction

Precipitation is a type of atmospheric phenomenon in the form of rain, hail or snow. Its characteristics, spatial, temporal and intensity, form the basis for understanding the relationship between hydrological dynamics, the enhancement of the landscape and interactions with society. Considered the most important variable, it can cause changes in the physical environment and spatial arrangements, thus interfering in the execution of agricultural, industrial, tourist activities, as well as in the rational use of water in the upper, middle and lower course of the hydrographic basin. (BERTONI; TUCCI, 2001; FRANCHITO et al., 2009).

Among the episodes of precipitation, the extremes have the greatest potential to generate significant impacts in relation to human activities (MARENGO, 2009). According to the IPCC (2012), such events are generally defined by unusually high or low values considering a range of observations. In the case of precipitation, they include heavy rains (maximum events) and periods of prolonged droughts (minimum events).

The areas affected by maximum volumes can suffer from highly destructive phenomena, such as floods, floods, floods, soil erosion, rupture of dams, silting of water reservoirs, landslides, among others, which cause significant socioeconomic impacts on society (FUTREL et al., 2005; MARENGO, 2010).

Such impacts are mainly enhanced when associated with the lack of infrastructure in cities and the social and economic conditions of the poorest population, which makes preventive actions related to facing hydrological problems in the basin difficult. Therefore, Bastos et al. (1998) state that an economic decision is to try to predict future occurrences of these extreme events, using statistical techniques.

One of these techniques is the “return time” or “return period”, which is understood as the estimate of the frequency with which an event of a certain magnitude can occur, be equalized or even overcome (PINTO et al., 2008). The Gumbel method, also known as extreme event distribution or FicherTippett, is applied to extreme events, in annual series. According to Righetto (1998), the Gumbel distribution aims to identify the maximum values of a river's flood, the maximum precipitation, the maximum wind, etc. According to Alves (2013), among other methods, Gumbel's allows to determine, with a certain degree of accuracy, these periods, aiming to improve the planning of various human activities, from the productive sector to public health, from sports to leisure activities (INMET, 2018).

For such information to be applied in different sectors of society, it is necessary to understand the spatial and temporal dynamics of precipitation. Behavior conditioned by characteristics of the area such as latitude, altitude, relief, vegetation, continentality, maritime and by the main climatic systems operating in the area (VIANELLO; ALVES, 1991; MENDONÇA; DANNI-OLIVEIRA, 2007).

Such understanding can be better observed through its representation on the map. Thus, spatialization techniques, through Geographic Information Systems (GIS), enable the analysis of how rainfall is distributed in space and are related to various environmental factors (ARAI, 2010).

Studies of the behavior of rains, based on the integrated knowledge of biotic and abiotic elements in a hydrographic basin, provide important information for the adequate management of water resources. Therefore, the objective of the studyis to understand the spatio-temporal variation of rainfall in BHRP, relating it to the main climatic mechanisms operating in the area.

2. Metodology

2.1 Study área

The Potengi River Basin (Figure 1) has an area of 4,093 km², covering part of the Central, Agreste and East mesoregions of the State of Rio Grande do Norte, between the geographical coordinates 5 ° 42 'and 6 ° 12' of south latitude and 35 ° 11 'and 36 ° 23' West longitude (WAKE, 2003).

It has its source in Serra de Santana, in the municipality of Cerro Corá. It extends from west to east with 135 km and from north to south 50 km, which makes the basin with longitudinal characteristics. It is limited to the south with the Rio Jacu basin and to the north with the Ceará Mirim river basin, flowing into the Atlantic Ocean in Natal, forming the largest estuary in the state. Much of the hydrographic network appears intermittently during most of the year, with the exception of the low course, where there are perennial channels due to the influence of tidal actions and the greater volume of rain (MEDEIROS, 2009).

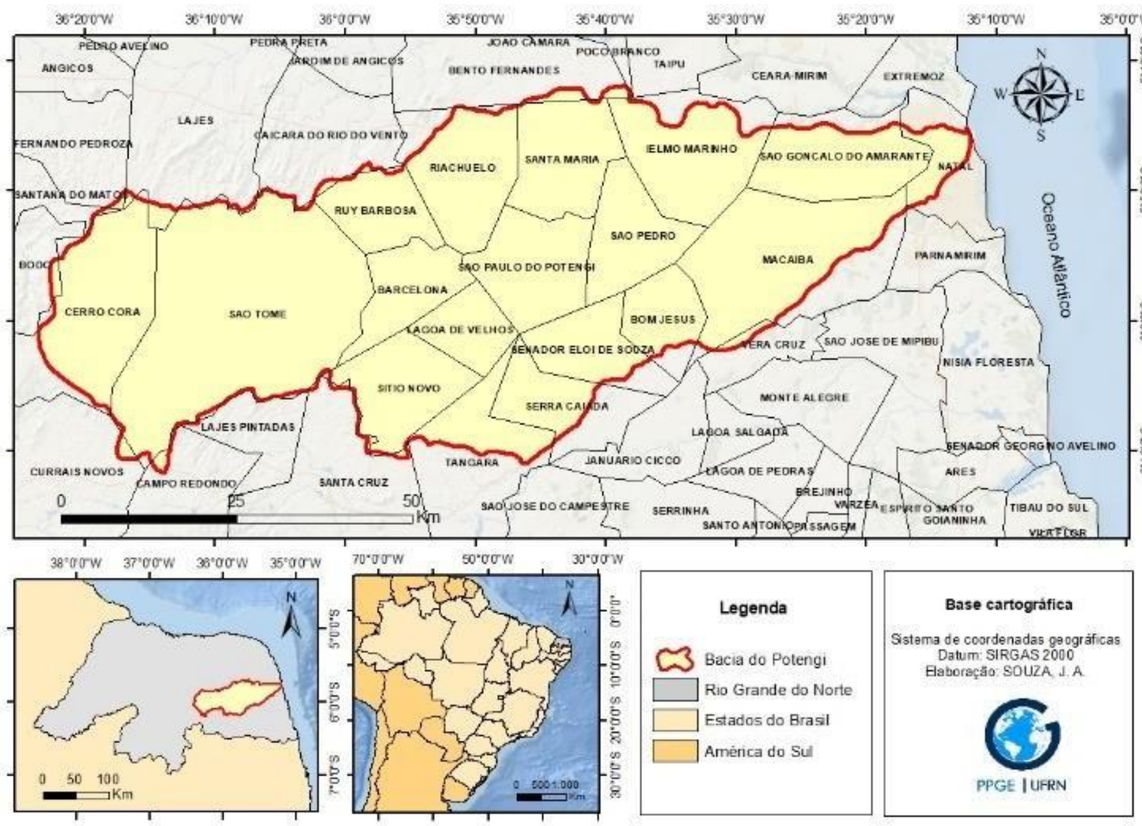

Figure 1 – Location map of the Potengi River Basin.
Elaboration: Author (2020).

2.2 Methodological procedures

The daily rainfall data for the rainfall stations, distributed in the 18 municipalities that comprise BHRP were provided by the Agricultural Research Corporation of Rio Grande do Norte (EMPARN), for a period of 57 years (1963-2019).

An initial screening of the daily precipitation data received from EMPARN was carried out, in order to evaluate them and organize them in tables in Microsoft Excel (2016) to perform the arithmetic mean, median and standard deviation calculations, in the other stages of the work. With the treated data, the graphs, tables and figures were elaborated, in order to better represent the results.

To understand the dynamics of rain in BHRP, the annual average values of precipitation were spatialized using the ArcGis software using the Krigagem method (YAMAMOTO; LANDIM, 2013). This processing allows interpolating data and spatializing rain information for the entire study area (VIOLA et al., 2010).

To calculate the return period, the Gumbel Method was used, according to Righetto (1998). Supported in the sequence of procedures for the application of such method, the organization of monthly data was made, in table, for the entire period. Four municipalities were chosen, as they represent representative samples along the low, medium and high course of the basin. From the historical series, only the maximum daily values of each year were chosen to calculate the arithmetic mean and standard deviation.

$$Q = 6^{0,5} . \frac{S}{\pi} \quad \textbf{(1)}$$

$$a = (\mu - 0,577 . Q) \quad \textbf{(2)}$$

$$\frac{P\,(1\,day\,T) - a}{Q} = -\ln(\ln(\frac{1}{1-(\frac{1}{t})})) \quad \textbf{(3)}$$

S = standard deviation;
μ = average;
α and **β** = parameters;
P = precipitation;
T = time

3. Outcomes

In order to understand the spatial-temporal behavior of precipitation in BHRP, the rainfall data for the 18 collection stations in the basin was based. Thus, the average annual precipitation was tabulated (Table 1) and spatialized (Figure 4).

Table 1 – Average annual rainfall (1963-2019)

Collection Station	**Latitude**	**Longitude**	**Annual average (in mm)**
São Tomé	-5°58’0,01”	-36°4’0,03”	425,4
Tangará	-6°10’59,96”	-35°47’0,04”	458,7
Rui Barbosa	-5°55’0,01”	-35°56’43,54”	475,2
São Paulo do Potengi	-5°54’0,03”	-35°46’0,03”	496,4
Sítio Novo	-6°6’0,01”	-35°55’0,01”	485,3
Lagoa de Velhos	-6°0’0,03”	-35°52’0,01”	520,4
Barcelona	-5°57’0,03”	-35°55’0,01”	524,8
Serra Caiada	-6°6’0,02”	-35°42’0,02”	580,3
Santa Maria	-5°50’0,02”	-35°43’0,03”	607,2
São Pedro	-5°54’0,02”	-35°38’0,02”	600,9
Senador Elói de Sousa	-6°2’0,00”	-35°42’0,03”	613,1
Cerro Cora	-6°3’0,03”	-36°21’0,00”	637,7
Riachuelo	-5°49’0,03”	-35°49’0,02”	664,2
Bom Jesus	-5°59’0,07”	-35°34’0,11”	704,7
Ielmo Marinho	-5°49’0,01”	-35°33’0,01”	848,0
Macaíba	-5°53’59,84”	-35°21’59,95”	1,245,9
São Gonçalo do Amarante	-5°48’0,03”	-35°20’0,01”	1289,0
Natal	-5°50’15,14”	-35°12’28,31”	1,625,7

Source: EMPARN, organized by the author (2020).

The calculation of average annual precipitation is essential to know the average volume of rainfall precipitated in the basin, as well as in each of its municipalities. Such information is important for several productive sectors of society, both from an economic and social point of view (MEDEIROS, 2013).

Data show that there is an average annual variation in the spatial distribution of precipitation in the basin, of approximately 1,200 mm, where São Tomé has the lowest volumes, around 425.4 mm and in contrast, the municipality of Natal with 1,625 mm, while the average annual precipitation at BHRP is 711 mm.

It is also important to know how this volume of rain is distributed throughout the year, considering that the representation of the seasonality of precipitation is of great relevance for the assessment of climate impacts on water resources and agriculture (SILVEIRA et al., 2013) . According to Meneghetti and Ferreira (2009), seasonality varies depending on the geographical location and the influence of climatic systems. This behavior can be seen in the graphs of each BHRP municipality (Figure 3).

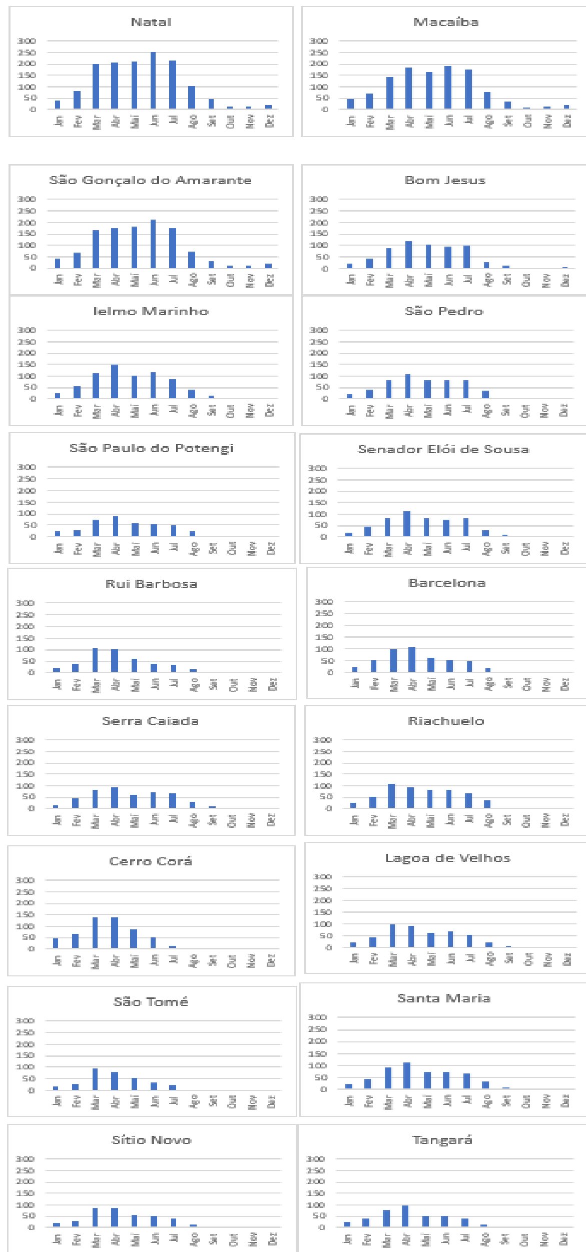

Figure 2 – Average monthly rainfall per municipality of BHRP (1963-2019).
Elaboration: Author (2020).

In most BHRP municipalities, the 6 rainiest months are concentrated from February to July. This semester coincides with the period of operation of the Intertropical Convergence Zone, which is in the southernmost position in the months of February to April and of the Sea Breezes intensified by the Eastern Wave Disorders, which operate from May to August (FERREIRA; MELO, 2005). The less rainy period extends from August to January, thus defining the dry and rainy semesters for the study area in question (Figure 3).

In relation to the average values of precipitation relative to the dry and rainy semesters, the difference in the amplitude of rainfall in these two periods of the year is evident. The rainy semester is responsible for almost 90% of the total annual rainfall at BHRP, with values ranging from 308 mm to 1,201 mm. In the period between the dry semester, rainfall is responsible for only 10% of the annual volume. The rain volumes are concentrated in the coastal area however these values are significantly low compared to the rainy season.

Spatialization

From the average annual rainfall values, the spatialization of rainfall data for the BHRP region was made, in order to graphically visualize the distribution of precipitation (Figure 4).

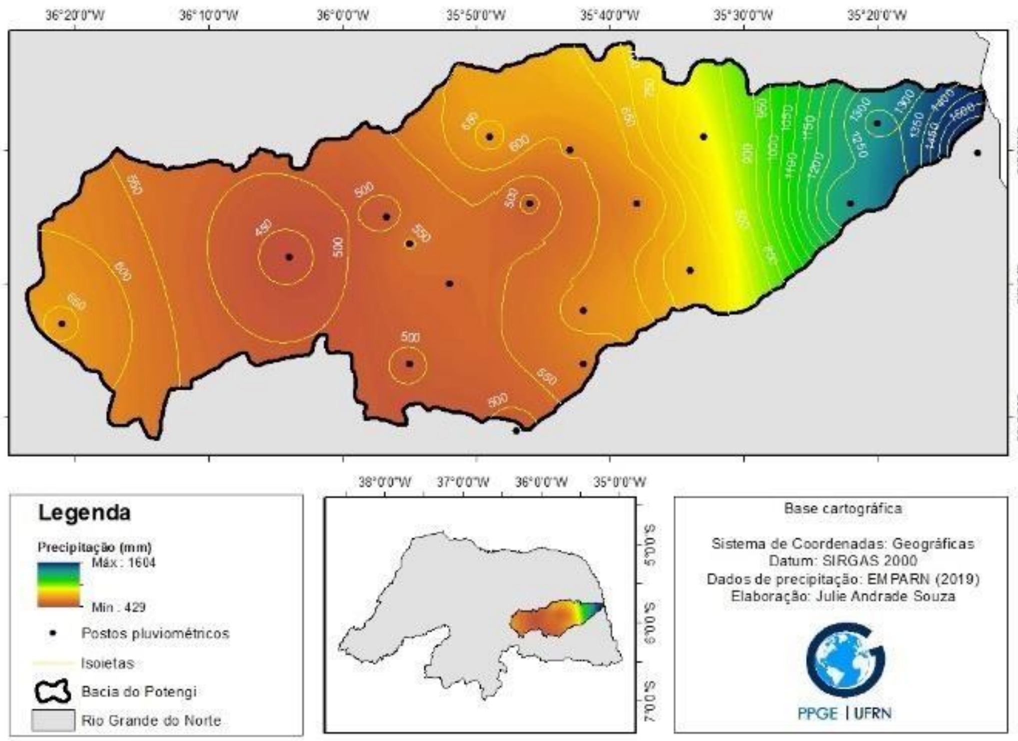

Figure 3 – Spatialization of BHRP average annual precipitation (1963-2019). Elaboration: Author (2020).

Figure 4 shows that the sectors closest to the coast have higher average precipitation values, which are decreasing in the east-west direction, with values ranging from 1,616 mm to 457 mm.

The gradient of decrease in rainfall is reversed as the elevation of the elevation levels increases, especially in the vicinity of the source of the Potengi River, in the municipality of Cerro Corá, where there is a small increase in the average value of annual precipitation. This condition results from the influence of the orographic factor, which tend to promote a forced convection of humid air that causes low atmospheric levels, resulting in localized precipitation (DINIZ; PEREIRA, 2015).

Return period

Based on historical rainfall data series from the Cerro Corá, São Paulo do Potengi, Ielmo Marinho and Natal meteorological stations, the maximum daily rainfall between 1992 and 2019 was identified.

Table 2 – Maximum daily precipitation events (1992-2019

Year	**Cerro Corá**	**São Paulo do Potengi**	**Ielmo Marinho**	**Natal**
1992	103,0	56,5	42,9	94,2
1993	88,0	30,4	59,0	70,0
1994	45,0	71,0	64,2	87,4
1995	110,0	60,0	35,1	103,8
1996	74,0	40,0	48,0	79,0
1997	156,0	156,0	141,5	122,2
1998	30,0	36,0	116,2	253,2
1999	98,0	45,0	75,4	122,6
2000	63,0	61,0	89,3	184,8
2001	64,0	89,0	43,5	153,1
2002	64,0	75,0	54,9	117,5
2003	48,0	26,8	40,8	82,6
2004	72,0	58,5	97,4	152,0
2005	45,0	105,6	58,0	163,5
2006	108,0	41,8	58,2	128,9
2007	119,0	79,9	70,5	118,4
2008	86,0	106,0	110,1	216,8
2009	100,0	62,0	50,4	115,5
2010	106,0	23,5	45,0	69,0
2011	142,0	75,0	103,0	115,6
2012	27,0	36,0	185,0	92,7
2013	91,0	77,0	143,0	125,6
2014	62,0	65,0	156,0	222,0
2015	50,0	66,2	72,0	69,9
2016	78,0	47,2	71,0	92,6
2017	93,0	86,0	78,0	116,1
2018	81,0	81,0	72,0	94,6
2019	114,8	43,5	46,0	100,9
Average	83,5	61,5	70,7	115,8
standard deviation	31,6	28,6	38,9	47,4
β	24,69	22,29	30,33	36,99
α	69,25	48,64	53,25	94,51

Source: EMPARN, organized by the author (2020).

At the post located in the municipality of Cerro Corá, 129.5 km from the coast at an altitude of 565 m, 23 events were identified with daily precipitation values above 50 mm, 9 of them with values above 100 mm.

The municipality of São Paulo do Potengi, 65.3 km from the coast, recorded 18 precipitation events with values above 50 mm. Of this total, 3 events exceeded 100 mm.

For the municipality of Ielmo Marinho, about 40 km from the coast, 21 even0ts were identified with daily precipitation values above 50 mm, and 7 of them above 100 mm.

For the city of Natal, 2.5 km from the coast, over the analyzed period, 28 events of maximum precipitation were identified, that is, daily values above 50mm, which represents the amount of at least one occurrence per year. Of this total, 19 had values greater than 100 mm and 3 greater than 200 mm.

Based on the maximum values for each year, the mean, standard deviation, parameters $^{\alpha}$ and $^{\beta}$ were calculated. The results obtained were used in the Gumbel method, to calculate the precipitation in the estimated periods (2, 5, 10, 25, 50, 100, 500 and 1,000 years).

Table 3 – Return times

Period return	**2**	**5**	**10**	**25**	**50**	**100**	**500**	**1.000**
Cerro Corá	78	106	125	148	165	183	223	240
São Paulo do Potengi	57	82	100	120	136	151	187	203
Ielmo Marinho	64	99	121	150	172	193	242	263
Natal	108	150	178	213	239	265	324	350

Source: EMPARN, organized by the author (2020).

It can be seen that there was a pattern between the measured rainfall totals and those verified according to the return period determined by the Gumbel method. Making the results obtained satisfactory, while demonstrating the great potential for the application of this study in the management of the territory.

In the 10-year return interval, all stations have precipitation values above 100mm in 24 hours, whereas in Natal this value is 178mm, demonstrating that the capital is subject to rainfall events that can trigger numerous consequences for the urban environment.

When the landscape is seen as an element of social change, with constructions and different types of changes in the physical environment, a return time of 10 to 20 years may seem long, but it is necessary to consider that the losses generated and the risks of human losses the need to adopt measures that justify the use of the soil to this natural dynamic is justified.

4. Final consideration

Regarding the variation in the spatial distribution of precipitation, an amplitude of 1,200 mm was observed, with a maximum average of 1,698 mm for the city of Natal and a minimum average of 456 mm in São Tomé. It was also found that the nearest municipalities the coast have higher average precipitation values, which decrease as they move away from the coast. However, the gradient of precipitation decrease is reversed as the topographic elevations increase, as is the case of Cerro Corá.

The rainy period of the basin was between the months of January to August, concentrating around 90% of the annual total of rains, the first four-month period mainly due to the Intertropical Convergence Zone and the second due to the sea breezes intensified by East.

Considering maximum events, those with rainfall values above 50 mm, it was found that in the years 1992 to 2019 (28 years), the municipality of Natal identified at least 1 maximum event per year. The municipality of São Paulo do Potengi recorded maximum events in just 18 years, Ielmo Marinho 21, while Cerro Corá recorded events of maximum precipitation in 22 of the 28 years studied.

In the 10-year return interval, all four municipalities have precipitation values above 100mm in 24 hours. The return times of maximum precipitations demonstrate the importance of visualizing the phenomena in a dynamic way, with the identification of values that surpass normality.

Regarding the analysis of the present study, it can be concluded that there is a significant spatio-temporal variation in precipitation in the different compartments of the basin and the climatological phenomena of precipitation with high magnitude and low recurrence are frequent over a decades-long time scale.

References

ALVES, A.V.P.; SANTOS, G.B.S.S.; MENEZES-FILHO, F.C. M.; SANCHES, L. Análise dos métodos de estimativa para os parâmetros das distribuições de Gumbel e GEV em eventos de precipitações máximas na cidade de Cuiabá MT. *Revista Eletrônica de Engenharia Civil*, v. 6, n. 1, p. 32 43, 201

ARAI, Fabiane K. et al. Espacialização da precipitação e erosividade na Bacia Hidrográfica do Rio Dourados – MS. *Eng. Agríc.* [online]. 2010, v..30, n.5, pp.922-931.

BASTOS, T. X., MARQUES, A. F., ROCHA, M. d., OLIVEIRA, R. P., PACHECO, N. A., & SÁ, T. D. (1998). *Chuvas máximas de 24 horas em Belém, probabilidade de ocorrência e Tempo de retorno*. In: CONGRESSO BRASILEIRO DE METEOROLOGIA, 10., CONGRESSO DA FLISMET, 8., Brasilia. Anais... [S.l.: s.n.], 2018.

BERTONI, J. C. e TUCCI, C. E. M. *Precipitação*. In.: Hidrologia: ciência e aplicação, Org. Carlos E. M. Tucci, 2ª ed., 2. Reimpr., Porto Alegre: Ed. Universidade/UFRGS: ABRH, 2001.

DINIZ, M.; PEREIRA, V. Climatologia do estado do Rio Grande do Norte, Brasil: sistemas atmosféricos atuantes e mapeamento de tipos de clima. *Goiânia: Boletim Goiano de Geografia* (Online), 2015.FRANCHITO, S. H.; RAO, V. B.; VASQUES, A. C.; SANTO, C. M. E.; CONFORTE, J. C. Validation of TRMM precipitation radar monthly rainfall estimates over Brazil. J. *Geophys. Res*., v. 114, D02105, 2009.

FUTREL, J. H., and Coauthors. *Water:* Challenges at the intersection of human and natural systems. NSF/DOE tech. Rep. PNWD-3597, 50 p., 2005.

INMET – Instituto Nacional de Meteorologia. *Normais Climatológicas do Brasil: Prefácio 1981-2010*. 2018.

IPCC (Intergovernmental Panel on Climate Change). Summary for policymakers. In: C. B. FIELD, V. BARROS, T. F. STOCKER, D. QIN, D. J. DOKKEN, K. L. EBI, *et al*. (Eds.). *Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of working groups I and II of the Intergovernmental Panel on Climate Change*. Cambridge, UK, and New York, NY, USA: Cambridge University Press, 2012. p. 3-21.

FERREIRA, A. G; MELLO, N. G. Principais SSistemas Atmosféricos atuantes sobre a região nordeste do Brasil e a influência dos oceanos Pacífico e Atlântico no clima da região. *Revista Brasileira de Climatologia* , 15-28 (2005).

MARENGO, J. A. *Impactos de extremos relacionados com o tempo e o clima - Impactos sociais e econômicos*. Boletim do Grupo de Pesquisa em Mudanças Climáticas - GPMC, Edição Especial, 2009.

MARENGO, J. A. *Mudanças climáticas e eventos extremos no Brasil*. Fundação Brasileira para o Desenvolvimento Sustentável – FBDS, 2010.

MEDEIROS, M. L. de. *Estudo multitemporal da dinâmica espacial do estuário Potengi/RN, utilizando como base os dados de sensoriamento remoto*. Dissertação (Mestrado em Geografia) – Universidade Federal do Rio Grande do Norte, Natal, 2009, 106p.

MEDEIROS, R. M.; SANTOS, D. C.; CORREIA, D. S.; OLIVEIRA, V.G.; RAFAEL, A. R. (2013). "*Estudo da precipitação pluviométrica no município de Campinas do Piauí*" in Anais do I Congresso internacional de Ciências Biológicas / II Congresso nacional de Ciências Biológicas / VI Simpósio de Ciências Biológicas, Recife-PE, Nov, 2013.

MENDONÇA, F. A; DANNI-OLIVEIRA, I. M. *Climatologia: noções básicas e climas do Brasil.* São Paulo: Oficina de Textos, 2007. 206p.

MENEGHETTI, G. T.; FERREIRA, N. J. *Variabilidade sazonal e interanual da precipitação no Nordeste Brasileiro*. In: SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO, 14. (SBSR), 2009, Natal. Anais… São José dos Campos: INPE, 2009. p. 1685-1689.

PINTO, N. L. S; HOLTZ, A. C. T.; MARTINS, J. A.; GOMIDE, F. L. S. *Hidrologia Básica*. 11ª reimp. São Paulo: Edgar Blucher, 2008.

RIGHETTO, A. M. (1998). *Hidrologia e Recursos hídricos* (1a Edição ed.). São Carlos: Escola de Engenharia de São Carlos-USP.

SILVEIRA, C. S; SOUZA FILHO, F. A; COSTA, A. A; CABRAL, S. L. Avaliação de desempenho dos modelos do CMIP5 quanto à representação dos padrões de variação da precipitação no século XX sobre a região Nordeste do Brasil, Amazônia e bacia do Prata e análise das projeções para o cenário RCP8.5. *Rev. bras. meteorol.* [online]. 2013, vol.28, n.3, pp.317-330.

VIANELLO, R. L & ALVES, A.R. *Meteorologia Básica e aplicações*. Ed. UFV. Viçosa (MG), 1991.

VIOLA, M.R.; MELLO, C.R. de; PINTO, D.B.F.; MELLO, J.M. de; ÁVILA, L.F. Métodos de interpolação espacial para o mapeamento da precipitação pluvial. *Revista Brasileira de Engenharia Agrícola e Ambiental*, v.14, p.970-978, 2010.

WAKE, M. *Zoneamento geoambiental da bacia hidrográfica do rio Potengi.* Dissertação (Mestrado em Geografia) – Universidade Federal do Rio Grande do Norte, Natal, 2003, 187p.

YAMAMOTO, J.K.; LANDIM, P.M.B. 2013. *Geoestatística: conceitos e aplicações.* São Paulo, Oficina de Textos. 215p.