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LONG-TERM INTENSE RAIN EQUATION FOR SANTA CATARINA, BRAZIL

Equação de chuvas intensas de longa duração para Santa Catarina, Brasil

Ecuación de lluvias intensas de largo plazo para Santa Catarina, Brasil

Álvaro José Back
Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Epagri)/Estação Experimental de Urussanga
email: ajb@epagri.sc.gov.br

Luísa Back
Programa de Pós Graduação em Epidemiologia/Universidade Federal do Rio Grande do Sul (UFRGS)
Porto Alegre, Rio Grande do Sul, Brasil
luisasmback@gmail.com

Beatriz Back
Instituto de Matemática e Estatística/ Universidade Federal do Rio Grande do Sul
Porto Alegre, Rio Grande do Sul, Brasil
beatrizsmback@gmail.com

Gabriel da Silva Souza
Programa de Pós-graduação em Ciências Ambientais/Universidade do Extremo Sul Catarinense (Unesc)
eng.agrimensorgabriel@gmail.com

Abstract: Reliable estimates of extreme long-term rainfall are important for understanding the risks of natural disasters such as floods and landslides. In Brazil, there are few studies on the risk of extreme long-term rainfall events. The available IDF equations only allow estimating heavy rainfall lasting less than 24 hours. This study aimed to adjust the Intensity-Duration-Frequency (IDF) equation for rainfall lasting ten days for the state of Santa Catarina. 176 rainfall stations with data series over 30 years were used. Maximum rainfall lasting from one to ten days and return periods of 2, 5, 10, 20, 25, 50, and 100 years were estimated. The coefficients of the heavy rainfall equation were adjusted. The performance indices confirmed the good fit of the equations, with R^2 greater than 0.969 and Nash-Sutcliffe coefficient greater than 0.928. The K coefficient showed greater variation between the coefficients of the heavy rainfall equation given with higher values on the north coast of the state. The intense rains show spatial variation, with higher values observed in the regions of the North Coast and Far West of the state and lower values in the Middle Valley of Itajaí region. The IDF equations make it possible to obtain estimates for rainfall lasting from one to ten days and a return period from 2 to 100 years and can be used to estimate the risks of extreme events for the State of Santa Catarina.

Keywords: Extreme event. Natural disasters. Inundation. Drainage.

Resumo: Estimativas confiáveis de chuvas extremas de longa duração são importantes para o conhecimento dos riscos desastres naturais como inundações e deslizamentos. No Brasil existem poucos estudos sobre riscos de eventos extremos de chuvas de longa duração. As equações IDF disponíveis somente permitem estimar chuvas intensas com duração inferior a 24h. Este estudo teve como objetivo ajustar as equação Intensidade-Duração-Frequência (IDF) para chuvas com duração de uma dez dias para o estado de Santa Catarina. Foram utilizadas 176 estações pluviométricas com séries de dados superior a 30 anos. Foram estimadas as chuvas máximas com duração de um a dez dias e períodos de retorno de 2, 5, 10, 20, 25, 50 e 100 anos. Foram ajustados os coeficientes da equação de chuvas intensas. Os índices de desempenho confirmaram o bom ajuste das equações, com R^2 superior a 0,969 e Coeficiente de Nash-Sutcliffe superior a 0,928. O coeficiente K mostrou maior variação entre os coeficientes da equação de chuvas intensas dados com maiores valores no litoral norte do estado. As chuvas intensas apresentam variação espacial, com maiores valores observados nas regiões do Litoral Norte e Extremo Oeste do estado e menores valores na região do Médio Vale do Itajaí. As equações IDF permitem obter as estimativas para chuvas com duração de um a dez dias e período de retorno de 2 a 100 anos, podendo ser usadas na estimativa dos riscos de eventos extremos para o Estado de Santa Catarina.

Palavras-chave: Evento extremo. Desastres naturais. Inundação. Drenagem.

Resumen: Las estimaciones confiables de precipitaciones extremas a largo plazo son importantes para comprender los riesgos de desastres naturales como inundaciones y derrumbes de tierra. En Brasil, existen pocos estudios sobre el riesgo de eventos extremos de lluvia a largo plazo. Las ecuaciones IDF disponibles solo permiten estimar lluvias intensas con duración inferior a 24 horas. Este estudio tuvo como objetivo ajustar la ecuación Intensidad-Duración-Frecuencia (IDF) para lluvias con duración de diez días para el estado de Santa Catarina. Se utilizaron 176 estaciones pluviométricas con series de datos superiores a 30 años. Se estimaron precipitaciones máximas con duración entre uno y diez días y períodos de retorno de 2, 5, 10, 20, 25, 50 y 100 años. Se ajustaron los coeficientes de la ecuación de lluvias intensas. Los índices de desempeño confirmaron el buen ajuste de esas ecuaciones, con R^2 superior a 0,969 y coeficiente de Nash-Sutcliffe superior a 0,928. El coeficiente K presentó variación más grande entre los coeficientes de la ecuación de lluvias fuertes con valores más altos en la costa norte del estado. Las lluvias intensas muestran variación espacial, con valores más altos observados en las regiones de la Costa Norte y Extremo Oeste del estado y valores más bajos en la región del Valle Medio del Itajaí. Las ecuaciones IDF permiten obtener estimaciones para lluvias con duración entre uno y diez días y un período de retorno de 2 a 100 años, cuales pueden ser utilizadas para estimar los riesgos de eventos extremos para el estado de Santa Catarina.

Palabras clave: Evento extremo. Desastres naturales. Inundación Drenaje.

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1. INTRODUCTION

Knowing the value of intense rainfall is fundamental for estimating the maximum flows to be used in the design of engineering infrastructure projects and hydraulic works such as bridges, culverts, dam spillways (MAMOON et al., 2014; PENNER; LIMA, 2016).

Mouri et al. (2013) highlight the need for studies of extreme events to assess the risk of natural disasters. Realistic and reliable estimates of rainfall and extreme runoff are important for the preservation of human life and property and are necessary for the proper assessment of the risks and economic impacts of eventual failures where the costs associated with repairs can be significant (GREEN et al., 2015; JOHNSON; SMITHERS, 2019).

The dimensioning of hydraulic works is based on a specific amount of rainfall, which varies according to the type of work, the costs involved and the risks of failure, called project rainfall (BALBASTRE-SOLDEVILA et al., 2019; COOK et al., 2020). The project rainfall should consider the relationship between intensity, duration and frequency, called IDF relationships (MIRHOSSEINI et al., 2012; SUN et al., 2019). Some authors use the height or depth ratio instead of intensity, calling it the DDF ratio (YAMOAT et al., 2022). These relationships can be expressed graphically, the so-called IDF curves, or through equations, called IDF (or DDF) equations.

The IDF curve was presented by Sherman (1931) and Bernard (1932) and has since been widely used around the world (BEZAK et al., 2018). The IDF relations were initially established for short-term rainfall (less than 24 h), obtained from the analysis of pluviographic data. In recent decades, IDF equations have been established using techniques to disaggregate daily rainfall and from shorter duration rainfall (BACK; CADORIN, 2021).

In urban drainage, which generally involves studies in small basins or contribution areas, the project rainfall is of short duration, often less than two hours in duration. For projects involving large basins, or in agricultural drainage studies, it is often necessary to consider the frequency of long-term rainfall (NAMITHA; VINOTHKUMAR, 2019). In agricultural drainage, it is also common to use rain lasting up to seven days (BELTRAN, 1987). Similarly, landslide risk studies may require data on rainfall accumulated over several days. Vieira et al. (2005), in their analysis to identify areas susceptible to landslides in Bairro da Velha Grande, in the municipality of Blumenau, found a correlation between the accumulated precipitation in the previous four days and the precipitation on the day of the landslide event. According to Dias and Herrmann (2002), there is a greater probability of occurrence of mass movements when a heavy downpour is preceded by consecutive days of rain. Valverde et al. (2018) considered that the maximum accumulated rainfall in 5 days is a good indicator for the occurrence of landslides, noting that, when persistent rains occur for several days, the most vulnerable areas, considered at geological/geotectonic risk, suffer the greatest impacts.

Rain can be considered as the main triggering factor of landslides, mainly in places of relative tectonic stability. Stabile and Colângelo (2017) showed that the main mass movement events in Brazil were related to extreme rainfall with duration ranging from 6 to 96 hours. XUE et al (2016) evaluated the effect of long-term rainfall on soil stability and showed that soil stability reduced for rainfall lasting longer than 4 days. Ng and Shi (1997), investigating the influence of rain on soil stability, concluded that the factor of safety decreases as the duration of rain increases until the critical duration is reached. The authors concluded that the critical duration ranges from 3 to 7 days. Soares and Ramos Filho (2014), observed that a threshold close to 50 mm of accumulated rain for 7 days was a good reference to indicate the possibility of landslides in João Pessoa (PB)

The long-term heavy rainfall equation can be used in mathematical modeling for extreme events and hydrological simulation of events in large basins. Froelich (1995) developed IDF equations for durations from one to ten days. Green et al. (2016) presented project rainfall estimates for return periods ranging from 1 to 100 years and durations ranging from 1 minute to 7 days. Smithers and Schulze (2000) used daily rainfall data from 1,806 Australian rainfall stations, all with at least 40 years of record, to determine maximum rainfall for longer durations (1 to 7 days).

In Brazil, there are few studies of heavy rainfall lasting more than 1 day, and mainly of IDF equations to be applied in estimating rainfall lasting more than 24 h. Back (2022) carried out a study of intense rainfall for the state of Santa Catarina, presenting the maximum rainfall lasting from one to ten days for 224 rainfall stations, where she used the Gumbel and GEV probability distributions for the maximum series of each duration. This study aims to adjust the IDF equation to obtain an estimate of intense rainfall lasting from one to ten days for the State of Santa Catarina.

2. METHODOLOGY

2.1. Methodological procedures

From the study by Back (2022), the pluviometric stations with a data series of more than 30 years were selected. Table 1 contains the list of stations and the period of data used, and Figure 1 shows the spatial distribution of stations.

For each station, the height of maximum rainfall lasting from 24 to 240 hours (one to ten days) and a return period of 2, 5, 10, 25, 50 and 100 years were estimated from the HidroChuSC2.0 program (BACK, 2022). The rainfall estimate is performed with the Gumbel and GEV probability distributions, according to the selection criteria adopted for each duration described in Back and Bonfante (2021) and Back (2022).

Rainfall heights were converted into intensities, and thus, the equation was adjusted to estimate rainfall intensity as follows:

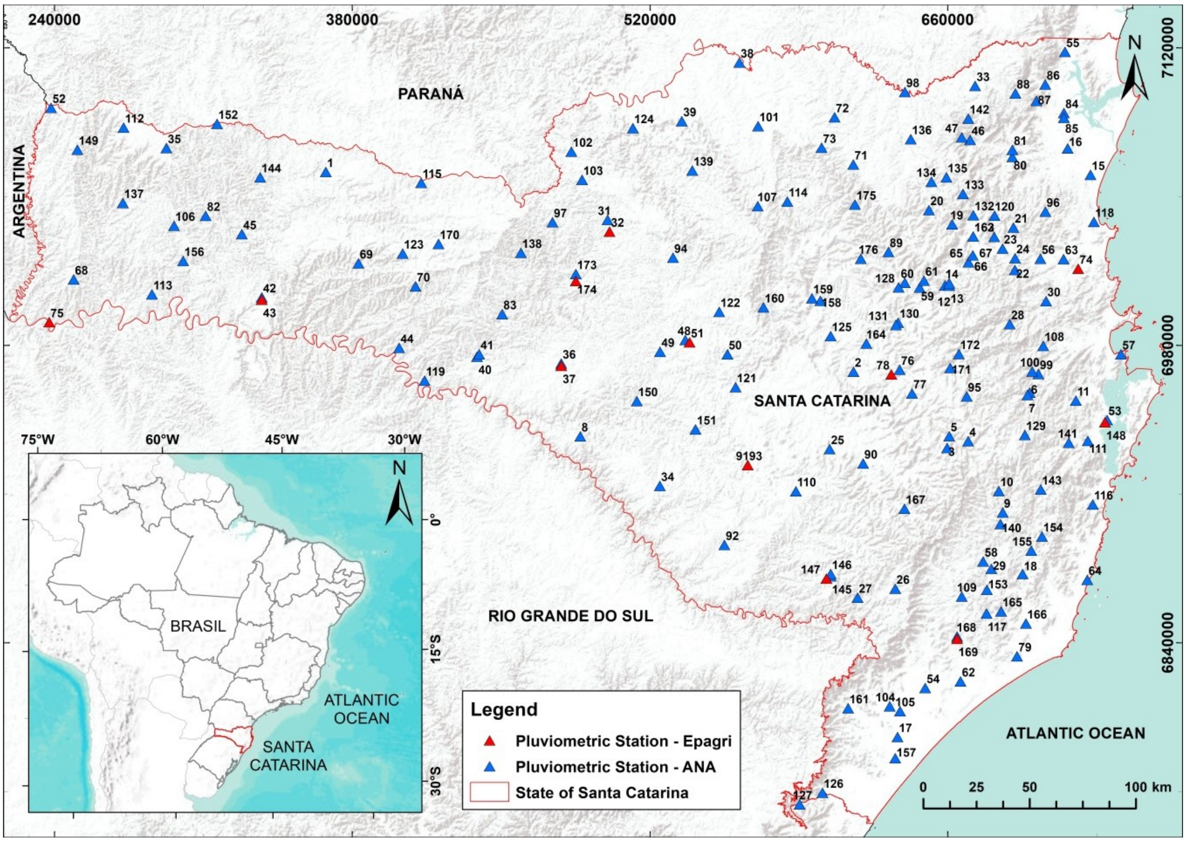
(1) $$i = \frac{KT^m}{(t+b)^n}$$

Where i: rainfall intensity (mm h^{-1}); T = return period (years); t = duration of rain (hours); K, m, b, n coefficients to be adjusted. The adjustment of the parameters was performed by minimizing the expression:

(2) $$S = \sum_{t=1}^{10} \sum_{T=1}^{8} \left(\frac{(Ie_{t,T} - Io_{t,T}}{Io_{t,T}} \right)^2$$

Where $Ie_{t,T}$ is the rainfall intensity with duration t and return period T estimated by the IDF equation; $Io_{t,T}$ is the rainfall intensity with duration t and return period T obtained from HidroChuSC2.0.

Figure 1 – Spatial distribution of rainfall stations with more than 30 years of data in the state of Santa Catarina.



To assess the accuracy of the estimate, the standard error of estimate (EP), Nash-Sutcliffe Coefficient (NS), concordance index (d), mean percentage error (PBIAS), mean absolute error (MAE) and coefficient of determination (R²) were calculated, respectively, by equations 3 to 8.

(3) $$EP = \sqrt{\frac{\sum_{i=1}^{n}(Ei-O_i)^2}{N}}$$

(4) $$NS = 1 - \frac{\sum_{i=1}^{N}(Ei-Oi)^2}{\sum_{i=1}^{N}(Ei-O)^2}$$

(5) $$d = 1 - \frac{\sum_{i=1}^{n}(Ei-Oi)^2}{\sum_{I=1}^{N}(|Ei-O|+|Oi-O|)^2}$$

(6) $$PBIAS(\%) = \sum_{i=1}^{n}\frac{(Oi-Ei)}{\sum Oi}100$$

(7) $$MAE = \frac{\sum_{i=1}^{N}|Oi-Ei|}{N}$$

(8) $$R^2 = \frac{\sum_{i=1}^{n}(Ei-O)^2}{\sum_{i=1}^{n}(Ei-O)^2\sum_{i=1}^{n}(Ei-E)^2}$$

Where: EP = standard error of estimation, Ei = intensity value estimated by the equation, Oi = intensity value from Table 1, N = number of values (N = 80); NS = Nash-Sutcliffe Coefficient; d = concordance index; O = mean value from Table 1; PBIAS = mean percentage error; MAE = mean absolute error; R^2 = coefficient of determination; E = average value of the estimates by the equation.

Table 1 - Rainfall stations used and maximum series data period.

Station	Code	Municipality	Start	End	N, years	Entity
1	2652000	Abelardo Luz	1958	2019	61	ANA
2	2749041	Agrolândia	1983	2019	36	ANA
3	2749007	Alfredo Wagner	1941	2019	78	ANA
4	2749014	Alfredo Wagner	1941	1975	34	ANA
5	2749037	Alfredo Wagner	1977	2019	42	ANA
6	2748003	Angelina	1946	2019	73	ANA
7	2749019	Angelina	1955	1989	34	ANA
8	2751001	Anita Garibaldi	1965	2019	54	ANA
9	2749012	Anitápolis	1946	2019	73	ANA
10	2749027	Anitápolis	1973	2019	46	ANA
11	2748016	Antônio Carlos	1977	2019	42	ANA
12	2749000	Apiúna	1941	2019	78	ANA
13	2749016	Apiúna	1957	2019	62	ANA
14	2749025	Apiúna	1951	1989	38	ANA
15	2648020	Araquari	1976	2019	43	ANA
16	2648028	Araquari	1978	2019	41	ANA
17	2849004	Araranguá	1946	2010	64	ANA
18	2848000	Armazém	1946	2019	73	ANA
19	2649003	Benedito Novo	1941	2019	78	ANA
20	2649017	Benedito Novo	1954	2019	65	ANA
21	2649010	Blumenau	1941	2019	78	ANA
22	2649009	Blumenau	1941	2019	78	ANA
23	2649025	Blumenau	1944	1989	45	ANA
24	2649007	Blumenau	1945	2019	74	ANA
25	2749035	Bocaina do Sul	1977	2019	42	ANA
26	2849009	Bom Jardim da Serra	1970	2019	49	ANA
27	2849023	Bom Jardim da Serra	1977	2019	42	ANA
28	2749045	Botuverá	1987	2019	32	ANA
29	2849030	Braço do Norte	1987	2019	32	ANA
30	2748000	Brusque	1941	2019	78	ANA
31	2651002	Caçador	1944	1975	31	ANA
32	60	Caçador	1961	2019	51	Epagri
33	2649057	Campo Alegre	1977	2017	40	ANA
34	2750001	Campo Belo do Sul	1970	2019	49	ANA
35	2653001	Campo Erê	1970	2019	49	ANA
36	2751002	Campos Novos	1923	1998	75	ANA
37	94	Campos Novos	1969	2019	50	Epagri
38	2650003	Canoinhas	1940	1995	55	ANA
39	2650018	Canoinhas	1977	2014	37	ANA
40	2751003	Capinzal	1940	1977	37	ANA
41	2751012	Capinzal	1977	2019	42	ANA
42	2752016	Chapecó	1975	2014	39	ANA
43	108	Chapecó	1974	2019	46	Epagri
44	2752005	Concordia	1956	2019	63	ANA
45	2652034	Coronel Freitas	1979	2019	40	ANA
46	2649013	Corupá	1946	2019	73	ANA
47	2649064	Corupá	1985	2019	34	ANA
48	2750002	Curitibanos	1912	1957	45	ANA
49	2750009	Curitibanos	1959	2019	60	ANA
50	2750012	Curitibanos	1962	2019	57	ANA
51	507	Curitibanos	1988	2019	31	Epagri
52	2653002	Dionísio Cerqueira	1973	2019	46	ANA
53	2748006	Florianópolis	1949	2018	69	ANA
54	2849006	Forquilhinha	1946	2017	71	ANA
55	2648027	Garuva	1977	2019	42	ANA
56	2648000	Gaspar	1935	1966	31	ANA
57	2748019	Governador Celso Ramos	1977	2016	39	ANA
58	2849008	Grão Pará	1946	2019	73	ANA
59	2749001	Ibirama	1934	2019	85	ANA
60	2749005	Ibirama	1941	2019	78	ANA
61	2749022	Ibirama	1944	1988	44	ANA
62	2849022	Içara	1978	2019	41	ANA
63	2648001	Ilhota	1928	2014	86	ANA
64	2848007	Imbituba	1977	2019	42	ANA
65	2649001	Indaial	1941	2015	74	ANA
66	2649005	Indaial	1941	2015	74	ANA
67	2649027	Indaial	1944	1989	45	ANA
68	2753013	Iporã do Oeste	1977	2019	42	ANA
69	2652001	Ipumirim	1970	2019	49	ANA
70	2751011	Irani	1977	2019	42	ANA
71	2649054	Itaiópolis	1977	2014	37	ANA
72	2649056	Itaiópolis	1977	2015	38	ANA
73	2650022	Itaiópolis	1983	2019	36	ANA
74	183	Itajaí	1981	2019	35	Epagri
75	477	Itapiranga	1988	2019	31	Epagri
76	2749002	Ituporanga	1941	2019	78	ANA
77	2749017	Ituporanga	1971	2019	48	ANA
78	191	Ituporanga	1987	2019	31	Epagri
79	2849020	Jaguaruna	1977	2019	42	ANA
80	2649012	Jaraguá do Sul	1962	2007	45	ANA
81	2649037	Jaraguá do Sul	1943	2014	71	ANA
82	2652021	Jardinópolis	1977	2019	42	ANA
83	2751004	Joaçaba	1944	2019	75	ANA
84	2648005	Joinville	1953	1989	36	ANA
85	2648014	Joinville	1940	2019	79	ANA
86	2648033	Joinville	1988	2019	31	ANA
87	2648034	Joinville	1987	2019	32	ANA
88	2649060	Joinville	1982	2019	37	ANA
89	2649061	José Boiteux	1977	2019	42	ANA
90	2749031	Lages	1958	2019	61	ANA
91	2750005	Lages	1946	2013	67	ANA
92	2850004	Lages	1959	2019	60	ANA
93	230	Lages	1961	2015	43	Epagri
94	2650019	Lebon Regis	1977	2019	42	ANA
95	2749034	Leoberto Leal	1977	2019	42	ANA
96	2648002	Luiz Alves	1941	2019	78	ANA
97	2651036	Macieira	1977	2019	42	ANA
98	2649016	Mafra	1951	2009	58	ANA
99	2748001	Major Gercino	1946	2019	73	ANA
100	2749015	Major Gercino	1956	2019	63	ANA
101	2650000	Major Vieira	1952	2015	63	ANA
102	2651011	Matos Costa	1940	1995	55	ANA
103	2651044	Matos Costa	1980	2014	34	ANA
104	2849005	Meleiro	1943	2019	76	ANA
105	2849024	Meleiro	1978	2019	41	ANA
106	2653003	Modelo	1972	2019	47	ANA
107	2650015	Monte Castelo	1977	2015	38	ANA
108	2748002	Nova Trento	1946	2019	73	ANA
109	2849001	Orleans	1940	2019	79	ANA
110	2750007	Painel	1959	2019	60	ANA
111	2748004	Palhoça	1946	2019	73	ANA
112	2653013	Palma Sola	1977	2019	42	ANA
113	2753006	Palmitos	1960	2019	59	ANA
114	2650023	Papanduva	1985	2019	34	ANA
115	2651022	Passos Maia	1973	2019	46	ANA
116	2748017	Paulo Lopes	1977	2019	42	ANA
117	2849028	Pedras Grandes	1987	2019	32	ANA
118	2648019	Piçarras	1976	2019	43	ANA
119	2751010	Piratuba	1938	1977	39	ANA
120	2649002	Pomerode	1930	2019	89	ANA
121	2750011	Ponte Alta	1958	2019	61	ANA
122	2750010	Ponte Alta do Norte	1960	2019	59	ANA
123	2651040	Ponte Serrada	1977	2019	42	ANA
124	2650008	Porto União	1975	2012	37	ANA
125	2749006	Pouso Redondo	1941	2019	78	ANA
126	2949001	Praia Grande	1977	2019	42	ANA
127	2950056	Praia Grande	1983	2019	36	ANA
128	2749023	Presidente Getúlio	1944	1989	45	ANA
129	2749020	Rancho Queimado	1977	2019	42	ANA
130	2749024	Rio do Sul	1944	1989	45	ANA
131	2749039	Rio do Sul	1979	2019	40	ANA
132	2649008	Rio dos Cedros	1941	2019	78	ANA
133	2649030	Rio dos Cedros	1951	1993	42	ANA
134	2649031	Rio dos Cedros	1958	1993	35	ANA
135	2649032	Rio dos Cedros	1945	1993	48	ANA
136	2649055	Rio Negrinho	1977	2014	37	ANA
137	2653004	Romelandia	1970	2006	36	ANA
138	2651052	Salto Veloso	1988	2019	31	ANA
139	2650016	Santa Cecília	1978	2015	37	ANA
140	2849031	Santa Rosa de Lima	1987	2019	32	ANA
141	2748005	Santo Amaro da Imperatriz	1951	2019	68	ANA
142	2649033	São Bento do Sul	1940	1983	43	ANA
143	2748018	São Bonifácio	1979	2019	40	ANA
144	2652002	São Domingos	1973	2019	46	ANA
145	2849003	São Joaquim	1943	1975	32	ANA
146	2849014	São Joaquim	1961	1998	37	ANA
147	523	São Joaquim	1961	2019	56	Epagri
148	124	São José	1969	2019	51	Epagri
149	2653005	São José do Cedro	1973	2019	46	ANA
150	2750008	São José do Cerrito	1961	2019	58	ANA
151	2750020	São José do Cerrito	1977	2019	42	ANA
152	2652031	São Lourenço do Oeste	1977	2019	42	ANA
153	2849002	São Ludgero	1940	2019	79	ANA
154	2848006	São Martinho	1977	2019	42	ANA
155	2848009	São Martinho	1987	2019	32	ANA
156	2653007	Saudades	1955	2019	64	ANA
157	2949003	Sombrio	1977	2019	42	ANA
158	2749003	Taió	1930	2019	89	ANA
159	2750014	Taió	1966	2019	53	ANA
160	2750021	Taió	1985	2019	34	ANA
161	2849019	Timbé do Sul	1977	2019	42	ANA
162	2649004	Timbó	1929	2019	90	ANA
163	2649026	Timbó	1944	1989	45	ANA
164	2749013	Trombudo Central	1946	2019	73	ANA
165	2849000	Tubarão	1940	2019	79	ANA
166	2849027	Tubarão	1987	2019	32	ANA
167	2849021	Urubici	1944	2019	75	ANA
168	2849011	Urussanga	1949	1994	45	ANA
169	434	Urussanga	1961	2018	52	Epagri
170	2651001	Vargem Bonita	1944	2019	75	ANA
171	2749033	Vidal Ramos	1977	2019	42	ANA
172	2749046	Vidal Ramos	1988	2019	31	ANA
173	2751009	Videira	1940	1979	39	ANA
174	442	Videira	1987	2019	32	Epagri
175	2649058	Vitor Meireles	1978	2019	41	ANA
176	2649053	Witmarsum	1977	2019	42	ANA

The spatialization of the data and the elaboration of the maps were carried out with the geoprocessing software ArcGis 10.8 (ESRI) and the application of the *kriging ordinary* geostatistical interpolation tools

3. DEVELOPMENT

Table 2 contains the coefficients of the heavy rainfall equations for each rainfall station and the evaluation criteria. The standard error (EP) of the adjusted equation ranged from 0.031 to 0.082 mm h^{-1}, with EP values equal to zero indicating a perfect fit of the data. The NS Coefficient ranged from 0.9282 to 0.9967. The NS is widely used to evaluate hydrological models and can vary from 0 to 1, where the NS value equal to 1 indicates a perfect fit of the model to the observed data (NASH; SUTCLIFFE, 1970). According to Silva et al. (2012), NS values greater than 0.75 are considered good, between 0.36 and 0.75 are considered acceptable and, below than 0.36, the model is unacceptable. Lima Neto et al. (2021), adjusting the IDF equation by disaggregating daily rainfall for 31 cities in the state of Pernambuco, obtained NS above 0.98. The concordance index (d) ranged from 0.983 to 0.999. This index can assume values from 0 (no agreement) to 1.0 (perfect agreement). The mean percentage error (PBIAS) ranged from -0.0012 to 0.0244% showing that the deviations are small. The simulation is considered perfect when PBIAS equals 0; values greater than 0 indicate model underestimation bias and values lower than 0 indicate model overestimation bias. The mean absolute error (MAE) varied between 0.0494 and 0.2590 mm h^{-1}. MAE indicates the error in the units of the study variable, and is therefore useful in evaluating the results. The model is considered perfect when MAE is equal to 0 (MORIASI et al., 2007). The coefficient of determination (R^2) ranged from 0.9696 to 0.9984, indicating that the equations explain over 96% of the intensity variation. Some works with IDF equation adjustments for duration lower than 1 day report R^2 coefficient above 0.94 (OLIVEIRA et al., 2005; SOUZA et al, 2012). Aragão et al. (2013) emphasize that the high values of R^2 indicate that this can be a biased indicator to assess the adjustment of the equation to the sample data.

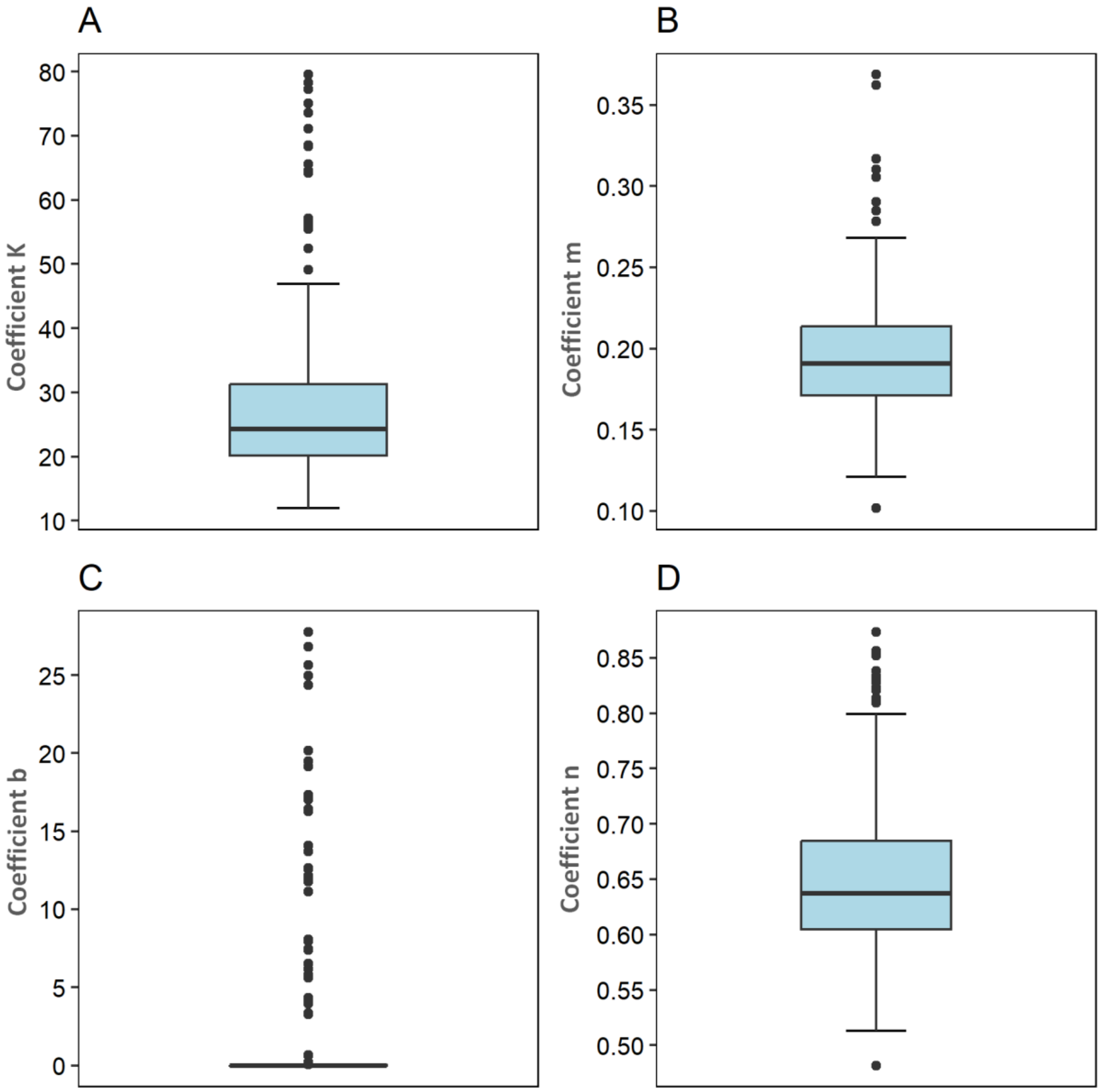
Table 2 - Coefficients of the heavy rainfall equation and evaluation criteria.

	Coefficients of the IDF equation				Coefficients of the IDF equation					
Station	K	m	b	n	EP	NS	d	PBIAS	MAE	R²
1	24,16	0,2054	0,00	0,6227	0,0425	0,9892	0,9974	0,0017	0,0952	0,9952
2	18,31	0,2001	0,00	0,5807	0,0461	0,9806	0,9954	0,0005	0,0931	0,9924
3	18,76	0,1848	0,00	0,5979	0,0457	0,9811	0,9955	0,0012	0,0828	0,9920
4	21,72	0,1696	0,00	0,6695	0,0443	0,9847	0,9959	0,0115	0,0747	0,9943
5	22,74	0,1586	0,00	0,6200	0,0583	0,9806	0,9953	0,0036	0,1097	0,9917
6	22,82	0,1791	0,00	0,6324	0,0369	0,9954	0,9989	0,0030	0,0667	0,9977
7	24,29	0,1763	0,00	0,6541	0,0402	0,9910	0,9976	0,0080	0,0781	0,9964
8	26,09	0,1510	0,00	0,6256	0,0532	0,9851	0,9961	0,0099	0,1099	0,9934
9	18,20	0,1745	0,00	0,6098	0,0643	0,9527	0,9889	0,0059	0,1099	0,9803
10	27,59	0,1576	0,00	0,6501	0,0344	0,9927	0,9982	0,0010	0,0694	0,9966
11	31,31	0,2118	0,00	0,6536	0,0454	0,9877	0,9970	0,0025	0,1237	0,9943
12	21,75	0,1763	0,00	0,6394	0,0424	0,9916	0,9979	0,0011	0,0706	0,9963
13	22,59	0,1760	0,00	0,6451	0,0449	0,9862	0,9967	0,0014	0,0822	0,9941
14	22,26	0,1921	3,33	0,6549	0,0507	0,9868	0,9968	0,0025	0,0783	0,9940
15	78,25	0,2137	16,27	0,8381	0,0805	0,9820	0,9954	0,0157	0,1837	0,9912
16	31,18	0,2249	0,00	0,6562	0,0773	0,9497	0,9878	0,0119	0,2412	0,9771
17	23,09	0,1954	0,00	0,6447	0,0743	0,9629	0,9912	0,0074	0,1507	0,9846
18	46,93	0,2559	11,78	0,7990	0,0427	0,9894	0,9974	0,0013	0,0922	0,9952
19	30,91	0,1622	6,18	0,6854	0,0423	0,9953	0,9988	0,0042	0,0643	0,9977
20	29,13	0,2024	5,80	0,6840	0,0418	0,9893	0,9974	0,0024	0,0823	0,9949
21	27,41	0,1998	0,20	0,6643	0,0469	0,9882	0,9971	0,0027	0,1063	0,9947
22	26,38	0,1898	0,00	0,6647	0,0323	0,9952	0,9988	0,0022	0,0623	0,9976
23	42,59	0,1852	7,39	0,7536	0,0465	0,9900	0,9975	0,0061	0,0876	0,9950
24	57,11	0,2473	17,03	0,8094	0,0434	0,9879	0,9970	0,0034	0,0942	0,9943
25	39,19	0,1821	6,52	0,7146	0,0481	0,9919	0,9979	0,0061	0,0966	0,9960
26	68,33	0,1892	26,82	0,8233	0,0501	0,9783	0,9947	0,0043	0,0930	0,9898
27	43,11	0,1712	12,66	0,7356	0,0466	0,9852	0,9964	0,0031	0,0915	0,9930
28	35,32	0,1018	0,09	0,8139	0,0726	0,9738	0,9928	0,0244	0,0826	0,9901
29	19,29	0,1932	0,09	0,6200	0,0532	0,9750	0,9941	0,0017	0,0954	0,9898
30	56,55	0,1692	11,94	0,7962	0,0404	0,9952	0,9988	0,0060	0,0694	0,9978
31	64,54	0,1729	27,76	0,8316	0,0525	0,9713	0,9929	0,0073	0,0866	0,9860
32	28,79	0,1476	5,63	0,6678	0,0311	0,9966	0,9991	0,0020	0,0494	0,9983
33	75,04	0,1987	25,65	0,8564	0,0409	0,9899	0,9975	0,0030	0,0752	0,9952
34	42,01	0,2016	7,44	0,7333	0,0455	0,9934	0,9983	0,0041	0,0948	0,9967
35	22,90	0,2195	0,00	0,5992	0,0506	0,9810	0,9953	0,0038	0,1295	0,9911
36	12,71	0,1773	0,01	0,4818	0,0647	0,9532	0,9888	0,0065	0,1243	0,9794
37	19,11	0,1975	0,01	0,5648	0,0477	0,9812	0,9955	0,0011	0,1024	0,9922
38	21,69	0,1612	0,01	0,6114	0,0595	0,9865	0,9967	0,0061	0,1009	0,9936
39	21,97	0,2288	0,01	0,6103	0,0650	0,9557	0,9896	0,0053	0,1605	0,9817
40	29,55	0,1511	0,01	0,6842	0,0505	0,9889	0,9971	0,0094	0,0938	0,9950
41	19,11	0,2058	0,01	0,5786	0,0509	0,9793	0,9950	0,0024	0,1117	0,9907
42	21,75	0,2191	0,01	0,5913	0,0515	0,9891	0,9974	0,0017	0,1167	0,9955
43	19,09	0,2276	0,01	0,5683	0,0454	0,9837	0,9961	-0,0002	0,1097	0,9937
44	18,17	0,1994	0,01	0,5570	0,0466	0,9805	0,9953	0,0011	0,0989	0,9919
45	27,57	0,1492	0,01	0,6402	0,0473	0,9916	0,9979	0,0024	0,0854	0,9962
46	21,88	0,2020	0,01	0,6050	0,0579	0,9721	0,9933	0,0042	0,1442	0,9881
47	37,05	0,1919	0,01	0,7069	0,0580	0,9890	0,9973	0,0056	0,1349	0,9948
48	25,33	0,1595	0,01	0,6559	0,0418	0,9927	0,9982	0,0020	0,0734	0,9967
49	18,79	0,1938	0,01	0,5960	0,0527	0,9731	0,9937	0,0008	0,0967	0,9896
50	19,58	0,2064	0,01	0,6053	0,0453	0,9839	0,9961	0,0006	0,0895	0,9935
51	25,33	0,1814	0,01	0,6064	0,0513	0,9900	0,9975	0,0028	0,1043	0,9954
52	28,25	0,1714	0,01	0,6168	0,0458	0,9879	0,9971	0,0018	0,1086	0,9946
53	35,48	0,2783	0,01	0,7128	0,0547	0,9748	0,9939	0,0057	0,1763	0,9883
54	20,37	0,2199	0,01	0,6165	0,0598	0,9646	0,9917	0,0020	0,1213	0,9864
55	20,02	0,2034	0,01	0,5128	0,0670	0,9586	0,9896	0,0112	0,2087	0,9797
56	29,56	0,2133	0,01	0,6929	0,0563	0,9922	0,9980	0,0084	0,1058	0,9962
57	30,36	0,2018	0,01	0,6641	0,0643	0,9837	0,9960	0,0051	0,1475	0,9926
58	25,64	0,2089	0,01	0,6600	0,0426	0,9912	0,9979	0,0016	0,0874	0,9960
59	20,92	0,1862	0,01	0,6388	0,0392	0,9884	0,9972	-0,0008	0,0686	0,9956
60	18,87	0,1944	0,01	0,6252	0,0393	0,9916	0,9980	0,0013	0,0648	0,9962
61	73,60	0,1679	20,15	0,8734	0,0341	0,9960	0,9990	0,0030	0,0510	0,9980
62	32,49	0,2128	5,61	0,6947	0,0398	0,9900	0,9976	0,0012	0,0865	0,9954
63	71,06	0,1878	19,48	0,8518	0,0413	0,9914	0,9979	0,0029	0,0729	0,9958
64	52,40	0,1683	4,31	0,7845	0,0575	0,9914	0,9978	0,0094	0,1086	0,9958
65	30,82	0,2013	12,17	0,6862	0,0474	0,9882	0,9971	0,0026	0,0855	0,9946
66	35,99	0,1960	13,69	0,7261	0,0414	0,9864	0,9967	0,0017	0,0739	0,9938
67	20,92	0,1700	0,00	0,6228	0,0512	0,9850	0,9963	0,0052	0,0858	0,9927
68	23,76	0,2196	3,97	0,5987	0,0462	0,9771	0,9945	0,0022	0,1128	0,9899
69	17,00	0,2303	0,00	0,5533	0,0612	0,9672	0,9920	0,0066	0,1476	0,9847
70	55,49	0,2315	24,37	0,7630	0,0437	0,9856	0,9965	0,0027	0,0903	0,9934
71	65,56	0,2369	14,06	0,8280	0,0434	0,9890	0,9973	0,0018	0,1075	0,9949
72	55,87	0,2681	12,58	0,8207	0,0347	0,9967	0,9992	0,0041	0,0682	0,9984
73	16,94	0,2295	0,00	0,5593	0,0779	0,9363	0,9853	0,0082	0,1900	0,9750
74	55,91	0,2465	11,15	0,7888	0,0306	0,9955	0,9989	0,0006	0,0767	0,9979
75	27,47	0,1826	0,00	0,6232	0,0520	0,9906	0,9976	0,0052	0,1093	0,9953
76	18,36	0,1877	0,00	0,5947	0,0413	0,9918	0,9980	0,0035	0,0745	0,9959
77	19,59	0,2214	0,68	0,6150	0,0441	0,9806	0,9954	0,0002	0,0925	0,9922
78	37,36	0,1385	7,45	0,7192	0,0341	0,9928	0,9982	0,0023	0,0564	0,9965
79	37,75	0,1982	0,00	0,7181	0,0792	0,9773	0,9945	0,0109	0,1892	0,9896
80	43,79	0,1659	3,28	0,7315	0,0401	0,9953	0,9988	0,0053	0,0795	0,9978
81	77,26	0,2902	24,96	0,8324	0,0446	0,9740	0,9936	0,0046	0,1358	0,9878
82	22,91	0,1643	0,00	0,5984	0,0389	0,9928	0,9982	0,0028	0,0790	0,9964
83	18,10	0,2138	0,05	0,5833	0,0449	0,9833	0,9960	0,0002	0,0895	0,9933
84	49,16	0,1343	0,61	0,7279	0,0612	0,9832	0,9957	0,0112	0,1453	0,9917
85	64,17	0,2017	16,43	0,7981	0,0661	0,9881	0,9969	0,0112	0,1389	0,9942
86	37,63	0,1948	4,13	0,6578	0,0337	0,9963	0,9991	0,0023	0,0845	0,9982
87	79,52	0,1658	17,34	0,7399	0,0395	0,9953	0,9988	0,0032	0,1116	0,9977
88	45,63	0,1620	7,94	0,6880	0,0427	0,9950	0,9987	0,0045	0,0932	0,9975
89	68,57	0,1858	19,14	0,8332	0,0400	0,9921	0,9981	0,0022	0,0739	0,9963
90	31,24	0,2236	8,08	0,7145	0,0359	0,9958	0,9989	0,0023	0,0646	0,9979
91	20,32	0,1880	0,00	0,6071	0,0670	0,9565	0,9897	0,0063	0,1397	0,9817
92	23,68	0,2606	0,00	0,6616	0,0564	0,9709	0,9930	0,0045	0,1463	0,9873
93	30,22	0,1634	0,00	0,6711	0,0570	0,9804	0,9953	0,0042	0,1283	0,9915
94	23,80	0,1604	0,00	0,6272	0,0402	0,9940	0,9985	0,0029	0,0647	0,9970
95	22,44	0,1439	0,00	0,6175	0,0348	0,9944	0,9986	0,0035	0,0593	0,9973
96	28,58	0,2049	0,00	0,6553	0,0430	0,9890	0,9973	0,0014	0,1000	0,9951
97	20,15	0,1811	0,00	0,5882	0,0562	0,9730	0,9936	0,0034	0,1210	0,9889
98	19,56	0,1995	0,00	0,6208	0,0330	0,9929	0,9983	0,0002	0,0611	0,9968
99	30,17	0,3167	0,00	0,7207	0,0364	0,9966	0,9991	0,0064	0,0859	0,9984
100	19,12	0,2256	0,00	0,6048	0,0342	0,9850	0,9964	-0,0007	0,0683	0,9939
101	22,94	0,1991	0,00	0,6256	0,0319	0,9932	0,9984	-0,0011	0,0618	0,9973
102	12,31	0,1570	0,00	0,5247	0,0734	0,9658	0,9911	0,0137	0,1099	0,9832
103	19,35	0,2388	0,00	0,6006	0,0642	0,9832	0,9960	0,0026	0,1274	0,9936
104	21,79	0,1625	0,00	0,6124	0,0374	0,9935	0,9984	0,0017	0,0651	0,9969
105	31,33	0,1579	0,00	0,6669	0,0533	0,9792	0,9949	0,0044	0,1250	0,9905
106	24,16	0,1801	0,00	0,5975	0,0469	0,9861	0,9965	0,0042	0,1071	0,9931
107	16,29	0,2214	0,00	0,5619	0,0797	0,9282	0,9831	0,0111	0,1785	0,9696
108	28,52	0,2067	0,00	0,6820	0,0758	0,9864	0,9965	0,0136	0,1430	0,9934
109	14,31	0,2498	0,00	0,5460	0,0638	0,9535	0,9892	0,0032	0,1355	0,9822
110	18,80	0,2130	0,00	0,5950	0,0483	0,9788	0,9950	0,0008	0,1019	0,9917
111	28,98	0,2495	0,00	0,6484	0,0500	0,9765	0,9945	-0,0003	0,1401	0,9909
112	23,13	0,1711	0,00	0,5676	0,0617	0,9702	0,9929	0,0041	0,1474	0,9875
113	24,67	0,1804	0,00	0,6093	0,0524	0,9736	0,9938	0,0009	0,1189	0,9901
114	22,50	0,1737	0,00	0,5976	0,0622	0,9654	0,9917	0,0056	0,1365	0,9849
115	29,13	0,1735	0,00	0,6434	0,0415	0,9951	0,9988	0,0035	0,0781	0,9976
116	33,78	0,2460	0,00	0,6520	0,0544	0,9840	0,9962	-0,0006	0,1776	0,9944
117	11,97	0,3622	0,00	0,5358	0,0733	0,9411	0,9865	0,0042	0,1949	0,9778
118	24,68	0,2850	0,00	0,6443	0,0537	0,9674	0,9925	-0,0008	0,1549	0,9883
119	14,85	0,3686	0,00	0,5749	0,0795	0,9318	0,9840	0,0100	0,2590	0,9714
120	30,05	0,1783	0,00	0,6730	0,0418	0,9957	0,9989	0,0038	0,0722	0,9979
121	19,54	0,1829	0,00	0,6084	0,0533	0,9842	0,9962	0,0031	0,0901	0,9927
122	14,98	0,1889	0,00	0,5566	0,0405	0,9867	0,9968	-0,0002	0,0682	0,9947
123	16,00	0,2146	0,00	0,5201	0,0521	0,9738	0,9938	0,0020	0,1215	0,9891
124	13,02	0,2197	0,00	0,5240	0,0652	0,9488	0,9881	0,0049	0,1265	0,9796
125	17,78	0,1776	0,00	0,5953	0,0377	0,9894	0,9975	0,0000	0,0620	0,9957
126	34,22	0,1734	0,00	0,6731	0,0408	0,9931	0,9983	0,0012	0,0955	0,9969
127	24,46	0,1524	0,00	0,6047	0,0818	0,9637	0,9914	0,0094	0,1735	0,9849
128	19,38	0,1617	0,00	0,6314	0,0443	0,9870	0,9968	0,0024	0,0646	0,9939
129	32,18	0,1696	0,00	0,6668	0,0476	0,9872	0,9966	0,0110	0,1121	0,9951
130	24,35	0,2018	0,00	0,6690	0,0391	0,9956	0,9989	0,0022	0,0655	0,9978
131	15,17	0,2111	0,00	0,5796	0,0513	0,9666	0,9921	0,0017	0,0913	0,9866
132	29,34	0,1986	0,00	0,6714	0,0398	0,9956	0,9989	0,0020	0,0787	0,9979
133	25,99	0,1545	0,00	0,6106	0,0538	0,9843	0,9962	0,0032	0,1206	0,9933
134	23,72	0,1781	0,00	0,6301	0,0389	0,9919	0,9980	0,0003	0,0752	0,9966
135	22,66	0,1759	0,00	0,6110	0,0537	0,9821	0,9957	0,0033	0,1051	0,9922
136	19,88	0,2309	0,00	0,6193	0,0481	0,9872	0,9970	-0,0002	0,0945	0,9952
137	25,93	0,1624	0,00	0,6019	0,0515	0,9849	0,9963	0,0039	0,1167	0,9928
138	27,68	0,1683	0,00	0,6550	0,0562	0,9738	0,9937	0,0039	0,1288	0,9889
139	20,89	0,1868	0,00	0,5854	0,0670	0,9598	0,9906	0,0052	0,1609	0,9842
140	24,73	0,1502	0,00	0,6163	0,0407	0,9940	0,9985	0,0049	0,0771	0,9971
141	35,44	0,2011	0,00	0,6946	0,0606	0,9842	0,9962	0,0054	0,1507	0,9928
142	22,52	0,1710	0,00	0,6784	0,0445	0,9918	0,9979	0,0056	0,0650	0,9959
143	23,20	0,1850	0,00	0,6126	0,0527	0,9843	0,9961	0,0037	0,1066	0,9926
144	26,14	0,1796	0,00	0,6184	0,0464	0,9879	0,9968	0,0086	0,1123	0,9947
145	25,05	0,2360	0,00	0,6906	0,0571	0,9922	0,9980	0,0074	0,0971	0,9961
146	16,64	0,3104	0,00	0,5964	0,0736	0,9563	0,9898	0,0060	0,1983	0,9825
147	23,57	0,2115	0,00	0,6360	0,0567	0,9770	0,9945	0,0036	0,1294	0,9903
148	41,74	0,2549	0,00	0,7299	0,0530	0,9724	0,9933	0,0049	0,1790	0,9874
149	32,16	0,1777	0,00	0,6494	0,0504	0,9878	0,9969	0,0069	0,1219	0,9940
150	19,11	0,2164	0,00	0,5959	0,0457	0,9839	0,9962	-0,0012	0,0932	0,9943
151	16,98	0,1883	0,00	0,5598	0,0531	0,9791	0,9949	0,0045	0,1044	0,9900
152	21,03	0,1939	0,00	0,5678	0,0519	0,9766	0,9945	0,0015	0,1230	0,9905
153	20,01	0,2312	0,00	0,6244	0,0440	0,9866	0,9968	-0,0009	0,0888	0,9950
154	24,30	0,2026	0,00	0,6158	0,0711	0,9688	0,9926	0,0059	0,1635	0,9867
155	34,04	0,1896	0,00	0,7232	0,0425	0,9949	0,9987	0,0044	0,0751	0,9975
156	27,60	0,2193	0,00	0,6489	0,0452	0,9896	0,9975	0,0005	0,1064	0,9959
157	37,59	0,1373	0,00	0,7095	0,0577	0,9798	0,9952	0,0038	0,1266	0,9914
158	23,18	0,1596	0,00	0,6316	0,0365	0,9949	0,9987	0,0015	0,0645	0,9975
159	26,55	0,1428	0,00	0,6389	0,0443	0,9888	0,9973	0,0015	0,0821	0,9950
160	21,08	0,1840	0,00	0,6098	0,0436	0,9913	0,9978	0,0043	0,0760	0,9957
161	33,50	0,1211	0,00	0,6403	0,0468	0,9847	0,9963	0,0008	0,1080	0,9939
162	27,05	0,1787	0,00	0,6634	0,0349	0,9963	0,9991	0,0022	0,0638	0,9981
163	30,40	0,1819	0,00	0,7054	0,0469	0,9935	0,9983	0,0072	0,0779	0,9969
164	18,52	0,1957	0,00	0,6102	0,0412	0,9863	0,9967	-0,0010	0,0701	0,9949
165	23,73	0,2290	0,00	0,6569	0,0579	0,9723	0,9935	0,0008	0,1237	0,9895
166	30,52	0,1914	0,00	0,6403	0,0625	0,9902	0,9975	0,0084	0,1382	0,9952
167	20,41	0,1809	0,00	0,6128	0,0501	0,9826	0,9958	0,0023	0,1001	0,9926
168	26,39	0,3054	0,00	0,6849	0,0444	0,9918	0,9980	0,0003	0,1208	0,9967
169	20,03	0,2359	0,00	0,6026	0,0666	0,9557	0,9897	0,0039	0,1653	0,9832
170	20,78	0,2184	0,00	0,5895	0,0632	0,9562	0,9898	0,0038	0,1513	0,9827
171	21,64	0,1911	0,00	0,6297	0,0469	0,9918	0,9979	0,0074	0,0863	0,9962
172	19,11	0,1657	0,00	0,6025	0,0383	0,9907	0,9977	0,0035	0,0686	0,9954
173	20,17	0,1506	0,00	0,6306	0,0499	0,9871	0,9968	0,0046	0,0737	0,9936
174	24,73	0,1635	0,00	0,6200	0,0385	0,9905	0,9977	0,0014	0,0779	0,9957
175	17,99	0,1908	0,00	0,5974	0,0611	0,9642	0,9916	0,0036	0,1173	0,9855
176	23,61	0,1637	0,00	0,6422	0,0495	0,9807	0,9954	0,0020	0,0904	0,9919

The performance indices show that the adjusted equations allow estimating rainfall intensities lasting from one to ten days and a return period from 2 to 100 years with small deviations in relation to the maximum rainfall values of the HidroChuSC2.0 program. It is important to consider that, as the maximum rainfall lasting from one to ten days was obtained through adjusted probability distributions for each duration, in some seasons inconsistencies occur in such a way that for some durations the estimated maximum rainfall is lower than the estimated rainfall with shorter duration. This is especially true for the longer return periods. Back and Back (2020) had already highlighted this inconsistency in other works (MOMIM et al., 2011). The use of the IDF equation corrects these inconsistencies in such a way that the longer the duration, the greater the intensity (or height) of the rain. The IDF equation also has the advantage of being able to implement calculation routines in hydrological models, allowing the insertion of rainfall data with different durations and return periods.

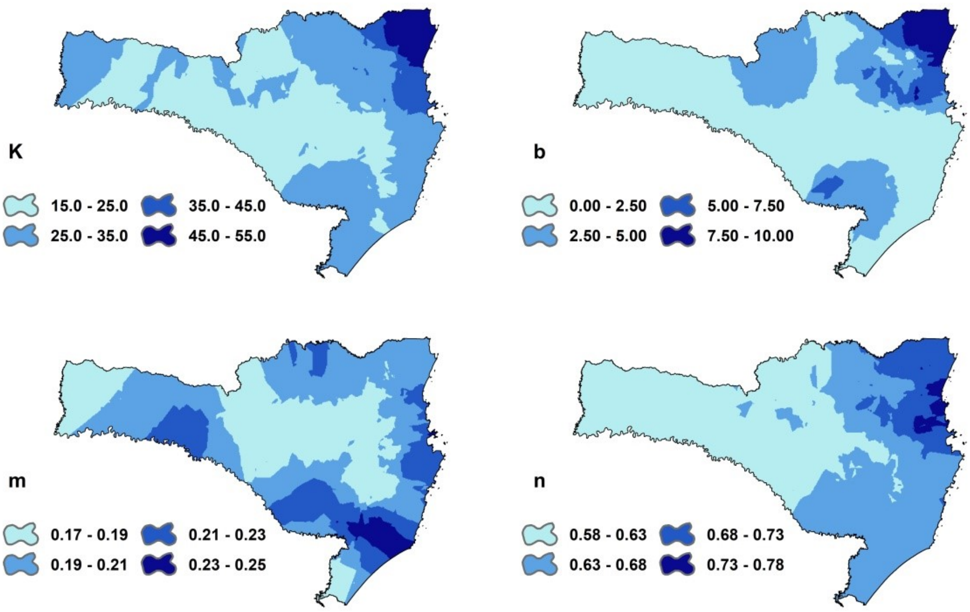
The K Coefficient ranged from 11.97 to 79.52, however it is observed that 50% of the values are in the range of 20 to 32 (Figure 2A). The intensity of the rain is directly proportional to the value of the "K" coefficient. The highest values occur in the coastal region of the state, especially in the north coast region, which is the region of the state with the highest average monthly rainfall (BACK, 2020). However, in the southern region of the state, where the lowest average annual rainfall occurs, valleys of "K" greater than 45 were also recorded, showing that this coefficient of the heavy rainfall equation is not directly correlated with the annual totals. In the plateau region and west of the state, values range from 15 to 30. The value of "m" ranged from 0.10 to 0.37, with 50% of the data between 0.17 and 0.21 (Figure 2 B). Several authors observed that the "K" coefficient presents the greatest variation when compared to the other coefficients (SILVA et al., 2018). These results indicate variation in precipitation intensities expected for different regions (SOUZA et al., 2012). However, CAMPOS et al. (2014) point out that there is an interaction between these parameters (K, m, b and n), that is, mutual influence between their estimates. In this way, the value of one parameter is influenced by the value of the other, although the combination of these parameters generally results in good IDF prediction models. The spatial distribution of the "m" coefficient was similar to the "K" coefficient (Figure 3B). The "b" coefficient ranged from 0 to 27.8, however, 75% of the values were 0 (Figure 2C). The spatial distribution of the “b” values is similar to the “K” coefficient values.

Figure 2 - Box-plot of the coefficients of the heavy rainfall equations



The “n” coefficient ranged from 0.48 to 0.87 with 50% of the values between 0.60 and 0.68. In Figure 2D, it can be seen that there was less dispersion for this coefficient compared to the others and the spatial distribution showed higher values on the coast and lower values in the west of the state (Figure 3D). Souza et al (2012), adjusting the heavy rainfall equation for 74 stations in the state of Pará, observed that parameters “b” and “n” showed values close to the average of 9.79 and 0.72, respectively. Several authors (OLIVEIRA et al., 2005; SANTOS et al., 2009; ARAGÃO et al., 2013; BORTOLINI et al., 2020), obtained constant values for the "b" and "m" coefficients when adjusting IDF equations for several rainfall stations. Aragão et al. (2013) attribute this occurrence to the disaggregation of daily rainfall by the method of relationships, since such a trend is not reported in studies that use data from pluviographs.

Figure 3 - Spatial distribution of the coefficients of the intense long-term rainfall equation in Santa Catarina



Suda (2018) highlights that the values "K" and "b" represent characteristics of short-term heavy rainfall, finding large differences in the geographic distribution of these coefficients. The "b" value and the "m" value in Sherman's formula represent continuation of heavy rainfall. According to Suda (2018), the geographic distributions of the two values are closely related to the topography. In the state of Santa Catarina, rainfall is directly related to the circulation of the atmosphere and the relief, and several authors highlight the effect of orography on the formation and distribution of rainfall (COAN et al., 2014; GOTARDO et al. 2018).

Figures 4 and 5 show the heights of maximum rainfall estimated using the IDF equations for durations of one to ten days and a return period of 10 years (Figure 4) and 100 years (Figure 5). It is observed that there is a marked spatial variation with the highest values in the North and West coast of the State and lowest values in the Medium Itajaí Valley.

Figure 4 – Maximum rainfall lasting from one to ten days and a return period of ten years in Santa Catarina.

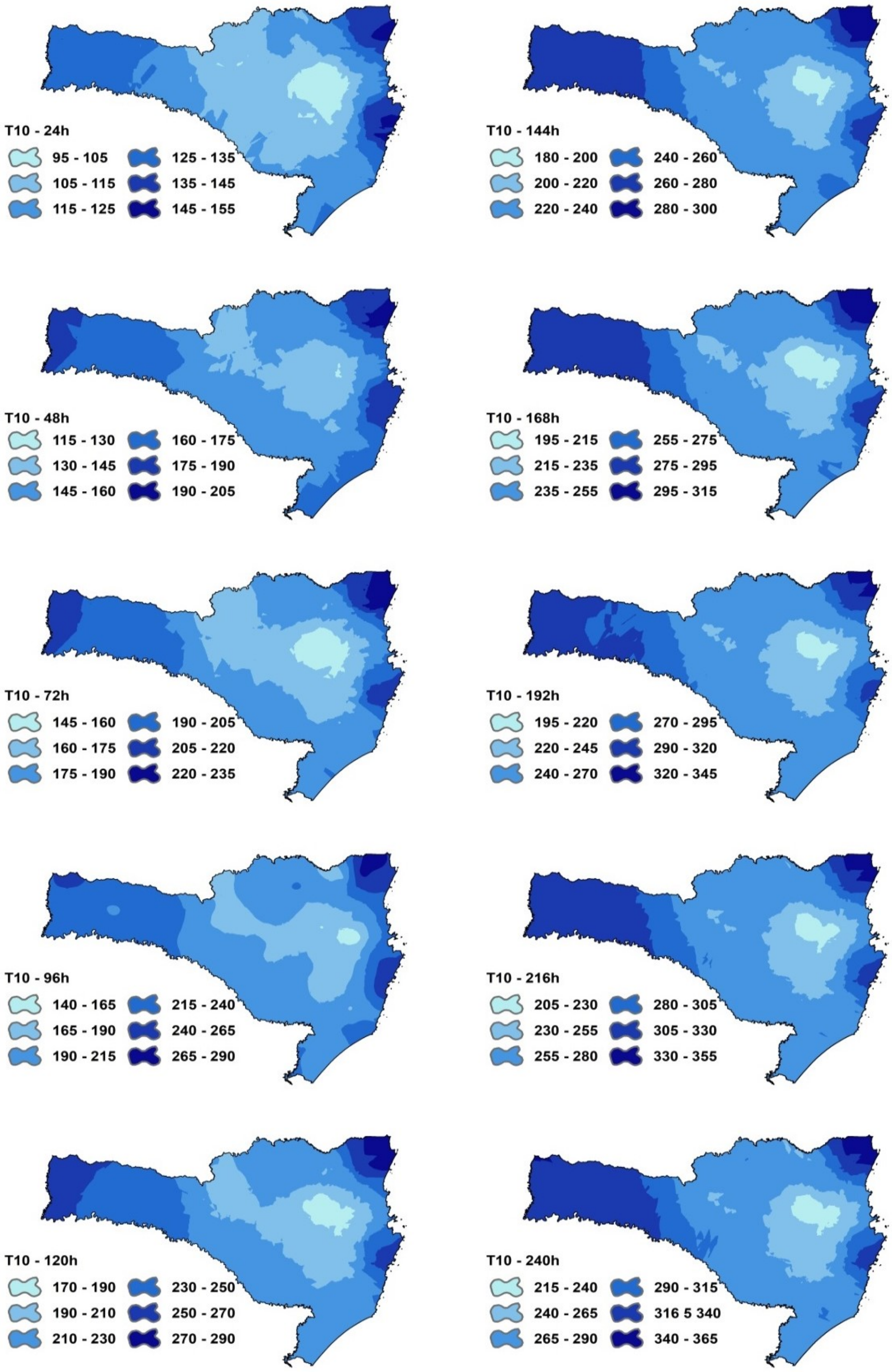
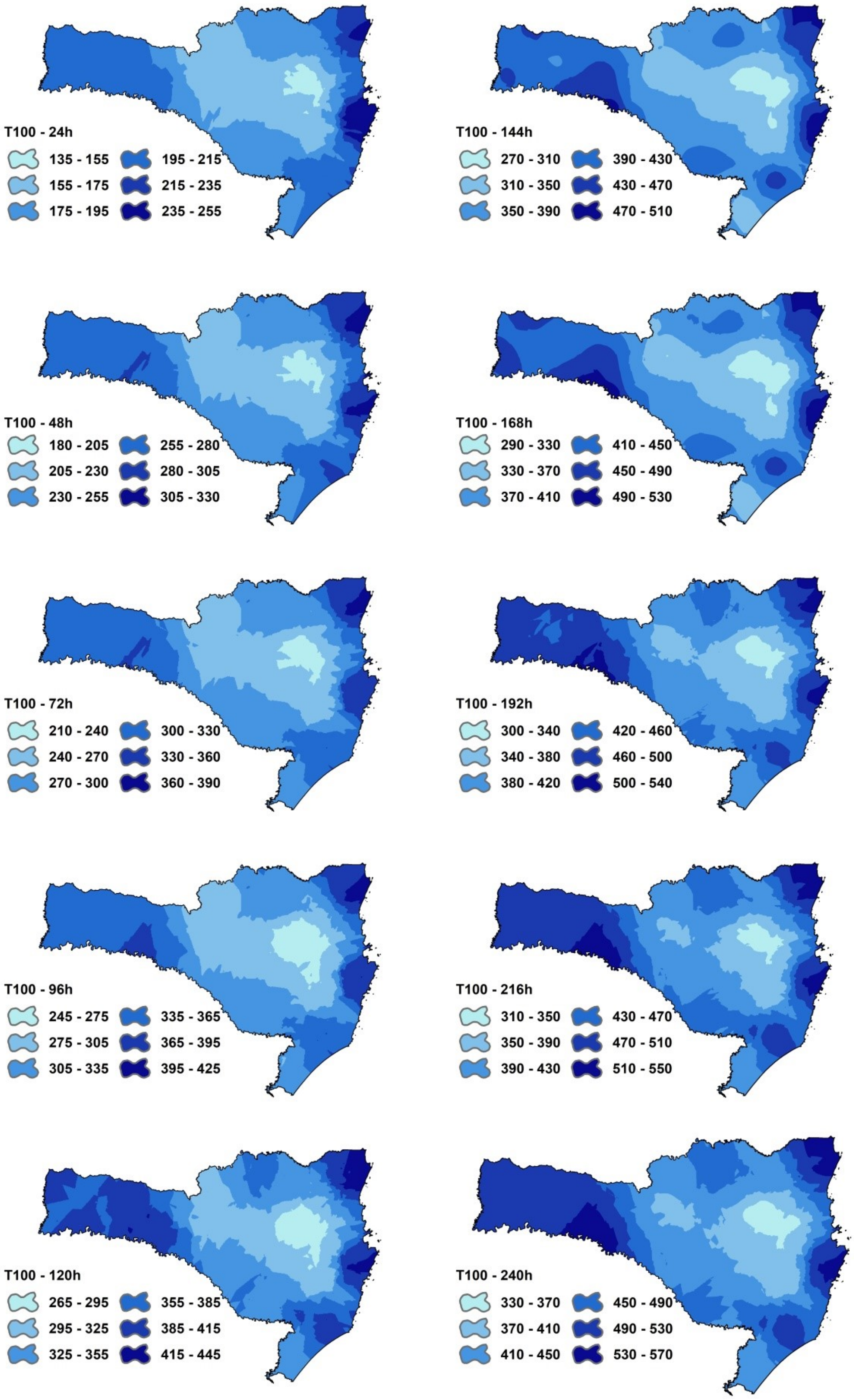


Figure 5 – Maximum rainfall lasting from one to ten days and a 100-year return period in Santa Catarina



4. FINAL CONSIDERATIONS

The adjusted IDF equations allow estimating the intensity of rainfall lasting from 24 to 240 hours (one to ten days) and a return period from 2 to 100 years for the various rainfall stations in Santa Catarina. The performance indices show that the equations have excellent estimation accuracy and their use corrects possible inconsistencies in the use of probability distributions for each duration.

It was possible to observe spatial variation of the coefficients, especially the coefficient K and b, which may be related to the orography of the region. Intense rainfall has higher values in the north and west coast of the state and lower values in the Middle Itajaí Valley.

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