EFFECT OF TEMPORAL DISCRETIZATION ON THE ESTIMATION OF ANNUAL MAXIMUM PRECIPITATION IN RIO GRANDE DO SUL

Larissa Zaira Rafael Rolim[1]; Tomás Antonio Quezado Duval[2]; Carlos Henrique Ribeiro Lima[3] & Dirceu Silveira Reis Junior[3]

Keywords – Precipitation extremes; Moving windows; Hershfield factor.

1. INTRODUCTION

Reliable estimation of design rainfall depends on the adequate characterization of precipitation extremes, since underestimations may affect the design of drainage systems, spillways, flood-protection structures, and intensity–duration–frequency curves (Papalexiou, Koutsoyiannis, Makropoulos, 2013; Merz *et al*., 2022). Because precipitation is continuous in time, its representation by accumulated totals in fixed windows may introduce temporal discretization errors. As a result, annual maxima obtained from fixed windows, here referred to as F-maxima, may underestimate maxima computed from moving windows, or S-maxima, for the same duration (Llabrés-Brustenga *et al*., 2020; Morbidelli *et al*., 2021).

This issue is particularly relevant in Brazil, where many historical rainfall series use the conventional pluviometric day, frequently defined from 09:00 to 09:00 h. When intense events cross this boundary, rainfall depth may be split between consecutive days, reducing the maximum extracted from fixed-window records. To reduce this temporal-discretization bias, the literature has commonly used a correction factor, here denoted as H, to convert F-maxima into estimates of 24-h S-maxima (Papalexiou, Dialynas, Grimaldi, 2016; Mazzoglio, Butera, Claps, 2024). However, H should not be treated as a universal constant. Classical work in the United States suggested $H \approx 1.13$ for converting fixed daily maxima into estimates of 24-h moving-window maxima (Hershfield, 1961), while more recent U.S. analyses found values near 1.14 (Papalexiou, Dialynas, Grimaldi, 2016). Applications in India suggested $H \approx 1.15$ (Harihara Ayyar, Tripathi, 1973), and studies in China reported a broader range of roughly 1.04–1.17 (Van Montfort, 1997). Additional studies proposed regime-dependent factors around 1.15–1.17, and analyses in Catalonia (Spain) found a mean near 1.125 for 24-h maxima (Llabrés-Brustenga *et al.*, 2020) but also showed that the factor varies with the fixed starting time, seasonality, and rainfall-event characteristics. Therefore, adopting a single deterministic value may mask relevant regional, seasonal, and operational differences.

In this context, this study evaluates the effect of temporal discretization on annual maximum precipitation in Rio Grande do Sul by comparing F-maxima and S-maxima. The analysis quantifies the bias using the factors H_μ and H_σ for selected durations, respectively, with emphasis on the operational 09:00 h starting time. The study also evaluates the sensitivity of H to the anchoring time of fixed windows for the 24-h duration and analyzes the seasonal and spatial variability of the correction factor.

2. METHODS

The study area comprises the state of Rio Grande do Sul, southern Brazil, a subtropical region affected by latitudinal, topographic, and orographic gradients in precipitation. Extreme rainfall in the state is often associated with organized systems, such as mesoscale convective systems and persistent frontal precipitation, which may affect the duration, timing, and clustering of rainfall events

1) Pesquisadora colaboradora, Universidade de Brasília. E-mail: larissazairarr@gmail.com
2) Mestrando, Universidade de Brasília. E-mail: tqduval@gmail.com
3) Professor Adjunto, Universidade de Brasília. E-mails: chrlima@unb.br; dirceureis@unb.br

(Nogueira, Machado, Reboita, 2024). Subdaily precipitation records from automatic stations were used (Almeida *et al*., 2025) and converted to regular temporal grids according to each station's original resolution. Years with more than 10% missing data were excluded, and remaining missing values were filled with the modal value of each series, which was 0 mm in the selected stations, following a procedure similar to Papalexiou, Dialynas, Grimaldi (2016). Only stations with at least six valid years of data were retained.

For each station, year, and duration, annual maximum precipitation were calculated using both S-maxima and F-maxima. The relationship between S-maxima and F-maxima was summarized using correction factors associated with the mean and dispersion. For each duration d, $H_\mu(d) = \mu_S(d)/\mu_F(d)$ and $H_\sigma(d) = \sigma_S(d)/\sigma_F(d)$ were calculated. Values of H_μ greater than 1 indicate that, on average, moving-window maxima are greater than fixed-window maxima, characterizing temporal discretization bias. Similarly, values of H_σ greater than 1 indicate greater dispersion of the maxima obtained from moving windows.

The sensitivity of the correction factor to fixed-window timing was assessed for the 24-h duration using anchors at 00:00, 09:00, 12:00, and 16:00 h. For each anchor, annual ratios were computed as H = S/F and summarized using the median H and the relative frequency of exact agreement, f(H = 1). Second, a seasonal analysis was performed for the 24-h duration using the operational 09:00 h anchor. In this step, monthly S-maxima and F-maxima were calculated, H was derived for each station-year-month, and the resulting values were grouped by climatological season. Third, the spatial pattern of seasonal H was explored by calculating station-level seasonal medians and interpolating these values using inverse distance weighting.

3. RESULTS

After the annual quality-control procedure, the final dataset comprised 108 rainfall stations in Rio Grande do Sul, each with at least six valid years of data. The comparison between F-maxima and S-maxima showed a systematic temporal discretization bias. This bias occurs because intense rainfall events may be split between consecutive fixed accumulation windows when their timing does not coincide with the fixed anchoring time, leading to an underestimation of the corresponding moving-window maximum (Papalexiou, Dialynas, Grimaldi, 2016).

Following the approach of Papalexiou, Dialynas, and Grimaldi (2016), annual S-maxima and F-maxima were first computed for each station, year, duration, and anchoring time. Individual annual correction ratios were then obtained as $H = S/F$. Regional mean-based correction factors were calculated as the ratio between the pooled mean of S-maxima and the pooled mean of F-maxima, rather than as the average of the individual annual ratios. Dispersion-based correction factors were calculated analogously using the corresponding standard deviations. The empirical distribution of annual ratios was additionally summarized using the median H and the relative frequency of exact agreement, $f(H = 1)$.

For the 24-h duration, the regional mean correction factor H_μ ranged from 1.123 to 1.133, depending on the anchoring time (Table 1). These values are close to the classical Hershfield factor of approximately 1.13. For the operational 09:00 h anchoring time, $H_\mu = 1.123$, while the median annual ratio $H = S/F$ was 1.068.

Table 1 – Correction factors for 24-h maxima according to the fixed-window anchoring time.

Ancora	Hμ	Hσ	Mediana H	f(H = 1)
00:00	1.125	1.157	1.078	0.195
09:00	1.123	1.084	1.068	0.209
12:00	1.133	1.107	1.102	0.171
16:00	1.131	1.099	1.084	0.203

This difference occurs because H_μ is based on pooled mean annual maxima, whereas the median Hrepresents the central value of the individual station-year ratios. Thus, H_μ is more affected by cases with large differences between S- and F- maxima. The relative frequency of exact agrément between S-maxima and F-maxima occurred in only 20.9% of the cases, indicating that the fixed window reproduced the moving-window annual maximum in about one fifth of the station-year records. The effect of the anchoring time was secondary compared with the overall discretization bias, but it was not negligible. The lowest H_μ was observed for 09:00 h, while the highest value occurred for 12:00 h. The dispersion factor H_σ was also greater than 1 for all anchoring times, ranging from 1.084 to 1.157, indicating that moving-window maxima are not only larger on average but may also be more variable than fixed-window maxima.

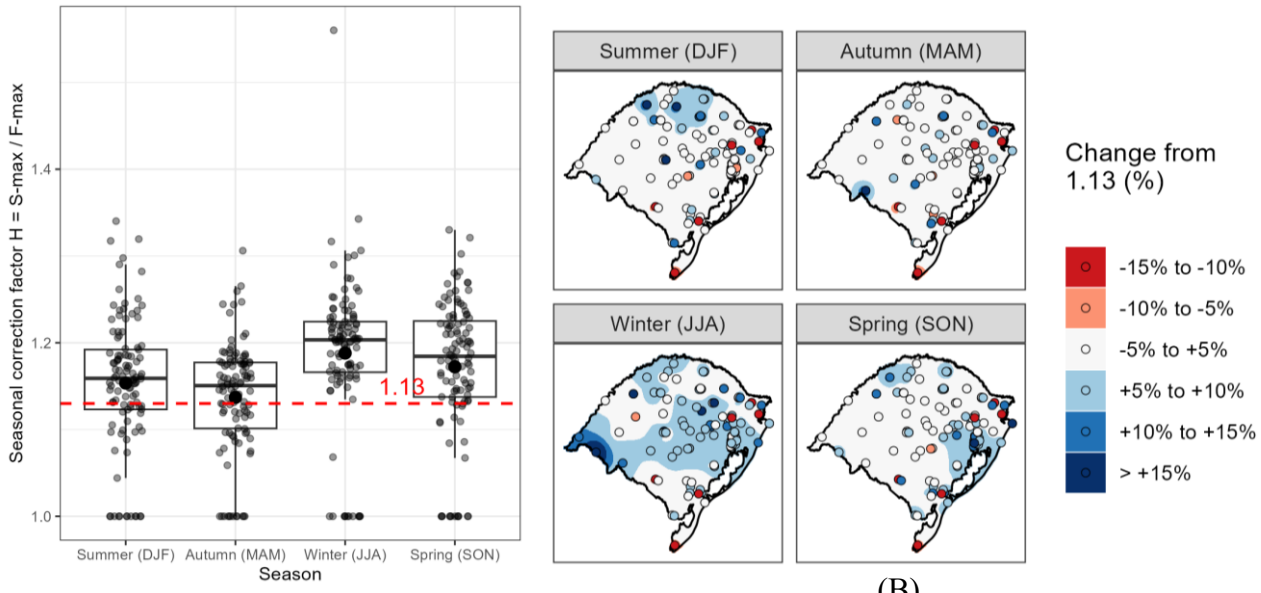


Figure 1. Seasonal and spatial patterns of the 24-h correction factor H=S-max/F-max for the 09:00 h anchoring time.

The seasonal analysis showed mean H values greater than 1 in all seasons, confirming the systematic effect of temporal discretization on 24-h maxima (Figure 1a). The highest mean values were observed in winter (H = 1.19) and spring (H = 1.17), while seasonal medians ranged from 1.03 to 1.08. This contrast between means and medians indicates a right-skewed distribution, in which many monthly maxima were well captured by the fixed window, but some events produced substantially larger moving-window accumulations. The proportion of exact agreement, f($H = 1$), ranged from 24.7% in winter to 33.1% in autumn, suggesting that the fixed window coincided less frequently with the moving-window maximum during winter. These cases correspond to events not split by the 09:00h boundary, a mechanism consistent with the interpretation of Llabrés-Brustenga et al. (2020). The higher winter and spring correction factors are mainly associated with a larger relative discrepancy between moving-window and fixed-window maxima, rather than with rainfall magnitude alone.

Spatially, the seasonal maps show the percentage anomaly of H relative to the classical Hershfield factor of 1.13 (Figure 1b). White areas indicate correction factors close to the classical value, blue areas indicate positive anomalies, and red areas indicate negative anomalies. Most of the state presented anomalies within ±5%, especially in autumn. However, winter showed a broader area with positive anomalies, particularly in western and southwestern Rio Grande do Sul, indicating that the correction factor frequently exceeds 1.13 during this season. These spatial patterns reinforce that the discretization bias is seasonally dependent and more pronounced in winter and spring.

4. CONCLUSION

The results show that fixed-window rainfall maxima systematically underestimate moving-window maxima in Rio Grande do Sul. For the 24-h duration and the operational 09:00 h anchor, the regional mean correction factor was $H_\mu = 1.123$, close to the classical Hershfield factor of 1.13. However, exact agreement between S-maxima and F-maxima occurred in only 20.9% of the cases, indicating that fixed windows underestimated the moving-window maximum in most station-year records. The bias persisted throughout the year, with stronger effects in winter and spring, when fixed windows missed a larger fraction of the moving-window 24-h maxima. Spatial deviations from the classical factor were also not uniform, with broader positive anomalies in winter. Therefore, although the Hershfield factor provides a reasonable first approximation, correction factors should not be treated as universal constants. Regional estimates that account for anchoring time and seasonal variability may provide more consistent support for design rainfall estimation and IDF curve development.

REFERENCES

ALMEIDA, C. D. N. et al. (2025). *"Avaliação de curvas Intensidade-Duração-Frequência (IDF) para o Rio Grande do Sul"*. Relatório técnico, João Pessoa/PB, 123 p. Available from: https://biblioteca.ana.gov.br/sophia_web/acervo/detalhe/111791.

HARIHARA AYYAR, P. S.; TRIPATHI, N. (1973). "*Relationship of the clockhour to 60-min and the observational day to 1440-min rainfall*". Indian Journal of Meteorology and Geophysics, v.24, p.279–282.

HERSHFIELD, D. M. (1961). *Rainfall frequency atlas of the United States*. Weather Bureau Technical Paper 40, U.S. Weather Bureau, Washington, D.C., 115 p.

LLABRÉS-BRUSTENGA, A.; RIUS, A.; RODRÍGUEZ-SOLÀ, R.; CASAS-CASTILLO, M. C. (2020). "*Influence of regional and seasonal rainfall patterns on the ratio between fixed and unrestricted measured intervals of rainfall amounts*". Theoretical and Applied Climatology, v.140, p.389–399.

MAZZOGLIO, P.; BUTERA, I.; CLAPS, P. (2024). "*Rainfall data augmentation in Northern Italy through daily extremes and the Hershfield factor*". Proceedings of IAHS, v.385, p.147–153.

MERZ, B.; BASSO, S.; FISCHER, S.; LUN, D.; BLÖSCHL, G.; MERZ, R.; SCHUMANN, A. (2022). "*Understanding heavy tails of flood peak distributions*". Water Resources Research, v.58, n.6, p.e2021WR030506.

MORBIDELLI, R.; SALTALIPPI, C.; DARI, J.; FLAMMINI, A. (2021). "*A review on rainfall data resolution and its role in the hydrological practice*". Water, v.13, n.8, p.1012.

NOGUEIRA, N. C. O.; MACHADO, P. H. G.; REBOITA, M. S. (2024). "*Climatological Study of Frontal Systems Acting in the South of Rio Grande do Sul and South of Minas Gerais between 2009 and 2021*". Brazilian Journal of Climatology, v.34, n.20, p.306–334.

PAPALEXIOU, S. M.; DIALYNAS, Y. G.; GRIMALDI, S. (2016). "*Hershfield factor revisited: Correcting annual maximum precipitation*". Journal of Hydrology, v.542, p.884–895.

PAPALEXIOU, S. M.; KOUTSOYIANNIS, D.; MAKROPOULOS, C. (2013). "*How extreme is extreme? An assessment of daily rainfall distribution tails*". Hydrology and Earth System Sciences, v.17, n.2, p.851–862.

VAN MONTFORT, M. A. J. (1997). "*Concomitants of the Hershfield factor*". Journal of Hydrology, v.194, p.357–365.

ACKNOWLEDGEMENTS

The authors acknowledge the National Water and Basic Sanitation Agency (ANA), under SEI Process No. 23106.017474/2024-93, and the Foundation for Scientific and Technological Enterprises (FINATEC) for the institutional, technical, and financial support that made the development of this work possible.