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ANALYSIS OF THE HISTORICAL SERIES OF MONTHLY PRECIPITATION IN THE CAMAQUÃ HYDROGRAPHIC BASIN, BRAZIL, BASED ON OBSERVED AND HIGH-RESOLUTION NUMERICAL DATA

Análise das séries históricas de precipitação na Bacia Hidrográfica do Camaquã, RS, Brasil, a partir de dados observados e numéricos de alta resolução

Análisis de las series históricas de precipitación en la Cuenca Hidrográfica del Camaquã, RS, Brasil, a partir de datos observados y numéricos de alta resolución

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Abstract: This study broaches the analysis of historical precipitation series in the Camaquã Hydrographic Basin (CHB), located in Rio Grande do Sul State, Brazil. The relevance of climate monitoring, especially in understanding variations in precipitation that impact local economic activities, such as agriculture and livestock, is highlighted. The main objective is to identify and fill gaps in historical precipitation data, using statistical methods such as multiple linear regression, and verify precipitation trends over 40 years (1981-2020). This work also correlates historical data with the ERA5 reanalysis, aiming to evaluate the accuracy of this model. The results show a reasonably homogeneous mean distribution across the months, with spring showing slightly higher values. The historical series

showed no significant trends. It was observed that ERA5 strongly correlates with the observed data, although it tends to overestimate precipitation, particularly in the warmer.
Keywords: ERA5. Precipitation Trends. Water Resources.

Resumo: O presente artigo aborda a análise das séries históricas de precipitação na Bacia Hidrográfica do Camaquã (BHC), localizada no Rio Grande do Sul, Brasil. O estudo destaca a relevância do monitoramento climático, especialmente para entender variações na precipitação, que impactam atividades econômicas locais, como a agricultura e a pecuária. O objetivo principal é identificar e preencher lacunas nos dados históricos de precipitação, utilizando métodos estatísticos, como a regressão linear múltipla, e verificar tendências de precipitação ao longo de 40 anos (1981-2020). A pesquisa também correlaciona dados históricos com a reanálise, visando avaliar a precisão desse modelo. Os resultados mostram uma distribuição média razoavelmente homogênea ao longo dos meses, com a primavera apresentando valores um poco maiores. A série histórica não apresentou tendências significativas. Observou-se que o ERA5 apresenta forte correlação com os dados observados, embora tenda a superestimar a precipitação principalmente nos meses mais quentes.
Palavras-chave: ERA5. Tendências de Precipitação. Recursos Hídricos.

Resumen: El presente artículo aborda el análisis de las series históricas de precipitación en la Cuenca Hidrográfica del Camaquã (BHC), ubicada en Rio Grande do Sul, Brasil. El estudio destaca la relevancia del monitoreo climático, especialmente para entender las variaciones en la precipitación, que impactan en actividades económicas locales como la agricultura y la ganadería. El objetivo principal es identificar y llenar las brechas en los datos históricos de precipitación, utilizando métodos estadísticos como la regresión lineal múltiple, y verificar las tendencias de precipitación a lo largo de 40 años (1981-2020). La investigación también correlaciona datos históricos con el reanálisis, con el fin de evaluar la precisión de este modelo. Los resultados indican una distribución media casi homogénea a lo largo de los meses, con valores ligeramente superiores en la primavera. La serie histórica no mostró tendencias significativas. Cabe destacar que el ERA5 presenta una fuerte correlación con los datos observados, aunque tiende a sobreestimar la precipitación, especialmente en los meses más cálidos.
Palabras clave: ERA5. Tendencias de Precipitación. Recursos Hídricos.

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1. INTRODUCTION

Due to its large territory and geographical position, Brazil is influenced by different air masses, having Equatorial, Tropical and Subtropical climates, which characterize the country's rainfall regime (Cavalcanti, 2016; Mendonça, Danni-Oliveira, 2017).

However, in certain regions, the precipitation regime has been altered, either due to climate variability or climate changes intensified by anthropogenic actions. Therefore, monitoring and recording meteorological/climatological data are fundamental for quantifying the hydrological cycle, which drives agricultural cycles and other human activities (Sarkar *et al.,* 2021).

To satisfactorily monitor climate variations, especially the precipitation regime, a consistent network of meteorological or pluviometric stations is necessary, covering a significant geographic area, with complete data series and significant period, preferably 30 years or more, that represent the historical series (INMET, 2024).

However, flaws in historical series are frequently found. These failures are due to damage to instruments, insufficient maintenance, failures in observation (of analog weather stations), recording, storage and transmission of data (Freitas *et al*., 2023; Santos *et al*., 2022; Oliveira; Sanches; Ferreira, 2021).

For data series to be used reliably, it is necessary to apply statistical techniques to fill the gaps. Such techniques can correlate data from neighboring stations with similar topographic and environmental conditions (Cardoso *et al.*, 2024). Alternatively, utilizing global meteorological reanalysis data platforms is another option. The reanalysis dataset combines a climate model with observational data from satellites and in situ sensors to create a consistent, long-term grid point record, enabling a better understanding of past and present climate, and allowing a current diagnosis of a region's climate (Aparecido *et al*., 2020; Cardoso *et al.,* 2024).

Spatialization and availability of meteorological data are essential factors in decision making. Due to the high cost and difficulty of obtaining precipitation measurements in difficult-to-access areas, numerical simulations and satellite data have been increasingly used in climatological and hydrological studies (Diaz; Pereira; Nóbrega, 2018; Sales *et al*., 2023; Tang *et al*., 2022).

Observing the existence and sign of trends in historical precipitation series, which may indicate periods of increased or reduced rainfall in river basins, is important for assessing possible climate variations. The identification of periods with trends contributes to decision-making, aiming to mitigate socioeconomic impacts in the region, especially in agriculture and water resources (Barros *et al.,* 2021; Rodrigues *et al.,* 2023).

Therefore, this study proposes to carry out a survey of historical series of monthly precipitation data on the Camaquã Hydrographic Basin (CHB), an important region in the State of Rio Grande do Sul (RS), in the extreme south of Brazil. The climatic conditions and geology, geomorphology and soil characteristics of the basin are suitable for livestock farming, rainfed and irrigated agriculture, forestry and mining, primary activities that boost the regional economy (Rosa; Silva; Silva, 2016).

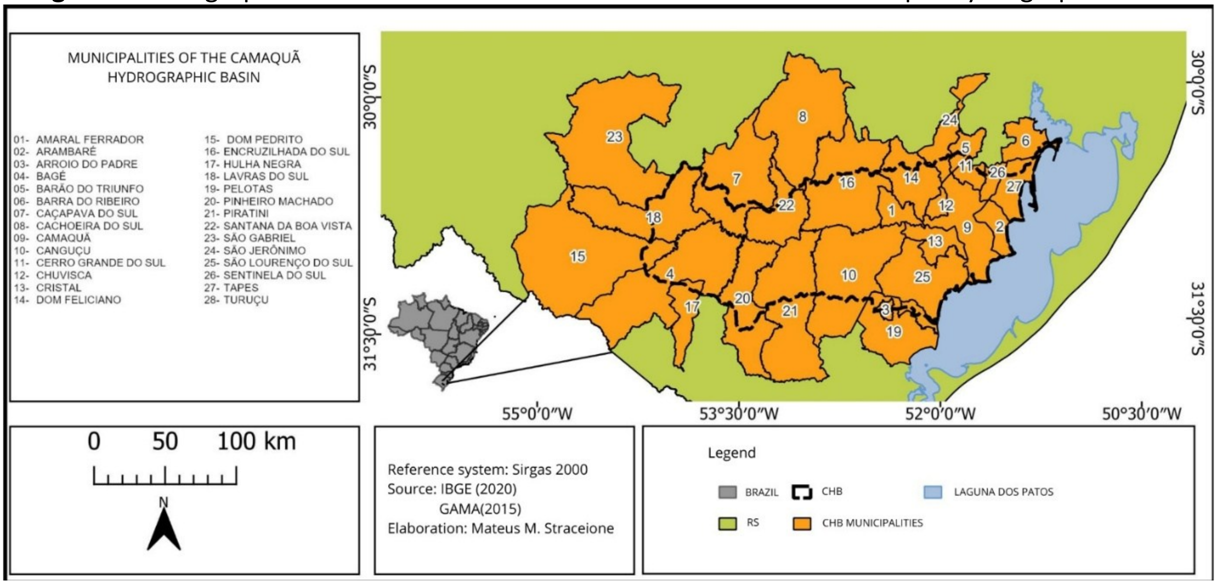
Furthermore, this work aims to identify and fill gaps in precipitation data, as highlighted in the Basin Plan report (Rosa; Silva; Silva, 2016). Precipitation trend analysis and correlation between historical series and reanalysis data from the ERA5 model will also be carried out.

2. METHODOLOGY

2.1. Area of the Study

The Camaquã Hydrographic Basin (CHB) is located in the central region of Rio Grande do Sul State, belonging to the coastal hydrographic zone, between 30º15' – 31º35'S and 51º00 – 54º15'W (Figure 1). The horizontal projection area of the basin is 21,657.1km², made up of 28 cities, and the main river has an approximate length of 430km (Rosa; Silva; Silva, 2016).

Figure 1 – Geographic location of the cities and delimitation of the Camaquã Hydrographic Basin.



Source: the authors

The climate in CHB, as in the state of RS in general, is characterized by being a region with good water availability, due to the insertion of climatologically active precipitating systems, such as frontal systems (Nogueira; Machado; Reboita, 2024), mesoscale convective systems (Piersante et al., 2021), cyclones (Reboita et al., 2021), South Atlantic subtropical anticyclone (Ferreira; Reboita, 2022), among others. The frequency and intensity of such systems are responsible for the distribution of precipitation, which ranges from 1200-1500 mm annually, presenting 7 to 9 days with rain/month, characterizing the climate of the region as humid subtropical (Rossato, 2020).

2.2. Data and Methods

The historical precipitation series from the 122 rainfall stations of CHB were obtained from Agência Nacional das Águas e Saneamento Básico (ANA), through the HidroWeb portal – Hydrological Information System, from 1981 to 2020. Afterwards, the possible rainfall stations for applying gap-filling techniques were verified.

To fill in gaps, the statistical technique of multiple linear regression was used, which consists of correlating neighboring rainfall stations. Historical series with more than 10% failures were discarded (Oliveira *et al.*, 2010; Coutinho *et al.*, 2018; Brubacher *et al.*, 2020; Cunha Júnior; Firmino, 2022). To select neighboring rainfall stations, the following criteria were considered: similar geographic characteristics, geographic distance between stations of up to 50km, similar altitude, Pearson correlation equal to or greater than 0.7 with two or more rainfall stations. Similar criteria were established in Barbosa *et al*., (2005) e Brubacher, *et al*., (2020).

Once the gaps were filled, it was necessary to apply the consistency technique, with the Double Mass being the most traditional method (WMO, 2018), which consists of comparing the series under analysis with a reference series, which must be homogeneous and representative of the same hydrological region (Collischonn; Dornelles, 2013; Bertoni; Tucci, 2020). If the series are consistent, the points should line up on a tilted straight line. Otherwise, there may be signs of errors or climatic changes in the series under analysis (Sanches; Verdum; Fisch, 2014).

The Thiessen Polygon Method, a spatial interpolation technique that enables the estimation of the average precipitation in a river basin based on data from rain gauges, was also applied here. The methodology consists of drawing the perpendicular bisectors of the segments that connect the rainfall stations, forming polygons that delineate the areas of influence of each station. The average precipitation in the basin is then calculated by the weighted average of the precipitation at the stations, using the polygon areas as weights (Bertoni; Tucci, 2020; Cardoso *et al*., 2024).

After adjustments and checking the consistency of the historical precipitation series, the normal average of monthly ~~of the~~ observed precipitation was calculated. Later, the Pearson Coefficient between the monthly normal of the observed data and those estimated by the ERA5 reanalysis (Cardoso *et al*., 2024) was assessed. In addition, the accuracy of ERA5 was evaluated by measuring the Root Mean Square Error (RMSE) (Jiang, *et al*. 2024).

ERA5 is the fifth generation of global climate atmospheric reanalysis from the *European Center for Medium Range Weather Forecasts* (ECMWF) (Hersbach *et al*., 2020; C3S, 2024), with 0.25° (31 km) horizontal resolution and 137 vertical levels, available on the Copernicus platform (https://cds.climate.copernicus.eu/cdsapp#!/home). To obtain the estimated precipitation, the area of interest was selected (Figure 1), and then the file was downloaded in NetCDF format and manipulated using the Grid Analysis and Display System (GrADS) software. The value of the variable was extracted to the grid point closest to the coordinates of each rainfall station, in order to obtain the monthly climatological average for each of the 12 stations (Table 1), and then the monthly climatological average (1981-2020) of the CHB was calculated (Appendix A).

Table 1 - Location of the CHB rain gauges stations.

Code	Rain Gauge Station	Latitude	Longitude	Altitude (m)	Latitude ERA5	Longitude ERA5	Municipality
3152002	Boqueirão	-31.2839	-52.0831	120	-31.25	-52.00	São Lourenço do Sul
3051016	Camaquã	-30.8658	-51.7958	65	-30.75	-51.75	Camaquã
3051004	Cerro Grande	-30.5939	-51.7567	120	-30.50	-51.75	Cerro Grande do Sul
3051017	Fazenda da Boa Vista	-30.7719	-51.6603	25	-30.75	-51.75	Camaquã
3053007	Lavras do Sul	-30.8175	-53.9014	300	-30.75	-54.00	Lavras do Sul
3153003	Paraíso	-31.2267	-53.9014	368	-31.25	-54.00	Bagé
3153006	Passo da Capela	-31.1342	-53.0539	120	-31.25	-53.00	Piratini
3052007	Passo da Guarda Ceee	-30.9064	-52.4619	60	-31.00	-52.50	Encruzilhada do Sul
3152011	Passo do Mendonça	-31.0006	-52.0492	40	-31.00	-52.00	Cristal
3151003	São Lourenço do Sul	-31.3675	-51.9867	2	-31.25	-52.00	São Lourenço do Sul
3154003	Torquato Severo	-31.0283	-54.1789	390	-31.00	-54.25	Dom Pedrito
3153017	Torrinhas	-31.3142	-53.4994	420	-31.00	-54.25	Pinheiro Machado

Source: the authors

For the historical series of observed precipitation data in the CHB the decadal (1981-1990; 1991-2000; 2001-2010; 2011-2020) and seasonal (December/January/February (DJF) - summer; March/April/May (MAM) - autumn; June/July/August (JJA) - winter; September/October/November (SON) - spring) trends were also verified. To identify periods of increase/decrease in the volume of precipitation on the Basin, the Mann-Kendall non-parametric statistical test was used (Kendall, 1975; Mann, 1945), which has been usually applied in similar studies (Barros *et al.*, 2021, Rodrigues *et al.*, 2023; Cardoso *et al.*, 2024). Likewise, to assess the magnitude of this increase/decrease in precipitation, the Sen Slope test (Sen, 1968) was used.

3. RESULTS

3.1. Analysis of the historical precipitation series

Only 14 of the 122 stations found in the CHB had failures of up to 10%, which were filled using the multiple linear regression technique (Table 2). Pacheca station (3151002) did not meet the criteria established to fill the gaps due to the low Pearson correlation coefficient (0.4) and was excluded from the analysis. Porto Tarumã (3052010) was another station excluded from the analysis, as it presented discontinuity in the consistency graph of the homogeneity of the completed data, which may be related to data completion errors or climate change. Finally, this study analyzed 12 rainfall stations distributed throughout the CHB, which showed homogeneity in the precipitation data, with a regression coefficient greater than 0.99.

Table 2- Rain gauge stations with data gaps and those used for filling, based on the statistical technique of multiple linear regression.

ID	Rain Gauge Station with Fault	Positions used in Multiple Linear Regression
1	Boqueirão	São Lourenço do Sul; Pacheca; Passo do Mendonça
2	Camaquã	Pacheca; Fazenda Boa Vista; Passo do Mendonça.
3	Cerro Grande	Fazenda Boa Vista; Camaquã; Passo do Mendonça
4	Fazenda da Boa Vista	Camaquã; Cerro Grande; Pacheca
5	Lavras do Sul	Paraíso; Torquato Severo.
6	Paraíso	Torrinhas; Torquato Severo
7	Passo da Capela	Torrinhas; Porto Tarumã; Canguçu.
8	Passo da Guarda Ceee	Passo da Capela; Passo do Mendonça
9	Passo do Mendonça	Fazenda Boa Vista; Passo da Guarda Ceee; Pacheca.
10	São Lourenço do Sul	Pacheca; Boqueirão; Passo do Mendonça.
11	Torquato Severo	Paraíso; Lavras do Sul.
12	Torrinhas	Passo da Capela; Paraíso.

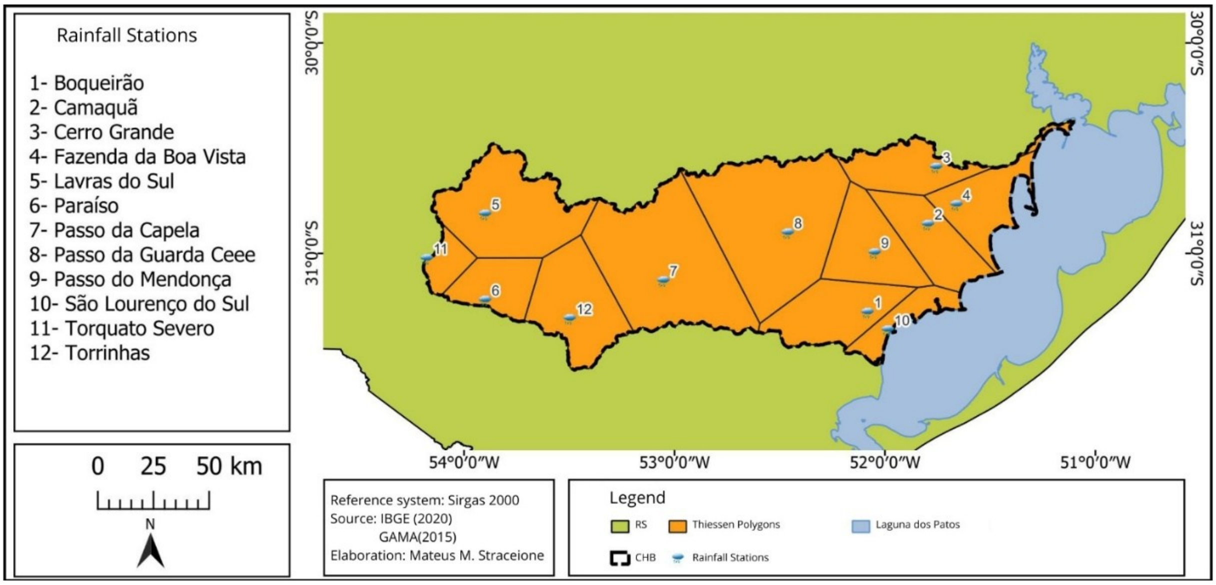
Source: the authors

The average distribution of precipitation based on the Thiessen polygon method (Figure 2) can be seen in Table 3, based on the area of influence of each rainfall station. The rainfall stations in the Baixo Camaquã region (cities of São Lourenço do Sul, Cristal, Camaquã and Cerro Grande do Sul) showed higher rainfall, on average exceeding 1500mm, in the Médio Camaquã region (cities of Piratini and Encruzilhada do Sul) the thresholds were between

1300mm-1400mm and in the Alto Camaquã region (cities of Bagé, Lavras do Sul, Pinheiro Machado and Dom Pedrito) the average accumulations were around 1450mm. Similar results were also verified in Rossato (2020) for RS.

When the climatological average annual precipitation in the basin was evaluated, according to the area of influence of each station, a volume of 1464.8mm was observed. Silva and Campos (2011), when evaluating the distribution of precipitation in RS from 1977 to 2006, in the vicinity of the CHB, they identified annual values around 1500mm. More recently, Cardoso *et al.* (2024) in the Mirim-São Gonçalo/RS transboundary river basin, south of the CHB, identified an average annual precipitation of 1394.69mm in the period 1981-2020.

Figure 2 - Thiessen polygons and the location of the 12 rainfall stations in the CHB.



Source: the authors

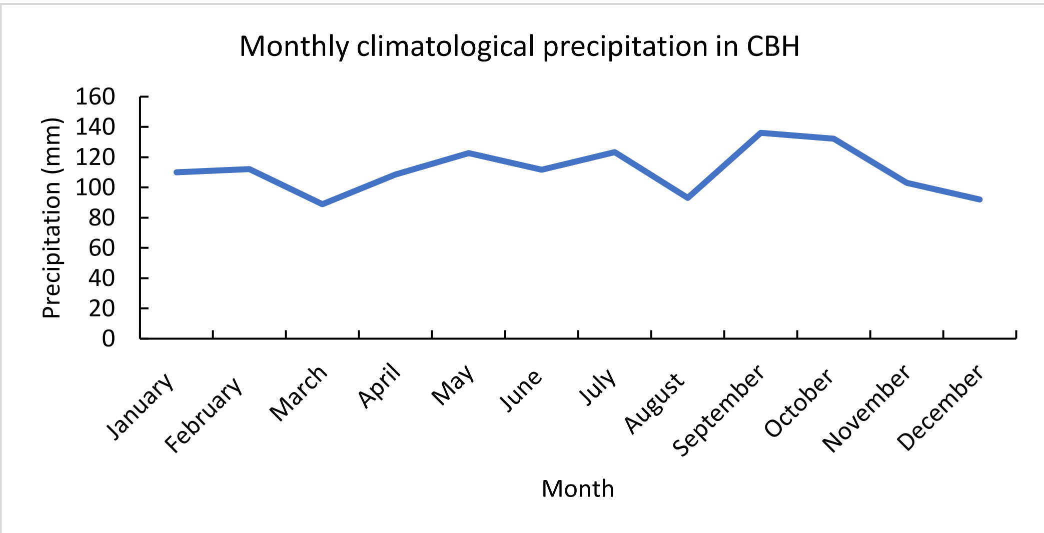
Table 3- Rainfall stations, area of influence and annual precipitation.

ID	rain gauge station	Code	Area (Km^2)	Precipitation (mm)
1	Boqueirão	3152002	1542	1629.4
2	Camaquã	3051016	1357	1477.6
3	Cerro Grande	3051004	1250	1604.3
4	Fazenda da Boa Vista	3051017	1260	1526.7
5	Lavras do Sul	3053007	2649	1495.7
6	Paraíso	3153003	983	1375.2
7	Passo da Capela	3153006	3983	1429.7
8	Passo da Guarda Ceee	3052007	4046	1323.1
9	Passo do Mendonça	3152011	1503	1486.2
10	São Lourenço do Sul	3151003	651	1574.4
11	Torquato Severo	3154003	450	1602.4
12	Torrinhas	3153017	1896	1481.4

Source: the authors

The monthly climatological normal precipitation in the basin (Figure 3) showed a good reasonably homogeneous distribution (between 100mm and 140mm) throughout the months. The lowest averages were found in March, August, November and December, while the highest were found in February, July, September and October. Future studies on local circulation over the basin may explain this monthly variability, given that the precipitation systems that act in the rainiest months also act in the less rainy months.

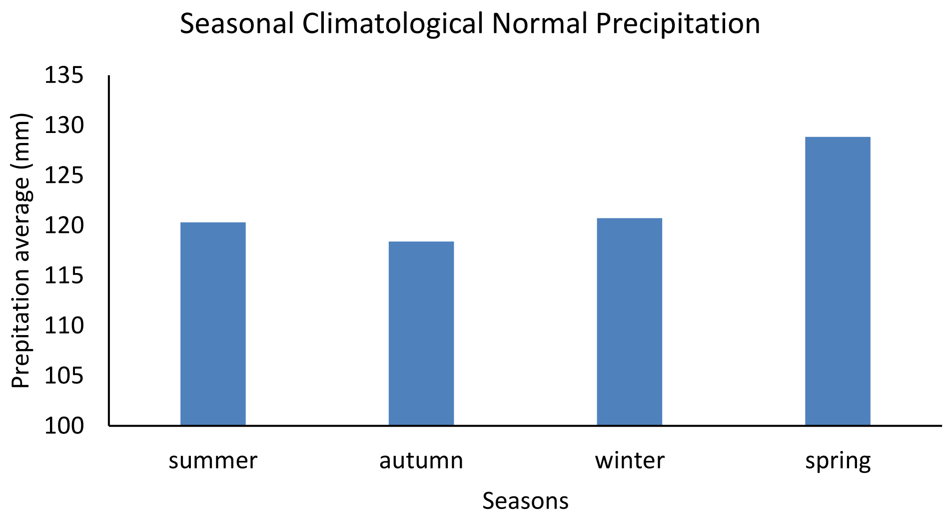
Figure 3 - Monthly climatological normal precipitation (1981- 2020) in CHB.



Source: the authors

Seasonally, that is, according to the seasons of the year over this 40-year period (Figure 4), autumn has the lowest average monthly precipitation (118 mm), while spring has the highest, 129 mm. These values indicate good annual distribution in the basin, which is due to it being located in mid-latitudes and, therefore, being influenced by tropical and extratropical precipitation systems (Gonçalves; Back, 2018). However, the higher value in spring can be explained by the greater influence of the El Niño phenomenon on precipitation in the state during this season (Grimm; Ferraz; Gomes, 1998; Arruda; Centeno; Nunes, 2025).

Figure 4 – Seasonal climatological normal precipitation, Summer, Autumn, Winter, Spring, in CHB, period 1981-2020.



Source: the authors

3.2. Precipitation trends analysis

According to the Sen Slope method, in summer, autumn and winter the trend was negative, showing a reduction in the magnitude of precipitation between -0.075 to -0.152mm/quarter, while in spring there was a positive trend of 0.046 mm/quarter (Figure 4). However, tests showed that the trends were not significant in any of the seasons.

Table 4 - Linear trends, Mann-Kendall and Sen Slope test, with a significance level of 5%, applied to each season in the CHB, for 1981-2020.

Season of the year	Equation	Linear Trend	Mann-Kendall (p-value)	Sen Slope (mm/quarter)
SUMMER	y = -0.0015x + 179.18	Negative	0.35	-0.156
AUTUMN	y = -0.0012x + 166.54	Negative	0.48	-0.123
WINTER	y = -0.0011x + 165.53	Negative	0.66	-0.075
SPRING	y = 0.0014x + 78.204	Positive	0.75	0.046

Source: the authors

Table 5 presents information on trends over the decades: 1981-1990 and 2001-2010, which showed negative trends, with a Sen Slope magnitude of -10.2mm/decade and -74.5mm/decade, respectively, and 1991-2000 and 2011-2020 which showed positive trends, with a Sen Slope magnitude of 7.9 mm/decade and 29.6 mm/decade, respectively. However, in all decades these trends were non-significant.

Scaglioni, Fernandes and Nunes (2022) in an analysis of precipitation excess/deficit events in the CHB between 1991-2020, found that in the period 2001-2010 there was a lower number of excess events recorded (8, with precipition rate above 133mm/day) when compared to the others periods. Scaglioni *et al.* (2023) observed six rainfall stations distributed throughout the CHB, and found that practically all of them recorded non-significant negative trends in the period 1991-2020. Therefore, a certain relationship is observed between the behavior of the average precipitation trend and the trend of extreme events in the CHB.

Table 5 - Decadal average precipitation, linear trends, Mann-Kendall and Sen Slope test, with a significance level of 5%, applied to each season in the CHB, for 1981-2020.

Decades	Average precipitation (mm/decade)	Equation	Linear Trend	Mann-Kendall (p-value)	Sen Slope (mm/decade)
1981-1990	1453.3	y = -25.838x + 1600.9	Negative	1.00	-10.2
1991-2000	1487.6	y = 2.1867x + 1475.6	Positive	0.86	7.9
2001-2010	1448.4	y = -87.312x + 1928.6	Negative	0.07	-74.5
2011-2020	1464.5	y = 13.597x + 1389.7	Positive	0.59	29.6

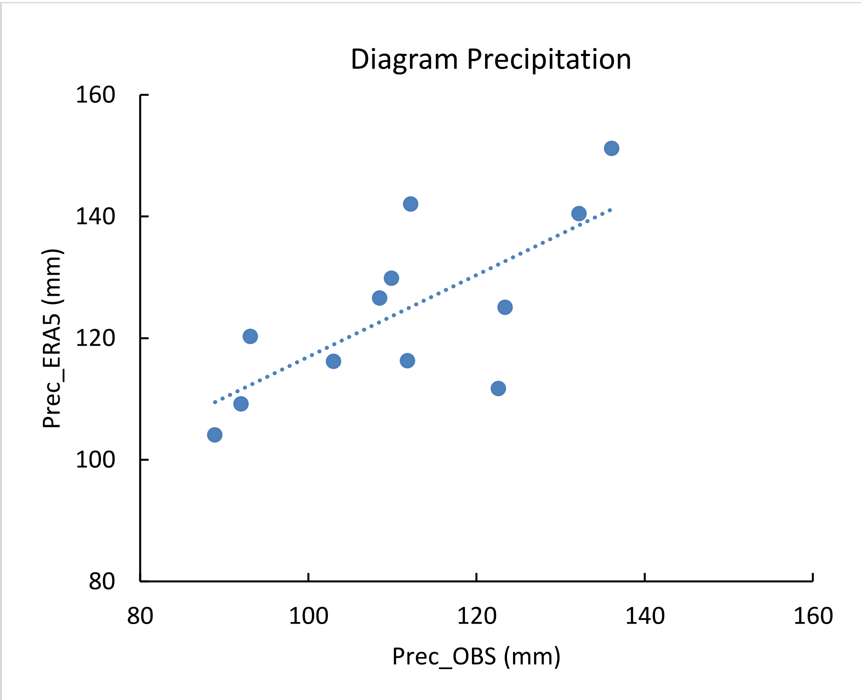
Source: the authors

3.3. Correlation between historical series of observed and estimated precipitation

The relationship between the monthly climatological normals of precipitation observed at the rain gauge stations and the normal precipitation estimated by ERA5 (Figure 5), presented a linear correlation coefficient of 0.73, which according to Mukaka's classification (2012) represents a strong correlation between the observed and estimated data. Lavers *et al.* (2022) compared the estimated data from ERA5 with daily precipitation data observed, at 5,637 stations distributed worldwide, from 2001 to 2020 and the results showed that the best correlations (above 0.8) between the observed data and the estimates are located in the extratropical region, which corroborates the results found here - although it should be noted that monthly, not daily, data were used here.

Cardoso *et al.* (2024), in an analysis of 15 rainfall stations located in the Mirim - São Gonçalo river basin, south of the CHB, in an assessment of monthly precipitation, 1981-2020, from ERA5, found a coefficient equal to or above 0.8 in 10 out of 12 months, with the correlation in the months of February, April and July classified as very strong.

Figure 5 – Observed (Prec_OBS) and ERA5 (Prec_ERA5) monthly climatological precipitation, for 1981-2020, CHB.



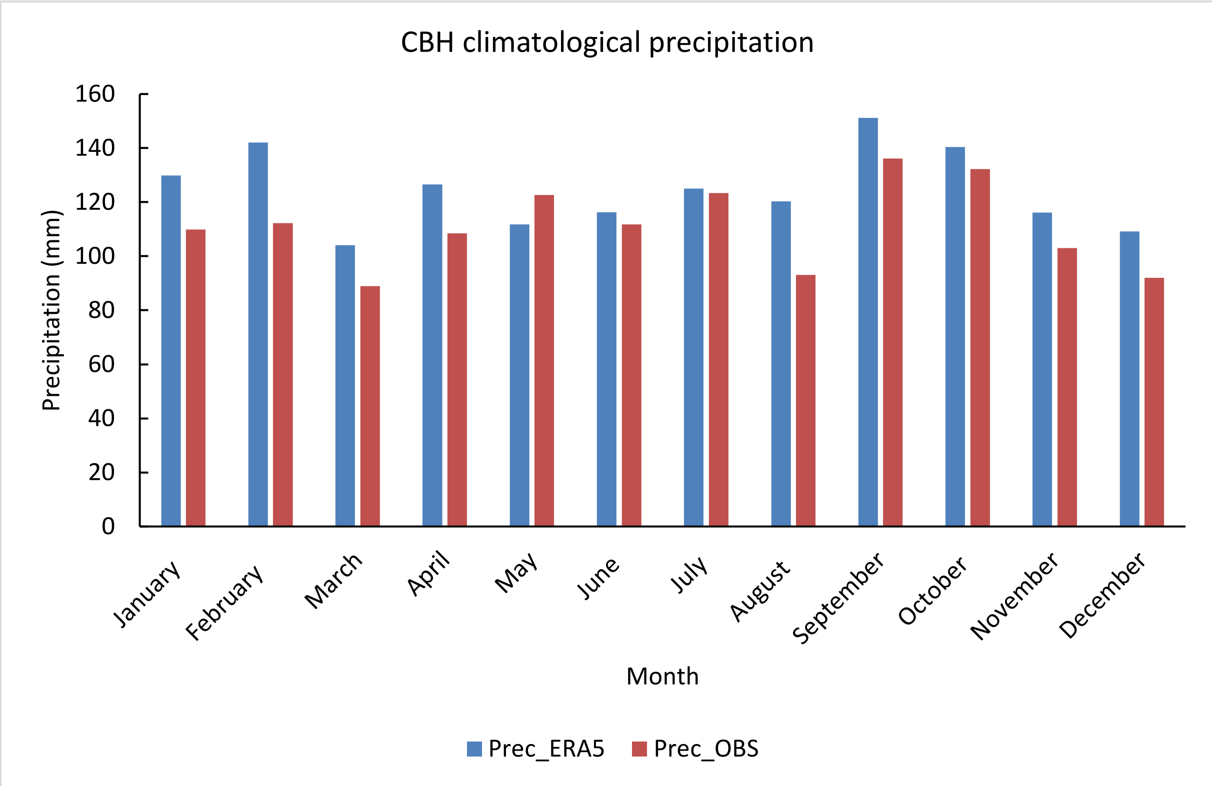
Source: the authors

Overestimation of normal monthly data was observed, except for May (Figure 6). The largest differences were found in February and August (almost 30mm) and the smallest differences were found in June, July and October (less than 8mm). Differences are highlighted in the seasonal analysis. In summer and spring the difference between estimated and observed data was 22.3mm and 12.2mm, and in autumn and winter 7.5mm and 11.1mm, respectively. Therefore, it can be concluded that the ERA5 model overestimated normal monthly precipitation, especially in the warmer months.

According to Lavers *et al.* (2022), this seasonal variation in performance is justified, as in the winter months the reanalysis model is able to represent the atmospheric environment more accurately, while in warmer months the model presents more difficulties in adequately representing the amounts of precipitation due to to the convective activities most present in this season.

Here, an RMSE of 17.06mm was observed between the observed and estimated monthly climatological averages, for 1981-2020, a satisfactory result when compared with other research (Cardoso *et al*., 2024; Jiang *et al.,* 2024, for example). ERA5, as a model data, may present some representativeness error, because it is spatially distributed and represents average values in a given area. Features of the terrain, urban areas, vegetation, and other features may not be well simulated in the model, causing changes in atmospheric circulation and, consequently, changes in the estimates of meteorological variables, resulting in considerable differences from reality (Haiden *et al*., 2018; Lavers *et al*., 2022).

Figure 6 – Observed (Prec_OBS) and ERA5 (Prec_ERA5) monthly climatological precipitation.



Source: the authors

4. CONCLUSIONS

In this work, historical monthly precipitation series from rainfall stations in the Camaquã Hydrographic Basin (CHB), in southern Brazil, were analyzed for 1981-2020. After filling in gaps and obtaining the average behavior of the basin, the trend of the historical series was analyzed. Data analysis revealed the consistency of historical precipitation series and temporal distribution over the study area.

The accuracy of the ERA5 reanalysis in estimating the monthly climatological normal (1981 to 2020) was verified using Pearson's linear correlation. A value of 0.72 was found, that is, a strong correlation, between the model data and data from the rainfall stations. The estimated monthly climatological normal precipitation overestimated the observed values, except in May. The months where the greatest differences were observed were in February and August (almost 30 mm) and the smallest differences were in the months of June, July and

October (less than 8 mm), with the smallest differences being recorded in winter and autumn. Therefore, ERA5 performed better in winter and autumn.

Linear trend analysis showed different behavior over 1981-2020. However, no statistical significance was observed. In the decades 1981 - 1990 and 2001 - 2010 the trend was negative, while in the periods 1991 - 2000 and 2011 - 2020 it was positive. In the seasonal analysis, a positive trend was found only in spring.

Briefly, we can conclude that the average precipitation over the CHB presents little monthly variation and non-significant trends. The ERA5 reanalyses showed satisfactory performance in describing the expected behavior of monthly precipitation in the basin. The results obtained may support the execution of actions related to the management of water resources and adaptation to climate change in the region.

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Appendix A - Monthly climatological precipitation (mm) estimated by the ERA5 reanalysis model at rainfall stations distributed in the CHB, and the monthly climatological average in the BHC, in the period 1981-2020

CODE	STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
3052007	PASSO DA GUARDA CEEE	112.7	120.0	94.5	118.2	99.3	102.1	117.8	113.1	142.8	131.5	102.9	97.7	1353.3
3152002	BOQUEIRÃO	110.6	129.1	99.9	114.3	108.5	104.5	129.1	116.5	143.8	126.7	105.0	100.1	1388.8
3051017	FAZENDA DA BOA VISTA	144.9	166.2	115.2	124.7	114.8	119.5	133.2	133.6	168.9	155.3	128.5	121.2	1626.3
3051004	CERRO GRANDE	153.2	170.5	121.7	134.7	120.3	125.8	136.4	141.6	179.5	161.2	132.9	131.6	1709.9
3153003	PARAÍSO	137.0	140.6	103.6	134.1	112.7	124.9	118.9	114.2	141.4	135.3	119.6	107.5	1490.4
3153017	TORRINHAS	138.7	140.2	101.9	133.1	113.4	123.8	121.6	115.9	141.9	133.5	116.0	106.6	1487.3
3153006	PASSO DA CAPELA	123.4	127.6	95.1	123.1	105.2	108.7	115.6	110.9	140.8	127.5	106.6	101.1	1386.0
3154003	TORQUATO SEVERO	135.8	145.1	104.0	141.3	117.8	129.1	121.9	114.7	144.6	145.9	121.0	110.2	1532.0
3152011	PASSO DO MENDONÇA	109.9	121.1	93.3	105.7	98.5	96.4	112.8	109.6	137.7	124.2	102.4	94.1	1306.1
3053007	LAVRAS DO SUL	135.8	148.3	113.8	150.4	126.2	136.2	130.4	122.6	159.7	161.8	125.2	118.4	1515.5
3051016	CAMAQUÃ	144.9	166.2	115.2	124.7	114.8	119.5	133.2	133.6	168.9	155.3	128.5	121.2	1626.3
3151003	SÃO LOURENÇO DO SUL	110.6	129.1	99.9	114.3	108.5	104.5	129.1	116.5	143.8	126.7	105.0	100.1	1388.8
BASIN AVERAGE_estimated data ERA5		**129.8**	**142.0**	**104.1**	**126.6**	**111.7**	**116.2**	**125.1**	**120.3**	**151.2**	**140.5**	**116.2**	**109.2**	**1492.9**

Appendix B - Monthly climatological precipitation (mm) observed at rainfall stations distributed in BHC, and the monthly climatological average in CHB, in the period 1981-2020

CODE	STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
3052007	PASSO DA GUARDA CEEE	118.2	107.8	88.9	111.6	116.2	108.1	130.7	100.6	132.9	120.9	92.0	95.3	1323.1
3152002	BOQUEIRÃO	132.7	164.9	122.1	130.8	139.0	120.4	150.0	125.2	159.6	152.3	115.2	117.1	1629.4
3051017	FAZENDA DA BOA VISTA	129.3	135.8	107.4	114.5	118.5	127.8	150,00	113.9	158.6	139.3	117.7	113.8	1526.7
3051004	CERRO GRANDE	142.5	143.2	116.5	117.4	136.8	131.1	157.2	112.1	154.2	151.9	119.9	121.5	1604.3
3153003	PARAÍSO	118.9	113.6	95.3	121.4	125.8	119.9	115.1	96.5	119.4	144.3	111.1	93.9	1375.2
3153017	TORRINHAS	120.5	128.2	109.8	135.3	134.5	119.2	127.7	106.2	138.2	135.0	119.9	106.9	1481.4
3153006	PASSO DA CAPELA	123.1	131.2	99.0	124.2	126.6	120.5	128.1	104.8	126.8	142.4	102.6	100.3	1429.7
3154003	TORQUATO SEVERO	144.9	140.9	123.3	157.5	145.3	126.7	137.4	108.7	145.1	146.2	117.9	108.5	1602.4
3152011	PASSO DO MENDONÇA	130.6	140.0	103.5	119.1	119.5	128.4	138.9	109.0	144.1	145.7	102.2	105.1	1486.2
3053007	LAVRAS DO SUL	128.5	127.0	114.1	140.6	128.7	119.8	132.6	100.6	136.4	149.8	114.7	102.9	1495.7
3051016	CAMAQUÃ	123.0	135.6	104.9	117.5	121.4	122.5	143.7	109.0	152.5	130.0	103.7	113.7	1477.6
3151003	SÃO LOURENÇO DO SUL	120.8	155.8	115.5	126.8	135.9	123.6	147.7	119.1	155.9	144.3	113.2	115.7	1574.4
BASIN AVERAGE_observed data		**127.8**	**135.3**	**108.4**	**126.4**	**129.0**	**122.4**	**138.3**	**108.8**	**143.6**	**141.8**	**110.8**	**107.9**	**1500.5**