

Supplementary Material

Climate types in Brazil

1. Tropical Zone (A), consisting of four classifications
 - Equatorial climate or no dry season (Af): found mainly in the Amazon region and part of Roraima, characterized by high temperatures and abundant rainfall throughout the year;
 - Monsoon (Am): covers part of the northern region of the country;
 - With dry winter (Aw): found in central and northeastern Brazil, with two distinct seasons: a wet season during the summer, with frequent rainfall, and a dry season during the winter, with little precipitation;
 - With dry summer: covers the Northeast region of Brazil and is characterized by low rainfall in the summer.
2. Dry Zone (B), displays only one class:
 - Semi-arid (Bs), with the subclassification of low latitude and altitude (bsh), present in the Northeastern region of Brazil, with scarce and irregular rainfall, usually concentrated in few months of the year. Temperatures are high and areas are prone to drought.
3. Wet subtropical zone (C), composed of three classifications:
 - Oceanic climate without dry season (Cf), which covers most part of the southern region of the country and presents two subclasses, with hot summer (Cfa) and with temperate summer (Cfb);
 - With dry winter (Cw), which is present in elevated areas, such as the southern Amazon region and parts of the southeast region, with more pronounced seasonal variations in temperature and precipitation. This class has three subclasses, with dry winter and hot summer (Cwa), with dry winter and temperate summer (Cwb) and with dry winter and short and weak summer (Cwc);
 - With dry summer (Cs), present in the Northeast region of Brazil and exhibiting low rainfall in the summer, with rainfall concentrated in one season of the year. This class has two subclasses, with dry and hot summer (Csa) and with hot and temperate summer (Csb).

Total precipitation and simple daily intensity index

The map in Figure 3A shows the places with the highest and lowest rainfall accumulations, which portrays the climatology of each region of Brazil. The North region has the highest annual TOTPR accumulations, the only area with states that exceed the 2,700 mm/year mark, which are: Amazonas, Pará and Amapá—with emphasis on Amazonas where values above 2,100 mm/year were recorded in almost all its territory. These results may be related to the presence of the Amazon forest, considered the largest tropical forest in the world, which thus receives large volumes of rain (Portella et al., 2022). The Northeast region has

the lowest annual accumulated rainfall, most evident in the zone that encompasses the northeastern hinterland, with values that vary mainly between 300 and 1,200 mm/year. The other regions have intermediate values, ranging between 1,200 and 2,100 mm/year. Among the three remaining regions, the South has the highest annual accumulations.

Figure 3B indicates the Sen slope (SS), a variable indicative of trend for TOTPR in the period analyzed in this study. Its values suggest that there is a positive trend, which means an increase in accumulated annual rainfall in a large part of the North region, and a negative trend in part of the Midwest region. The Southeast region presents a downward trend in rainfall, especially in the center-north of the state of São Paulo and on the border with Minas Gerais, while there is a positive trend on the coasts of São Paulo and Rio de Janeiro. In the Northeast and South regions there are no significant signs of trend in most of the areas.

The SDII in Figure 3C, which calculates the average rainfall on rainy days, shows that the regions with the lowest and highest daily rainfall are the Northeast and South, respectively. The other regions of the country predominantly present average rainfall between 8 and 12 mm/day, with the exception of the center-north portion of the state of Amapá, which receives a rainfall volume that exceeds 12 mm/day. The Northeast is in a range of values of large variation, starting between 4 and 6 mm/day (the lowest average in the country) in an area that goes from eastern Bahia to Paraíba, and reaching 12 mm/day in other territorial parts, such as southwestern Bahia, northern Maranhão and southeastern/coastal Ceará. The South of the country, on the other hand, is characterized by rainfall above 12 mm/day in more than half of its territory, even exceeding 16 mm/day in the state of Rio Grande do Sul. It is notable that although the TOTPR and DPR indexes showed higher accumulated rainfall and a large number of days with rain, respectively, for the North Region, the SDII is still higher in the South region. This indicates that the South has large intensity in its precipitation, in other words, a larger volume of concentrated water on the same day with rains.

The SS corresponding to SDII is shown in Figure 3D and demonstrates significant trends in most of the country, both positive and negative in each of the Brazilian states. The states with a positive trend in their daily rainfall intensities are mainly those in the North region, as well as Rio de Janeiro and Espírito Santo in the Southeast, and Paraná and Rio Grande do Sul in the South region. São Paulo, on the other hand, is the state that shows most signs of reduced rainfall intensity. The Northeast and Midwest have both areas with a positive and negative trend, although areas with a negative trend are higher.

Days with annual precipitation

The map in Figure 1SA represents the DPR values, which depict the total annual days with rain (considering a rainy day with precipitation ≥ 1 mm). The results are similar to those obtained for TOTPR, with the North region having the highest number of days with rain and the

Northeast region with the lowest number. However, it is worth mentioning the number of days considered rainy in each of these places and the differentiation presented between them. In the North region, more specifically in the state of Amazonas, practically all of its territory has rainfall in at least 150 days (five months) of the year, with places that exceed the mark of 270 days (nine months). This represents more than 74% of the total number of days in a year. In the Northeast, there is a larger territorial dispersion, with areas with more than 150 days of rain a year, such as in the north of the state of Maranhão and in a portion that goes from Bahia to Paraíba, and at the same time areas with less than 90 days of rain a year (three months), such as the territorial strip that goes from Ceará/Rio Grande do Norte to the north of Minas Gerais. In the rest of the Brazilian territory, the number of days with rain is more concentrated in the range of values between 90 and 210 days.

Figure 1SB depicts the SS obtained by the DPR series. The results show that in almost all Brazilian states, with the exception of some states in the Northeast, there are areas with positive and negative trends, simultaneously. Even so, there is a larger area with a positive trend in the North and a larger area with a negative trend in the Midwest. In the Southeast and South, there is also a larger part of places with a downward trend, especially in the states of Minas Gerais and Espírito Santo, as well as in Paraná, respectively. In the other states of these two regions, there are places with a tendency to increase days with rainfall, being more significant on their coasts where most metropolitan regions are found.

Maximum precipitation in five days

Maximum precipitation in five days (MAXPR-5D) verified the maximum accumulated rainfall in five consecutive days for the historical series studied. Figure 4C shows that maximum rainfall of five days was lower in almost the entire Northeast, as well as in the Amazon in the North region, in part of Mato Grosso and throughout Mato Grosso do Sul in the Midwest region, with values between 160 and 200 mm. In the rest of these regions, values between 200 and 320 mm predominated. Also in the North, the states of Acre, Rondônia, Pará and Amapá had, in some places, even higher rainfall, exceeding the accumulated 360 mm/5 days. The Southeast and South, on the other hand, were the regions with the highest aggregate values, of above 200 mm in almost all their territories, surpassing the 360 mm/5 day mark in several locations, such as in part of the coastal strip of Rio de Janeiro and São Paulo, and in most part of the state of Santa Catarina. The SS shown in Figure 4D and which relates the trend of the highest annual accumulations of five consecutive days over the years indicates an increase in these consecutive rainfall events in almost the entire country, with negative trends only in much of the North region, in some places in the Northeast (closer to the coast), and in a few places in the Southeast and South.

Frequency of days with high rainfall and frequency of days with extreme rainfall

The frequency of days with high rainfall (FDHR-P95) through the average annual count of days with rainfall higher than or

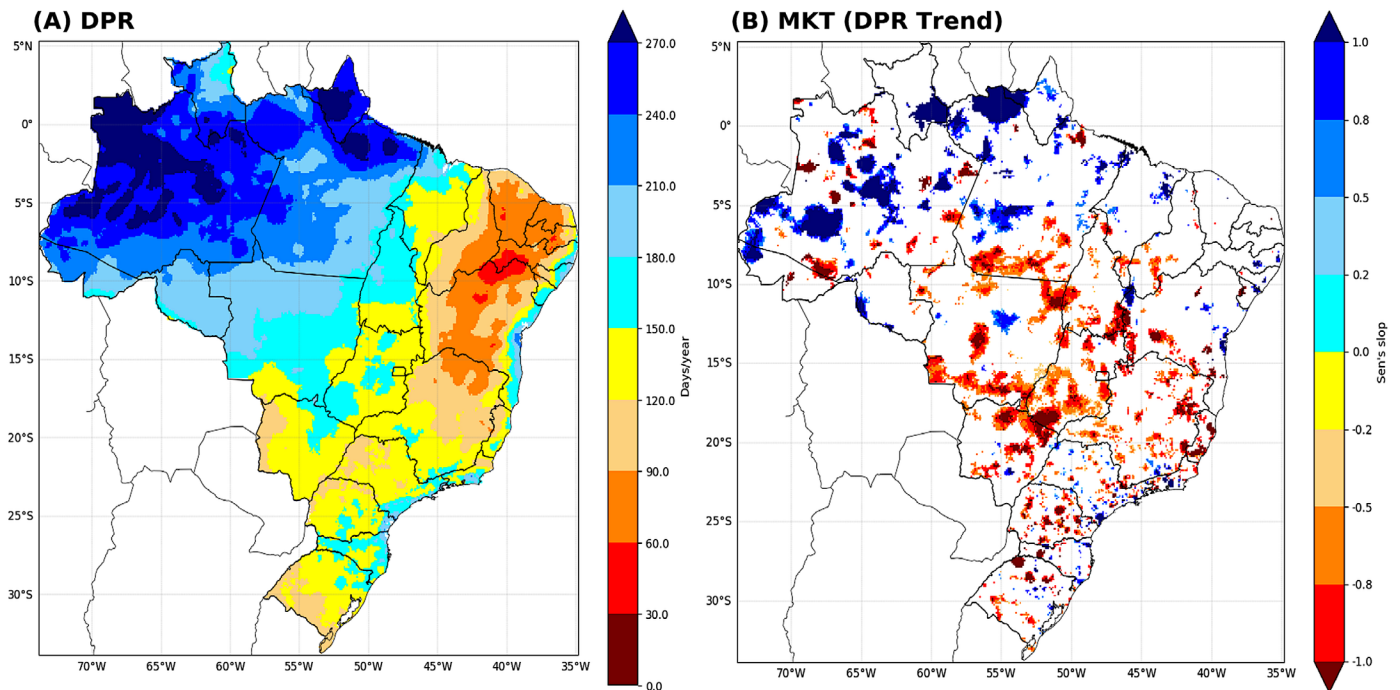


Figure 1S – Map of Brazil containing: (A) Days with Precipitation (DPR); (B) Trend of DPR. The white color indicates no trend.

equal to the 95 percentile (P95) demonstrates its results in the map of Figure 2SA. The same indicates that the rains above this level occurred on a larger scale in the states of the North region, on at least 9 days/year in almost all locations. This part of the north of the country corresponds to the tropical climate zone (A), both without dry season (Af) and with monsoon (Am).

The Northeast is characterized by the inverse, with the lowest quantification of days with rain above P95, varying in most of its territory between 7.5 and 1.5 days/year, the latter being the lowest level found and corresponding to the region where the climate zone is dry (B) and semi-arid (Bs). The other regions of the country concentrate these precipitations in a range that is mainly

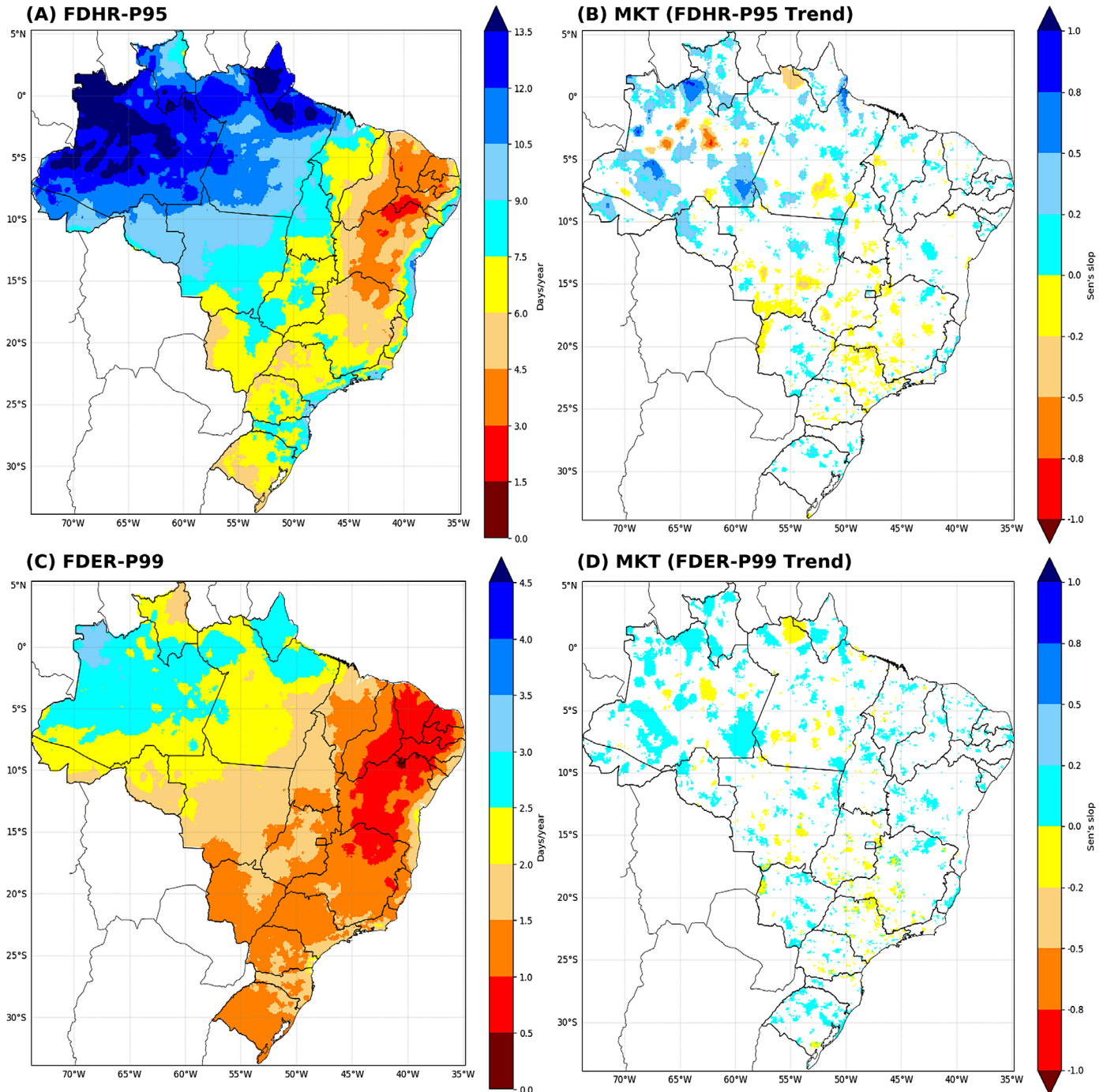


Figure 2S – Map of Brazil containing: (A) Frequency of Days with High Rainfall ($\geq P95$) (FDHR-P95); (B) Trend of FDHR-P95; (C) Frequency of Days with Extreme Rainfall ($\geq P99$) (FDER-P99); (D) Trend of FDER-P99. The white color indicates no trend.

between 6 and 9 days/year. It is worth mentioning the similarity of results between the FDHR-P95 and DPR metrics regarding the spatialization of rainfall, which indicates the proportion of distribution of the series, either considering all data or only those found after the P95.

However, regarding the trend of the series used in FDHR-P95 (Figure 2SB), Amazonas presented both the smallest and the largest slopes, being more negative in the most central portion of the state and more positive at its extremities, more specifically in its areas to the north, southeast and southwest. The rest of the North region also showed a higher upward trend. The other states of the federation showed trends in different locations within their geographical spaces, both positive and negative, with a decrease in high rainfall (≥ 95) mainly in the center-south of Mato Grosso, and most of Goiás, Minas Gerais and São Paulo, and an increase in all northeastern states, as well as in the southern states of Paraná and Rio Grande do Sul.

Figure 2SC deals with the frequency of days with extreme rainfall (FDER-P99), that is, it is the average annual count of days with rainfall greater than or equal to the 99 percentile. The results provide the information that, throughout Brazil, only in the North region were there extreme rains above 2.5 days/year. The northeastern *sertão*—backlands of Brazil—, on the other hand, did not exceed 1 day/year, and the rest of the Northeast, as well as most other Brazilian regions (Midwest, Southeast and South) remained between 1 and 2 days/year. Only in the northwest of the states of Mato Grosso and Maranhão, a portion to the east of Bahia and in places close to the coasts of Rio de Janeiro, São Paulo, Paraná and Santa Catarina, showed extreme rainfall between 2 and 2.5 days/year. When observing Figure 2SD, which shows the SS obtained through FDER-P99, a tendency can be noticed for this type of rainfall to increase in different places in all Brazilian states, especially in those belonging to the North, Northeast and South regions. In Pará (North region), in Goiás (Midwest region) and on the border between the states of Minas Gerais and São Paulo (Southeast region) were the places where more negative trends were detected.

Intensity of days with high rainfall and intensity of days with extreme rainfall

The intensity of days with high rainfall (IDHR-P95) is related to the average cumulative annual rainfall, of days with rainfall greater than or equal to the 95 percentile, and is in Figure 3SA. It is noticeable that in several places in the northern states, as well as in a portion of Rio de Janeiro and on the coasts of São Paulo, Paraná and Santa Catarina, there were average annual accumulations of over 150 mm/year. The opposite occurred in the Northeast, where most of the territory was below 60 mm/year. The Midwest and Southeast showed values that are between 60 and 90 mm/year. The South region, just like the North region, has a higher intensity of rainfall, with more

frequent values between 90 and 150 mm/year. The slope related to the IDHR-P95 metric is shown in Figure 3SB, and it indicates that there are both positive and negative trends in different locations in the North, Midwest and Southeast regions, with the North having the highest increase slope. The Northeast and South were the Brazilian regions with the highest incidence of only an increase in their slopes. In other words, higher intensity of high rainfall over the years in these areas.

The IDER-P99 is related to the intensity of days with extreme rainfall, which is the average cumulative annual rainfall of days with rainfall higher than or equal to the 99 percentile. Figure 3SC demonstrates these results, which are spatially similar to those of the IDHR-P95 metric, with a variation only in the magnitude of rainfall intensity values. The North region shows places with accumulated rainfall above 210 mm/year, while in the north of Bahia there is a portion that is below 30 mm/year. In the rest of the North, in the South, and in the coastal area of Rio de Janeiro and São Paulo located in the Southeast, the intensity of accumulated rains is mostly between 90 and 180 mm/year, thus these are the regions that concentrate the most extreme rains in the country. Meanwhile, the other regions have values that fall between 30 and 90 mm/day.

The SS linked to the IDER-P99, shown in Figure 3SD, reports that the most positive trends were detected in the states of the North region, in addition to several locations in the states of the Northeast, as well as in Mato Grosso do Sul, in the north of Minas Gerais, in Espírito Santo, and with an even greater incidence in Rio Grande do Sul. The negative trend was obtained in several points of Pará, as well as in most parts of Goiás, Minas Gerais and São Paulo.

Proportion of days with high rainfall and proportion of days with high rainfall

The PDHR-P95, considering the high rainfall that exceeds 95% of the precipitation records, is shown in Figure 5A. The results suggest that the states of the North and Midwest regions, as well as Maranhão, part of Piauí and western Bahia and much of Minas Gerais and São Paulo are the areas with the lowest percentage rates, with values in the range of 17 and 21%. And there are still places that are shown to be below 17%, as occurs in most of Amapá and other states. In the territorial range that extends from the north of Bahia to the south of Espírito Santo (in the area that covers the tropical climate zone (A)), and the coast between the states of Rio Grande do Norte and Rio Grande do Sul (tropical and humid subtropical climate zone), there are percentages above 22%. The South was, in general, the region with the highest average percentage, having almost all its territory with numbers above 21%.

The SS obtained for the annual PDHR-P95 is shown in the map of Figure 5B. In it, it is possible to observe an increasing trend of PDCE-95 in the North, Northeast and South regions, and a decreasing trend

in the Midwest and Southeast regions. To a lesser extent, there were also areas of negative trends in the states of Amazonas, Pará, Maranhão and Bahia. Likewise, locations with a positive trend were found in the states of Mato Grosso, Mato Grosso do Sul, Minas Gerais and Espírito Santo.

Figure 5C shows the PDER-P99, in which accumulated rainfall higher than 99% of the total annual precipitation records is considered extreme rainfall. For this metric, the results have a spatial distribution similar to that of PDHR-P95, but with lower percentages, which is expected since extreme rainfall corresponds to a smaller portion of the total annual rainfall.

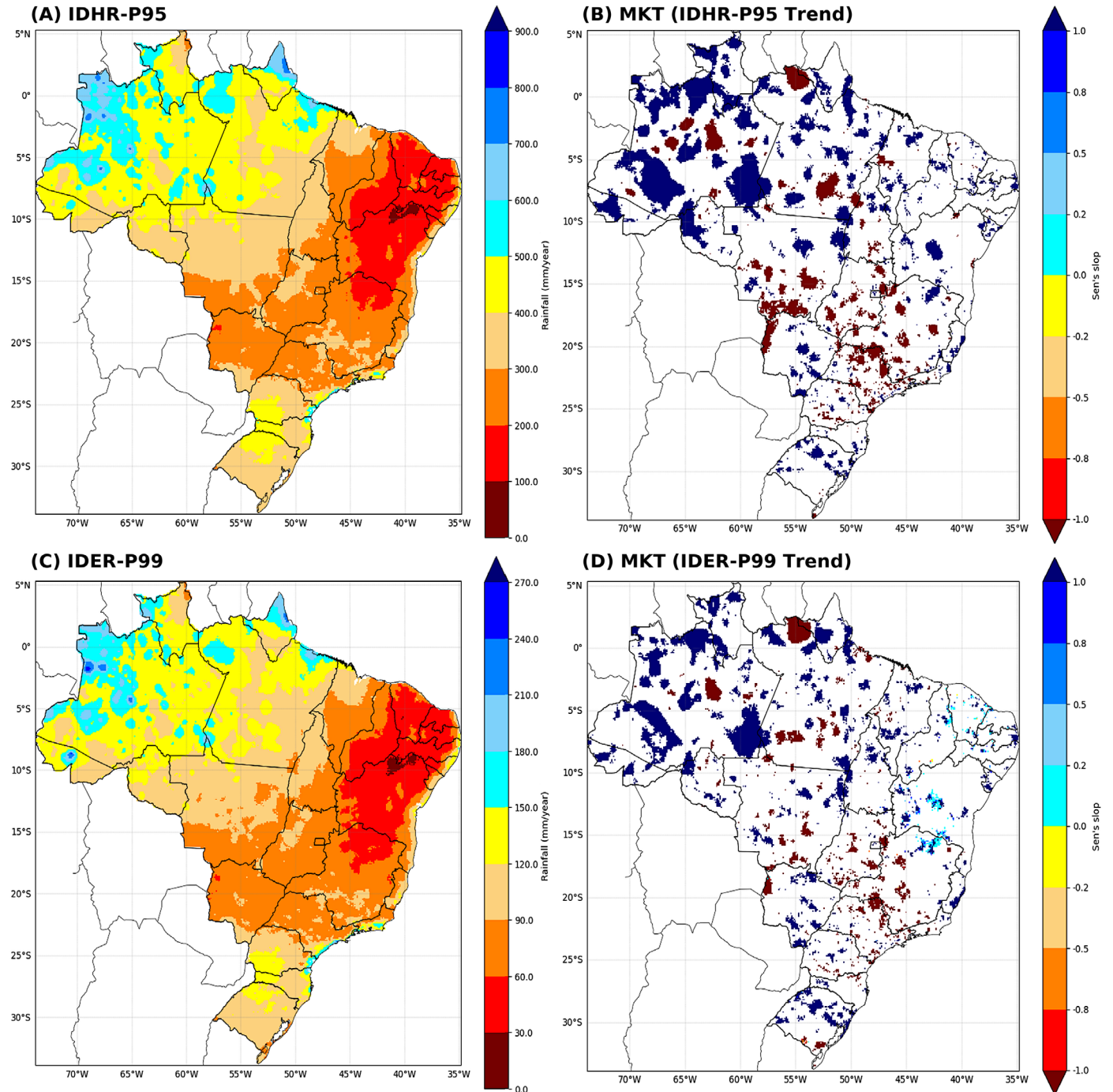


Figure 3S – Map of Brazil containing: (A) Intensity of Days with High Rainfall ($\geq P95$) (IDHR-P95); (B) Trend of IDHR-P95; (C) Intensity of Days with Extreme Rainfall ($\geq P99$) (IDER-P99); (D) Trend of IDER-P99. The white color indicates no trend.

Thus, it appears that the South was, in general, the region with the highest average percentage, with values above 6% in most of its territory. And with the exception of some specific locations in states in the North region and in the southwest of Mato Grosso, the territorial range that goes from Piauí in the Northeast to Rio Grande do Sul in the South of the country even presents average percentage values above 7%, so it is possible to consider them as the areas with the highest occurrence of extreme rainfall in Brazil in the analyzed period (1991–2022).

The series of annual percentages referring to the PDER-P99 was used to obtain the SS (Figure 5D), which shows most of the country with positive trends, and occur in all Brazilian states, with greater frequency in the North, Northeast and South regions, mainly in the states of Amazonas, Bahia and Rio Grande do Sul, respectively. The states of Mato Grosso do Sul, Espírito Santo and northern Minas Gerais also have positive trends. Therefore, these are the places with the highest indication of an increase in extreme annual rainfall. On the other hand, the negative trend of these rains was better detected in some portions of the states of Pará, Goiás, Minas Gerais and São Paulo.

Maximum average and minimum average temperatures, and daily thermal amplitude

The average maximum temperature (TX-M), shown in Figure 6A, indicates that the highest maximum temperatures occur between the North, Northeast and Midwest regions, mainly in a transversal range between the last two mentioned, which exceeds 33°C. This result is consistent with the climate zones shown in Figure 2, which shows these two regions being in the Tropical climate zone (A), and the Northeast beyond this still has a dry climate zone (B) in a smaller portion of its territory. On the other hand, in the Southeast and mostly in the South, there were average maximum temperatures that reached below 25°C, and both are inserted in the Subtropical Humid climatic zone (C). The SS of the TX-M, which is shown in Figure 6B, indicates a positive trend for most of Brazil, especially the Northeast. Only in small portions of the Southeast and South states, and Pará in the North and Maranhão in the Northeast, was there a negative trend.

The average minimum temperature (TN-M) in Figure 6C shows that the highest minimum temperatures are in the North and Northeast regions, with values above 20°C in most of these territories (with the exception of Bahia, which had the highest values below 20°C). The other regions have milder temperatures, especially in the South, which shows almost all its territory below 17°C. Figure 6D shows the SS, which showed a tendency to increase the TN-M throughout the North region, in a large part of the Northeast, and mainly Mato Grosso in the Midwest, Minas Gerais in the Southeast and Paraná in the South. There was also a decrease trend in Tocantins, Bahia and São Paulo.

Figure 6E shows the daily thermal amplitude (DTA), and it can be seen that the places where there was less daily variation in temperatures were coastal regions throughout the country, ranging from Rio Grande do Sul to Amapá, as well as throughout Roraima and most of Amazonas and Pará. The highest thermal amplitudes were recorded in the most central part of the country, mainly in the range from the south of Piauí to the south of Minas Gerais, and in the southeast of Mato Grosso, extending to most of the Midwest region. In Figure 6F, the SS obtained for DTA indicates that there are regions with a positive and negative trend in the country, with a positive sign in the Northeast and Midwest, a negative sign in the North and Southeast, and both signs in the South.

Maximum maximum temperature, maximum minimum temperature, minimum maximum temperature and minimum minimum temperature

The TX-X, which represents the highest maximum temperatures of the historical period studied, shows in Figure 4SA that, like the TX-M, the area with the highest temperatures extended from the north of the state of Piauí, expanding in a range that goes to the south of Mato Grosso and Mato Grosso do Sul, and the northwest of São Paulo, with values that exceeded 42°C. This area corresponds precisely to the tropical zone (A) with dry winter (Aw), which eventually tends to have higher temperatures. On the other hand, the lowest maximum temperatures occurred with a higher incidence in Pará (tropical zone [A] without dry season [Af] and with monsoon [Am]), in the coastal region of the Northeast (tropical zone [A] with dry summer [As]), and in the area from the south of Minas Gerais to the north of Rio Grande do Sul (humid subtropical zone [C]), with maximum temperatures reaching below 34°C. In Figure 4SB, SS shows a trend of increase in TX-X in all Brazilian states, with a greater absence of trend only in the Southeast states (with the exception of São Paulo) and Rio Grande do Sul.

The maximum minimum temperatures (TN-X) are shown in Figure 4SC and exhibit a greater standardization of these minimum temperatures (TN) in most of the country, with general values above 24°C. There are also high heat points, mainly in Amazonas, Rio Grande do Sul and the same cross-sectional area that goes from the Northeast to the Midwest (tropical [A] and dry [B] zones), with NT that reached above 28°C. Only in the south of Minas Gerais and in the region between Paraná and the north of Rio Grande do Sul were there temperatures below 22°C. As for the SS (Figure 4SD) of the TN-X, the main trend of the series is an increase, present in all states of the North and Northeast regions, in the most central part of the Midwest region, and in the states of Minas Gerais in the Southeast and Paraná in the South. In most other places there was no significant trend, with few areas showing a negative trend (more visible only in the north of São Paulo).

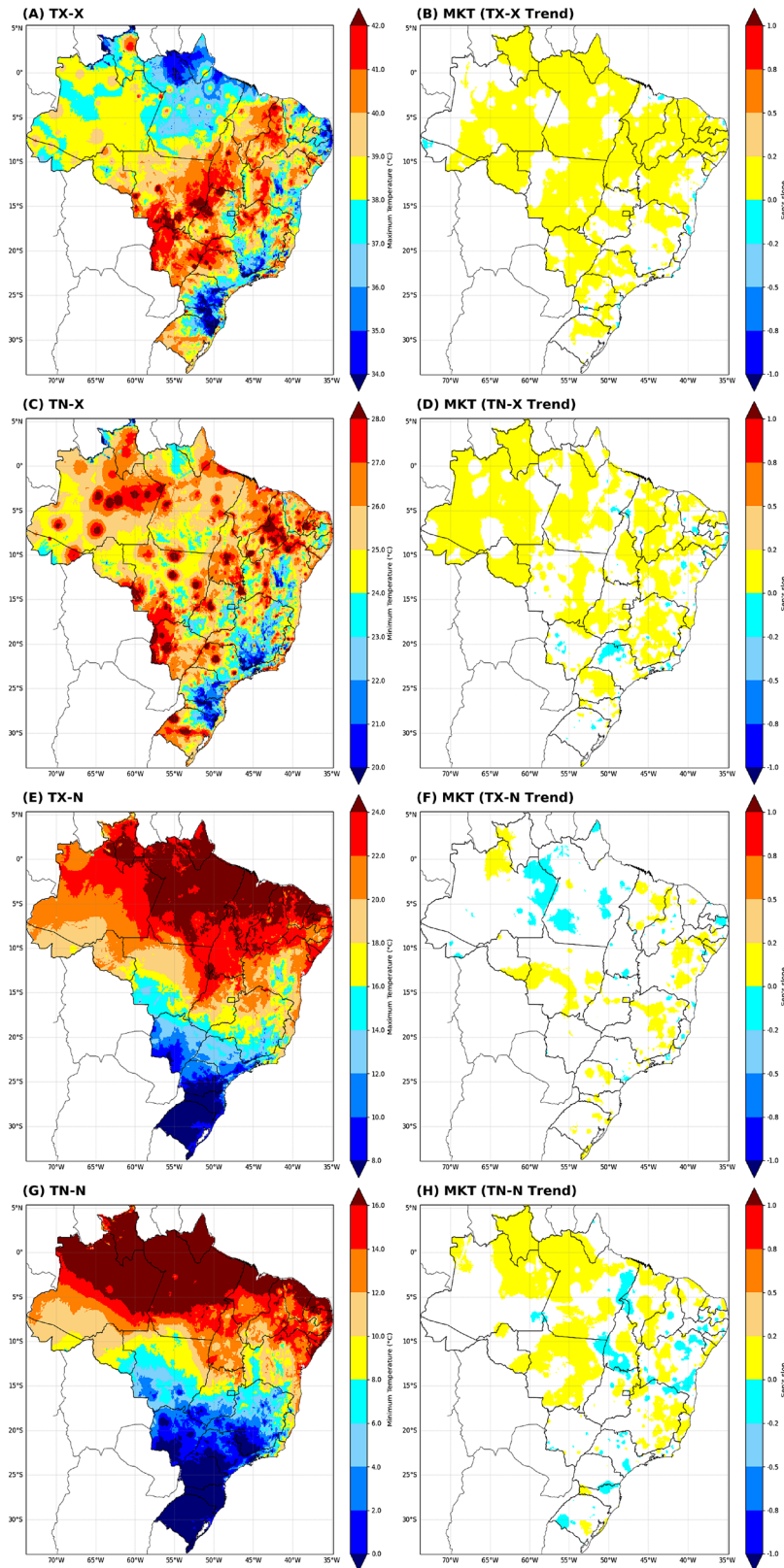


Figure 4S – Map of Brazil containing: (A) Maximum TX (TX-X); (B) TX-X Trend; (C) Maximum TN (TN-X); (D) TN-X Trend; (E) Minimum TX (TX-N); (F) TX-N Trend; (G) Minimum TN (TN-N); (H) TN-N Trend.

The minimum maximum temperatures (TX-N), in Figure 4SE, were higher throughout the North and Northeast, with a better focus in the states from Roraima to Paraíba, where they exceeded the 24°C mark. In the other places belonging to these two regions, temperatures ranged between 20 and 24°C. In the Midwest and Southeast, temperatures were more concentrated between 20 and 14°C. The South of the country was the place where the lowest temperatures were recorded, reaching below 8°C. The SS of TX-N showed a non-significant trend for most of the country (Figure 4SF). However, there were still portions of some states with a positive trend (such as Mato-Grosso, Bahia and Minas Gerais), as well as negative (in Amazon, Pará and Paraíba, for example).

Figure 4SG shows the minimum temperatures (TN-N), which for this metric showed a decreasing uniform distribution, with higher temperatures in the North and Northeast, and which decrease until reaching the South of the country, with maximums above 16°C and minimums that were below 0°C. Figure 4SH shows the trend obtained by the SS of the TN-N, which was positive and more pronounced in the entire state of Roraima, as well as in parts of the other states of the North region (with the exception of Acre) and the Northeast states, and also in most of Mato Grosso, Minas Gerais and Espírito Santo. The negative trend was also observed in small areas located in all regions of the country, with a lower incidence only in the Midwest.

Cold days (tx-p10), cold nights (tn-p10), hot days (tx-p90) and hot nights (tn-p90)

The map in Figure 5SA shows in percentage terms the average of the coldest days in each year. This percentage was obtained through temperatures that were at or below the 10 percentile ($TX \leq P10$). In it, a proportion of days can be observed throughout the national territory that mostly fell between 9.9 and 10.1%. In the states of Pará, Maranhão, Piauí and Minas Gerais, percentages above 10.2% were recorded. Figure 5SB, SS of TX-P10, indicates a negative trend in almost the entire northeastern territory, with values that exceed -0.5, as occurs in some areas of Ceará, Paraíba, Pernambuco and Bahia. There is also a negative trend in part of the North, Midwest and Southeast, mainly in Amazonas and Roraima, Mato Grosso and Goiás, and Minas Gerais and São Paulo, respectively. In the South, in Santa Catarina, the trend was more negative, while the other two states did not obtain a trend in almost all of their territories. Positive trends were higher (between 0.2 and 0.5) in Amapá, Pará, Espírito Santo, Rio de Janeiro and southern São Paulo.

TN-P10, which follows the same premise as TX-P10, but uses the minimum temperatures in order to find the nights considered cooler ($TN \leq P10$), shows through Figure 5SC that the proportion of cooler nights, according to the respective percentile of each location, was higher (above 10.2%) on the borders between the states

of Amazonas and Mato Grosso, and Bahia and Minas Gerais, in addition to most parts of the states of Pará, Piauí, Ceará, Tocantins and Goiás. Overall, the North region and the state of Mato Grosso had the lowest percentages (below 10%). The SS (Figure 5SD) generated through TN-P10 indicates a trend of marked reduction in the percentage of cold nights throughout the North region, in much of the Northeast region, and in the states of Mato Grosso, Goiás, Minas Gerais and Espírito Santo. However, there is a tendency for a more significant increase in the border between Tocantins and Goiás, as well as in São Paulo and in parts of Bahia and Mato Grosso do Sul.

The TX-P90 metric (Figure 5SE), which considers the hottest days according to the 90 percentile ($TX \geq P90$), indicates that the highest proportion between hot days and the total days of the year is found in the North region, more precisely in the states of Roraima, Amazonas, Pará and Amapá, as well as in the places closest to the northeastern coast, more precisely between the states of Paraíba and Bahia (above 10.2%). There is a small area in Mato Grosso (between the center and the west side) that also has a high percentage of hot days. In the states of Mato Grosso do Sul and São Paulo, and also throughout the South region, the values are distributed between 10.0 and 10.1%. Elsewhere, the proportion of hot days is below 10%. In terms of trend, the SS (Figure 5SF) shows that there is a significant upward trend of TX-P90 in most of the Brazilian territory, with higher values in the North and Northeast, more specifically in Amapá and Pará, and from Ceará to Pernambuco, respectively.

As for the nights considered warmer ($TN \geq P90$), TN-P90 (Figure 5SG) shows that there was a higher proportion of these nights in all regions of the country, but with higher values (above 10.4%) in most of the northern states (Amazonas, Roraima, Acre, Rondônia and southern Pará), Mato Grosso and Goiás in the Midwest, at the ends of the Northeast region, and in Minas Gerais and Espírito Santo in the Southeast. The entire south of the country, together with the states of Rio de Janeiro and São Paulo, obtained lower and more concentrated values between 10.0 and 10.1%. Only the most central part of the Northeast, and sporadic locations throughout the country, obtained values below 10%.

As for SS obtained through the annual series of TN-P90 (Figure 5SH), the results show a trend of increasing hot nights throughout the North, especially in the region considered Amazonian, with a greater focus on the states between Roraima and Mato Grosso (between 0.5 and ≥ 1.0). The Northeast also showed a positive trend in all its states, with more areas showing high values among the states from Maranhão to Bahia, as well as Minas Gerais in the Southeast (between 0.2 and 1.0), and the state of Paraná in the South (more frequent between 0.2 and 0.5). Only the north of the state of São Paulo presented the largest area with a negative trend (below -0.5).

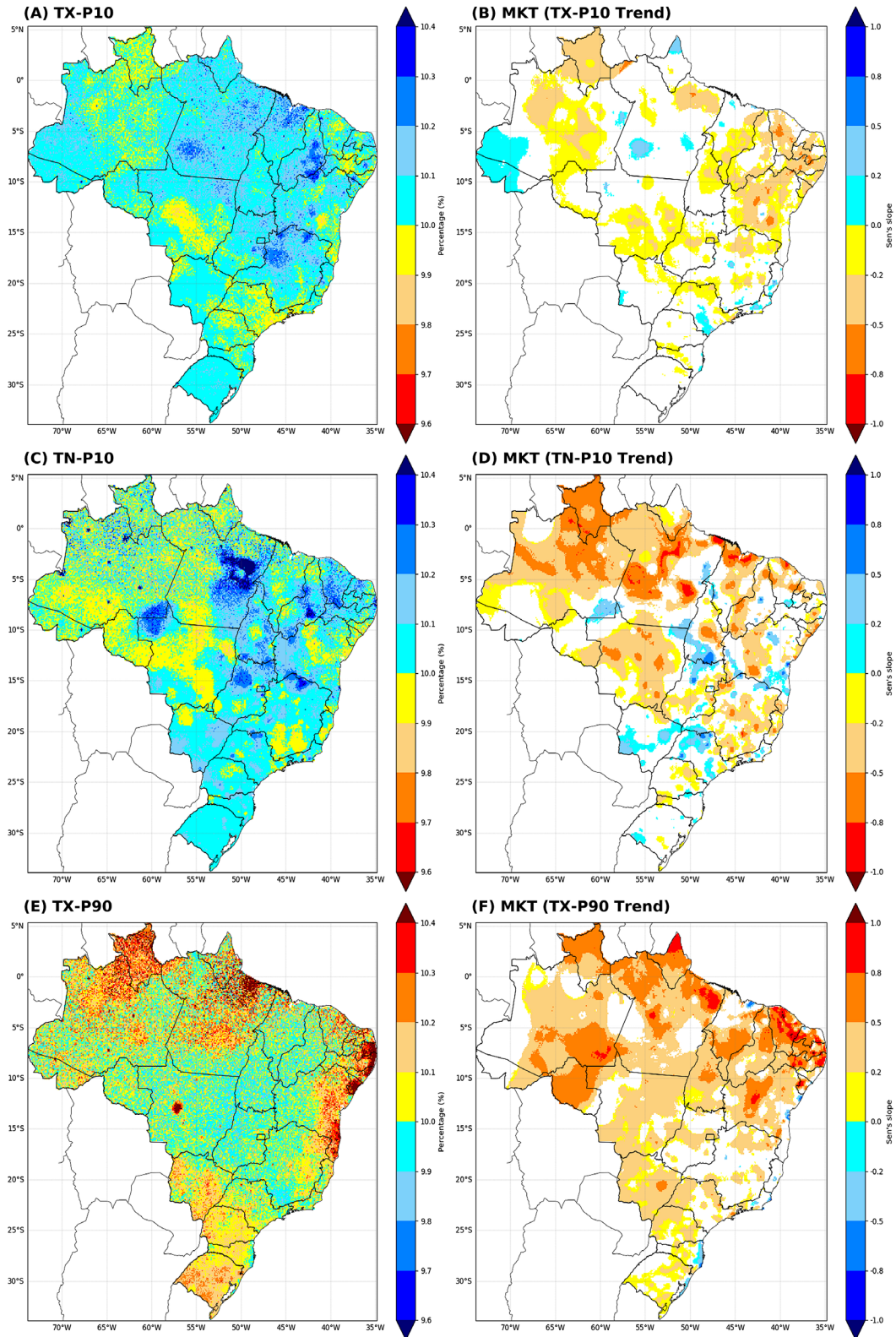


Figure 5S – Map of Brazil containing: (A) Cold Days (TX-P10); (B) TX-P10 Trend; (C) Cold Nights (TN-P10); (D) TN-P10 Trend; (E) Hot Days (TX-P90); (F) TX-P90 Trend; (G) Hot Nights (TN-P90); (H) TN-P90 Trend. The ascending (blue) and descending (red) color scale indicate positive and negative trends, respectively, for the cold extremes (A, B); the ascending (red) and descending (blue) color scale indicate positive and negative trends, respectively, for the hot extremes (C, D). The white color indicates no trend.

Correlation between evaluation of high and extreme precipitation and evaluation of maximum and minimum temperatures

The PCC was applied between EHEP and EMMT indices in order to correlate them and verify if there is dependence between climate variables. Figure 7 shows the result of these correlations, the first being made between TOTPR and TX-M (Figure 7A), which relates the annual accumulated rainfall to the annual average maximum temperatures, and its results indicate a negative correlation in most parts of the country, which indicates that the variables analyzed are inversely interdependent. And this negative correlation was more significant (with values between -0.6 and -0.8) in most states of the Northeast (with the exception of Sergipe), as well as in Tocantins, Goiás, Minas Gerais, Espírito Santo, and parts of Rio de Janeiro and Mato Grosso, which according to the classification in Table 2 range from moderate to high. In some of these states, small areas with even more negative correlations (between -0.8 and -1.0), classified from high to very high, were also recorded. In the South, the most significant correlations were in the range of -0.4 and -0.6, considered low to moderate. The North was the region that presented the most negative and positive correlations, being more prominent in Roraima, Rondônia and Amazon (with values that came to be between 0.6 and 0.8: moderate to high classification).

The second analysis was performed using TOTPR again, but this time correlating it with TN-M (Figure 7B). The results suggest that the correlation in most part of the country ranged between 0.2 and -0.2, indicating a very low relation between the variables in these locations. However, in part of the Northeast, especially in the states of Piauí, Ceará and Pernambuco, there were higher negative correlations, ranging between -0.6 and -0.8 (moderate to high) mainly, still containing a small region in the east of Piauí with even more negative values (between -0.8 and -1: high to very high correlation). The South region was the one that presented the most positive correlation values in general, although they are between 0.0 and 0.4 in almost all the territory (very low to low classification). However, the highlight is on Rio Grande do Sul, which presented higher correlation values, reaching up to 0.8 (high classification), indicating that it is the state in which (TN-M) and average rainfall are more directly correlated. Amazon also stands out for being the state that showed the most positive and negative correlations (mostly between 0.4 and 0.6: low to moderate), followed by Rondônia, Mato Grosso, Goiás and Minas Gerais. In Rio de Janeiro and São Paulo, there were also positive correlations in the southern coastal regions of the states for this same classification range.

The correlation between TX-M and rainfall is greater than or equal to the 95 percentile ($\geq p95$) was also calculated (Figure 7C), which cover the FDHR-P95, IDHR-P95 and PDHR-P95 index, in order to verify if there is a connection between the average maximum temperature and rainfall considered high. The result obtained shows that there were different places in the country with very low correlation (-0.2 to 0.2). The most positive correlations (between 0.4 and 0.8) occurred most frequently in the states of Amazonas and Rondônia, followed by small parts of Pará, Sergipe, Tocantins, the southern coast of São Paulo and Rio Grande do Sul. The negative correlation (between -0.4 and -0.8) is more present in parts of the states of the Northeast, Amazonas and Tocantins in the North, Goiás in the Midwest and Espírito Santo, Minas Gerais and its border with São Paulo.

The correlation between TN-M and rainfall related to P95 (Figure 7D) is positive in the South of the country, with values ranging from 0.6 to 0.8 (moderate to high classification). The same occurs in several states in the Northern region, mainly in Amazonas and Rondônia, as well as in Sergipe, eastern Bahia, Mato Grosso, and the north and south of São Paulo. On the other hand, the negative correlation was higher in parts of Amazonas (moderate to high classification), followed by Pará, in the north-central region of the Northeast, Mato Grosso, Goiás and Minas Gerais (low to moderate classification).

TX-M was also correlated with IDER-P99, when some link was sought between the average maximum temperature and rainfall considered extreme (Figure 6SA). Thus, the negative correlation was found to be more recurrent in most of the country, with a higher incidence in the Northeast (with the exception of Sergipe), throughout the Southeast and in Goiás, in the Midwest. The North showed high correlations in both directions (positive and negative). Still, it was in Amazonas, Sergipe, Mato Grosso and Rio Grande do Sul that higher positive correlations were recorded. In other words, in these states the increase in TX-M is aligned with the increase in extreme rainfall.

Figure 6SB depicts the relationship between the TN-M and rainfall considered extreme (IDHR-P95 metric). There was a huge territorial dispersion of correlations, with positive and negative portions in each state of the country, with emphasis on Amazonas, Pará and Mato Grosso, the states with the highest values in both cases. Rio Grande do Sul, on the other hand, obtained higher positive correlation values.

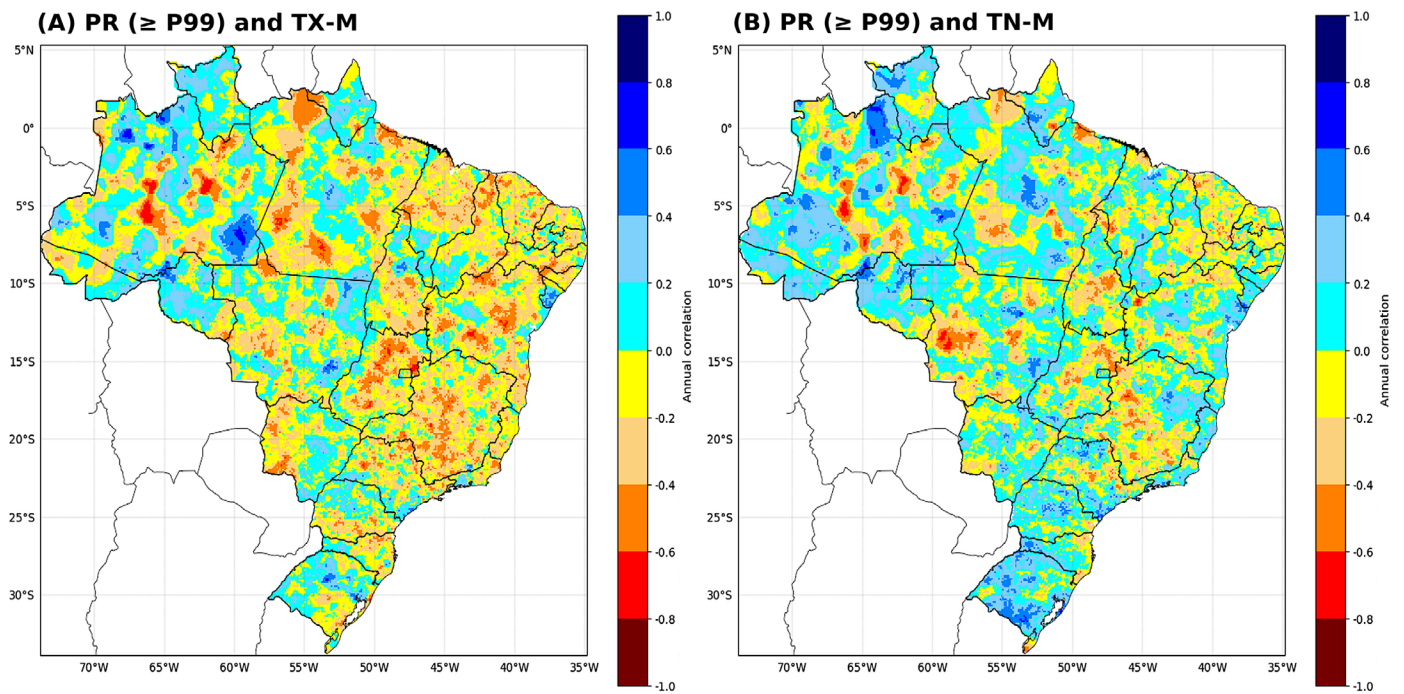


Figure 6S – Map of Brazil containing: (A) The correlation between precipitation— PR (≥P99) and average maximum temperature—TX-M; (B) The correlation between PR (≥P99) and average minimum temperature—TN-M.

Reference

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