ISSN 1831-9424

European Commission

JRC Technical Report

Drought in the Amazon basin November 2023

GDO Analytical Report

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Emergency Management Service

Toreti, A., Bavera, D., Acosta Navarro, J., Arias Muñoz, C., Barbosa, P., Branco, A., Cunha, A. P.,de Jager, A., Fioravanti, G., Grimaldi, S., Hrast Essenfelder, A., Libertà, G., Maetens, W., Magni, D., Marengo, J.A., Masante, D., Mazzeschi, M., McCormick, N., Meroni, M., Oom, D., Rembold, F., Salamon, P., San Miguel, J.

2023

Preparedness Response Recovery

Rapid Mapping | Risk & Recovery Mapping | Floods | Fires | Droughts | Population | Built-up areas

Joint Research Centre

EUR 31777 EN

Contact information
Name: Andrea Toreti
Address: Via E. Fermi 2749, I-21027 ISPRA (VA), Italy
Email : Andrea.TORETI@ec.europa.eu

EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC136439

EUR 31777 EN

PDF ISBN 978-92-68-10332-6 ISSN 1831-9424 doi:10.2760/756827 KJ-NA-31-777-EN-N

Luxembourg: Publications Office of the European Union, 2023

How to cite this report: Toreti, A., Bavera, D., Acosta Navarro, J., Arias Muñoz, C., Barbosa, P., Branco, A., Cunha, A. P.,de Jager, A., Fioravanti, G., Grimaldi, S., Hrast Essenfelder, A., Libertà, G., Maetens, W., Magni, D., Marengo, J.A., Masante, D., Mazzeschi, M., McCormick, N., Meroni, M., Oom, D., Rembold, F., Salamon, P., San Miguel, J. *Drought in the Amazon basin - November 2023*, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/756827, JRC136439.

Drought in the Amazon basin - November 2023

JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) - GDO data up to 30/10/2023

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Abstract

- A severe drought is affecting the western Amazon basin and most of northern South America, due to dry conditions that have persisted since July 2023. The spatio-temporal evolution of the drought indicates an increase in extent and severity.
- A sequence of extreme heatwaves is exacerbating the impact of the lack of precipitation, and the average temperature is abnormally high for the austral spring.
- Soil moisture has been severely affected, with negative anomalies over large parts of the region.
- Impacts on hydrology are huge: river flows are extremely low, with many at the lowest value for the season.
- The wildfire risk is increasing, and it is high mainly in central-eastern Brazil.
- The drought is affecting navigation, with impacts also on basic food and water supply. River flow forecasts suggest that these impacts are likely to worsen in the coming months.
- Seasonal forecasts point to warmer and drier than average conditions in the entire Amazon region, which are typical for a strong to very strong El Niño event.

Introduction

In the last hydrological year (i.e. October 2022 - September 2023), the Amazon basin recorded extraordinarily below-average rainfall[1], particularly in the following areas: the basin's western part; the headwaters of the Solimões, Purus and Juruá rivers; the southwest part of the Madeira basin, including the Peruvian and Bolivian Amazon. In the last 6 months, the situation in terms of rainfall deficit has become more critical. Furthermore, in the last 3 months, maximum temperatures have been above the historical average maximum values (with anomalies between 2 and 5 °C). The ongoing current drought appears to be comparable with the drought in spring 2015, during the 2014-2016 El Niño event. According to INMET (Instituto Nacional de Meteorologia, Brazil)[2], one of the most acute droughts in the Amazon began in the dry period (i.e. May-October) of 2015 and continued through the wet period until the first half of 2016, with rainfall 50% below expected levels.

During 2023, all Amazonian countries recorded the lowest July to September rainfall in over 40 years. Rainfall anomalies in the Brazilian States of western Amazonia, particularly Amazonas, range from 100 to 350 mm below normal corresponding to about 40-50% reduction compared to the average values (300-540 mm). The combination of a dry and very warm austral winter and spring in the western Amazon, plus four heat waves that occurred in the region from August to November 2023, have determined the current warm drought event. In 2015, temperature anomalies were very similar. 2023 is also an El Niño year, so a drier summer and autumn are expected. Hence, a dry and warm rainy season is forecast in the Amazon region, with an associated extremely high risk of fire and low river levels, which may cause impacts on the regional economy and population, perhaps comparable with the impacts of El Niño in 1982-83, 1997-98, and 2015-16.

The current drought in the Amazon region has been classified according to the Integrated Drought Index (IDI), which combines a meteorological-based drought index and a remote sensing-based index to assess drought events (Fig. 1)[3]. As can be seen, in August 2023 the drought affected mainly the western Amazon region of Brazil, as well as the Bolivian and Peruvian regions. Then, in September, it was more concentrated in the Peruvian region, the south-western Amazon in Brazil and the Bolivian Amazon. In October 2023, the situation extended to the state of Amazonas in Brazil.

[1] CEMADEN www.cemaden.gov

[2] https://portal.inmet.gov.br/uploads/notastecnicas/seca_amazonia.pdf

[3] Cunha, A.P.M.A. et al. 2019. Extreme Drought Events over Brazil from 2011 to 2019. Atmosphere, 10, 642. http://dx.doi.org/10.3390/atmos10110642

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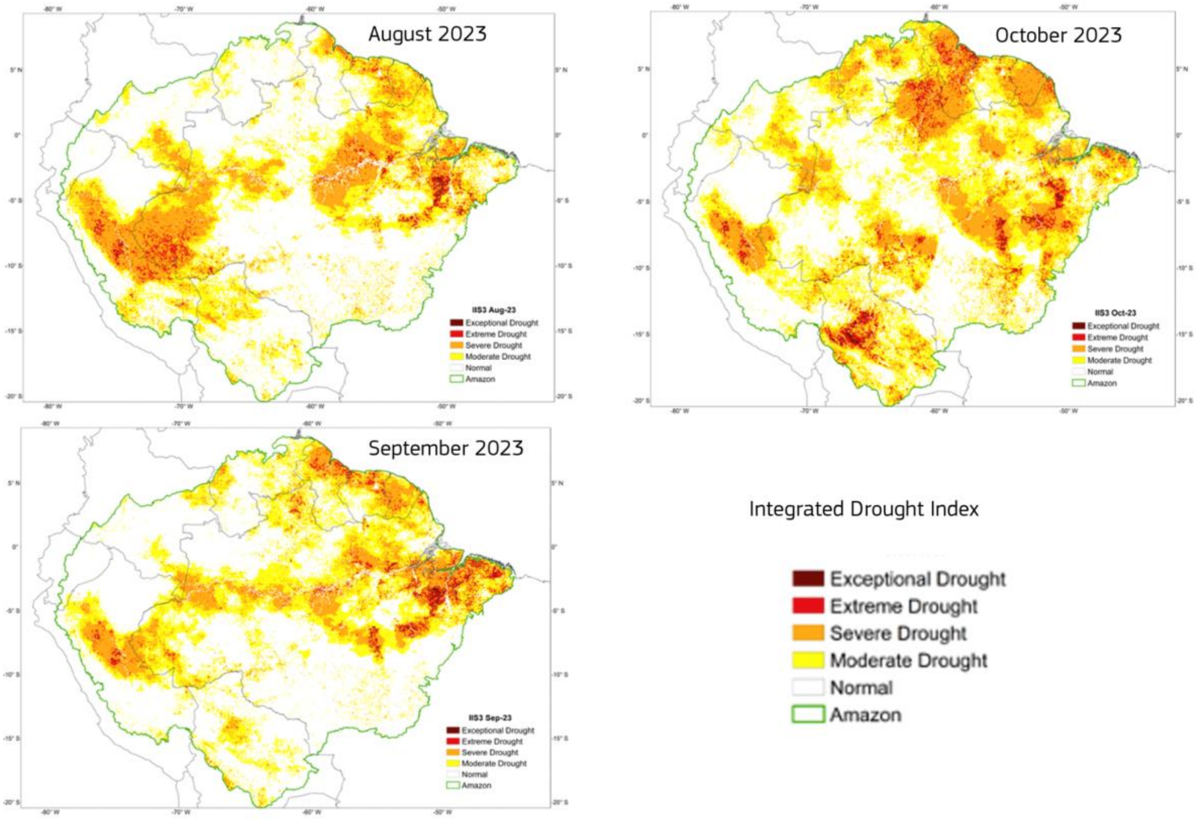

Figure 1: Integrated Drought Index (IDI) over the Amazon region, during August, September and October 2023. Source: CEMADEN[4], based on the SPI (Standardized Precipitation Index) calculated from CHIRPS data[5], combined with the Vegetation Health Index data from NOAA - STAR (Centre for Satellite Applications and Research).

Standardized Precipitation Index (SPI)

Negative anomalies of precipitation are currently affecting many parts of northern South America. The SPI-3 (i.e. SPI for an accumulation period of 3 months) shows dry conditions in most of the Amazon basin and in most of the northern countries in South America (Fig. 2, left panel).[6] The SPI-6 (6-month accumulation period) shows severe negative anomalies mainly in the central Amazon basin (Fig. 2, right panel).

The sequence of SPI-3 from April to September 2023 (Fig. 3) shows the evolution of the meteorological drought starting in sparse spots in Brazil (April-June) and expanding to wider regions covering most of the Amazon basin (July-September). As can be seen, August shows the worst lack of precipitation, affecting in particular northern Brazil and northern Peru. From June-July onwards, a change in the precipitation pattern is clearly visible, with a switch from positive to negative anomalies over most of north-western South America. These months are climatologically characterized by low rain accumulation. Hence anomalies are less relevant in terms of absolute values, but changes in the atmospheric configuration due to the El-Niño transition seem to be stable, and point to drier than normal conditions in the near future.

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[4] Centro Nacional de Monitoramento e Alertas de Desastres Naturais (CEMADEN): www.cemaden.gov

[5] Funk, C. et al. 2015. The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. Sci Data 2, 150066. https://doi.org/10.1038/sdata.2015.66

[6] For more details on the SPI, and the other GDO and EDO indicators of drought-related information used in this report, see the Appendix at the end of the document.

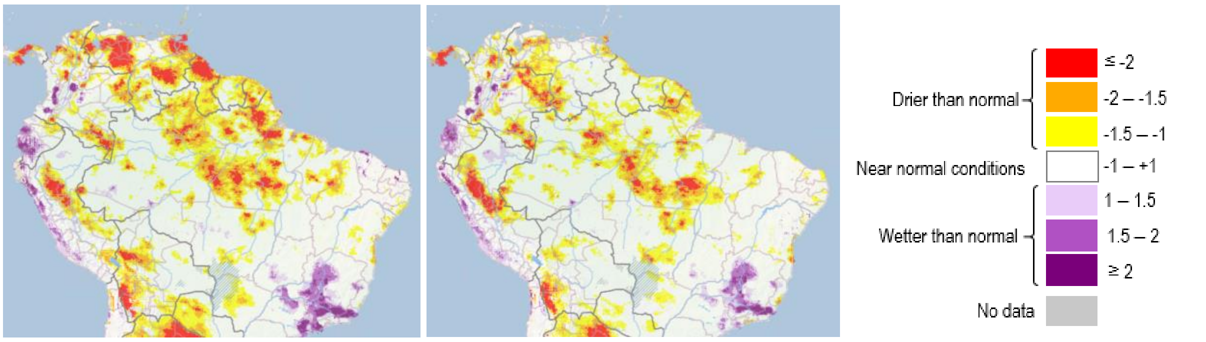

Figure 2: Standardized Precipitation Index - SPI-3 for the 3-month accumulation period ending on 30 October 2023 (left panel), and SPI-6 for the 6-month accumulation period ending on 30 October 2023 (right panel).[6]

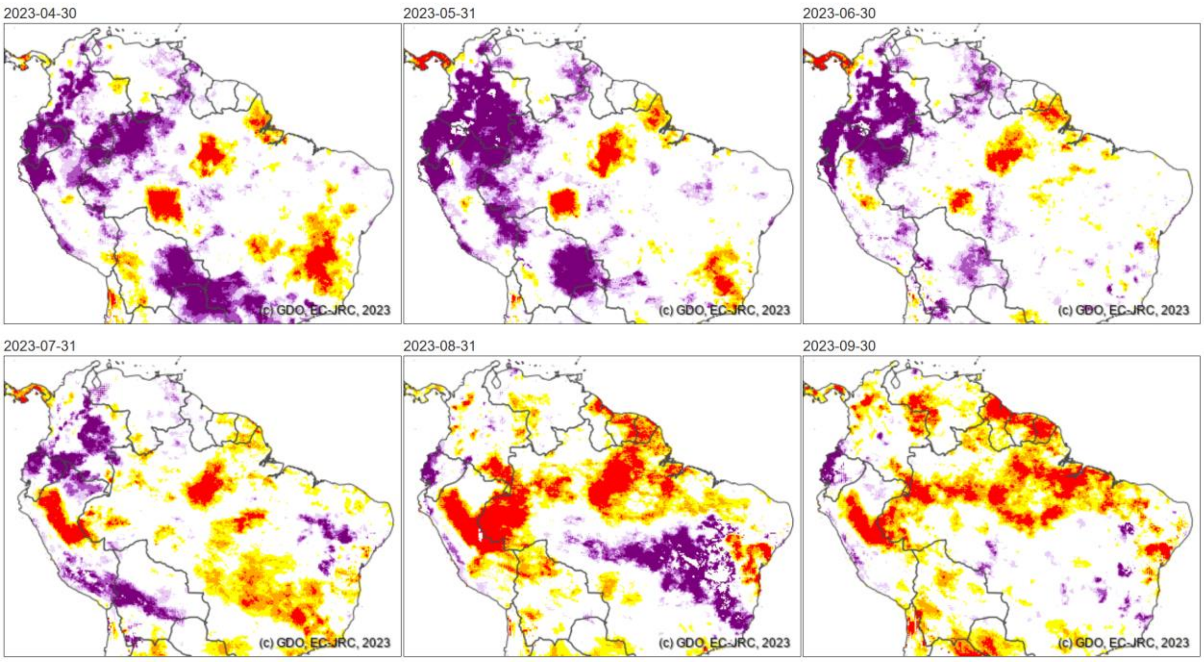

Figure 3*: Standardized Precipitation Index SPI-3 for 3-month accumulation periods. Panels: April to September 2023.*[6]

The drought event in northern South America is affecting regions in several countries, including southern and central-eastern Colombia, northern Brazil, and parts of Bolivia, Peru, Ecuador, Venezuela, Guiana and Suriname. The spatial and temporal dynamics of the drought can be estimated using the recently developed method for drought tracking (based on a generalized three-dimensional density-based clustering algorithm, DBSCAN)[7]. By applying this algorithm, those areas under drought conditions since November 2022 are identified (Fig. 4).

[7] Cammalleri, C., and A. Toreti, 2023: A Generalized Density-Based Algorithm for the Spatiotemporal Tracking of Drought Events. J. Hydrometeor., 24, 537–548, https://doi.org/10.1175/JHM-D-22-0115.1.

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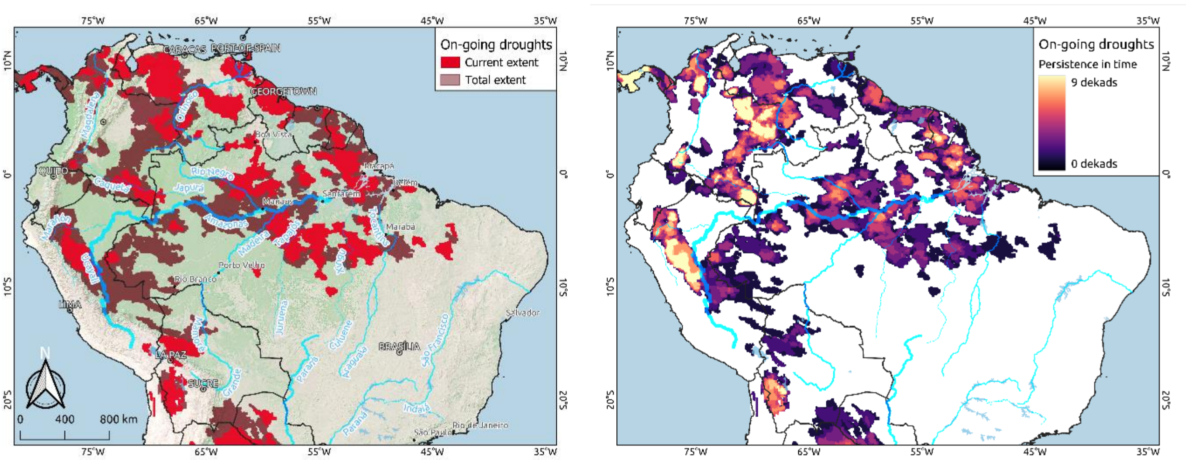

Figure 4: *Spatio-temporal evolution of the drought. Left panel: extent of the ongoing drought (light red, updated to late October 2023) and of areas that, at any time since November 2022, were affected by drought conditions (dark red). Right panel: Persistence (number of 10-day intervals) of drought conditions. The analysis was carried out using the DBSCAN methodology[7], and based on Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)[5].*

Temperature

Most of South America experienced prolonged above-average temperatures from August to September 2023. The 3-month average temperature anomaly (baseline 1991-2020) was generally above 1 °C, and even above 2 °C in Bolivia, Paraguay, and most of Brazil (Fig. 5). Maximum temperatures in the Amazonian states of Amazonas, Roraima, Acre and Rondônia reached 2 to 5 ºC above normal, according to INMET[8] and CEMADEN[4]. These conditions are much warmer than those in 2022, but similar to conditions observed during the previous El Niño in 2015, particularly over the state of Amazonas. Long-lasting and intense heatwaves worsened the effect of the precipitation deficit on soil moisture content, particularly in August and September 2023.

According to the Heat and Cold Wave Index (HCWI)[9], a sequence of continuous and constantly increasing heatwaves hit mainly the Amazon basin with a total duration of about 3-4 months. The heatwaves peaked over an increasingly large area on 29 July, 31 August, and 7 October 2023, with only partial and temporary subsequent reductions (Fig. 6). The severity and the spatial extent of the heatwave increased continuously.

South America was hit by unusually hot weather in the middle of the 2023 winter. In August and September 2023, temperatures in parts of Brazil reached over 41 ºC. Moreover, Peru, Bolivia, Paraguay and Argentina recorded their highest September temperatures after months of unusually warm winter conditions. The extreme heat was observed, mainly, from the middle to the end of September 2023, as a mass of hot air gained strength across the interior of Brazil. The heatwave event began on 18 September 2023, in the centre-south of the country, but after 24 September, the hot air mass prevailed in the centre-north of the country, extending to the north and northeast regions[10].

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[8] National Institute for Meteorology (INMET), Brazil: https://portal.inmet.gov.br

[9] For more details on the Heat and Cold Wave Index (HCWI), and the other GDO and EDO indicators of drought-related information used in this report, see the Appendix at the end of the document.

[10] https://portal.inmet.gov.br/uploads/notastecnicas/Nota_EventosExtremos_Brasil_Setembro_2023

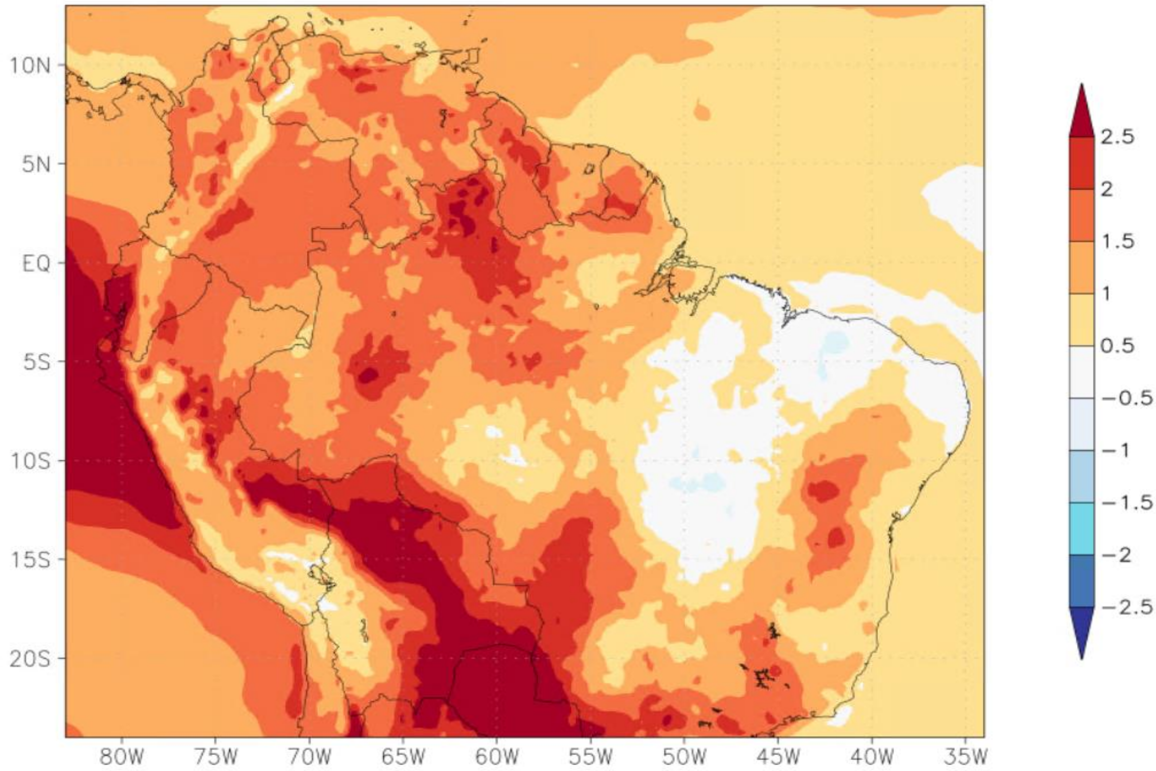

Figure 5: *Average temperature anomaly (ERA5, ECMWF Reanalysis v5) computed for the period August - September 2023 (baseline 1991-2020). Source: The KNMI (Royal Netherlands Meteorological Institute) Climate Explorer.*[11]

[11] The KNMI Climate Explorer https://climexp.knmi.nl

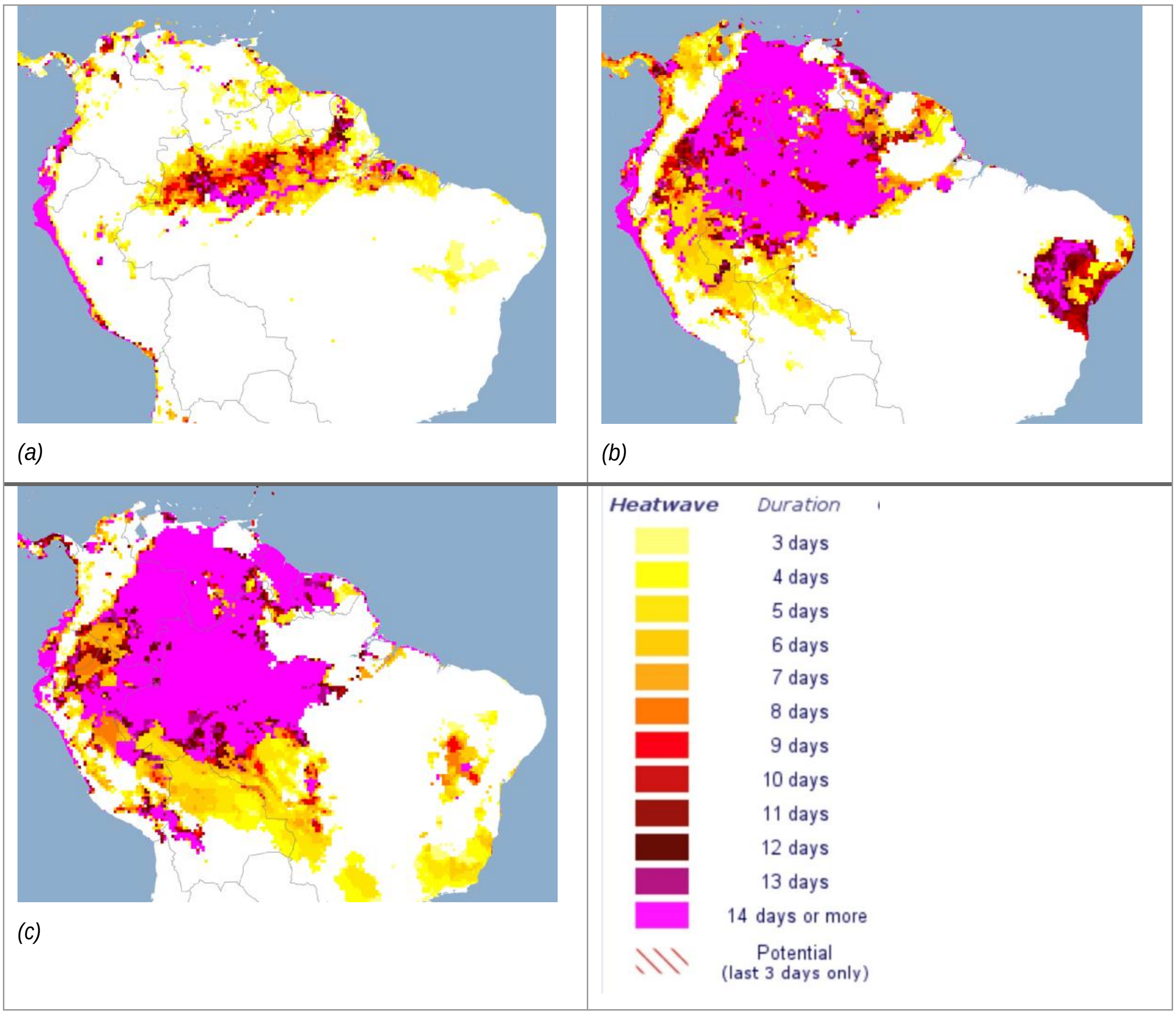

Figure 6: *Duration (in days) of the heatwave, computed on (a) 29 July 2023, (b) 31 August 2023, and (c) 7 October 2023, based on the Heat and Cold Wave Index (HCWI)[9]. The yellow to purple scheme represents increasing heatwave duration.*

Soil moisture

In mid-October 2023, soil moisture anomalies were remarkably negative over most of the Amazon basin and beyond its northern borders (Fig. 7). This was due to the compound effect of a severe low precipitation, the high temperatures in the previous months, and the sequence of the severe heatwaves. Despite the lack of data in the Amazon forest, the spatial pattern of the dry conditions is consistent with the latest heatwave. This contributed to exacerbate water losses from the soil due to stronger evapotranspiration potential. The regions with wetter than normal soil conditions (eastern Brazil) correspond with the latest precipitation positive anomalies (SPI-3, Fig. 2 left and Fig. 3 last panel). Large areas show soil moisture anomalies below -2, corresponding to the driest class of the GDO indicator (Fig. 5).[12]

[12] For more details on the Soil Moisture Anomaly, and the other GDO and EDO indicators of drought-related information used in the report, see the Appendix at the end of the document.

Regarding the evolution of soil moisture anomalies (Fig. 8), a generally close to normal situation is evident in April, with only slight dry or wet anomalies. Similarly to the precipitation patterns in Figure 3, the soil moisture anomalies changed continuously and slowly towards dry values in the northern and western regions, while the eastern ones became progressively wetter than normal. The most significant dry anomalies are detected in September-October 2023, clearly related to the strong heatwaves (Fig. 6).

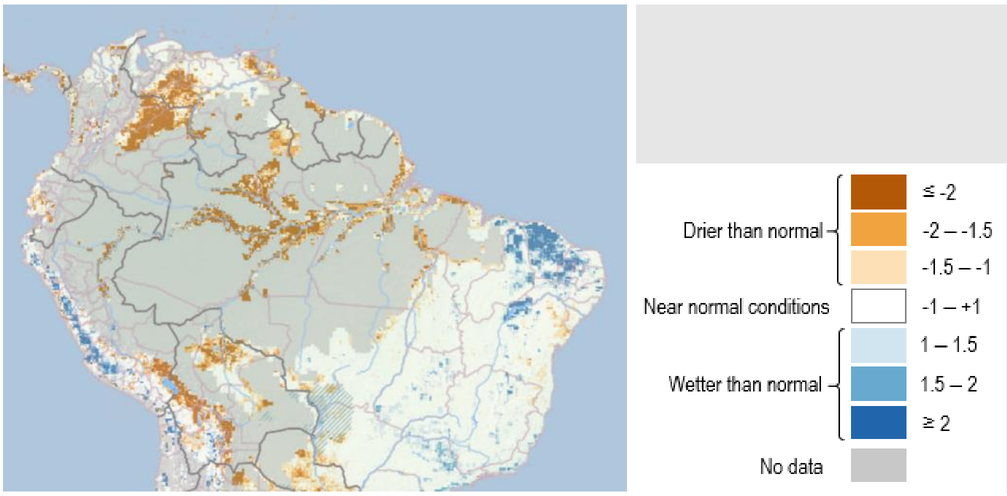

Figure 7: *Soil Moisture Anomaly, mid-October 2023.*[12]

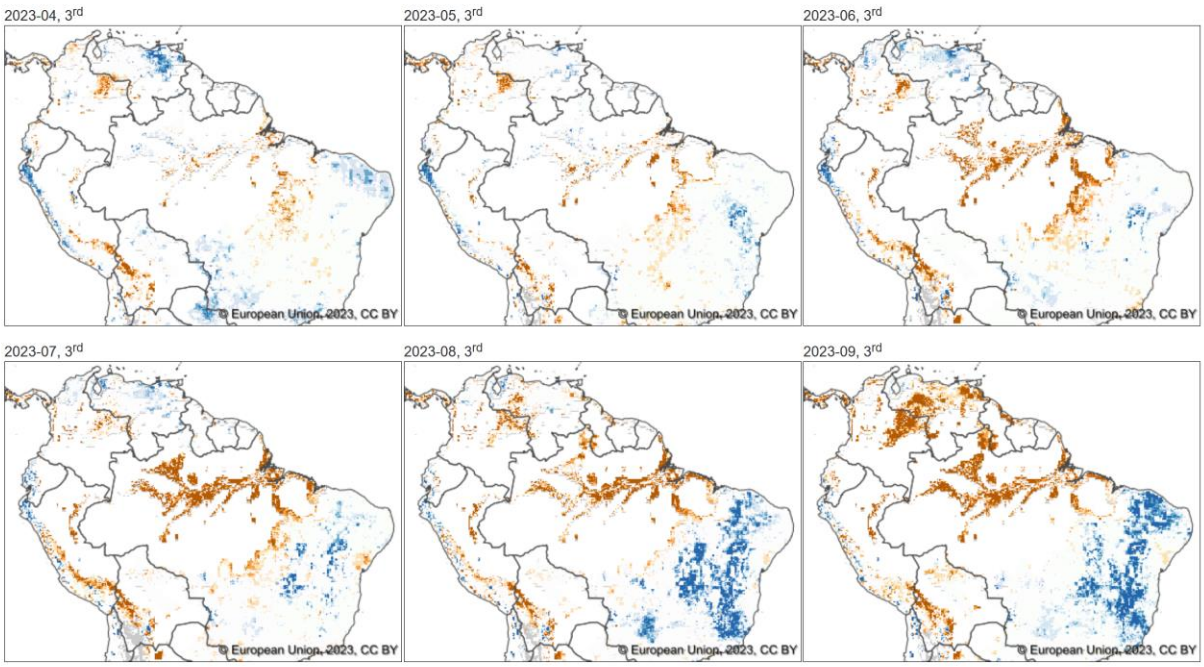

Figure 8: *Soil Moisture Anomaly, from April to September 2023.*[12]

Hydrology

According to national water authorities and federal Brazilian agencies (i.e. ANA[13] / National Water Agency of Brazil, SGB-CPRM[14] / Brazilian Geological Survey, CEMADEN, INPE / Instituto Nacional de Pesquisas Espaciais) the drought has affected most of the main rivers in the Amazon. On 3 October 2023, the City of São Gabriel da Cachoeira in the state of Amazonas (the most affected state), declared an emergency for a period of 90 days in the areas affected by drought. According to SGB-CPRM, in São Gabriel da Cachoeira the lowest level of the Rio Negro was recorded on 6 October 1992, when the river reached a level of 6.02 m. In October 2022, when the level was 7.27 m, the city was at risk of blackout. According to ANA and SGB-CPRM, the level of the Madeira River in Porto Velho showed the minimum level observed in the 56-year of measurements: 15 m on 15 October 2023. On 26 October the Rio Negro recorded its lowest level since measurements began. According to the Port of Manaus, the river recorded a tide of 12.70 m. It is the lowest since 1902, when measurements began (SGB-CPRM).

Figure 9 shows the levels / discharges of some rivers in the Brazilian Amazon (source: ANA). Each panel shows the long-term mean, the mean maximum and minimum levels, and the level during 2023 and other dry years (2005, 2010). In all cases, 2023 stands out either as the lowest, or very close the minimum level. The level of the Amazon River is declining according to the stations of ANA, from the station Itapéua to the station Itacoatiara. In Itapéua, the river level is close to the historical minimum levels recorded in 2010, and 1.15 m was measured on 18 October 2023. The station Manacapuru registered 3.08 m on 25 October 2023, close to the historical minimum at that station (2.9 m). In Manaus, at the ANA station, the river level has recorded minimum values since 10 April 2023. The 26 October 2023 it was 12.65 m, the lowest value of the historical series. In Itacoatiara, the stations have been recording minimum levels since 15 September 2023, on 25 October 2023 it registered 0.53 m.

The meteorological services of Bolivia (SENAMHI / Servicio National de Meteorología e Hidrología)[15] has shown that for the Bolivian Amazonia most of the river that are tributaries of the Solimoes River are very low. On 2 October, the Mamoré River was at 2.9 m in Puerto Siles and 1.94 m in Camiaco, while the long term normal values are 6.88 m and 10.09 m, respectively.

Figure 10 shows the reduction of water surface in the Amazon comparing satellite images from Landsat 8 and 9, Sentinel-1 and Sentinel-2 in September 2022 and September 2023[16]. The central Amazon region near the Solimoes River along the towns of Sao Sebastião, Moura, and Lima in September 2022, was covered by water, whereas in September 2023 the Lakes Aruã and Mamiá almost dried up. The same situation was observed in the Ururucú River, as shown by the light brown colours in Figure 10.

[13] www.ana.gov

[14] www.sgb.gov.br

[15] https://senamhi.gob.bo/index.php/rhidrologico

[16] For details, see: https://brasil.mapbiomas.org/wp-content/uploads/sites/4/2023/10/MAPBIOMAS-SECA-AMAZONAS-Nota-Tecnica-v4.pdf

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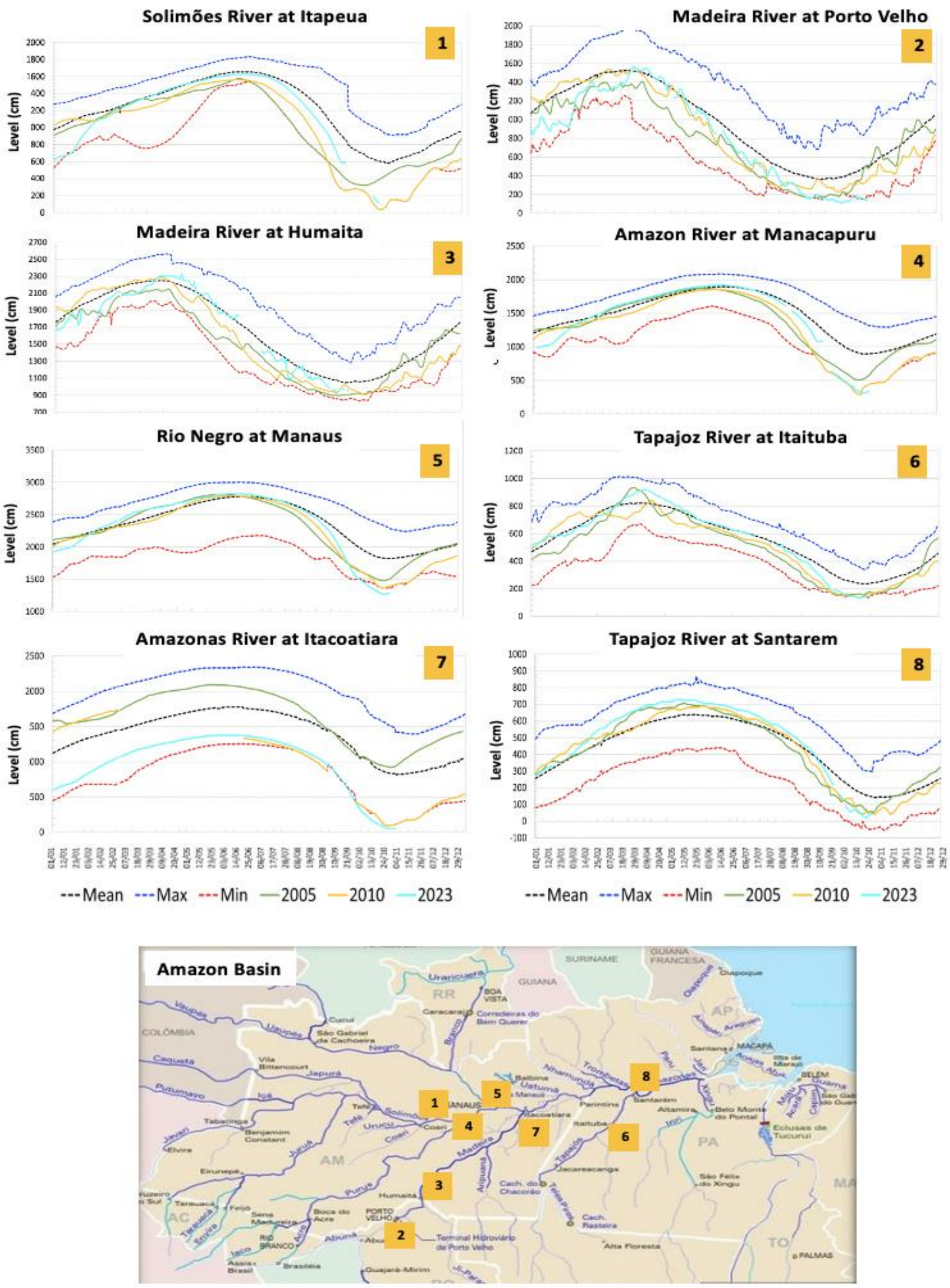

Figure 9: *Hydrometric levels (cm) of (1) Solimões Rover at Itapeua; (2) Madeira River at Porto Velho; (3) Madeira River at Humaitá; (4) Amazon River at Manacapuru; (5) Rio Negro at Manaus; (6) Tapajoz River at Itaituba; (7) Amazon River at Itacoatiuara; (8) Tapajoz River at Santarém. See text below.*

In Figure 9 above, the turquoise line refers to the level in 2023, until 31 October. The dotted lines in blue and red correspond, respectively, to the absolute maximum and minimum, and the dotted line in black corresponds to the long term mean since the beginning of the record. The solid lines in green, yellow and light blue represent, respectively, the levels of previous dry years (2005, 2010) and 2023. Locations of the station are shown by numbers in the map in the lower panel. Source: ANA, SGB-CPRM, CEMADEN.

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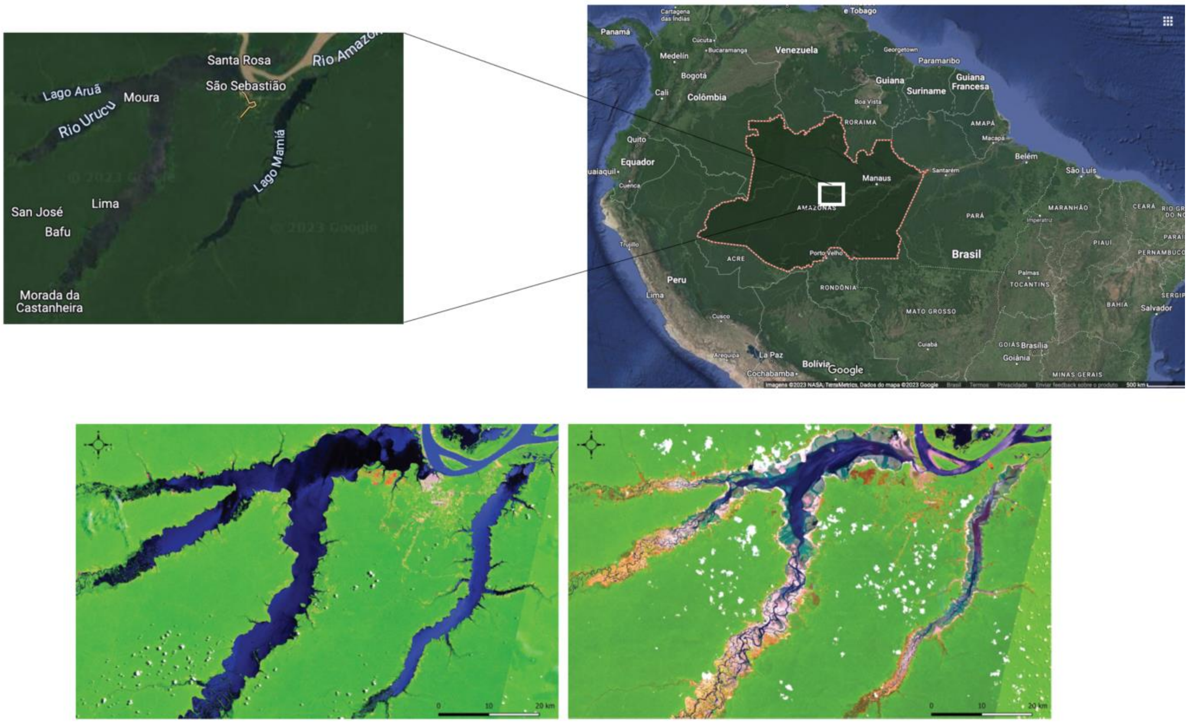

September 2022 September 2023

Figure 10: *Reduction of water surface in the Amazon River near the Urucú River in central Amazonas state in September 2022 and in September 2023 (Source: MapBiomas, Souza Jr et al 2023 - in preparation).*

Vegetation biomass

At the end of October 2023, the satellite-derived NDVI (Normalized Difference Vegetation Index) anomaly indicator shows vegetation stress scattered over most of the Amazon basin, and severe stress in south-eastern regions and into Bolivia (Fig. 11) [17]. Mild vegetation stress also affects north-western regions. These conditions are due to a combination of the dry season and higher than normal temperatures, compounded with heatwaves.

The evolution of NDVI anomalies from April to September 2023 (Fig. 12) indicates a progressive worsening of the vegetation conditions from April to July and then a stabilization up to September. Finally, as was highlighted in Figure 11, NDVI anomalies worsened again in October, mainly because of the severe heatwaves.

The dense and thick rainforest covering large areas of the Amazon basin exhibits NDVI anomaly values that are not always consistent with the other drought indicators, and are sometimes difficult to interpret properly. This is because the forest canopy layer has very large biomass, often saturating the remote sensing signal during the whole year, making NDVI and other satellite measures of vegetation biomass (e.g. fAPAR) not sufficiently sensitive to foliage variations to allow quantitative monitoring of canopy drought stress[18]. As a result, the already critical condition depicted by NDVI anomalies may nonetheless underestimate the actual impact on the green biomass. For this reason, it is useful to analyse also the Evaporative Stress Index (ESI), which compares actual compared to potential evapotranspiration, thus providing information about water stress. At the end of October, the ESI shows critical conditions over most of the Amazon basin and beyond (Fig. 13), in better agreement with precipitation and temperature anomalies than the NDVI anomalies.

[17] For more details on the satellite-derived NDVI anomaly indicator used in ASAP (Anomaly hotSpots of Agricultural Production), see: https://agricultural-production-hotspots.ec.europa.eu/documentation.php

[18] https://www.pnas.org/doi/10.1073/pnas.0400168101

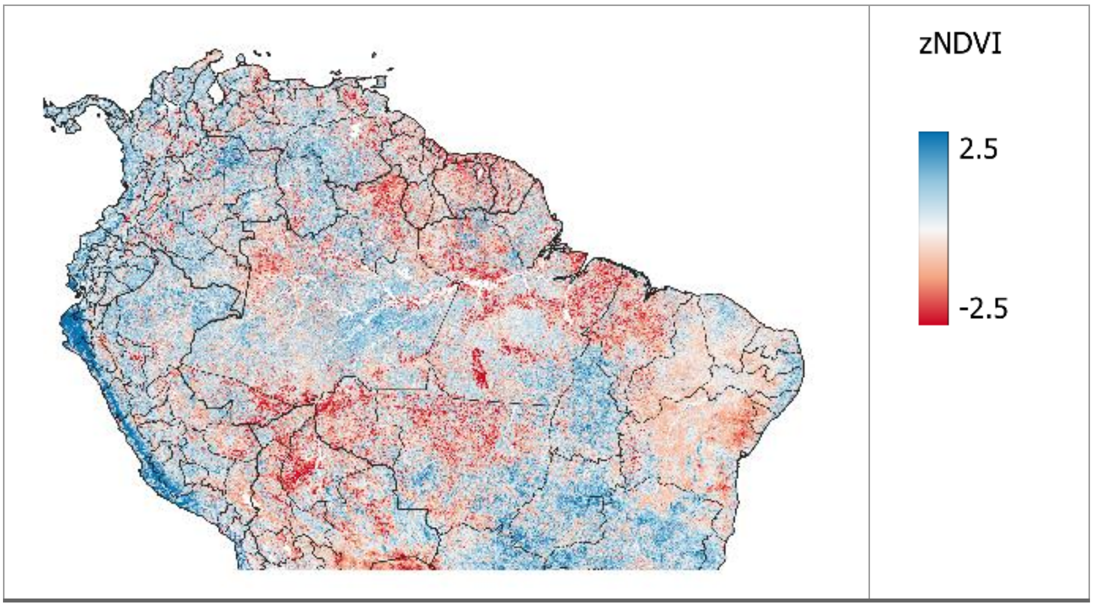

Figure 11: *Satellite-derived NDVI anomaly indicator at the end of October 2023. Source: JRC ASAP (Anomaly hotSpots of Agricultural Production), https://agricultural-production-hotspots.ec.europa.eu/* [17]

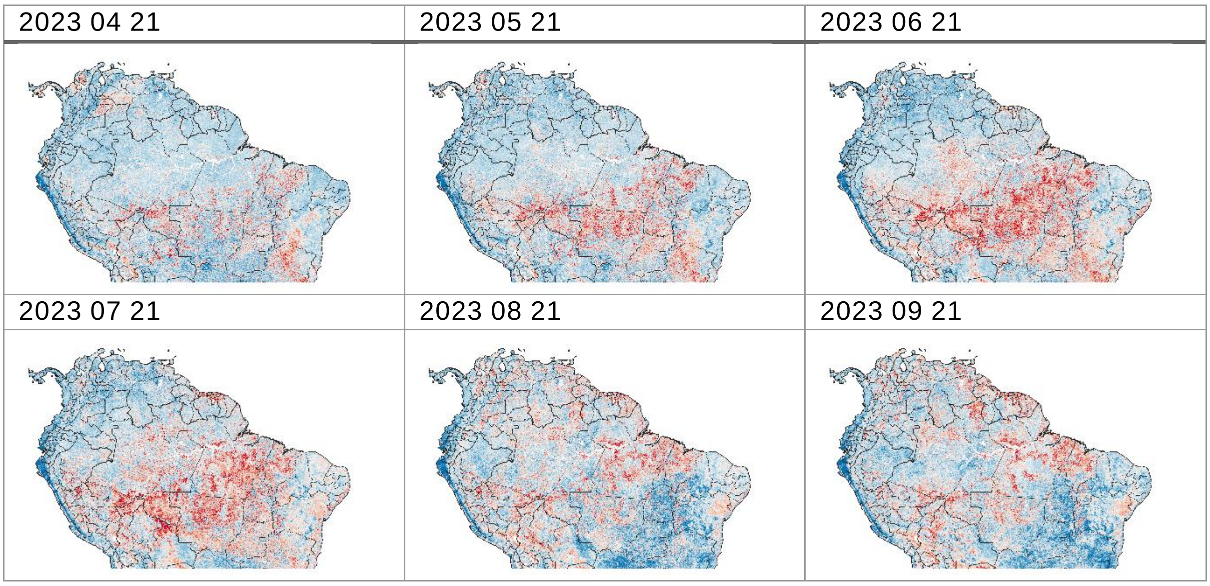

Figure 12: *Satellite-derived NDVI anomaly indicator from April to September 2023. Source: JRC ASAP (Anomaly hotSpots of Agricultural Production), https://agricultural-production-hotspots.ec.europa.eu/* [17]

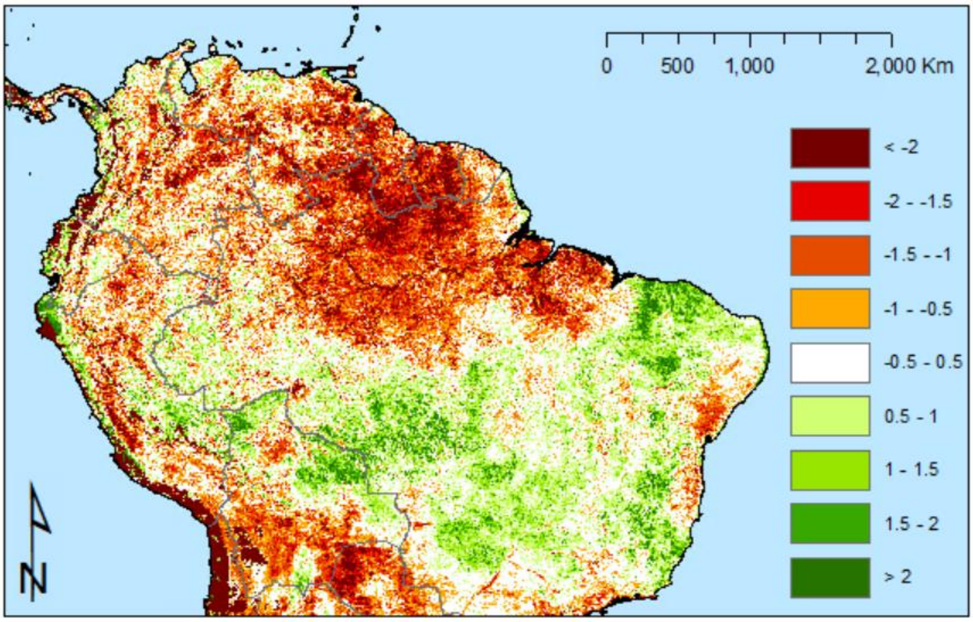

Figure 13: *Satellite-derived Evaporative Stress Index (ESI) on 30 October 2023. Data Source: National Aeronautics and Space Atmospheric Administration (NASA), United States Department of Agriculture (USDA).*[19]

Large-scale climatic conditions

Rainfall and temperature in the Amazon region are largely modulated by the tropical Pacific and tropical Atlantic[20] [21]. During El Niño events, the typical Walker circulation over the Amazon - tropical Pacific shifts eastward. The warm phase of the tropical central / eastern Pacific (El Niño) leads to both local enhancement of convection and sinking air motion over the Amazon, particularly strongly during the Southern Hemisphere spring and summer[20]. The sinking motion over the Amazon basin leads to lower-than-average precipitation and higher than average temperatures.

The warm phase of the tropical North Atlantic leads to a weakening of the northern branch of the Hadley circulation in the Caribbean / northern South American region. This in turn leads to both a decreased transport of moisture from the Atlantic into northern South America, due to weaker cross-equator winds, and an anomalous sinking / rising air motion in the Amazon / tropical North Atlantic[21]. Indeed, the tropical North Atlantic is the main source of external humidity in the Amazon[22].

Figure 14a shows the sea surface temperature anomalies during April-September 2023 in the basins around South America. There are both warm phases in the tropical central / eastern Pacific and North Atlantic. El Niño is underway, while the North Atlantic is in its most extreme warm phase since observations began[23]. Linear regression analysis of the NINO3.4 index against precipitation during the Amazon dry season (Fig. 14b) reveals a statistically significant relation between positive ENSO phase and reduced rainfall in the northern part of South America (north of the equator). Similar analysis during the rainy season (Fig. 14c) shows statistically

[19] https://www.drought.gov/data-maps-tools/evaporative-stress-index-esi

[20] Cai, W., et al. 2020. Climate impacts of the El Niño–Southern Oscillation on South America. *Nat Rev Earth Environ* 1, 215–231. https://doi.org/10.1038/s43017-020-0040-3

[21] Yoon, J.-H. & Zeng, N. 2010. An Atlantic influence on Amazon rainfall. *Clim Dyn* 34, 249–264. https://doi.org/10.1007/s00382-009-0551-6

[22] Drumond, A., et al. 2014. The role of the Amazon Basin moisture in the atmospheric branch of the hydrological cycle: a Lagrangian analysis, Hydrol. Earth Syst. Sci., 18, 2577–2598, https://doi.org/10.5194/hess-18-2577-2014, 2014

[23] https://www.washingtonpost.com/weather/2023/10/24/climate-change-extremes-el-nino-global-warming/

significant reduced rainfall in the central and eastern Amazon during El Niño. Similarly, a warm phase of the tropical North Atlantic (as defined by Yoon and Zeng[21]) shows statistically significant reduced rainfall in the western Amazon and over most of the Amazon during the dry (Fig. 14d) and wet (Fig. 14e) seasons.

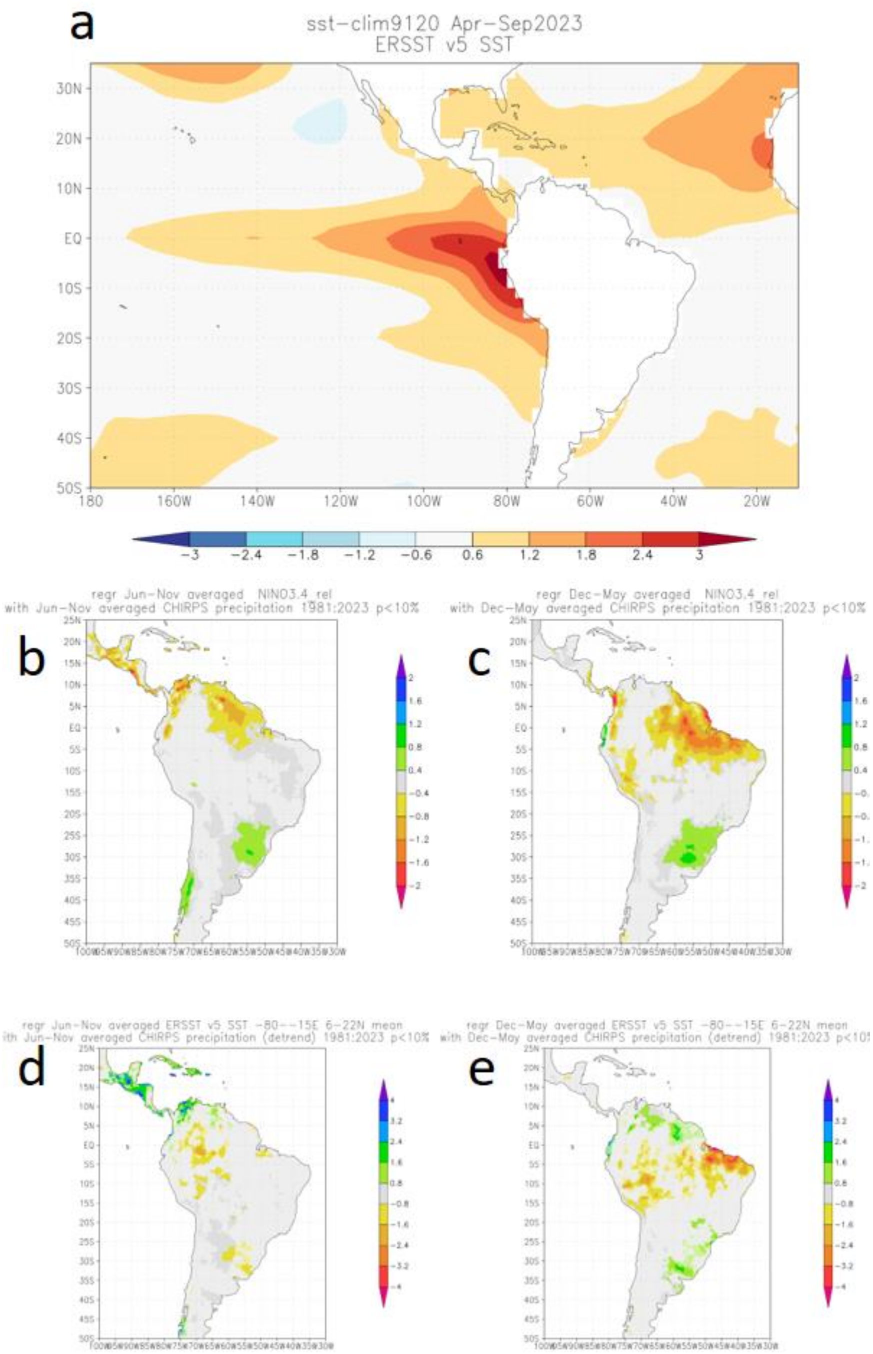

Figure 14: *(a) Sea surface temperature anomalies (relative to the 1991-2020 mean) for 6 months (April-September 2023). (b) and (c) Linear regression coefficient, for the period 1981-2023, between the NINO3.4 index and precipitation in South America during the dry (b) and wet (c) seasons. (d) and (e) Linear regression coefficient, for the period 1981-2023, between*

the detrended tropical North Atlantic index and precipitation in South America during the dry (d) and wet (e) seasons. In (b) to (e), lighter shading shows statistically insignificant values at the 90% confidence. Source: The KNMI Climate Explorer.[24]

Fire danger

Wildfire hazard is a direct consequence of elevated temperature anomalies and dry surface conditions, combined with availability of fuel (i.e. dry litter and wood) and a potential ignition source. The Global Wildfire Information System (GWIS)[25] offers worldwide mapping services, providing insights into near real time and forecasted fire danger. This danger, which reflects the likelihood of a fire igniting, spreading, and behaving in a particular manner considering the weather conditions, can be numerically estimated through fire danger indices. One example used by GWIS is the Fire Weather Index (FWI)[26], which is widely used to assess the level of fire danger. The FWI evaluates how weather conditions impact fire behaviour, ignition, and propagation by incorporating climatic data, including relative humidity, temperature, wind speed, and rainfall. A higher FWI score indicates more favourable meteorological conditions for fire initiation.

Figure 15 depicts the monthly maps of fire danger for the South America region, for the seven months from April to October 2023. A discernible upward trend in the prevalence of higher danger classes is evident, particularly in the central-eastern part of the region.

To gauge the challenge of controlling fires, a data transformation model of the FWI is utilized to calculate the Daily Severity Rating (DSR), as introduced by Van Wagner and Pickett (1985)[26]. A weekly average of these daily estimates, known as the Weekly Severity Rating (WSR), emphasizes higher values, thus highlighting the increased firefighting efforts required for more intense fires[27]. Figure 16 displays the WSR for South America in 2023, showing that the current year (red line) surpasses the average for the 1980-2022 period (blue line).

[24] The KNMI Climate Explorer https://climexp.knmi.nl

[25] GWIS uses daily meteorological forecast data from ECMWF to classify fire danger into 7 categories, at 8x8 km resolution, providing forecasts up to 9 days. GWIS gives a unified view of fire danger distribution across various regions. https://gwis.jrc.ec.europa.eu/

[26] Van Wagner, C.E. and T.L. Pickett. 1985. Equations and FORTRAN program for the Canadian Forest Fire Weather Index System. *Forestry Technical Report*. Canadian Forestry Service, Ottawa, Canada. https://purl.org/INRMM-MiD/c-14026112. See also: Wang, Y.; et al. 2015. Updated source code for calculating fire danger indices in the Canadian Forest Fire Weather Index System. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta. Information Report NOR-X-424. https://cfs.nrcan.gc.ca/publications?id=36461

[27] Pearce H.G. and J.R. Moore. 2004 Use of long-term fire danger data sets to predict fire season severity. Forest Research Client Report. (Fendalton, Christchurch).

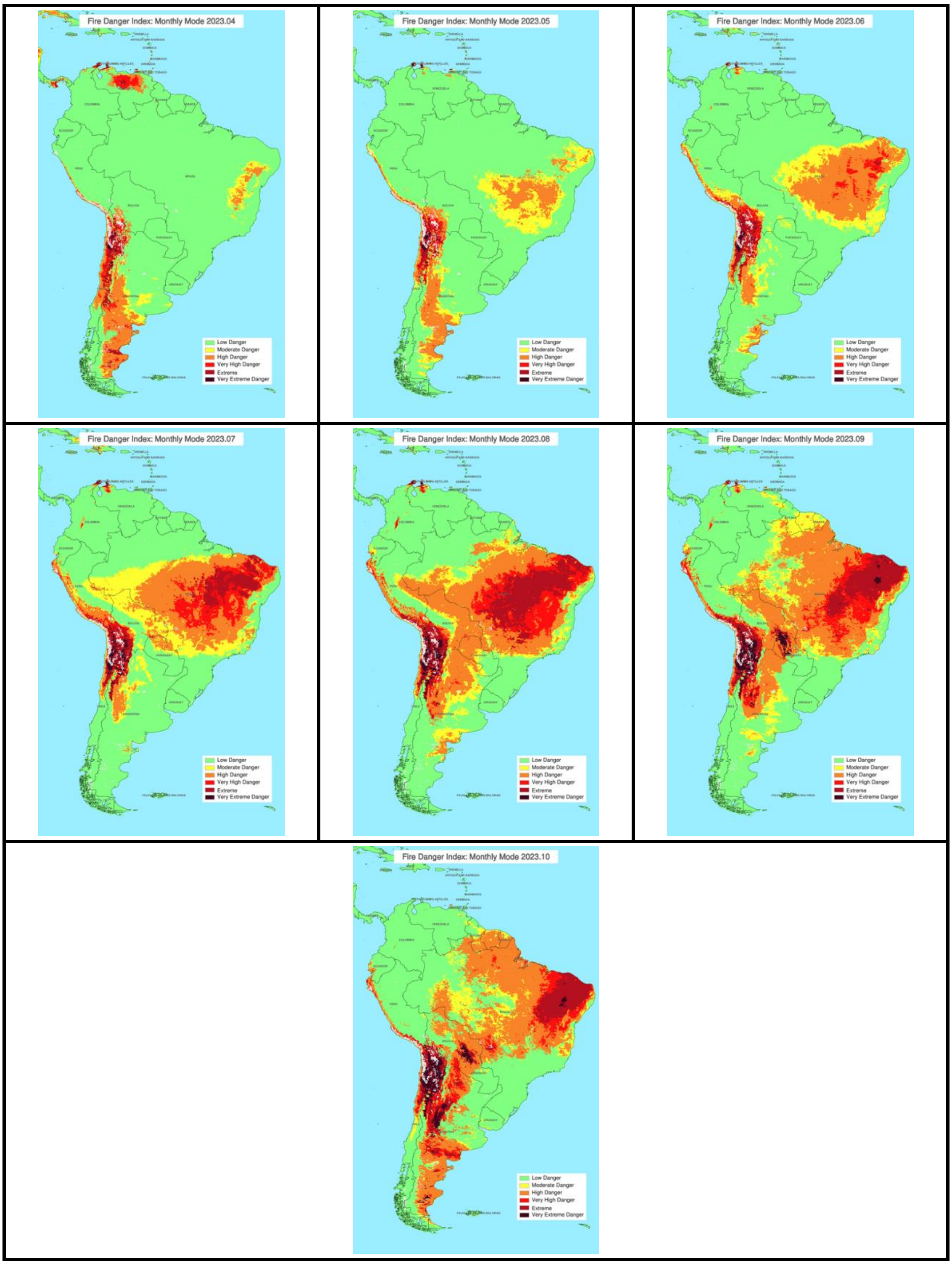

Figure 15: *Fire danger - monthly mode, expressed by the Fire Weather Index (FWI) classes. Left-to-right, top-to-bottom: FWI monthly maps for April to October 2023. Data source: Global Wildfire Information System (GWIS)*[25].

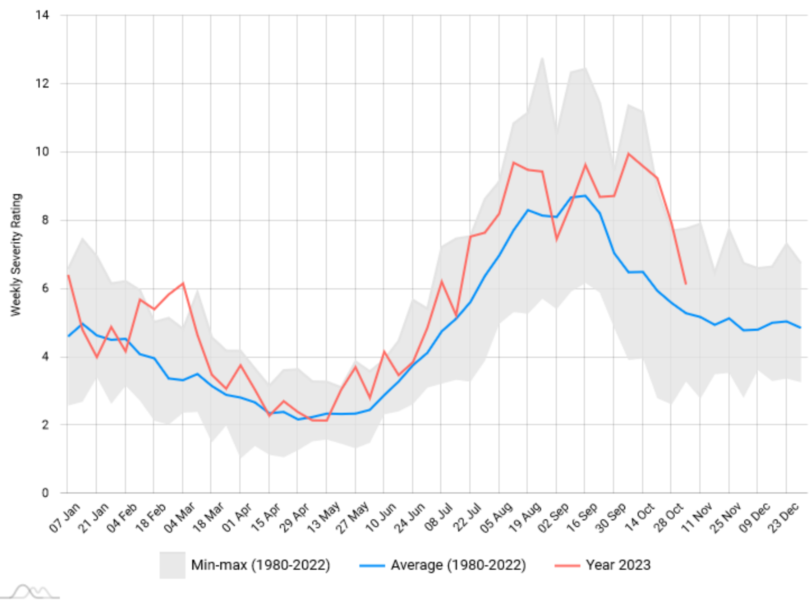

Figure 16: *Weekly Severity Rating (WSR) for South America in 2023 (red line). The blue line represents the average WSR for the period 1980-2022. The grey area represents the maximum and minim values of WSR for the period 1980-2022. Data source: Global Wildfire Information System (GWIS)* [25].

Seasonal forecast

From November 2023 to January 2024, drier-than-average conditions (baseline 1981-2016) are predicted for the most of the southern regions of the Amazon River basin, Bolivia and eastern Brazil. Wetter–than-average conditions are predicted in north-western South America (Colombia, Ecuador, Peru; Fig. 17)

According to the Copernicus C3S seasonal forecasts[28] up to December 2023, warmer-than-usual conditions are likely to occur in the whole of South America (Fig. 18). Precipitation forecasts point to drier-than-average conditions in most of South America with the severest anomalies in central-eastern Brazil. Wetter than average conditions are predicted only for the north-western and central-eastern regions of South America (Fig. 19).

In December 2023, temperature anomalies are forecasted to decrease (Fig. 20), but still be above average in the north-eastern parts of Brazil. The rest of the Amazon region should see temperatures closer to the average.

The probability of occurrence of low flow anomalies (compared with the seasonal discharge thresholds generated using the GloFAS seasonal reforecast[29]) for the major basins from November 2023 to February 2024, is high or moderate over the Amazon region and almost the whole northern and central regions of South America. High flow anomalies are predicted only for some streams in the northern pacific coastal regions (Fig. 21).[30] The prolonged lack of precipitation, the severe heatwaves, and the warmer-than-average and dry forecast drive the low flow predictions.

[28] https://climate.copernicus.eu/seasonal-forecasts

[29] https://www.globalfloods.eu/technical-information/glofas-seasonal/

[30] The analysis is based on the open source LISFLOOD hydrological model outputs driven by 51 ensemble members of the ECMWF SEAS5 forecast. For more information: https://ec-jrc.github.io/lisflood/

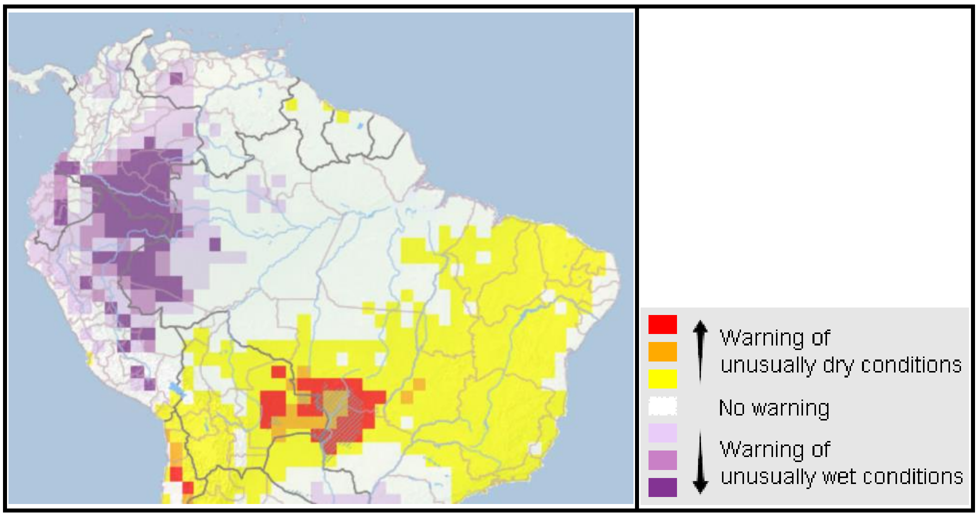

Figure 17: Indicator for Forecasting Unusually Wet and Dry Conditions, November 2023 - January 2024 (based on ECMWF SEAS5).[31]

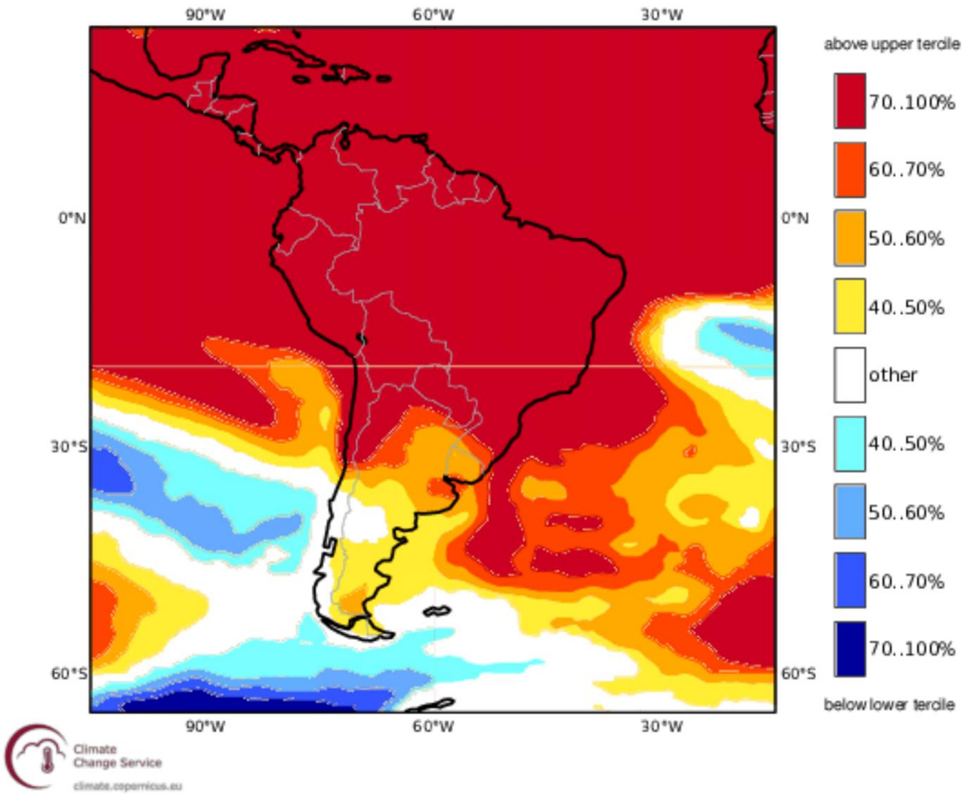

Figure 18: *Temperature (most likely category) multi-system seasonal forecast, November 2023 – January 2024. Source: Copernicus C3S[28].*

[31] For more details on the Indicator for Forecasting Unusually Wet and Dry Conditions, and the other GDO and EDO indicators of drought-related information used in the report, see the Appendix at the end of the document.

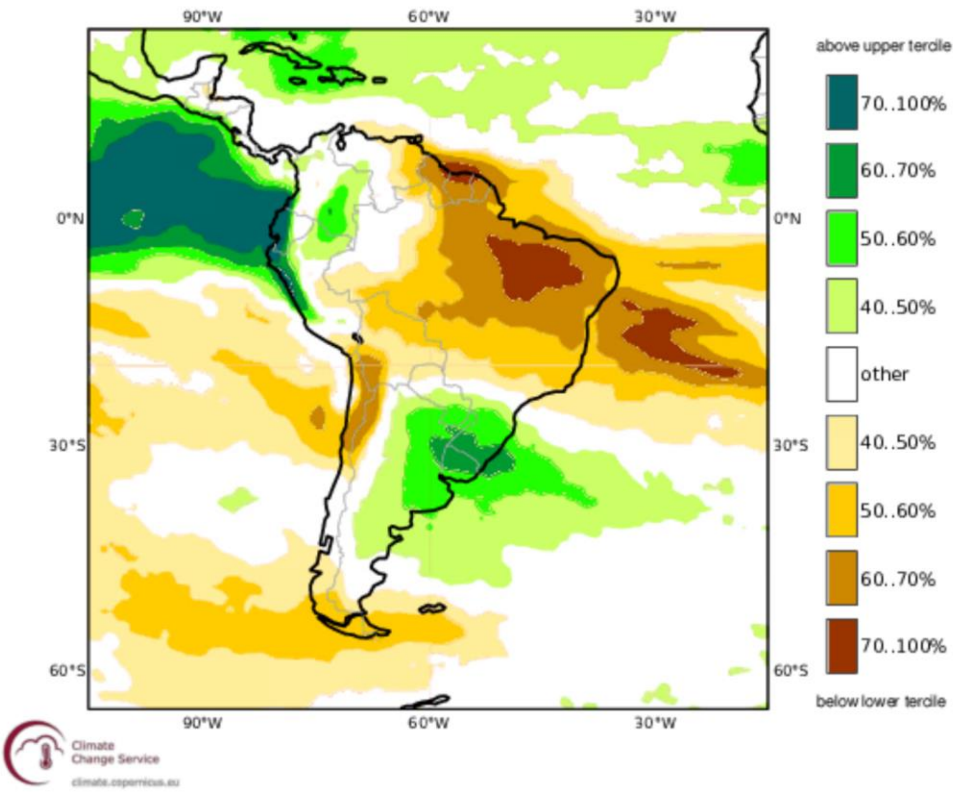

Figure 19: *Precipitation (most likely category) multi-system seasonal forecast, November 2023 – January 2024. Source: Copernicus C3S*[28].

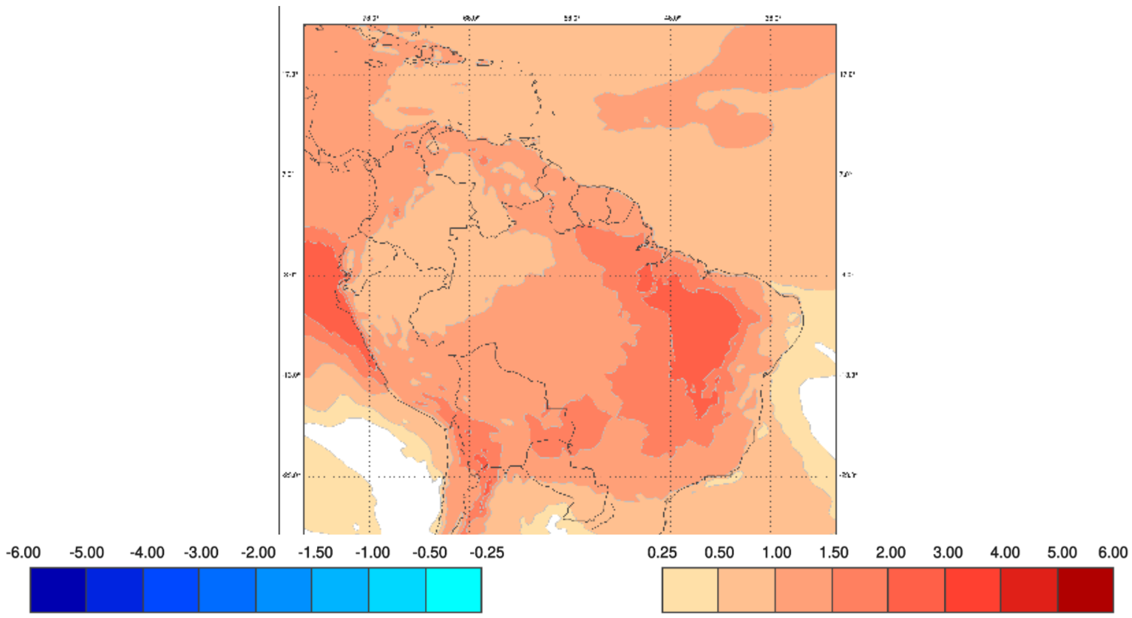

Figure 20: Mean temperature anomalies (°C) forecast for December 2023. *Data source: Global Wildfire Information System (GWIS)* [25].

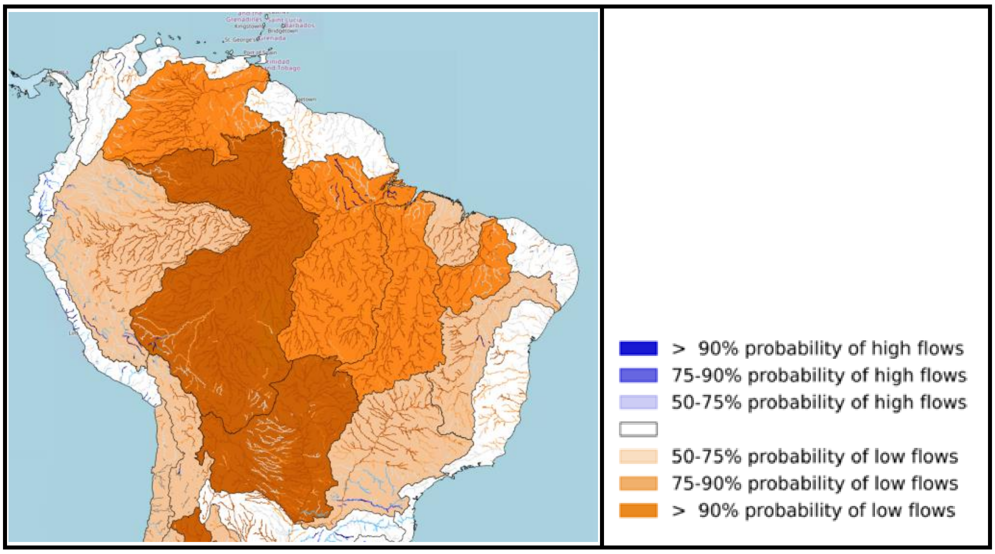

Figure 21: *Maximum probability [%] of high (> 80th percentile) or low (< 20th percentile) river flow, during the 4-month forecast horizon (November 2023 – February 2024) for basins and river network. Source: CEMS Global Flood Awareness System (GloFAS).*[32]

Reported impacts

Amongst the observed impacts of the current drought, in the Brazilian Amazon in the Tefé Lake (500 km far from Manaus) over 120 Amazon River dolphins ("botos cor de rosa") were found dead after the water reached 40 °C, an unprecedented record for the region[33].

The drought has had impacts on the entire Amazon basin. According to the latest bulletin from CEMADEN[4], 59 of the 62 municipalities in the state of Amazonas are in an emergency situation, and 146,000 families (i.e. about 590 thousand people) have been affected. More recently, the Brazilian Navy, through the Hospital Assistance Ship Soares de Meirelles, in joint action with the Army and local authorities, distributed more than 6,000 basic food baskets and 1,100 boxes of mineral water in the municipalities of the Alto Solimões region. Distribution began in the municipality of Tabatinga, close to the border with Colombia and Peru. Many riverside communities experienced difficulties for mobility: rivers represent the main transport routes to the interior of the state and, with low levels, large boats do not have the required navigation conditions. Also the distribution of essential supplies have been affected.[34] With rivers levels below normal, the production flow and the supply of basic inputs are affected. According to the Brazilian Association of Cabotage Shipowners (ABAC), current measurements of waterway levels indicate that the initial projection of loss of impact on navigation has intensified: more than 60% of what should be transported may no longer be transported during this period.

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32 https://www.globalfloods.eu

33 https://noticias.uol.com.br/colunas/carlos-madeiro/2023/09/29/morte-em-massa-de-botos-da-amazonia-choca-pesquisadores-sem-precedentes.htm

34 https://www.cnnbrasil.com.br/nacional/nivel-do-rio-negro-para-de-descer-pela-primeira-vez-em-mais-de-130-dias/

Drought in the Amazon basin - November 2023

JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) - GDO data up to 30/10/2023

Appendix: GDO and EDO indicators of drought-related information

- The Standardized Precipitation Index (SPI) provides information on the intensity and duration of the precipitation deficit (or surplus). SPI is used to monitor the occurrence of drought. The lower (i.e., more negative) the SPI, the more intense is the drought. SPI can be computed for different accumulation periods: the 3-month period is often used to evaluate agricultural drought and the 12-month (or even 24-month) period for hydrological drought, when rivers fall dry and groundwater tables lower.
- The Heat and Cold Wave Index (HCWI) is used to detect and monitor periods of extreme-temperature anomalies (i.e., heat and cold waves) that can have strong impacts on human activities, health and ecosystem services such as sprouting of crops. It is based on the persistence for at least three consecutive days of events with both daily minimum and maximum temperatures (Tmin and Tmax) above the 90th percentile daily threshold (for heat waves) or below the 10th percentile daily threshold (for cold waves). For each location, the daily threshold values for Tmin and Tmax are derived from a 30-year climatological baseline period (1991-2020), using the GloFAS/ERA5 derived temperature data.
- Lack of precipitation induces a reduction of soil water content. The Soil Moisture Anomaly provides an assessment of the deviations from normal conditions of root zone water content. It is a direct measure of drought associated with the difficulty of plants in extracting water from the soil.
- The Indicator for Forecasting Unusually Wet and Dry Conditions provides early risk information for Europe. The indicator is computed from forecasted SPI-1, SPI-3, and SPI-6 derived from the ECMWF seasonal forecast system SEAS5.
- Check https://edo.jrc.ec.europa.eu/factsheets for more details on the GDO and EDO indicators.

Glossary of terms and acronyms

ABAC:	Association of Cabotage Shipowners (Brazil)	GWIS:	Global Wildfire Information System of CEMS
ANA:	National Water Authority (Brazil)	HCWI:	Heat & Cold Wave Index
ASAP:	Anomaly Hotspots of Agricultural Production	IDI:	Integrated Drought Index
CEMADEN:	National Centre for Monitoring & Early Warning of Natural Disasters (Brazil)	INMET:	National Institute for Meteorology (Brazil)
CEMS:	Copernicus Emergency Management Service	INPE:	National Institute for Space Research (Brazil)
CHIRPS:	Climate Hazards Group InfraRed Precipitation with Station data	JRC:	Joint Research Centre of the European Commission
SGB-CPRM:	Geological Survey of Brazil	KNMI:	Royal Netherlands Meteorological Institute
DSR:	Daily Severity Rating	LFI:	Low-Flow Index
EC:	European Commission	NDVI:	Normalized Difference Vegetation Index
ECMWF:	European Centre for Medium-Range Weather Forecasts	NOAA:	National Oceanic & Atmospheric Administration (USA)
EDO:	European Drought Observatory of CEMS	SENAMHI:	National Meteorological & Hydrological Service (Brazil)
ERA5:	ECMWF Reanalysis v5	SMA:	Soil Moisture Anomaly
ERCC:	European Emergency Response Coordination Centre	SPI:	Standardized Precipitation Index
ESI:	Evaporative Stress Index	STAR:	Centre for Satellite Applications & Research (USA)
FWI:	Fire Weather Index	VIIRS:	Visible Infrared Imaging Radiometer Suite
GDO:	Global Drought Observatory of CEMS	WMO:	World Meteorological Organization
GloFAS:	Global Flood Awareness System of CEMS	WSR:	Weekly Severity Rating

Drought in the Amazon basin - November 2023

JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) - GDO data up to 30/10/2023

GDO and EDO indicators versioning

The GDO and EDO indicators appear in this report with the following versions:

GDO, EDO indicator	Version
▪ fAPAR (fraction of Absorbed Photosynthetically Active Radiation) Anomaly (VIIRS)	*v.1.0.0*
▪ Ensemble Soil Moisture Anomaly (SMA)	*v.3.0.1*
▪ Indicator for Forecasting Unusually Wet and Dry Conditions	*v .1.1.0*
▪ Standardized Precipitation Index (SPI)	*v.1.0.0*
▪ Heat and Cold Wave Index (HCWI)	*v.1.0.0*
▪ Meteorological Drought Tracking (ERA5)	*v.1.0.0*

Check https://edo.jrc.ec.europa.eu/download for more details on indicator versions.

Distribution

For use by the ERCC and related partners, and publicly available for download at GDO website: https://edo.jrc.ec.europa.eu/reports

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Authors

European Commission, Joint Research Centre, Dir. E Space, Security & Migration, Disaster Risk Management Unit - Drought Team

Toreti A. [i] *(Team Leader)*
Bavera D. [ii]
Acosta Navarro J. [i]
Arias Muñoz C. [iii]
Barbosa P. [i]
de Jager A. [i]
Fioravanti G. [i]
Hrast Essenfelder A. [i]
Maetens W. [i]
Masante D. [i]
Magni D. [ii]
Mazzeschi M. [iv]

CEMADEN - Centro Nacional de Monitoramento e Alertas de Desastres Naturais

Marengo J. A.
Cunha A. P.

European Commission, Joint Research Centre, Directorate D Sustainable Resources, Food Security Unit

Rembold F. [i] *(Team Leader)*
Meroni M. [v]

European Commission, Joint Research Centre, Dir. E Space, Security & Migration, Disaster Risk Management Unit - Wildfire Team

San Miguel J. [i] *(Team Leader)*
Oom D. [i]
Branco A. [i]
Libertà G. [i]

European Commission, Joint Research Centre, Dir. E Space, Security & Migration, Disaster Risk Management Unit - Floods Team

Salamon P. [i] *(Team Leader)*
McCormick N. [i]
Grimaldi S. [i]

[i] European Commission Joint Research Centre, Ispra, Italy
[ii] Arcadia SIT, Vigevano, Italy
[iii] NRB, Italy
[iv] Uni Systems, Luxembourg
[v] Seidor, Milan, Italy

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