Sidebar 7.3: **Major floods in the Amazon**—G. Koren

The Amazon forest has experienced several extreme events in the last decade, including large-scale floods and droughts. In 2021, with La Niña conditions present most of the year, the Amazon experienced higher-than-normal precipitation, leading to anomalously high river discharge and floods in downstream regions. Here, a quantification of the severity and extent of these anomalies are reported, including an assessment of the societal impacts of these extreme events, which coincided with the ongoing COVID pandemic.

Earlier major floods occurred in 2009, following extreme rainfall that progressed from the western to eastern part of the Amazon during the first months of that year (Filizola et al. 2014). A few years later, in 2012, record-high water levels were reached in the Manaus Port, as a result of excess atmospheric moisture supply in the preceding months, focused mostly on the western part of the Amazon basin (Satyamurty et al. 2013). There were also major floods in 2014, but these were located primarily in the southwestern region of the Amazon basin (Espinoza et al. 2014).

Precipitation anomalies

An overview of precipitation estimated by CHIRPS (Funk et al. 2015) over the Amazon forest and surrounding regions is presented in Fig. SB7.4. The map shows the accumulated precipitation anomalies over the first four months of 2021. These anomalies were calculated with respect to the 1991–2020 baseline, which includes the aforementioned wet years, but also

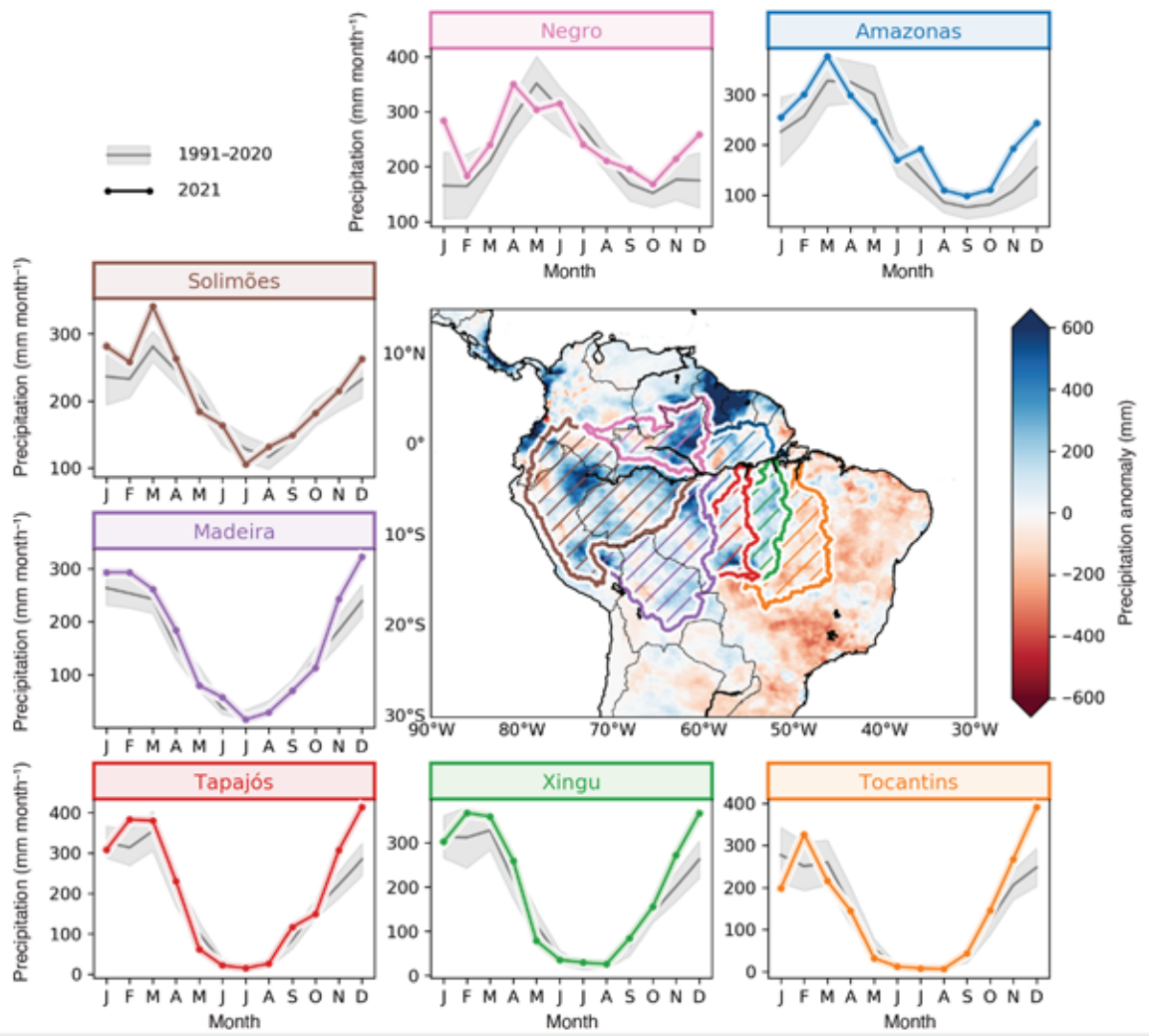

Fig. SB7.4. Precipitation (mm month^{-1}) over the Amazon forest and surrounding areas. The map shows the accumulated precipitation anomalies over Jan–Apr 2021, relative to the baseline 1991–2020. The time series plots show the mean precipitation (gray line) and its standard deviation (gray shading) with the 2021 precipitation averaged over the Tocantins basin (orange) and sub-basins of the Amazon (other colors). The location of these (sub-)basins follows the HydroBASIN definition (Lehner and Grill 2013) and is illustrated by the corresponding color in the map. (Source: CHIRPS [Funk et al. 2015].)

the dry years 2010 (Lewis et al. 2011) and 2015–16 (Koren et al. 2018). Across the Amazon basin, above-average precipitation anomalies were dominant, and are linked to strengthening of the Walker circulation (Espinoza et al. 2022). High rainfall totals are also apparent north of the Brazilian Amazon, in Guyana and Suriname, whereas drier-than-usual conditions were found to the east of the Amazon, in the Caatinga and Cerrado regions.

The temporal variation of precipitation averaged over the Tocantins basin and several sub-basins of the Amazon basin was calculated using the HydroBASIN definitions from Lerner and Grill (2013) and is included in Fig. SB7.4. The climatologies (gray lines and shading) reveal a substantial difference between the dry season minima for the northwestern sub-basins (e.g., always exceeding 100 mm month^{-1} for the Negro sub-basin), whereas precipitation over the Xingu sub-basin remained for a period of roughly five months below the 100 mm month^{-1} threshold. Focusing on the 2021 precipitation (colored lines), it is clear that both the start and end of the year 2021 were anomalously wet, whereas the drier period in the middle of the year was not exceptional. There is also a spatial dependency in the anomalies: the western sub-basins (e.g., Solimões) experienced high anomalies in the early part of 2021, whereas for the southeastern (sub-)basins (e.g., Xingu, Tocantins), the wet anomalies at the end of 2021 are most pronounced.

River discharge and floods

The anomalous rainfall in 2021 resulted in extreme discharge in the Amazon basin. Discharge measurements from the Óbidos station, which is situated along the Amazon River and drains an area of approximately 4.7 million km2 (van Schaik et al. 2018), show positive anomalies throughout the year, even exceeding 2-σ standard deviation (Fig. SB7.5). To verify that this is not simply resulting from the intensification of the hydrological cycle in the Amazon (Barichivich et al. 2018), the effect of removing the long-term linear trend is also included.

Figure. SB7.5 also contains a map of discharge anomalies from the GloFAS-ERA5 reanalysis product v3.1 (Harrigan et al. 2020) integrated over the period March–June (the integration period was delayed by two months relative to the map in Fig. SB7.4, as the discharge peaks for Óbidos were delayed by roughly two months relative to the peaks in rainfall). Spatial patterns in the discharge anomalies resemble the precipitation anomalies in Fig. SB7.4, with positive anomalies in the Amazon basin and the Guyanas, whereas the Cerrado and Caatinga areas to the southeast of the Amazon show negative anomalies.

Impacts

The floods during May and June affected several villages and cities around the Amazon River, including the Amazonas state capital Manaus. The town Anamã with its ~13,000 inhabitants, which is situated alongside the Amazon river in the Solimões region, was completely flooded. Unfortunately, the floods coincided with high infection rates of COVID-19 in this region, complicating evacuations and other means to manage the flood impact.

Several months later, at the end of 2021, regions outside the Amazon forest also experienced heavy rainfall, culminating in major floods in the northeastern state of Bahia. Two dams in the region collapsed, leading to major floods that resulted in severe damage and casualties in the city of Itabuna with its ~200,000 inhabitants. The impacts of these extreme events extend into 2022.

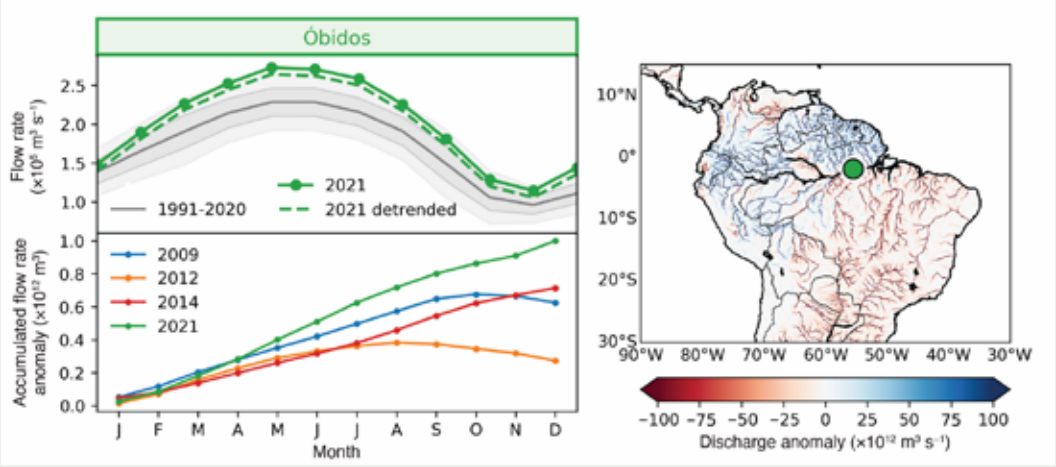

Fig. SB7.5. River discharge (m^3 s^{-1}) from in situ observations. The time series plot (top panel) shows the mean climatology (gray solid line) and the 1 std. dev. (dark gray shading) and 2 std. dev. (light gray shading) areas are indicated, alongside the discharge for 2021 (green line) for the Óbidos station. The bottom panel shows the accumulation of the discharge anomaly over time for four recent wet years (2009, 2012, 2014, and 2021). The map shows GloFAS discharge anomalies for Mar–Jun 2021, and the location of the Óbidos station is indicated (green circle). (Source: National Water Agency of Brazil (ANA 2021) and the GloFAS-ERA5 reanalysis product v3.1 [Harrigan et al. 2020].)