AMAZONIAN TRAJECTORIES

River Monitoring Network

Under Present And Future Scenarios

Tigre River

Key Messages

- Amazonian rivers connect the Andes to the Atlantic, transporting water, sediments, minerals, and nutrients, while supporting biodiversity, energy, transportation, and other functions.
- Along rivers, water balance is the outcome of complex atmospheric-surface and surface-groundwater interactions.
- Currently, countries monitor rivers using hydrological and water quality stations but without an extensive regional discussion on the spatiotemporal density of collected data. However, present and future external forcing, such as anthropogenic activities and climate change introduce disturbances to the measured river parameters.
- Countries need to address the following questions: *Which processes modify hydrological and water quality river parameters? Do monitoring designs need to consider atmospheric-surface and surface-groundwater interactions? Which technical measures and regulations are required to optimally monitor present and future hydrological and water quality processes?*

POLICY BRIEF No. 7

ACTO
Amazon Cooperation Treaty Organization

ARO
AMAZON REGIONAL OBSERVATORY


Guama River

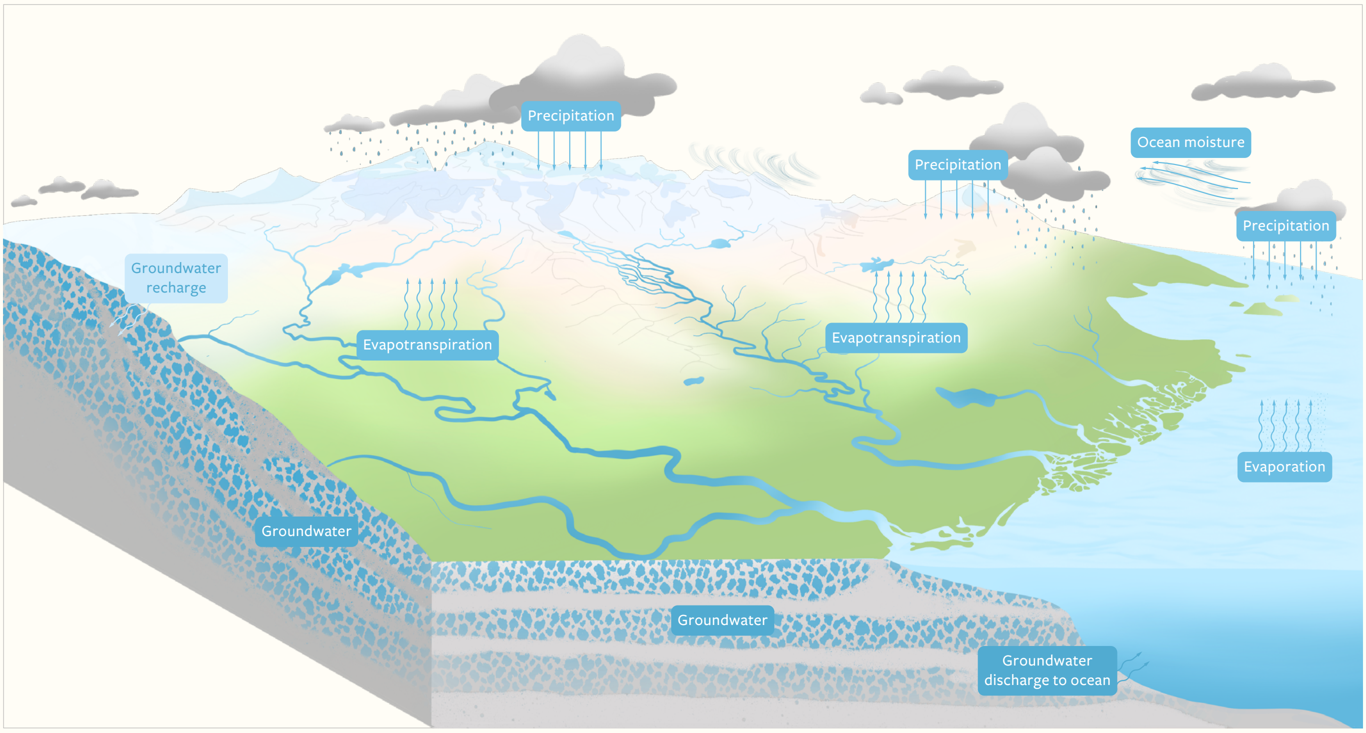
Complex hydrological processes

The Amazon River Basin, the world's largest watershed, spans eight countries from the Andes to the Atlantic Ocean (~6.1 million km²). With an average annual discharge of ~206,000–210,000 m³/s, it delivers about 20% of global freshwater to the oceans. Basin hydrology reflects complex interactions among high rates of rainfall with large spatial and temporal variability, oceanic influences, dense tropical forests, diverse topography, extensive floodplains, and large seasonal changes in freshwater storage and discharge.[1,2] High precipitation in the region results from complex interactions among large-scale and local processes, notably oceanic moisture supply and forest evapotranspiration (Fig. 1). These mechanisms regulate rainfall, not only locally but also regionally. Examples of this mechanism are the Amazon's "flying rivers", which transport moisture beyond the basin and support agriculture and hydropower across South America. The region is also globally significant for its rich biodiversity[3] and key role in climate regulation, acting as a major carbon sink in recent decades.[4]

The Amazon's floodplain is the largest and most biodiverse on Earth, roughly one-sixth of Amazonian tree diversity depends on floodplain habitats.[5] Ongoing deforestation (including floodplain degradation), wildfires, and climate change, threaten to push parts of the forest toward a "tipping point", with potential savannization and a shift of these regions to carbon sources.[4] Moreover, anthropogenic change (especially deforestation) combined with climate change are already disturbing the water cycling and the measured hydrological and water quality parameters, including sediment transport (Fig. 2). Over the long-term, these changes could undermine the region's provision of critical ecosystem services and affect economies and societies within and beyond the Amazon basin.

Several studies have suggested that groundwater in the Amazon basin plays a major role in the hydrological and ecological cycles,[2,6,7] and largely influence the rainforest ecosystems and climate variability, especially during the dry season, where the increasing frequency of unprecedented droughts indicates a potential tipping point.[8] Droughts disrupt navigation and transport, agriculture, and power supply. To better understand these effects and manage this transboundary resource, more targeted studies are needed in response to an altered climate and landscape.[7] ACTO's Amazon Aquifer Project (GEF 11108) directly addresses surface-groundwater interactions.

Figure 1. Global hydrological processes.[23]



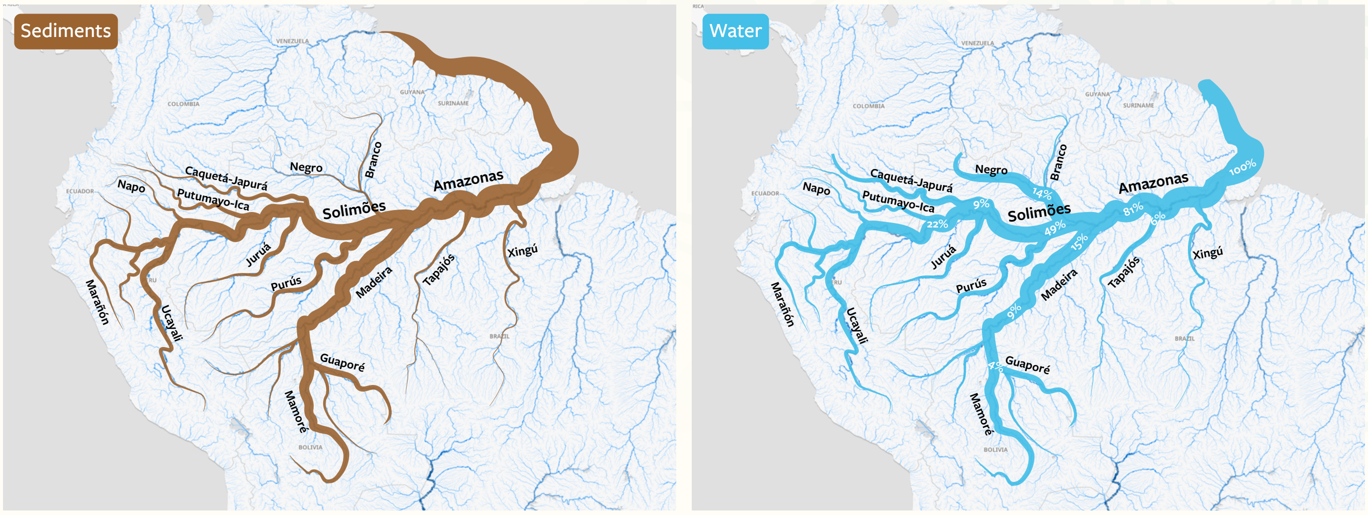


Figure 2. River processes. [22]

Climate change trajectories

Climate change is intensifying the global hydrological cycle, altering average and extreme hydroclimatic patterns worldwide. In the Amazon, temperatures have risen by ~0.15°C/decade since 1950, rainfall regimes are shifting, and the dry season has lengthened by ~6.5 days/decade since 1979 over the Southern Amazon.[9] Climate change is also expected to increase the frequency, intensity, and extent of hydrological extremes in the Amazon basin. There is observational evidence of intensified extremes in streamflow with trends of decreasing low flows in southern Amazonia and increasing flood flows across the region.[10] Modeling studies reveal declining trends in future water availability (precipitation, runoff, discharge), with stronger impacts under high-emissions scenarios and during low-water months.[11,12] While climatic impacts vary largely spatially, the Brazilian Amazon appears particularly vulnerable to declines in annual river discharge.[13] Significant reductions in annual and seasonal discharge are projected for the Madeira, Purus, Tapajós, and Xingu subbasins,[11] with recent estimates suggesting 14–20% losses in annual water availability for Abacaxis, Javari, and Trombetas, and 11–14% for other major subbasins under high emissions.[12] In terms of extremes, climate models project longer dry seasons, reduced dry-season rainfall and more frequent droughts for most of the basin, except for the western Amazonia where wet events may increase and droughts may lessen.[14]

Recent work has investigated the role of the contributions of climate change and deforestation in the Amazon basin, which highlights the major role of deforestation in driving the reductions in dry-season precipitation over the past 35 years.[15] As observed in Fig. 3, projected precipitation patterns for 2030 and 2050 imply substantial changes in runoff and water quantity changes at Amazonian gaging stations. A regionally coordinated monitoring design is therefore essential.

Nanay River

ANTHROPOGENIC CHANGE

Pressures from alluvial mining, agriculture, pasture ranching, deforestation, and oil development in the Amazon basin have increased in recent years, threatening water resources and affecting vulnerable riverine communities. Hydropower dams alter flow regimes through their operations[16] and can modify water and sediment boundary conditions if placed along the Andes-lowland transition.[17] Minimizing further damage requires considering diverse environmental impacts at the basin scale.

HYDRO-DEPENDENCY: THE CASE FOR A REGIONAL MONITORING SYSTEM

The Amazon's hydrological system sustains millions of people and safeguards biodiversity and ecosystem services. This hydro-dependency is a complex, reciprocal relationship where the very existence of the rainforest is dependent on its own internal hydrological cycle. "Flying rivers" depend on the massive evaporation from the Amazon's vast river network and dense forest illustrate this coupling. Annually, the Amazon basin recycles an estimated amount of 24% to 35% of its water, which supplies tropical glaciers, páramos, and major cities[18]. These connections transcend political borders and directly link the Amazon's health to the food and water security of the South America continent.

The region's connectivity is multilayered, involving longitudinal, lateral, vertical, temporal, biocultural, and socio-bioeconomic dimensions.[18] Much biological diversity happens longitudinally (up and down the river) and laterally (from the river channel to the floodplain and surrounding landscape), creating natural ecological corridors with specific environmental conditions that dictate where species occur and facilitate their movement across the landscape[19]. An example of this connectivity is the migratory journey of the goliath catfishes (*Brachyplatystoma spp.*), which migrates thousands of kilometers between the Amazonian lowlands and the Andes, representing the longest strict freshwater migration known.[20]

The reliance of populations, economies and ecosystems on water resources is a key part of the multidimensional connections that exist within the basin, where human communities and natural systems are intertwined with its rivers. Indigenous peoples and traditional communities are directly dependent on rivers for their economic, cultural and social survival. Therefore, any changes in water quality or quantity directly threaten the health and way of life of these communities.

Juruena River

DEVELOPING PROTOCOLS FOR A CHANGING ENVIRONMENT

As observed in Fig. 3, the Manacapuru gaging station has recorded decreasing water-surface elevations in recent years, with implications for fluvial transport, which may intensify by 2030 and 2050.

Given heterogeneous climate-driven changes in precipitation, water discharge along rivers will also vary. In response ACTO, together with Country Members, has developed the Amazon Monitoring Network module to analyze river regimes and its correlation to mesoscale or regional phenomena, aligned with global-change contexts. In accordance with the standards of the World Meteorological Organization (WMO), whose experience in standardizing procedures is recognized, ACTO has produced a set of recommendations on river monitoring. These recommendations were approved by the Amazon Network of Water Authorities (RADA) as their Regional Protocols for the Amazon Hydrological Network (RHA) and the Water Quality Network (RCA). The protocols cover: 1) Adaptation, installation and operation of RHA and RCA monitoring stations, 2) field analysis and sample collection, 3) verification, processing, storage, provision, security and publication of data, 4) guidance on flows and responsibilities for implementation, operation and publication of RHA and RCA data. These protocols conclude with the indication of processes for integrating data from each country and its relationship with the interoperable databases of the Amazon Regional Observatory (ORA) in the context of regional water resources, enabling scenario planning across meso-geographical and temporal scales and supporting sustainable, cooperative management of transboundary rivers. This initiative will strengthen monitoring for both current conditions and future scenarios.

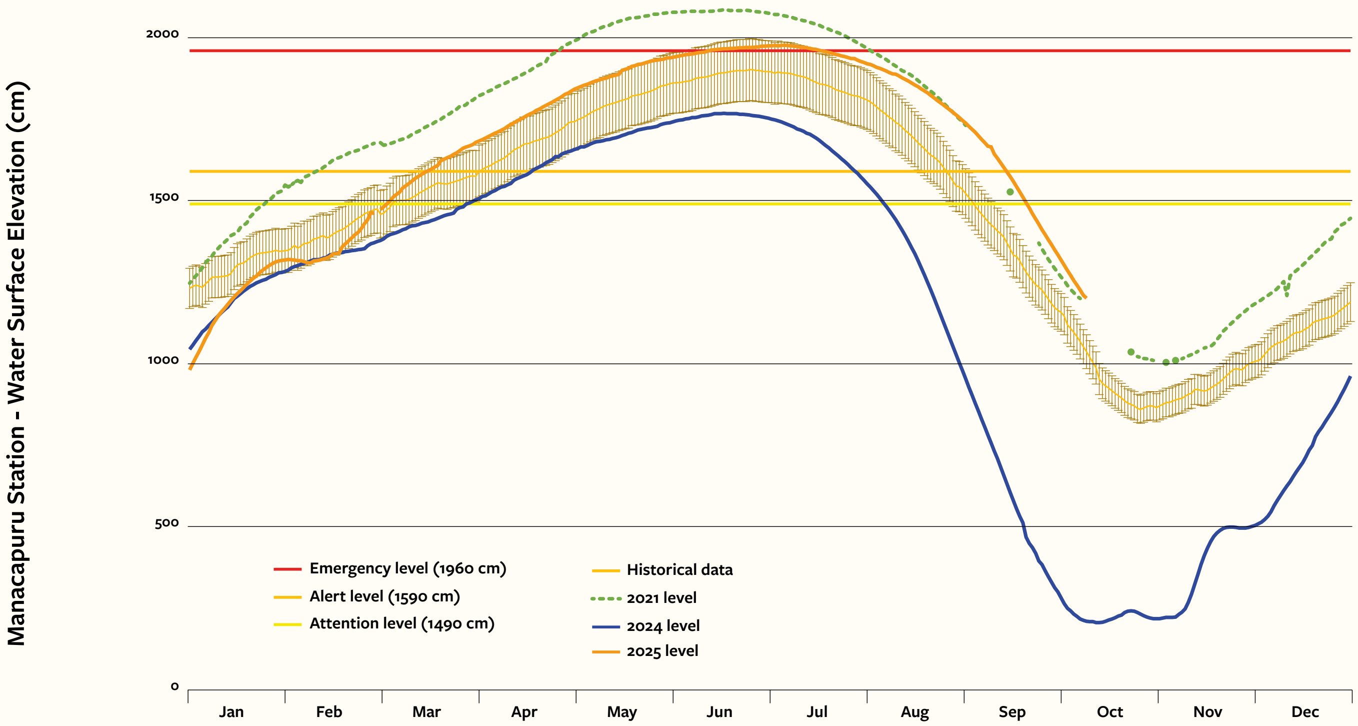


Figure 3. Water Surfave Elevation at the Manacapuru Station

Recommendations

STRENGTHEN CLIMATE ADAPTATION VIA AN IMPROVED MONITORING SYSTEM

Carefully-planned climate adaptation is expected to help countries mitigate the harm associated with climate change. Countries should contribute toward the development of an enhanced river basin monitoring system to (1) improve detection of climatic trends enabling more efficient adaptation responses; (2) better understand of the available water resources, which will, in turn, improve water management systems; (3) better-inform decisions in water allocation, infrastructure design, agriculture and/or energy planning; (4) improve of real-time hydrometeorological warning systems to minimize economic losses during extreme flood/drought events; (5) develop of a transboundary hydrologic modeling system that will assess the river response to global changes; (6) complement in-situ measurements with remote-sensing estimations of hydrological and water quality parameters, and (7) include a groundwater monitoring network and its correlations to surface processes.

SUSTAIN CLIMATE MITIGATION

Continued regional commitment to climate mitigation is vital as climate impacts on Amazon's water resources are projected to intensify under higher global warming levels. Over the long-term, ambitious actions raise the chances of limiting global warming to below 20°C, reducing the risk of severe climatic impacts and improving the effectiveness of water-sector climate adaptation. In this regard, Nationally Determined Contributions (NDCs) and Long-Term Low Emission Development Strategies (LT-LEDS) are key tools for advancing ambitious mitigation. Additionally, controlling deforestation is vital to preserve the Amazon's ecosystem services, including freshwater supply basin-wide and across South America.

DESIGN THE REGIONAL SYSTEM AROUND CONNECTIVITY AND COUPLE PROCESSES

Regional monitoring should be designed including surface and groundwater interactions and Andes-to-Atlantic connectivity (including Guyana, Suriname and Venezuela).

Tributary of the Amazon River

Amazonian Trajectories

Hydrological and water quality stations are located throughout the Amazon basin (Fig. 4). Some of the gaging stations are located in regions where positive and negative variations of precipitation patterns are projected for 2030 and 2050 Amazonian climatic trajectories. Precipitation converts into runoff, and then as water discharge along the rivers. Depending on the climatic trajectories, some stations will detect the increase and decrease on the magnitude of the hydrological parameters.

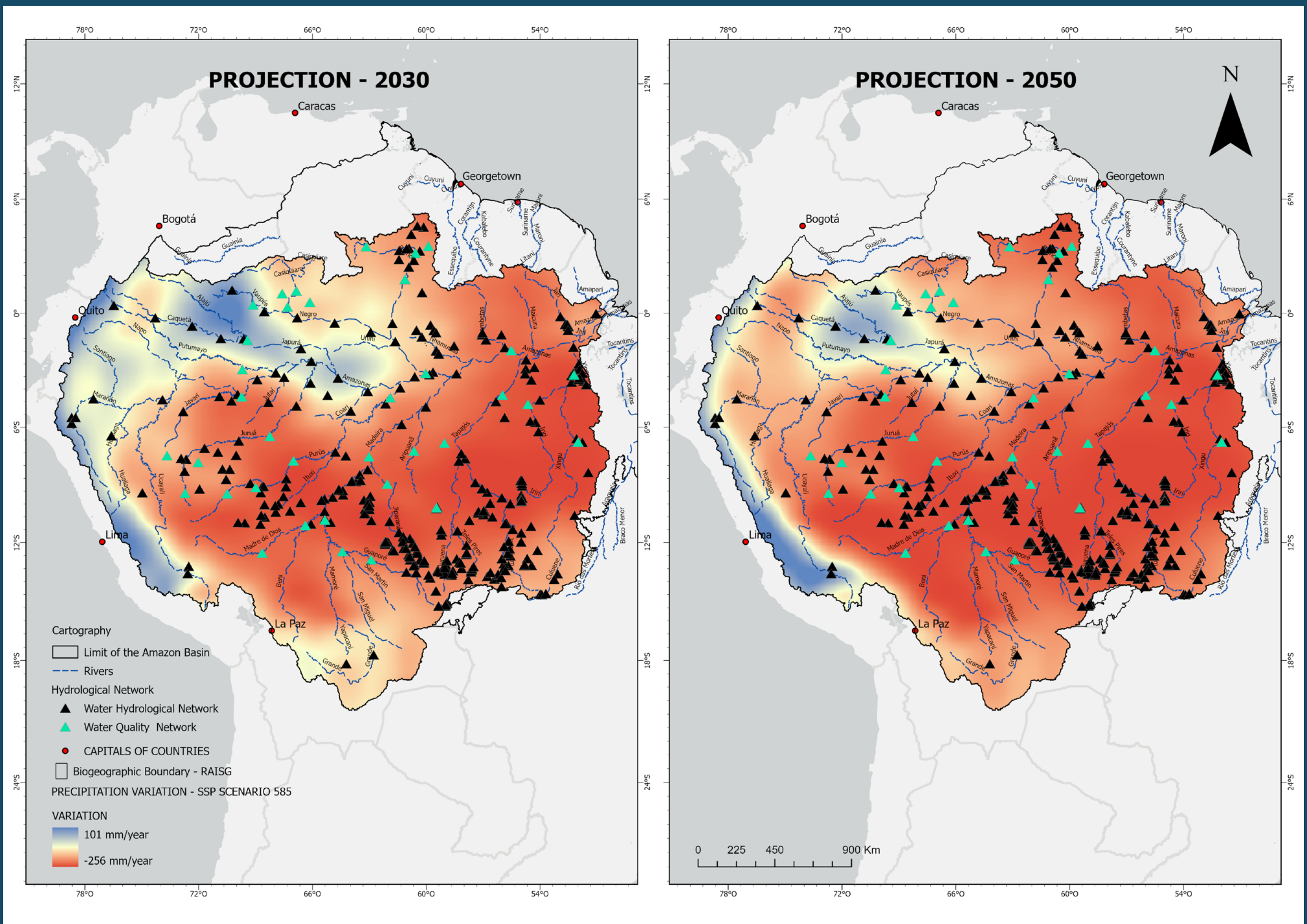


Figure 4. CMIP6 multimodel ensemble mean of precipitation (mm/year) projected change in 2030 and 2050 for the SSP-585 scenario (high emission)[21] and Amazon River network (hydrology and water quality).

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AMAZON REGIONAL OBSERVATORY (ARO)
ARO is ACTO's reference center that integrates data, tests innovations, and disseminates information to support member countries in cooperation and decision-making.

AMAZON COOPERATION TREATY ORGANIZATION (ACTO)
ACTO is an intergovernmental organization formed by eight Amazon countries: Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, and Venezuela, which signed the Amazon Cooperation Treaty, making it the only socio-environmental bloc in Latin America.

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