2021 historical flood and 2024 historical drought of the Amazon River: Seamless modelling of their impacts on the Amazon estuary water level

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Abstract

The Amazon estuary conveys the largest river discharge to the global ocean, accounting for about 20% of the global runoff. It connects the Amazon watershed with the western Atlantic Ocean, outflowing at the equator, onto a macrotidal shelf. It is home to a marked variability of the sea surface height over a broad range of timescales, ranging from intra-daily phenomena (tide, surges) to intra-seasonal and seasonal timescales (Amazon flood and drought events) and longer trends (global sea level rise). The tide penetrates upstream over 800 km. Despite its importance in the global water cycle as well as in the socio-economic dynamics of the riparian population, this vast and remote estuarine region remains poorly documented and sparsely observed by sea level monitoring systems.

In this study, we begin by presenting a novel altimetry-based coastal tidal dataset, encompassing the whole shelf located off the mouths of the Amazon delta. Our approach relies on a blending of a large cohort of along-track satellite altimetric datasets, covering the past three decades. Our dataset, of unprecedented spatial resolution, reveals original features of this macrotidal area, such as a prominent variability of the semi-diurnal M2 tidal constituent at seasonal timescales.

The second part of our presentation is dedicated to a seamless barotropic hydrodynamic modeling of the Amazon estuary and delta. Our SCHISM-based model, duly validated against the above-mentioned altimetric tidal atlas, is used to hindcast the record-breaker flood and drought events that occurred recently, in summer 2021 and fall 2024 respectively. Our cross-scale river-delta-ocean modeling framework reveals the spatio-temporal imprint of these recent climate extremes in terms of sea level anomaly, and highlights some of the underlying dynamics. It is concluded that the river discharge anomalies are the main driver of water level anomalies over the upstream half of the estuary (400 km). Further downstream, the water level extremes are rather driven by the ocean tide, primarily. The atmospheric surges generated by trade wind bursts play a sensible role in the overall water level variability, all along the estuary.