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Temporal dynamics of water and sediment exchanges between the Curuaí floodplain and the Amazon River, Brazil

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Summary The fluvial transport and storage of sediments within channel—floodplain systems can act as important sinks of sediments.

In this study, we document the role of an Amazonian floodplain (Curuaí) for sediment storage. Located on the right bank of the Amazon River, 900 km upstream of the mouth, the complex system contains more than 30 interconnected lakes linked to the mainstream by permanent and temporary channels. With an open-water area varying between 600 km^2 and 2500 km^2, it represents ~13% of the total flooded area of the Amazon River, between Manaus and Óbidos. For the period 2000—2003, daily liquid and solid fluxes exchanged between the floodplain system and the Amazon River were determined using an hydrological model based on a network of gauging, meteorological and sediment monitoring stations and satellite data including radar altimetry data. Sediment accumulation occurs during the five months of the flood rise, from December to April. The export of sediments to the mainstream occurs during the low water stage while depositional processes in lakes and channels are disrupted by the wind induced re-suspension of sediments. The mean average sediment storage calculated varies between 558 and 828 $\times$ 10^3 t yr^{-1} correspond-

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ing to 5.4 (±19%) × 10^3 t km^{-1} yr^{-1} of sediment deposited along the 130 km reach between Juruti and Santarem. This annual storage represents between 41% and 53% of the annual flux of sediments entering this floodplain through the main channels. The associated mean specific sedimentation rate is ~517 (±23%) t km^{-2} yr^{-1} leading to a sediment accretion rate of 1.6 mm yr^{-1} ± 23%.

Introduction

The floodplains extension associated to the Amazon River is expected to alter the transport of water from upland watersheds through river systems to the sea (Junk et al., 1989). They store water during the rising stage of the Amazon River and release it when the river level is decreasing. Richey et al. (1989) indirectly estimated that 30% of the Amazon River flow is routed through the floodplain along a 2010 km long reach between São Paulo de Olivença and Óbidos. Floodplains also play a major role in the storage of suspended solids transported from the Andes (Meade et al., 1985). Suspended solid fluxes along the river corridor suggest that more than 80% of the suspended solids entering the floodplains are deposited (Mertes et al., 1996) but the storage in the floodplain is temporary. Dunne et al. (1998) estimated that, in the 2010 km reach, between São Paulo de Olivença and Óbidos, the amount of sediment transferred to bars was 380 Mt yr^{-1} and the amount of sediment transferred from the main channel to the floodplain was 460 Mt yr^{-1} by channelized flow, and 1230 Mt yr^{-1}, by diffuse overbank flow.

During residence in floodplains, floodwaters frequently undergo substantial biogeochemical modifications under the influence of processes such as sorption, redox processes and biota uptake which directly influence the chemistry of the Amazon river surface waters (Junk and Furch, 1985; Richey et al., 1990; Seyler and Boaventura, 2003).

However, both sediment and biogeochemical dynamics are constrained by the spatial and temporal patterns of hydrology which is, in turn, influenced by the topography, soils and vegetation in the floodplain (Mertes et al., 1995). Geomorphologically, the Amazon floodplain is complex (Mertes et al., 1996). Along the Solimões River, it is dominated by scroll-bar topography and hundreds of narrow lakes (Sippel et al., 1991). Downstream, to the confluence with the Madeira River, the floodplain is narrower. From the Madeira confluence to Óbidos, the relatively low and incomplete levee system, breached by large distributary channels, results in the inundation of a wide floodplain, containing hundreds of lakes of irregular outline that appear to be due to subsidence of compacting sediment (Dunne et al., 1998).

There is therefore a great variety among floodplains along the Amazon River and tributaries and their influence on hydrology, sedimentary and biogeochemistry of the main streams is still not well understood. Due to the difficulties in acquiring *in situ* data for remote sites, few direct estimation of the fluxes exchanged between floodplains and rivers have been attempted. To our knowledge, direct water fluxes has only been measured for the Lake Calado (near Manacapuru) on the Solimões River (Lesack and Melack, 1995).

In this paper, we present the results of a study designed to measure and model sediment dynamics of a mid-Amazon floodplain lakes and channels system, the *várzea* (in Brazilian) of Lago Grande de Curuaí. This floodplain formed by large lakes connected to the main stream by nine channels can be considered as representative of the floodplain systems located in the downstream part of the Amazon river valley.

For several years, in the framework of the HyBAm (Hydrology and Geochemistry of the Amazonian Basin, IRD-CNPq agreement www.mpl.ird.fr/hybam/) research program, *in situ* hydrological, sediment and geochemical data have been obtained (Kosuth, 2002; Maurice-Bourgoin et al., 2005; Moreira-Turcq et al., 2005). The dataset enables to undertake numerical modelling of this area (Kosuth, 2002; Maurice-Bourgoin et al., 2005; Bonnet et al., 2005). The first step was to propose an hydrological model of the floodplain system, representing it conceptually as a single large reservoir connected to the mainstream by six channels (Bonnet et al., 2005; Bonnet et al., submitted for publication). We chose to keep the model in a relatively simple form in order not only to ensure agreement between data requirements and data availability but also, because of its transportability. The model is mainly based on remotely sensed images and only has a slight requirement of *in situ* data in order to be applied to other similar systems. The resulting understanding of floodplain behaviour facilitates a more general assessment of the contemporary role of the mid-Amazon floodplain in the sediment storage and dynamics.

Study area

General data

The Amazon basin is the largest drainage basin in the world, covering about 6 × 10^6 km^2 and discharging a mean annual flow of 163,000 m^3 s^{-1}, at Óbidos, ~800 km upstream of its mouth (Callède et al., 2002). The Óbidos gauging station (01°56′S, 55°30′W) has a catchment area of 4,677,000 km^2, and is the only gauging station on the Amazon River, from Manaus to the mouth (Fig. 1), with reliable and long-term water level records (over 30 years) and regular discharge measurements. It is the gauging station on the River closest to the estuary and the tidal effect does not influence mean daily water level by more than 10 cm, during the low water stage (Callède et al., 2004), which corresponds to a standard deviation of the discharge measurements of only ±2%.

At this location, the maximum rainfall is observed between February and April (Fig. 2) and the mean annual precipitation for the 1971–1998 period was 1820 mm. In this region, the rainfall is influenced by the activity and position