THE AMANAUS CRUISE (5-25 July 2023) IN THE CENTRAL-EASTERN AMAZONIA TO BETTER UNDERSTAND SOURCE 2 SINK SEDIMENT TRANSFER

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ABSRACT

The AMANAUS cruise has been undertaken from 5th-25th July 2023 on two boats: the Samara Lopes XII and Yane Jose IV boats from Manaus to Santarém (Leg 1) and on Samara Lopes XII boat only on the way back from Santarém to Manaus (Leg 2). The cruise was based on an international collaboration between Brazilian and French Researchers. The Yane Jose IV boat undertook hydrological measurements in the framework of the HYBAM program with ANA, CPRM, and IRD members (www.ore-hybam.org/) while the Samara Lopes XII undertook geophysical-geological measurements funded by ISBlue EUR school, ANR, CAPES-COFECUB. The present abstract focuses on the achievements of the Samara Lopes boat only. The aim was to deploy several tools never used in the Amazon River and acquire new geophysical (bathymetry and multichannel high-resolution seismic), sedimentological, and geochemical data (cores, bedload, and suspended particulate material) for a better understanding of source-to-sink transport of sediments and their evolution through time with the concomitant role of climate, sea-level, and tectonic changes.

KEYWORDS: Source to Sink; Multichannel Seismic; Bathymetry; Geochemistry; Central-eastern Amazonian.

INTRODUCTION

The quantification of sediment budgets is a difficult target because it requires a complete quantitative view from source (on the continent) to sink (in the ocean) of sedimentary environments, sediment nature, and volumes. In tropical systems, these kinds of studies are very scarce (Syvitski et al., 2009; do Nascimento *et al*., 2015). The estimation of such budgets, in the case of the Amazon River, is even more problematic considering the size of the system. Indeed, the Amazon drainage basin itself is the biggest on Earth today (5.8 million km^2, situated at the northern part of South America) (Roddaz *et al.*, 2005), as for its water discharge (220,000 m^3/s) that represents 20% of all freshwater inputs to the ocean (Milliman & Farnsworth, 2011). In terms of sediment discharge, Martinez *et al*. (2009) observed and increase in the annual mean from approximately $688 \cdot 10^6$tons/year before 2001 to $801 \cdot 10^6$tons/year after, suggesting a significant change in the sediment transport regime of the Amazon River, while no trend was observed for water discharge, such difference possibly is due to impact of anthropic activities and climate changes.

As for its marine counterpart, the Amazon Fan is the third largest modern deep-sea fan and is located in the Foz do Amazonas Basin. This basin covers an area of about 268,000 km^2 and includes the continental shelf, slope, and deep basin down to the 3000 m isobath with thickness up to 10 km of sediments (Bradão and Feijó, 1994; Figueiredo *et al*., 2007).

The post-rift sedimentation (100-0 Ma) can be subdivided into two-time intervals:

- The pre-Amazon Fan interval (ca 100-11 Ma), which is Cenomanian through Middle Miocene in age and represents deposition in the basin prior to the establishment of the Amazon River as a major, continental-scale drainage system.
- The Amazon Fan interval (c.a 11.8 – Present), begins in Middle Miocene with the transition from a cratonic-derived sediment regime to one dominated by Andean-derived sedimentation, resulting in the onset of the transcontinental Amazon River and the buildup of the Amazon Fan. Sediments of Andean origin seem to have reached the Foz do Amazonas Basin between 11.8 and 11.3 Ma (Figueiredo *et al*., 2009). However, other authors suggested a much younger age around 6-5 Ma (Latrubesse et al., 2010) or around 3 Ma (Ribas *et al.*, 2011) coinciding with a large increase in sedimentation rates (Cruz et al., 2019).

The importance of monitoring the behaviour of the Amazon River resides in the fact that: a) it responds to local and global changes in climate as well as changes in land use in the catchment (Marengo et al., 2018; Guimberteu *et al.*, 2017; Nobre et al., 2016); b) its geomorphology and discharge can be affected by the damming planned and already in operation, causing impact in the floodplains, estuary and sediment dynamics (Latrubesse *et al.*, 2017); c) the water discharge of the river contributes to regional sea level in the Tropical Atlantic Ocean, as far as 3000 km from the river mouth (Giffard et a., 2019); d) it plays an important role in the carbon cycle, acting as a CO_2 sink due to the input of nutrients that promote diazotrophic activity and consumption of CO_2 in surface waters (Weber *et al*., 2017; Subramanian *et al*., 2008).

The acquisition and processing of unprecedented bathymetry and multichannel seismic data along the Central-Eastern Amazonia might give new clues for this major change in the course of the Amazon River. Additionally, sedimentological and geochemical analysis of modern sediments will give important insights into modern crustal denudation and transportation processes in the basin.

MATERIALS AND METHODS

The geophysical and geochemical AMANAUS cruise was carried out on the Samara Lopes XII boat, which underwent specific arrangements to handle the installation of bathymetry, seismic and coring equipment. This installation was a challenge by itself due to the weight of each of those equipment (>250 kg).

During the 20 days of cruise were continuously acquired bathymetric data using a Reson Seabat T50P, operating in the frequency band 200-400kHz, with 511 equidistant beams, along with Novatel Vector dual-antenna GNSS differential positioning system. Multichannel very high-resolution seismic data were acquired using a freshwater-designed Sparker Source by Geo Marine Survey Systems with a geo-source 400 FW (400 tips). The streamer used was a 48 channels streamer Geo-Sense also from Geo Marine Survey systems with a total length of 150m. The streamer was kept at a constant depth using two buoys: a head buoy with two mooring points on the structure allowing recovery effort of the streamer and streamer depth adjustment; a tail buoy with a flag and flash for visibility. Undertaking such an exploration with 200m of material behind the boat (**Figure 1A**) was a challenge due to the number of small and randomly navigating boats on the Amazon and the even more randomly distributed big trunks and small *matupás* floating at the surface or subsurface in the river.

Figura 1. (A) Seismic equipment in acquisition and (B) Coring equipment being deployed, both from Samara Lopes XII vessel.

Water samples for geochemical analysis of the suspended particulate material (SPM) were collected in every major Amazon River tributary (Solimões, Negro, Madeira, and Tapajós), and several locations along the Amazon River between Manaus and Santarém (**Figure 2**). These samples are going to be analyzed for major and trace elements; Li, Hf, and Nd isotopes, and fish DNA composition. Additionally, we used the Ronanberg system developed at IFREMER to sample 1m cores (**Figure 1B**), together with surface sediment samples collected with a small Van Veen drag. All samples were sent and stored in Univ. Brasília to undertake a full set of laboratory analysis. Additional hydrology measurements (ADCP and water samples) were undertaken specifically around Obidos and Juruti in Leg 2, to complement analysis of Yan José IV from the Leg1.

Figure 2 shows the location map of all geophysical and samples acquired on the Samara Lopes XII boat during AMANAUS cruise. In total, were acquired about 600 km of seismic profiles and more than 1500 km of multibeam bathymetric data along Rio Amazonas. Two areas, in front of Itacoatiara (AM) and Óbidos (PA), were surveyed in more detail as those locations host fluviometric stations regularly monitored by CPRM and ANA for liquid and solid discharge. In addition, 7 Ronanberg cores, 26 sediments samples (clay and sand), 32 water samples (for Hf, Nd, Li isotopic studies of suspended particles) and biology DNA analysis were successfully collected. All data are still under processing and interpretation that will be handled jointly between brasilian and french teams.

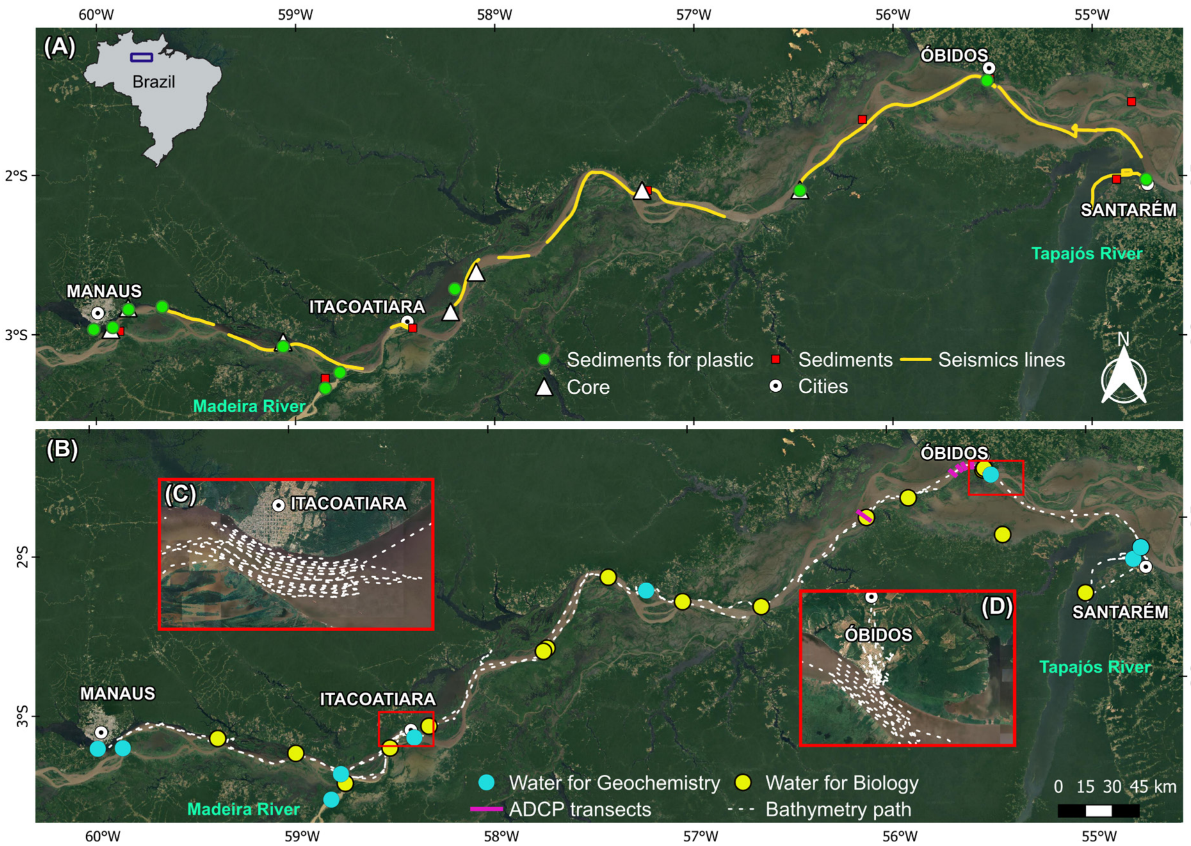

Figura 2. Map of Data Acquisition : showing location of geophysical data, water and sediment samples acquired on the SAMARA Lopes XII boat during AMANAUS cruise, July 2023.

PRELIMINARY RESULTS

The preliminary analysis of MBES data revealed the complex structures of the riverbed: at Itacoatiara (**Figure 3A**), the thalweg attains more than 100m of depth and large dunes trains are observed, with wavelenghts ranging from 100 to more than 200m, and heights o more than 5m (varying according to water depth). In the middle of the channel, the thalweg is crossed by two rocky terraces, probably result of erosion of the cretacic sandstones of Alter do Chão Formation, that constitutes the basement of the middle Amazon River. The two riverbanks show different features, while the right bank appears less steep and with erosional channels in the middle part, the left bank shows a steep cliff carved in the rocks of the Alter do Chão Formation.

Further downstream, at Óbidos (**Figure 3A**), the channel narrows due to the constraint of the left rocky margin (Alter do Chão Formation) and the thalweg reaches the highest depth observed during the cruise, attaining more than 110m.

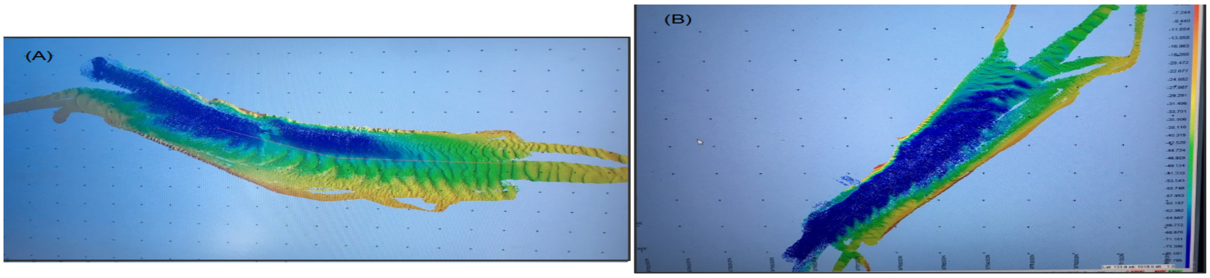

Figure 3 - **Bathymetric map of the channel reach next to Itacoatiara (A) in front of Itacoitiara and (B) Bathymetric map of the channel reach next to Óbidos.**

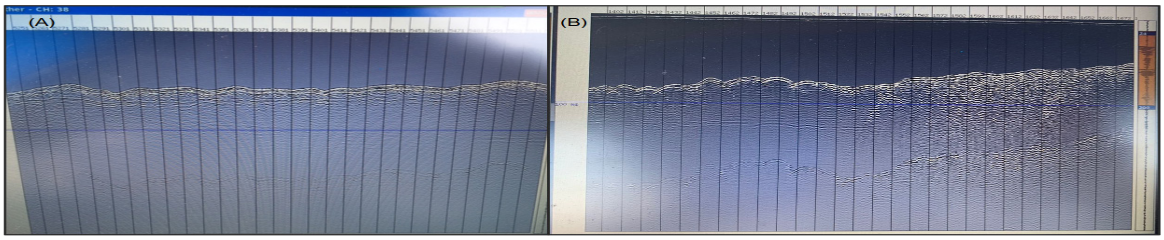

Figure 4. Preliminary results of not processed seismic data showing (A) giant dunes and (B) abrupt contact between Sandy/Rocky river-floor

CONCLUSIONS

The aim of the AMANAUS mission was to look at the same object from different points of view (geodynamic, geophysical, sedimentological, biological, envoronmental, etc.). Setting up such a campaign, which in many ways is unprecedented, requires a certain amount of adaptation. When the team, which is small in size and multi-disciplinary, it requires even greater flexibility, in order to get past the jargon that is inherent in each discipline. Amanaus was a great success, both in terms of the unprecedented data it yielded and the forecasts we can expect to see, and in terms of the human adventure involved. The processing and interpretation of the full set of data will be made in the framework of our Brazilian-French collaborations (UnB, UFAM, Ufopa, CRPM and Ifremer, CNRS, IRD, UBO, Univ. Nantes, Univ. Toulouse)

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