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Purus River suspended sediment variability and contributions to the Amazon River from satellite data (2000–2015)

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ABSTRACT

The Purus River is one of the major tributaries of Solimões River in Brazil, draining an area of 370,091 km^2 and stretching over 2765 km. Unlike those of the other main tributaries of the Amazon River, the Purus River's sediment discharge is poorly characterized. In this study, as an alternative to the logistic difficulties and considering high monitoring costs, we report an experiment where field measurement data and 2700 satellite (MODIS) images are combined to retrieve both seasonal and interannual dynamics in terms of the Purus river sediment discharge near its confluence with the Solimões River. Field radiometric and hydrologic measurements were acquired during 18 sampling trips, including 115 surface water samples and 61 river discharge measurements. Remote sensing reflectance gave important results in the red and infrared levels. They were very well correlated with suspended sediment concentration. The values of R^2 are greater than 0.8 (red band) and 0.9 (NIR band). A retrieval algorithm based on the reflectance in both the red and the infrared was calibrated using the water samples collected for the determination of the surface-suspended sediment concentration (SSS). The algorithm was used to calculate 16 years of SSS time series with MODIS images at the Purus River near its confluence with the Solimões River. Results from satellite data correlated with *in situ* SSS values validate the use of satellite data to be used as a tool to monitor SSS in the Purus River. We evidenced a very short and intense sediment discharge pulse with 55% of the annual sediment budget discharged during the months of January and February. Using river discharge records, we calculated the mean annual sediment discharge of the Purus River at about of 17 $Mt{\cdot}yr^{-1}$.

1. Introduction

Every year, the oceans receive approximately 20 billion tons of suspended sediments because of erosion and transportation through river systems (Allen, 2008). Tropical basins are the largest suppliers of that amount. The Amazon River's sediment discharge has been estimated at

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between 800 and 1200 Mt·yr^{-1} (Filizola et al., 2011; Guyot et al., 2005; Meade et al., 1985), with the Andean region being the main source of suspended sediments (Filizola and Guyot, 2009, 2011; Gibbs, 1967, Latrubesse et al., 2005).

The Purus River (Fig. 1A) is one of the major tributaries of the Solimões River, with an average annual water discharge (Q) of 10,700 m^3 s^{-1} (Filizola and Guyot, 2009). The high-water period usually extends from April to May, while the low-water period usually occurs from October to November (Fig. 1B). The erosive process acting in the river basin moves sediments deposited in the Andean forestland. This region had been experiencing an uplift of the basement by tectonic action (Espurt et al., 2007), favoring a greater supply of sedimentary material to be transported by the Amazon River and its tributaries that have their headwaters at this region. This is the case of the Purus and Juruá Rivers, for example. Recent data on SSS indicate significant longitudinal variability in those rivers (Filizola and Guyot, 2009). The Purus basin extends over 370,091 km^2 (Melo, 2012) and its sediment discharge was reported as 47.2 Mt·yr^{-1} (Filizola et al., 2011). However, the Brazilian Ministry of the Environment (http://www.mma.gov.br) has put this basin on alert due to the rapid land-use changes resulting from increasing illegal logging, which may drastically alter sediment production and transportation. To monitor these changes, the Brazilian National Water Agency (ANA) conducts quarterly water sampling at key stations, but that frequency is not enough to assessing seasonal and interannual dynamics of the river sediment discharge.

Monitoring of suspended sediment in large rivers, such as those at the Amazon basin, is time-consuming, and its accuracy is generally limited by operating costs and local infrastructure. This makes it difficult to collect frequent SSS samples. More recently, indirect techniques, especially those using satellite images, have been proven to supplement conventional sampling techniques efficiently in large rivers. These methods, which have been tested since the early 21st century, are less expensive and less time-consuming (Filizola et al., 2011; Martinez et al., 2009). Remote sensing techniques were first applied to hydro-sediment data assessment several decades ago in the Amazon Basin (Bradley et al., 1979, Mertes et al., 1993), but the use of satellite images for sediment flux monitoring is far more recent (Espinoza Villar et al., 2012; Martinez et al., 2009).

This new method offers enhanced spatial and temporal resolutions compared to conventional water sampling practices based on field gauging stations, particularly in poorly gauged basins for large rivers. Using the Moderate Resolution Imaging Spectroradiometer (MODIS) image time series, Martinez et al. (2009) demonstrated the possibility of assessing the evolution of river sediment discharge from space over the Amazon River. Similarly, Park and Latrubesse (2015) by MODIS images have investigated water-mixing processes at the confluence of the Negro River and of the Solimões River. Adding field spectroradiometry data to the calibration of the reflectance

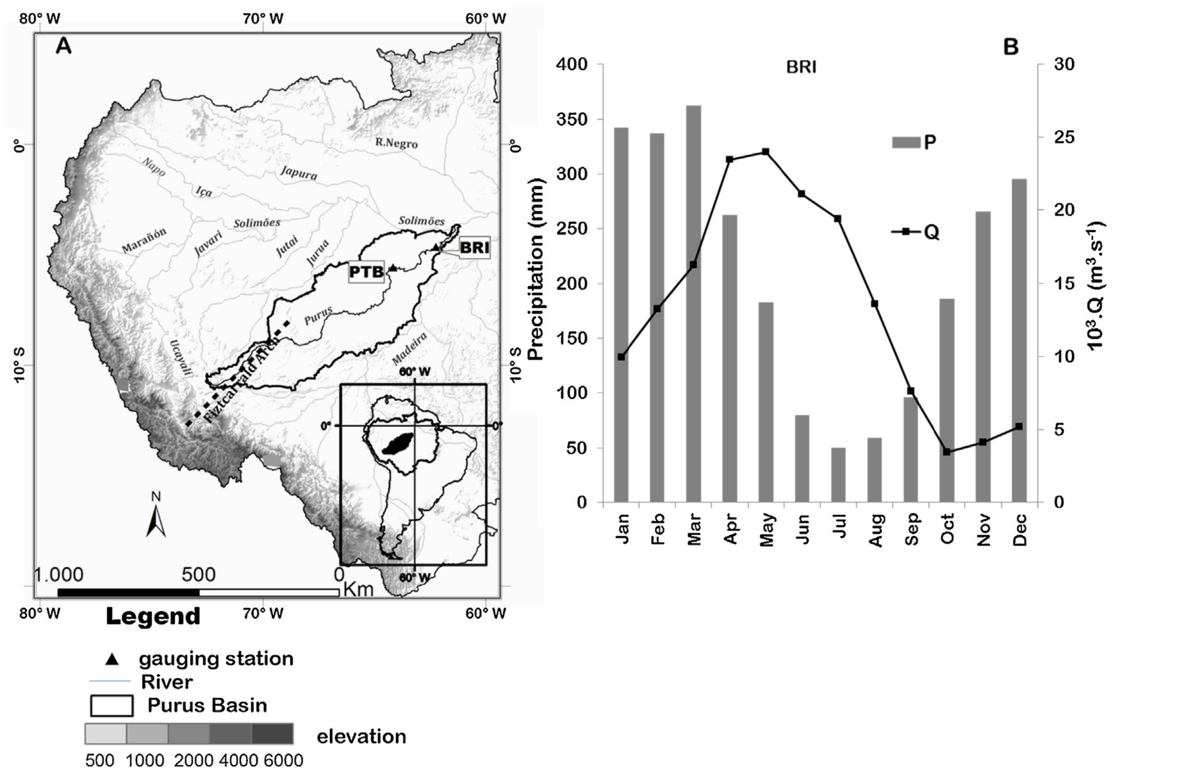

Fig. 1. A. Location of the Purus River catchment. B. Average water discharge at the Beruri gauging station (2009–2014) and mean rainfall over the catchment as retrieved by TRMM (2001–2014).