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The flood recession period in Western Amazonia and its variability during the 1985–2015 period

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A R T I C L E I N F O

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A B S T R A C T

Study region: The upper Amazon River, where the water level measured at the Tamshiyacu station (Peru) shows seasonal variability of seven meters.
Study focus: Key parameters for the flood recession period (beginning, end and duration of the low-water period, velocity of water falling and rising, and inversions in the direction of stage change known as "repiquete" events) are analyzed for the period 1985–2015, along with their relationship to rainfall integrated in the upper Amazon basin at Tamshiyacu.
New hydrological insights: The low-water period lasts about four months, beginning, on average, at the end of July and ending in early November. Since the late 1990s, the low-water period has tended to end later, last longer and the flood recession ends more abruptly than it used to. This may be related to the increased frequency of dry days during the austral winter in the central and southern part of the basin and to increased and more intense rainfall in late spring (November–December). Repiquete events are frequent, 8 each year on average, and sometimes very acute: 18 events with a water-level reversal greater than one meter were registered during the 1985–2015 period. They are related to unusual, intense and extended rainfall during the week preceding the repiquete. Extensions of this preliminary work are suggested, as well as possible implications for recessional agriculture.

1. Introduction

While hydroclimatic extremes have been carefully studied in the Amazon basin (Callede et al., 2004; Marengo and Espinoza, 2015; Marengo et al., 2008, 2013; Zeng et al., 2008; Chen et al., 2010; Espinoza et al., 2011, 2013, 2014; Satyamurty et al., 2013; Molina-Carpio et al., 2017), there has been little study of the annual water-level cycle of the Amazon River. In the western Amazon,

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precipitation is highly variable, with a rainy season in the austral summer, which is related to the onset of the South American Monsoon System and the translation of convergence in the southern hemisphere, and a drier season in the austral winter, related to their retreat (Zhou and Lau, 1998; Vera et al., 2006). This rainfall seasonality causes a seven-meter fluctuation between low- and high-water stages of the Amazon River at the Tamshiyacu station (Peru), upstream from Iquitos. This study focuses on the flood recession period, which is characterized by the decrease of the water level.

This period of the year is of particular interest for local food security and economic activity in the region. The fertile riverbanks and floodplains ("varzeas"), which are flooded during the high-water period, are exposed during the flood recession period (Junk, 1982; Junk and Furch, 1993) making them available for recessional agriculture during those months (Hiraoka, 1985; Bahri, 1993; Noda, 2007; Kvist and Nebel, 2001; Adams et al., 2005). Moreover, food prices are lower when the varzeas are producing (Moraes and Schor, 2010). When the average cycle is perturbed, for example when the duration of the recession is too short for plants to mature or when the onset of the rainy season and rising water occur very suddenly, crops may be lost (Kvist and Nebel, 2001; Labarta et al., 2007; Drapeau et al., 2011; Hofmeijer et al., 2013; Pinho et al., 2015; Sherman et al., 2015; MINAG, 2011, 2013). Food security may then be affected, despite the tradition of diversifying the landscape and the location of cultivated plots and of taking advantage of multiple habitats (Pinedo-Vasquez et al., 2002; Arce-Nazario, 2011). The importance of unexpected stage reversals ("repiquetes") on the rice-planting strategies of farmers near Iquitos has been described by various authors (see for instance Hiraoka, 1985; Rios Arevalo, 2005), and the associated high risk of crop loss due to this natural hazard has been assessed by Coomes et al. (2016), List (2016) and List and Coomes (2017). Water-level variations strongly affect not only production, but also the transportation of produce as both transportation time and distance significantly increase during the flood recession period (Tenkanen et al., 2015). This topic is an important variable in cash-crops for local markets (Hiraoka, 1985).

Local biota has developed specific adaptations that enable it to live in constantly changing physical conditions, either aquatic or terrestrial, depending on the season (Junk, 1982). Despite these adaptations, losses are high, especially when extreme water levels are observed during the high- or low-water season. Fish, game and fruit are important components of the local diet, and shortages can affect both local food security and cash-crop systems (Takasaki et al., 2004; Nascimento, 2017). Variations in water level also have an important impact on the quantity and quality of water available to the local population (Cidade, 2017), which affects health and quality of life.

Analysis of the flood recession period is also of particular interest because the annual rainfall cycle has changed in recent decades in the Amazon basin. Longer dry seasons have been observed since the 1980s, particularly in the southern Amazon, with later onsets and earlier ends of the wet season (Li and Fu, 2006; Carvalho et al., 2011; Marengo et al., 2011; Dubreuil et al., 2012; Fu et al., 2013; Yin et al., 2014; Arias et al., 2015; Debortoli et al., 2015; Espinoza et al., 2016). This may be related to changes in convection due to deforestation and modifications in regional circulation (Li and Fu, 2006; Yin et al., 2014; Arias et al., 2015; Wright et al., 2017). Fernandes et al. (2015) also suggest the existence of a decadal variability in western Amazon rainfall related to the decadal variability in tropical Atlantic Ocean sea surface temperature (SST).

Corresponding to these changes, a significant decrease in rainfall during the dry season has been documented in the upper Amazon basin since the 1970s (Espinoza et al., 2006, 2011), including an increase in the frequency of dry days since 1986 (Espinoza et al., 2016). Hydrological conditions are expected to change further with climate change. Rainfall is projected to increase in western Amazonia during the wet season, contributing to augmented mean and maximum discharge in large rivers draining the Andes (Guimberteau et al., 2013; Boisier et al., 2015; Zulkalfi et al., 2016). These changes would lead to an average increase of three months in the duration of inundation by the end of the 21st century (Langerwisch et al., 2013) and to more widespread flooding over Peruvian floodplains in western Amazonia (Sorribas et al., 2016).

This paper is a contribution to the analysis of key parameters of the flood recession period (dates of beginning and end of the low-water period, duration of the low-water period, speed of water falling and rising, occurrence of repiquetes) in the upper Amazon basin at the Tamshiyacu station and their evolution during the 1985–2015 period. Section 2 describes the data and methodologies on which this study is based. Section 3 describes the time evolution of the main parameters of the flood recession period. They will be related to rainfall averaged in the upper Amazon basin at Tamshiyacu and to the frequency of dry and wet days in this basin. Results are synthetized in Section 4 and extensions of this preliminary work are suggested.

2. Data and methods

2.1. Data

The National Meteorology and Hydrology Service of Peru (SENAMHI) provided high-quality daily water level data for the Amazon River at Tamshiyacu (Fig. 1b). These data are gathered by the National Observation Service SNO-HYBAM "Geodynamical, hydrological and biogeochemical control of erosion/alteration and material transport in the Amazon, Orinoco and Congo basins." Daily water level values are available as of 1985. SNO-HYBAM also provided Hybam Observed Precipitation data (HOP), a gridded dataset for the entire Amazon basin derived from 752 meteorological stations in five countries (Espinoza et al., 2009a). Data are collected by the national institutions in charge of hydro-meteorological monitoring: National Agency of Water (ANA) in Brazil; SENAMHI in Peru and Bolivia; the National Meteorology and Hydrology Institute (INAMHI) in Ecuador; and the Hydrology, Meteorology, and Environmental Studies Institute (IDEAM) in Colombia. The HOP dataset is available from 1980 to 2009 on a daily time step and a 1°x1° grid (Guimberteau et al., 2012). In the Peruvian-Ecuadorian Amazon basin, delimited by the Tamshiyacu hydrological station, basin-integrated rainfall is computed from 234 meteorological stations from the HOP dataset (Espinoza et al., 2011). For more details about quality control of rainfall data and geostatistical interpolation of rainfall observations, see Guimberteau et al. (2012). Gridded HOP