Journal of Hydrology: Regional Studies 4 (2015) 41–59

Contents lists available at ScienceDirect

Journal of Hydrology: Regional Studies

journal homepage: www.elsevier.com/locate/ejrh

# Exploratory analyses for the assessment of climate change impacts on the energy production in an Amazon run-of-river hydropower plant

Guilherme Samprogna Mohor, Daniel Andrés Rodriguez*, Javier Tomasella[1], José Lázaro Siqueira Júnior

*Earth System Science Center, National Institute for Space Research, Cachoeira Paulista, SP, Brazil*

ARTICLE INFO

*Article history:*
Received 10 November 2014
Received in revised form 2 April 2015
Accepted 5 April 2015
Available online 15 June 2015

*Keywords:*
Adaptation
Amazon river basin
Climate change
Hydrologic modeling
Hydropower
MHD-INPE

ABSTRACT

**Study region:** The Tapajós Basin is an important Amazon tributary affected by human activities with great potential for water conflicts. The basin, as others within the Amazon region, is receiving a number of hydropower plants, among them the Teles Pires plant, projected to operate in 2015.

**Study focus:** Hydrological impacts due to climate change affect human activities, such as hydroelectric generation, and should be carefully studied for better planning of water management. In this study, we assess climate change impacts by applying the MHD-INPE hydrological model using several climate models projections as inputs. The impact assessment consisted of statistical shifts of precipitation and discharge. Energy production in a projected hydropower plant was assessed through the development of annual power duration curves for each projection, also considering its design and structural limitations.

**New hydrological insights for the region:** The high inter-model variability in the climate projections drives a high variability in the projected hydrological impacts. Results indicate an increase of basin's sensitivity to climate change and vulnerability of water exploitation. Uncertainties prevent the identification of a singular optimal solution for impacts assessment. However, exploratory analysis of the plant design robustness for hydropower generation show a reduction in the energy production even under projections of increased discharge, due to plant capacity limitations. This is valuable information for stakeholders to decide about energy production strategies.



* Corresponding author at: Earth System Science Center, National Institute for Space Research, Cachoeira Paulista, SP 12630-000, Brazil. Tel.: +55 1231868461.

*E-mail address:* daniel.andres@inpe.br (D.A. Rodriguez).

[1] Temporary affiliation to the National Center for Monitoring and Natural Disasters Warning, Cachoeira Paulista, SP, Brazil.

http://dx.doi.org/10.1016/j.ejrh.2015.04.003

## 1. Introduction

Brazil is highly dependent on water resources for several economic activities, particularly for hydropower generation and agriculture (Marengo, 2008; Nóbrega et al., 2011). In this context, an increased need for energy to sustain economic growth has boosted governmental plans to expand hydropower in Amazonia. The Growth Acceleration Program – PAC (BRASIL, 2013) is a governmental plan of investments to promote development, including the construction of hydropower plants, and has allocated 45 billion Brazilian Reais (approximately 23 billion dollars) to the Amazon region. The new plants will increase the contribution of the Amazon region to the Brazilian power generation from 10% up to 24% (Empresa de Pesquisa Energética (EPE), 2012).

Water resources availability in the Amazonian region is influenced by climate variability, climate change and human activities (Espinoza-Villar et al., 2009a,b; Rodriguez et al., 2010; Costa et al., 2003). Therefore, understanding the effects of that variability on the hydrological cycle is crucial for private and government development plans and for mitigation of adverse effects (if any) of climate change. Recent studies (Marengo et al., 2011a,c; Joetzjer et al., 2013) have indicated significant potential impacts due to global climate changes until the end of the century in the Amazon region. Most likely, the air temperature will increase, while the annual precipitation over the region will decrease, mainly due to a longer dry season. Those changes will potentially have a profound impact on the basin's hydrological regime (Cox et al., 2004, 2008; Li et al., 2006; Salazar et al., 2007).

In large basins, the impacts on the hydrologic cycle depend not only on the average climate anomalies over the drainage area but also on the geographical distribution of the drivers of such changes combined with the geomorphologic features of the basin (Tomasella et al., 2011). By studying the 2005 Amazon drought, Tomasella et al. (2011) concluded that, if a precipitation deficiency occurs in a geographically restricted region of the drainage area during a critical period of the main channel recession, then the impacts downstream could be more severe than those of a geographically wider drought. In this context, hydrological distributed models should be able to realistically represent the spatial distribution of runoff, evapotranspiration, and soil water storage for a reliable assessment of the impacts due to climate changes or human activities (Cong et al., 2009; Leavesley, 1994).

Climate change impacts on river discharge are generally evaluated through the application of hydrological models using climate model data as input (Demaria et al., 2013; Nóbrega et al., 2011; Cloke et al., 2013; Bravo et al., 2013). Decision-making processes related to climate adaptation demand accurate and detailed information at a wide range of spatial and temporal scales (Dessai et al., 2009). However, there is substantial uncertainty in the assessment of climate change impacts, and this uncertainty is associated with the model chain's propagation of errors (Jones, 2000), which are mainly related to the climate models rather than the hydrologic model (Bates et al., 2008; Nóbrega et al., 2011).

Although climate model projections are affected by irreducible uncertainties (Dessai and Hulme, 2004), impact studies are based on the assumption that projected climate change signals are reliable when obtained from differences in the model "climatology" (model long-term mean values for the simulation period) rather than those in the observed climatology (Wood et al., 2002). Therefore, instead of using absolute values of the predicted scenarios, differences between model climatologies for historical and future periods should be considered (Allen and Ingram, 2002; Bravo et al., 2013) after statistical adjustments to minimize climate model biases (Bates et al., 2008; Bárdossy and Pegram, 2011; Demaria et al., 2013).

Early experience with ensembles of climate models showed significant dispersion among members (Kling et al., 2012; Cloke et al., 2013; Knutti and Sedlacek, 2013); this was also shown in hydrologic model simulations using ensembles or multi-model runs (Nóbrega et al., 2011; Bravo et al., 2013; Siqueira Júnior et al., 2015). Regarding the Amazon basin, published literature showed a lack of agreement about changes in river discharge when different climate model projections were considered (Arora and Boer, 2001; Milly et al., 2005; Salati et al., 2009; Lavado Casimiro et al., 2011; Guimberteau et al., 2013; Siqueira Júnior et al., 2015). These differences were due to inter-model uncertainties in projected precipitation changes, even when those were estimated for the same climate change scenario. Other South American basins studies, such as the upper Paraguay River Basin (Bravo et al., 2013), the Rio Grande River Basin in Brazil (Nóbrega et al., 2011) and a Chilean snow-driven basin (Demaria et al., 2013) presented the same lack of agreement in terms of river discharge changes for different