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Assessment of different precipitation datasets and their impacts on the water balance of the Negro River basin

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SUMMARY

With the objective of understanding the potential and limitations of available precipitation products for hydrological studies, this paper compares six daily and sub-daily precipitation datasets and their impacts on the water balance of the Negro River basin in the Amazon basin. The precipitation datasets contain gauge-based data [data derived from the Hybam Observatory Precipitation (HOP) dataset and provided by the Climate Prediction Center (CPC)], satellite-based data [the Global Precipitation Climatology Project (GPCP) one-degree daily and TRMM Multisatellite Precipitation Analysis (TMPA) datasets] and model-based data [the NCEP-DOE AMIP-II re-analysis (NCEP-2) and 40-year ECMWF Re-Analysis (ERA-40) datasets]. Each dataset has a common set of meteorological forcing data which are used to run the MGB-IPH hydrological model for the period from January 1998 to August 2002.

The average precipitation of all the datasets is 2542 mm for the Negro River basin, with a standard deviation of 317 mm. TMPA and NCEP-2 have the lowest (2216 mm/year) and the highest (3065 mm/year) precipitation rates, respectively. The HOP and CPC datasets agree best with observed discharge. GPCP gives the best results among the ungauged datasets, followed by ERA-40. TMPA and NCEP-2 are found to be the least accurate. TMPA can reproduce the water cycles reasonably well, but underestimates the precipitation fields and discharges over the basin, while NCEP-2 is unable to represent the rainfall quantity and cycles, and the water discharge. Results suggest that gauge-based data are still the most representative of the actual precipitation in the northern Amazon basin. However, some satellite and model-based can reproduce fairly well the water cycle at the basin scale and monthly time step.

1. Introduction

In the past several decades, numerous global and quasi-global precipitation datasets have been developed at different time scales using input sources such as ground-based observations, satellite estimates and outputs from general circulation models (Willmott et al., 1994; Kalnay et al., 1996; Sorooshian et al., 2000; New et al., 2000; Adam and Lettenmaier, 2003; Rudolf and Schneider, 2005; Uppala et al., 2005; Huffman et al., 2007; among others). In view of the many precipitation datasets available, several analyses have been carried out to identify their differences at regional (e.g. Gebremichael and Krajewski, 2004; Dinku and Anagnostou, 2005), continental (e.g. Syed et al., 2004; Marengo, 2005; Juarez et al., 2009) and global (e.g. Sapiano et al., 2006) scales. Most studies have found that the datasets typically agree in terms of the main temporal precipitation trends and their global spatial distribution but, regionally, they often exhibit marked differences. For example, Costa and Foley (1998) highlighted regional differences for the Amazon basin, and Adler et al. (2001) showed differences among datasets globally. Other comparisons suggest that the largest differences among available precipitation datasets occur in the tropics (Fekete et al., 2004), particularly in the Amazon basin (Rao et al., 2002).

Our main objective is to compare the spatio-temporal heterogeneities of six precipitation datasets at the daily time step over the Negro River basin, in the northern Amazon basin (Fig. 1). The comparison of satellite-based and model-based data to gauge-based datasets allows us to identify the strengths and weaknesses of the different precipitation products. Another objective of this paper is to analyze the effects of different precipitation datasets on the simulated water cycle of the Negro River basin. Indeed, comparing simulated and observed discharges can be an efficient way to complement assessments of precipitation datasets. Several studies of this type have been already carried out in recent years (e.g. Yilmaz

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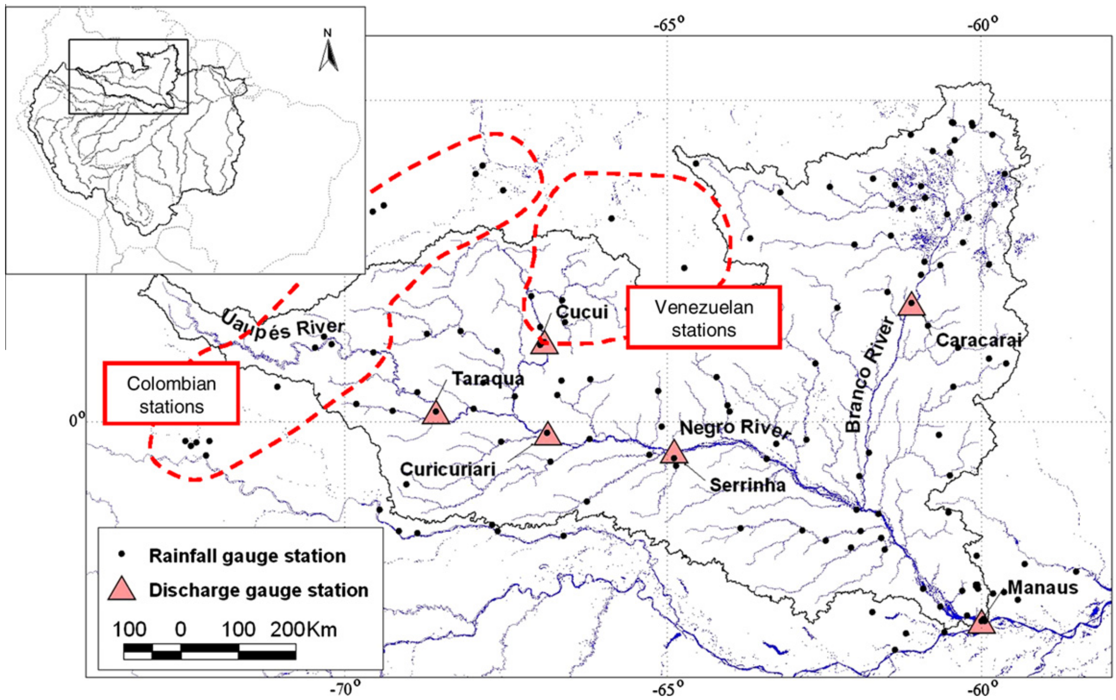

Fig. 1. Map of the Negro River basin, including the locations of pluviometric stations with data for the period 1980–2006, and of six fluviometric stations used to evaluate model performance. The additional Colombian and Venezuelan stations are found within the dashed lines.

et al., 2005; Wilk et al., 2006). Here, the MGB-IPH model (Collischonn et al., 2007), forced with different precipitation datasets and using the same atmospheric forcings (i.e. solar radiation, pressure, relative humidity, wind speed and temperature at sea level), has been used to simulate the daily hydrological processes of the Negro River basin for the period from January 1998 to August 2002, for which all datasets are available. Then, sets of simulated runoff, evapotranspiration and soil moisture content have been compared among themselves and water discharge time series have been evaluated with observed data in order to quantify the reliability of each dataset in terms of providing estimates of the water cycle. Evaluating spatio-temporal differences between data sources is particularly useful for identifying how various components of the water cycle (such as runoff, evapotranspiration and soil moisture) are affected by changes in the precipitation field used in the hydrological models. So, this paper provides important information to both the hydrological and rainfall-retrieval communities.

This paper is organized as follows: Section 2 gives a brief description of the Negro River basin and the datasets used in this study. It also provides information about MGB-IPH model, the modeling setup for the study area and the methodology used to evaluate the datasets. In Section 3, the results obtained are presented and discussed. Finally, the conclusions are presented in Section 4.

2. Data sets and methodology

2.1. Study area and available data sets

The Negro River basin covers parts of both the northern and southern hemispheres with an area of about 712,000 km^2, from 3°14′S to 5°80′N latitude and from 72°57′W to 58°16′W longitude, in the northern Amazon basin (Fig. 1). The Negro River is the most important tributary of the Solimões/Amazon River in terms of runoff [4.36 mm/day – the mean runoff of the Amazon basin is about 2.9 mm/day (Marengo, 2005)], and the second after the Madeira River in terms of total discharge.

Daily discharge data are available at several gauge stations within the Negro River basin and are freely provided by the Brazilian Water Agency (ANA – Agência Nacional de Águas). These stations drain areas varying from 611 km^2 to 291,150 km^2 [a list of most of gauge stations in service in the Negro River basin can be found in Getirana et al. (2010)]. Five gauge stations (Caracaraí, Taraqua, Cucuí, Curicuriari and Serrinha) representing different regions and hydrological regimes of the basin have been selected to evaluate simulated discharges. The total discharge produced in the basin cannot be evaluated since daily discharges are not available at the basin's outlet. However, other hydrological variables such as precipitation, runoff, evapotranspiration and soil moisture are analyzed at the basin scale (represented by the drainage area of the Negro River when it passes by Manaus). The main characteristics of these stations are given in Table 1.

Indeed, the Negro River basin is one of the rainiest regions of the Amazon basin (about 3000 mm/year). The Guyana Shield, one of the three cratons of the South American Plate that underlies Guyana, French Guiana, Suriname and parts of Colombia, Venezuela and Brazil, creates a strong gradient in the rainfall spatial distribution over the basin: humid flow from the Atlantic is hindered by

Table 1
Main characteristics of the sub-basins defined by the six gauge stations considered in this study.

Station	Drainage area (km^2)	Mean discharge		Mean precipitation (mm/year)	Upstream sub-basin
		(m^3/s)	(mm/year)		
Caracaraí	126.085	2903	731	2044	–
Taraqua	44.255	2755	1972	3557	–
Cucuí	71.132	4940	2207	3192	–
Curicuriari	191.787	12,.613	2092	3441	Cucuí and Taraqua
Serrinha	291.150	18,.082	2211	3241	Curicuriari
Manaus	712.451	35,943	1591	2667	Caracaraí and Serrinha