Journal of Hydrology: Regional Studies 13 (2017) 26–42

Contents lists available at ScienceDirect

Journal of Hydrology: Regional Studies

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

Downscaling climate projections for the Peruvian coastal Chancay-Huaral Basin to support river discharge modeling with WEAP

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A R T I C L E I N F O

Keywords:
Bias correction general circulation model
Climate change
Hydrological modeling
Quantile mapping
Peru

A B S T R A C T

Study region: The Chancay-Huaral (CH) coastal river basin in the Lima Region, Peru, between the Pacific Ocean and the Andean Cordillera.
Study focus: Climate change impacts on annual and monthly discharges in the CH Basin are assessed for the future period 2051–2080. Hydrological modeling is sensitive to biases in input variables. Therefore, bias-corrected time series of temperature and precipitation from 31 General Circulation Models (GCMs) with the emission scenarios RCP4.5 and RCP8.5 (Representative Concentration Pathways) were used as inputs for the Water Evaluation and Planning System model (WEAP). Bias correction and downscaling of the GCMs were implemented using a quantile mapping method.
New hydrological insights for the region: On average, GCMs indicate increased annual mean temperatures by 3.1 °C (RCP4.5) and by 4.3 °C (RCP8.5) and precipitation sum by 20% (RCP4.5) and by 28% (RCP8.5). With increasing total precipitation, river discharges are also found to increase, but the variability among the GCMs is considerable. The largest increases in monthly discharge are projected to occur in the wet season (November − April) − with up to 31% increase of December multi-model mean. Despite the larger annual discharge for the mean multi-model result, discharges in the dry season may decrease according to some GCMs, showing the need for an adapted future water management.

1. Introduction

The North–South Andean Cordillera divides Peru (1.3 × 10^6 km^2) into three watersheds (hydrographic regions, Fig. 1): one toward the Pacific Ocean (Pacific drainage, Pd), another toward the Amazon Basin, and the third is the Lake Titicaca Basin on the Altiplano to the south. According to the Peruvian National Water Agency, Pd represents 22% of the Peruvian territory (Ruiz et al., 2008). The annual water balance (precipitation minus evapotranspiration) computed by UNESCO (UNESCO, 2006) for 1969–1999

Abbreviations: BC, bias correction; CH, Chancay-Huaral; CMIP3, CMIP5, the coupled model intercomparison project phase 3/5; EHSD, Santo Domingo Hydrological Station (Estación Hidrológica Santo Domingo); ENSO, El Niño southern oscillation; EP, Eastern Pacific; FAO, United Nations Food and Agriculture Organization; GCM, general circulation model; GDP, gross domestic product; GIS, geographic information system; IPCC, Intergovernmental Panel on Climate Change; IPCC AR4, AR5, IPCC Fourth/Fifth Assessment Report; MMC, Million cubic meters; MTM, multitaper spectral analysis method; Pd, Pacific drainage; RCP, representative concentration pathways; RLS, regulated lagoon system; RMSE, root mean square error; SENAMHI, Servicio Nacional de Meteorologia e Hidrologia del Perú; SPI-6, 6-monthly standardized precipitation index; STL, loess based seasonal trend decomposition; UNESCO, United Nations Educational, Scientific and Cultural Organization; YPS, yearly sum of precipitation; YWD, yearly number of wet days; WEAP, water evaluation and planning system model

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http://dx.doi.org/10.1016/j.ejrh.2017.05.011
Received 22 September 2016; Received in revised form 11 May 2017; Accepted 26 May 2017
Available online 12 August 2017

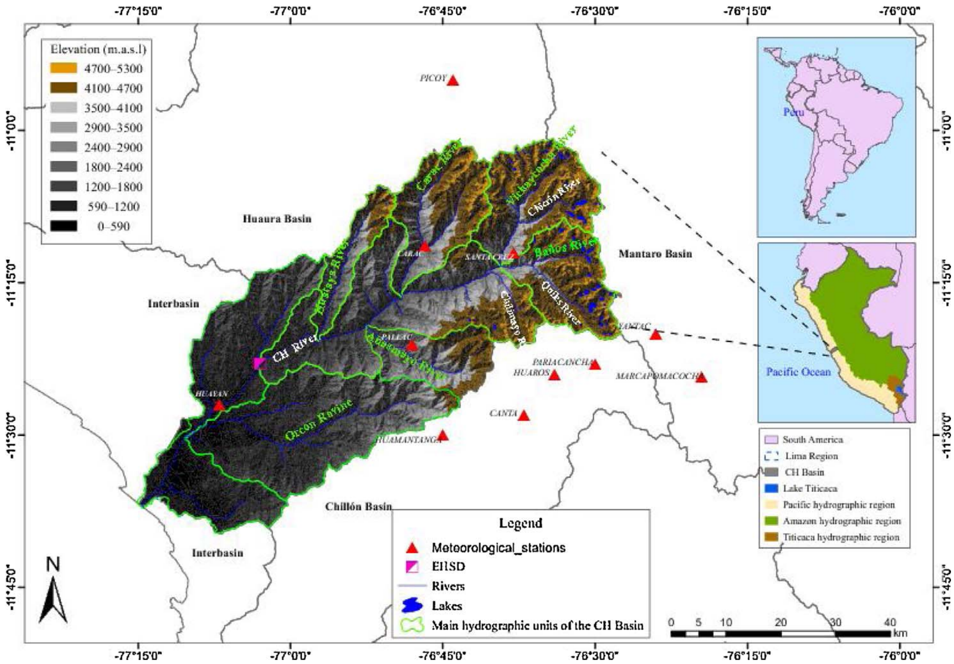

Fig. 1. Map of the location of the Chancay-Huaral Basin and adjacent basins (Huaura, Chillón, Mantaro) as well as the meteorological and hydrological stations that collected the data interpolated as input into the WEAP model. The main parameters of these observational stations are listed in Table 1. EHSD = hydrological station.

shows that the average annual available surficial water in Pd is only 16 mm. The Pd features small basins with bare and steep slopes that favor erosion and flooding during occasional rainy episodes. Rainfall is more abundant along the northern coast of Peru and declines toward the south where conditions are extremely arid (Garreaud et al., 2009).

The flow of the Chancay-Huaral (CH) River, which is recorded at the Santo Domingo Hydrological Station (*Estación Hidrológica Santo Domingo*, EHSD), plays a very important role in the economic development of the basin. The agricultural sector in the CH Basin accounts for 17% of the total gross domestic product (GDP) of the entire province of Lima (PMGRH-I, 2012). Precipitation in the upper part of the basin contributes to feeding a set of reservoirs that are discharged mainly during the dry season for hydropower purposes, agricultural use, and residential water use. In the lower part of the basin, runoff generated by seasonal rainfall supplies aquifers that are mainly used for agricultural irrigation and domestic water usage. In this regard, an uneven spatio-temporal distribution of rainfall would greatly affect water resources in this basin. For example, between 1940 and 1973, communities of the upper valley of Chancay were severely affected by five periods of drought (Lausent-Herrera, 1994).

There are increasing and competing demands on the use of water resources in Peru. The multifaceted issue of sustainable water usage and the water–food–energy security nexus has been widely acknowledged and discussed (WBCSD, 2014; WWAP, 2015). First, the population of Peru is projected to grow by 40% from 2007 to 2050, which would correspond to a population of about 40 million (PRB, 2010). Currently, 73% of the population lives in urban environments, and this proportion, as well as their living standards, is projected to increase. Therefore, domestic water usage is likely to increase rapidly. Secondly, much of the current agricultural production relies on irrigation, and consumes about 85% of the surface water in Peru (FAO, 2013). The share of agricultural water reaches 93% in the Chancay-Huaral Basin. However, the agricultural use of water depends not only on socio-economic factors and policies (e.g., land use and agricultural policy) but also on climatological and agrological conditions (e.g., land quality, crop water requirement, and evapotranspiration). Thirdly, planning for water resources management also affects industrial development, hydropower production and population health via sanitation.

Climatic variability and change pose major scientific challenges for projections of future water resources. Even with the best available Earth system models, the uncertainty surrounding future water resources may remain large. Major investments and far-reaching policy decisions regarding the development of water management may be needed to secure the future water supply and sustainable adaptation to climate change. Therefore, it is important to explore methods to project future scenarios of river discharge (discharge scenarios, hereafter) to support planning and decision-making. The studies presented in this article are part of the Peru-AquaFutura project conducted to support decision making for water resource management, including hydrological modeling and modeling of payments for watershed services (Haavisto et al., submitted).

Although it is preferable to use the most up-to-date climate models for climate change impact studies such as hydrological modeling, the raw output from low-resolution General Circulation Models (GCMs) should not be used directly to force impact models. Instead, common practice is to increase the spatial variability of GCM output data by means of statistical or dynamical downscaling. Statistical downscaling is a way to resolve the scale mismatch between local information and large-scale GCM information by applying statistical links between large-scale fields and local observations. In the dynamical downscaling approach, a regional climate