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Assessment of possible impacts of climate change on the hydrological regimes of different regions in China

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Abstract

The aim of this work is to investigate the soil water budget across China by means of hydrological modeling under current and future climate conditions and to evaluate the sensitivity to soil parameters. For this purpose, observed precipitation and temperature data (1981−2010) and climate simulations (2021−2050, 2071−2100) at high resolution (about 14 km) on a large part of China are used as weather forcing. The simulated weather forcing has been bias corrected by means of the distribution derived quantile mapping method to eliminate the effects of systematic biases in current climate modeling on water cycle components. As hydrological models, two 1D models are tested: TERRA-ML and HELP. Concerning soil properties, two datasets, provided respectively by Food and Agriculture Organization and U.S. Department of Agriculture, are separately tested. The combination of two hydrological models, two soil parameter datasets and three weather forcing inputs (observations, raw and bias corrected climate simulations) results in five different simulation chains.

The study highlights how the choice of some approaches or soil parameterizations can affect the results both in absolute and in relative terms and how these differences could be highly related to weather forcing in inputs or investigated soil. The analyses point out a decrease in average water content in the shallower part of the soil with different extents according to climate zone, concentration scenario and soil/cover features. Moreover, the projected increase in temperature and then in evapotranspirative demand do not ever result in higher actual evapotranspiration values, due to the concurrent variations in precipitation patterns.

Keywords: Water balance models; Model comparison; Bias correction; Hydrological impacts; Soil parameters; China

1. Introduction

In recent years, some relevant studies have shown that the global warming could affect the precipitation patterns and the water cycle at the global and regional scale and at different time scales (Allen and Ingram, 2002; Held and Soden, 2006; Lenderink and van Meijgaard, 2010). However, under the current observational and modeling uncertainties, the Intergovernmental Panel on Climate Change (IPCC) assesses only with "medium confidence" the anthropogenic contribution to changes in precipitation patterns, although it recognizes as "virtual certain" the ongoing processes of global warming and

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the emerging of new evidences about the variations in global precipitation (IPCC, 2014).

This topic and its huge implications for the development of effective adaptation strategies in crucial sectors (agriculture, natural disaster mitigation, water resources, water supply) have meant numerous researches aimed to investigate how climate changes may affect the entire water cycle (Fischer et al., 2007). The main studies focus on:

- the potential intensification of water cycle (Easterling et al., 2000a, 2000b; Huntington, 2006; Kyoung et al., 2011; Mason et al., 1999; Zollo et al., 2015);
- the variations (mainly increases) in occurrence and magnitude of droughts (Piao et al., 2010; Qiu, 2010; Schiermeier, 2008; Zhai et al., 2010) and flood events (Kwon et al., 2011; Prudhomme et al., 2003; Vezzoli et al., 2015; Zhou et al., 2011);
- the average trends and the associated effects on water resources (Arnell, 2004; Bates et al., 2008; Jackson et al., 2001; Obeysekera et al., 2011).

Of course, since the significance, extension and extreme geomorphological and climate heterogeneity, numerous studies have investigated such issues for China. China played indeed a key political and economic role in the mitigation of climate change and it is considered as one of the most vulnerable societies in terms of water resources and agriculture sustainability (IPCC, 2014; SC, 2011). Moreover, significant resources have been invested in climate change adaptation strategies and actions (SC, 2014). Concerning the topics already introduced, Wu et al. (2015) adopted the Soil and Water Assessment Tool (SWAT) model forced by available historical weather observation to assess the ongoing variations in the water cycle potentially induced by climate change for the Xiangjiang River Basin. On the same river basin, Luo et al. (2013) adopted the same tools for investigating the effect of current and planned scenarios of land use. Zhang et al. (2009) simulated evapotranspiration and soil water balance for different tillage systems on the 2010–2040 time span using as driver the monthly precipitation data provided by statistical downscaling of the Global Climate Model (GCM) HadCM3 projections. Wang et al. (2013) estimated the impacts of climate change on water demand for agriculture in ten basins covering the entire Chinese territory. They coupled the climate inputs provided by the Regional Climate Model (RCM) PRECIS (at 0.44° horizontal resolution; Yang et al., 2010) under A1B, A2 and B2 emission scenarios to the China Water Simulation Model (CWSM), assessing water demand and supply and allocating water among its users within the river basins. They showed how the effects could vary in function of severity of emission scenarios but, at the same time, proper adaptation strategies may satisfactorily cope with these issues.

However, for China, relatively much fewer studies have had as specific goal the investigation on potential changes induced by climate change in the soil moisture at local or regional scale. At local scale, e.g. Zhou et al. (2011) (again through the SWAT approach) assessed the effect of climate change on soil moisture dynamics and hydrological variables in an intact-forested watershed in southern China. Through the analysis of observed data, they show how current soil drying processes could be associated to relevant changes in weather forcing. Similarly, Jiang et al. (2007) perform an exhaustive comparison work analyzing the response of six different hydrological models in assessment of variations of soil hydrological balance induced by climate change (using hypothetical future scenarios) in the Dongjiang Basin (southern China).

On the other side, at country level (not only for China), this topic has been hardly investigated until now (Wu et al., 2015) also probably due to the limited availability of reliable and continuous soil moisture datasets around the world (Keshta et al., 2012). Among available studies, Komuscu et al. (1998) investigated the variations of soil moisture availability in the Southeast Anatolia (Turkey) both under the prescribed variations in weather forcing, and under those provided by the GCM, using a modified version of Thornthwaite water balance model. Naden and Watts (2001) evaluated the variations of monthly soil moisture in five typical areas of ecological interest in the United Kingdom taking into account the actual land covers and soil types. Bormann (2009) performed a sensitivity study for five different regions in Germany, aimed to understand the joined role of soil type and lower boundary conditions in response to variation of weather forcing induced by climate change. Keshta et al. (2012) adopted the Generic System Dynamics Watershed (GSDW) model (Keshta et al., 2009) to simulate the potential future soil moisture and evapotranspiration dynamics; the weather input forcing are obtained through the Statistical DownScaling Model (SDSM) proposed by Wilby et al. (2002) of Coupled General Circulation Model (CGCM3) under A2 and B1 emission scenarios. Finally, Bormann (2012) utilized the SIMULAT model (Bormann, 2008), a Soil Vegetation Atmosphere Transfer scheme (SVAT) for analysis of virtual soil columns, to assess the soil texture-specific sensitivity of simulated soil moisture to projected climate change. To this aim, he also took into account, in a simplified way, the role played by upper (land cover) and lower (shallow groundwater/free drainage) hydraulic boundary conditions of soil specimens.

Given the state of the art, the availability of climate projections at a very high resolution (0.125°, about 14 km) up to 2100 from RCM COSMO_CLM (Bucchignani et al., 2014) under RCP4.5 and RCP8.5 scenarios (Meinshausen et al., 2011) for a large part of the Chinese territory, grants an opportunity to attempt partly bridging such gap estimating the main variations assessed in soil water budget for the principal climate zones retrievable in the investigated domain.

The analysis are carried out adopting two hydrological models, two datasets for retrieving hydraulic and thermal soil properties, three weather forcing inputs. In this way, the effects of parameterizations and parameters on the assessment of seasonal and yearly soil water budget considering also the potential effect of soil type and land-use can be evaluated. Moreover, a first estimation about how current biases in weather forcing returned by climate simulations could affect the assessment of the soil water budget and its variation under