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Impacts of climate changes on water resources in Yellow River Basin, China

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Abstract

This study examined the impacts of future climate changes on water resources and extreme flows in Yellow River Basin (YRB), China, using the Coupled Land surface and Hydrology Model System (CLHMS) driven by the IPCC scenarios RCP 2.6, 4.5 and 8.5. First, the skill of 14 IPCC AR5 GCMS for simulating temporal and spatial temperature and precipitation in Yellow River Basin has been evaluated. Using the bias-corrected result of RCP storylines, the CLHMS model was developed to predict the 21 century climate and water cycle change. All the three simulation results indicate a reduction in water resources. The current situation of water shortage since 1980s will keep continue, the water resources reduction varies between 30 and 24% for RCP 2.6 and 4.5 scenarios. RCP 8.5 scenario simulation shows a decrease of water resources in the early and mid 21th century, but after 2080, with the increase of rainfall, the extreme flood events tends to increase.

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Keywords: Coupled land surface-hydrology model, Water resources, climate change, hydrological process simulation, Yellow River Basin

1. Introduction

The water cycle involves the continuous circulation of water in the Earth-Atmosphere system. It is the linkage

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among atmosphere, hydrosphere, biosphere and geosphere. Under the background of global warming, glacial ablation makes sea level rise and land water form change. It is indicated from the statistics of that climate change has already changed water cycle characteristics [1]. Climate change have been widely investigated throughout the world. But how climate change will affect the temporal and spatial distribution of water cycle in the future? This problem has become the key issue of international society [2, 3].

From General Circulation Model (GCMs) to Atmosphere-ocean General Circulation Model (AOGCMs). The scientists focus on the study of the physical process of climate system model to improve the simulation performance. As a powerful tool for climate change research, GCMs allow the simulated climate to adjust changes in climate forcing, it provide a method to reveal the water cycle processes and to predict the trend of future climate change.

The Yellow River (YRB) is located in northern China. It is the second longest river in China and the sixth longest river in the world at the estimated 5464 km. Its total basin area is 0.75 million km^2. Over the past 50 years, the precipitation of YRB presents downward trend, among which, the decreased rainfall in spring and autumn is the most obvious [4]. Meanwhile, the runoff in the basin is obviously decreasing [5]. The contradiction between supply and demand of water resource in YRB is increasingly severe.

This study is intended to estimate the changing trends of water resources in the YRB using a coupled land surface and hydrological model system (CLHMS) driven by the IPCC scenarios RCP 2.6, 4.5 and 8.5. Section 2 briefly describes the model and the YRB. In consideration of the GCMs simulation ability in different areas, firstly the temperature and precipitation simulation capabilities during the 20th century (1962-2005) of 14 GCMs in YRB are examined in section 3. On the basis of that, three different RCP scenarios (RCP2.6, RCP4.5 and RCP8.5) are used to drive the CLHMS model. And the climate and water resources changing trend in the 21st century in the Yellow River Basin are analysed and presented in section 4.

2. Model and Study area

2.1. Model description

The Coupled Land surface and Hydrology Model System (CLHMS) include a large scale land surface model LSX [6] and a fine grid distributed hydrological model HMS. The coupling between the LSX and HMS is based on predicted soil moisture and surface water depth [7]. The land-surface models include two-layer vegetation model, three-layer snow model and six-layer soil model; the hydrological models include terrestrial hydrologic model (THM), groundwater hydrologic model (GHM) and channel ground-water interaction (CGI).

The Parameters in the CLHMS model include soil texture, vegetation type, hydrological parameters and hydrogeological parameters. Soil texture is interpolated with the global dataset of Global Environmental and Ecological Simulation of Interactive System [8], vegetation type is used CLDH data (China Land-use Data for Hundred years) [9] Hydrologic parameters in the basin are developed from the USGS HYDRO1k DEM with ZB algorithm [10]. The hydrogeological parameters such as hydraulic conductivity and porosity are interpolated with the Harmonized World Soil Database [11]. The CLHMS reproduces well the natural hydrological processes, the simulation performances of the water balance and the seasonal and interannual variation of streamflow are already proved in the Yellow River Basin, Huaihe River Basin and Pearl River Basin in China [12-14].

2.2. Study area and data set

The Yellow River Basin (Figure 1) has an east-west extent of about 1900 km, it is located in the north area of East Asian monsoon region. Affected by atmospheric circulation and monsoon circulation, the spatial and temporal climate of the basin varies obviously. The upper reaches of YRB are in the arid and semi-arid area, and the lower reaches are in the semi humid area. The instability East Asian monsoon is also the cause of uneven seasonal distribution of rainfall, more than 50% of annual rainfall accurse form June to September, while the winter and spring are dry. During the last 50 years, the rainfall and runoff in the basin are significantly decreased.

The CMIP5 (Coupled Model Intercomparison Project Phase 5) experiments includes the historical climate simulation experiments for the 20th century and prediction experiments for the 21st century driven by "Representative Concentration Pathways" concentrations [15]. Based on the East Asia gauge-based analysis of daily precipitation data [16], daily temperature CN05 [17] and the historical run's outputs of 14 CMIP5 GCM models (Table