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Climate change and water resources: Case study of Eastern Monsoon Region of China

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Abstract

This paper addresses the impact of climate change on the water cycle and resource changes in the Eastern Monsoon Region of China (EMRC). It also represents a summary of the achievements made by the National Key Basic Research and Development Program (2010CB428400), where the major research focuses are detection and attribution, extreme floods and droughts, and adaptation of water resources management. Preliminary conclusions can be summarized into four points: 1) Water cycling and water resource changes in the EMRC are rather complicated as the region is impacted by natural changes relating to the strong monsoon influence and also by climate change impacts caused by CO_2 emissions due to anthropogenic forcing; 2) the rate of natural variability contributing to the influence on precipitation accounts for about 70%, and the rate from anthropogenic forcing accounts for 30% on average in the EMRC. However, with future scenarios of increasing CO_2 emissions, the contribution rate from anthropogenic forcing will increase and water resources management will experience greater issues related to the climate change impact; 3) Extreme floods and droughts in the EMRC will be an increasing trend, based on IPCC-AR5 scenarios; 4) Along with rising temperatures of 1 °C in North China, the agricultural water consumption will increase to about 4% of total water consumption. Therefore, climate change is making a significant impact and will be a risk to the EMRC, which covers almost all of the eight major river basins, such as the Yangtze River, Yellow River, Huaihe River, Haihe River, and Pearl River, and to the South-to-North Water Diversion Project (middle line). To ensure water security, it is urgently necessary to take adaptive countermeasures and reduce the vulnerability of water resources and associated risks.

Keywords: Climate change; Water cycle; Water resources; Vulnerability; Adaptation

1. Introduction

It is important to determine the impact of climate change on water resources to enable sustainable global water utilization (GTTWFH, 2013; IPCC, 2007a, 2007b, 2014a, 2014b; Pahl-Wostl et al., 2005). Considerable changes have occurred in the water cycle due to the integrated influence of climate change and human activities; such changes ultimately alter water resource distribution and the environmental evolution of

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soil and water (Chahine, 1992; Oki and Kanae, 2006). In China, precipitation is distributed extremely unevenly, both spatially and temporally, particularly in the Eastern Monsoon Region of China (EMRC). This area has the highest population density and has experienced the fastest speed of economic development in China; therefore, water shortages, drought, flooding, and eco-environmental problems are very prominent (Xia, 2012).

According to natural geographical regionalization in China (Xia and Chen, 2001), the country can be divided into three natural geo-regions: the EMRC, the Arid and Semi-arid Region in Western China (ASRWC), and the Tibetan Plateau Region in China. However, from the perspective of climatology, there is another terminology, namely the East Asian Monsoon Region, which is usually considered to be an area east of 100°E whose cover is larger than EMRC (Tao and Chen, 1987; Zhang et al., 1996; Wang et al., 2004). EMRC focuses on more on natural geography aspect in China, i.e., one of three natural geo-regions in China. EMRC is the largest of the three natural geo-regions and is home to 95% of the population. It occupies 46% the total land area of China and covers an area east of Great Khingan, south of the Inner Mongolia Plateau, and east of the Qinghai-Tibetan Plateau. As such, it has considerable socioeconomic importance, is very sensitive to climate change, and is also largely affected by serious water problems. The EMRC covers almost eight of the major river basins in China, such as the Yangtze River, Yellow River, Huaihe River, Haihe River, and Pearl River, which are focal areas for national water resource evaluation and planning, as well as regions covered by the South-to-North Water Diversion Project in China (Xia, 2012; Xia and Chen, 2001). Under the background of global warming, available water resources in northern China are decreasing, water consumption is increasing, and extreme hydrological events are occurring more frequently (Xia, 2012; Duan and Phillips, 2010). Such problems increase the vulnerability of water resources and will ultimately influence their allocation in China, thereby reducing the benefit of large water transfer and flooding control projects. It is thus necessary to explore four key scientific issues:

How has the climate and water cycle changed historically?

What will the changes be in the future?

What is the mechanism of change?

How should we adapt to these changes?

These questions are the research focus of the National Key Basic Research and Development Program with respect to, “The impact of climate change on terrestrial water cycle, regional water resources security and the adaptation strategy for Eastern Monsoon Region of China” (2010CB428400), and are the most prolific water science issues relating to the Earth's system. Under guidance from the project leader, the research team has been working for the past five years to obtain new ideas and knowledge, and applied to Ministry of Water Resources in China and other sections; these are briefly summarized in this paper.

2. New advances in understanding climate change and water resources in EMRC

The impact of climate change on the water cycle is a very complex and nonlinear inter-related process. Under the impact of nature climate change and anthropogenic forcing, the spatiotemporal distribution, intensity, and total amount of precipitation (and parameters such as movement of the rain belt, temperature, humidity, wind speed, and evaporation) will largely deviate in the long-term and will result in changes in global and regional water cycles. In addition, certain human activities such as land use and cover change, agricultural activities, deforestation, urbanization, water resource utilization, and ecological environment change also cause changes in evaporation, infiltration, runoff generation and concentration, and ultimately influence the water cycle. In general, none of these above-mentioned processes occur in isolation, and although they are both interdependent they impose mutual restraints on each other. In addition, they have their own particular characteristics. In the past five years, the research team has obtained new knowledge and technological advances, and these are described as follows.

(1) A gridded dataset has been developed in China; this provides quality control for correlations based on observations from high density meteorological stations (Liu and Xia, 2011). This fruitful gridded dataset provides a scientific basis for understanding the characteristics of regional water circulation in the EMRC under climate change. Furthermore, variability in hydrological and meteorological variables have been identified based on the new observations, and changes in the water balance between different time periods have been clarified. For example, based on new observations of both meteorological and hydrological stations in the EMRC, changes relating to hydrological cycling and water resources have been evaluated within China for the periods 1960−1985 and 1986−2013 (some of these results are presented in Table 1). In addition, Zhang (2015) has provided an overview of observed summer climate change over the EMRC during the past half century, and this study is extremely helpful for understanding the climate change aspect within the EMRC.

(2) A new two-layered Land-Atmosphere Coupling Model and land data assimilation system have been developed. Based on the developed model, the contribution of natural climate change and anthropogenic forcing to the water cycle of EMRC have been identified. This includes an evaluation of the attribution rate of climate change impact to precipitation and runoff, and also the impact on the South-to-North Water Diversion Project (middle route) and on the feedback involved between regional climate and groundwater exploitation (Liu and Xia, 2011; Zhang et al., 2015; Yu et al., 2014; Duan and Phillips, 2010). Research on the attribution aspect has shown that hydrological change in China is due to