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Projected changes in temperature and precipitation climatology of Central Asia CORDEX Region 8 by using RegCM4.3.5

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ABSTRACT

This work investigated projected future changes in seasonal mean air temperature (°C) and precipitation (mm/day) climatology for the three periods of 2011–2040, 2041–2070, and 2071–2100, with respect to the control period of 1971–2000 for the Central Asia domain via regional climate model simulations. In order to investigate the projected changes in near future climate conditions, the Regional Climate Model, RegCM4.3.5 of the International Centre for Theoretical Physics (ICTP) was driven by two different CMIP5 global climate models. The HadGEM2-ES global climate model of the Met Office Hadley Centre and the MPI-ESM-MR global climate model of the Max Planck Institute for Meteorology were downscaled to 50 km for the Coordinated Regional Climate Downscaling Experiment (CORDEX) Region 8. We investigated the seasonal time-scale performance of RegCM4.3.5 in reproducing observed climatology over the domain of the Central Asia by using two different global climate model outputs. For the future climatology of the domain, the regional model projects relatively high warming in the warm season with a decrease in precipitation in almost all parts of the domain. A warming trend is notable, especially for the northern part of the domain during the cold season. The results of our study show that surface air temperatures in the region will increase between 3 °C and about 7 °C on average, according to the emission scenarios for the period of 2071–2100 with respect to past period of 1971–2000. Therefore, the projected warming and decrease in precipitation might adversely affect the ecological and socio-economic systems of this region, which is already a mostly arid and semi-arid environment.

1. Introduction

The arid and semi-arid Central Asia domain, ranging from the Caspian Sea in the west to China in the east and from Russia in the north to Afghanistan in the south, is the core region of the Asian continent. The Central Asia region is identified as a large continental shadow basin (Türkeş, 2010) because of surrounding high mountains with high snow and glacial water capacity. Due to the diverse geography of Central Asia, such as large deserts (e.g. Gobi, Kyzylkum, Karakum, Taklamakan), high mountains (e.g. Himalayas, Karakurum, Tian Shan), and vast grassy steppes, variability and changes in climate can differ greatly. Water resources are very critical for the arid and semi-arid Central Asia region. Besides the seasonal melting of snow and glacial accumulations, the water supplied by the major natural water resources such as the Amu Darya, the Syr Darya, the Hari River, the Aral Sea, and the Caspian Sea are also vital to all living biota within the region.

Adverse effects of climate change have been becoming more severe on different spatial and temporal scales. The characteristics of its continental and dry climate make Central Asia more vulnerable to changes in climate than its surrounding regions. According to the 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), the occurrence frequency of heat waves was augmented and the number of heavy rainfall events has increased in most parts of Europe and Asia (IPCC, 2013). Agricultural production has already tended to decline and water resources are also at risk under climate change (Perelet, 2007). Climate change and variability studies about Central Asia, based on the observation and modeling, indicate that it is expected to be adversely affected by climate change (e.g. Lioubimtseva et al., 2005; Schiemann et al., 2008; Lioubimtseva and Henebry, 2009; Ozturk et al., 2012; Mannig et al., 2013; Forsythe et al., 2014). Most of the studies focus on the hydrological impacts of climate change on Central Asia's water resources (e.g. Small et al., 1999; Elguindi and Giorgi, 2006, 2007; Immerzeel et al., 2010; Sorg et al., 2012; Dietz et al., 2013; Hagg et al., 2013; Reyers et al., 2013; Eisfelder et al., 2014). Studies about the impacts of future climate change on water resources of the Central Asia are very precious in terms of the adaptation to climate

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change for a sustainable life in this large arid and semi-arid region. Elguindi and Giorgi (2006, 2007) revealed that under different climate change scenarios, significant seasonal changes in the Caspian Sea level may be observed in future. Ozturk et al. (2012) also showed that an increase in mean air temperature and decrease in the amount of precipitation in the Central Asia are expected for the period 2071–2100. Similarly, Mannig et al. (2013) projected air temperature changes between approximately 2 and 7 °C in the region for both summer and winter until the end of the 21st century. Also, their model results predicted a decrease in summer precipitation amounts in the monsoon season of Central Asia. There are relatively few studies that have investigated the future climatology of the region. No studies of this region have yet been performed by running regional climate models with multiple CMIP5 climate models (Taylor et al., 2012) as a forcing dataset.

In this work, the regional climate model, RegCM4.3.5, was forced by two different CMIP5 global climate models under the two new emission scenarios of the IPCC (i.e. RCP4.5 and RCP8.5) as an input in order to investigate the projected changes in the future climate conditions of the Region 8 domain (Central Asia) in the CORDEX framework.

2. Data and methodology

In order to assess the impacts of climate change and variability on the various socio-economic sectors, physiographic and ecological systems such as health, agriculture, forests and forestry, hydrology and water resources, etc., and to provide useful information for the development of essential mitigation and adaptation strategies, ensemble studies and coordinated researches become even more important. Hence, to produce high-resolution data the CORDEX was established in 2008 by the World Climate Research Programme (WCRP). Within the CORDEX framework, the Central Asia domain, known as “Region 8”, covers a vast domain with the corner points at 54.76°N-11.05°E, 56.48°N-139.13°E, 18.34°N-42.41°E, and 19.39°N-108.44°E with a horizontal resolution of 50 km. In the present study, fundamental climate variables for the Central Asia region were simulated via RegCM4.3.5 under the two different RCPs (Van Vuuren et al., 2011). The performance of the regional climate model in reproducing the observed climatology was tested by using the ERA-Interim (Simmons et al., 2007) reanalysis dataset, which is the latest ECMWF global atmospheric reanalysis of the period 1979 to present, with a grid resolution of 0.75° × 0.75°. CMIP5 global climate models of the HadGEM2-ES and MPI-ESM-MR were used for the CORDEX Region 8 as forcing data for future simulations. HadGEM2-ES is a coupled Earth System Model that was developed by the Met Office Hadley Centre for the CMIP5 centennial simulations (Collins et al., 2008). MPI-ESM-MR, which is an Earth-System Model running on medium resolution grid, was developed by the Max Planck Institute for Meteorology (Giorgetta et al., 2013).

3. Model description and experimental design

RegCM4.3.5 is a hydrostatic nature regional climate model, which was first developed by Giorgi et al. (1993a, 1993b). The dynamic structure of the RegCM is formed from the hydrostatic version of Pennsylvania State University's National Atmospheric Research Center (National Center for Atmospheric Research, NCAR), which is called MM5 (the Mesoscale model) (Grell et al., 1994). SUBBATS (Giorgi et al., 2003a, 2003b), which is the sub-grid scaled version of the previous scheme of BATS1E (Biosphere-Atmosphere Transfer Scheme), has been used for the surface (Dickinson et al., 1993) and Community Land Model (CLM) version 3.5 is also included in the dynamic structure of the code as an option (Oleson et al., 2008; Tawfik and Steiner, 2011). In this study, BATS1E was used for land surface processes.

Radiative transfer in the RegCM has been modeled by using NCAR Community Climate Model, version CCM3 (Kiehl et al., 1996) radiation package. It has been modeled through the solar radiation transfer δ-Eddington (Kiehl et al., 1996) approach. The part of the cloud radiation

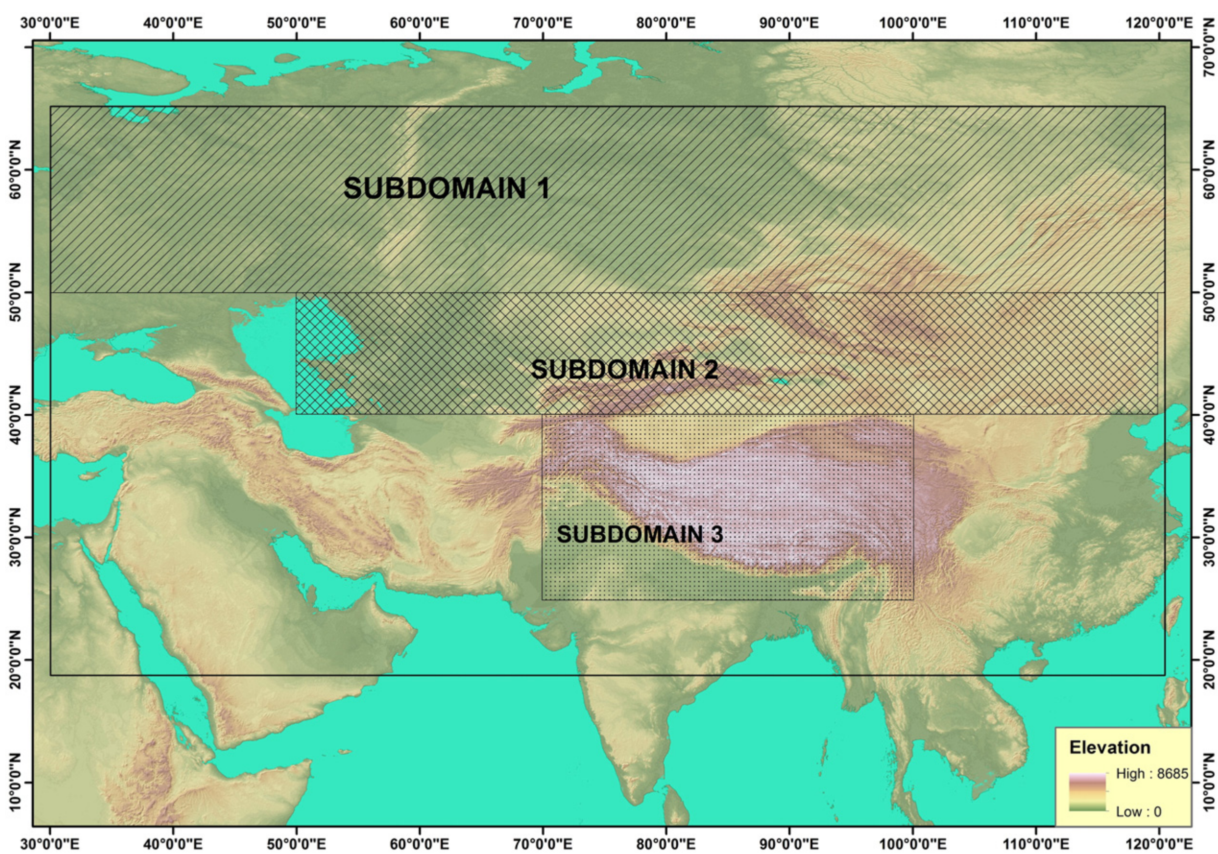

Fig. 1. General physical/relief map of Eurasia, subdomains delimitated for the study and its surroundings.