

Simulations of Future Drought Conditions in Central Asia CORDEX Region 8 by Using RegCM 4.3.5

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Abstract

In this work, projected future changes in mean surface air temperature and precipitation climatology, inter-annual and seasonal variability and climatic aridity/humidity conditions for the period 2070-2100 over the large Central Asia region with respect to present climate (from 1970 to 2000) were simulated based on the RCP4.5 and RCP8.5 emission scenarios. Regional Climate Model (RegCM4.3.5) of the International Centre for Theoretical Physics (ICTP) was used for projections of future and present climate conditions. HadGEM2 global climate model of the Met Office Hadley Centre and MPI-ESM-MR global climate model of the Max Planck Institute for Meteorology were downscaled to 50 km for the CORDEX Region 8. We investigated the seasonal time-scale performance of RegCM4.3.5 in reproducing observed climatology over the domain of Central Asia by using 2 different global climate model outputs. For the future climatology of the domain, the regional model predicts relatively high warming in the warm season and northern part of the domain at cold season with a decrease in precipitation almost all part of the domain. The results of our study show that surface temperatures in the region will increase from 3 °C up to more than 7 °C on average according to the emission scenarios for the period 2070-2100 with respect to past period 1970-2000. Therefore, the projected warming and decrease in precipitation and also resultant or associated increased aridity and more frequent and severe drought events very likely adversely affect the ecological and socio-economic systems of this region, which is already characterised with mostly arid and semi-arid climate and ecosystems.

Keywords: *Central Asia, climate change, RegCM.*

1 Introduction

Climate change can be considered as one of the most significant challenges that the world has ever faced in the 21st century. According to the 5th Assessment Report (AR5) of Intergovernmental Panel on Climate Change (IPCC), warming in our climate system is explicit and since the 1950s never-before-seen changes in global climate have been observed for decades (IPCC 2013). Negative effects of climate change have been becoming more severe on different spatial and temporal scales. Characteristics of the continental climate make Central Asia more vulnerable to global climate change than other areas (Türkeş 2010). Climate change studies about Central Asia based on the observation and modeling results indicate that Central Asia region is expected to be adversely affected by climate change

(Liobimtseva and Henebry 2009, Schiemann et al. 2008, Ozturk et al. 2012, Mannig et al. 2013). Water resources are very critical for the arid and semi-arid Central Asia region, and its water resources are under the risk of climate change. Therefore, most of the studies focus on the hydrological impacts of climate change on Central Asia's water resources (Eisfelder et al. 2011, Elguindi and Giorgi 2007, Hagg et al. 2013, Immerzeel 2010, Reyers et al. 2013, Small et al. 2013, Sorg 2012, Zou 2014).

1.1 Data and Methodology

CORDEX Central Asia (Region 8) is defined as a 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.

Projected changes for the period 2070-2100 in air temperature and precipitation climatology and variability with respect to the control period 1970-2000 were assessed for the extended Central Asia. The results obtained from the regional climate model (RegCM4.3.5) of ICTP (International Centre for Theoretical Physics) were evaluated for future projections with respect to simulated present climate conditions. HadGEM2 global climate model of the Met Office Hadley Centre and MPI-ESM-MR of the Max Planck Institute for Meteorology were downscaled to 50 km for the extended Central Asia by using the regional climate model. The future simulations were applied based on IPCC's mid-range mitigation emission scenario RCP4.5 and high-emission scenario RCP8.5. In addition, in order to address model's performance, simulated mean air temperature and precipitation amounts of the regional climate model were compared with the Climatic Research Unit's (CRU) observational dataset over Central Asia for the reference period 1970-2000. For the parameterization part of the model, the best agreement with observational data was obtained by choosing the Grell scheme with the Fritsch-Chappell type closure.

2 Results and Discussions

2.1 Air Temperature and Precipitation Simulations for the Reference Period

Firstly, RegCM4.3.5's downscaling skill was examined by comparing the model results with the CRU observational datasets for seasonal temperature and precipitation within the reference period 1970-2000. The results of the model which is run by the HadGEM2 show that there is a cold bias in the northern part of the domain for winter season. However, cold bias is not generated by the model which is driven by the MPI-ESM-MR. This model has a strong warm bias in northeast part of the region. Cold bias is seen during all four seasons and in all datasets around mountainous part of the domain like Himalayas and Plateau of Tibet. Since we observe this cold bias in all outputs of the model which is run by two different datasets, this could be due to station bias. The meteorological stations are probably constructed in the valleys of this region. In other parts of the domain, an overall bias of model is between -1.5 and 1.5 °C for temperature. Thus, performance of the regional climate model is reliable in that parts of the Central Asia domain.

For the northern and eastern parts of the domain, precipitation is generally overestimated especially for MPI-ESM-MR data with respect to observational data for all seasons except summer. Precipitation is slightly underestimated for the southern part of the domain except the Asian monsoon region including the Himalayas and other mountainous areas. During the spring, autumn and winter seasons, results of all datasets show excess precipitation over the mountainous areas of the Asian monsoon region. However, results are obviously different in summer season. In summer, precipitation is underestimated for most parts of the domain,

compared with the observation, whereas highly increased precipitation is estimated for the continental semiarid eastern and humid/semi-humid southeastern parts of the domain.

2.2 Future Projections of Air Temperature

In this part, we presented air temperature change projections for the future period 2070-2100 with respect to the present period 1970-2000 based on the IPCC's RCP4.5 and RCP8.5 emission scenarios. For both of future periods, the projections results indicate a warming trend throughout the region. According to RCP4.5 model scenario results, there will be 3-4 °C increase in temperature for summer season at all part of the region between 2070 and 2100. Warming will be the most at northern part of the domain at winter season. The results of RCP8.5 emission scenario outputs of HadGEM2 global model dataset for the period 2070-2100 is presented in Figure 1. According to RCP8.5 model scenario results, this increase will be more severe and it will be more than 7 °C for almost all part of the domain and for all seasons.

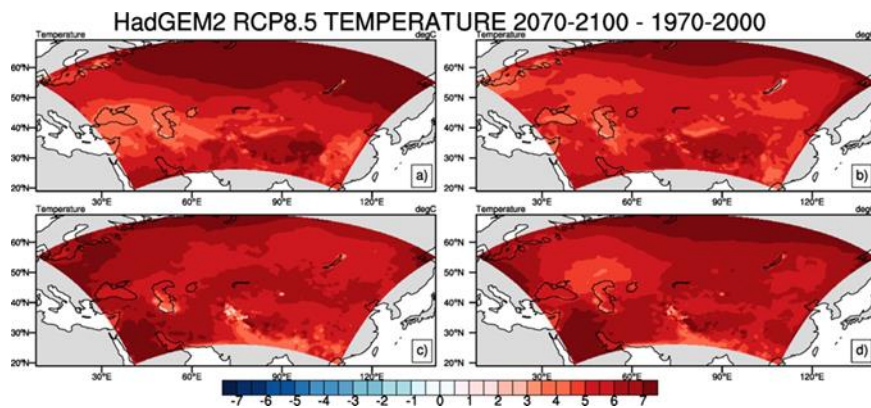


Figure - 1 Distribution patterns of changes in projected mean air temperatures: (a) winter, (b) spring, (c) summer and (d) autumn seasons

The outputs of MPI-ESM-MR global model dataset show similar trend with outputs of HadGEM2 global model dataset. However, the intensity of warming projected by using MPI-ESM-MR global model is slightly less than HadGEM2 global model projections especially in RCP8.5 emission scenario.

2.3 Future Projections of Precipitation

The results of RCP8.5 emission scenario outputs of HadGEM2 global model dataset for the period 2070-2100 is presented in Figure 2. In almost all seasons and for both cases, amounts of precipitation in the northern part of the domain do not change with respect to the present period of 1970-2000, except RCP8.5 scenario output in winter and autumn seasons. Both emission scenarios' output estimate similar results for future projections. Drier conditions will occur for the most part of the region which is already arid and semi-arid according to the projections.

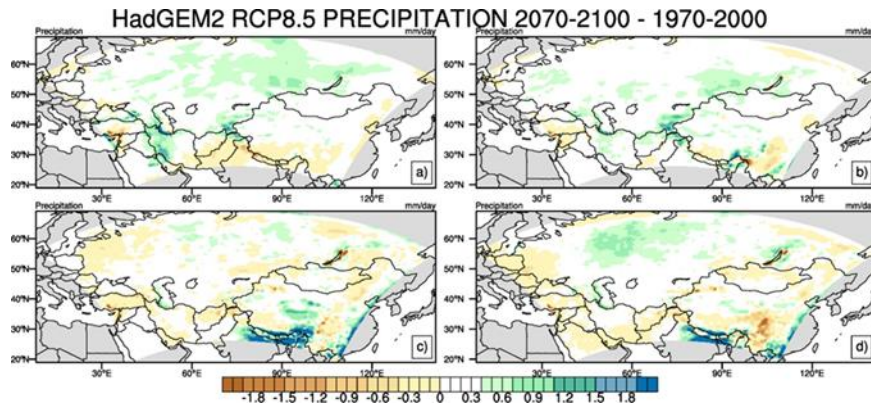


Figure - 2 Distribution patterns of changes in projected total precipitation amounts: (a) winter, (b) spring, (c) summer and (d) autumn seasons.

For the MPI-ESM-MR global model, in all parts of the Central Asia domain, we observe almost no change or decrease in precipitation except the RCP8.5 emission scenario outputs. According to the RCP8.5 emission scenario output of regional climate model which is forced by MPI-ESM-MR global climate dataset, there will be an increase in precipitation in the northern part of the domain for all seasons. Decrease in precipitation is observed prominently, especially in the southeastern part of the domain.

2.4 Conclusion

We simulated future air temperature and precipitation climatology of the Central Asia domain by using regional climate model RegCM version 4.3.5 with different forcing data. For the future climatology of the domain, the regional model which is forced by two distinct global climate models predicts relatively high warming in the cold season and a decrease in precipitation almost all part of the domain. The large Central Asian region is an area which is extremely vulnerable to global climate change. The results of our studies indicate that surface temperatures in the region will increase from 3°C up to 8°C on average for period of 2070-2100. In the future, a decrease in the amount of precipitation is also expected for the region. Even though we have used the results of two different global climate models together with regional climate model run, warming and decrease in precipitation for the domain is projected by both of them. Therefore, the projected warming and decrease in precipitation might strongly affect the ecological and socio-economic systems of this region, which is already a mostly arid and semi-arid environment.

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