High Resolution Projection of Climate Change and Climate Extremes (Drought/Zud) in Mongolia under the Increasing Green House Gas

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Abstract

In this study, a high resolution climate change scenario has been developed over Mongolia using regional climate model (RegCM3) under A1B GHG emission scenarios of fourth assessment report of IPCC. The model obtains initial and time dependent boundary data from ECHAM5 global climate model and totally 120 years integration is done.

The model well simulated seasonal mean of cold and warm seasons and their intra-annual variability. There are less than few degrees of warm bias in winter and cold bias in summer seasons. Relative high bias corresponds to high mountain region of the country. Spatial correlation coefficients between observed and model simulated mean are 0.81 in winter and 0.89 in summer for temperature, and 0.40 in winter and 0.91 in summer for precipitation as respectively.

According to climate change scenario over Mongolia, seasonal temperature is projected to increase 0.5-6.0^{0}C through beginning to end of century. Summer precipitation will decrease by 10-20% in 2011-2030, increase by 10-20% in 2046-2065 and decrease again by 10-40% in 2080-2099. Winter precipitation will increase by 10-60% in almost whole territory, especially over mountains. Drought/zud frequency will be projected to increase/decrease.

Introduction

Over the territory of Mongolia, the annual mean air temperature at 2m has been increased by 2.1^{0}C ($p<0.05$) and annual total precipitation is decreased by 10 percent in last 70 years (P.Gomboluudev, 2011). Particularly, dryness has been detected in summer season and actual process was intensifying especially since mid of 1990s (Figure 1). The summer condition affects to winter season as combining with more severe harsh winter, consequently brings huge number of livestock loss (zud) in herder's community (Figure 2).

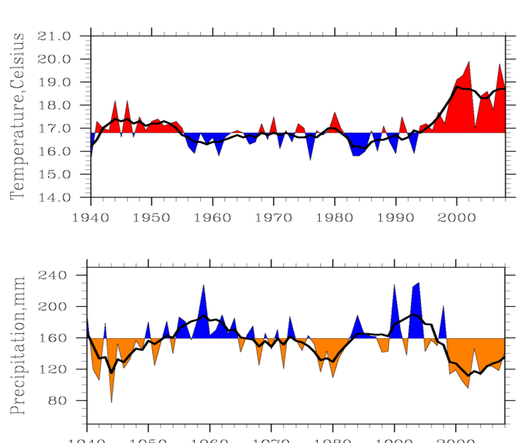


Figure 1. Summer a) air temperature (^{0}C), b) precipitation change (mm) over Mongolia

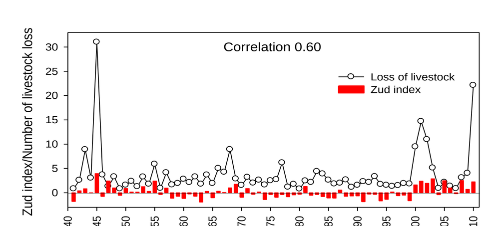


Figure 2. Relationship between zud index and number of livestock loss (L.Natsagdorj, 2010)

Its impact is becoming higher year to year. Therefore, high resolution climate change scenarios is needed in detailed impact assessment of climate change, in terms of temporal and spatial resolution. Toward that objective, a dynamic downscaling method is used in the study performing regional climate model (RCM) under the A1B GHG, fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). We have done 3 sets of integrations using latest version of ICTP Regional Climate Model (RegCM3, Giorgi et al. 1993a, b, Pal et al.2007). First simulation is forced at lateral boundary by NCEP reanalysis data and second one is by global climate model (GCM, ECHAM5) output. These are considered to assess RCM model skill and GCM model bias against present climate/reference period from 1981 to 2000 as respectively. Third integration is forced by ECHAM5 model output to project future climate over Mongolia from 2011 to 2100.

Warm (JJA) and cold (DJF) seasons are selected to determine the seasonal change of temperature and precipitation in the three time slice of future climate periods such as beginning (2011-2030), middle (2046-2065) and end (2080-2099) of this century. Finally, drought and zud frequency are calculated in the same periods as well.

Model design and configuration

Figure 3 depicts the model topography and vegetation category in the domain. Our focused region (41.5-52^0 N, 87.5-120^{0}E) is located large enough from the lateral boundary and synoptic system disturbances could be captured over the domain. High mountainous region in Mongolia such as Altai, Khangai and Khentii mountains and dominant vegetation type are well represented in model domain. CRU grid data and 69 meteorological stations data have been used in validation.

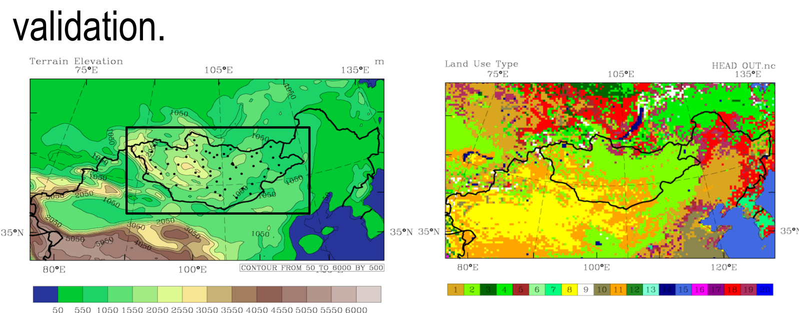


Figure 3. Model domain a) topography, m and b) land use category

The model physics and parameters are shown as following:

- SUBEX large scale precipitation
- Grell cumulus
- Holtslag PBL
- BATS1E land surface model
- Grid distance 30km

Validation results and analysis

Mean of DJF and JJA intra-annual temperature and precipitation over the focused region are depicted in Figure 4 with their standard deviations. Generally, winter temperature is overestimated (warm bias) and summer temperature underestimated (cold bias) less than 3^{0}C degrees in most area of the country and 6-9^{0}C degree in high mountain peak.

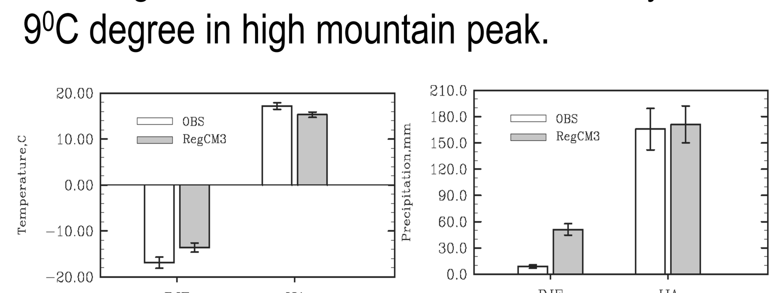


Figure 4. Mean of intra-annual seasonal temperature, ^{0}C and b) precipitation, mm

Spatial correlation coefficients between 20 year mean of observation and model simulation are 0.81 in winter and 0.89 in summer time as respectively. Precipitation is overestimated in both seasons and especially its value is large over high mountainous region in winter. Spatial correlation coefficients between observed and model simulated precipitation are 0.40 in winter and 0.91 in summer. There is more high skill to predict summer precipitation in the model according to validation result. Figure 5 and 6 show the annual mean temperature and precipitation spatial pattern.

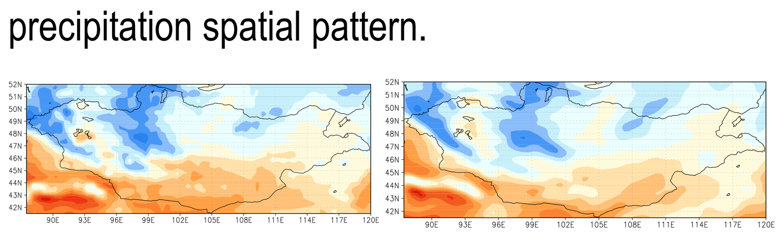


Figure 5. Annual mean temperature ^{0}C 1981-2000 a) CRU b) model simulation

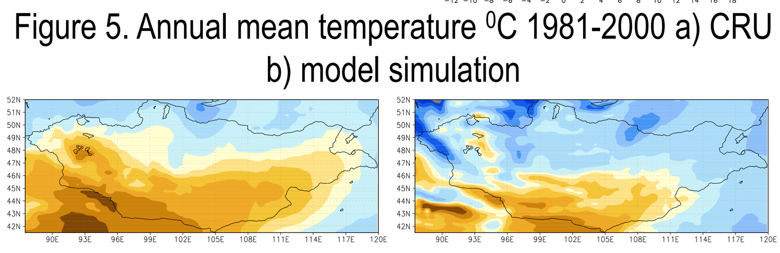


Figure 6. Annual mean precipitation mm, 1981-2000 a)CRU b) model simulation

However, the model reasonably well simulates temperature and precipitation anomaly (Figure 7). Their correlations between observation and simulation vary from 0.67 to 0.85.

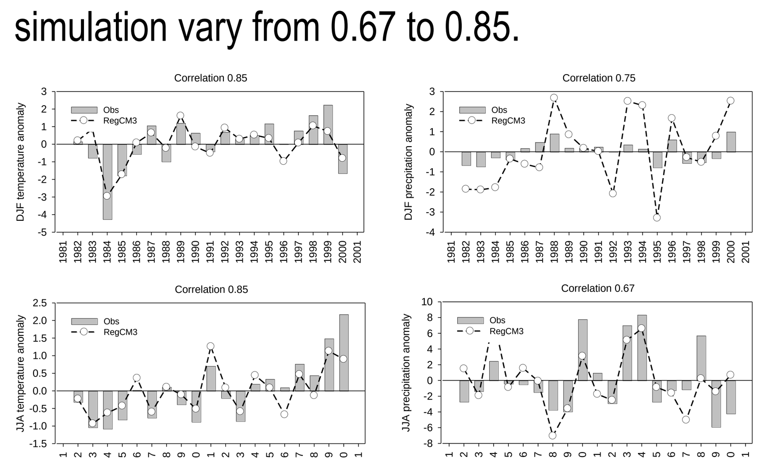


Figure 7. DJF and JJA intra annual temperature and precipitation anomaly

Validation results and analysis

Simple drought and zud indices have been estimated using both 69 stations observation and model simulation data. They are defined as applying based on normalized monthly precipitation and temperature as following:

***Drought (summer) index**= (Normalized Temperature - Normalized Precipitation) >2.0*

***Harsh (winter) index** = (Normalized Temperature - Normalized Precipitation) <-2.0*

***Zud index** = Drought index –Harsh index >2*

The model reasonably well simulates drought and harsh indices over Mongolia. Their correlation are 0.76 and 0.80 as respectively.

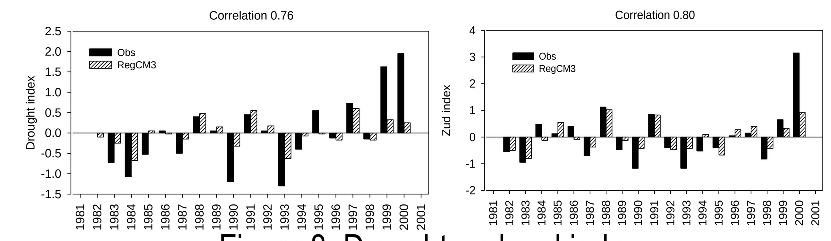


Figure 8. Drought and zud index

Climate change projection results

Figure 9 shows changes of temperature and precipitation in different climatic periods in future. Generally, temperature will change from 0.5 to 2.0^{0}C in 2011-2030, 2.0-3.5^{0}C in 2046-2065 and 4.0-6.0^{0}C in 2080-2099. High intensity of increasing of temperature is projected in south-east, south and south west part of Mongolia (Figure 9a). Precipitation change is expressed as its climate mean by percent. If look at its pattern trends, precipitation will decrease by 10-20% in 2011-2030, increase by 10-20% in 2046-2065 and decrease again by 10-40% in 2080-2099. Relative high intensity of decreasing is projected in south east, south west and southern part of the country as coinciding with increasing temperature (Figure 9b). High increasing is projected south western part in 2011-2030.

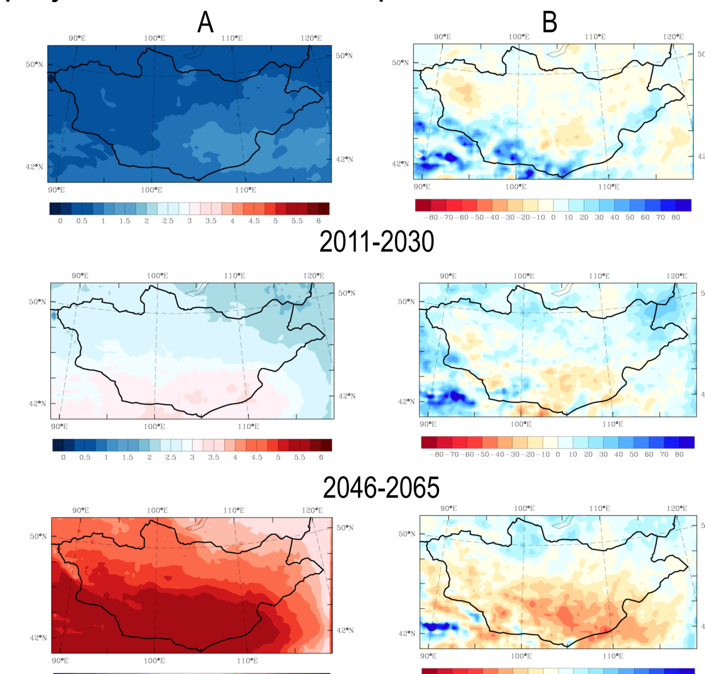
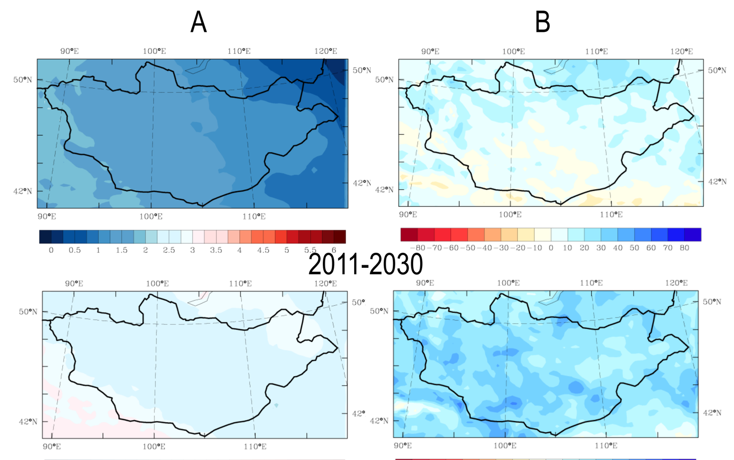


Figure 9. Changes of JJA a) temperature and b) precipitation in different climatic periods

In winter, temperature is projected to increase by 0.5-4.5^{0}C. It is a little bit lower than summer temperature change through all periods. Relative high intensity increasing is expecting in mainly central part of Mongolia (Figure 10a). Winter precipitation will increase by 10-60% in almost whole territory, especially over mountains. However, small amount of decreasing less than 10%, is expecting in some part of southern region in 2011-2030 (Figure 10b).



Climate change projection results

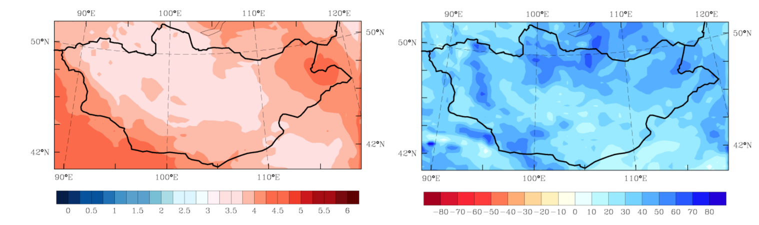


Figure 10. Changes of JJA a) temperature and b) precipitation in different climatic periods

Figure 11 shows number of drought occurrence in different climatic periods in the future. Generally, drought condition will be strengthening. According to present climate, the number occurrence varies 2-10 times in 60 months (3-17%). But this number will be reached to 10-18 times (17-30%) over the country in the future, especially in south east part in 2046-2065 (Figure 11c).

Harsh winter condition will be weakening. Number of zud occurrence is projected to decrease whole territory of Mongolia.

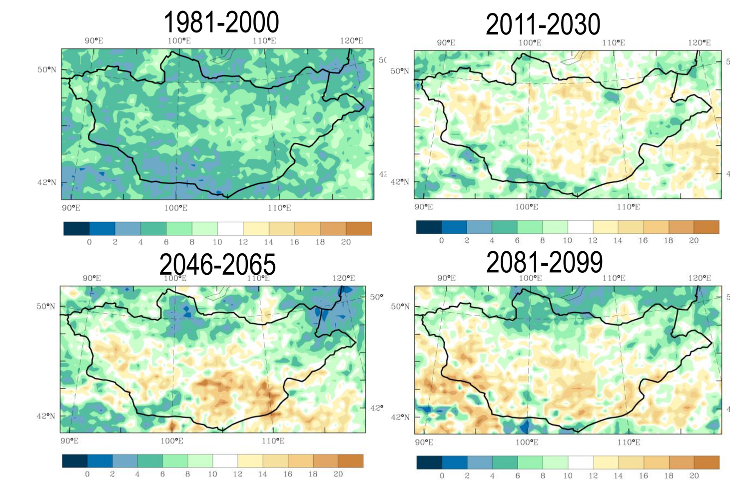


Figure 11. Number of drought occurrence in the different climatic periods in the future

Conclusions

The model well simulated seasonal mean of cold and warm seasons and their intra-annual variability. There are less than few degrees of warm bias in winter and cold bias in summer seasons. Relative high bias corresponds to high mountain region of the country. Spatial correlation coefficients between observed and model simulated mean are 0.81 in winter and 0.89 in summer for temperature, and 0.40 in winter and 0.91 in summer for precipitation as respectively.

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Drought/zud frequency will be projected to increase/decrease.

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