The atmospheric water circulation patterns over the Khangai mountainous region, Mongolia

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Abstract

In this study we investigated the atmospheric water circulation patterns over Mongolia, we focus on the Khangai mountainous region. The annual average surface air pressure around 780-930 hPa over Mongolia, and 780-870 hPa over the Khangai mountainous region, and the annual average air temperature around -9 ºC to -24 ºC over Mongolia, and -12 ºC to -21 ºC over the Khangai mountainous region, at the 780-810 hPa. The Khangai mountainous region, there are dominated radical-continental climatic conditions with variance of temperature high-4 seasons including long and cold winter, short and dry summer, generally colder than other regions of the same latitude because of the high altitude (the average elevation is 2000 m above sea level). In northern site of the Khangai mountainous region there were steadied dominated arctic cyclonic in winter time, annual average wind speed is 7-10 m/sec, and in spring time were steadied dominated anticyclonic specially, southern site of the Khangai mountainous region, investigated period of time since 1979 to 2016. Then we estimated annual average horizontal and meridional column integrated annual and seasonal (June, July, August) moisture flux convergence. The atmospheric moisture fluxes were vertically integrated at the 850 hPa at the atmosphere, to set reanalysis model field, after which the convergence was calculated, the annual average precipitable water was 0-3 mm/day, and precipitation was -1 to 3 mm over Mongolia, and the precipitable water and precipitation was 2-3 mm/day over the Khangai mountainous region. The annual variability of summer precipitation and summer moisture flux convergence it has corresponds to precipitation over the Khangai mountainous region.

Keywords: Enter up to five keywords on this line, alphabetized and separated by semicolons.

Introduction

In 1980-2012s, the global mean temperature has increased by 0.65 to 1.05 ℃/100s, and precipitation has increased by 1-2 %/100s (Hiro Musunaga et al., 2019).

The interannual variations in summer precipitation and atmospheric circulation patterns showed a significant increasing trend in geopotential height in the lower-level of the troposphere since the mid-1980s over European Russia and Mongolia (Hiyama et al., 2016).

Recently, Oshima et al (2015), Hiyama et al (2016) investigated climatological features over the Siberian major river basins, using a decomposition analysis of the moisture flux, and revealed that moisture transport associated with cyclone activity and seasonal mean winds dominated in the Siberia and northern site of Mongolia.

In recent 70 years, near surface air temperature has increased by 2.07 ℃ in Mongolia. This quite large warming has occurred more intensively in the mountainous regions than in the Gobi and steppe regions of Mongolia (MARCC, 2014).

Hydrological processes are directly connected by the climatic conditions. The main indicator of climate changes which is river runoff, sea (lake) level, snow, glacier and permafrost are more sensitive, than other land surface components.

In recent decades, many regions in the northern hemisphere have witnessed increases in the thickness of the active layer and decreases in the thickness of seasonally frozen ground as a result of climate change (Frauenfeld et al., 2004; Zhang et al., 2005; Sharkhuu et al., 2007; Wu and Zang, 2010; Zhao et al., 2010; Frauenfeld and Zhang, 2011).

Thus, we need to investigate the atmospheric water circulation patterns over Mongolia, such us the Khangai mountainous region.

Method

Estimation of atmospheric water budget analysis, we used precipitation data are from NOAA’s Multi-Source Weighted-Ensemble Precipitation MSWEP V2.1 global 3-hourly precipitation dataset with a 0.1° resolution: methodology and quantitative assessment B.A. Metreorol. Soc. 100477-500 (Beck H E et al., 2019). And also, we used the ERA-Interim reanalysis: configuration and performance of the data assimilation system Q. J. R. Meteorol. Soc. 137 553-97 (Dee D P et al 2011).

The data were calculated from 6-hourly original (00, 06, 12 and 18 UTC), daily, monthly, seasonal (3 months), and annual data. A geopotential height of 850 hPa (m) and water vapor fluxes in the fu (zonal component) and fv (meridional component) (kg m-1 s-1) were mainly used in this study. The atmospheric moisture fluxes were vertically integrated from the bottom to top of the atmosphere in the reanalysis model field, after which the convergence was calculated. MSWEP V2.1 global 3-hourly precipitation dataset and ERA-Interim reanalysis data set were analyzed in the Grid Analysis and Display System (GrADS) software.

The concept of atmospheric water budget analysis (i.e., Peixoto and Oort 1983, 1992) was applied using the following equations:

$$\frac{\partial PW}{\partial t} = -\nabla \cdot \frac{1}{g}\int_{P_b}^{P_t} qv dp + E - P = -\nabla \cdot \langle qv \rangle + E - P \qquad (1)$$

$$P - E = -\nabla \cdot \langle qv \rangle - \frac{\partial PW}{\partial t} \qquad (2)$$

where P is precipitation, E is evapotranspiration, and PW denotes precipitable water, which is an integral of q in the atmospheric column. The g, q and v terms represent acceleration due to gravity, specific humidity, and the horizontal wind vector, respectively. The range of the integral in the first term on the right-hand side of equation (1) and PW are from the bottom (Pb) to the top of the atmosphere (Pt).

Result

The Khangai mountainous region, there are dominated radical-continental climatic conditions with variance of temperature high-4 seasons including long and cold winter, short and dry summer. Because of the high altitude (the average elevation is 2000 m above sea level), in the Khangai mountainous region's climate is generally colder than other regions of the same latitude.

The annual average surface air pressure around 780-930 hPa over Mongolia, and annual average surface air pressure around 780-870 hPa over the Khangai mountainous region (figure 1), and the annual average air temperature around -9ºC to -24ºC over Mongolia, and annual average air temperature around -12ºC to -21ºC over the Khangai mountainous region at the 780-810 hPa, (figure 2), investigated period of time since 1979 to 2016.

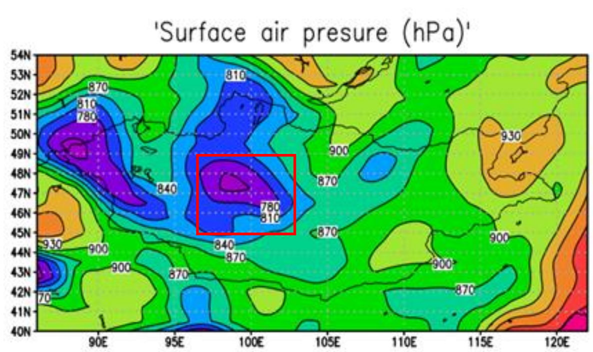

Figure 1. Annual average surface air pressure.

In the ground, the extreme minimum temperature is -41.1°C to -55.3°C in January and the extreme maximum temperature is +28.5°C to +44.0°C in July, and annual average humidity is 60% -75%, in the Khangai mountainous region (MARCC 2014).

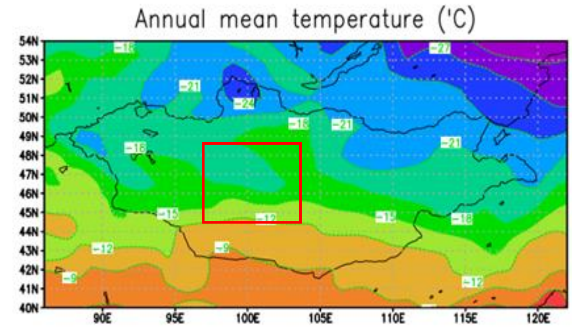

Figure 2. Annual average air temperature.

Also, we estimated dominated wind stress over Mongolia, including the Khangai mountainous region. In northern site of the Khangai mountainous region there were steadied dominated arctic cyclonic in winter time, annual average wind speed is 7-10 m/sec, and in spring time were steadied dominated anticyclonic specially, southern site of the Khangai mountainous region (figure 3 a, b), investigated period of time since 1979 to 2016s.

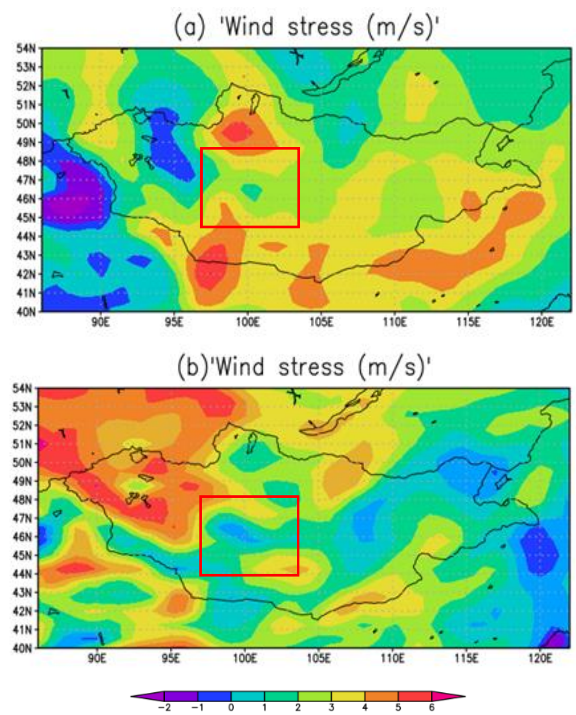

Figure 3 (a, b) Annual average wind stress.

Based on the climatic conditions we need to investigate the atmospheric moisture flux convergence over Mongolia, including the Khangai mountainous region. So, we estimated annual average horizontal and meridional moisture flux convergence (figure 4 a, b), and then horizontal and meridional column integrated annual average moisture flux convergence.

The atmospheric moisture fluxes were vertically integrated at the 850 hPa of the atmosphere, to set reanalysis model field, after which the convergence was calculated.

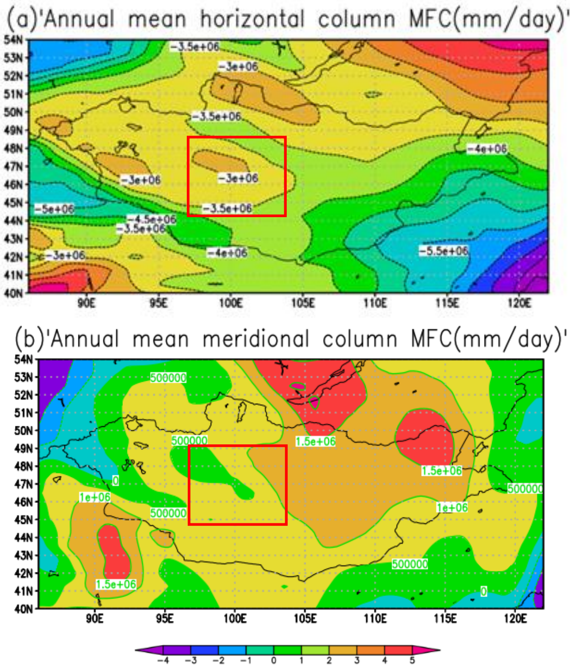

Figure 4 (a, b). Moisture flux.

Figure 5 (a) shows the integrated horizontal and meridional column annual average moisture flux convergence (mm/day) and (b) seasonal (June, July, August) average moisture flux convergence, and the red line box is the Khangai mountainous region, investigated period of time since 1979 to 2016s.

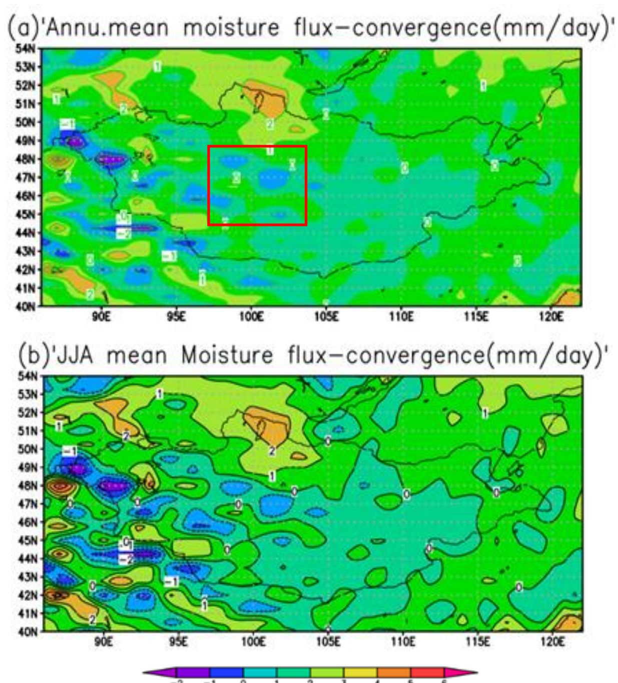

Figure 5. Integrated annual average moisture flux convergence.

Then we estimated annual average precipitable water and precipitation over Mongolia including the Khangai mountainous region, the precipitable water was 0-3 mm/day, and precipitation, was -1 to 3 mm over Mongolia, and the precipitable water and precipitation was 2-3 mm/day (figure 5 a, b), over the Khangai mountainous region. The annual variability of summer precipitation and summer moisture flux convergence it has corresponds to precipitation over the Khangai mountainous region.

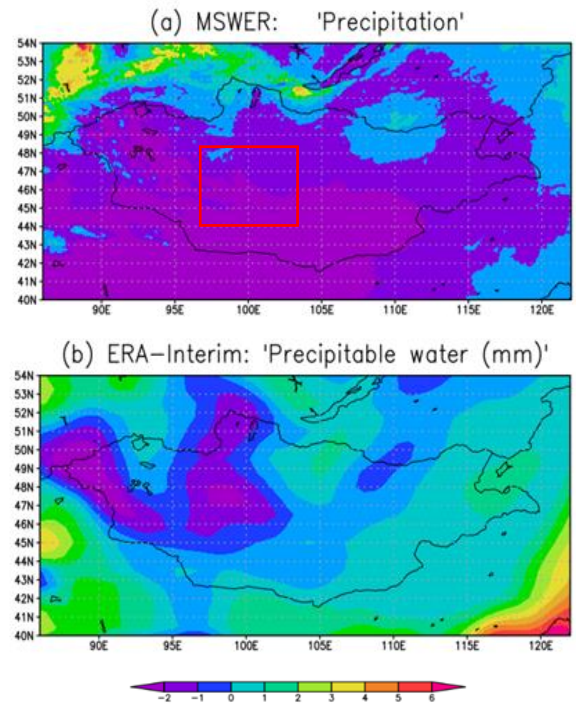

Figure 6. Annual averaged precipitation.

Discussions

The contribution of moisture flux convergence to precipitation can be assumed small over the southern site of the Khangai region, which implies the impact of topographic condition, large-scales circulation on moisture convergence has less than for other regions. And mountains peak surrounding there are moisture flux convergence is very weak despite pronounced precipitation it has related to cyclonic and northwesterly wind over northern site of the Khangai mountainous region. Although the enhancement of cyclonic circulation was significant, there was clear enhancement of the atmospheric moisture flux over the northern site of Khangai mountainous region. The mountain peak there are air pressure was 830 hPa, and interestingly, surrounding peak increasing trend air pressure. To investigate the contribution of the diurnal precipitation cycle to total precipitation variation, it is relatively small over the Khangai mountainous region. The temporal change in precipitable water content W shows high variation and it is negligible compared with other components. Based on the results from figure 12 (b) shows the mean annual precipitation patterns fields clearly shown difference between over the north and south site of the Khangai mountainous region. The variability in summer precipitation was the main contributor to the variation in annual and summer season's precipitation and MFC. Additionally, the atmospheric water cycle change in summer precipitation was coincident with that of annual precipitation. The annual mean of the percentage of total variance explained by the diurnal precipitation cycle is calculated to classify the atmospheric water cycle more objectively. Based on the percentage variance of the diurnal precipitation cycle, we estimated the atmospheric water budget analysis over the Khangai mountainous region.

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