Numerical study on the arid climate formation in middle latitude Asia

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1. Introduction

Global distribution of arid climate can be classified into several types according to the reason of few rainfall events (Houghton, 1984). The desert region in NE Asia is located in relatively higher latitude compared with other major deserts within subtropical zone. The fact means that the Hadley circulation is only little related with the formation of the aridity. The absence of rain-inducing disturbances is indeed prominent in winter; however it contributes slightly to the summer dryness because zonal wind velocity is relatively weaker during summer. The role of the TianShan Mountain ranges, which divides central Asia and northwestern China, as a barrier of water vapor transport had been considered to be a most probable reason of the aridity since the desert regions are surrounded with the TianShan and the Altai mountain ranges except for the east side of them. This study aims at clarifying the formation mechanism of the arid region as well as to investigate the mechanical effect of those mountain ranges.

2. Experimental design

The Terrestrial Environmental Research Center - Regional Atmospheric Modeling System (TERC-RAMS; Sato and Kimura, 2005) is adopted. In no mountain run (NoM), not only TianShan Mountains but also any topography over Mongolian plateau is assumed to be flat with 500 m elevation. In NoC run, the convective parameterization is turned off, and zonal mean variables are used as a boundary forcing so that the model simulates the interaction between zonal westerly and topography with radiation process. Horizontal resolution of the model is 150 km. The numerical domain contains almost whole Asia and Siberia region.

3. Result

Figure 1 illustrates ten-year mean of monthly precipitation and vertically integrated water vapor flux simulated in NoM run. The amount of water vapor flux is larger over whole Mongolian plateau since the precipitable water vapor is relatively larger in NoM run due to the lower elevations. Nevertheless, very similar rainfall distribution with observation is obtained in NoM run in respect with the position of arid region. This means that the arid region is formed even though the TianShan Mountain is absent.

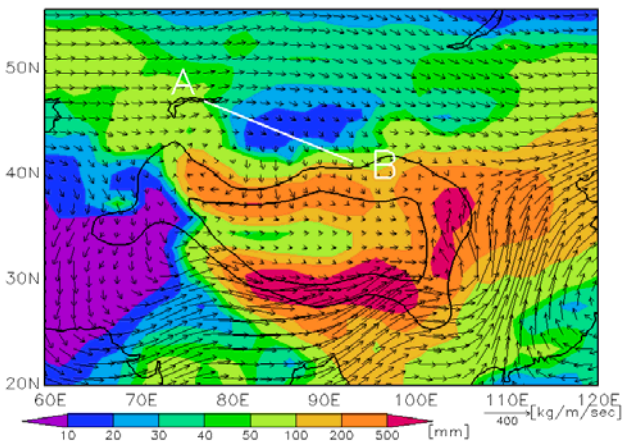

Figure 1: Ten-years mean monthly precipitation and vertically integrated water vapor flux in NoM run. Solid contours indicate 2000 and 4000 m of the topography.

The vertical motion and horizontal wind at 400 hPa in the NoC experiment is shown in Fig. 2. Ascending motion is not so evident over Southeast and South Asia regions since convection process is turned off. Figure 2, however, shows that the steady upward motion is generated over the Plateau without condensation process. A robust subsidence motion, greater than 2×10^{-2} m s^{-1} in magnitude, also appears over the desert region. Since the level of 400 hPa almost corresponds to the mean height of the planetary boundary layer over the Plateau. The upward motion should be mainly driven by the sensible heat flux caused by the radiative heating on the Plateau surface. This means the heating process is inducing the subsidence over the arid region, and it is not always related to condensation heating associated with cumulus convection.

4. Summary

The role of mountain ranges upon the arid climate formation in NE Asia is investigated using regional climate model. Before this study, the rain shadow effect by the mountains is considered to be a major reason of the arid region. However, numerical experiment without the TianShan Mountains simulates the distinct arid region as well. This fact indicates that the arid climate in northwestern China is formed even though the rain shadow effect is absent. The regional descending motion tends to prevail in NoM and NoC runs over the arid region. It is indicated that the precipitation over the arid region is suppressed by the subsidence which is induced by the interaction between zonal westerly and the surface heating over the Tibetan Plateau.

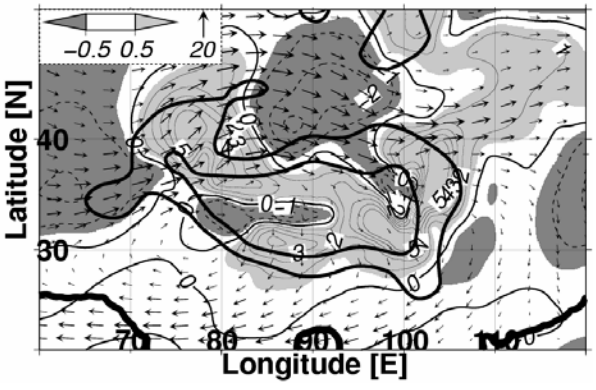

Figure 2: Vertical wind velocity (cm s^{-1}) and wind direction (m s^{-1}) at 400 hPa in NoC run. The dark shade indicates downward motion.