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学　位　論　文　題　名

Statistical and numerical study of hot extremes in Mongolia: possible contribution of soil moisture to the recent increase in heat waves

(モンゴルにおける極端高温に関する統計解析と数値実験：近年の熱波増加に対する土壌水分の寄与の可能性)

The frequency and intensity of extremely hot weather events have increased worldwide since the 1950s, particularly over Europe, North Asia, and Australia. In this study, temporal and spatial changes in hot extremes around Mongolia were investigated by using domestic meteorological observations and reanalysis data. Heat wave (HW) is defined as a number of days when a daily maximum temperature is at least 5K higher than its climatological mean of a corresponding calendar day, and this requirement satisfied at least 4 consecutive days. During 1981–2010, daily maximum temperature and hot days are increased 1.21°C decade^{-1} and 3.7 days decade^{-1}, respectively with a sudden increase since late 1990s. A similar trend is identified for HW. Global reanalysis data indicated that the change in HW is statistically significant for successive two decades around Mongolia that no other places in the northern Eurasia had a similar trend.

A decadal mean JJA geopotential height pattern indicates a dominant high pressure anomaly at 500-hPa level appeared over Mongolia in the 2000s, with similar positive anomaly over Europe. Moreover, a composite analysis for widespread HWs in Mongolia exhibits a ridge at 500 hPa covering over Mongolia together with ridge and trough structure over Europe and Central Asia, respectively. To capture this dominant atmospheric circulation pattern, a new index, called atmospheric circulation forcing (ACF), is introduced. The ACF is defined as the number of days per year when the geopotential height difference at 500 hPa between the Taklimakan Desert (40°N, 80°E) and the area around Lake Khovsgol (50°N, 100°E) is equal or less than 50 m over more than 3 consecutive days. The HW frequency during 1981–2010 increases with ACF that suggests atmospheric circulation is the key driver for HW. Data analysis demonstrates that modest

HW tends to appear with wetter soil moisture. Despite the similar ACF condition, the maximum surface air temperature is responded differently according to soil moisture condition; larger (smaller) air temperature increase for the drier (wetter) soil condition, suggesting the importance of soil moisture on the HW intensity. An additional observational data analysis for each HW event during the 2000s indicates that the rate of temperature increase prior to HW is sensitive to soil moisture condition. For the drier soil moisture condition, preceding warming before HW onset tends to begin earlier while under wetter soil moisture condition it occurs more slowly with a few days delay. Therefore, it is suggested that the recent drier soil conditions played a role in enhancing the frequency and intensity of HWs.

Numerical experiments were conducted by the Weather Research and Forecasting (WRF) model in order to evaluate the role of soil moisture quantitatively. A simulation with realistic soil moisture successfully reproduces recent HW increase in Mongolia although the model underestimated the observed daily maximum temperature and HW. The extreme dry run with −60% initial soil moisture anomaly demonstrates drastic increase of HW by 69.0% during the summer of 2007. Moreover, the model experiments confirm the delayed onset of HW under wet soil moisture condition as ground-based observation. Based on aforementioned results, it is concluded that long-term soil moisture drying appears to be responsible for the recent increase in HW around Mongolia, together with the atmospheric circulation change by regulating surface energy partitioning that pushes near surface air temperature efficiently.

This dissertation provides a new observational evidence and responsible mechanism of the change in extreme weather events that have occurred in Northeast Asia. All the committee members recognized that this achievement was significant, suggesting an importance of atmosphere-land interaction in recent extreme weather. The committee also evaluated enthusiasm of the applicant during the course of graduate school. Therefore, the committee reached a conclusion that the applicant deserves to become a Doctor of Environmental Science.