博　士（環境科学）　バットボルド　アルタンゲレル

学位論文題名

Extreme weather events in Mongolia: numerical modeling and sensitivity experiments

（モンゴルにおける極端気象現象：数値計算と感度実験）

学位論文内容の要旨

Extreme weather event (EWE), natural disasters driven by atmospheric phenomena, includes windstorms, drought, temperature drop, heavy rainfall, thunderstorms, heavy snow and flood. EWEs potentially result in significant impacts on the economy and thus sustainable developments. Since 1970 Mongolia has experienced about 25–30 times of EWEs every year and one-third of them have resulted in natural disasters. The most destructive EWEs in Mongolia are severe windstorm and drought, which are defined by rapid increases in wind speeds exceeding 28 m s^{-1} and Ped's dryness index greater than 2.0, respectively. The severe windstorm, occupies 38% of total EWEs, occurred when cyclone with cold fronts are passing. The 62% of total economic loss are due to recent increases of the frequency of severe windstorm. The drought also damages on economies of the wider areas for the longer periods, and cause substantial degradation of the ecosystem and agriculture in the regional to country scales. Since drought reduces vegetation cover and fodder for livestock, it causes loss of livestock. More than 10 million of livestock has lost due to drought between 1999 and 2002. This suggests that it is crucially important to forecast such destructive EWEs for minimizing economic loss. Numerical modeling is the effective way to predict severe windstorm and drought. A global forecast from general circulation model (GCM) is inadequate because its spatial and temporal resolutions are too coarse to simulate EWEs. Instead, dynamic downscaling (DD) using a regional climate model (RCM) is expected to improve extreme weather forecast. The purpose of this study is to improve the prediction of (1) severe windstorm and of (2) drought using RCM over Mongolia.

As the first experiment to simulate the severe windstorm, I evaluated the performance of DD using mesoscale model, MM5. For this I intensively investigated a severe windstorm with snow and dust outbreak during 26 and 27 May 2008 in the eastern Mongolia, This storm caused considerable damage, i.e. 52 human deaths, and more than 360,000 livestock losses. The Bayan-Ovoo meteorological station, eastern Mongolia, recorded temperature drop from 22°C to 1°C only within 3 hours and the wind speed reached 28 m s^{-1}. The MM5 is set up with three nested domains (D1, D2, and D3), the horizontal grid spacing

of which is 27, 9, and 3 km, respectively. The 3 km resolution is finer than that of Mongolian operational weather forecast system in which grid spacing is 10 km. The experimental results demonstrated realistic features of the windstorm in terms of drastic changes in wind and temperature. The National Center for Environmental Prediction final analysis data (NCEP-FNL), which is used as a boundary condition of the numerical experiments, did not represent temperature drop and maximum winds and did not satisfy the Mongolian criteria as the EWE. The DD experiment, however, simulated temperature drop and maximum winds close to those observed. Analyses on the nested domains indicate that the DD has successfully enhanced the performance for simulating severe wind storm even with a moderate-resolution domain (D1), and further nesting (D2 and D3) plays a role to improve it. The maximum wind speeds closed to the observed value as the horizontal resolution increases. The rapid decrease in temperature was captured well even in the low-resolution domains (D1 and D2). These findings suggested that uses of moderate resolution are sufficient to simulate temperature drop while wind speed should be simulated by using the highest resolution.

The second experiment was designed to simulate the impact of drought-affected vegetation cover on summer precipitation. The example to be experimented was from the most intensive drought occurred over central Mongolia during summer (June-July-August) 2002. I improved weather forecast model (Weather Research and Forecasting, WRF), which has conventionally used climatology vegetation fraction from Advanced Very High Resolution Imaging Spectroradiometer (AVHRR) during 1985-1990 as the default. The real-time AVHRR vegetation fractions of 2002 were generally lower than that climatology vegetation fraction in the central Mongolia. Summer precipitations were simulated by two numerical simulations with different vegetation fractions mentioned above. The default-based simulation estimated greater precipitations than those observed, while the real-time-based simulation estimated precipitations close to observation. These results suggested that the simulation of seasonal precipitation in the RCM is sensitive to the parameters related to vegetation cover. Owing to reduction of vegetation cover, the fractions of latent heat to the total net radiation are replaced by those of sensible heat flux. This is the most probable explanation of the increases in surface temperature. Finally, the real-time satellite derived vegetation fraction has critical importance for drought monitoring and forecasting.

Numerical forecast model is most useful to operations for early prediction of extreme weather events. This study contributed to improve the prediction of extreme weather events over Mongolia using RCM.

学位論文審査の要旨

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The examination committee of this paper recognized that these results provide essential information for the reducing climatic disaster in the dry and cold land regions. The committee also evaluated the great effort of the applicant in intensive modeling work in climatologic science, thereby concluded that the applicant is eligible for the degree of Doctor of Philosophy (Environmental Science).