Modeling approach to the atmosphere-hydrosphere-biosphere interactions in Mongolia

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1. Background

The global scale projection toward understanding of the global warming induced by the rapid increase of greenhouse gases begin to be appeared recently using general circulation models in several research institutes in the world. In general, such attempts were carried out in order to comprehend the direction of global scale climate change. The computational restricts and accuracies are not still enough to discuss the detail structure and amounts of the changes in regional scale or national scale due to the low horizontal resolutions of the GCMs. In latest report of the Intergovernmental Panel on Climate Change (IPCC), the regional climate models are addressed as one of the possibility to obtain more detail structures of the climate change induced by the global warming.

Mongolian territory locates in the typical rangeland of vegetation; Gobi desert with less than 100 mm/year rainfall covers southern part of Mongolia, and steppe with short grass distributes its surrounding region, while the forests with deciduous needle leaf and deciduous shrubs cover the mountainous region in northern Mongolia. This rangeland is thought to be easily affected by the changes of external forcing, such as climate change.

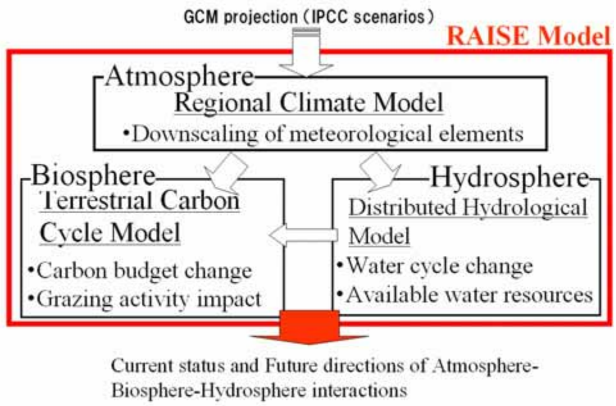


Figure 1: Architecture of RAISE modeling study.

2. Purpose and method

In the RAISE project, three kinds of models, global biosphere model, regional climate model and distributed hydrological model, are utilized to study and parameterize the interactions among atmosphere, biosphere and hydrosphere systems (Fig. 1). The dynamic downscaling method by the regional climate model is carried out to estimate the atmospheric system with fine resolution which is enough to describe the horizontal structure of the vegetation rangeland. The simulated high-resolved meteorological variables are used as input parameters of the biosphere model and hydrological model.

During the RAISE intensive observational period of 2003, many interesting elements are observed which can be essential to develop new physical models, and are important for model tunings. For example, sensible heat, latent heat and CO_2 flux data at two observational sites and river discharge data in three sites are most principal values to test the validity of the models. Field observation of biological elements, for example biomass, net ecosystem production (NEP) in grazed and ungrazed site, gives reference values to parameterize the grazing effects in the mechanical biosphere model, which should

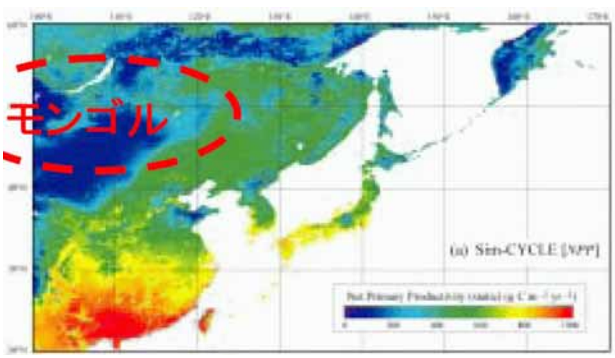


Figure 2: Carbon budget calculated by Sim-CYCLE.

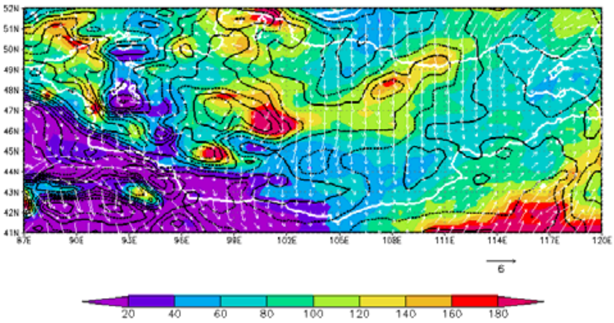
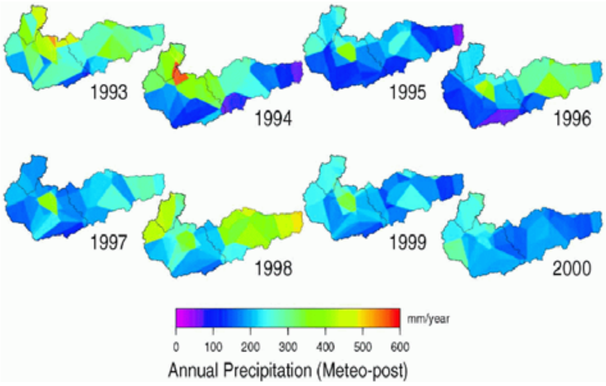


Figure 3: Simulated mean precipitation in July during 1993-2002.



Fiugre 4: Observed annual rainfall distribution in the Kherlen river basin.

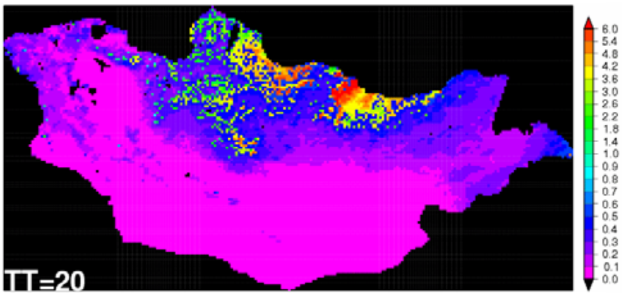


Figure 5: Estimated climatology LAI distribution in middle July.

be very useful for further sensitivity studies to know the impact of grazing activity on carbon cycle.

3. Model descriptions

3-1. Biosphere model

The Simulation model of Carbon cYCle in Land Ecosystems (Sim-CYCLE, Ito and Oikawa, 2000) is adopted as biosphere model. The Sim-CYCLE can be divided into five main components, that is, leaf, stem, root, dead biomass and mineral soil. The net ecosystem production (NEP) is calculated from gross primary production (GPP), respiration, and soil decomposition in a given atmospheric CO_2 concentration and meteorological conditions as an equilibrium value (Fig. 2). Grazing activity by livestock is especially incorporated in the model based on the field investigations and Mongolian statistics database.

3-2. Regional climate model

The Terrestrial Environmental Research Center - Regional Atmospheric Modeling System (TERC-RAMS, Sato and Kimura, 2004) is developed by replacing the physical parameterizations from the original RAMS (Pielke et al., 1992). Dynamic downscaling of the meteorological variables is achieved by this model using 6-hourly GCM output for the global warming test as well as reanalysis data such as NCEP/NCAR and ERA40 for IOP period simulation (Fig. 3).

3-3. Distributed hydrological model

A distributed hydrological modeling system developed by Lu et al., (1989) is used in this study. Rainfall distribution and surface energy budget calculated by the regional climate model is utilized in order to drive the hydrological model. Currently, rainfall GIS database (Fig. 4), which is prepared originally using local meteorological stations, is applied instead of the climate model data to examine the current runoff process in the Kherlen river basin. By using downscaled climate model projection, the direction of the changes in hydrological cycle and the changes of water resources available will be conducted after global warming.

4. Data sets

Special GIS database is prepared for the boundary condition of each model (Saandar and Sugita, 2004). The seasonal variation of leaf area index is additionally estimated using climatology NDVI data (Fig. 5). Soil characteristics database, e.g. transmissivity, will be prepared as well by soil samples obtained during IOP.

5. Future works

The reanalysis calculation during RAISE IOP period of 2003 will be completed in summer of 2005 by each model, and the results will be compared with field observations. Then, global warming projection over Mongolia will be conducted using GCM output in IPCC scenarios. Additionally, other sensitivity tests against uniform temperature increase are under planning.

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