RAISE
The Rangelands Atmosphere-Hydrosphere-Biosphere Interaction Study Experiment in Northeastern Asia
-- Outline and Implementation Plan --

In the northeastern Asia including Mongolia and the northeastern China, a climatic shift from humid condition in the northern part to arid condition in the southern part can be found in a relatively narrow, boundary zone. As a consequence of the steep, meridional gradient in climatic conditions, a distinct "ecotone" (i.e., forest-grassland-desert) is formed in the northeastern Asia (Fig. 1). Such a ecotone is sensitive to changes in external environment (e.g., global warming) even though those changes are very small. For instance, changes in external environment may result in desertification in this region. In reality, it has been reported that air temperature in winter and spring gradually increased and precipitation amount decreased in the last four decade. A possibility can be pointed out that the warming and drying of the atmosphere induce drastic changes in plant growth and vegetation distribution through changes in hydrological cycle. On the other hand, changes in human activity as an external forcing also can affect natural environment in this region. Overgrazing and inappropriate water use have already disturbed ecosystem and hydrological cycle of this region in part.

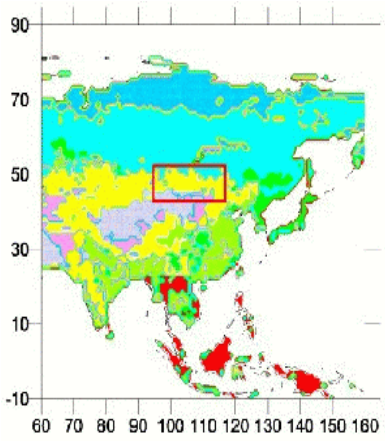

Fig.1 Ecotone in northeastern Asia. The area enclosed by a rectangular is the target of the study

The above arguments are accepted among scientific communities in general. However, the general idea alone may not be sufficient. To reduce harmful influences due to changes in external factors, it is necessary to make clear the detailed linkage between forcing and responses. In this research project, we will evaluate the effects of climate change and human activities on the hydrological cycle and ecosystem in the northeastern Asia ecotone, first, mainly through observations. Then, the resulting knowledge and new inslights will be combined to create models of the atmosphere, hydrosphere, and biosphere, which then will be used for future prediction of the regional hydrological, biological and atmospheric processes. Finally, we will try to evaluate preferable land use for sustainable management of rangelands and appropriate water use based on likely scenarios of future climate and land use changes (Fig. 2).

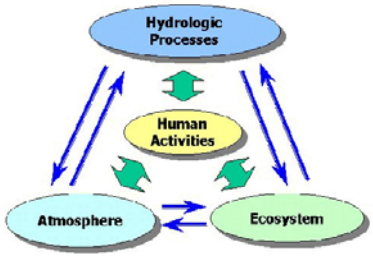

Fig.2 Interrelation among hydrosphere, biosphere, atmosphere with human activity

We have selected the semi-arid region in Mongolia as a main study area. In this region, hydrological components including precipitation, river runoff and soil moisture have been observed for a long time by the Mongolia government, and those data are useful for hydrological study. In addition, basic studies have been carried out on the geographical distribution and interannual variation of hydrological components in and around this region. However, detailed processes of land surface-

atmosphere interaction have not yet been revealed. In the last decade, our group members have conducted field monitoring of hydrometeorological components in this region within the framework of an international research program GAME (GEWEX Asian Monsoon Experiment) and elucidated that water and energy exchanges between the atmosphere and land surfaces largely depend on soil moisture status introducing interannual change in biomass. Unfortunately, an interdisciplinary study covering atmospheric, hydrologic, and biologic sciences have not been realized. Considering such a background, we will establish a drainage-basin for the interdisciplinary experiments, where many specialists from different scientific fields can collaborate in the study. We have tentatively selected Khelren River Basin with a catchment area of approximately 122,500 km2 (total area in Mongolia), 71500 km^2 (upriver part from Choybalsan) or 39400 km^2 (upriver part from Undorhaan) located in the northeastern part of Mongolia (Fig. 3). Khelren River has its headwater source at Henty mountain in the northeast of Ulaanbaatar and runs eastward through moderately hilly plane. Annual runoff is from 100 to 200 mm at western headwater part consisting of mountainous forest, and decreases down to approximately 25 mm at the central and downstream parts mainly consisting of grassland. In this experimental basin, we will carry out intensive field observations on two different vegetation areas: mountainous forest and grassland.

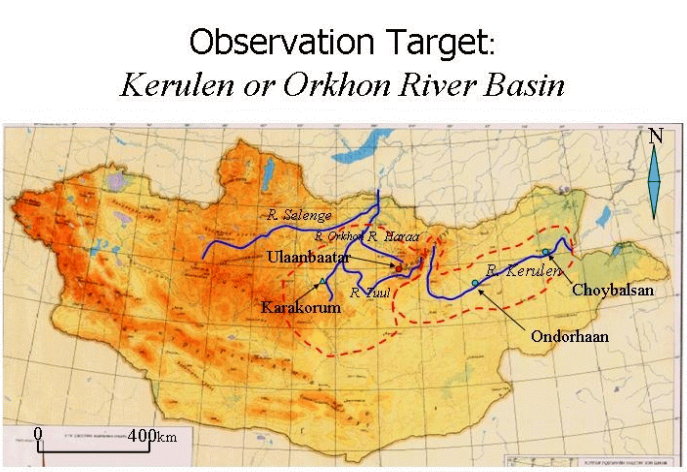

Fig.3 Observational Area with Kherlen river the leading candidate area.

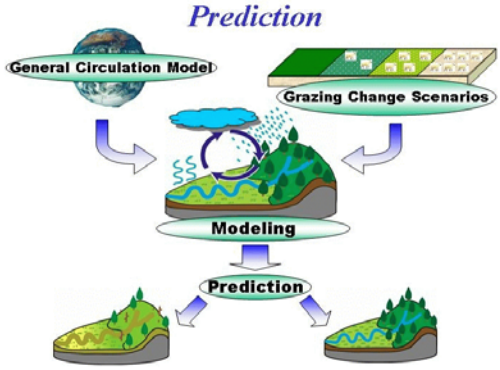

Fig.4 Prediction of hydrologic and resulting biospheric change

In this research project, firstly, we will make clear the current status of hydrological cycle, ecosystem and the atmosphere, and then create models of them. The validity of the models will be checked by comparison of model outputs with observed results. The models will be also utilized to simulate environmental changes in the past and its validity will be checked by historical data and/or paleo-environmental estimates. After validating the models by using the current and the past data, we will attempt to predict environmental changes in the future on the basis of likely scenarios (Fig.4). In order to execute this plan illustrated schematically in Fig 5, five subprojects will be started for analysis of the current status, and three subprojects for the future prediction. All subprojects will be well organized to be able to use research products in other subprojects. This framework is effective in studying the atmosphere-hydrosphere-biosphere interaction in the East Asian semi-arid region and must be suitable for

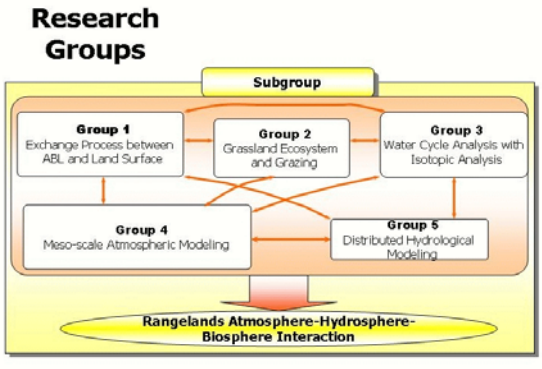

Fig. 5 Subgroups within RAISE project

establishment of appropriate management of rangeland and water use within limited time and cost.

I. Comprehensive study on physical processes and their modeling

In order to get observation data for analysis of the current status of hydrological cycle, ecosystem and the atmosphere, two study areas for intensive field observation will be established: One is the mountainous forest area and another is in the grassland (Fig. 6).

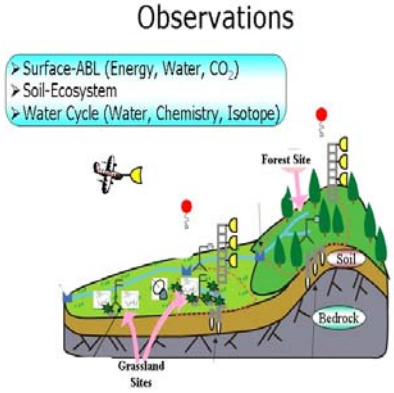

Fig.6 Schematic figure showing planned observation activities

(1) Understanding of land surface-atmosphere energy/water exchanges and estimation of regional evapotranspiration

The objective of this subproject is to make clear the processes of energy and water exchanges between land surface and atmosphere. Results of this subproject will be utilized to refine and validate models in subprojects (4) and (5). In addition, summing up of the research results from subprojects (2) and (3) as well as from this subproject allows us to evaluate the relationship between ecosystem and hydrological cycle and to elucidate hydrological processes over the whole study area. In order to achieve this goal, observations will be carried out to measure meteorological variables from from surface up to the free atmosphere (see Fig. 7).

1.1 Surface flux determination using energy balance model and satellite remote sensing data

a) Linear surface energy balance model

For the evaluation of surface albedo and leaf area index in the study area, a spectrometer measurements aboard an airplane will be carried out

b) Mixed layer model

Using vertical profiles of potential temperature and specific humidity as well as horizontal advection of heat and water vapor calculated with numerical models of subproject (4), spatially averaged surface fluxes are calculated.

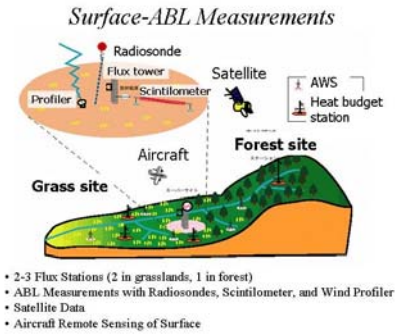

Fig. 7 Planned observation from surface to free atmosphere.

1.2 Estimation of areal evaporation

Regional evaporation is estimated based on the results of 1.1. Estimated value can be utilized for validation of parameterization of distributed hydrological model (subproject (5)) and atmospheric model (subproject (4)).

(2) Understanding of the relationship between grassland ecosystem and human activity

The objective of this subproject is to reveal processes of grassland ecosystem change due to overgrazing. Comparative observation is carried out at overgrazed grassland and no stressed grassland. In particular, water/energy/carbon fluxes are focused as well as plant growth and soil environment.

2.1 Understanding of water/carbon cycle processes in the grassland ecosystem

Investigations of soil physical and chemical properties, soil respiration, biomass and net primary production will be carried out. By comparing results at two grassland sites under different grazing stress, effect of overgrazing on grassland ecosystem can be evaluated. In addition, measurements of soil moisture, soil temperature, and surface water/heat/carbon fluxes are done to evaluate the relationship between plant growth and moisture/meteorological conditions (Fig.8).

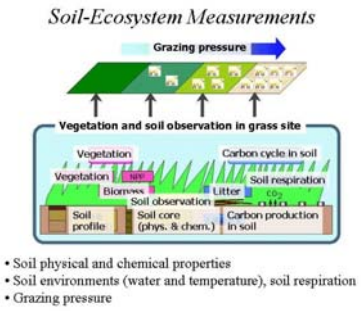

Fig. 8 Schematic figure showing needed observations for sub project (2).

2.2 Modeling of terrestrial ecosystem carbon cycle

On the basis of the results of 2.1, terrestrial ecosystem carbon cycle model (Sim-CYCLE) is refined and applied to this study area.

(3) Understanding of water/mass cycle processes using isotopes

The objectives of this subproject are to elucidate not only fluxes of hydrological cycle but also hydrological flow path and residence time by using isotopes including ^{2}H, ^{3}H, and ^{18}O. In particular, integrated measurements of isotopic compositions in precipitation, surface water, subsurface water and atmospheric water vapor are carried out.

3.1 Understanding of hydrological cycle in the East Asia semi-arid region

Collection of precipitation samples is done over the whole study area. River water, subsurface water and atmospheric water vapor samples are collected at both grassland area and mountainous forest area. Multi-level water vapor sampling within the atmospheric boundary layer and free atmosphere will be conducted using an airplane. Isotopic compositions of the collected water samples are determined by mass spectrometer in a laboratory in Japan. In addition to the isotopic measurements, river runoff and subsurface water flow are investigated by means of physical methods at the two study areas.

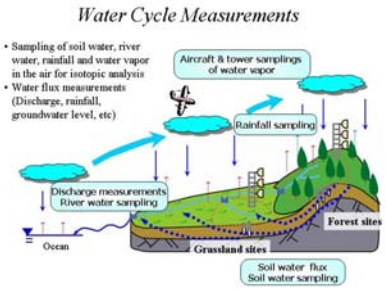

Fig. 9 Observations for sub-project (3).

3.2 Modeling of hydrological cycle and isotopic variation

A model to represent hydrological cycle and isotopic variation is developed. This model is incorporated in the meso-scale atmosphere model (subproject (4)) and distributed hydrological model (subproject (5)) and is utilized to estimate accurate residence time and to predict future hydrological changes.

(4) Development of meso-scale atmosphere model and understanding of monsoon circulation and water vapor transport process over the East Asia semi-arid region

The objectives of this subproject are to understand atmospheric water transport into the East Asia semi-arid region and to develop reliable meso-scale model. Multi-scale analysis is carried out: continental scale, meso scale and local scale.

4.1. Understanding of formation mechanism of the East Asia semi-arid climate and its variability

To clarify the formation mechanism of the East Asia semi-arid climate and climatological factors of variability in hydrological cycle, a meso-scale atmosphere model is developed and utilized to investigate precipitation system and water vapor convergence. Surface meteorological data, 4DDA data and satellite remote sensing data are also used.

4.2. Modeling and understanding of atmospheric circulation over semi-arid region and its interaction to monsoon circulation

Reliability of model outputs depends largely on validity of parameterizations of various processes including cumulus convection, cloud-radiation feedback and surface energy balance: the latter two are particularly important in semi-arid region. These parameterization schemes are refined based on the results of subprojects (1), (2) and (3). The refined atmosphere model is run under three different spatial scale: boundary layer scale, river basin scale and the East Asia scale.

(5) Runoff analysis by distributed hydrological model

The objective of this subproject is to develop a distributed hydrological model and is to get direction for appropriate water use. This model is compatible with meso-scale atmosphere model of subproject (4). Subcomponents of the model are validated and refined by results of subprojects (1)-(3).

5.1 Development of distributed hydrological model

The distributed hydrological model applicable to this study area must include various processes: interception, evaporation, snow accumulating and melting, soil freezing, river flow, and saturated/unsaturated subsurface flows (Fig. 6). To select or to newly develop subcomponents of the model, DEM (Digital Elevation Model), numeric geographical information including river network and basin boundary, soil/vegetation information including soil physical properties and LAI (Leaf Area Index) are collected and integrated. Also in conjunction with the activity of subproject (3), observation of hydrologica cycles that are relevant to create the model will be carried out and that should include river discharge, water table of groundwater, among others. Time-space distribution of hydrological variables are produced and verified by observed results in other subprojects.

Inter-subprojects corporation

Without a close cooperation and linkage among subprojects, we cannot achieve our goal as an integrate research project. Framework of the inter-subprojects cooperation is as follows:

(1)-(2)-(3) : relationship between ecosystem and hydrological cycle, regional hydrological processes
(2)-(4)-(5) : Exchange and utilization of model outputs of the atmosphere, hydrosphere and biosphere
(1)-(3), (4)-(5) : Integration of process study and model predication

II. Prediction of the future status

After understanding of the current status of atmosphere-hydrosphere-biosphere and completing its modeling, numerical simulation for future prediction is carried out by using developed models (Fig. 10). Firstly, atmospheric conditions will be simulated based on likely environmental scenarios. Also several possible scenarios on the future grazing activities will be prepared. The simulated results of the atmospheric conditions and grazing change scenario will be utilized to conduct prediction of hydrological cycle change. The future prediction of ecosystem will also be done by terrestrial ecosystem carbon cycle model. By conducting numerical simulations under several possible scenarios, schemes for sustainable management of rangeland and appropriate water use can be proposed (Fig. 4).

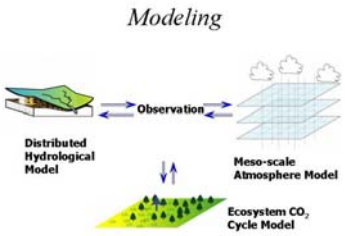

Fig. 10 Model linkage with observation

(1) Simulation of atmospheric environment

Inputting several scenarios on global warming predicted by existing GCM (General Circulation Model), variation of atmospheric circulation field in this study area is predicted by using meso-scale model developed in this research project.

(2) Simulation of hydrological cycle and proposal of appropriate water use

Inputting local climatic change predicted in subproject (1), variation of water resources are predicted. Based on this result, system for appropriate water use in this study area is proposed.

(3) Simulation of rangeland biomass

Inputting simulation results of subprojects (1) and (2) and also scenarios for the future grazing activity change, biomass variability in rangeland is predicted. In addition, by comparing simulation results under hypothetical meteorological and moisture conditions, methodology of sustainable management of rangeland is established.

The plan of this research project described above will be executed following Fig. 11.

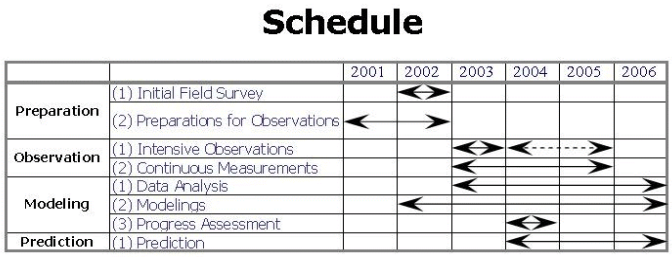

Fig. 11 Brief schedule of RAISE project

III. Detailed Observation Plan

Observations will be carried out both during intensive observation period(s) IOP and non-IOP periods. The exact location of the observation sites should be determined early 2002.

(1) Intensive observations in 2003

An intensive observations will be carried out for 1-2 months in the summer of 2003, and possibly additonal observations will be made in the winter of 2003/2004 and/or in the summner of 2004 to collect and supplement needed data.

(2) Continuous Observations

After the IOP, many of the observations wil be continued either automatically or manually through cooporation with IMH personels

(3) Itemized List of Special Measurement for RAISE

The following summerizes current plan of the itemized list of measurements sorted by the site. (See also Table 1)

I. Forest site A
   a. Surface Meteorology and Hydrology by means of AWS operation
      i. Fluxes of water, heat, momentum, and CO_2 by eddy correolation method
      ii. Four components of radiation and soil heat flux
      iii. Regular meteorlogy of air temperature, humidity, wind speed, pressure, soil temperature (10depths)
      iv. Precipitation, groundwater, soil moisture and potential (10 depths)
   b. Water and water vapor sampling of precipitaion, permfrost (?), vegetation (leaf and trunk), groundwater (or spring water at headwater part), soil, and atmosphere
   c. Biological parameter measurement with a porpmeter and others

II. Forest site B
   a. Surface Meteorology and Hydrology by means of AWS operation
      i. Regular meteorlogy of air temperature, humidity, wind speed, pressure, soil temperature (5depths)
      ii. Precipitation
      iii. Four-component radiation
   b. GPS measurement

III. Grassland site A (to be collocated with IMH station)
   a. Surface Meteorology and Hydrology including fluxes by means of AWS operation
      i. Fluxes of water, and heat and CO_2 by eddy correolation method
      ii. Four-component radiation and soil heat flux
      iii. Regular meteorlogy of air temperature, humidity, wind speed, pressure, soil temperature (10depths)
      iv. Precipitation, groundwater, soil moisture and potential (10 depths)
   b. Radiosonde measurements of upper air
   c. GPS measurement
   d. Sintilometer measurements of averaged sensible heat flux at 5 km scale
   e. Water and water vapor sampling of precipitation, permfrost (?), vegetation (leaf and trunk), groundwater, soil, and atmosphere

IV. Grassland site B (to be collocated with IMH station)
   a. Surface Meteorology and Hydrology including fluxes by means of AWS operation
      i. Fluxes of water, heat, momentum by means of Bowen ratio method
      ii. Net radiation and soil heat flux
      iii. Regular meteorlogy of air temperature (2 heights), humidity (2 heights), wind speed, pressure, soil temperature (10depths)
      iv. Precipitation, groundwater, soil moisture and potential (10 depths)
   b. Water and water vapor sampling of precipitation, permfrost (?), groundwater, and soil
   c. Determination of biological parameters of plant and soil with a porpmeter and others

V. Grassland site C-E (to be collocated with IMH station)
   a. Surface Meteorology and Hydrology by means of AWS operation

i. Regular meteorlogy of air temperature, humidity, wind speed, pressure, soil temperature (5depths)
ii. Precipitation, groundwater, soil moisture and potential (5 depths)
iii. Four-component radiation

b. Water sampling of precipitation, permfrost (?), groundwater, and soil

VI. IMH Gauging stations (4-5 stations along the river)
   a. Continuous measurements of water level
   b. Water sampling of precipitation, and river water

VII. IMH Meteorology station and Meteopost (numbers to be determined)
   a. Graoundwater monitoring (with construction of observation well)

VIII. Aircraft Measurements
   a. Surface remote sensing of spectral radiance in visible wave length range
   b. Surface remote sensing of temperature
   c. Air and water vapor
   d. Sampling of air

(3) Itemized List of Needed Routine Measurement DATA

In addition to the special measurements, the available and on-going routine observations by IMH and other relevant organizations should be utilized through cooporation and collaborative research works.

- Meteorological Station and Meteopost data (If possible, All available data (from past-present) of all stations in Mongolia; the numbers of years and stations should be determined from needed cost)
- Gauging Station data of Kherlen river basin (from past through present)
- Groundwater related data (geology screen depth and water table data of wells in Kherlen river basin)
- Soil and soil moisture profile data
- Radiosonde data
- Rader observation data at Ulaanbaatar
- DEM of USGS
- Satellite data (ADEOSII, Landsat, AVHRR, GMS、SSM/I, ASTER)

(4) Itemized List of Needed Research Product

Several research projects have been or will be carrried out in Mongolia and they are expected to produce relevant data products. It is necessary to cooperate with these projects and make full use of such products. Currently the following products are under consideration.

- Biomass distribution in Mongoila from satellite visible data
- Surface soil moisture distribution from satellite microwave data

IV. Participating Organization

The RAISE project will be carried out by the participation of the following organizations.

(1) Japanese Side

- Japan Science and Technology Corpotayion (funding agency)
- University of Tsukuba
  - Terrestrial Environment Research Center
  - Institute of Geoscience
  - Institute of Biological Sciences
  - Institute of Applied Biochemistry
- Faculty of Education, Gunma Universiy
- Faculty of Science, Tohoku University
- Faculty of Engineering, Nagaoka University of Technology

- Center for Ecological Research, Kyoto University
- Department of Geography, Kyunghee University of Korea

(2) Mongolian Side

- Institute of Meteorology and Hydrology
- Environmental Education and Research Institute

Table 1 Summary of Planned Observations for RAISE (separate sheet)