Summary of the result obtained by GAME-Siberia and future research issues

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1. Introduction

In order to advance the study, our study group set up the following objectives (From GAME ISP, 1998).

1) Clarify the physical processes of the land-surface / atmosphere interacting system.

2) Clarify the characteristics and variability of regional energy/water cycle.

3) Obtain the climate trend and land-surface change during the past 50 years and evaluate possible feedback processes.

4) Improve and develop models describing the energy/water exchange and atmosphere-land surface systems.

5) Collection and archive regional ground based/satellite data.

6) Establishment of observational network for long-term study, and development of hardware.

2. Strategies

The four main strategies for implementation were set.

1)Select one large drainage for study, which was Lena River, eastern most drainage among the three large Arctic flowing rivers. Yenisei and Ob was a candidate at the beginning, but they were omitted due to warmer climate and more anthropogenic influence than Lena.

2)To establish three local observation sites for intensive study from the criteria of land surface condition and climate in the drainage (Tundra area facing Arctic Ocean, flat taiga with little precipitation, mountain taiga with much precipitation). The location of these sites are shown in Fig. 1.

3)To hold an intensive study period for investigating the land surface / atmosphere interaction and spatial and temporal variability of water/energy fluxes in a regional scale (100km scale), which was implemented in year 2000.

4)Involve researchers of various disciplines other than meteorology/climatology, hydrology and glaciology, such as biology, soil science and others that can contribute to the understanding of the water/energy cycle in this region.

3. Main results

The main results derived from observations and analysis are the followings. The main papers which are already published are cited.

(1) Understanding of the annual land hydrological processes were clarified, for first time for a Siberian watershed (5.5 km2). Similarity and difference of land surface condition and hydrological process from tundra of North America were shown. Importance of winter snow process was found. A annual land hydrological model was developed and from this future variability of hydrological processes under future warming were discussed. (Hirashima

et al., 2004)

(2) The seasonal variation, predominant processes of heat/water exchange for Taiga forest were clarified, and difference among species and ages were clarified using three tower systems. Good quality tower data-set were established. (Ohta et al/, 2001; Hamada and Ohta, 2003; Toba et al., 2002)

(3) Hydrological process studies using stable isotope were developed. The sub-surface level of uptake of soil moisture was clarified and stability of inter-annual evapotranspiration was confirmed, and characteristics of lake water variation was found. (Sugimoto et al., 2002; Sugimoto et al., 2003; Ichiyanagi et al., 2003)

(4) Necessity of scale up of heat/water fluxes were clarified. The difference in the magnitude of sensible/latent heat fluxes were measured at grassland and forest, two dominant surfaces in Taiga region, and the former showed larger values throughout the snow-free period. These difference show up-scaling of fluxes for evaluating spatial total. (Yamazaki et al., 2004).

(5) Hydrological characteristics of headwater regions of Lena River were clarified. Seasonal variation of evapotranspiration values differs from Taiga in Yakutsk area. Main runoff amount of snowmelt has correlation not only to winter snow amount, but also to soil moisture content of previous autumn, meaning inter-annual effect on runoff. (Suzuki et al., 2002)

(6) Hydrological models of snow cover/permafrost area was developed, and showed good simulation to a certain degree. (Ma et al., 2001)

(7) Large scale characteristics of water cycle, land surface conditions such as vegetation, snow and other were clarified. Characteristics of spatial/temporal distribution of NDVI, snow cover depth from satellite sensing, precipitation recycling and sea-saw like pattern of precipitation for Lena and Ob River drainage were found. (Suzuki et al., ;Suzuki et al., ;Suzuki and Matsuda, 2004; Kurita et al., 2003; Kurita et al., 2003; Fukutomi et al., 2004)

(8) Land surface modeling were developed in good relation with observation, and influence of land surface processes to large scale atmospheric circulation was discussed. (Yamazaki, 2001; Takata and Kimoto, 2000; Takata, 2001)

(9) Aircraft measurement in spring-summer season found new boundary layer characteristics. (Hiyama et al., 2003; Strunin et al., 2004)

(10) Observation system in cold region were improved and made basis for long-term monitoring, and CD-ROM was published for data up to 2000. (Suzuki and Ohata, 2003)

4. Future issues

Several development which needs future investigation, and also expansion of study techniques were found. Some are the followings.

(1) Physiological and structural characteristics of forest need to be investigated more to reproduce the seasonal variation of heat/water exchange. Need to answer the following questions. What determines the start of the foliation? Is there any water stress for trees, and when and why does it occur? How does the structure of the trees affect the water(snow) exchange in the cold seasons?

(2) Stable isotope seems to be useful tool to investigate water cycle, using in addition to the information on amount of water cycle.

(3) There were found some lag processes for hydrological cycle. Precipitation and runoff through certain characteristics of soil, and precipitation and evapo-transpiration through soil and water uptake process of trees. Detail measurements and model simulation should lead to interesting results.

(4) Difference in permafrost and frozen ground condition lead to different

hydrological consequences. Extension of study areas and regions will be a fruitful way for understanding the hydrological influence of frozen ground. There is a necessity to find the amount of ice underground and its potentiality of melting under global warming.

(5) Large scale snow cover influence to atmospheric condition and circulation

(6) Long-term variation study was one of the main objectives which was set at the beginning. Such studies are very important from the standpoint of global change, but could not implement at necessary degree. One of the reason was that, we could not develop new long-term data-set for these studies. Another was that main effort was directed to the process studies and in-situ observation. It is rather important to develop and extend the data-set we already have to earlier times, and analyze according to new point of view.

(7) The measurement and detail study was mostly made for warm season. Cold season process such as, process related to snow cover ground freezing and climate warming of winter seasons, formation of Siberian high was done not at needed degree. A part of the reason for such condition is the small magnitude of water/heat fluxes, which decrease the interest of land surface specialist, and difficulty of measurement related to cold conditions. In order to understand the cold region processes totally, more effort is needed.

(8) Regional modeling which is a good tool in order to understand the process at certain spatial/temporal scale that can never be could be done only by in-situ observation, was not implemented fully, due to scarcity of human resources. These studies need to be done more.

5. Future prospectives

Proceeding projects for GAME-Siberia is being considered and some are implemented. The main are the followings.

(1) In relation to above (1), CREST (Core Research of Evolution of Project on “Role and function of vegetation in Water Cycle” has started in November 2002, as a 5 years project. It will focus on

(a) Frontier Research System for Global Change and Frontier Observational Research Systems for Global Change in JAMSTEC: Northern Eurasia studies were done in cooperation with GAME Project since 1997. This is still continuing and producing large scale analysis studies, modeling studies, continuance of observational network in eastern Siberia area which was primarily initiated and developed by GAME-Siberia. Main body of Frontier, JAMSTEC will be reformed and become an Independent Agency from April 2004 (Japanese National Universities will also change to Independent Agency) is expected to be re-organized and extend its research area. This research activity is presently mainly lead by Profs. T. Yasunari and T. Ohata.

(b)CREST (Core Research of Evolution of Science and Technology): Forest function studies (mainly structure and physiology) related to water cycle is being done under this project with more participation of ecological scientists, taking data at four study sites from eastern Siberia, Kamchatka, Hokkaido and central Japan. The target of this study is to treat forest and trees as variables (land component which change its size and function according to time interacting with energy/water/material cycle). Prof. T. Ohta of Nagoya University is leading this study.

(c) CliC: CliC Project component in Japan will start its activity in 2005 (if funded), and northern Eurasia will be one important component of the study. Cryospheric component of northern Eurasia will be focused under this project. This component will be strongly promoted by Frontier Observational Research System for Global Change in collaboration with Universities. This is lead by T. Ohata with strong cooperation of NIPR.