Report on research progress of Siberia Regional Project

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1. Background and general information

GAME (GEWEX Asian Monsoon Experiment) selected one of their field experiment sites in Siberia. Importance of this area was, first, that it is a northern region with widely covered snow cover/permafrost and possess typical surface such as taiga forest and tundra which occupies a large area on Eurasia Continent. Second is that there is abundant freshwater runoff to the Arctic Ocean which may strongly affect the ocean circulation. Thirdly, this region is one center of the recent intense warming and better understanding is needed on the response of the land surface and possible feedback to the climate system.

In order to advance the study, we set up the following objectives.

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 of regional ground based/satellite data.
6) Establishment of observational network for long-term study, and development of hardware.

Four main strategies for implementation were set. The first was to select one large drainage for study, which was Lena River, eastern most drainage among the three large Arctic flowing rivers. Enisei and Ob were candidates at the beginning, but they were omitted due to warmer climate and more anthropogenic influence than Lena. Second was 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. Third was 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 (100 km scale), which was implemented in year 2000. The fourth is to involve researchers of various disciplines such as biology, soil science and others that can contribute to the understanding of the water/energy cycle in this region.

The study period was 1996-2001, and tight cooperation between Japanese and Russian institutions/scientists lead to a success. Table 1 shows the time sequence of the research progress for the group. The main results obtained in various study groups based on Japanese scientists will be presented were.

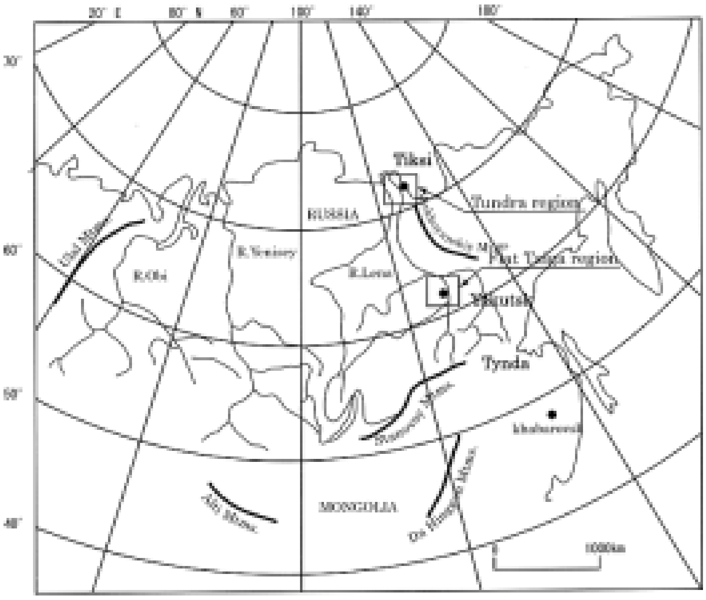

Fig. 1. The map of the study region and position of local observation sites.

Table 1. Yearly progress of the essential part of the Siberia Regional Project.

Year	1995	1996	1997	1998	1999	2000	2001
General Main meetings	GAME Conference (Pataya) GAME 1st Int. Workshop on Siberia (Nagoya)		GAME Conference (Cheju) 2nd Int. Workshop on Siberia (Moscow)		GEWEX/GAME Conference (Beijing) MAGS-GAME Meeting (Edmonton)		GAME Conference (Nagoya) planned 2nd MAGS-GAME Meeting (Sapporo) planned
Local patch drainage scale study	Tundra(tiksi) Patch	Construction of preliminary mast in the study area	Installment of the whole obs. system Start of runoff meas. and drainage study	Continued Upgraded the obs. system.	Continued	Continued	Continued
	Drainage				Helicopter obs. started	Continued	Continued
	Taiga Forest (Spasskaya) Patch	Aug.:Construction of 32m tower (larch) Setting of part of instrument and soil moisture/temp meas.	Setting of the whole obs. system	Continued	Continued	Continued	Continued
	Areal				Construction of 2nd 24m tower (pine)	Continued	Continued
	Taiga(Tynda) Patch Drainage			Started negociations with SHI	Negociation takes time	Construction of 24m tower and network within the drainage And start of obs.	Intensive obs. is being made
Regional intensive obs. study					Setting of tower, several masts and AWS at 7 sites in the right bank	April to June: Aircraft meas. were made. August: half of land obs. finish	
Variation, large scale analysis, Model studies		Made on personal basis	Made on personal basis	Made on personal basis	Made on personal basis	Made on personal basis	Made on personal basis

2. Tundra region

Tundra group stressed the following topics to be investigated.

(1) Seasonal and inter-annual variation of water balance of tundra watershed

(2) Seasonal variation of 1-dimensinal energy and water fluxes on tundra surface.

(3) Spatial distribution of surface and soil conditions

The following preliminary results have been obtained.

Figure 2 shows the map of the observation site. The observations for the patch scale energy and water exchange (theme 2) were carried out by ACOS (Automatic Climate Observation System) with a 10 m meteorological mast including the profiles of soil temperature and water contents for 4 years from 1997 to 2001. The result shows that, about 24 % of the net radiation reached at the ground during summer was spent as sensible heat fluxes back to atmosphere, 45-55 % as latent heat flux to the atmosphere, and 20-30 % as conductive heat flux into the ground. (Fig. 3.). Rather large amount of heat is used to melt the frozen ground where the melted depth is 50-100 cm at the most. Seasonal and inter-annual variations of summertime sensible and latent heat fluxes are relatively small. The dependence of these fluxes to the wind direction is seen as being reported by Yoshimura et al. (1999) for a coast site at Alaskan tundra. In case of southwest wind from interior with hot and dry air mass, sensible fluxes is small (sometimes changes its direction) and the latent heat fluxes large, while the northeasterly air masses is cold and damp, sensible heat flux is relatively large and the latent heat flux small.

Concerning the water balance (theme 1) of a watershed of 5.5 km^2, runoff, spatial distribution of snow cover and precipitation were studied. Inter-annual variation in annual precipitation was large (150-400 mm). About 80-150 mm of annual precipitation was as snow. The distribution of precipitation in the watershed was homogeneous at least from the study in 1998. Small vegetation height and strong wind enhance the redistribution of snow and form the snow drift, which acts as a natural snow dam during snowmelt season and becomes a source of summer discharge of the stream in the tundra watershed. The first day of snowmelt runoff was rather constant at the beginning of June for 4 years from 1997 to 2000. It is different from northern Alaska, where the first day of snowmelt runoff varies for more than one month. Most of initial snowmelt was refrozen inside the snow pack. The water level of a lake in the watershed changed seasonally with the ground water level. The change of water storage in ground could be estimated from the runoff curve. The evapo-transpiration was different by the vegetation, such moss, sedges, gravel. The water balance of tundra watershed was obtained for three years. (Table 2)

Seasonal variation of water cycle was simulated well by a one-dimensional model. The simulation of discharge by a nested hydrological model was improved by putting the place of snowdrift into account in the model.

Distribution of vegetation in the watershed was investigated and it was found that average LAI of moss was about 5. The distribution of thaw depth has auto-correlated patterns about every 7 m, which might be reflecting the hexagonal ground patterns. The thaw depth at the depression in the ground where soil water was relatively deep and different from general information in the past, which might be caused by the percolation of snowmelt water or rain.

The system of water and energy exchange and drainage runoff in this area seems to show different characteristics in certain aspects from the reports for the Alaskan sites.

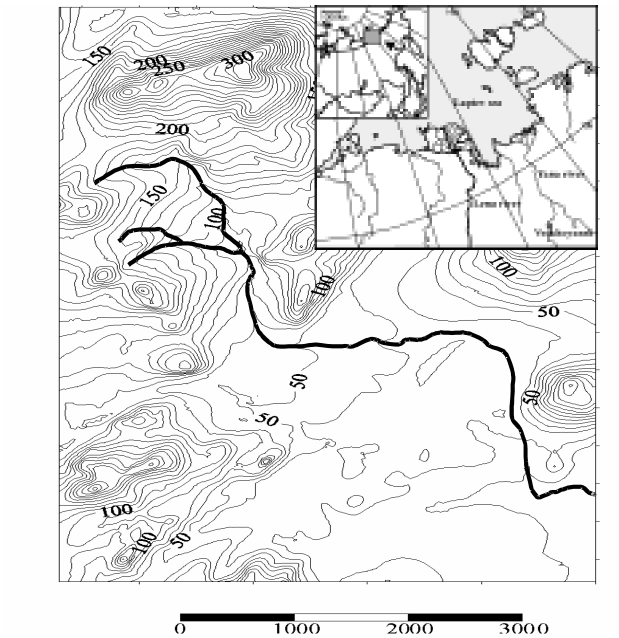

Fig. 2. Map of observational site at Tiksi (tundra)
1: hydrological station, 2: meteorological station

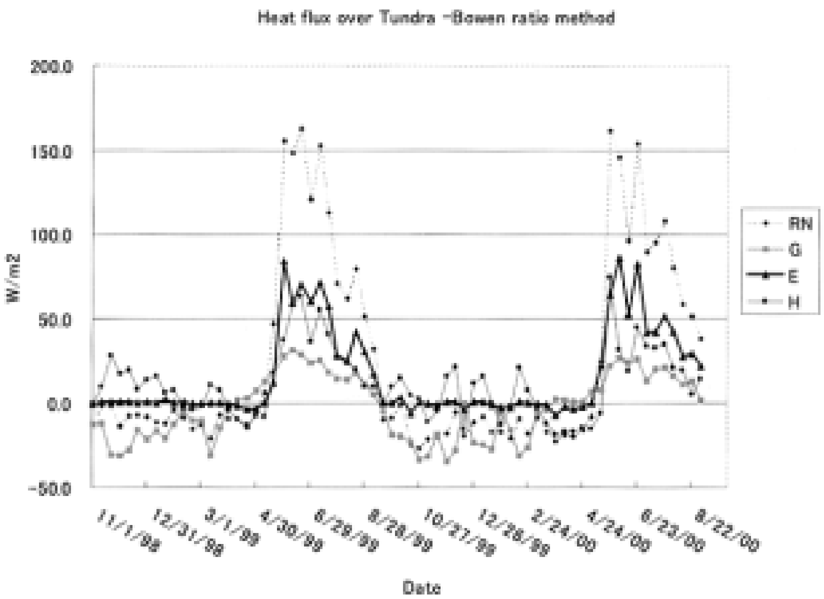

Fig. 3. Seasonal variation (10 days mean) of heat balance components at Tiksi from 1998 to 2000.

Table 2. Summer water balance at Tiksi watershed.
P: Precipitation, M: Snowmelt contribution, E: Evaporation,

Q: Runoff, dS: Change in ground storage.

Year	Period	P	M	E	Q	dS
1997	6/18-9/4	220*1	187*2	67*3	381*1	-41*4
1998	6/18-9/4	76*1	120*2	44*3	148*1	5*4
1999	6/13-9/8	99*1	65*5	55*6	110*1	-1*4
average		131	124	55	213	-13
Std.Dev.		77	61	11	146	24

*1 Observed, *2 Degree day Method, *3 Bulk Method
*4 Recession Analysis, *5 Residual, *6 Penman Method

3. Taiga forest

The predominant land surface condition in Siberia is the taiga forest, and this strongly influences the water and energy cycle in this region. Study was done at Spasskaya Pad near Yakutsk.

3.1 Meteorological conditions during the observation period 1997-2000

The meteorological data was obtained from 1997 to 2000. The amounts of precipitation from May to August were 81.5 mm, 235.7 mm and 131.7 mm in 1998, 1999, 2000, respectively and shows broad fluctuation year to year. The depth of active layer is 1 to 4 m in this area, deeper than Tiksi, the tundra site.

3.2 Seasonal and inter-annual variation of energy budget of larch forest

Figure 4 shows the seasonal variation of the sensible heat flux from 1998 to 2000. The sensible heat fluxes had maximal values at the end of May when it was just after a snow ablation, every year. The sensible heat fluxes decreased gradually ups to August, although the effective radiation increased until the end of June.

Figure 5 shows the time series of energy budget components above the larch forest in 1998. The energy incoming and outgoing were not balanced in this site, and the relationship between the avilable energy (Rn-G) and the sum of turbulent heat fluxes (H + lE) was presented as a following equation,

$$H + lE = 0.752\ (Rn-G)$$

where Rn is the net radiation, G the ground heat flux, H the sensible heat flux, and lE is the latent heat flux. The latent heat flux increased rapidly when larch stands begun to foliate. On the other hand, the sensible heat flux dropped at that time. According to these results, the latent heat flux might have the same as that in 1998. This result showed that the plant physiological activity affected the seasonal variation of energy budget strongly.

The canopy resistance in the Penman-Monteith formula varied widely and canopy resistance and evapo-transpiration efficiency were strongly controlled by the saturation deficit, and the efficiency decreased exponentially with the increase of the saturation deficit.

3.3 Differences of the energy balance characteristics between the larch forest and the pine forest.

The energy budget above a pine forest was observed in a warm season in 2000. The effective radiation and the sum of turbulent fluxes were almost balanced in this site. Figure 6 shows the time series of energy budget components above the pine forest. The latent heat flux indicated high values, 50 - 100 Wm^{-2} even at the beginning of May. Consequently, the seasonal variation of Bowen ratio did not show "U-shape" as that in the larch forest shown in Fig. 5 during the observation period.

Figure 7 shows the spatial and temporal distributions of soil temperature at the larch and pine forests. The thawing depth reached up to 60 - 80 cm depth at the beginning of May in the pine forest. On the other hand, the thawing depth was only 10 - 20 cm depth even at the beginning of June in the larch forest. Pine stands were evergreen and the thawing of permafrost begun early in the pine forest. Consequently, transpiration activity became high in a nearly spring in the pine forest.

3.4 Water flow and balance at the surface

Transpiration from the larch stands, not including evapo-transpiration from under-story vegetation, was estimated using a heat pulse method. The amount of transpiration was similar in two years, although there was a significant difference of precipitation. The result suggests that the soil moisture did not control transpiration and that transpiration was affected by atmospheric condition.

The percentages of stem flow to precipitation at the open site were less than 1 % in the larch and the pine forests. On the other hand, the percentages of through fall were around 15-25 % in the both forests, so under-story precipitation consisted of only through fall. The interception rate was around 15 % of the gross precipitation in the larch forest.

Snow adds complexity in the seasonal sequence of water flow at the surface. Maximum snow depth was 25 to 45 cm in this area. During the first half of thawing season, it was estimated that 40 % of the surface snow melt water percolated in to the frozen permafrost, although snow temperature was below the freezing point in almost layer. It was considered that the snow melt water flowed down through snow fingers formed in a snow pack.

Water balance in a at this larch forest for the warm season, including a snow-melting period, in1998 is as followed. Total water input was 211 mm. 105 mm of total input consisted of snowmelt water, and 106 mm was precipitation during the warm season. Evapo-transpiration from a whole ecosystem was 151 mm, and the under-story evapo-transpiration was equal to 35 % of total evapo-traspiration. The interception evaporation, 16 mm, was 15 % of the gross precipitation at the open site. The total evapo-transpiration exceeded the total precipitation, and snowmelt water compensated for this deficit.

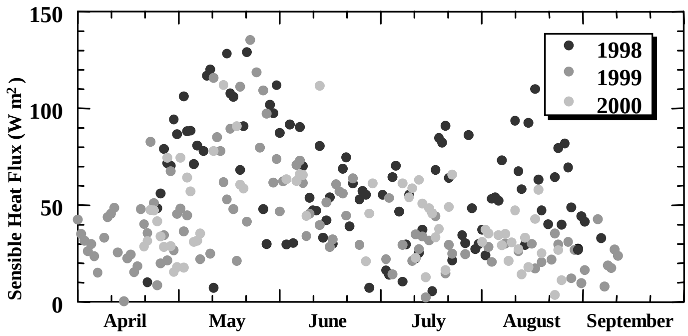

Fig. 4. Seasonal variation of sensible heat flux above the larch forest.

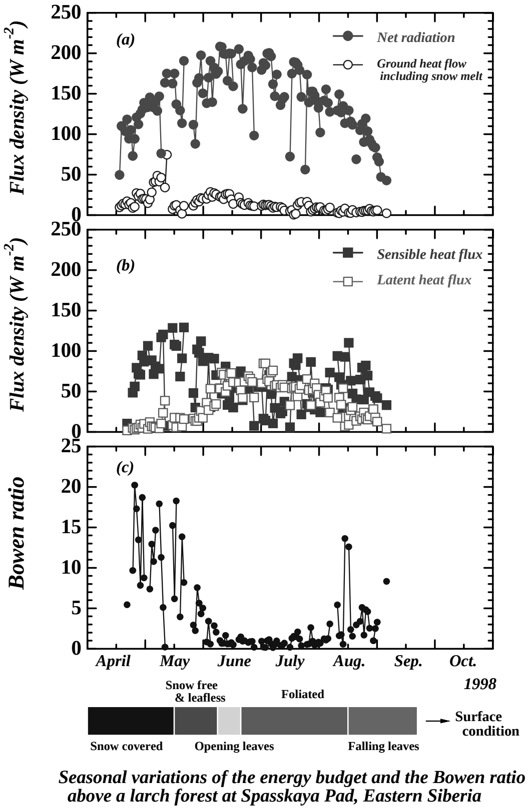

Fig. 5. Seasonal variation of each component of energy budget and Bowen ratio at above the larch forest in 1998. (Ohta *et al*., 2001)

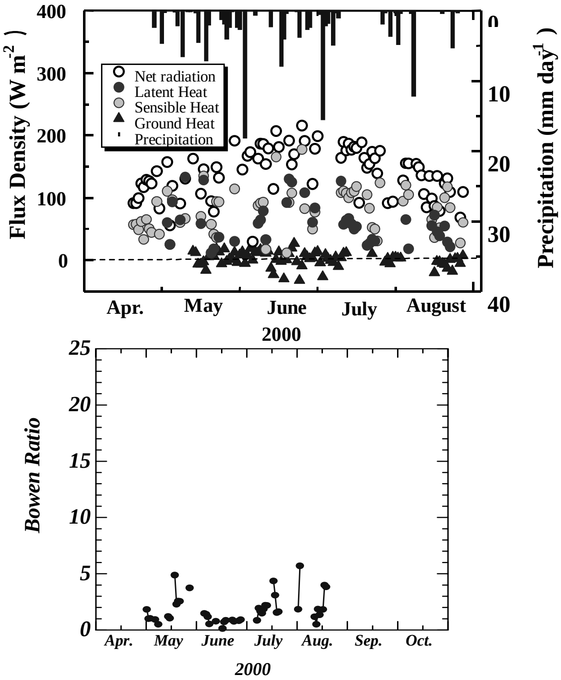

Fig. 6. The seasonal variations of energy budget components and Bowen ratio above the pine forest in 2000.

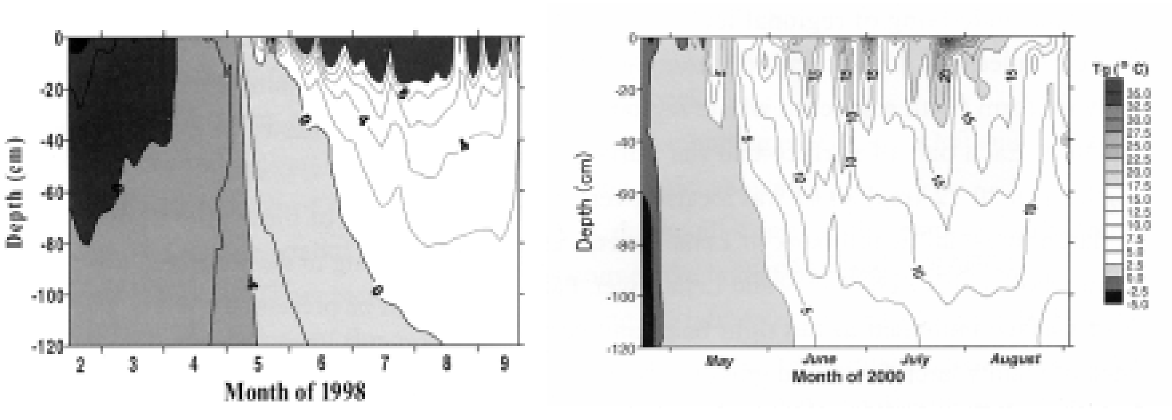

Fig. 7. Spatial and temporal distribution of soil temperature at the larch site in 1998 and at the pine site in 2000.

4. Intensive observation for spatial heat/water exchange in year 2000.

In year 2000, additional surface observation network was prepared in the Yakutsk area including a tower which was set in the taiga forest at the left bank of Lena River since 1997 (Sec. 2), to evaluate the heterogeneity of surface heat/exchange and spatial evaluation introducing the aircraft measurements. Observational network and flight courses are shown in Fig. 8.

4.1 Surface studies in right bank of Lena

4.1.1 Objectives for study and description of the area

There is a large number of sporadic grassland especially in the right bank of the Lena River inside the forest. These grasslands are called “alas”, occupying up to 20 % of this area. The alas is a concave landform that is formed after the forest has been cleared in an area where the ice content of permafrost was high. Usually the alas has a lake near the center of it. The field campaign of the year 2000 was carried out from April to September 2000, in an alas site near Tungulu village in the right bank of the Lena River.

The main objectives of this research are as follows:

(1) To characterize the one-dimensional water, energy, and CO_2 fluxes over the three typical land surfaces, that is, young larch forest, alas grassland, and alas lake.
(2) To clarify the difference in the surface energy balance between alas grassland and the forest floor, and to determine the moisture and thermal regime in the active layer at each site that reflect the surface energy condition.
(3) To learn how the water balance components affect the seasonal and inter-annual variation in water level/area of the alas lake.

The observation site in the right bank of the Lena River is called “Ulakhan Sykkhan”, and is a public alas, located 8 km west of the Tungulu village. It is oval-shaped, and is 1200 m long from west to east and 600 m long from north to south. It has an area of 0.64 km^2, including a 0.1 km^2 lake at the center. A 23 m high PBL tower in the young larch forest and a single mast system was set up at the center of alas grassland. Measurement on heat/water exchange was made at forest, grassland and lake.

These observations were made intensively between April and June 2000, in conjunction with the regional flux observations from the aircraft, then regularly from July to September.

4.1.2 Brief results

(1) Difference of seasonal change in energy flux among forest/grassland/lake surface (Fig. 9.)
- Net radiation: forest = grassland = lake
- Sensible heat: forest » grassland > 0, | lake | > grassland
- Latent heat: lake > forest > grassland > 0

(2) Difference in the surface energy balance between grassland and forest floor
- Solar radiation: floor/canopy = 0.4
- Soil heat flux: forest/grassland = 0.5 (Fig. 10.)

However, small soil heat flux value at the forest is also depending on the insulation effect of the litter layer on the forest floor.

(3) Unique water balance of the alas lake (Table 3)

Lateral groundwater inflow/outflow component during the summer seems to be very small.

It means that vertical components, precipitation and evaporation, are more important for the lake water balance. Because the lake water-level/area shows its maximum in just after the snowmelt period and decreases continuously after that, its inter-annual variation is mainly dependent on the snow storage volume in each year.

4.2 Spatial observation by aircraft

Aircraft observation in Yakutsk area (Eastern Siberia) was performed from April to June 2000. The object of investigations was ABL over Lena river and surrounding area and specially equipped Russian built ILYUSHIN-18 aircraft was used for observations. Main study topics were, spatial distribution of meteorological elements, sensible/latent heat and water vapor flux, atmospheric boundary layer structure, isotopic composition of water vapor at an altitude from 100 to 4000 m in the flight area shown in Fig. 8.

The aircraft was ILYUSHIN-18 operated by CAO, and it was equipped with the GPS, device for measuring dew-point temperature, system for measuring high response fluctuations of the horizontal/longitudinal wind respect to flight direction and vertical components of wind speed, high response temperature sensor, high response humidity sensor, high response closed-path CO_2/H_2O gas analyzer, infrared radiometer thermometer and video camera.

According to the schedule of observation days and the real weather conditions the experimental flights were made on April 24, May 1, 9, 12, 20, June 1, 5, 9 and 19, 2000. Each of these nine flights was made punctually according to the scheme.

Main results will be presented.

Large variability of meteorological and turbulent conditions in the studied area:

Surface underlying of regional legs (NW to SE) can be divided into 4 parts with different and relatively uniform (with respect to whole regional leg) structure. Each part of surface had the horizontal length about 20-22 km. Part #1 was located over pine and larch forest at the left bank of Lena River, Part #2 was chosen over Lena valley and Lena River. Part #3 of surface belonged to the right bank and consisted of mainly larch forest and grass fields and Part #4 (right bank) had complex profile with small hills covered with forests. The data obtained over these four parts of surface were taken into the analysis of the CBL models application.

Examples of obtained turbulent data (horizontal and vertical wind speed fluctuations, air humidity and air temperature fluctuations both with surface temperature and structure of underlying surface) and scheme of dividing the flight path are presented in Fig. 11.

Distribution of fluxes are variable in the area:

Flights over grid sampling area at the left and right bank sides of Lena River at a height of 100 m allowed to obtained horizontal distributions of turbulent sensible and latent heat fluxes and carbon dioxide fluxes. Examples of such horizontal distributions for flight made on May 1 are presented in Fig. 12 .

Data obtained during measurements on grid legs at a height of 100 m were the base for calculating square averaged turbulent fluxes. This gave possibility to estimate seasonal variations of sensible and latent heat fluxes and carbon dioxide fluxes. Results of aircraft observed and averaged fluxes are shown in Fig. 13. Seasonal variations of surface temperature and potential virtual temperature are also presented.

Observations made on regional flights allowed us to get spatial distributions of turbulent sensible and latent heat fluxes and carbon dioxide fluxes. These distributions for flight days of May 1, June 1 and 19, which we named as fine spatial structure of fluxes are presented in Fig. 14. These pictures also give image about seasonal variations of fluxes in Yakutsk region.

(1) Different characteristics of the ABL in the left and right bank:

Vertical sounding of ABL over left and right banks of Lena River showed:

ABL during all 9 days of observations can be treated as convective boundary layer (CBL)

During 5 flight days (on May 12 and 20, June 5, 9 and 19) development of thermal internal boundary sub-layers (TIBL) through the total depth of the CBL were observed. These also proved by fine spatial structure of potential virtual temperature, specific humidity, sensible heat and latent heat fluxes (see figs. 5 -7). On the others flight days (on April 24, May 1 and 9, June 1) there were no any internal sub-layers. Example of vertical sounding of CBL on two days without TIBL (May 1 and June 1) and with TIBL (June 9 and 19) is presented in Fig. 15

Spectra of coherence between vertical wind speed fluctuations and air temperature fluctuations also prove existing of TIBL developed in CBL through the total depth. These spectra obtained on May 1, June 1, 9 and 19 at the different height from 100 m up to 1500 m show clear differences between spectra of coherence at Part #2 for the days with and without TIBL. Threshold value of 0.15 for spectra of coherence was exceeded only on days without TIBL

Distributions of wavelet coefficients (or wavelet spectra) allow us to get not only existing of some events (heterogeneity zones of turbulent fluctuations), but also its locations in space (along the flight path) and scales (wave numbers). Wavelet spectra were the base for calculating distributions of wavelet variances or scalograms, which are the analogs of Fourier spectra.

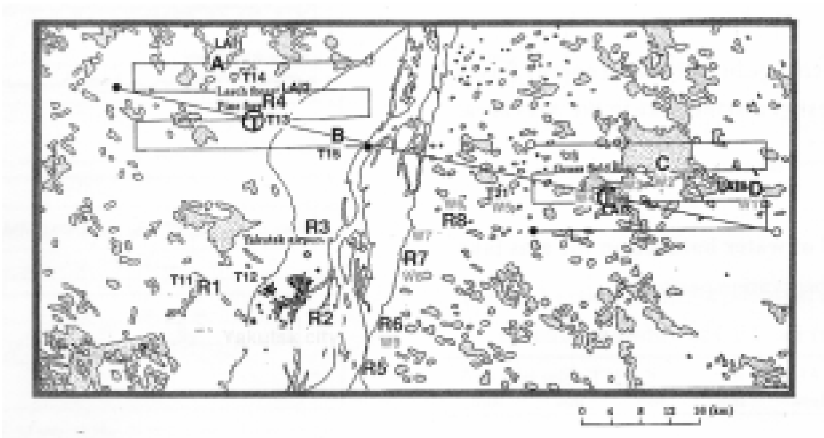

Fig. 8. The map showing the position of ground station during the intensive observation year 2000 and the flight course made from April to June. The shaded area in the map is the grasslands, and Lena River runs south-north at the center.

A-D: Radiation and precipitation and precipitation sampling

R1-R8: Precipitation and precipitation sampling **LAI**: Leaf Area Index

WO-9: Alas and lake water sampling

Tll-21: Surface soil moisture measurement with TDR (1*)

T: Observation tower at Spaskayapaid and alas station

(1*) Surface soil moisture was also observed at another sites for radiation and/or precipitation observation sites

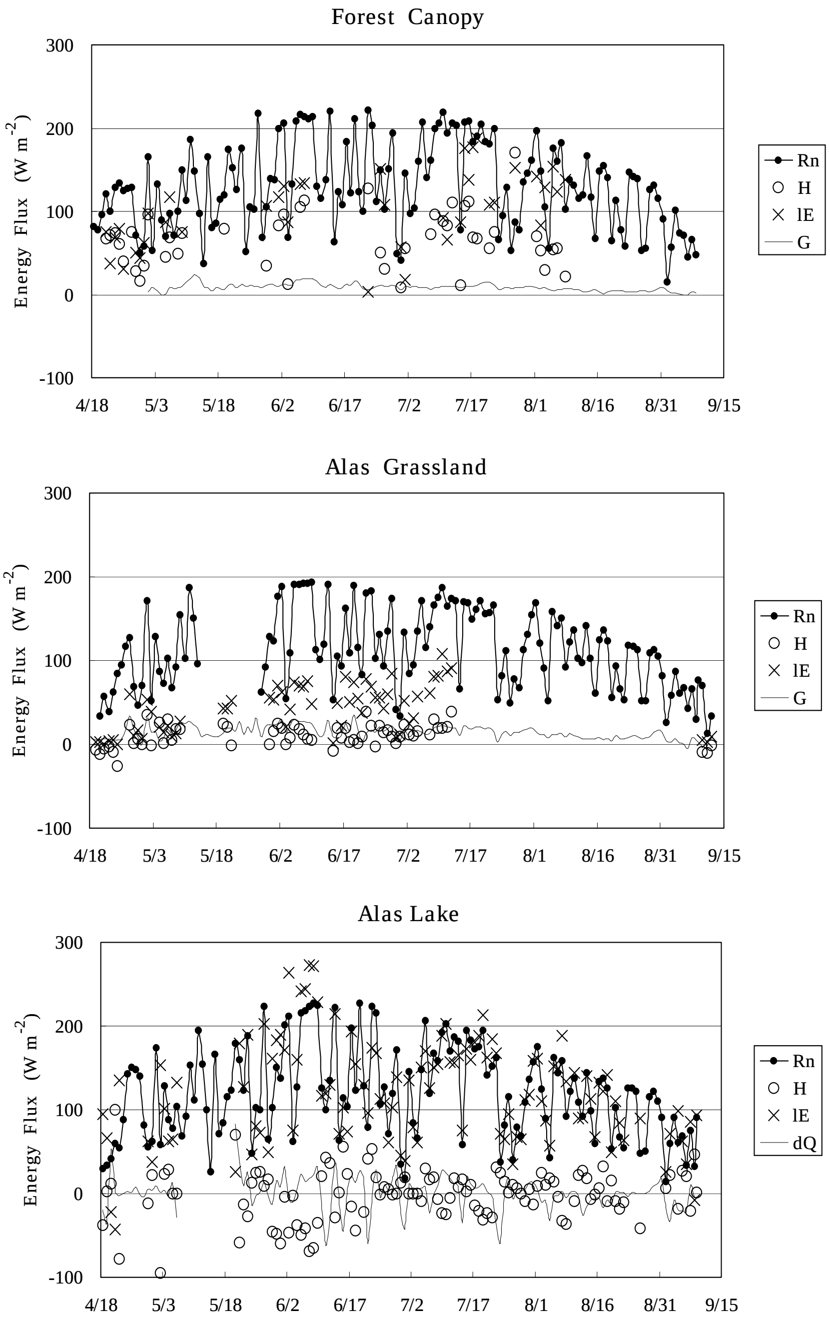

Fig. 9. Seasonal change in daily mean energy fluxes over the forest/grassland/lake in the Alas area.

Table 3. Result of water balance on the alas lake during the observation period.

Period	Δt days	Δh mm	P mm	E mm	$Qi \cdot \Delta t/A$ Mm
21 May – 9 Sept.	111	-288	129	451	34

Water balance equation on the closed lake is as follows:

$$A \cdot \Delta h = (P - E) \cdot A + Qi \cdot \Delta t$$

where, A : surface area of the lake, Δh : changes of water level, Δt : duration, P : precipitation, E : evaporation, and Qi : rate of surface/subsurface inflow.

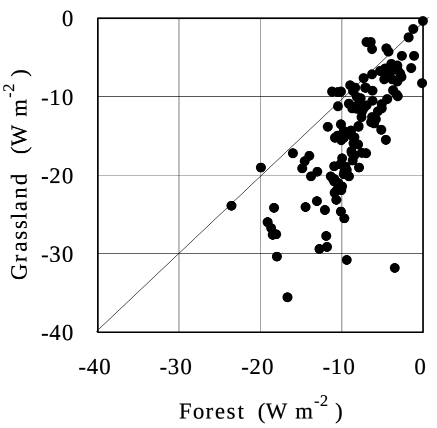

Fig. 10. Comparison of soil heat flux between forest and grassland at the Alas area in the summer season. Negative value show that heat is conducted into the ground from the surface

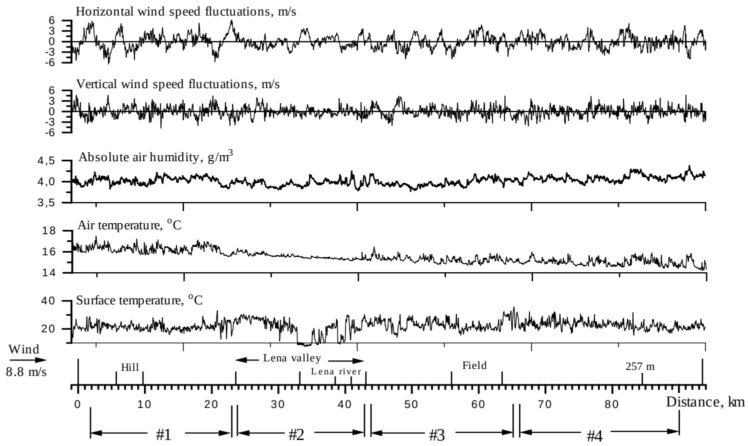

Fig. 11. The meteorological and turbulent elements at 100 m along the regionalleg (NW to SE) during the flight on May 1.

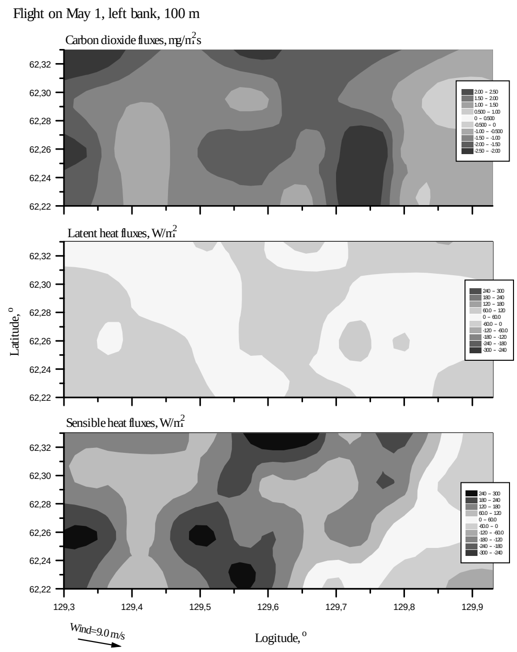

Fig. 12. Spatial distribution of CO2, sensible/latent heat on May 1 at the right bank.

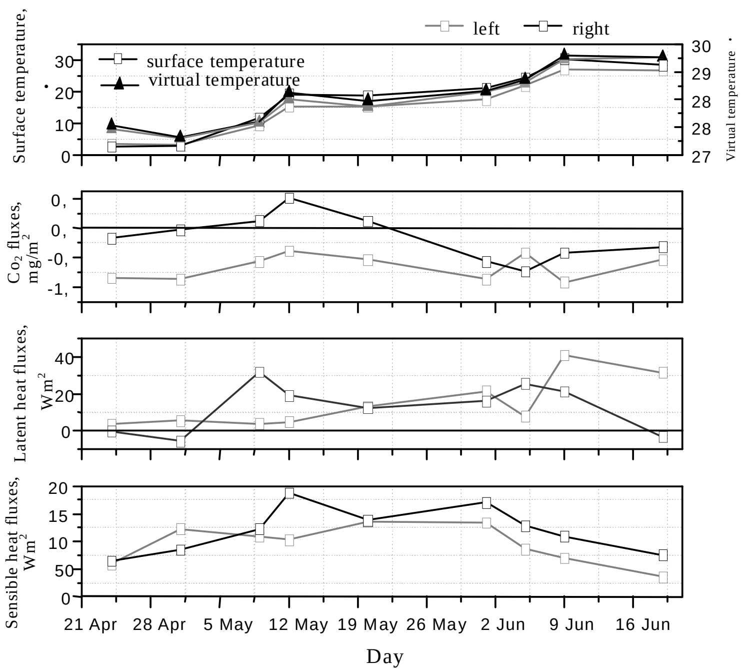

Fig. l3. Seasonal variation of meteorological elements and fluxes at the right and left bank. The values are areaverage.

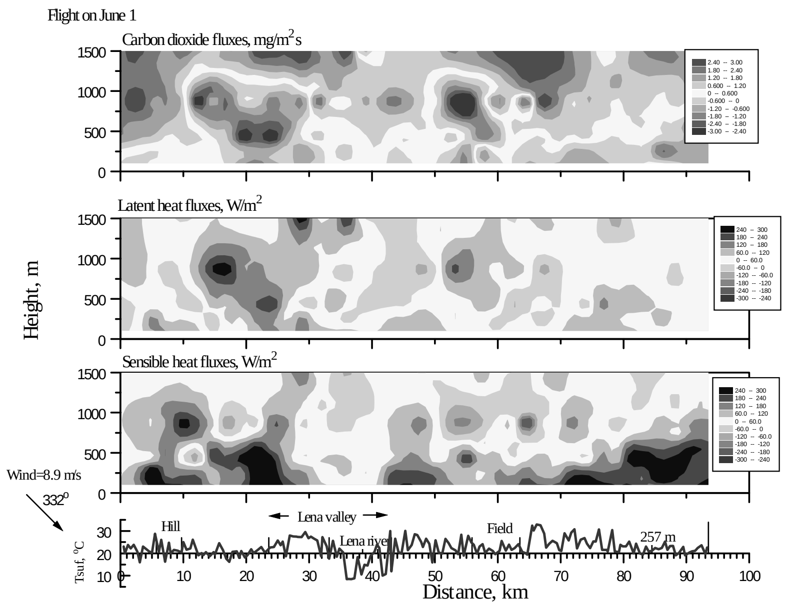

Fig. 14. The vertical distribution of fluxes along the regional leg flight on June 1.

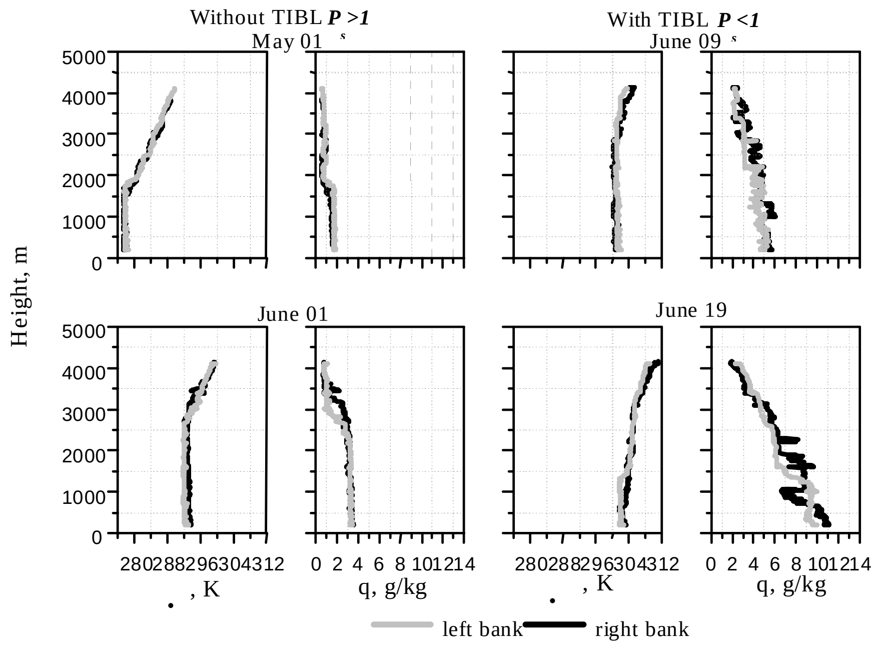

Fig.15. Vertical profile of potential temperature and specific humidity of CBL on two days without and with TIBL.

5. Large scale analysis using 4DDA and satellite data

5.1 Water circulation study of the atmosphere/land system.

Water budget study of the Lena River drainage was made using ECMWF and other global datasets. Results showed that there may be a lag in the precipitation and evaporation in these area for two years, evaporation proceeding the precipitation. The reason of this may be the influence of water storage and release system in the permafrost zone. However, there need to be more analysis to be made, since surface observation (patch scale such as the one at Spasskaya) of water fluxes shows rather small inter-annual variation.

5.2 NDVI analysis

Two analysis was mostly advanced with the use of satellite data. One was on vegetation using NDVI data and the other was snow cover estimation using microwave data.

The difference in the reflectance of chlorophyll pigment between the visible and near-infrared parts of the spectrum provides a means for monitoring the density and vigor of green vegetation. The Normalized Difference Vegetation Index (NDVI), a well-known vegetation index, is computed as NDVI =(Ch2-Ch1)/(Ch2+Ch1), where Ch1 and Ch2 are the surface reflectance from AVHRR Channels 1 and 2, respectively.

In summer, a zonal (west-east) high NDVI belt is found around 60N where a taiga forest flourishes in Siberia. By contrast, its southern and northern regions are characterized by a low NDVI due to arid climate and tundra climate, respectively. To examine these meridional changes, two meridional (south-north) transects were established, i.e., the arid-taiga transect (along 75E) and the taiga-tundra transect (along 110E) in Siberia (Suzuki et al., 2000). The meridional profile of annual mean NDVI, annual precipitation and warmth index (a cumulative temperature of monthly mean temperature above 0C) were compared. In arid-taiga transect, as indicated in Fig. 16, a strong positive correlation between NDVI and precipitation meridional changes, and a negative correlation between the NDVI and warmth index were found. From this result, it was suggested that aridity is the limiting factor for the vegetation amount in this transect.

In taiga-tundra transect, a strong correlation was found between the NDVI and warmth index meridional changes, suggesting that the limiting factor is temperature. Furthermore, it was revealed that the temperature spatial variation due to station's elevation causes a NDVI variation. This fact suggests that the vegetation is quite sensitive to the temperature regionality.

Another study was done on vegetation regionality and its climatological implication over an extensive region of Siberia and surrounding areas, from a plant geographical stand point of view (Suzuki et al. , 2001a). By the cluster analysis, the NDVI seasonal cycles at 611 stations were classified into 10 classes (A, B, C, D1, D2, E1-E4, F) and it was suggested that each local region contains vegetation with a distinct phenological cycle. It was revealed that the high NDVI is zonally distributed mainly in the latitudinal lines from 50 to 60N, and this zone roughly coincides to the zone where the annual maximum monthly temperature is around 18C. From this result, it can be considered that the zone where the maximum temperature is around 18C has climatologically the greatest potential for the highest NDVI.

As for local area where intensive observation of 2000 were made, analysis for April 1992 to September 1993 was made (Suzuki and Ochi, 1999; Suzuki, 2000). It was revealed that the NDVI regionality should be partly characterized by the land cover type and topography. However, the NDVI indicates regional variations which do not correspond to both topography and land cover. Those unknown factors of the NDVI regionality should be focused by the future work, such as airborne field observation.

Photograph observation was carried out at a station Spasskaya Pad to record the forest/snow condition and phenological transition from August 25, 1997 up to October 15, 2000. In the winter season, the frequency was reduced. The time of major event of the forest was roughly revealed by the photographs.

5.3 Snow cover study

Snow cover distribution was studied using microwave signals of SSM/I for the north-east Eurasian part. The brightness temperature difference (ΔT) between 19 and 37 GHz were taken as index for snow depth. The seasonal change in ΔT was able to be classified into 9 types. There were areas where snow depth can be estimated by ΔT rather well throughout the winter, but some region had bad relation. Forest conditions, absolute value of snow depth and snow texture seemed to have influence on this relation.

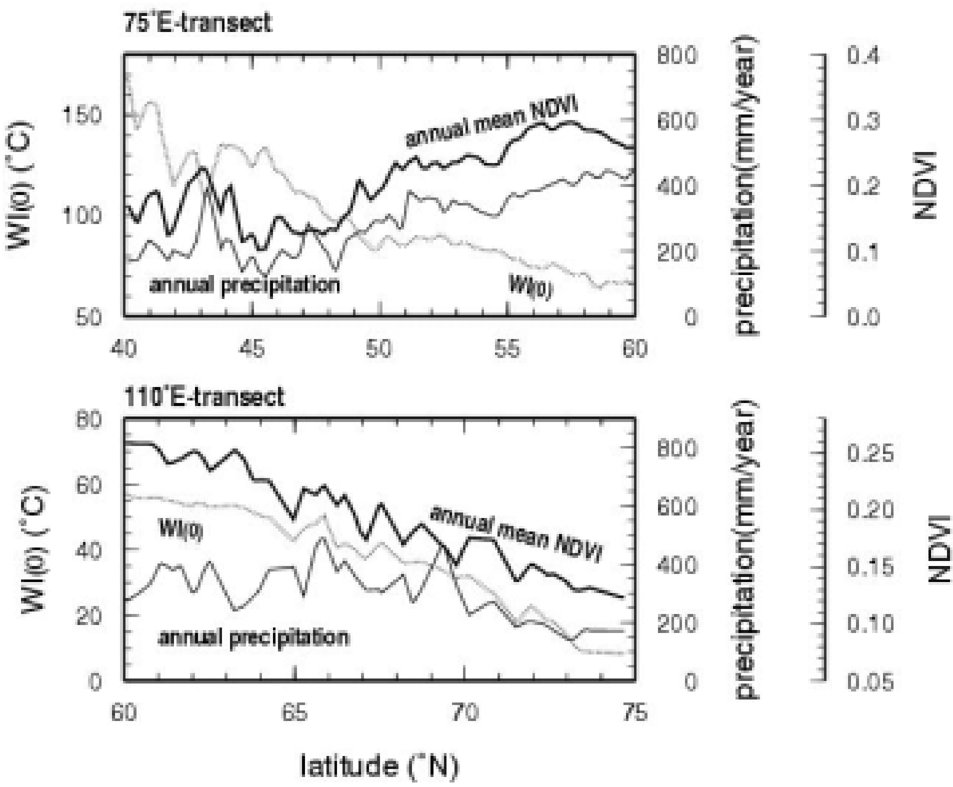

Fig. 16. Meridional profiles of the warmth index (WI(0)), annual precipitation, and the annual mean NDVl in 75 and 110E-transects

6. Modeling

6.1 One-dimensional models

Objectives of these models are estimating energy and water fluxes over various land surfaces, understanding of meteorological and hydrological processes and clarifying flux dependence on vegetation and terrain. A model, which was developed for intensively cold regions including vegetation, snow and soil layers, has been adapted to the plain taiga site. In 1998, diurnal and seasonal variations of fluxes are simulated reasonably, however, snowmelt is slightly earlier than observation. Another model, which was developed to couple with GCM or regional climate model, has been adapted to the tundra site (off-line simulation). In addition to these two simple models, two kinds of model have been developed to simulate CO_2 transfer and vertical fine structure of profiles. Remaining subjects are as follows: water flow in snow and soil, especially water channel in snow and water flow in frozen soil, and comparison with other site including right bank of Lena River.

6.2 Coupling one-dimensional models with atmospheric models

Preliminary results are obtained on simulation of a thunderstorm in 1998 near Yakutsk using a regional atmospheric model (RAMS). The followings are subjects in the near future: to estimate regional flux distribution and compare with aircraft observations, and to simulate precipitation events including cloud formation and comparison between left and right bank of Lena River.

6.3 Hydrological models

A macro-scale hydrological model combined with a simple SVAT model has been adapted to whole Lena River (Ma et al., 2000). When considering the effect of river freezing, seasonal change of runoff has been simulated reasonably. Remaining subject is long-term simulation to understand inter-annual variation. Two models joined the “Intercomparison of hydrological models” of PILPS-2e which is presently going on, and succeeded in getting good results.

7. Concluding remarks

The Siberia group had its main observation period in 2000, and the southern Taiga area only was able to implement its observation in 2001. Therefore, one or two more years are needed to elucidate major results.

7.1 Major scientific results

Although analysis is going on, there have been new findings up to now. The main ones are:

(1) Understanding advanced on the annual rhythm of the heat/water exchange at typical Siberian forest (larch and pine) using sophisticated observation systems. The amount and the timing of the heat/water fluxes especially from April to September were understood in more detail, comparing to the several observation done in the past (Pavlov, 1984). The absolute evaporation amount is smaller than previously estimated

and it can be said that the physiological characteristics of the vegetation determine the heat/water balance at patch scale and even at larger spatial scale.
(2) In tundra area, the amount of summer runoff seem to be regulated rather strongly on the distribution of winter snow cover, compared with Alaskan cases owing possibly to topography and wind climate. Also the difference of evaporation on low and high precipitation year does not differ much.
(3) Spatial distribution of regional sensible/latent heat (vapor) fluxes and ABL are complex due to influence of topography, land surface condition and dynamic response of atmosphere. The possibility that surface fluxes is partly regulated by atmospheric response was shown.
(4) The inter-annual variability of summer evaporation was obtained by a surface network and 4DDA analysis data, and they show rather contradicting results up to now.
(5) From NDVI analysis vegetation characteristics show latitudinal distribution implying zone of high vegetation activity. It will be interesting to know whether it is reflected in the heat/water exchange on land surface.
(6) Complexity of obtaining snow data from microwave information in Siberia region was shown.
(7) Through the application of various models to the observational and newly collected operational data, the models were improved, and in some cases, they were validated to be a good model.

7.2 Publication, international relations and contributions

The Siberia group has made following other progress.
(1) Our group has already published several project results, review monographs and papers listed at the end of this section.
(2) The Japanese research group has held approximately 15 domestic meetings since 1994 to discuss projects and its results.
(3) As part of interaction with foreign scientists and communities, we held two international workshop with Russian and scientists from other countries (Fukushima and Ohata, 1997; Ohata and Hiyama, 1998). Another direction was to hold scientific meeting with MAGS group, another continental experiment in clod region within the framework of GEWEX (MAGS and GAME, 2000) . The second of such meeting is planned in October, 2001.
(4) Members of the Siberia Group has attended SSGs of international project such as ACSYS/CLIC, IGBP-BAHC to have interference with them.

Publications

(Publications up to now: Individual reports and papers in the Activity Reports of GAME-Siberia, GAME Conference Proceedings and GAME-Siberia Workshops are omitted)

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