3.5 Siberia Region (GAME-Siberia)

Land surface processes have been acknowledged as one of the important processes in the climate system, which is formed through the interactions between the atmosphere, land and the oceans. However, the processes have not yet been studied enough to understand fully, nor have they been properly integrated into GCM models. Much effort to overcome these shortcomings has been made in recent years by conducting intensive atmosphere-land surface simultaneous observations, application of satellite data which can provide spatial data, and long term measurement of the complex land system with the cooperation of scientists from multi-disciplinary fields using instruments based on advanced technology.

The study in the Siberian Region will primarily contribute to one of the main objectives of GAME, "To understand multi-scale interactions in the energy and hydrological cycles in the Asian monsoon region", and secondly to the scientific objective, "To assess the impact of monsoon variability on the regional hydrological cycle" (JNC-WCRP, 1994).

The study objectives of the Siberian region are to clarify the characteristics and processes of water accumulation and transfer and their relation to the energy cycle at the atmosphere-land surface interface of a cold environment from a seasonal to an inter-annual time scale. The spatial scale of the phenomena to be studied will be from the local scale to the large scale of continental river basins draining to the Arctic Ocean.

The hydrological characteristics in this region, not only have a direct influence on the atmospheric system, but also on the Arctic Ocean system through the supply of abundant fresh water to them from spring to summer, in turn influencing to the climate of the Arctic and surrounding areas (WMO, 1992). These studies of the energy and water cycles on land surface layers will contribute to solving the problem of carbon dioxide, and the recently discussed trace gas emissions such as methane, which are conditioned by the hydrological conditions.

3.5.1 Scientific background for Siberia.

In addition to the general scientific aims of GAME (JNC-WCRP, 1994), there are certain conditions and reasons which demand descriptive research on the energy/water cycles in the Siberian region. Some preliminary objectives along these lines are written in Ohata and Ohta (1995). The followings are the main aspects.

The permafrost region is an area where studies on the energy/water exchange on land surfaces, atmosphere-land surface interaction and hydrological processes have been few, due to its difficult accessibility and complexity. The cold temperatures and low precipitation in this region generate the following conditions.

- Structural conditions: Due to the existence of frozen ground, a unique shallow frost table (bottom of the melted layer) exists during the warm period and this operates as an impermeable layer to water penetration.

- Vegetation conditions: The forests which develops in this area are generally deciduous coniferous trees which are rather low in height (10 to 20 m high), and amount of leaves (LAI) have a low value. The distribution and physiological functions of these forests should be different from warm regions. There are typical vegetation conditions in the tundra.

- Snow cover: Water exists in the form of snow cover, which affects the surface albedo which is an important parameter in the energy cycle and characterize ground surface water storage in spring. The duration of snow cover in Siberia extends to more than half of the year.

(1) Study of surface processes

Precipitation and snow storage have time lags and soil moisture tends to be high near the surface. Although such complex conditions exist, only limited studies on energy/water exchange on the land surfaces have been made. Previous observational studies in tundra areas were made only on certain components of the land surface processes for certain seasons in a certain year (Ohmura, 1983; Rouse, 1992). These measurements did not have complete data sets nor were they long enough to understand "why such intensity there at that certain time". Study of multi-year measurement of summer heat/water balance on tundra surface (Rouse, 1992) showed evapotranspiration values were similar each year, notwithstanding the difference in the summer climate, precipitation and air temperature. However, the reason was not clear due to the limited measured components and to short period of summer measurements. Two recent studies in Siberia and Canada (Kelliher et al., 1994; Sellers et al., 1995), showed that the heat balance in boreal forests in summer is characterized by the high sensible heat transfer and the high Bowen ratio regardless of the continents and the stand species. However, these differ from the study made in the 1970's (Pavlov, 1984) in Siberia which showed high evaporation during summer. These demand longer term, at least one year, measurements including the whole water/energy components. Especially soil moisture is a component which is uncertain and needs to be investigated in detail.

The water budget terms in a catchment area are affected by snow, existence of frost table, vegetation characteristics and others, which form certain characteristics. There have been only a few measurements of the time series of water/energy fluxes at the catchment scale (few tens to 10,000 km^2) in complex land surfaces. Land surface anomalies of a few tens of km have effects on meso-scale circulation. Alas, which is a concave landform formed after the clearing of forest in an area of high ground ice content, is one complex closed land surface system which shows an interesting local water/energy cycle, from the standpoint of non-stationary land surface system.

(2) Models

One-dimensional atmosphere-vegetation-soil models for energy transfer and water accumulation and transfer, have been studied from many aspects in the past. However, they still have some shortcomings such as poor representation of frozen ground and the active layer. More data in the permafrost region are needed to verify and also upgrade these models. Research on climate change is providing a degree of urgency for fundamental research on the modeling of hydrological processes at large scales, not only to simulate the impacts of any changes on catchment and regional scale water balance, but also to improve the land surface schemes in the current generation of atmospheric models.

Basin scale hydrological models have been developed in other tundra areas (Hinzman and Kane, 1991). However, such models have not been applied to Siberian conditions, nor have they shown their universal applicability.

Such present conditions, require us to obtain a comprehensive data set, and to upgrade and/or develop models to understand the land surface processes in these regions.

(3) Large scale water circulation

Annual values of precipitation, discharge and evapotranspiration in the Lena River basin are 404 mm, 215 mm and 189 mm, respectively from analysis using ECMWF objective analysis data and others data sources (Oki, 1994). Large winter to spring storage was obtained, probably as snow cover, but it was not possible to separate ground moisture and snow cover. The ratio of evapotranspiration to precipitation in these analysis was larger than the surface point measurements in central taiga area. More work is needed to clarify the characteristics of the large scale water cycle, both in the atmosphere and on diverse land surface conditions.

(4) Climatic trends and variations

There are indication of surface temperature warming in the past 30-50 years, and a long term precipitation increases in the Siberian region to Central Asia on Eurasian Continent (IPCC, 1992; JMA, 1993). There are data which have possibily been disturbed by anthropogenic influences and instrumental changes. Clarification of the true trends and variations, and evaluation of possible land surface feedback processes related to water/energy cycles in this area are awaited.

(5) Data base for advanced research

Analysis of multi-scale water/energy cycle can be progressed by incorporating all the available data sets, land based data from permanent stations and satellite derived data. It will be necessary to archive all measured components including ground moisture, radiosonde data and ground based data.

3.5.2 Study objectives

Based upon the backgrounds written in sec. 3.5.1, the objectives of the regional study in Siberian region will be composed of the following two categories, scientific objectives concerning natural phenomena, and technical and operational objectives. The relationships between the study topics are shown in Fig. 3-5-1 and the study region is shown in Fig. 3-5-2.

A) Scientific objectives
1) Clarify the physical processes of the land-surface/atmosphere interacting system.
2) Clarify the characteristics and variability of regional energy and water cycles.
3) Determine any climate trends and land-surface changes during the past 50 years, and evaluate possible feedback.
4) Improve and develop models.

B) Technical and operational objectives
1) Collect and archive regional ground based and satellite data.
2) Establish an observation network for study of long-term variation.

(1) Land-surface/atmosphere interaction system at seasonal to inter-annual time scales

The most important objective is to understand how the cold environment (frozen ground, snow cover, vegetation, etc.) affects the water and energy cycles in the land surface-atmosphere system, especially the conditions of the land surface and surface fluxes.

a) Energy and water exchange and accumulation over representative land surfaces (Topic A-1a):

Understanding the characteristics of the response of the land surface to atmospheric forcing for representative land surfaces for annual cycle is the first study priority. In order to fulfill this goal, data on all of the hydrological components, thermal components (radiation, sensible heat, latent heat above and within the vegetation, ground heat flow), heat accumulation and loss, structural components should be obtained. The data on plant physiology (for example stomatal control) and forest structure (for example LAI, open area index and roughness) constitute one important part in these data sets. The observations will be made at a range of scales, at leaf or shoot level, and from tower, tethered balloon and from the air. These observations will contribute to the development of physical models capable of determining the long term response of land surfaces. Stable isotopes are being considered for validating spatial evaporation and runoff at various spatial scales.

The sites for the above purpose are classified into two groups. One is distributed over the main study drainage in the Lena River basin, and the second in other regions in Siberia and

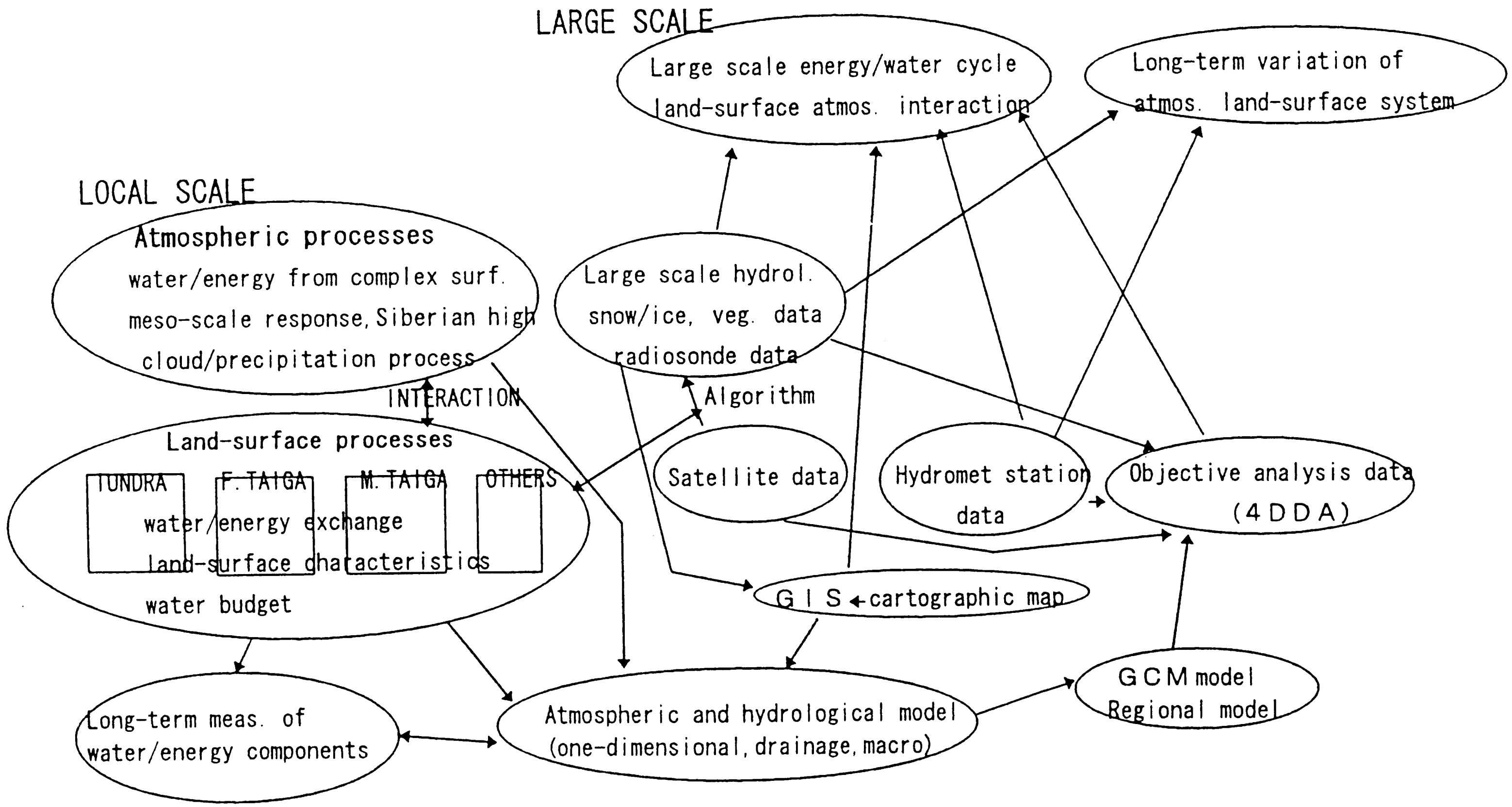


Fig. 3.5-1. Relation between study topics within Siberia project.

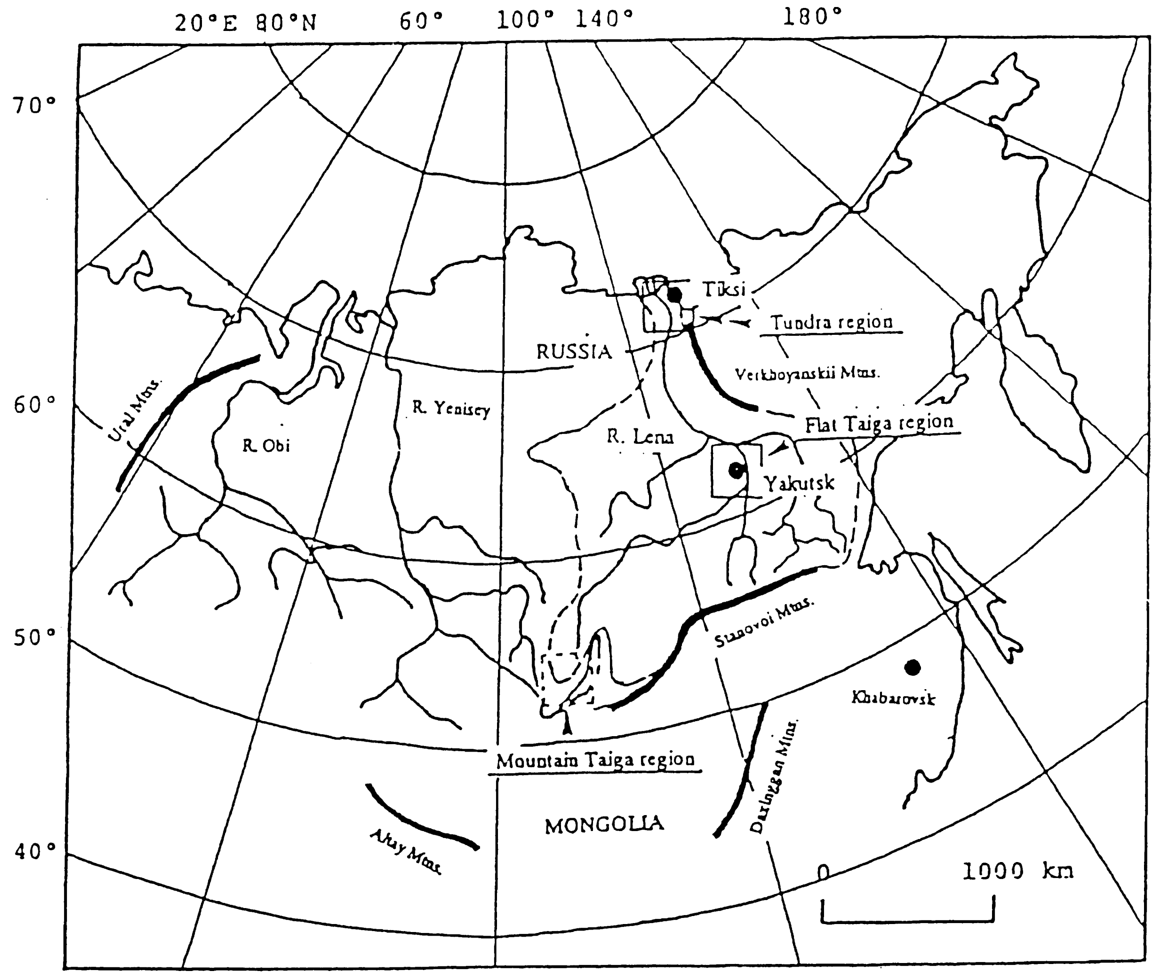


Fig.3.5-2 Study region and position of intensive observation area

Mongolia where seasonal frozen ground exists. Three areas in the Lena River basin are selected according to surface vegetation and precipitation (topography) conditions, that is, the northern tundra region, the central flat taiga region and the southern mountain taiga region. These also constitute a part of AAN.

b) Hydrological characteristics of complex land surfaces (A-1b)

The land surface of certain areas, for example 100 x 100 km scale, in general, is composed of a complex and heterogeneous structure in their form and texture. The response of such complex land surfaces to atmospheric forcing will be investigated. Dry steep surfaces and wet gentle surfaces, predominate in the tundra region. These conditions are reflected in the type and density of the vegetation cover in the taiga regions. The vegetation patches in the transition area from tundra to taiga may be due to the anomalies of ground moisture caused by the topography. There should be a typical hydrological cycle in the "alas system" within the forest, which is grassland, often with lakes at the center.

The scales of land surface process are inherently different from atmospheric scales. Atmospheric phenomena such as precipitation, are affected by averaged land surface conditions of a few to a few tens of km. On the other hand, surface water and energy fluxes are rather dependent on smaller variations of land surface conditions and topography, where the fluxes in the lower atmosphere has larger scales due to atmospheric processes. Therefore, the classification of land surfaces for energy and water cycle studies will be determined and integrated into a GIS. This will then be applied to the regional hydrological analysis and will be the inputs to the modeling. The ideal area of the candidate study area is 100 x 100 km or less. This is for two reasons; one is that it is a comparable scale to the GCM grid, and another is the ease of accessibility by a vehicle and aircraft.

Within the study area, the distribution of land surface variables, such as vegetation parameters, ground temperature and soil moisture, frost table and active layer distribution will be measured and their variability will be investigated. Measurement and determination of the seasonal variation of hydrological components, such as precipitation, storage, evaporation and runoff will be made by a measurement network, aircraft measurement and use of models .

The most important but hardest task will be to obtain the distribution and mean spatial evaporation from complex land surfaces, under a daily to seasonal cycle. The land surface parameters related to aerodynamic characteristics such as surface roughness and displacement height will be obtained and compared with turbulent flux measurements. This result will be used to obtain the mean momentum and sensible and latent heat fluxes. Towers, tethered balloons and aircraft measurements will be the basis for this study.

These studies will be conducted in the tundra and flat taiga areas in the Lena River basin.

c) Atmospheric response, cloud and precipitation processes (A-1c):

The rather dry surfaces in the summer in the taiga regions affects the convective boundary layer and cloud systems. There is probably a strong diurnal cycle of precipitation, and precipitation system should be rather localized. The humidity conditions in the winter season are said to be affecting the radiation conditions, to produce gradual warming trend especially in winter.

Snow cover formation in autumn and snowmelt in spring will abruptly change the surface radiation conditions and various heat fluxes. These should modify the atmospheric dynamic conditions and moisture conditions in this season with certain feedback effects.

This will be investigated in the latter two years of the project at flat taiga region in Lena River basin.

(2) Characteristics of the regional scale water and energy cycles.

The second objective is to clarify the hydrological cycle of the land-atmosphere system at the scale of continental river basins (order of 0.1 to 1 million km^2) which are regulated seasonally and also year to year by climate variations. The atmospheric water cycle have rather uniform structure within 10^2 to 10^4 km^2, but there is much variability at larger scales.

In studying the large scale water circulation, the Lena River which has the eighth largest drainage area on earth (23,837km^2) was selected for the following reasons;

· It is unaffected by anthropogenic disturbances such as land use and dam construction.
· Representative land surfaces (tundra, taiga and various land forms) of Siberia are included.
· This is a drainage large enough to have an influence on the fresh water supply to the Arctic Ocean.

The outcomes from studies in this area will be applicable to other large continental rivers.

a) Seasonal variation of regional scale water cycles (A-2a)

1) Atmospheric moisture budget

Evaluation of each component of the atmospheric water balance equation will be made. As the Siberian region is so vast, this seems to be the most appropriate method for evaluating the extended hydrological cycle over Siberia. The following procedures will be used;

· Collection of all the aerological data available in Russia,
· Enhanced radiosonde measurements during the research period.

Further analyses will be made by using ECMWF re-analysis data set, which will be compiled in 1996, to examine the relationship between the change of the hydrological balance and meteorological (and climatic) conditions. Seasonal changes in precipitable water need to be made. NDVI data will be used to obtain spatial evaporation and possibly precipitation data. A weekly evaporation map for this region will be one target product.

2) Land surface water budget (A-2b)

Drainage areas of 1 million km^2 and one order smaller will be investigated. Precipitation, snow cover storage, ground moisture storage, evaporation and runoff will be the required components. The Lena River (2.4 million km^2) and lower order drainage areas will be selected. In this study, inclusion of a region of high snow storage will be important. Generally, they are located in the east, south, west mountain regions, and spatial estimation of water cycle components within these areas will be made. The effects of a topography on precipitation, will be considered.

The required data for this study comes from

· Existing data from hydrometeorological stations
· Spatial values of components such as snow cover, precipitation and ground moisture using spatial extension methods (with models) .
· Results from objective analysis data from 4DDA.
· Satellite derived physical data.

Satellite data are effective for such study, but the algorithms need to be improved to obtain required accuracy. At present, additional measurement network (snow cover, ground moisture) for improving these will be considered for this study. These data need to be derived on at least a weekly basis.

b) Development of the Siberia High (A-2b)

An important phenomenon in the land surface/atmosphere system during winter in Siberian region is the development of Siberian high. Its relation to the moisture conditions and land surface conditions (amount of snow cover etc.), directly or indirectly, needs to be clearified. The heat balance study of atmospheric column and the inter-annual variability study may be a key to answering to these questions. Other important work may be the analysis of the data and the re-examination of the vertical radiation budget which was made by CAO (Central Aerological

Observatory) up to the beginning of the 1980's using radiation-sondes. This may give some clues to the warming in this region.

c) Continental-scale land-surface/atmosphere interactions (A-2c)

The following advanced analyses will be made in relation to this topic. The scale of study will be larger than the spatial scale described in the past sections, including Northern Eurasia.

· Inter-relation between Northern Eurasia soil moisture and general circulation such as the intensity of the Indian monsoon: The key to this study will be the data collection of un-archived soil moisture data. This study can suggest the land surface process studies which need to be made in reference to the large scale phenomena.

· Interaction between variation of snow cover, soil moisture and atmospheric circulation: This will be made by using the snow cover, land surface and surface temperature data obtained from the SSM/I and other satellite sensors, along with the atmospheric circulation patterns, and their analyses at the diurnal, seasonal to inter-annual time scale.

(3) Changes in the atmosphere-land surface system in the past 50 years (A-3).

The actual variation of the energy and water cycle in recent decades, and the resultant thermal, hydrological and structural changes will be the main targets of investigation. Anthropogenic effects such as urban areas, change in the position and surroundings of observation sites, dam construction and instrumental changes will be evaluated to obtain accurate long-term data. Possible effects are urban climate changes on air temperature and fog; dam construction and land use effects on runoff data; instrumental influences on precipitation due to change in the type of rain gauge; site and surround changes on all of the climate elements. The detection of true trends and variations in the water and energy cycle components will be obtained using the above data sets and the aerological data. An important study topic to be studied is the recent warming and its mechanisms and evidence of changes in biological, cryological or hydrological components, and their inter-relation will be analyzed statistically.

(4) Improvement and development of models (A-4)

Development of one-dimensional and sub-grid scale (so called macro-scale) cold earth surface model. This is needed for the following purposes.

· To comprehensively understand the energy and water accumulation and transfer of the atmosphere-vegetation-ground system, and to undertake land surface sensitivity study.

· To improve the land surface schemes in the land-surface/atmosphere system (coupled) model, GCM and climate models.

· To improve the evaluation and estimation of the hydrological variables. The models which are considered in the present study are as follows.

· One dimensional complex model: A model that can calculate the energy and water exchange between the atmosphere and ground surface when the atmospheric conditions are given, will be developed. Permafrost, snow cover, plant physiological parameters and canopy snow will be components of special interest and complexity.

· Land surface schemes for GCMs: Soil freezing will be introduced explicitly. Parameterizations of soil moisture to take account of freezing needs to be improved. Measured flux data will be obtained for model validation. Since it is necessary to obtain representative parameters, we must study methods to obtain a data set for model validation using the observed mean and variance of heat fluxes. Snow albedo parametarization in forested areas, will be investigated to take account of snow albedo feedback

・Hydrological model: There is a wide gap in the scales of time and space between hydrology and meteorology. Sometimes this gap has been ignored, and theories and models that are only applicable at small scales have been used at the scales of a GCMs grid, ignoring the effects of hydrological heterogeneity. Approaches which integrate, or aggregate small scale processes to develop lumped models at the larger scales should be preferable.

In the Siberian region, there has been little work on hydrological modeling at any scales, so the first step of our work is to establish or develop an appropriate simple model that can express the hydrological characteristics of the Lena River basin. This model can then be coupled with atmospheric models or GCMs. Using existing Rissian data, an initial model should be tested before the intensive observation period.

(5) Data collection and archive of regional ground based and satellite data (B-1)

The collection, archive and distribution of un-archived hydrological, meteorological, geographical and biological data are essential tasks for the phenomenological studies, and developmental studies to be done in the future. One important component is the GIS (Geographical Information System).

Some of these data sets will compose a part of GAIN. In order to meet this requirement, the development of satellite sensor algorithms, their validation and the development of spatially distributed data will be made in cooperation with NASA. The derivation of objective analysis data (4DDA) are planned to be made in collaboration with JMA.

Soil moisture and snow cover (depth and water equivalent) data will be the main component for improvement of the algorithm and validation. The satellite sensors which will be examined are NIMBUS-SMMR, DMSP-SSM/I, SAR, ADEOS2-AMSR and GLI, and NOAA-AVHRR. There are two types of data which can be used for verification and development of algorithms; a) Data from measurement network to be established in the GAME study area, and b) Data from permanent stations.

(6) Establishment of the measurement network for the long-term variation study of the land surface system (B-2).

The requirement for a long-term measurement system (one full year and more) is as follows.

・To obtain near-mean values of the land surface parameters and land surface responses, multi-year measurements are necessary, since the year-to-year variations of climatic conditions are large.

・To clarify climate "trend", multi-year measurements are needed.

・To improve the algorithms and validate the satellite data of land surface components, ground-based measurement at different land surfaces are required for satellite validation.

The probable number of stations is around 10 in Siberia, including the intensive study area of the Lena River. It is planned to use the existing field stations of various institutes in Siberia and other sites. The requirement to establish such an observation system in the Siberian region is now being determined in collaboration with AAN.

3.5.3 Implementation details

(1) Time schedule of implementing topics and observations

The overall time schedule of the studies over the five years and the detail schedule for the local scale study from 1996 to 2000 is shown in Table 3-5-1. Data collection analyses and model works will be continued for the whole five years, with early collection of past Russian data.

Two periods of IOP are planned for observation. One is from the summer of 1997 to the summer 1999 (1st IOP), in which the one year measurement of one dimensional processes at representative surfaces and local scale water and energy exchange will be the main target. Another is planned from 1999 to 2000 (2nd IOP) when evaluation of the atmosphere-land surface interaction, water and energy exchange of the atmospheric boundary layer and the land surface based on simultaneous measurements on land and atmosphere will be made. The detailed planning of the 2nd IOP will finish in 1998.

The main plan for the 1st IOP is local scale study related to the surface water and energy exchange part of objectives A-1a and A-1b. This observation also contributes to the objectives A-4 and B-2 (in Sec. 3.5.2.). Local scale studies will be implemented in two areas, the flat taiga and the Arctic tundra. Besides, preliminary work will be undertaken in the southern mountain taiga which is now under pre-survey.

In the 2nd IOP, interaction part of objectives A-1, data set for A-2 and A-4 will be implemented. The following specific topics are now being under consideration.

- Snow cover-atmosphere interaction during transition period and snow cover seasons.
- Hydrological feedback of snow cover to atmpospheric systems during the snowmelt to summer season.
- Derivation of good quality data for hydrological modelling.
- Continuation and reinforcement of long-term ground based network system.
- Satellite vaidation and application

The measurement systems which will be put in for the 2nd IOP are enhanced sonde measurement sites, increased ground flux stations, in-situ and remote airborne observations, radar systems and others.

Details of 1st IOP are cited below.

(2) Observation plan for the tundra site at Tiksi

The main objectives in this area are as follows.

- One-dimensional water and heat fluxes and their modelling for a representative surface.
- Seasonal variation of the drainage scale water budget from hydrological observations.
- Mapping of land surface conditions for modelling.

a) Tower scale observation

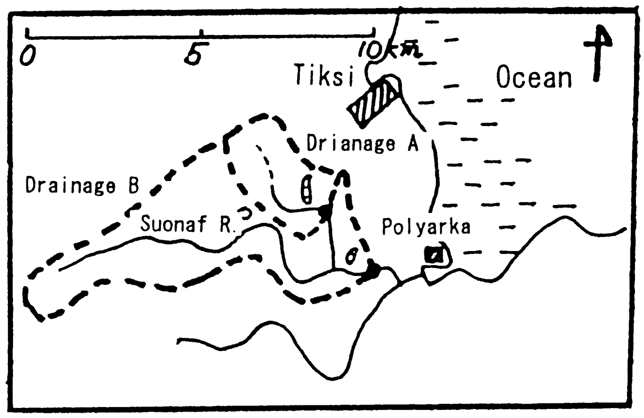
The main observations of fluxes and water/energy exchanges are to be made by using the observational mast, with additional measurement using plot, mooring balloon and airborne techniques. The intensive study will be made at the site near Tiksi (Fig. 3-5-3). The observations are composed of two groups: automatic and long term observations and short term intensive observations.

The automatic, long-term observations (local scale) consist of;

- Surface boundary layer observations with a 10 m mast,
- Surface radiation balance components,

Table3.5-1 Time schedule of study

YEAR	1996	1997	1998	1999	2000
General	Agreements Preliminary observation year	1st IOP 2nd IOP plan.	Compilation of 1st IOP	2nd IOP	Compilation of 2nd IOP
Topic 1 (Local Scale Study)	Preliminary field obs. Selection of mountain taiga site.	1st IOP start *one-dimesional, *catchment scale meas., *(aircraft meas.)	1st IOP end Analysis	2nd IOP *land surface meas. *complex land surface, *atmospheric processes	2nd IOP end Aircraft measurement corresponding to 2nd IOP Analysis
Topic 2 (Regional Scale Study)	Analysis	Analysis	Analysis of IOP year	2nd IOP *radiosonde network *surface meas. network	Analysis of IOP year
Topic 3 (Variation Study)		Related observation for evaluation Analysis	Sensitivity study with models Analysis	Analysis	
Topic 4 (Model)	Model pre-run, input to 1st IOP	Improvement	Model-run, input to 2nd IOP	Improvement	
Topic 5 (Data)	Documentation of available data set catalogue Negociation process	Negociation process Collection and digitizing of data sets	Selection for GAIN data sets	Completion	
Topic 6 (Long-term Measurement Network)	Finalize strategy Develop automatic instr.	Continue IOP site station	~1999 Set additional station		
Local scale obs.(Tundra)		**Manned obs.** **May-June, August** **Sept.**	**Manned obs.** **January, May-June, August**	To be determined	
Local scale obs.(Taiga)		**Manned obs.** **January** **May** **July-August** **October**	**Manned obs.** **January** **April-June**	To be determined	



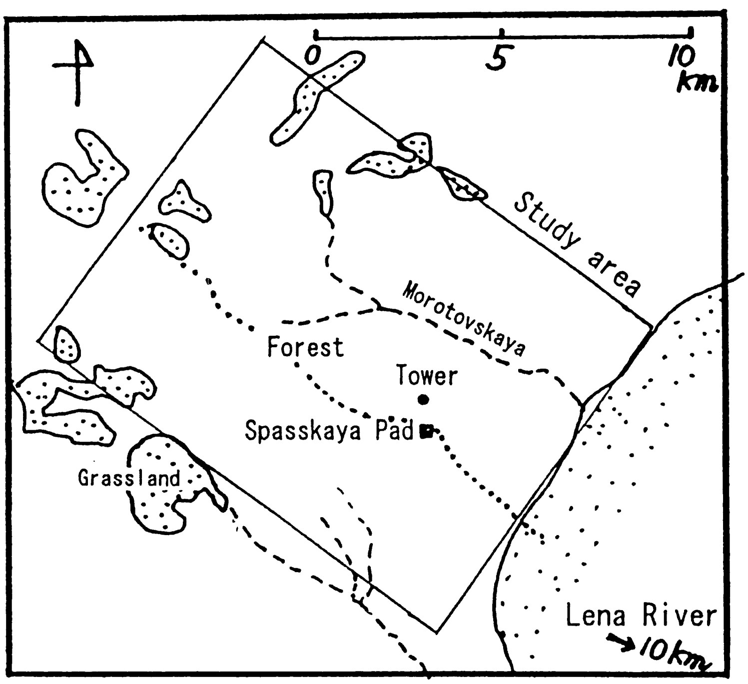


Fig. 3.5-3 The schematic map of the local study area at tundra near Tiksi (above), and taiga 20km north of Yakutsk (below).

· Measurement at the ground surface layer such as water contents, frost table, soil temperature and heat flux,
· Others components including snow depth, ground surface temperature and atmospheric pressure.

In August, 1996, a preliminary measurement system was build at the observation site, and a full-set observation system was installed in August 1997. Other temporary sites will be established on the ridge and slopes where surface conditions are different.

The intensive observations during the first IOP (manned for 3 weeks in 4 seasons, local scale) are as follows:

· All seasons: General meteorology, heat and water fluxes and soil samplings.
· Winter: Evaporation measurements and pit observations.
· Pre-snowmelt, snowmelt and post snowmelt period:

Snowmelt heat balance observations, plot observations, snow surveys and hydrological observations:

· Summer: Active layer depth, evaporation pans, transect observations.
· Autumn: Water content of the active layer and transect observations.

b) Catchment scale

Watersheds are located at about 7 km south west of Tiksi, the area being about 10 km^2 and 100 km^2 scale (Suonannaf River basin, Fig.3-5-3). 1997 will focused on the former scale and in 1998, latter scale will be treated also. Catchment scale observations are as follows which will be made during the period of manned observation.

· Non-frozen period: hydrological observations.
· Winter: snow survey (a snow course will be established in the catchment).
· Snowmelt period: snow survey
· Transect observations within the watershed
· Autumn: Transect observations

Lakes are an essential land surface component in the tundra water circulation. Lake water budgets will be obtained from the measurement of surface temperature, water level, runoff and net radiation.

(3) Observation plan for the taiga site in central Yakutia

The main objectives of the study in 1996-98 are:

· Determination of the characteristics of the one-dimensional water and heat fluxes and their modelling for typical land surfaces in typical seasons.
· Determination of the seasonal variation of water and heat fluxes.
· Modelling of the water and heat fluxes and estimation at the local scale (100 km^2)
· The water budget for a middle scale drainage basin (3000 km^2) in the central Lena River basin.
· The determination of the characteristics of the water cycle from stable isotope of water.

a) Tower scale

The study scales here are divided into two scales; One is the tower scale (one-dimensional) representing 0.1 to a few 10 kms and the other is the catchment scale representing a few 10 to 100 km scale. The measurement systems at these areas are shown in Figs. 3.5-4 and 3.5-5. As the tower scale site, one forest site and one grassland site will be established.

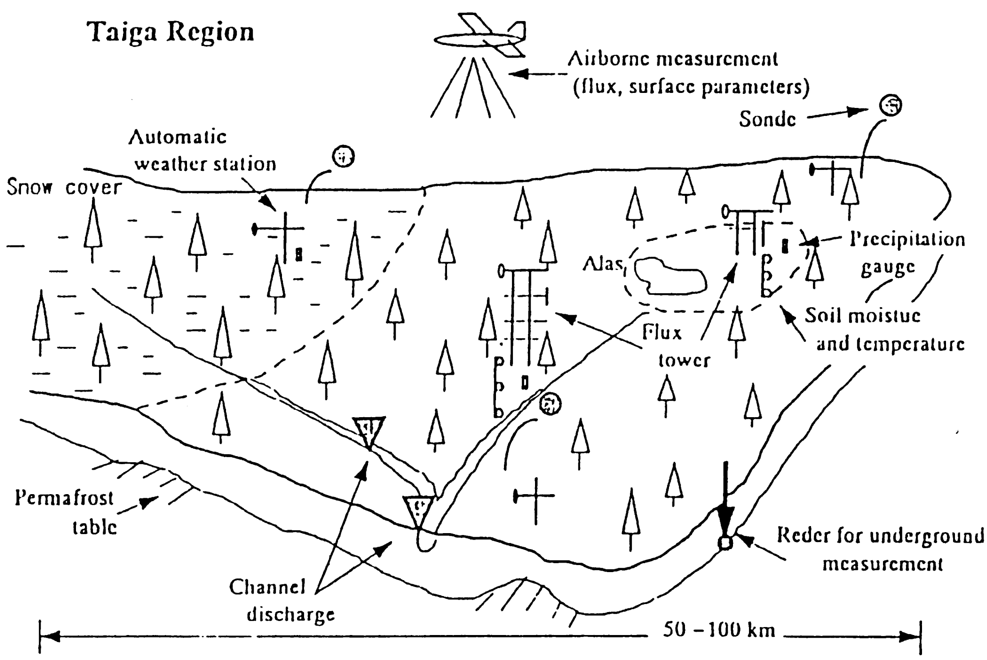


Fig.3.5-4 Observational schemes of catchment scale study.

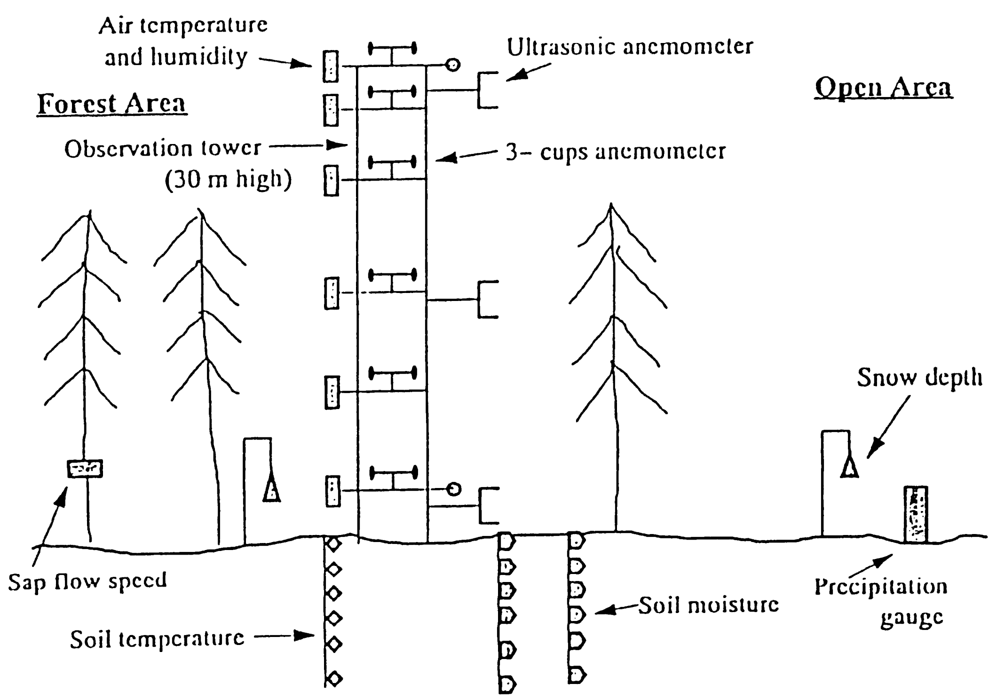


Fig.3.5-5 Tower measurement

Tower flux observations are as follows. a 30 m tower was build in the larch forest in September, 1996, 20 km north of Yakutsk City shown in Fig. 3.5-3. Preliminary instruments were installed at that time. Full set of instruments were set in August, 1997. From the tower, one-dimensional heat fluxes and water cycles in the typical vegetation including soil layers for whole year will be measured. Wind, air temperature and humidity will be measured at three heights above the canopy, and other three below the canopy. The basic meteorological and hydrological elements will be measured during the whole year.

Measurements of the ground surface layer soil moisture, soil temperature and heat flux through soil layers will be made at the tower site. In addition, precipitation at the open site, through fall in the forest and their spatial distribution are the basic variables to be observed for a year. Sensible and latent heat transfers at the top of the tower and forest floor will be directly measured during the (IOP). The IOPs will be planned in specific seasons; the thawing season, the mid-summer, refreezing season and mid-winter. Research on plant physiological field investigations related to the water potential of trees and stomatal closure will be carried out.

A site in grassland will be build 10 km from the forest site. A 10 m mast will be build to obtain similar meteorological and hydrological components as at the forest site.

b) Catchment scale

The target here is to clarify the water and energy cycles at scale of approximately 10 km x 20 km. Ground-based measurements and airborne measurements constitute this research. Content of catchment scale observation is as follows: Data sets of discharge, the spatial distribution of precipitation, snow depth, soil moisture and thaw depth will be derived. The discharge data will be provided from hydrological stations. Networks or transects of precipitation and soil moisture are required. These will be made manually every week or ten days.

The spatial heat flux will be evaluated from mooring balloon and radio-sonde measurements in each season. Aircraft measurement will be made to obtain the following terms during the 2nd IOP.

· Diurnal cycle of the distribution of heat fluxes and vapor fluxes for several days during several periods from spring to autumn.
· Multi-spectral measurements (including surface temperature) in relation to the above measurement.

c) Other studies

First, stable isotopes of water will be analyzed to investigate the following hydrological characteristics:

· Isotope characteristics of precipitation, water in trees, and soil water in relation to evaporation in the forested area.
· Isotope characteristics of water circulation in the rivers, lakes and the ground.

Landscape mapping will be made in the 10 x 20 km area, and observation and measurements of varying components such as ground moisture, frost table, vegetation condition will be made during the IOP.

From the measurements at the tower and mast at the forest and grassland sites, one-dimensional water and heat exchange model will be improved to simulate the seasonal cycle. Landscape mapping of the study area will be undertaken to obtain the basical data for the catchment scale modelling.

(4) Preliminary studies in the taiga region in the southern mountains

The scientific objectives are basically same as those in the central Yakutia, but the catchment study should be given more weight in this area from following reasons;

- The topography is so complex that it is difficult to obtain representative basic fluxes from one-dimesional measurements.
- The ease of the determination of the drainage basin because of the steep slopes and deep valleys.

The common factor and diversity of the heat and water mass exchanges in the east Siberia will be made clear by a comparative study in the three typical regions. The transect flux measurements at the forest and mountain taiga sites by the airborne method will be made. This method provides the extended turbulent transfer distribution.

To find the best study site is rather difficult in this area, due to the decrease of the meteorological and hydrological measurements by the operational agencies, and the closing of field stations. Preliminary study will be made at an experimental watershed in the Tynda district in 1998, based on the previous work made by Russian Institute in the 1970s and 80s.

(5) Development of a long-term land surface monitoring system

The long-term study of the surface water and energy exchange will be commenced at the above local study area in the flat-taiga and tundra, and will continue till the end of the study period. The main tower and mast sites will constitute a part of this long term measurement. The Japanese group has been establishing preliminary systems in the tundra and taiga area., and will establish an additional new system in 1997.

Automatic measurement systems operating under remote, cold and high latitude conditions still have large problems, such as mal-function of electronic equipment under cold environments, stable electricity supply, the occurrence of frost and strong winds which influence the functioning of the instruments. These need to be overcome by using suitable equipment and also development of new systems which stably work under these conditions. Operational procedures such as check systems and real time data transfer are also needed.

These effort will be made continuously in cooperation with AAN Group, personnel working in polar regions and high-technology company which is interested in these kind of measurement systems.

(6) Large scale study of the energy and water cycles based on satellite data

The science program on the use of satellites to determine energy and water flow has been started in Japan. Studies under the following topics will contribute to GAME-Siberia.

- Interaction between the atmosphere and snow cover and soil moisture in Northern Eurasia.
- Regional comparison of satellite derived continental snow water equivalent (SWE).
- Estimation of soil moisture in the active layer of tundra from SAR data.

SAR data will be used to obtain soil moisture for the local scale hydrological modelling activity.

A few sites of the above local scale study area will provide a measurement network for the satellite validation, and several other sites will be used to compensate for their biased distribution. The sites will be selected according to the following criteria: To cover the wide range of ground moisture, snow cover and vegetation amount across this area. The last component will be rather difficult since there are variety of species and density in this region. Aircraft measurements (microwave and multi-spectral) will be made in the 2nd IOP in order to obtain detailed information within the single satellite pixel to relate the parameters to continuous point measurements.

(7) Data collection and archive

Analysis of existing data will be important for the design of the experiment and to a degree understanding of the phenomena. The diversity of the objectives of the present project covers wide spatial and temporal scales, and many forms of water such as rivers, ground water, and atmospheric moisture. Many kinds of meteorological and hydrological data are needed.

a) Operational data

Many valuable data which can be the basis for such studies are collected by Russian agencies. For example, soil moisture has been collected at the agro-meteorological agency but not yet been compiled for wide usage. Runoff data have a good compilation up to 1988, but is hard to access afterwards. Snow and other cryospheric data are accumulated in institutes, but are not yet easy to access. There are radiosonde data which are collected, but not transmitted though the GTS. In order to facilitate access to the basic data related to water and energy cycle, GAME needs to promote cooperation between Russian agencies, institutes and scientists and foreign scientists to establish usable data sets.

The goal of this task is to archive various meteorological and hydrological data sets which are useful, and to distribute these data sets to scientists interested in GAME-related studies. Moreover, this task is a prospective contribution to GAIN (GAME Archive and Information Network) activities. In this respect, the Siberian Group is planning to offer archived data sets as many as possible, which are suitable for world-wide distribution, to GAIN.

The priorities for data archiving has been determined cooperatively between Japanese and Russian Institutes are as follows. (M/H stand for meteorological/hydrological)

(a) Daily M/H data set for 1986-1989 period.
(b) Monthly M/H for 1950 to present.
(c) Other miscellaneous data.
(d) Daily M/H data for 1996-2000 GAME period.
(e) Daily M/H 1990-1995 period.

An archive of these data will be made in cooperation with International Data Centers such as the GRDC (Global Runoff Data Center), WDC for Snow and Ice (Boulder, USA)

In addition to the surface data, aerological data set will be archived completely, for the non-reported stations, for the Siberian region during the period of GAME IOP in 1998 focussed on the summer monsoon.

b) Evaluation of data-sets

The understanding of the natural system needs to be based on the true physical quantities of elements constituting the water/energy cycle. Water flux due to precipitation, which is principally obtained from precipitation gauge, is one major element of water cycle, but not yet accurate as cited in the WMO Reports, especially for cold regions. The reason is the errors related to the measurement method of the gauge. Study will be made during 1997-98 to determine the optimum calibration schemes for transforming the values obtained from precipitation gauges to true water flux.

3.5.4 Cooperation with other international projects

Siberia is a region where other international projects have already undertaken certain research work and additional planning is also being made.

The WCRP-ACSYS is a project which has strong interest in the runoff characteristics in the large rivers in Siberia which supply fresh water to the Arctic Sea. The GAME study will contribute to the understanding of the characteristics of the seasonal variation of runoff and estimation of the runoff from the moderate to small size rivers where runoff are not measured.

The IGBP-NES (Northern Eurasian Study) is planning to study the carbon cycle, and related land water and biological characteristics in the whole Siberian region. Although the measurement network will be planned according to individual objectives, cooperation such as mutual use of towers, logistics and aircraft measurements will be discussed in order to increase the efficiency of both observation network.

3.5.5 Promoting organization and list of contributing institutes

The regional project in Siberia is now being promoted under cooperation between Japan and Russia. Japan's main body for this promotion is the sub-committee of the Japan National Committee for GAME (Chairman of sub-committee: Y. Fukushima, Nagoya University) formed by scientists from various universities. Russia has formed a National Committee within Russian Academy of Sciences (Chairman: V. Kotlyakov, Institute of Geography, RAS), functioning since 1995. These two committee will be the main bodies for promoting and coordinating the project.

The following is the list of the institutions which are already contributing or planning to contribute to the study in the Siberia region. (City name cited)

<Japan>
1) Institute for Hydrospheric-Atmospheric Sciences, Nagoya University (Nagoya)
2) Institute of Geoscience, University of Tsukuba (Tsukuba)
3) School of Environmental Sciences, The University of Shiga Prefecture (Hikone)
4) Faculty of Agriculture, Iwate University (Morioka)
5) Institute of Low Temperature Science, Hokkaido University (Sapporo)
6) Faculty of Agriculture, Tokyo University of Agriculture and Technology (Fuchu)
7) Faculty of Science, Tohoku University (Sendai)
8) Center for Climate System Research, University of Tokyo (Tokyo)
9) Faculty of Science, Tokyo Metropolitan University (Hachiouji)
10) Shinjo Branch of Snow and Ice Studies, National Research Institute for Earth Science and Disaster Prevention, Science and Technology Agency (Shinjo)
11) Faculty of Science, University of Tokyo (Tokyo)
12) Faculty of Agriculture, Okayama University (Okayama)
13) Center for Ecological Studies, Kyoto University (Ohtsu)
14) Frontier Research System for Global Change (Tokyo)

<Russia>
1) Institute of Geography, RAS (Moscow)
2) State Hydrological Institute (St. Petersburg)
3) All Russia Research Institute of Hydrometeorological Information - World Data Center (Obninsk)
4) Central Aerological Observatory (Moscow)
5) Permafrost Institute, RAS, Siberian Branch (Yakutsk)
6) Institute of Physical-Technical Problems of the North, RAS, Siberian Branch (Yakutsk)
7) Institute of Biology, RAS, Siberian Branch (Yakutsk)
8) Hydrometeorological Survey of Yakutia (Yakutsk)
9) Institute of Cosmophysic Research and Aeronomy, RAS, Siberian Branch (Yakutsk)
10) Faculty of Sciences, Moscow University (Moscow)
11) Institute of Geography, RAS, Siberian Branch (Irukutsk)
12) Institute of Atmospheric Physics, RAS (Moscow)
13) Institute of Water Problems, RAS (Moscow)
14) Institute of Water and Ecological Problems, RAS (Khabarovsk)

(RAS: Russian Academy of Science)

<United States>
1) Water Research Center, University of Alaska (Fairbanks)

Table3.5-2 Time schedule of data aquisition for taiga (left) and tundra (right). All of the meteorological/hydrological elements to be measured and other products are shown.