WCRP REPORT
World Climate Research Programme

1st Asia Climate and Cryosphere (CliC) Symposium: “The State and Fate of Asian Cryosphere”

Yokohama Institute for Earth Science (JAMSTEC)

Yokohama, Japan
April 20 to 22, 2006

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Contact information;
CliC International Project Office
Norwegian Polar Institute
The Polar Environmental Centre
N-9296 Tromsø, Norway
http://clic.npolar.no
clic@npolar.no
Tel: +47 77 75 01 05
Fax: +47 77 75 05 01

WCRP report of the

1st Asia Climate and Cryosphere (CliC) Symposium:

"The state and fate of Asian Cryosphere"

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Symposium sponsors

Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
World Climate Research Program (WCRP)
China Meteorological Administration (CMA)
Chinese Academy of Sciences (CAS)
National Science Foundation of China (NSFC)
Japan Aerospace Exploration Agency (JAXA)
Research Institute for Humanity and Nature (RIHN)

Organized by

WCRP/CliC SSG
China CliC Committee
Japan CliC Committee

Symposium Website: http://www.jamstec.go.jp/iorgc/sympo/asiaclic2006/

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Symposium Statement

From 20-22 April 2006, at Yokohama Institute of Earth Science, JAMSTEC in Yokohama Japan, 107 people 11 from countries met to present scientific results and CliC related activities, and to discuss the state and fate of Asian cryosphere and identify the necessities for further development of CliC in Asia. Status and activities of CliC, IPY, GEOSS, IGOS and related WCRP program, national CliC programs and related activities in Asia were reported. About 100 outstanding scientific results were presented (40 oral and 42 poster presentations), covering a range of cryosphere topics including glaciers, snow, hydrology and water resources, permafrost, atmosphere-cryosphere interactions, data management, and modeling.

The Symposium identified that the amount of existing data on meteorological, cryospheric, and hydrological variables related to the Asian cryosphere is immense in this region. However, the collaboration among researchers and groups is not sufficient to make optimal use of these data. Required future actions include high-priority involvement in data management and archiving efforts by the Asia-CliC community, the establishment of a better network for present and future observations, obtaining higher quality data, and application of various models to overcome the spatial/temporal constraints. The Symposium also revealed unique characteristics of the cryosphere in Asia. A high degree of diversity among various cryospheric components was noted. At the same time, it was recognized that climatic forcing influencing the Asian cryosphere varies considerably within the region, such as monsoon in low latitude and N/AO in high latitude. This diversity makes it extremely difficult to interpret the regional cryospheric data, especially when examined in the context of global warming.

The Symposium was highly successful in providing an opportunity for the participants to meet and discuss the wide range of scientific and related issues, leading to fruitful future collaborations. The Asian countries need to contribute to international activities through Newsletter, Specialist registration, and Meetings in the future. An Asia CliC Committee may be established to promote future Asia CliC activities, and JAMSTEC may take the role of the support of the activity and information exchange for the immediate future. The Asian participants will be considered as national correspondents. The implementation structure will be discussed further and finalized at the CliC Scientific Steering Group (SSG) meeting in December 2006 (Boulder, USA). Several suggestions to arrange workshops on subjects such as “satellite and snow/hydrology” and “atmosphere-cryosphere interaction” were made, depending on necessity and availability. The result of the 1st Asia CliC Symposium will serve as a strong momentum to the future activities, which leads to the 2nd Asia CliC Symposium that is scheduled to be held in China in 2007.

1 Outline and Objectives

The background for the *1st Asia-CliC Symposium – the state and fate of Asian Cryosphere* was as follows. The cryosphere is changing in Asia, as well as globally, due mainly to global warming and related climate variation. The long-term impact of these changes on the environment is still uncertain, and there is an urgent need to clarify the present condition and evaluate the possible changes.

The Symposium was organized to focus on the Asian Region component of the WCRP CliC (Climate and Cryosphere) Project[1]. The objectives of the Asia-CliC Symposium were to exchange scientific results and information, to discuss the main issues of CliC in this region, to develop plans for implementation, and to inform Asian countries about CliC activities. The Organizers expected the participation of scientists/engineers, students and also funding bodies from various Asian countries and international community.

The Symposium focused on the eastern part of the Eurasian continent which is considered as Asian Region and surrounding regions. The main topics of interest were:

(1) Glacier distribution/changes
(2) Frozen ground/Permafrost condition and changes
(3) Snow cover, cold region hydrology and water resources
(4) Land surface and atmosphere processes in cold region and mountains
(5) Large-scale cryosphere-atmosphere interactions
(6) Cryospheric database
(7) Satellite and ground base observations of cryosphere
(8) Modeling of cryosphere
(9) Strategy for future cryospheric research

In addition to general presentation (oral and posters) on the aforementioned topics, one day was reserved for split-sessions talks on specified topics needing more in-depth discussion and/or immediate action by the community. The working language was English.

The Symposium was followed by a semi-opened *Integrated Global Observing Strategy Cryosphere (IGOS-Cryo) Theme Meeting* (April 24-25), which discussed the satellite and in-situ observations of the cryosphere, including capabilities, requirements, and applications.

[1] , CliC had its first Science Conference in April, 2005 in Beijing, China.

2 Organization and Support

The Symposium was organized by WCRP-CliC Science Steering Group, Japan CliC Committee, and China CliC Committee. The Organizing Committee members were: Barry Goodison (CliC SSG, Chairman), Dahe Qin (China CliC Committee, Chair), Tetsuo Ohata (Japan CliC Committee, Chair), Vladimir Ryabinin (WCRP, Joint Planning Staff), and Victoria Lytle (CliC International Project Office, Director). The Local Organizing Committee (IORGC and FRCGC, JAMSTEC) included Tetsuo Ohata (IORGC), Hironori Yabuki (IORGC), Konosuke Sugiura (IORGC), Setsuko Ichikawa (IORGC), and Miyoko Oki (FRCGC).

The event was sponsored by various Institutes, generally in the form of travel support. These include:

Japan Agency for Marine-Earth Science and Technology (JAMSTEC) – host and main sponsor,
World Climate Research Program (WCRP),
China Meteorological Administration (CMA)
Chinese Academy of Sciences (CAS)
National Science Foundation of China (NSFC)
Japan Aerospace Exploration Agency (JAXA), and the
Research Institute for Humanity and Nature (RIHN)

3 Participants and presentation

The meeting was first announced in December 2005, through, among others, the CryoList, the Symposium- and main CliC web-sites. Finally, 107 actual people representing 11 countries participated. Of these, only six were women (Refer to participants list, Appendix 2). There were 49 oral- and 42 poster- presentations.

4 Symposium Sessions

4.1 Opening and program/project session

Following opening remarks by Taro Matsuno, former director of Frontier Research Center for Global Change, and talks by the organizers, the program began with an introduction to the CliC project by Barry Goodison, Chairman of the CliC SSG (see agenda, Appendix 1).

4.2 Scientific and technical presentations

General scientific presentations were grouped into the eight following topics. Oral and poster presentations were held simultaneously.

(1) Glacier distribution/changes mainly chaired by T. Yao and K. Fujita, 9 oral- and 10 poster presentations

(2) Frozen ground/permafrost condition and changes chaired by T. Zhang, 4 oral- and 8 poster- presentations

(3) Snow cover, cold region hydrology and water resources mainly chaired by V. Vuglinsky and D. Yang, 10 oral- and 4 poster- presentations

(4) Land surface and atmosphere processes in cold region and mountains chaired by A.G. Georgiadi, 2 oral- and 5 poster- presentations

(5) Large-scale cryosphere-atmosphere interactions chaired by J. Ukita, 3 oral- and 5 poster presentations

(6) Cryospheric database chaired by L. Bian, 2 oral presentations

(7) Satellite and ground base observations of cryosphere chaired by L. Bian, 1 oral- and 4 poster- presentation

(8) Modeling of cryosphere chaired by L. Bian, 2 oral- and 6 poster- presentations

4.3 National/international activity session

Early in the planning stages of this symposium, prospected participants from several Asian countries suggested to have a session on national/international research activities in the region. The session was made on the second day (April 21), chaired by T. Ohata and research activities in the Asia Region by many countries were presented. Some national presentations made were summarized and attached as Appendix 3, as National Reports (Russia, Mongolia, Pakistan, and Nepal Himala

4.4 Split group sessions

In this - perhaps the most important - session, the groups were asked to discuss issues related cryospheric research in Asia. Topics included:

(1) Data- sharing and archive
(2) Observation needs
(3) Gaps in knowledge
(4) What activities needed to contribute to "state"?
(5) Common programs and projects
(6) Modeling needs
(7) Future workshops
(8) Other people and agency
(9) CEOP super sites
(10) Data management

Discussions took place in the following six groups:

(1) Glacier (Chair: T. Yao, Reporter: K. Fujita)

(2) Permafrost and frozen ground (Chair: T. Zhang, Reporter: M. Ishikawa)
(3) Snow/ hydrology (Chair: V. Vuglinsky, Reporters: D. Yang and K. Sugiura)
(4) Cryosphere-atmosphere interaction (Chair: Bian. L, Reporters: R.P. Singh and K. Saito)
(5) In situ/ satellite observations (Chair: H. Enomoto, Reporters: B. Raup and C. Xiao)
(6) Model (Chair: T. Yamazaki, Reporter: T. Graf)

4.5 Plenary sessions

The split group session reports (see section 5) were presented at the plenary sessions. Afterwards, the Symposium had a general discussion time for drafting the Symposium statement in the afternoon of third day April 22, and terminated the Symposium at 16:30. The Symposium statement was slightly changed afterwards by adding scientific discussion parts to it, but not changing the basic agreement made during the plenary session.

5 Report of the Split Group Discussion

5.1 Glacier

Asian CliC issues addressed were: 1) Distribution of glaciers, improved understanding, but still not sufficient when climate warming is considered, 2) Little observational data on volume change and continuous mass balance, and 3) Little knowledge on modeling glacier responses to changing climate.

One approach is observation such as volume change and mass balance, but area and terminus changes are not enough. These are possible by satellites although ground truth is necessary. The other is modeling such as mass-balance and flow model, and coupling with GCM product, based on precise inventory by GLIMS and SRTM products.

Data-sharing and archive

1. WGMS: “fluctuations of glaciers”. Limited targets and reducing monitored glaciers
2. GLIMS: present state and future monitoring. Who completes Himalayan database? Volume evaluation?
3. NSIDC/NOAA: ice core and meteorological data
4. NASA/NEESPI: database for meteorology, hydrology and biology
5. TORP (Tibetan observation and monitoring research platform): Institute of Tibetan Plateau Research glacier lake

Observation needs

1. Monitoring mass balance and volume changes in glaciers
2. Monitoring glaciers by Chinese National Program and the biggest problem for the other country

3. Ice cores by Chinese National Program and CADIP (Central Asia Deep Ice Core Project)
4. Satellite based analyses by GLIMS members and others

Gaps in Knowledge

1. Ice volume and its change
2. Impact of atmospheric aerosol and dust on mass balance and change of glaciers
3. Regional/global gaps in observation and modeling
4. Determination of sources of precipitation and influences on snow accumulation processes

Contribution to "state" Concerning International Polar Year (IPY)

1. High Asia as a "Third pole"
2. Making snapshot of glaciers for completion GLIMS inventory
3. Influence of high Asia on atmospheric processes: interaction between mountain glaciers and atmosphere

Common Programs and Projects

Insufficient financing for research is a common problem in all Asian countries represented. Russia, Uzbekistan, Kazakhstan, Tajikistan, Kyrgyzstan, Afghanistan, Nepal, Bhutan, India, Pakistan, Mongolia, and China: ice cores, monitoring glaciers and glacier inventory, Japan: a project of Ili River Basin (RIHN, contribution to CADIP) and USA: NASA/GLIMS/NEESPI/LCUC (satellite) and NSF/NOAA/CADIP (ice cores).

Modeling

1. Need precise meteorological data
2. Downscaling grid data or GCM output to regional one
3. Fluctuation model for worldwide estimation

Future Workshops

1. GLIMS WS at Cambridge, 17-18 Aug. 2006
2. IGS-meeting at Cambridge, 21-25 Aug. 2006

Other People and Agencies

Where to apply for financial support? The World Bank, Asian Research Development Bank, Asian Pacific Network, UNEP and HKH-Friends, others??

CEOP 35 Super Sites

Glacier monitoring is a more urgent issue for glacier group.

5.2 Permafrost and Frozen Ground

Gaps in Knowledge

There exist large environmental gradients in Asia involving Tundra, Taiga, Steppe, and Mountain, where various types of permafrost, active layer, and seasonally frozen ground occur. Several following questions were raised. Do we really understand the distribution, energy and water condition of them? Are currently available observational networks sufficient? Although isotope has been known to be useful tool for analyzing hydrological cycle, do we have knowledge on isotopic composition involved in frozen grounds?

Observation Needs

Asia, including Eastern Siberia, is the largest permafrost region on earth. However permafrost observatories are sparse and poorly equipped. Moisture conditions, including water- and ice-contents, are crucially important but are less measured. The observational components are:

1. Active layer thickness
2. Soil temperature (ice & unfrozen water contents)
3. Deep permafrost temperatures
4. Isotopic composition of ground ice
5. (Sub-)surface energy and water balance fluxes
6. Snow cover thickness and duration that significantly influence frozen ground temperatures
7. Vegetation cover that also influence frozen ground temperatures
8. Carbon contents of soil, determining thermal characteristics of frozen ground
9. Periglacial features as indirect phenomenon of permafrost degradation, involving Rock glacier, pingo, thaw lakes, thermokarst, slope stability and rock fall phenomena

Special attention should be paid to seasonally frozen ground issues, because it is the largest cryospheric component of the earth. Some parameters characterizing soil and seasonal freezing and thawing should be also measured intensively. This includes thickness, timing and duration, frequency of frozen soil, soil temperature, moisture, and area extent.

What Activities are needed to contribute to "state"

1. Permafrost mapping in Asia, alpine permafrost, document changes
2. Thermal State of Permafrost (TSP) of Russia, Mongolia, Tibet and others – Snapshot

Common Programs and Projects

1. Mapping high altitude permafrost in Asia – plateau and mountain permafrost
2. National and international projects of TSP (Russia, Mongolia, Japan)
3. Developing model coupled with atmosphere through surface energy and water balance
4. Data exchange and archiving program

Modeling Needs

1. Develop a model coupled with atmosphere through surface energy and water balance. This needs closer corporations with land-surface hydro-meteorologists.
2. Develop distributive model suitable for permafrost studies in Asian high altitudes.
3. Working with GCM community to better represent soil freezing and thawing processes in land surface schemes.

CEOP Super Sites

Observations

Implement long-term permafrost observation to pre-existing super stations in Russia, Japan, and Mongolia – including the Altay Mountains, Tibetan Plateau and surrounding mountains.

Data issues

Data management and exchange, contribute to GEOSS.

Future Workshops

1. Mountain permafrost mapping workshop in Lanzhou, August, 2006
2. 1st Asian Conference on Permafrost, Lanzhou, August, 2006
3. 9th International Conference on Permafrost, Fairbanks, 2008

5.3 Snow/ Hydrology

Specific features of Asian cryosphere are

1) Permafrost,

2) Snow cover,

3) Mountain, and

4) Mountain river run-off formation

Main goal is to assess snow cover and hydrology changes under global climate changes in cryospheric zone of Asia.

Possible research projects include 1) Assess snow-cover characteristics for hydrological purposes, 2) Improve solid precipitation measurements methods in Asian Arctic, 3) Assess river and lake ice changing, 4) Hydrology of large river basins in permafrost region (mountain and plain parts), and 5) Make use of remote sensing data to assess snow cover characteristics.

Problem areas: 1) Snow cover and hydrological data are sparse in mountain, Arctic zones and developing countries in the Asian region, 2) Data availability and unrestricted data exchange, 3) Insufficient use of remote sensing data to assess snow cover characteristics, 4) Shortage of instruments and equipment to measure snow-cover characteristics, and 5) Insufficient gridded data and products (downscaling) for hydrological simulation model development and validation.

Recommended suggestions to solve the problems are 1) To prepare a scientific program for Asia-CliC regional project as a part of CliC, and 2) To organize working group on snow cover/hydrology.

5.4 Cryospher-Atmosphere Interaction

The Symposium identified that the Cryosphere plays a significant role in climate interactions between the atmosphere, snow cover, ice, frozen ground, water vapor and energy transmission during summer and winter monsoon seasons. Recently, numerous studies show a strong interaction between the atmosphere and climate on the cryosphere; and therefore, it is important to **understand the coupling between cryosphere-atmosphere- and climate.** Current understanding of this interaction is limited. To fill in the knowledge gaps, we must study the effect of the atmospheric parameters (dust, radiation, meteorological) to quantify the effect on cryosphere.

It was agreed upon that the existing gaps between Hydrologists, Atmospheric and Climate scientists and Cryospheric scientists must be overcome by detailed and collaborative study on the changes in cryosphere - including surface/subsurface runoff. Network of observatories must be enhanced.

Through the elaborative efforts of data mining, yet-unavailable data related to Cryosphere, Atmosphere and Meteorological conditions may be discovered and made available to the scientists from various Asian countries. Asia-CliC may play an important role in organizing efforts to mine and compile these data by contacting individual scientists in these countries who are willing to share their data.

In Asian countries, various representative locations with different climatic conditions may be taken up where the data dealing with atmosphere, weather and data related to cryosphere may be collected to quantify the effect of coupling between atmosphere-climate-cryosphere. Various parameters such as dust, forest fires, temperature, radiation, precipitation, grain size, albedo, brightness temperature; etc., should be studied. The participants also identified the lack of observatories in the mountain regions, and stressed that observatories in such areas may be enhanced, which will help in understanding snow and glacier dynamics. Observatories for multi parameters may be planned at few critical locations such as: Japan, Western and Eastern Himalaya, China, Mongolia, few locations in Siberia.

Recent studies have revealed the impact of El-Nino/ENSO and monsoon on cryospheric parameters. Quantitative estimates of the impact could be made. The participants strongly encourage planning of a workshop focused on detailed discussion on coupling between cryosphere-atmosphere-climate in the Asian region.

5.5 In-situ / Satellite Observations

Satellite observation is an interdisciplinary contribution to the CliC projects.

In this group, we exchanged information on satellite data sets, and asked other splinter groups about their requests for satellite data.

Main cryospheric data from satellites have been snow-cover, glacier- and sea-ice data. But these data cover mainly areal- extent and periodic. Thickness and mass information are scarce. Other observations are movement, accumulation, freezing and melting. This information is partly available. The thickness data are targets for future acquisitions.

New Satellites

The Chinese satellite FY3 that carries 11 instruments, VNIR and more, will be launched in 2007-01. Possible use for snow cover-, albedo-, snow depth-, moisture-, and temperature- observations. FY1d, FY2c, FY2d are 10-channel instruments that can be used for snow cover observations. Data are freely downloadable from website.

Japanese satellite ADEOS2. Microwave snow-depth data is open to the public. As microwave snow survey has an accuracy problem, depending on the surface conditions, ground-based observations for validation remain important.

Satellite and other Data-desires and Difficulties

There are requests to obtain multiple sensor data in same season. Access to these type data will reduce classification errors. It will supply new components. Hybrid approaches to combine satellite data to other methodology is required.

Assimilation of satellite data into modeling should be encouraged. We need products that are merged from different sources.

We need more data on volume changes; this is weak compared to map-plane information. For this we need a precise DEM to determine the current state.

PRISM sensor data on ALOS satellite have recently become available. Such new satellite information, and guidance on how to use it, should be distributed within the Asian countries. We would like to ask JAXA to distribute widely on the new satellite data is classifications.

Field Observations

We need field coordination, GPS measurements, validation for satellite data use.
Snow-cover data is one of the more useful satellite data, but observations are difficult in rough terrain, mountainous areas.

Ground observations are rare in regions where access is difficult. To carry out effective field investigations, we need sufficient portable instruments for the necessary field observations.

CEOP super site data is now integrated and waiting to be used. However, the data is not used actively in the Asian community. We should utilize this data resource more. Use guidelines for accumulated CEOP data may be helpful.

Other Splinter Groups

Permafrost group: various satellite data are used for frozen ground, permafrost, but there is not enough data, especially for mountain regions, e.g. in central Asia. Need information from different countries on permafrost distribution.

Glacier group: talked about data derived from satellite imagery, but not specifically about satellite data or specific platforms.

Snow hydrology group: inter-comparison of products from different sources is important, but difficult.

5.6 Model

Target of Model

Modeling of cryosphere elements (e.g. glacier, snow cover, permafrost) should be discussed in each group. Climate simulation models (GCM, regional climate model) will be included in this split group discussion. Identified models capabilities and applications include disaster prevention, water resources management, and so forth.

Data- sharing, -archiving, and -management

Data are needed for input and validation of models. Many data are available in printed form, however, it is difficult to get and use them. It is necessary to archive data electronically.
A centralized inventory of data sources could be created by collecting information about available data through a survey, metadata should include information on how to access the data, data policy and contact person.

Observation Needs

The most important meteorological variables required for model forcing are precipitation, particularly snowfall (or phase of precipitation), and radiation. It is necessary to determine spatial variability because in-situ data are very local. Metadata are required in all cases and should include error, methodology, site characteristics (vegetation, topography, scale, hydraulic parameters).

For snow data, minimum requirements are snow depth and snow water equivalent. Snow stratigraphy is needed as well, although there are some problems (e.g. who-does-what, how to get the data?), and new observation methods are also required.

Ideally, observation should be standardized. Exchange of observation-technique knowledge is recommended. High-altitude sites are very important for model studies. In order to perform these requests, international cooperation is required.

On the other hand, output data from climate model are available for snow models. However, the quality of the output data is a problem, and error analyses are needed over the higher latitudes.

Knowledge Gaps

Because our group included mainly snow modelers, the discussion was limited to problems related to snow models. The followings issues/questions were raised.

1. How good are the satellite data sets? More validation?
2. Snow model
   - Intercepted snow in forest area (SnowMIP2)
   - Snow drift in non-forested areas
   - Snow Melt
3. Present climate models can simulate cryosphere reasonably?
   - Focus on the atmosphere, neglect state of the land surface? Is there any validation?
   - Down-scaling technique
   - Check model outputs to identify problems (snow cover, permafrost…)
   - How do climate model integrate permafrost?
   - Is GCM information of frozen soil used?

What activities are needed to contribute to 'state'

Suggested activities are to increase the use of models to evaluate the state of the cryosphere, to create model output data sets for cryosphere, and to validate the models.

Common Programs and Projects

Future water-resource predictions in Asia should be planned. For example, is snow cover increasing or decreasing? Where do the changes occur? These problems should be studied with GCM (e.g. CCSR, MRI), and be downscaled to regional scale. A difficult point is how the prediction in mountain areas is performed, and how to prove that the results are validated. How can we address the problems in this area? Down-Scaling studies are essential. Output from GCM is used as input for local scale model.

Demonstration project should be planned to identify the needs and capabilities of models. For example, evaluation of water resources is proposed in the upper Indus basin in Pakistan by using output from regional models. Water resources-, disaster-, and cryosphere- change are the targets for model studies. At any rate, more modelers – especially regional climate modelers – are needed.

Future Workshops

Workshops should be arranged to involve more modelers, and should stress the importance of models for CliC. It is necessary to make attending the meeting attractive for modelers by actively inviting them to participate. Session for modeling (Atmospheric and Hydrological Modeling in Cryosphere) should be enriched. Model contribution from China and Russia are welcomed, because there was only little contribution from these countries in this meeting.

Activities and Recommendation

1. Providing data inventory. It is valuable for model studies.
2. Demonstration projects for model as mentioned in "Common program and project"

6 Discussions – Plenary Session

Data Management

Oral and poster presentations showed meteorological, hydrological and cryospheric data, and that observation networks were scattered far and wide. An active collaborative study is expected by the Asian CliC community for the effective and good use of data.

Asia CliC Committee

In order to enhance CliC studies in the region, the establishment of an Asia CliC committee were identified and advised and international level activities through newsletter, specialist registration and meetings were desired. The function and structure of the Asia CliC committee will be discussed later. The participants expect that JAMSTEC continue to lead the activity and information exchange at least for the present.

Workshops

Some of the split groups required to have relevant workshops. Workshops on subjects such as "satellite and snow/hydrology" and "atmosphere-cryosphere interaction" we were suggested in the Symposium. These workshops will be held in future.

Next Asia CliC Symposium

China graciously offered to host the 2nd Asia CliC Symposium near Beijing in 2007. India also expressed an interest in becoming a future host.

Program/Agenda

April 20, 2006 (Thursday)

08:30 Entrance and Registration
09:30-10:00 Opening Speech
Welcome speech (Matsuno, T., Frontier Research Center for Global Change, Japan)
Talk by organizers
CliC-SSG (Goodison, B., Meteorological Service of Canada, Canada)
China CliC (Yao, T., Institute of Tibetan Plateau Research, China)
Japan CliC (Ohata, T., Institute of Observational Research for Global Change, Japan)

10:00-11:20 CliC and other programs
O-1: Climate and Cryosphere (CliC) Project (Goodison, B., Meteorological Service of Canada, Canada)
O-2: CliC and the International Polar Year (IPY) (Goodison, B., Meteorological Service of Canada, Canada)
O-3: GEWEX and MAHASRI (Matsumoto, J., University of Tokyo/ Institute of Observational Research for Global Change, Japan)
O-4: Asia CliC from WCRP/COPES perspective (Yasunari, T., Nagoya University/Frontier Research Center for Global Change, Japan)
O-5: Past related meeting and objective of the Symposium (Ohata, T., Institute of Observational Research for Global Change, Japan)

< *Symposium photograph and coffee break*>

11:40-12:50 Session 1 - Yao, T. -
Topic 1 (Glacier distribution/changes)
OT1-2: Mountain glaciation of Central Asia and its change for last half a century (Glazirin, G., Hydrometeorological Research Institute, Uzbekistan)
OT1-3: A revised glacier inventory for the Buordakh Massif, Cherskiy Range, NE Siberia, and evidence for recent glacier recession (Popovnin, V., Moscow state University, Russia)
OT1-4: Recent change of glaciers in Suntar-Khayata and Cherskiy ranges from second half of 20th century till present: new assessments by LANDSAT imagery (Ananicheva, M. D., Institute of Geography, Russia)
OT1-5: Preliminary results of study on flat-top glacier at Tsambagarav Mts. Mongolia (Davaa, G., Institute of Meteorology and Hydrology, Mongolia)

12:50-13:00 Poster introduction (Topic 1) - Sugiura, K. -

13:00-14:00 Poster session (Topics 1 to 3) and lunch

14:00- 16:00 Session 2 - Fujita, K. and Vuglinsky, V. -
Topic 1 (Glacier distribution/changes)
OT1-6: Contemporary and prognoses changes of glaciation in Balkhash lake basin Mts. and their probable impact on water resources (Severskiy, I., Institute of Geography, Kazakhstan)
OT1-7: Glacial retreat in 20th century in Tibetan Plateau and surrounding regions and its impact on water resources in Northwest China (Yao, T., Institute of Tibetan Plateau Research/ Cold and Arid Regions Environmental and Engineering Research Institute, China)
OT1-8: Glacial lake expansion and regional difference in the eastern Himalayas (Komori, J., Nihon University, Japan)
OT1-9: Effect of precipitation seasonality on glacier mass balance (Fujita, K., Nagoya University, Japan)
Topic 3 (Snow cover, cold region hydrology and water resources)
OT3-1: Variations in snow cover characteristics over the Russian territory in recent decades (Razuvaev, V., All-Russian Research Institute of Hydrometeorological Information, Russia)
OT3-2: Spatial-temporal variability of snow cover in China - Derived from remote sensing and conventional observation (Guo, Y., National Climate Center, China)
OT3-3: Changing cryosphere in China: a review of observations in the past decades (Xiao, C., Chinese Academy of Meteorological Science/Joint Key Laboratory of Cryosphere and Environment, China)

16:00-16:10 Poster introduction (Topics 2 and 3) - Sugiura, K. -

16:10-16:45 Poster session (Topics 1 to 3) and coffee

16:45-18:30 Session 3 - Yang, D. -
Topic 3 (Snow cover, cold region hydrology and water resources)
OT3-4: Snow cover and glacier change study in Nepalese Himalaya using remote sensing and geographic information system (Shrestha, A. B., Department of hydrology and meteorology, Nepal)
OT3-5: Characteristics and inter-annual variability of the snow covered in the Himalayan Region (Singh, R. P., Indian Institute of Technology, India)

OT3-6: Recent fluctuations of snow cover in the mountainous areas of Japan (Sato, A., National Research Institute for Earth Science and Disaster Prevention, Japan)

OT3-7: River runoff changes within Lena river basin (Eastern Siberia) under recent and future climate warming (Georgiadi, A. G., Institute of Geography, Russia)

OT3-8: Current and expected changes in the ice regimes in rivers within the Asian Russia (Vuglinsky, V., State Hydrological Institute, Russia)

OT3-9: Hydrologic regime and change in the large northern watersheds (Yang, D., University of Alaska, USA)

18:30-20:00 Icebreaker (Guest House) (Speech: Kinoshita, H., Operating Executive Director, JAMSTEC)

April 21, 2006 (Friday)

08:30 Entrance and Registration

09:00-10:55 Session 4 - Zhang, T. and Georgiadi, A. G. -

Topic 2 (Frozen ground/permafrost condition and changes)

OT2-1: Variability and trends of area extent of seasonally frozen ground in China (Zhang, T., National Snow and Ice Data Center, USA)

OT2-2: Permafrost changes and its impacts on water resources on the Tibetan Plateau (Zhao, L., Cold and Arid Regions Environmental and Engineering Research Institute, China)

OT2-3: Mountain permafrost in the South Chuyskiy Range, the Russia Altai Mountains (Fukui, K., National Institute of Polar Research, Japan)

OT2-4: Impacts of climate warming and human activities on permafrost in the Hovsgol Mountain Region, Mongolia (Sharkhuu, N., Institute of Geo-Ecology, Mongolia)

Topic 3 (Snow cover, cold region hydrology and water resources)

OT3-10: Winter streamflow, high-latitude permafrost and climate change in NE- and NW-China (Liu, J., Institute of Tibetan Plateau Research, China)

Topic 4 (Land surface and atmosphere processes in cold region and mountains)

OT4-1: Use of stable isotopes of water for investigation of water cycle in permafrost region with special reference to soil water as a branch point of partitioning of precipitation to evapotranspiration and runoff (Sugimoto, A., Hokkaido University, Japan)

OT4-2: Global warming and expected snowline shift along northern mountains of Pakistan (Rasul, G., Pakistan Meteorological Department, Pakistan)

<Coffee break>

11:10-12:40 Session 5 - Ukita, J. and Ohata, T. -

Topic 5 (Large-scale cryosphere-atmosphere interactions)

OT5-1: Effect of snow on the local circulation in the Tibetan Plateau by using the field observation and the regional climate model (Hirose, N., University of Tsukuba, Japan)

OT5-2: δ^{18}O records from Himalayan ice core and the intensity variations of Indian Summer Monsoon (Zhang, D., Chinese Academy of Meteorology Sciences/Key Laboratory of Cryosphere and Environment, China)

OT5-3: Chinese Antarctic atmospheric research progress (Bian, L., Chinese Academy of Meteorology Sciences, China)

Topic 9 (International projects)

OT9-1: CEOP and GEOSS (Koike, T., University of Tokyo, Japan)

OT9-2: The Integrated Global Observing Strategy Cryosphere Theme (Key, J., National Oceanic and Atmospheric Administration, USA)

12:40-12:55 Poster introduction (Topic 4 to 9) - Sugiura, K. -

12:55-13:45 Poster session (Topic 4 to 9) and lunch

13:45-15:30 Session 6 - Bian, L. -

Topic 6 (Cryospheric database)

OT6-1: The Siberian platform geocryological database (Zheleznyak, M., Melnikov Permafrost Institute, Russia)

OT6-2: GLIMS: status and Asian activity (Raup, B., National Snow and Ice Data Center, USA)

Topic 7 (Satellite and ground base observations of cryosphere)

OT7-1: Assimilating Passive Microwave Observation into a snow model to improve the snow depth estimation (Graf, T., University of Tokyo, Japan)

Topic 8 (Modeling of cryosphere)

OT8-1: Streamflow simulation of Gilgit river basin using remote sensing data (Ahmad, B., Water Resources Research Institute, Pakistan)

OT8-2: Evolution of Rhonegletscher in Switzerland over the past 125 years and in the future: application of an improved flowline model (Sugiyama, S., Hokkaido University, Japan)

Topic 1 (Glacier distribution/changes)

OT1-1: Climate and Central Asia glaciers, changes and consequences (Aizen, V., University of Idaho, USA)

15:30-16:15 Poster session (Topic 4 to 9) and coffee

16:15-18:00 Session 7 - Ohata, T. -

Topic 9 (National/ international activities/projects in Asian Region)

China (Chinese National Committee of WCRP/CliC)

Russia (Razuvaev, V., All-Russian Research Institute of Hydrometeorological Information, Russia, Kotlyakov, V., Institute of Geography, Russia, and Khromova, T., Institute of Geography, Russia)

Mongolia (Davaa, G., Institute of Meteorology and Hydrology, Mongolia, and Sharkhuu, N., Institute of Geo-Ecology, Mongolia)

Pakistan (Ahmad, B., Water Resources Research Institute, Pakistan, and Rasul, G., Pakistan Meteorological Department, Pakistan)

Uzbekistan (Glazirin, G., Hydrometeorological Research Institute, Uzbekistan)

India (Singh, R. P., Indian Institute of Technology, India)

Nepal (Shrestha, A. B., Department of hydrology and meteorology, Nepal)

Kazakhstan (Severskiy, I., Kazakh Institute of Geography, Kazakhstan)

Japan and CABIN (Ohata, T., Institute of Observational Research for Global Change, Japan)

18:30-18:30 Plenary session - Yang, D. -

Discussion about split group discussion, groups, objectives, questions, and targets

April 22, 2006 (Saturday)

08:30 Entrance

09:00-10:30 1st Split group discussion

1 Glacier (Leader: Yao, T., Reporter: Fujita, K.), Small Meeting Room

2 Permafrost and frozen ground (Leader: Zhang, T., Reporter: Ishikawa, M.), Information and Technology Building 403 and 404

3 Snow cover/hydrology (Leader: Vuglinsky, V.., Reporter1: Yang, D., Reporter2: Sugiura, K.), Miyoshi Memorial Auditorium

<Coffee break>

11:00-12:30 2nd Split group discussion

4 Cryosphere-atmosphere interaction/climate cryosphere relation (Leader: Lingen, B., Reporter1: Singh, R.P., Reporter2: Saito, K.), Small Meeting Room

5 In situ/satellite observations (Leader: Enomoto, H., Reporter1: Raup, B., Reporter2: Xiao, C.), Miyoshi Memorial Auditorium

6 Model (Leader: Yamazaki, T., Reporter: Graf, T.), Information and Technology Building 403 and 404

<Lunch break>

13:00-15:00 Plenary session - Ohata, T. -

Result of the split group discussions

Key issues in WCRP

Overall problem

<Coffee break>

15:30-16:00 Plenary session - Ohata, T. -

Symposium announcement, and future plans

Closing speech

Poster presentation on April 20 <09:00-18:00>

* The first author is mentioned.

Topic 1 (Glacier distribution/changes)

PT1-1: Glaciological observations in Suntar-Khayata Range, Eastern Siberia, in 2004-2005 (Takahashi, S., Kitami Institute of Technology, Japan)

PT1-2: Recent glacier variations in Mongolia (Kadota, T., Institute of Observational Research for Global Change, Japan)

PT1-3: Recent changes of the glacial meltwater in the Terskey-Alatoo Range, Kyrgyz Republic (Narama, C., Nagoya University, Japan)

PT1-4: Production of porous ice on glacier surface and its contribution to albedo and mass balance of July 1st glacier, China (Matsuda, Y., Nagoya University, Japan)

PT1-5: Comparison of glacier variations in Mt. Naimona'Nyi and Mt. Geladandong region on Tibet (Ye, Q., Institute of Tibetan Plateau Research/Institute of Remote Sensing Applications, China)

PT1-6: An image based inventory of glaciers resources of Pakistan (Rakhshan, R., Water Resources Research Institute, Pakistan)
PT1-7: Estimating melt pattern on debris-covered glaciers in the Himalayas using ASTER images (Suzuki, R., Nagoya University, Japan)
PT1-8: Expansion rates of eleven moraine-dammed glacial lakes in northwestern part of Bhutan, derived from satellite images (Naito, N., Hiroshima Institute of Technology, Japan)
PT1-9: Glacial lake expansion in Bhutan and adjacent areas (Iwata, S., Rikkyo University, Japan)
PT1-10: Responses of glaciers under various precipitation conditions (Yamaguchi, S., National Research Institute for Earth Science and Disaster Prevention, Japan)

Topic 2 (Frozen ground/permafrost condition and changes)
PT2-1: International Permafrost Association project on monitoring periglacial processes: strategy towards International Polar Year (Matsuoka, N., University of Tsukuba, Japan)
PT2-2: Long-term ground temperature changes following human disturbance, Central Yakutia (Varlamov, S., Melnikov Permafrost Institute, Russia)
PT2-3: Heat and water exchange between the active layer and atmosphere in Yakutia (Gavriliev, P., Melnikov Permafrost Institute, Russia)
PT2-4: Cryogenic processes and changes in ice-rich permafrost stability associated with climate warming and surface disturbance, Central Yakutia (Gavriliev, P., Melnikov Permafrost Institute, Russia)
PT2-5: Permafrost monitoring of agricultural lands in the taiga zone, Central Yakutia (Efremov, P. V., Melnikov Permafrost Institute, Russia)
PT2-6: About influence of soil moisture on the radial growth of the larch (Fedorov, P. P., Institute for Biological Problems of Cryolithozone, Russia)
PT2-7: Measuring land-surface energy interactions on permafrost and permafrost-free slopes at the southern boundary of Eurasian permafrost regions, Mongolia (Ishikawa, M., Institute of Observational Research for Global Change, Japan)
PT2-8: Permafrost sounding (2003-2005) in the source area of the Yellow River, Northeastern Tibet (Ikeda, A., University of Tsukuba, Japan)

Topic 3 (Snow cover, cold region hydrology and water resources)
PT3-1: The influence of the snow cover on temperature mode of soil grounds of the Siberian taiga (Desyatkin, R. V., Institute for Biological Problems of Cryolithozone, Russia)
PT3-2: The variation and distribution of snow cover in China (Liu, Y., National Satellite Meteorological Center, China)
PT3-4: Recent changing in snow cover in Mongolia (Zhang Y., Institute of Observational Research for Global Change, Japan)
PT3-5: Snowiness of winters in Kazakhstan at the end of XX century (Pimankina, N., Institute of Geography, Kazakhstan)

Poster presentation on April 21<09:00-18:00>
* The first author is mentioned.

Topic 4 (Land surface and atmosphere processes in cold region and mountains)
PT4-1: Estimation of changes to the ground thermal regime following fire, Central Yakutia (Skryabin, P. N., Melnikov Permafrost Institute, Russia)
PT4-2: Global warming, disturbances and salinization in Central Yakutia, eastern Siberia (Lopez, L., Hokkaido University, Japan)
PT4-3: Transport of organic carbon from the Mogot Experimental Watershed in the southern mountainous taiga of eastern Siberia (Suzuki, K., Institute of Observational Research for Global Change, Japan)
PT4-4: Chemical characteristics of snow and aerosol on Mt. Qomolangma (Everest) (Kang, S., Institute of Tibetan Plateau Research/Key Laboratory of Cryosphere and Environment, China)
PT4-6: Undercatch and overcatch of solid precipitation by gauges in high latitude regions with high winds (Sugiura, K., Institute of Observational Research for Global Change, Japan)

Topic 5 (Large-scale cryosphere-atmosphere interactions)
PT5-1: Changes in snow cover and snow water equivalent due to global warming simulated by a 20km-mesh global atmospheric model (Hosaka, M., Meteorological Research Institute, Japan)
PT5-2: Stable isotopic variations in West China: a moisture sources consideration (Tian, L., Institute of Tibetan Plateau Research, China/University of Colorado, USA)
PT5-3: Impacts of seasonal frozen soil on the Spring Dust Storms(SDS) over Northern China (Yu, Y., Key Laboratory of Arid Climatic Change and Reducing Disaster/Lanzhou University/Institute of Arid Meteorology, China)
PT5-4: Coherent structure of NH sea-ice variability and its climatic implications (Ukita, J., Chiba University, Japan)

PT5-5: The Antarctic Sea-ice Extent Oscillation Index (ASEOI) and the relationship between ASEOI and synoptic climate in summer of China (Ma, L., Chinese Academy of Meteorological Sciences, China)

Topic 7 (Satellite and ground base observations of cryosphere)

PT7-1: Development of a dry snow satellite algorithm based on a microwave radiative transfer theory (Tsutsui, H., University of Tokyo, Japan)

PT7-2: The characteristic analysis of soil moisture variations in Tibetan Plateau from AMSR-E microwave data (Li, Z., Institute of Remote Sensing Applications, China)

PT7-3: Satellite snow and ice information around Okhotsk (Enomoto, H., Kitami Institute of Technology, Japan)

PT7-4: Effects of snow grain size and snow impurities on albedo measured in Sapporo (Aoki, T., Meteorological Research Institute, Japan)

Topic 8 (Modeling of cryosphere)

PT8-1: Basic study on coupling a land surface scheme and distributed hydrological model for cold regions (Koudelova, P., Japan Science and Technology Agency, Japan)

PT8-2: Topographic effects on surface ablation of mountain glaciers revealed by spatially distributed empirical modelling (Konya, K., Hokkaido University, Japan)

PT8-3: Reconstruction of glacier runoff from long-term climatic record in the arid region of China (Sakai, A., Nagoya University, Japan)

PT8-4: Response of Greenland ice sheet to the global warming simulated by a high resolution atmosphere-ocean GCM coupled by an ice sheet model (Saito, F., Frontier Research Center for Global Change, Japan)

PT8-5: Snow simulations in Siberian and Japanese forests (Yamazaki, T., Tohoku University/Institute of Observational Research for Global Change, Japan)

PT8-6: Numerical simulation of wind-hole circulation at Ice Valley Korea using a simple 2D Model (Tanaka, H. L., University of Tsukuba, Japan)

List of Participants

Ageta, Yutaka Graduate School of Environmental Studies Nagoya University Furo-cho, Chikusa-ku, Nagoya 464-8601 Japan **Tel:**+81-52-789-3480 **Fax:**+81-52-789-3436 **E-mail:**ageta@nagoya-u.jp	**Aizen, Vladimir** Glacio-Climatic Group, College of Science University of Idaho P.O. Box 443025, University of Idaho, Moscow, ID 83844 USA **Tel:**+1-208-885-3778 **Fax:**+1-208-882-3778 **E-mail:**aizen@uidaho.edu
Ananicheva, Maria Institute of geography Russian Academy of Science Staromonetniy per, 29 Moscow 119017 Russia **Tel:**+7-495-9590033 **E-mail:**cest@online.ru	**Aoki, Teruo** Meteorological Research Institute 1-1 Nagamine, Tsukuba, Ibaraki 305-0052 Japan **Tel:**+81-29-853-8716 **Fax:**+81-29-855-6936 **E-mail:**teaoki@mri-jma.go.jp
Bashir, Ahmad Water Resources Research Institute (WRRI) National Agriculture Research Centre (NARC) P.O. NIH, Chak Shehzad Park Road Islamabad Pakistan **Tel:**+92-3335487506 **Fax:**+92-51-9255074 **E-mail:**bashirad@hotmail.com	**Bian, Lingen** Chinese Academy of Meteorological Science, 46 Zhongguancun South Street, Beijing 100081 China **Tel:**+86-10-68406566 **Fax:**+86-10-62175931 **E-mail:**blg@cams.cma.gov.cn
Cline, Donald National Operational Hydrologic Remote Sensing Center NOAA/NWS 1735 Lake Drive West, Chanhassen, MN 55317 USA **Tel:**+1-952-361-6610 Ext. 252 **E-mail:**DONALD.CLINE@NOAA.GOV	**Davaa, Gombo** Institute of Meteorology and Hydrology Hudaldaany St. 5, Ulaanbaatar 46 Mongolia **Tel:**+976-11-312765 **E-mail:**watersect@yahoo.com
Desyatkin, Alexey Soil science faculty Hokkaido University Kita9, Nishi9, Kita-ku, Sapporo, 060-8589 Japan **Tel:**+81-11-706-2503 **Fax:**+81-11-706-4960 **E-mail:**alesha@chem.agr.hokudai.ac.jp	**Dye, Dennis** Frontier Research Center for Global Change JAMSTEC 3175-25 Show-machi, Kanazawa-ku, Yokohama-shi, Kanagawa-ken, 236-0001 Japan **Tel:**+81-045-778-5594 **E-mail:**dye@jamstec.go.jp
Endo, Nobuhiko Institute of Observational Research for Global Change JAMSTEC 3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001 Japan **Tel:**+81-45-778-5537 **Fax:**+81-46-867-9255 **E-mail:**nobu@jamstec.go.jp	**Enomoto, Hiroyuki** Kitami Institute of Technology Koen-cho 165, Kitami, 090-8507 Japan **Tel:**+81-157-26-9499 **Fax:**+81-157-25-8772 **E-mail:**enomoto@mail.kitami-it.ac.jp

Fujita, Koji
Graduate School of Environmental Studies
Nagoya University
Chikusa-ku, Nagoya 464-8601
Japan
Tel:+81-52-789-3479
Fax:+81-52-789-3436
E-mail:cozy@nagoya-u.jp

Fukui, Kotaro
National Institute of Polar Research
1-9-10 Kaga, Itabashi-ku, Tokyo 173-8515
Japan
Tel:+81-3-3962-5514
Fax:+81-3-3962-5719
E-mail:fukui@pmg.nipr.ac.jp

Georgiadi, Alexander
Institute of Geography
Russian Academy of Science
29 Staromonetny, Moscow 109017
Russia
Tel:+7-095-1290474
Fax:+7-495-9590033
E-mail:galex50@gmail.com

Glazirin, Gleb
Hydrometeorological Research Institute
72 K. makhsumov st., Tashkent,700052
Uzbekistan
E-mail:gleb.glazirin@gmx.net

Goodison, Barry
Environment Canada
4905 Dufferin St, Toronoto, Ontario M3H 5T4
Canada
Tel:+1-416-739-4345
Fax:+1-416-739-4265
E-mail: Barry.goodison@ec.gc.ca, barrygo@rogers.com

Graf, Tobias
Department of Civil Engineering, River and Environmental Engineering Laboratory
The University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656
Japan
Tel:+81-3-5841-6107
Fax:+81-3-5841-6130
E-mail:tgraf@hydra.t.u-tokyo.ac.jp

Guo, Yanjun
National Climate Center
China Meterological Administration
46 Zhongguancun South Street, Beijing 100081
China
Tel:+8610-68408728
Fax:+8610-62172591
E-mail:gyj@cma.gov.cn

Hara, Masayuki
Frontier reserch center fot Global Change
JAMSTEC
3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001
Japan
E-mail:hara.masayuki@jamstec.go.jp

Hirose, Nozomu
JST, Tsukuba university
1-1-1 Tennodai, Tsukuba-shi Ibaraki-ken, 305-8577
Japan
Tel:+81-029-853-5692
E-mail:hirose@hydra.t.u-tokyo.ac.jp

Hosaka, Masahiro
Meteorological Research Institute
1-1 Nagamine, Tsukuba, Ibaraki, 305-0052
Japan
Tel:+81-29-853-8598
Fax:+81-29-855-2552
E-mail:mhosaka@mri-jma.go.jp

Ikeda, Atsushi
Graduate School of Life and Environmental Sciences
University of Tsukuba
1-1-1 Tennoudai, Tsukuba, Ibaraki 305-8572
Japan
Tel:+81-29-853-5691
E-mail:aikeda@nipr.ac.jp

Ishida, Chu
Earth Observation Research Center
JAXA
Triton Square Office Tower-X 23F, 1-8-10 Harumi, Chuo-ku, Tokyo 104-6023
Japan
Tel:+81-3-6221-9139
Fax:+81-3-6221-9191
E-mail:ishida.chu@jaxa.jp

Ishii, Reiichiro
Frontier reserch center fot Global Change
JAMSTEC
3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001
Japan
E-mail:r.ishii@jamstec.go.jp

Ishikawa, Mamoru
Institute of Observational Research for Global Change
JAMSTEC
2-15 Natsushima-cho, Yokosuka 237-0061
Japan
Tel:+81-46-867-9278
Fax:+81-46-867-9255
E-mail:ishikawm@jamstec.go.jp

Iwata, Shuji
Department of Turism
Rikkyo University
1-2-26 Kitano, Niza, Saitama, 352-8558
Japan
Tel:+81-48-471-7435
E-mail:iwata-s@rikkyo.ac.jp

Kadota, Tsutomu
Institute of Observational Research for Global Change
JAMSTEC
2-15 Natsushima-cho Yokosuka, 237-0061
Japan
Tel:+81-46-867-9272
Fax:+81-46-867-9255
E-mail:kadota@jamstec.go.jp

Kaihotsu, Ichiro
Hiroshima University
1-7-1 Kagamiyama Higasihiroshima 739-0046
Japan
Tel:+81-824-24-6497
Fax:+81-824-24-0758
E-mail:kaihotu@hiroshima-u.ac.jp

Kang, Shichang
Institute of Tibetan Plateau Research
Chinese Academy of Sciences
18 Shuangqing Rd., Haidian District, Beijing 100085
China
Tel:+861062849681
Fax:+861062849681
E-mail:shichang.kang@itpcas.ac.cn

Key, Jeffrey
NOAA/NESDIS
1225 West Dayton Street Madison, WI 53562
USA
Tel:+1-608-263-2605
Fax:+1-608-262-5974
E-mail:jkey@ssec.wisc.edu

Kinosita, Hajimu
JAMSTEC
2-15 Natsushima-cho, Yokosuka-city, Kanakawa, 237-0061
Japan
E-mail:jimmy@jamstec.go.jp

Koike, Toshio
The University of Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo, 113-8656
Japan
Tel:+81-3-5841-6106
Fax:+81-3-5841-6130
E-mail:tkoike@hydra.t.u-tokyo.ac.jp

Komori, Jiro
Institute of Natural Sciences
Nihon University
3-25-40, Sakurajosui, Setagaya, Tokyo
Japan
Tel:+81-3-5317-9726
Fax:+81-3-3290-5451
E-mail:j-k@e-mail.jp

Kondo, Hiroki
Frontier reserch center fot Global Change
JAMSTEC
3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001
Japan
E-mail:hkondo@jamstec.go.jp

Konya, Keiko
Institute of Low Temperature Science
Hokkaido University
Kita19Nishi8, Kita-ku, Sapporo, Hokkaido 060-0819
Japan
Tel:+81-11-706-7473
E-mail:konya@lowtem.hokudai.ac.jp

Koudelova, Petra
The University of Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo, 113-8656
Japan
Tel:+81-3-5841-6107
Fax:+81-3-5841-6130
E-mail:petra@hydra.t.u-tokyo.ac.jp

Kubota, Jumpei
Research Institute for Humanity and Nature
457-4, Motoyama, Kamigamo, Kita-ku, Kyoto, 603-8047
Japan
E-mail:jkubota@chikyu.ac.jp

Li, Zhen
Institute of Remote Sensing Application
Chinese Academy of Sciences
2 Dutun Road, Beijing 100101
China
Tel:+86 10 6487717
Fax:+86 10 64889570
E-mail:zli@irsa.ac.cn

Liu, Yujie
National Satellite Meteorological Center
China Meteorological Administration
46 Zhongguancun South Avenue, Beijing 100081
China
Tel:+86-10-68409762
Fax:+86-10-62176805
E-mail:liuyj@nsmc.cma.gov.cn

Liu, Jingshi
Institute of Tibetan Plateau Research
Chinese Academy of Sciences
18 Shuangqing Rd., Haidian District, Beijing 100085
China
Tel:+861062849373
Fax:+861062849373
E-mail:jsliu@itpcas.ac.cn

Lopez Caceres, Maximo Larry
Institute of Low Temperature
Hokkaido University
Nishi-8, Kita-19, Sapporo, 060-0819
Japan
Tel:+81-11-706-6884
E-mail:larry@lowtem.hokudai.ac.jp

Lu, Longhua
Chinese Academy of Meteorological Sciences
46 Zhongguancun Mandajie, Beijing 10081
China
Tel:+86-10-68406296
Fax:+86-10-68406296
E-mail:lulonghua@cams.cma.gov.cn

Ma, Xieyao
Frontier reserch center fot Global Change
JAMSTEC
3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001
Japan
Tel:+81-45-778-5546
Fax:+81-45-778-5706
E-mail:xyma@jamstec.go.jp

Masuda, Kooiti
Frontier reserch center fot Global Change
JAMSTEC
3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001
Japan
E-mail:masuda@jamstec.go.jp

Matsuda, Yoshihiro
Graduate School of Environmental Studies
Nagoya University
c/o Hydrospheric Atmospheric Research Center,
Furo-cho Chikusa-ku Nagoya 464-8601
Japan
Tel:+81-52-789-3479
E-mail:s030117d@mbox.nagoya-u.ac.jp

Matsumoto, Jun
Dept. of Earth & Planetary Sci.
The University of Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo 113-0033
Japan
Tel:+81-3-5841-4575
E-mail:jun@eps.s.u-tokyo.ac.jp

Matsuno, Taroh
Frontier reserch center fot Global Change
JAMSTEC
3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001
Japan
E-mail:matsuno@jamstec.go.jp

Matsuoka, Norikazu
Graduate School of Geoenvironmental Sciences
University of Tsukuba
Tennodai 1-1-1, Tsukuba 305-8572
Japan
Tel:+81-29-853-4540
E-mail:matsuoka@atm.geo.tsukuba.ac.jp

Meier, Walter
National Snow and Ice Data Center
University of Colorado
449 UCB Boulder, CO 80309-0449
USA
E-mail:walt@nsidc.org

Naito, Nozomu
Department of Global Environment Studies, Faculty of Environmental Studies
Hiroshima Institute of Technology
2-1-1 Miyake, Saeki-ku, Hiroshima 731-5193
Japan
Tel:+81-82-921-9402
Fax:+81-82-921-8993
E-mail:naito@cc.it-hiroshima.ac.jp

Nakawo, Masayoshi
Research Institute for Humanity and Nature
457-4 Motoyama, Kamigamo, Kita-ku, Kyoto 603-8047
Japan
Tel:+81-75-707-2390
E-mail:nakawo@chikyu.ac.jp

Narama, Chiyuki
Department of Environmental Studies
Nagoya University
Furo-cho, Chikusa-ku, Nagoya, 464-8601
Japan
Tel:+81-52-789-3477
E-mail:narama@nagoya-u.jp

Naruse, Renji
Glacier and Cryospheric Environment Research Laboratory
Higashi-machi 2-339, Tottori, 680-0011
Japan
Tel:+81-857-23-7755
E-mail:naruseren@npo-glacier.net

Nuimura, Takayuki
Graduate School of Environmental Studies
Nagoya University
c/o Hydrospheric Atmospheric Research Center,
Furo-cho Chikusa-ku Nagoya 464-8601
Japan
Tel:+81-052-789-3479
Fax:+81-52-789-3436
E-mail:s060107d@mbox.nagoya-u.ac.jp

Ogi, Msayo
Frontier reserch center fot Global Change
JAMSTEC
3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001
Japan
Tel:+81-45-778-5606
E-mail:masayo.ogi@jamstec.go.jp

Ohata, Tetsuo
Institute of Observational Research for Global Change
JAMSTEC
2-15 Natsushima-cho, Yokosuka-city, Kanakawa, 237-0061
Japan
Tel:+81-46-867-9250
Fax:+81-46-867-9255
E-mail:ohatat@jamstec.go.jp

Park, Hotaek
Institute of Observational Research for Global Change
JAMSTEC
2-15 Natsushima-cho, Yokosuka-city, Kanakawa, 237-0061
Japan
Tel:+81-46-867-9292
Fax:+81-46-867-9255
E-mail:park@jamstec.go.jp

Popovnin, Victor
Cryolithology and Glaciology Dept., Geographical Faculty
Moscow State University
Leninskiye Gory Moscow 119992
Russia
Tel:+7-095-939-3673
Fax:+7-095-932-8836
E-mail:po@geogr.msu.ru, v.popovnin@reading.ac.uk

Rajan, Devaraj
CEOP-Lab, Department of Civil Engg.
The University of Tokyo
7-3-1, Hongo, Tokyo
Japan
Tel:+81-80-5414-4566
E-mail:drajan@hydra.t.u-tokyo.ac.jp

Rasul, Ghulam
Pakistan Meteorological Department
P.O. Box 1214, Islamabad
Pakistan
Fax:+92-51-9250368
E-mail:grmet@yahoo.com

Rauniyar, Surendra Prasad
Dept. of Civil Engineering
University of Tokyo
7-3-1 Bunkyo ku, Tokyo
Japan
Tel:+81-3-5841-6107
E-mail:rauniyar@hydra.t.u-tokyo.ac.jp

Raup, Bruce
National Snow and Ice Data Center
University of Colorado
449 UCB Boulder, CO 80309-0449
USA
Tel:+1-303-492-8814
E-mail:braup@nsidc.org

Razuvaev, Viatcheslav
All-Russian Research Institute of Hydrometeorological Information
World Data Centre (RIHMI-WDC)
6, Korolyov Str., Obninsk 249035
Russia
Tel:+7-495-255-21-94
Fax:+7-495-255-22-25
E-mail:razuvaev@meteo.ru

Saito, Fuyuki
Frontier reserch center fot Global Change
JAMSTEC
3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001
Japan
Tel:+81-45-778-5569
E-mail:saitofuyuki@jamstec.go.jp

Saito, Kazuyuki
Frontier reserch center fot Global Change
JAMSTEC
3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001
Japan
Tel:+81-45-778-5536
E-mail:ksaito@jamstec.go.jp

Sato, Atsushi
National Research Institute for Earth Science and Disaster Prevention
Suyoshi-machi Nagaoka-shi Niigata-Ken 940-0821
Japan
Tel:+81-258-35-7521
Fax:+81-258-35-0020
E-mail:asato@bosai.go.jp

Segawa, Tomonori
Frontier reserch center fot Global Change
JAMSTEC
3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001
Japan
E-mail:segawa2@jamstec.go.jp

Severskiy, Igor
Kazakh Institute of Geography
National Academy of Science of the Republic of Kazahkstan
Kazakhstan
E-mail:i_severskiy@mail.kz

Sharkhuu, Natsagdorj
Institute of Geography
Mongolian Academy of Sciences
Geo-Ecology Institute-301, Baruun Selbe-13, Ulaanbaatar-211238
Mongolia
Tel:+976-11-315786
E-mail:sharkhuu_n@yahoo.com

Shrestha, Arun Bhakta
Department of Hydrology and Meteorology
PO Box 406 Babar Mahal Kathmandu
Nepal
Tel:+977-1-4262-974
Fax:+977-1-4262-348
E-mail:abs@wlink.com.np, arun@dhm.gov.np

Singh, Ramesh Pratap
Indian Institute of Technology, Kanpur
P.O.IIT Kanpur 208016
India
Tel:+91-512-2597295
Fax:+91-512-2597395
E-mail:ramesh@iitk.ac.in

Sueyoshi, Tetsuo
Institute of Low Temperature Science
Hokkaido University
Kita 19 Nishi 8, Kita-ku, Sapporo, 060-0819
Japan
Tel:+81-11-706-7442
E-mail:sue@lowtem.hokudai.ac.jp

Sugimoto, Atsuko
Faculty of Environmental Earth Science
Hokkaido University
Kita 10 Nishi 5, Kita-ku, Sapporo, 060-0810
Japan
Tel:+81-11-706-2233
E-mail:sugimoto@star.dti2.ne.jp

Sugiura, Konosuke
Institute of Observational Research for Global Change
JAMSTEC
2-15 Natsushima-cho, Yokosuka 237-0061
Japan
Tel:+81-46-867-9279
E-mail:sugiura@jamstec.go.jp

Sugiyama, Shin
Institute of Low Temperature Science
Nishi-8, Kita-19, Sapporo, 060-0819
Japan
Tel:+81-11-706-7441
E-mail:sugishin@lowtem.hokudai.ac.jp

Suzuki, Kazuyoshi
Institute of Observational Research for Global Change
JAMSTEC
2-15 Natsushima-cho, Yokosuka, Kanagawa, 237-0061
Japan
Tel:+81-46-867-9276
Fax:+81-46-867-9255
E-mail:skazu@jamstec.go.jp

Suzuki, Rikie
Frontier reserch center fot Global Change
JAMSTEC
3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001
Japan
Tel:+81-45-778-5541
Fax:+81-45-778-5706
E-mail:rikie@jamstec.go.jp

Suzuki, Ryohei
Graduate School of Environmental Studies
Nagoya University
c/o Hydrospheric Atmospheric Research Center,
Furo-cho Chikusa-ku Nagoya 464-8601
Japan
Tel:+81-52-789-3488
E-mail:s040107d@mbox.nagoya-u.ac.jp

Takahashi, Shuhei
Kitami Institute of Technology
Koen-cho 165, Kitami, 090-8507
Japan
Tel:+81-157-26-9494
E-mail:shuhei@mail.kitami-it.ac.jp

Takata, Kumiko
Frontier reserch center fot Global Change
JAMSTEC
3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001
Japan
E-mail:takata@jamstec.go.jp

Takeuchi, Nozomu
Graduate school of science and technology
Chiba University
1-33, Yayoi-cho, Inage-ku, Chiba, 263-8522
Japan
Tel:+81-43-290-2843
E-mail:ntakeuch@earth.s.chiba-u.ac.jp

Tanaka, Hiroshi
Center for Computational Sciences
University of Tsukuba
Teno-dai 1-1-1, Tsukuba, Ibaraki 305-8572
Japan
Tel:+81-29-853-4502
Fax:+81-29-853-6879
E-mail:tanaka@sakura.cc.tsukuba.ac.jp

Tanaka, Noriyuki
EORC, JAXA
Triton Square Office Tower-X 23F, 1-8-10 Harumi, Chuo-ku, Tokyo 104-6023
Japan
E-mail:tanaka.noriyuki@jaxa.jp, norit22999@hotmail.com

Tian, Lide
Institute of Tibetan Plateau Research
Chinese Academy of Sciences
18 Shuangqing Rd., Haidian District, Beijing 100085
China
Tel:+861062849390
E-mail:ldt@itpcas.ac.cn

Tsutsui, Hiroyuki
Department of Civil Engineering
The university of Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo, 113-8656
Japan
Tel:+81-3-5841-6105
E-mail:tsutsui@hydra.t.u-tokyo.ac.jp

Uekatke, Jun
Tokyo Institute of Technology
2-12-1 Ookayama, Meguro-ku, Tokyo, 152-8550
Japan

Ueno, Kenichi
The Univ. Tsukuba
Teno-dai 1-1-1, Tsukuba, Ibaraki 305-8572
Japan
E-mail: Kenueno@sakura.cc.tsukuba.ac.jp

Ukita, Jinro
Center for Environmental Remote Sensing
Chiba University
1-33, Yayoi-cho, Inage-ku, Chiba, 263-8522
Japan
Tel:+81-43-290-3847
E-mail:ukitaj@gmail.com, jukita@ldeo.colmobia.deu

Vuglinsky, Valery
State Hydrological Institute
2nd Line 23, St. Petersburg
Russia
E-mail:vvuglins@vv4218.spb.edu

Xiao, Cunde
Chinese Academy of Meteorological Sciences
46 Zhongguancun South Avenue, Beijing 10081
China
Tel:+86-10-68407410
Fax:+86-10-62175931
E-mail:cdxiao@cams.cma.gov.cn

Xu, Jianging
Frontier reserch center fot Global Change
JAMSTEC
3173-25 Showamachi, Kanazawa, Yokohama, Kanagawa 236-0001
Japan
E-mail:jxu@jamstec.go.jp

Yabuki, Hironori
Institute of Observational Research for Global Change
JAMSTEC
2-15 Natsushima-cho, Yokosuka-city, Kanakawa, 237-0061
Japan
Tel:+81-46-867-9268
Fax:+81-46-867-9255
E-mail:yabuki@jamstec.go.jp

Yamaguchi, Satoru
National Research Institute for Earth Science and Disaster Prevention
Suyoshi-machi Nagaoka-shi Niigata-Ken 940-0821
Japan
Tel:+81-258-35-7522
Fax:+81-258-0020
E-mail:yamasan@bosai.go.jp

Yamazaki, Takeshi
Tohoku Univ. / JAMSTEC IORGC
Aza-Aoba, Aramaki, Aoba-ku, Sendai, 980-8578
Japan
Tel:+81-22-795-5781
Fax:+81-22-795-7758
E-mail:yamaz@jamstec.go.jp

Yang, Daqing
Water and Environmental Research Center
University of Alaska Fairbanks
AK 99775
USA
Tel:+1-907-474-2468
E-mail:ffdy@uaf.edu

Yao, Tandong
Institute of Tibetan Plateau Research
Chinese Academy of Sciences
18 Shuangqing Rd., Haidian District, Beijing 100085
China
Tel:+861062849071
E-mail:tdyao@itpcas.ac.cn

Yasunari, Tetsuzo
Hydrospheric Atmospheric Research Center
Nagoya University / FRCGC, JAMSTEC
Furo-cho, Chikusa-ku, Nagoya 464-8601
Japan
Tel:+81-52-789-3465
Fax:+81-52-789-3436
E-mail:yasunari@hyarc.nagoya-u.ac.jp

Ye, Qinghua
Institute of Tibetan Plateau Research
Chinese Academy of Sciences
18 Shuangqing Rd., Haidian District, Beijing 100085
China
Tel:+861062849397
Fax:+861062849886
E-mail:yeqh@itpcas.ac.cn

Yoshizaki, Masanori
Institute of Observational Research for Global Change
JAMSTEC
2-15 Natsushima-cho, Yokosuka-city, Kanakawa, 237-0061
Japan
E-mail:myoshiza@jamstec.go.jp

Yu, Yaxun
Institute of Arid Meteorology, CMA, Lanzhou
Key Laboratory of Arid Climate Change and Reducing Disaster
2070, Donggang East Road, Lanzhau 730020, gansu
China
Tel:+86-931-4670216-2495
Fax:+86-931-4670216-2493
E-mail:yuyaxun@163.com

Zhang, Peiqun
National Climate Center
China Meterological Administration
46 Zhongguancun South Street, Beijing 100081
China
Tel:+8610-68407175
Fax:+8610-68407427
E-mail:zhangpq@cma.gov.cn

Zhang, Dongqi
Chinese Academy of Meteorological Sciences
46 Zhongguancun South Street, Beijing 100081
China
Tel:+861068407410
E-mail:zhangdq@cams.cma.gov.cn

Zhang, Yinsheng
Institute of Observational Research for Global Change
JAMSTEC
2-15 Natsushima-cho, Yokosuka-city, Kanakawa, 237-0061
Japan
Tel:+81-46-8679273
E-mail:yszhang@jamstec.go.jp

Zhang, Tingjun
National Snow and Ice Data Center
449 UCB Boulder, CO 80309-0449
USA
Tel:+1-303-492-5236
E-mail:tzhang@nsidc.org

Zhao, Lin
Cold and Arid Regions Environmental and Engineering Research Institute
Chinese Academy of Sciences
320 Donggang West Road, Lanzhou,Gansu, 730000
China
Tel:+86-931-4967391
Fax:+86-931-8276147
E-mail:linzhao@lzb.ac.cn

Zheleznyak, Mikhail
Melnikov Permafrost Institute SB RAS / Yakut State University Faculty of Ceology
Yakutsk, Respublica Sasha (Yakutia),677010
Russia
Tel:+7-4112-33-46-58
Fax:+7-4112-33-44-76
E-mail: Fe@mpi.ysn.ru

National Reports

Cryospheric Studies in Russia

Vyacheslav Razuvaev, Vladimir Kotlyakov, Tatiana Khromova

Selected ongoing Russia-CliC Activities

A. Glaciers

1. Evolution of the low limit of "hyonosphere" and glaciers in North Eastern Siberia, including the Pole of Cold of Eurasia

The *World Atlas of Snow and Ice Resources (1997)* introduced a new, "glacier-system" approach for the assessment of spatial distribution (fields) of Equilibrium Line Altitude (ELA) in high mountains, snow accumulation, solid precipitation and run-off. As a next step in the development of this approach, the ELA and climatic snow line (low limit of "khionosphere") field of evolution study for present and future climate change is proposed. This approach makes it possible to estimate the evolution of precipitation and run-off in the high mountains. Regions under investigation are North-East Siberia (IPY 274) including Kamchatka peninsula, Polar Ural and Franz-Joseph Land (Western Arctic). Other glacier systems will also be studied.

Contact persons: Alexander N.Krenke (ankrenke@nm.ru) and Maria D. Ananicheva (cest@online.ru)

2. The current development of mountain glaciers in Northern Eurasia in conditions of global climate warming

Glaciers are dynamically unstable systems which may react rapidly to climate change. The glacier melts saturating the soft till deposits leads to highly unstable moraine complexes. Glacier retreat suggests glacial zone landscape changes, new lakes being formed, and even activation of natural disaster processes, such as catastrophic mudslides, ice avalanches, floods, etc. The presence of glaciers in itself may pose a threat to human life, economic activity or growing infrastructures. But continued economical stability and human activity in mountain regions depend on access to current and relevant information on cryospheric processes. Lack of information and subsequent action may result in financial and human loss. One of the major aims of the project is to study the current development of mountain glaciers in Northern Eurasia in conditions of global climate warming and define of the role of local environmental changes - specifically the origin of natural disasters and glacial processes. The assessment of current and future glacier change requires an effective monitoring system, including ground-truth and remote-sensing studies. As instrumental time series from ground observations decrease, and remote sensing information increase, creating a continuous and consistent time series becomes very difficult. This project aims to resolve the problem and develop a mechanism to simultaneously analyze and assess glacier extent as a part of glacier monitoring system.

Contact person: Tatiana Khromova (tkhromova@gmail.com)

3. Glaciers retreat in the central Tien Shan Mountains

The retreat of the terminus of glaciers and reduction of glacier areas since their maximum extend during the "Little Ice Age" maximum (LIA) (XVIIth-XIXth centuries) were estimated using aerial photographs (from 1956 to 1987) and recent satellite images (2001 to 2004) in the central Tien Shan mountains (Kyrgyz Republic). The glaciers under investigation are located on Teskey Alatau, Suek and Dzhetim-bel. On average, glaciers in these areas have retreated 900-600 m since the LIA maximum. Thus, in the second part of XXth century, glacier areas changed by about 25-30% compared with 5-8% between 1880 and 1970s. Unprecedented melt and structural changes of glaciers in the Tien Shan from the mid-1970s till the beginning of the XXI century most likely resulted from increased summer air temperatures and decreased summer precipitation (meteorological records from Tien-Shan station and others.). The change in atmospheric pressure over the central North Atlantic Ocean during the mid-1970s may be one possible reason for these processes.

This study is supported by ISTC grant №2947

Contact person: Stanislav Kutuzov (kutuzoff@list.ru)

4. Polar glaciers and ice caps as indicator of climate change

All available data during the last decade indicate a negative development trend in glaciers and ice caps in polar regions. These negative trends are manifested in:

- reduced glacier length, area and ice surface elevation;
- long-term negative glacier mass balance records;
- shift of equilibrium line altitude (ELA) and ice facies zones;
- change in hydro-thermal state and internal structure of polythermal glaciers;
- temperature changes in the surficial active layer;
- instability of glacier behavior such as surge activity and iceberg outbursts;
- trends in shallow and deep ice cores records.

Nevertheless, these glaciological indicators of climate change derived from conventional observations are often scarce and sometimes completely lacking. Hence the IPY provides a unique opportunity to combine the extended field observations with a variety of remote sensing data and to reveal the comprehensive bipolar picture of the current state of glaciers as the indicator of climate change and the benchmark for comparison with past and future state, interpretation of most sensitive areas, and modelling. The primary lines of investigations are:

- State and dynamics of polar glaciers and ice caps
- Surficial and internal properties of polar glaciers and ice cap
- Deep ice-core drilling of polar glaciers and ice caps
- Iceberg calving of polar glaciers and ice caps

For each selected glacier, or ice cap, the following parameters will be measured in remotely or in the field:

- surface mass balance
- surface velocities (3-dimensional), preferably including seasonal cycle
- bed topography o surface topography (with high accuracy)
- surface albedo at the end of the ablation season
- calving rates

- water pressure in boreholes o temperature profiles in the ice (for polythermal glaciers).

In addition, historical and proxy information on glacier length/area will be combined with new maps and images to reconstruct glacier evolution from the Little Ice Age to the present. Study methods are:

- Ground mass-balance and hydrological studies on glaciers using standard approaches and snow radar transects and shallow drilling
- Glacier surface elevation and surface velocity measurements (ground-based, aerial and satellite surveys)
- Interpretation and analysis of radar and passive images in different bands for glacier geometry, velocity, dynamics and ice-facies studies
- Radio echo-sounding for internal structure and hydrothermal state studies
- Deep ice core drilling, bore hole and ice core studies
- Studies of glacial deposits and landforms

Contact person: Andrey Glazovsky (glazovsk@gol.ru)

5. The evaluation of the dynamics of Antarctic Ice Sheet discharge in the second part of XX century

The goal of this project is to measure the impact of climate change on the Antarctic Ice Sheet marginal zone. To do this, satellite images will be incorporated into a GIS database, these will be combined with direct instrumental geodetic and glaciological measurements and meteorological data from coastal and island stations. It allows the extension of time frame information for Antarctic Ice Sheet marginal zone change estimation, and the correlation of glacier and climate dynamics. So far, the structure and content of the data base has been developed, and several sources of spatial information have been analyzed. All this information now exists in database an ARCGIS coverage dataset in vector and raster formats. This arrangement allows simultaneous analyzes of any set of data, entering of new information into data base on-the-fly, and planning field studies. The databases for ground base-, remote-sensing- and meteorological information for selected ice drainage basins (II, III, IV, V and VI) of East Antarctica have been formed. These data were analyzed together with information on ice movement, sheet marginal zone dynamic and accumulations. It was found that the mass balance of these basins was positive for all instrumental observations periods.

Contact person: Maxim Moskalevsky (moskalevsky@mail.ru)

6. Changes of hydrothermal state of subsurface snow-firn sequences of Antarctic ice sheet derived from Kosmos-1500, ERS 1/2 and RADARSAT 1/2 radar images as an indicator of climate change

Variations in snow density stratigraphy of glaciers and ice sheets are very sensitive to the seasonal and annual surface temperature changes and therefore can be suggested as good indicators of short-term variations of climate conditions.

Radar images are very sensitive to the water and ice inclusions especially subsurface. They are probably the best instrument for remote sensing studies of current state and changes in hydrothermal state of upper layers over large areas such as Antarctic ice sheet. Changes are determined using the spatial and temporal differences in backscatter.

Radar images of Antarctic ice sheet were obtained for the first time in 1983-86 by Russian side-looking radar onboard Kosmos-1500 satellite. Using this data, the first digital radar mosaic of the whole Antarctic ice sheet (consing of 36 frames) was constructed.

From this, a number of zones with different brightness characteristics were found, indicating subsurface ice lenses. Subsequent missions of ERS 1/2 and RADARSAT 1/2 satellite provided more detailed radar mosaics of Antarctic ice sheet and the corresponding backscatter characteristics.

The goal of the project is to compare the data on hydrothermal state of snow-firn sequences derived from the different sensors to determine the changes which can be correlated with climate variations.

Contact person: Maxim Moskalevsky (moskalevsky@mail.ru)

B. Snow Cover

1. Change in snow-cover characteristics over Northern Eurasia under present climate change

The change in snow-cover characteristics over Northern Eurasia under present climate change is being studied. We created a homogeneous data base for the period 1936 -2000. Despite warming, the snow depth and snow-water equivalent increased due to more intensive cyclonic activity and winter precipitation in most of the regions, except in the southern and western parts of the East-European plain and part of the Turan plain. A method was developed to estimate the possible upper limit of snow storage that can accumulate due to increase in winter temperatures and precipitation over multiple years. This upper limit has reportedly not yet been achieved in the North Eurasia territory. This means that the continuing increase of winter temperatures is not yet likely to result in lower snow storage values. The relationship between snow cover and circulation patterns regime was studied using various circulation indices. The next step is to construct future snow cover scenarios using different climate scenarios.

Contact persons: Krenke (ankrenke@nm.ru), V.Razuvaev (Razuvaev@meteo.ru), L.Kitaev (lkitaev@online.ru).

2. Snow stratigraphy and long-term meteorological time series in various regions of Northern Eurasia

Data set of snow stratigraphy and long-term meteorological time series in various regions of Northern Eurasia has been created. Parameterization scheme of the snow cover stratigraphy classes for climate and hydrological models has been developed and tested against observed data.

This activity is accomplished within INTAS project No 03-515296

Contact person: Adrey B. Shmakin (andrey_shmakin@mail.ru)

3. Microwave data for an estimation of characteristics of snow cover

Snow cover exerts direct influence on climate dynamics. The ability to assess its current global state and water equivalent on a seasonal-and long-term scale is important in order to understand climate change and to develop forecast models. Moreover, assessing Snow-cover Water Equivalent (SWE) on the scale of a river basin is necessary in order to plan and manage water resources, including forecasting and prevention of floods during melting season. The current lack of ground-based data on the state of snow cover, especially for the Russian sub-polar regions, necessitates the collection of new microwave remote sensing data for SWE assessment. Preliminary studies based on AMSR-E and SSM/I data for the winter periods 2003-2005 on test sites in European part of Russia (the Polar Urals and Siberia) indicate a large (by 2-4 times) difference in ground snow survey data and SWE data retrieved by remote sensing. Thus, one universal algorithm does not provide the desired accuracy. Additional studies and regional approach in interpretation of remote sensing data are therefore required. One possible solution is zoning and adaptation of available algorithms, or searching for new ones that will be valid for the uniform areal climate or landscape conditions. Implementation of this approach is the major target of this project. Another aim is to calibrate the Russian radiometer planned for launch on the "Canopus-Vulkan» satellite in 2007. Considerable contribution in the problem solving might benefit from the synchronous measurements of snow cover parameters specially designed in the frame of IPY-2007.

Contact person: Gennady Nosenko (gnosenko@mail.ru)

C. Ice Cores

Ice-core studies on Western firn plateau of Mt. Elbrus in Caucasus

Shallow ice cores, 21.41 m depth, were recovered on the Western firn plateau of Mt. Elbrus (5150 m a.s.l.), Caucasus in 2003. Firn density and temperatures were measured at the drilling site, and distinct seasonal fluctuations of stable isotope composition were defined in the ice core. Detailed stratigraphic record indicates absence of surface melting and ice layers in firn pack. This record indicates that Western firn plateau of Mt. Elbrus is the best site for ice-core studies in Caucasus.

Contact person: Stanislav Kutuzov (kutuzoff@list.ru)

Russian National CliC Committee

The Russian National CliC Committee acts as a consulting scientific body of the Russian Academy of Sciences (RAS) and the Federal Ministry for Hydrometeorology and Environment Monitoring (ROSHYDROMET). The Committee is directed by the presidium of RAS and the Scientific Technical Council of ROSHYDROMET. Leading scientists and experts from various Russian universities, institutions and organizations were recruited to serve on the committee, which is co-chaired by Vladimir Kotlyakov (RAS) and Alexander Bedritzkiy (ROSHYDROMET). Its office is located at, and hosted by, the Institute of Geography RAS in Moscow. Infrastructure, overhead and operating expenses are borne by the host.

Since its inception in 2003, several meetings were held to discuss and move the project ahead. The first two meetings took place in St-Petersburg in November 2003 and May 2004, and the next in Moscow in October 2004. Following a declaration of the CliC project's importance for understanding climate change, particularly in polar areas, it was decided that the main task of Russia-CliC would be coordination of Russian Science efforts in this field of studies. It was decided to present results of Russian CliC studies on a larger scale and on national and international fora. The members decided to structure the Committee into four working groups, patterned after the four CliC Project Areas (CPAs).

1. The terrestrial cryosphere and hydrometeorology of cold regions (Oleg Anisimov and Alexander Krenke, lead).
2. Glaciers, ice caps and ice sheets, and their relations to sea level (Andrey Glazovsly, lead).

3. The marine cryosphere and its interactions with high latitude oceans and atmosphere (Alexander Danilov, lead)
4. Links between the cryosphere and global climate (Igor Mokhov and Vladimir Katzhov, lead).
5. Data and information management (Vycheslav Razuvaev and Tatiana Khromova).

It was also declared that IPY will be a unique opportunity to improve CliC ideas and CliC studies on both national and international levels, and a decision was made to actively promote Russian participation in the International Polar Year.

Russian Baseline Hydrometeorological Data Sets

RIHMI-WDC is responsible for data processing and storage in Russia for meteorology, aerology, oceanography, hydrology, and agrometeorology observation data (RIHMI-WDC has the State Hydrometeorological Data Holding).

In creating historical data sets, special emphasis should be given to data quality control and elimination of data inhomogeneity. The reasons for data inhomogeneity in Russia coincide in many respects. These are modifications in observation procedures (different frequency of observations), replacement of instruments (rain-gauge by precipitation gauge), modifications in data processing procedures (introducing corrections for instrumental moistening into precipitation observations), etc.

Creating sets of metadata on current machine-readable media is of great importance for data rescue challenge. Historical information on meteorological station is available from different sources; it requires checking, refining and digitizing.

Some specialized data sets, which may be useful for ASIA-CLiC purposes, were prepared in the recent years as a result of joint activity with other institutes and data centers in Russia and other countries. Among them:

1. "SNOW_DEPTH_DATA" for 223 meteorological stations of the former USSR

   "SNOW CHARACTERISTICS MEASURED ON FIXED PATHS" (This data set contains data of observations of snow cover on fixed paths on the FSU meteorological stations (1319). The data set contains data for 1966 – 2000). These data sets were prepared in framework of INTAS project 0077 "Snow Cover Changes Over Northern Eurasia during the last century: circulation consideration and hydrological consequences (SCCONE)". The data are distributed free of charge (http://www.intas0077snowchanges.narod.ru).

2. "Daily and Sub-daily Precipitation for the Former USSR" (DATASET 9813)

   This data set was prepared as a result of joint work of RIHMI-WDC (Russia) and National Climatic Data Center (USA). The data are distributed free of charge for use with a non-commercial purposes according to regulations outlined in WMO resolution 40. Contact NCDC's Climate Services about costs of copying of the off-line version of this dataset. (Phone 828-271-4800, Fax 828-271-4876, e-mail NCDC.Orders@noaa.gov)

Overview on National Cryosphere Monitoring Activities in Mongolia

G. Davaa[1] and N. Sharkhuu[2]

[1]Instutute of Meteorology and Hydrology

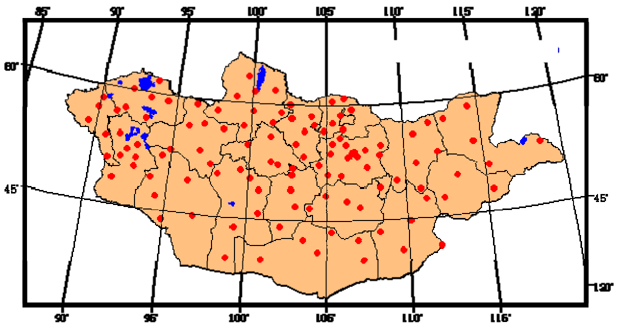
[2]Institute of Geo-ecology, Mongolia

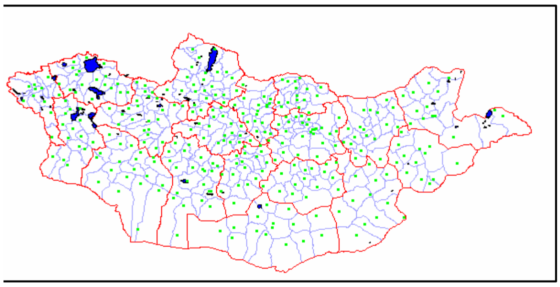
1. *The present observation network on cryosphere and some results*

a. Snow cover

Stationary observation network for snow cover has been established within the state hydrometeorological network in Mongolia in 1936. At the present, 319 permanent stations and posts operate under the National Agency for Meteorology, Hydrology and Environmental Monitoring (NAMHEM) and make observation on meteorological elements including snow cover, particularly, snow depth, density and snow water equivalent on decade bases (Figure 1). Since 1992, NAMHEM receives NOAA satellite data and produces snow cover images (Figure 2).

Figure 1. Observation network for snow cover in Mongolia





Snow cover condition on third decade of March, 2006

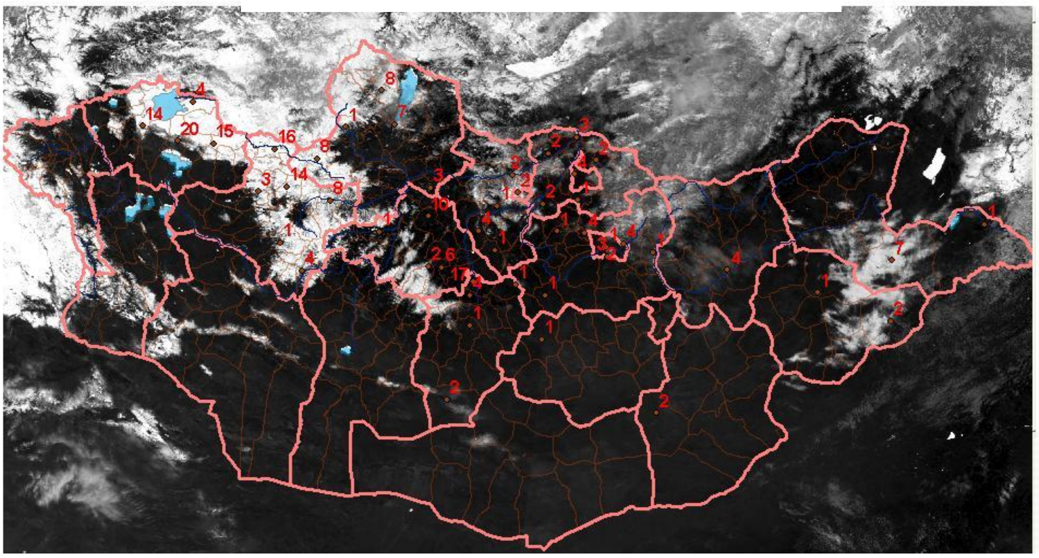


Figure 2. Snow cover image compiled by NOAA satellite and ground observation data

Snow cover is quite unevenly distributed with time and space, depending on microclimate in regions in Mongolia. Average thickness of snow cover in mountainous regions varies from 5 to 13 cm (T.Ganbaatar and B. Erdenetsetseg, 2004) in third decade of January in (Table 1).

Table 1. The average thickness of snow cover, cm, tendency of change, cm/year

zones	Stations name	Average thickness of snow cover, cm	Change of tendency, cm/year
North- western mountainous region	Baruunkharaa	9.8	0.032
	Bayan-Uul	15.6	-0.437
	Eroo	6.2	0.124
	Erdenemandal	3.1	-0.108
	Khatgal	5.2	-0.081
	Galuut	6.2	0.135
	Orkhon	9.4	0.216
	Tariat	3.7	0.021
	Tosontsengel	10.5	-0.045
	Tsetserleg	1.2	-0.003
	Ulaistai	7.0	0.109
	Baruunturuun	17.2	0.062
	Erdenesant	10.5	-0.003
	Sukhbaatar	6.8	0.004
	Khujirt	5.2	-0.273
	Ulaangom	13.9	0.024
	Average	8.2	- 0.01
Eastern region	Binder	1.6	-0.054
	Dadal	7.9	0.232
	Baruun-Urt	3.5	0.009
	Bayan-delger	7.4	0.151
	Bayan-Ovoo	7.0	0.004
	Choibalsan	3.3	-0.095
	Erdenetsagaan	5.6	-0.011
	Khalkhgol	7.9	-0.064
	Matat	2.2	0.111
	Underkhaan	2.5	-0.182
	Average	4.9	0.01
Southern region	Arbaikheer	0.5	0.013
	Bayankhongor	1.5	0.038
	Mandalgobi	4.0	-0.021
	Tonkhil	0.7	0.009
	Ylalt	1.2	0.033
	Dalanzadgad	0.5	-0.023
	Dorboljin	1.2	0.008
	Khubsgul	0.9	-0.026
	Saikhan-ovoo	1.7	0.089
	Tsogt-ovoo	0.5	0.052
	Gurbantes	0.2	-0.021
	Baitag	7.8	0.227
	Average	1.7	0.03

The area with annual average air temperature below 0oC or the area with stable snow cover that stands more than 50 days and it will be decreasing in future years. But stable snow cover will remain in Khuvsugul, Khangai, and Khentei Mountain area. Currently, the area with annual average air temperature below 0oC is 62 % of the country's territory. However, it is expected that the area will decrease by 43% in 2020, 31% in 2050 and 27 % in 2080 (T.Ganbaatar and B. Erdenetsetseg, 2004), see Figure 3.

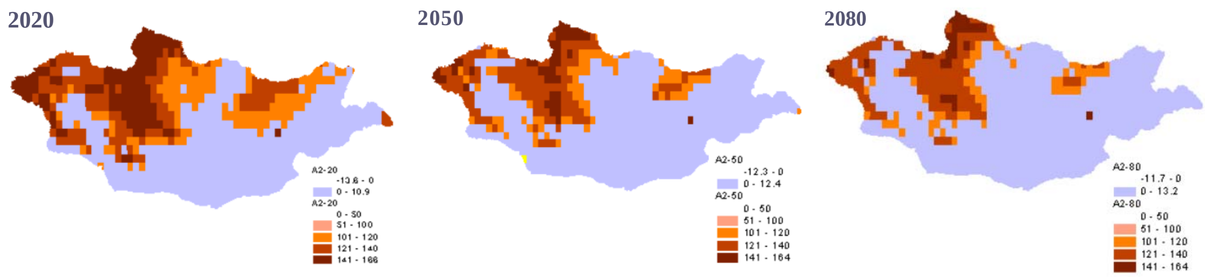


Figure 3. Change of number of days with stable snow cover in 2010-2030, 2040-2060, 2070-2090 periods /computed by scenarios of A2 HadCM3 model/

b. Cold area hydrology

Stationary hydrological observation network including ice depth and ice phenomena observation at rivers and lakes of Mongolia has been established also within the state hydrometeorological network under NAMHEM since 1942. At the moment 126 permanent hydrological stations are observe water level, discharge, ice depth and ice phenomena (Figure 4).

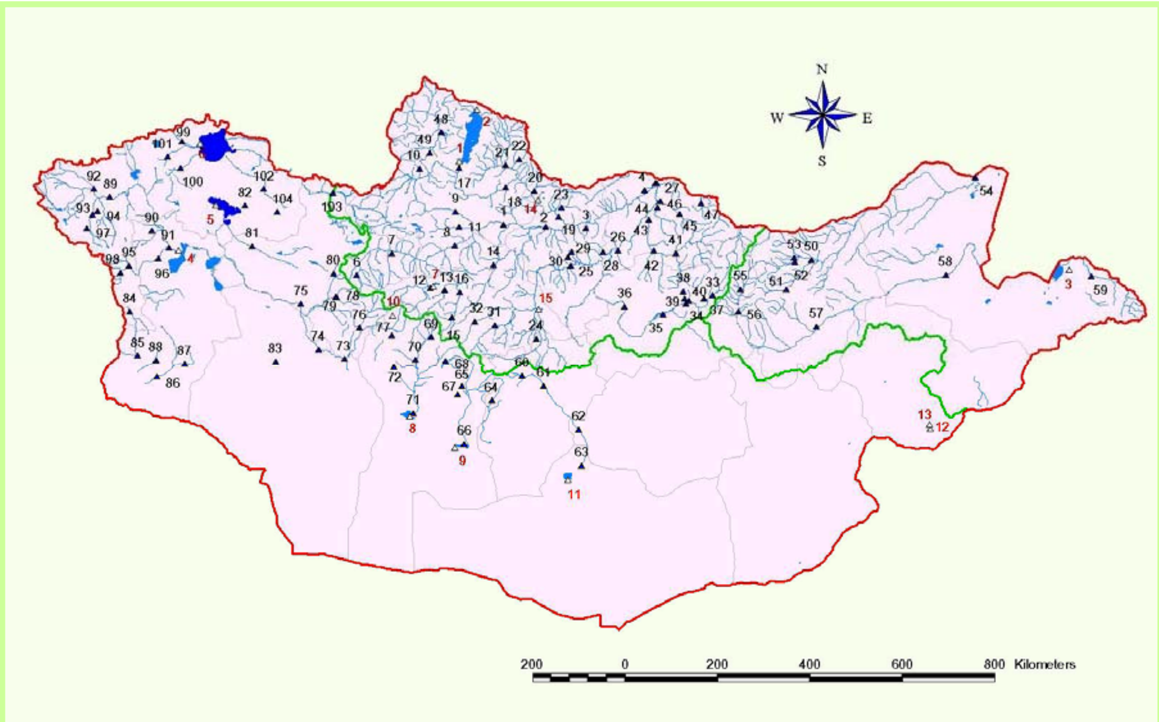


Figure 4. Observation network for ice depth and phenomena at rivers and lakes

Due to climate change effect on occurrence of ice cover and ice phenomena in rivers are getting late by 3-10 days. In the spring period, ice cover breaking processes starts much earlier than previous period by 5-15 days in Mongolian rivers.

Table 2. Change of duration of ice cover and ice phenomena at rivers

River and station	Period of analysis	Ice cover period		Ice phenomena period	
		Duration, days	Change in duration, days	Duration, days	Change in duration, days
1. Pacific ocean basin					
Kherlen-Baganuur	1945	163	-23	185	-2
	2000	140		183	
Kherlen-Underkhaan	1945	149	-10	190	-2
	2000	139		188	
Onon-Binder	1945	155	-14	186	1
	1993	141		187	
2. Arctic ocean basin					
Delgermuren-Moron	1945	167	-31	192	-5
	2000	136		187	
Kharaa-Baruunkharaa	1945	141	-16	187	-24
	2000	125		163	
Selenge-Khutag	1945	157	-42	111	3
	2000	115		113	
Orkhon-Orkhon	1945	149	-39	185	-6
	2000	110		179	
Tuul-Ulaanbaatar	1945	155	-12	194	-8
	2000	143		186	
3. Central Asian Internal basin					
Bogd-Uliastai	1945	169	-39	194	-5
	2000	131		189	

Snow cover-monitoring data such as ground observation and satellite images allow to forecasting spring floods in some selected river basins. For example, quite good relationship exists between area of snow cover and runoff volume during spring flood in the Khovd river basin (r=0.91) (Figure 5 b).

In case of 2005, for creation of snow cover map have been selected NOAA17 satellite data on decade base by taking into account NDSI (G.Adyabadam, 2005)

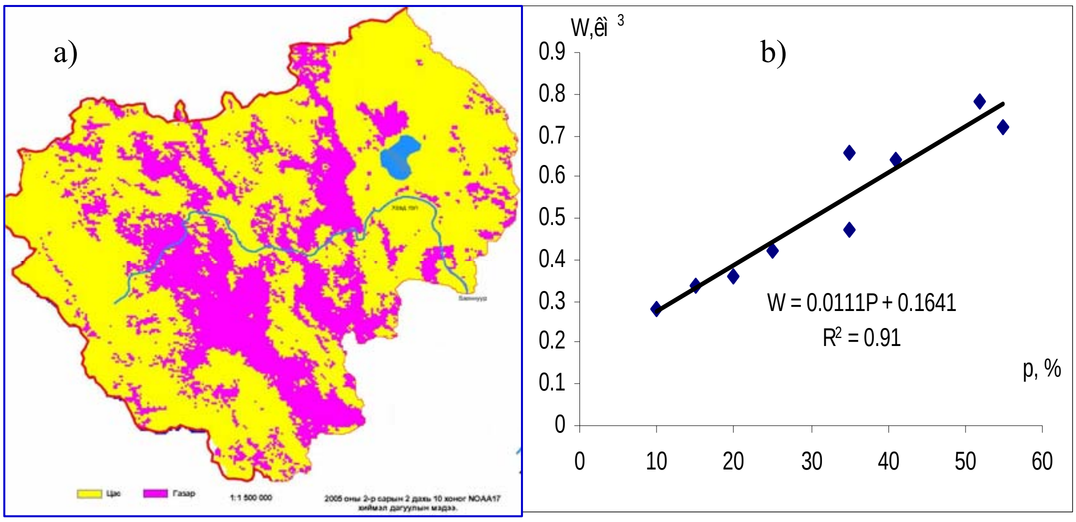


Fig. 5 Snow-cover area in yellow (a) and relationship between snow cover area and volume of spring flood runoff in the Khovd river basin (Source: G.Adyabadam, IMH, 2005)

c. Frozen ground or permafrost

Main component of cryosphere in Mongolia is permafrost, which occupies almost two thirds of Mongolia, predominantly in the Khentei, Huvsugul, Khangai and Altai Mountains and surrounding areas. The territory is characterized by mountain and arid-land permafrost, sporadic to continuous in its extent, and occupies the southern fringe of the Siberian permafrost zones. Most of the permafrost is at annual mean air temperatures close to 0°C, and thus, thermally unstable to climate change and human activities (see Fig. 6).

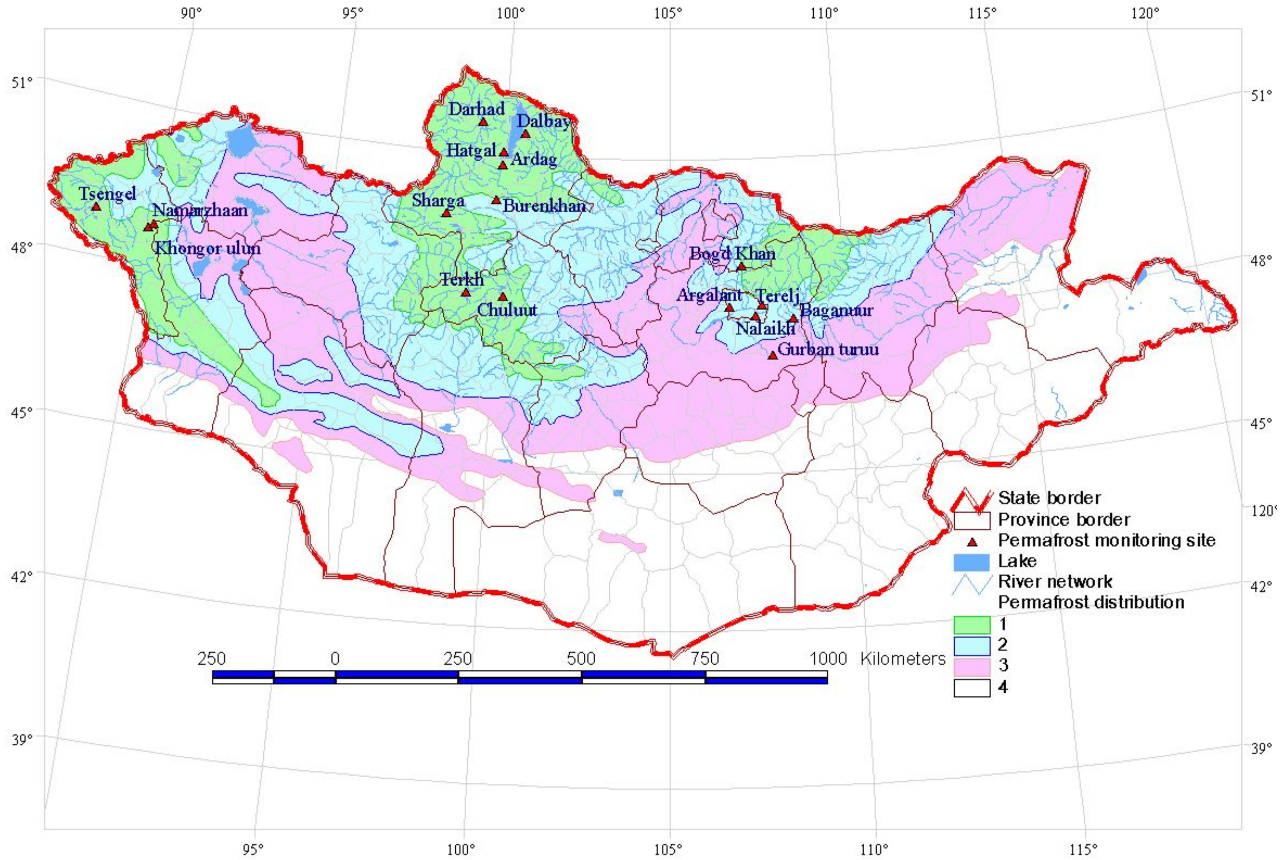


Figure 6. Schematic map of permafrost distribution and location of monitoring sites in Mongolia. 1. Continuous and discontinuous (50-100%); 2. Isolated (1-50%); 3. Sporadic (0-1%) permafrost areas. 4. No permafrost or seasonal frost area. Numbers on the map: 1. Baganuur (a, b), 2. Terelj (a, b, c), 3. Nalaikh (a, b, c), 4. Bogd Khan (c), 5. Argalant (a, b, c), 6. Gurbanturuu (a, c), 7. Baruun Kharaa (c), 8. Darhad (a, b, c), 9. Dalbay (a, b, c), 10. Ardag (a, b), 11. Hatgal (a, b), 12. Burenkhan (a, b), 13. Sharga (a, b), 14. Terkh (a, b, c), 15. Chuluut (a, b, c) and 16. Tsengel (a) monitoring sites. Letters in brackets: a. CALM; b. GTN-P; and c. CPPM measurements.

At present there are 16 permafrost-monitoring sites in Mongolia. These sites include 37 both CALM and GTN-P (5-15 m and deeper) monitoring boreholes, located in the Huvsugul, Khentei and Khangai Mountain regions. Monitoring of permafrost temperatures in the boreholes is started in mid 1990-s and extended from year to year. More than 10 boreholes with depths of 10 to 15 m were redrilled at the points where previous deeper temperature measurements in the old ones were made 17-35 years ago. Therefore, permafrost monitoring in most of the boreholes is long-term.

According to the selected 6 borehole data (in Table 3), the active layer depths and mean annual permafrost temperatures under influence of recent climate warming in Mongolia have risen at a rate of 3-30 cm and 0.1-0.3oC per decades, respectively. A rate of permafrost degradation in bedrock is more than in unconsolidated sediments and in ice-poor substrates more than ice-rich ones. In generally, the permafrost in Huvsugul mountain region is degrading more intensively than in Khentei and Khangai mountain regions.

At present, there are 10 active CPPM sites in Mongolia. Dynamics of thermokarst, thermoerosion, frost heaving, solifluction, kurum and icing have been studied at some monitoring sites. Active thermokarst is direct indicators of recent permafrost degradation under the influence of climate warming. A rate of settling due to thermokarst processes at Chuluut valley and Khangai region is estimated to be 3 – 7 cm per year (see Fig. 2). However, maximum subsidence of up to 20 – 40 cm per year was observed during the formation of incipient thermokarst lakes. During such events, spring water discharges of 0.2 to 1.0 liter per second can be observed in thaw ponds.

Table 3. Recent changes in active layers and permafrost temperatures

Mts region		Khentei				Khangai				Hovsgol			
Sites		Baganuur		Argalant		Terkh		Chuluut		Sharga		Hatgal	
Latitude, N		47041’		47055’		48005’		48002’		49029’		50038’	
Longitude, E		108016’		106033’		99023’		100024’		98009’		100009’	
Elevation, m asl		1342		1385		2075		1870		1864		1662	
Terrain		lake shore		arid valley bottom		high flood plain		top of 15m high pingo		wide valley flat bottom		lake-river flat terrace	
Predominant ground		ice and clay		loam and clay		gravelly sand		ice and clay		gravelly sand and loam		sandy gravel	
Ice content		high		medium		medium		high		medium		medium	
Measured dates		17.IX.1976	27.X.2004	8.IX.1988	5.XII.2004	20.X.1969	3.X.2004	28.X.1969	2.X.2004	21.IX.1968	4.X.2004	15.X.1983	20.IX.2004
Depth of active layer (h) m		3,35	3,75	2,90	7,10	1,95	2,10	1,25	1,30	2,70	2,80	4,20	4,70
Temperature at depth of	10m (t10)	-0,30	-0,18	-0,40	-0,25	-1,96	-1,60	-1,12	-0,72	-2,35	-1,40	-1,10	-0,49
	15m (t15)	0,10	-	-	-	-2,04	-1,57	-0,72	-0,47		-	-	-
Changes in (per year)	h, cm	1,43		-		0,43		0,14		0,28		2,38	
	t10, 0C	0,004		0,009		0,013		0,011		0,026		0,029	
	t15, 0C	-		-		0,013		0,007		-		-	
	t, 0C	0,005-0,01				0,01-0,02				0,02-0,03			

d. Glacier

Glacier studies were temporary and descriptive. 10 % of total water resources accumulated in glaciers in Mongolia. Glaciers are distributed in area of between 46o25-51o50 N, 87o40-100o50 E, at altitude of 2750-4374 m. Spatial distribution is sporadic and decrease from north-west to south-east. There are totally 262 glaciers with total area of 659 km2. Total water resources accumulated in glacier estimated to be 62.9 km3 (Dashdeleg et al., 1983). All glaciers are distributed in the Altai Mountain except 2 glaciers located in Khangai and Khuvsugul Mts.

Kharkhiraa, Turgen, Tsambagarav and Tavanbogd glacier areas were 50.13, 43.02, 105.09 and 88.88 sq.km, estimated from topographic map, scaled as 1:100 000 and compiled in 1940s (Kadota and Davaa, 2003, 2004, Davaa and Kadota 2005). Areas of the Kharkhiraa, Turgen, Munkhhairkhan, Tsambagarav and Sair glaciers were decreasing by 45.5, 33.7, 25.8, 21.4 and 42.5 percent since 1992 till 2002, respectively /table 4./.

Since 2003 up to present, Institute of observational research for global change, JAMSTEC, Japan and Institute of Meteorology and Hydrology (IMH), Mongolia are carrying out glacier surveys focused on mass balance studies in Tavanbogd, Turgen and Tsambagarav glaciers.

IMH initiated glacier mass balance and glacier hydrology study site at flat-top Tsambagarav Glacier since 2004 and obtained preliminary results of investigation.

Table 4. Changes in glacier areas

Glacier massif	1940th	25 June, 1992	10 Sep. 2000	8 Aug. 2002
Kharkhiraa	43.02	-	36.08	31.29
Turgen	50.13	-	34.74	33.83
Munhkhairkhan	-	36.96*	-	27.42
Tsambagarav	105.09	90.98	74.8	71.52
Sair	-	11.51	-	6.62

2. Organization and projects related or can contribute to "Climate and Cryosphere"

Organizations which have own observation network or research studies on Climate and Cryoshere are Institute of Meteorology and Hydrology of NAMHEM, Institute of observational research for global change, JAMSTEC, Japan. JICA, Japan, National Agency for Water of Ministry of Nature and Environment (MNE), Institute of Geography of MAS and Institute of Altai Studies are potential candidates to contribute the crysphere and glacier research and water resources management planning.

Concerning related projects, there are several ongoing international projects which could contribute to the Climate and Cryosphere study, such as Huvsugul Global Environment Facility/World Bank (GEF/WB) Project, Community based conservation of biological diversity in the mountain landscapes of Mongolia’s Altai Sayan Eco-Region.

Besides the mentioned ongoing projects, there are some national and internaional project proposals, which also have certain relation to the glacier studies. For example, “Regime and resources of surface water of the Khovd river basin and water use”, Integrated River Basin Management Strategy to develop National Program on water resources management and planning (Government of the Netherlands).

3. ***<u>Essential or urgent issues (observation, scientific studies) related to "Climate and Cryosphere" in Mongolia</u>***

Ice core often contain the most direct proxy information available concerning past changes in climate and environment and also glaciers and ice sheets preserve sequential information on both wet and dry deposition.

Climate change and anthropogenic effect, shortage of water resources and related consequences much clearly demonstrate importance of glacier study.

Therefore we propose following projects on:

- Integrated River Basin Management in the Khovd river basin with special concerns to climate change impact assessment on glaciers and to mitigate negative consequences (could be JICA supported, welcomed Regional Cooperation in the Altai Mts.)
- Will be organized new permafrost monitoring site near the Tsambagarav glacier for permafrost monitoring and will be combined with glacier monitoring to assess current gryospheric state in the Tsambagarav Mountain area to support water resource management and planning (National contribution to IPY).

The Government commitments:

- Use of regional hydrological and meteorological data and network
- Glacier study is officially included in long term program (for period of 2010-2015) of the National Agency for Hydrology, Meteorology and Environmental Monitoring of Mongolia
- Serious interest of people in the region to study glaciers for better understanding glacier phenomena and its interrelation with water resources and use, climate
- Human resources

4. ***<u>International cooperation and contribution to water resource management planning</u>***

Within the framework of Circumpolar Active Layer Monitoring (CALM) and the Global Terrestrial Network for Permafrost (GTN-P), Huvsugul Global Environment Facility/World Bank (GEF/WB) Project, Cryogenic Processes and Phenomena Monitoring (CPPM), Glacier study in Mongolia by IORGC, JAMSTEC, JAPAN and IMH, and cooperation with JICA, WMO, and UNESCO-IHP activities could make great contributions to cryosphere studies.

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State of Cryosphere in Pakistan

Bashir Ahmad[1] and Ghulam Rasul[2]

1 Scientific Officer, Water Resources Research Institute, National Agricultural Research Center, Park Road, Islamabad, Pakistan, Telephone: +92-51-9255022, Fax No: +92-51-9255074, E-Mail: bashirad@hotmail.com

2 Director, Research and Development Division, Pakistan Meteorological Department, P.O.Box 1214, Islamabad-Pakistan, Telephone: 0092-51-9250369, Fax No: 0092-51-9250368, E-Mail: grmet@yahoo.com

Country's Profile

Pakistan lies between 24° to 37° N latitude and 61° to 75° longitude, covering an area of 88.2 million hectares including northern areas. Inherently the country has highly variable topography, climate and culture. The three major mountain ranges namely: Hindu Kush, Karakoram and Himalaya border in the north followed by plateaus, plains and coastal areas. The climatic variability is expressed by humid zones in the north-east to hyper-arid in south-west and west. The major part of the country may be classified as arid to hyper-arid.

The country's high mountains comprise of the western end of 2,400 km long Himalayan range and some parts in the Hindu-Kush and Karakoram ranges. Northern areas spread over 72,496 sq. km. with amidst towering snow-clad peaks with heights varying from 1,000 masl to over 8,000 masl. Of the 14 over 8,000 masl peaks on earth, 4 occupy an amphitheater at the head of Baltoro glacier in the Karakoram Range. In addition to these, there are 68 peaks over 7,000 masl and hundreds which are over 6,000 masl.

Some of the lower sub-Himalaya mountain ranges in the northeast receive high summer monsoon rainfall and snow during winter. The forest covers are dense in this mountainous region due to abundant amount of rainfall from monsoon. The high northern and northwestern areas are out of monsoon reach so the climate is dry and precipitation occurs only due to western disturbances moving in from the west during winter. Sometimes, meso-scale convective systems develop due to heating in early summer and produce rain for a short period.

1. The present observation network on cryosphere (Snow cover, glacier, frozen ground, cold area hydrology)

Pakistan Metrological Department (PMD) and Water & Power Development Authority (WAPDA) are the main agencies having network for continuous monitoring of metrological and hydrological data in Pakistan. In addition to these government agencies, some international agencies have also established monitoring stations. A brief of monitoring agencies is as follows:

- Pakistan Meteorological Department (PMD) is a federal agency with a mandate to monitor and analyze meteorological data. It maintains a network of about 200 metrological stations across the country. In northern areas, the station elevation varies from few hundred meters to 2700m above mean sea level. These stations record data round the clock and transmit to the headquarters of PMD through V-Sat or SSB or wireless.

- During 1990, WAPDA in collaboration with International Development Research Centre (IDRC) and Canadian International Development Agency (CIDA) set up a program of snow and ice measurement in northern Pakistan, consisting of a network of automatic climatological stations. This consists of 18 automated stations at remote locations in Himalaya, Karakoram and Hindu Kush (highest at Khunjerab pass at 4420 m) which transmit data of precipitation, temperature, wind speed and direction, atmospheric pressure, relative humidity and solar radiation via meteor burst transmission to WAPDA headquarters in Lahore (Rizvi, 2001).

- Surface Water Hydrology Project (SWHP) of WAPDA operates and maintains a network of standard climate stations as shown in figure 1, out of which few are operational for as long as 30 years e.g. Yugo, Kachura, Doyien, Besham and Karimabad.

- Ev-K2-CNR maintains two Automatic Weather Stations at Urdukas and Askole, Karakoram under the network of **S**tations at **H**igh **A**ltitude for **R**esearch on **E**nvironment in Asia (SHARE-Asia). They have plans for installation of additional stations in Pakistan. These stations are now managed and maintained by PMD under MoU recently signed between the two organizations.

- Streamflow measurement in northern Pakistan (Figure 1) is carried out by the Water and Power Development Authority – Surface Water Hydrology Project (WAPDA-SWHP) with the earliest records commencing in 1960.

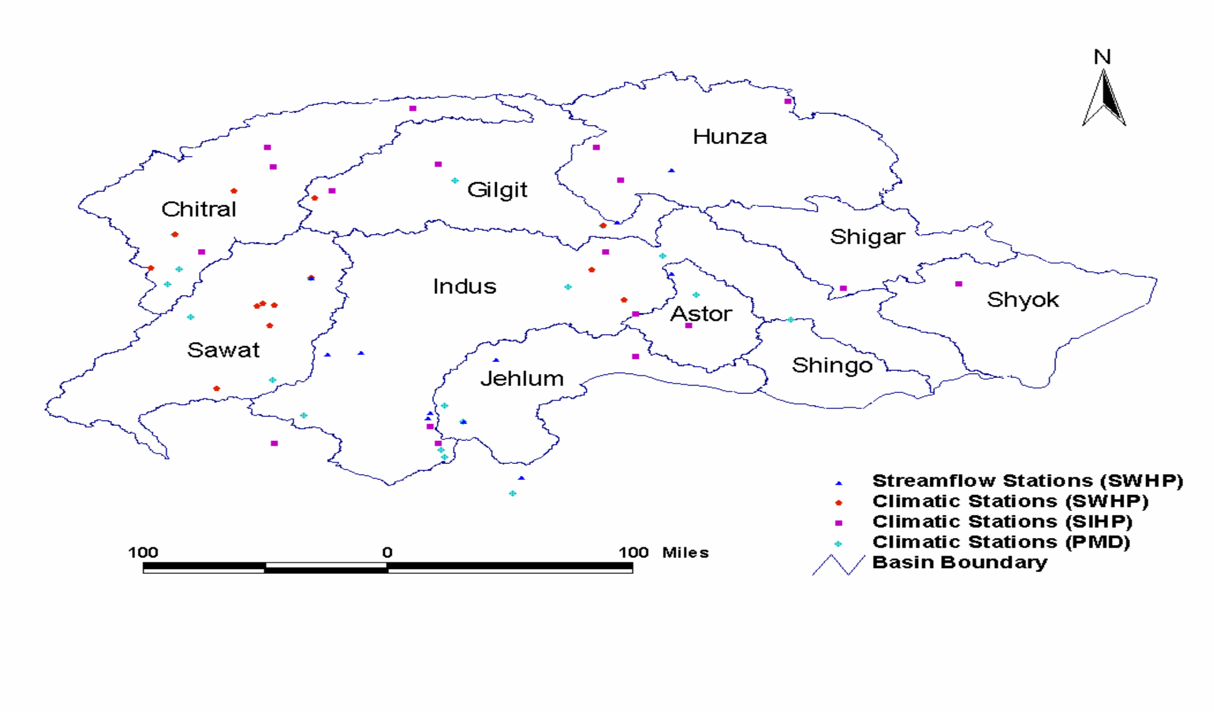

Fig.1 Metrological station from different agencies in the Gilgit River Basin, Pakistan

1. Organizations and projects related or can contribute to "Climate and Cryosphere".

- **Snow and Ice Hydrology Project (SIHP)**

  In the 1990s, the International Development Research Center (IDRC), CIDA and WAPDA, under the Snow and Ice Hydrology Project (SIHP), set up a program of snow and ice measurement in northern Pakistan. The aim of these stations is to develop a snowmelt forecasting system to estimate water inflows to Mangla and Tarbela, as well as into Kabul River.

- **Pakistan Metrological Department**

  Pakistan Meteorological Department has establishment a High Altitude Research Unit in Research and Development Division in collaboration with Ev-K2-CNR of Italy and China Meteorological Administration. PMD would provide the common plateform to Pakistani scientists of various disciplines to undertake collaborative research with participating organizations. PMD has been maintaining archives satellite and river discharge data in addition to meteorological data. High Resolution NOAA image HRPT has regularly been received since 1990. Now ground receiving station for Chinese Satellite Feng Yuan (FY-2d) has also been established at R& D Division of PMD to receive the image directly. Chinese colleagues will provide the previous images archived at home station for research purpose.

- **Water Resources Research Institute (WRRI), National Agricultural Research Center (NARC), Islamabad**

  WRRI-NARC is engaged in a project whereby it aims to do a complete inventory of glaciers and glacial lakes in the Northern Areas. Northern Areas have been divided into ten river sub-basins of Upper Indus basin. Using SRS data (Landsat ETM+) the inventory was completed and a comprehensive database of glaciers of Karakoram, Hindu Kush and Himalaya was developed.

- **Pakistan Council of Research in Water Resources (PCRWR)**

  A project entitled “Development of an Assessment System to Evaluate the Ecological Status of Rivers in the Hindu Kush-Hymalayan Region” has been launched by PCRWR. It includes the chain of activities to monitor water quality to gauge extent of pollution. In addition to water sample analysis, diversity of macro-invertebrates and rapid bio-assessment are the two major tools to monitor river water quality.

- **Global Change Impact Study Center, Islamabad**

  This group is also studying climate change and its impact on water and agricultural resources in Pakistan, including the Northern Areas. Through various models they are looking at how much water is coming from glaciers and from precipitation and predicting how climate change on a regional basis could affect these parameters which in turn would affect water usage and crop cultivation downstream.

- **Ev-K^2-CNR**

  Stations at High Altitude for Research on Environment in Asia (SHARE-Asia) grew out of Ev-K^2-CNR Committee’s expertise in high altitude and remote area climate research in Himalayan since 1990. The network has been expanded to Pakistan's Karakoram Mountains by automatic weather station at Baltoro glacier Urdukas and Askole near K^2. Plans for installation of additional stations in Pakistan and expansion to Tibet are underway. The main objectives of SAHRE-Asia are to acquire knowledge on high altitude climate in Himalaya and Karakoram, to study the complex mechanism of interaction between the local and synoptic atmospheric circulation; to contribute to studies to energy and water balance; and to improve comprehension of the mechanisms governing long-range pollutant transport. PMD and Ev-K2-CNR have signed an agreement for collaborative research on H_K_H (Hindu Kush-Karakoram-Himalaya) glaciers.

- **Sustainable Policy Research Institute, Islamabad**

  Although this research was not confined to the Northern Areas, yet it examined the impact of climate change on forestry and demand and supply of water in Pakistan with and without climate change over the next 50 years. The assumed change was an increase of 0.90C by 2020 and 1.80C by 2050 and a precipitation change of 3% by 2020 and 6% by 2050 (Khan, 2000).

- **Asia Pacific Network for Global Change Research, Japan**

  This is an inter-governmental network for the promotion of global change research in the Asia-Pacific region. Under its auspices a project was started in 2002 titled "Water resources in South Asia: an assessment of climate change associated vulnerabilities and coping mechanisms." The principle aims of this project are to analyze recent climatic variability and extreme events and their impact on water resources, and to assess the impact of projected climate change and associated extreme events on the water resources of the countries.

- **International Water Management Institute, Lahore**

  IWMI conducted a study whereby it searched various components of the water cycle in the Northern Areas to find clues for climate change (Khan, 2001). The assumption of this study was that a change in climate has a magnified affect on hydrologic time series. It analyzed temperature and precipitation data for 30 years, in monthly time step, from seven stations in the Indus catchment upstream from Tarbela, including Gilgit and Skardu. Monthly inflows into Tarbela reservoir for the same period were also analyzed.

3. Essential or urgent issues (observation, scientific studies) related to "Climate and Cryosphere" in your country.

Present studies conducted in the Northern Areas have studied indicators of climate change such as change in temperature and precipitation, vegetation trends and glacial retreats and surges. Some of them have tried to establish links between observed variables and climate change but so far such studies are sporadic. Research on a more consistent basis and larger scale is needed because if climate change is indeed taking place then that will have repercussions on the hydrology and forests of the region which in turn will be important in determining water management and flood risk assessment and mitigation strategies in the country. The following gaps and research needs have been identified and recommended:

- **Gaps in Data**
  - **High Altitude Climate**

    More extensive observations and recording of climate variables in the area need to be conducted. While there are many such recordings from lower elevations, many of them for a long period of time, there is a need to collect reliable climatic data in the higher regions.

  - **Snow and Ice data**

    More reliable data on ice and snow needs to be collected and analyzed. Although the Snow and Ice Hydrology Project of WAPDA has made an attempt in this direction, the data generated via this source is still not very reliable and is also rather scattered. It also needs to get data from elevations higher than 15,000 ft since this is about the limit for the present stations.

  - **Glacier data**

    Glaciers should be studied in greater depth, especially whether they are retreating or advancing and establish a cause for such phenomena, climatic or otherwise. In this regard some research has already been done but the picture is unclear at the moment. More primary data needs to be generated from a variety of locations in Northern Areas to get a clear picture. Furthermore, a better mechanism is required to estimate the ice reserves of the glaciers. A multi-organizational/ multi-national approach may work well to establish a denser observational network in the area of interest.

- **Climate Change and Forests**

  Since forests are expected to be critically affected by climate change, there is a need to find how and to what extent forest resources are susceptible to the projected climate change. Furthermore the implications of climate change on agriculture and agro-forestry in the region also need to be studied. Such research does not exist so far.

- **Climate Change and Global Phenomena**

  Detailed analysis of links between observed climatic variables and global phenomena such as El Niño, La Niña and the North Atlantic Oscillations (NAO) needs to be done. Some researchers have tentatively explored this subject and have found evidence for temperature and precipitation differences between El Niño and non-El Niño years, but more studies need to be conducted in this regard.

4. Other matters you think important to notify to the international community

Although there is not extensive literature and data on climate change in the Northern Areas, yet some research in this area does exist and some is underway. Study of climate change involves looking at trends in temperature, precipitation, glacial movements and vegetation changes, among others and linking them to global or regional causes. Therefore mountain areas such as the Karakorums and Himalaya region of Pakistan could prove to be a good laboratory for studying climate change. Here are some suggestions:

- **Systematic & Consistent Research**

  Climate change in the region needs to be studied more systematically and intensively because changes in precipitation and/or temperatures would have significant impacts on river flow rates, flood risk assessments, dam management, forests and forest management, and overall ecology of the region. Research should be conducted systematically and consistently on detecting trends in parameters of climate change such as temperature, precipitation, changes in vegetation or glaciers.

- **High Altitude Data**

  Greater emphasis should be placed on gathering higher altitude data on temperatures and precipitation changes because presently there is almost none. Reliability of such data should also be an important consideration when planning for the higher altitudes. Data on ice and snow conditions in the upper reaches of the mountains, that is, above 15,000 ft, should be gathered in order to get a complete picture of climate change in the region.

- **Glacier Data**

  Glaciers behavior and surges should be examined in greater detail and causal connection made with climate change. In this research a section could be devoted for documenting the view of people living around glaciers who could give anecdotal evidence of their movements over the span of their memories.

- **Better Coordination**

  There needs to be greater coordination and data sharing among various organizations and institutions doing climate change research, and also with international organizations and neighboring countries like China, Nepal and India. There should be frequent coordination/evaluation meetings to review the progress. This would enhance greater uniformity in data collection and methodology and provide for greater input into the interpretation of collected data.

- **Focal Agency**

  No major agency in Pakistan has the clear mandate of analyzing the climate change impacts in the country. However, different departments and individuals carried out few studies from time to time. Regarding glacier studies in the Karakoram region, many of these have been done by international organizations/researchers and there is no central repository for data/information generation. Therefore, a central/focal agency with a clear mandate should be constituted. In case of absence of focal agency, a committee needs to be formulated, responsible for providing guide lines, coordination and evaluation of these studies carried out under different departments.

  WRRI-NARC can serve as a focal agency because of multi-disciplinary team and its diverse research background. The Institute has a good facility and expertise in RS and GIS applications which is well proven by its outputs. There is a reasonable dataset on water resources, climate and mountain environments already available with the institute which can provide a base for initiating climate change studies. Being as a national institute, it is already well linked with several other research and development institutions as well as national and international NGOs.

- **Manpower Training**

  Pakistan lacks in trained and research oriented manpower. International community is requested to facilitate local scientists for professional training and research.

Snow and Glacier Activities in Nepal Himalaya

Arun B. Shrestha[1]

1 Department of Hydrology and Meteorology, Nepal

Introduction

The Himalayan region of Nepal is the home to 8 of the 10 highest mountain peaks in the world, including Mount Everest (8848 m a.s.l.) and contains larger numbers of glaciers. There are 3252 glaciers in Nepal covering a total area of 5323 km^2. (ICIMOD/UNEP, 2001). These glaciers are huge reservoirs of freshwater in frozen form which maintain perennial flow of major rivers of Nepal, such as Koshi, Gandaki, Karnali and Mahakali. A large proportion of the people living in downstream areas rely on these freshwaters to sustain their lives and livelihoods. Melt water generated by the glaciers are the only reliable source of freshwater which supply clean water for drinking, cooking, washing and industrial uses in the downstream areas. Moreover, a reliable supply of water in the high-energy mountain rivers and streams are extremely important for hydropower development and other water resources development in the area.

However, in recent decades global warming has brought some unprecedented changes in glaciers of Nepalese Himalaya. Studies have indicated that majority of glaciers are retreating in the wake of recent global warming and resulting climatic changes. Sixty-seven percentages of glaciers are retreating at a startling rate in the Himalayas and climate change has been identified as the major causal factor (Kadota and Ageta, 1992; Yamada et al., 1992). Retreat of Himalayan glaciers has raised serious concern with regard to future availability of freshwater in the region. At the same time, retreat of Himalayan glaciers has resulted into the formation of glaciers lakes at their terminus. Being dammed by unconsolidated weak natural moraines, these glacier lakes pose potential risk of their catastrophic failure, causing a huge flash flood in the downstream areas commonly known as Glacier Lake Outburst Flood (GLOF). GLOF is a relatively new kind of natural hazard in the Himalayan region which has emerged as direct consequence of ongoing warming. It is estimated that out of the 2,315 glacial lakes in the Nepalese Himalayas, 20 are potentially dangerous (ICIMOD/UNEP, 2001). Since 1935 Nepal has experienced more than 15 such GLOF events, which has become even more frequent in recent times. Besides human population developmental infrastructures such as hydropower, irrigation and drinking water supply projects are particularly vulnerable to such events.

Snow and glaciers play a very important role in the development of water resources of Nepal. Proper assessment of these natural resources is inevitable for the development of water resources of the country. This is particularly important in the present context when widespread glacier retreat is indicating the impending threat of a potential water shortage. Besides, the issue of GLOF hazard has also emerged as a serious threat to the water resources development. A clear cut understanding of the scientific basis of the processes that are taking place in glacier basins in high mountain areas is therefore a key factor for the development of huge water resources of the country. Understanding the scientific basis of the processes obviously demand a comprehensive database and accurate information.

Realizing these facts, Department of Hydrology and Meteorology (DHM) as an implementing agency of His Majesty's Government of Nepal, initiated "Snow and Glacier Hydrology Project" in 1987. The primary objective of the project is to gather information and build up a database concerning snow and glaciers in the country through establishment of network of hydro-meteorological stations in higher Himalaya. These information and database are to be used by the end user working in the relevant areas such as water resources, disaster management, tourism and others. Since its inception, besides operating the stations, DHM has been conducting measurements and research work in glacier basin which involve wide ranges of disciplines such as meteorology, hydrology, glaciology, topography, limnology, geology, geophysics, geomorphology etc.

Activities:

Collecting hydro-meteorological data

So far, 6 hydro-meteorological stations have been operating in higher Himalaya. The stations are situated at different location in Higher Himalaya stretching from Makalu in the east to Humla in the west. These stations are equipped to collect following parameters:

- Air temperature
- Relative humidity
- Precipitation
- Solar radiation
- Wind speed and direction
- River stage and discharge

These stations are both semiautomatic and automatic type. Data collected from these stations are being regularly published in book format.

Snow survey and snow measurement

Snow survey and snow pit measurements are conducted in 3 stations, namely, Khumbu, Langtang and Annapurna. Data collected from these measurements are later analyzed for estimating Snow Water Equivalent (SWE) as well as for estimating glacier accumulation. However this activity has not been conducted in a regular and continuous manner

Glacier mass balance measurement and monitoring

Glaciers are perfect indicator of climate change as they grow and shrink in response to changing climatic conditions. Mass balance measurement is the basic tool to monitor and evaluate the overall state of a glacier. A negative mass balance indicates a depleting ice reserve while a positive mass balance is the indication of growing glaciers. However, mass balance measurement of glaciers in High Mountain areas has often been hindered by remote location, difficult terrain and in many occasion due to lack of financial resources. There had been few mass balance measurement works conducted in the past by Japanese researchers in collaboration with DHM; however, they are not continuous and limited to one or two locations only. ICSI provided training to ten technicians from Nepal to conduct mass balance survey. Nepal has yet to decide on benchmark glaciers for long-term monitoring.

Another tool for glacier monitoring is Remote Sensing (RS) technique. There had been works in the past in which RS technique were used to assess the long term glacier fluctuation. But again they were limited to small areas; and the entire works were hindered by the difficulty in acquiring the Satellite Imageries as well as their high cost. Efforts are underway to bring up a long term mass balance measurement project through financial assistant of international agencies working in the similar areas. Currently, DHM with support from UNESCO/IHP has started a project on Rs and geographical information system (GIS) based study of snow cover area, glacier area and snowline elevation in Nepal.

Snow and glacier melt runoff modelling

Hydro-meteorological data collected from stations in glacier basin of Himalaya allows the application of wide range of empirical and mathematical models for the simulation and at a later stage forecast of snow and glacier melt runoff in mountain rivers as well as the regionalization of the specific basin runoff as an important basin parameter for the planning of water resources projects. Reasonable results have so far been achieved with the application of a parametric conceptual runoff model (HBV3-ETH) which is based on temperature and precipitation as input variables and a set of internal model parameters. The model simulates daily runoff from the Imja Khola basin in Khumbu, Langtang Khola basin in Langtang and Modi Khola basin in Annapurna region. Depending on the availability of data the model can be applied to other glacier basins in High Mountain areas.

Recently DHM and World Wildlife Conservation Fund-Nepal (WWF-Nepal) imitated a project titled "Climate change impact in Khumbu Region and identifying impacts of various sectors" (CCIKRIIVS). The objectives of this project are to study climate change impact assessments on glaciers, Freshwater vulnerability, and development of adaptation strategies.

Discharge measurement in high mountain rivers

The determination of discharge from snow and glacier fed rivers in the Nepalese Himalaya is of prime importance for the estimation of snow and glacier melt runoff needed for the improved water resources management. Because the conventional current meter method is not suitable to measure discharge in many steep rivers in High Mountain areas of Nepal an operational tracer measurement system, consisting of field and laboratory equipment, has been introduced first time in Nepal through Snow and Glacier Hydrology Project. Considerable discharge measurements data have so far been collected with the application of this technique. Combining these data with river stage data, rating curves have also been prepared for few stations.

Monitoring of potentially dangerous glacier lakes

There are 2,315 glacier lakes of various sizes in Nepal Himalaya, the total area of which is 75 km^2. Among them 20 glaciers lakes have been identified as potentially dangerous (ICIMOD/UNEP 2001). Past field investigation have identified few glacier lakes as potentially dangerous and recommended to adopt appropriate mitigation measures to minimize the possible damage in the event of a GLOF. These glacier lakes are Tsho Rolpa in central Nepal, Imja and Lower Barun in eastern Nepal and Thulagi in western Nepal Himalaya.

The importance of Glacier Lake studies in Nepal was realized only after the outburst of Dig Tsho Glacier Lake in the Khumbu region of eastern Nepal in 1985, which inflicted heavy losses to lives and properties including developmental infrastructures in the downstream areas. After this event Glacier Lakes and GLOF phenomenon were realized as a potential threat to the water resources development of the country. The event highlighted the gravity of this problem which led to the initiation of systematic study of glacier lakes and GLOF phenomenon in Nepal. As part of ongoing studies on glacier lakes, Department of Hydrology and Meteorology/HMGN in collaboration with German and Japanese Government; carried out several field studies of glacier lakes such as Thulagi in western Nepal, Tsho Rolpa, Imja and Lower Barun in eastern Nepal. The multidisciplinary field studies comprised of disciplines such as hydrology, glaciology, engineering geology, geophysics, topographic survey, geo-radar and geo-thermics. The objective of these studies has been to assess existing situation of the lake from the prospective of a GLOF and its potential impact on downstream areas.

The study of Thulagi Glacier Lake concluded that the lake is safe for another 50 years while the studies of Tsho Rolpa, Imja and Lower Barun revealed that these lakes are potentially dangerous and recommended to adopt some appropriate mitigation measures.

Tsho Rolpa Glacier Lake: This is the only glacier lake in Nepal Himalaya where mitigation measures have been adopted. Lake level has been lowered by 3 m on 2002 by constructing a canal structure at the end moraine of the lake. It has reduced the GLOF risk to some extent; however, the risk has not been completely eliminated.

Imja Glacier Lake: This is second dangerous glacier lake after Tsho Rolpa. Field investigations had shown that the lake is expanding rapidly and recommended to continuously monitor the lake unless some effective mitigation measures are adopted.

Lower Barun Glacier Lake: On the basis of field investigation made more than a decade ago, this lake had been put on the list of potentially dangerous glacier lake. However, a detailed investigations need to be made to assess the present situation.

Although the DHM has been conducting some studies on glacier lakes since last few years the information collected so far are still not adequate to draw any conclusions regarding their vulnerability. A more detail nationwide glacier lake studies and monitoring work need to be initiated with the aid of more sophisticated techniques such as Remote Sensing. Studies of this kind will eventually help assess GLOF hazard which is an important prerequisite while formulating water resources development projects in the country. Lack of adequate financial and human resources have been a major hindrance towards fulfilling these goals.

Future Plan

Recently approved National Water Plan (NWP) of HMG/N has included collecting, process and disseminating all hydro-meteorological information in the country. Further, it has clearly mentioned the importance of snow and glacier to the water resources development of the country particularly for managing water induced disasters. In order to address the issue of climate change to the water resources development of the country, the NWP has envisaged a separate research body within DHM, namely, "Himalayan Climate Change Study and Research Centre."

In this context, future activities will be mainly focused on conducting a nationwide scientific research on snow, glacier and glacier lakes to assess their vulnerability to climate change and potential impact they might impart to the water resources of the country. In order to achieve this goal following activities have been planned in future:

- Strengthen and extend existing network of hydro-meteorological station in higher Himalaya
- Provide relevant organizations and individual quality data and information relating to snow and glaciers.

- Initiate a nationwide long term glacier mass balance studies including long term monitoring of glaciers fluctuation in Himalaya.
- Initiate a systematic monitoring of potentially dangerous glacier lakes in High Mountain areas. Based on the long term monitoring vulnerability assessment of the lake will be made. Further, appropriate mitigation and adaptation measures will also be devised to minimize the risk of GLOF from these glacier lakes.
- Snow Melt Runoff Modelling work will be extended further to cover major glacier basins and sub-basins. Besides improving existing model, more sophisticated and state-of -the art model will be introduced for the accurate assessment of melt discharge in Mountain rivers.
- Research tools such Remote Sensing and GIS will be extensively adopted for studying glacier and glacier lake monitoring.
- Efforts will be made for the capacity building of the manpower by updating them with modern and sophisticated technologies and research methodologies through short term and long term trainings.