

WORLD METEOROLOGICAL ORGANIZATION GLOBAL CRYOSPHERE WATCH

REPORT No. 12



FINAL REPORT OF THE CRYONET ASIA WORKSHOP, SECOND SESSION

Salekhard, Russian Federation
2-5 February 2016



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Weather · Climate · Water



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EXECUTIVE SUMMARY

The second Session of the CryoNet/Asia Workshop was held at the Administration of Yamal-Nenets Autonomous Okrug (YaNAO). The workshop was organized jointly by the Arctic and Antarctic Research Institute (AARI) of Roshydromet, and the YaNAO.

There were 38 workshop participants, including scientists from 10 Members of WMO Regional Association II (RA-II) and some GCW experts from other Regions.

An overview of local scientific activities undertaken in the Salekhard region was given. The workshop particularly noted with appreciation support of YaNAO, the Russian Academy of Science and Roshydromet with regard to the proposal to include Belyi island scientific station to the CryoNet ([Annex 10](#)).

The participants were briefed about the status of the GCW implementation, including the GCW Working Structure, and the role and status of the GCW Steering Group. They also received an overview on CryoNet and the current status of the network. The key objectives of CryoNet were highlighted and the timeline of previous CryoNet meetings were shown. The following key tasks of CryoNet were discussed in detail (i) the concept of CryoNet stations and sites; (ii) the GCW station proposal; (iii) the minimum requirements for CryoNet stations; (iv) the initial list of CryoNet sites for the pre-operational testing; and (v) assessment and selection of CryoNet Sites with 36 Sites currently under evaluation.

The workshop noted with appreciation that the GCW data portal is available at <http://gcw.met.no/> in pre-operational form. Harvesting of metadata from 6 data centres was achieved, and the development of a WMO Information System (WIS) Data Collection and Production Centre (DCPC) is underway. Accessibility of metadata and data from 3 CryoNet sites was also initiated.

The workshop then reviewed the outcome of the first CryoNet Asia Workshop (Beijing, China, 2013), and of the first CryoNet South America workshop. The workshop expressed concerns that not all countries with potential interest in the GCW have been represented at the first and second CryoNet Asia workshops. The workshop invited participants to make direct contacts with those countries in the view to have national focal points nominated.

The workshop received national and provincial oral reports from China, Japan, Kazakhstan, Kyrgyzstan, Mongolia, Nepal, Pakistan, the Russian Federation, Tajikistan, and Uzbekistan. The information presented was useful for the project to further develop and for the planning of new stations and sites in Asia and the other regions of the world in the framework of GCW. The workshop noted that negative mass balance of many glaciers has been observed in Asia in the last few decades. It stressed that some focus should be placed on the Third Pole region because of the potential impact of cryosphere (snow and glaciers) changes on water resources due to climate change. GCW data should eventually be useful to facilitate adaptation measures. The GSG was invited to address this issue.

An overview of the CryoNet Sites Questionnaire was given together with the GCW Site evaluation and approval process. Participants in the Salekhard workshop were encouraged to complete and submit questionnaires for the stations they proposed.

The workshop was then introduced to the WMO Rolling Review of Requirements process, and methodology to assess gaps. The workshop identified some gaps with regard to cryospheric measurements by component (snow, glaciers, ice sheets, permafrost, sea ice, lake ice, solid precipitation) in the Arctic, sub-Arctic, and High Mountain regions of Regional Association II. The workshop noted that in Asia, there is currently only very sporadic

meteorological and cryospheric information available from high elevation regions over 4000-5000 m a.s.l. The workshop agreed that efforts ought to be made in order to address those gaps, and proposed establishing an *ad hoc* Steering Group to set up a project for GCW measurements in high elevation regions in Asia.

The workshop received several overviews of existing projects, experiments and activities that are relevant to CryoNet Asia. They included the International Atomic Energy Agency (IAEA) Interregional technical cooperation (TC) Project “Assessing the Impact of Climate Change and its Effects on Soil and Water Resources in Polar and Mountain Regions”, the Danish Programme for the monitoring of the Greenland Ice Sheet (PROMICE), some long term mass and energy balance monitoring of Himalayan glaciers (France/Nepal), glaciers monitoring in the Polar part of the Urals mountains, the Central Asia Elevation International Geophysical (HEIGE) Project.

The workshop discussed potential new CryoNet Sites and Stations in the Arctic, sub-Arctic, and High Mountain regions in Asia. Seven (7) Sites were proposed for the Arctic and sub-Arctic region, and Twenty-Six (26) for the High Mountain region. The workshop requested the WMO Secretariat to liaise with the participants of the workshop as appropriate in the view to write to the Permanent Representatives of the corresponding countries if needed (Tables 2 and 3) to invite them to indicate whether they concur to include the proposed Sites/Stations in the CryoNet under evaluation.

Fieldwork at a site on the river Ob was organized on Thursday morning, 4 February, with the participants. The work was focused on the measurement of fresh water river ice, and snow.

The workshop discussed the status of the development of standards and best practices for cryospheric measurements used by the GCW. The workshop noted with appreciation that a draft of the structure of a new GCW guide to cryospheric practices is planned for completion in June 2016. The participants were invited to provide feedback regarding the standards and best practices used by WMO Members, particularly in Asia.

Finally, the workshop proposed establishing a regional CryoNet-Asia Working Group (WG/CryoNet/Asia) whereby its Chair would be reporting to the GCW Steering Group and the WMO Regional Association II. The Working Group should provide an overall coordination function for all CryoNet activities in Asia, and should particularly address regional best practices, help identify gaps and potential new stations in Asia, liaise with other regional working groups (e.g. South America), and report to RA-II and the GCW Steering Group (GSG). The Workshop agreed that the membership of the Working Group should include representatives of the Arctic, sub-Arctic, High Mountain/Tibet, High Mountain/Tibet/Pamir, and High Mountain/Himalaya.

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WORKSHOP REPORT

1. ORGANIZATION OF THE SESSION

1.1. Welcome and opening of the session

1.1.1. Dr Vasily Smolyanitsky (Russian Federation) opened the Second Session of the CryoNet/Asia Workshop at the Conference Hall of the Administration of Yamal-Nenets Autonomous Okrug (YaNAO). The workshop was organized jointly by the Arctic and Antarctic Research Institute (AARI) of Roshydromet, and the YaNAO.

1.1.2. Opening remarks were then given by the following officials:

- Dr Alexandr Mazharov, deputy governor of YaNAO (see [Annex 4](#) for the text of the opening address of Dr Mazharov);
- Dr Alexandr Danilov, the Arctic and Antarctic Research Institute deputy director on behalf of the Dr Alexander Frolov, Head of Roshydromet, and Permanent Representative of the Russian Federation with the WMO;
- Mr Etienne Charpentier (WMO Secretariat) on behalf of the Secretary General of the WMO, Dr Petteri Taalas.

1.1.3. During the opening remarks, the following points were mentioned:

- The Seventeenth World Meteorological Congress decided that Polar and High Mountains regions activities is one of the seven priority-funded activities within the WMO Strategic Plan for 2016-2019, together with the WMO Integrated Global Observing System (WIGOS), Disaster Risk Reduction, the Global Framework for Climate Services (GFCS), Aviation meteorological services, Capacity development, and WMO Governance. The WMO Global Cryosphere Watch (GCW) falls directly in the Polar and High Mountains region priority activity, guided by the Executive Council Panel of Experts on Polar and High Mountain Observation, Research and Services (EC-PHORS), while contributing substantially to the other priority activities.
- GCW will help us understand, assess, predict, mitigate, and adapt to climate variability and change and improve weather forecasting and hazard warnings, thus helping reduce the risk of loss of life and property from natural and human-induced disasters. It will contribute to improved management of energy and water resources, including flood forecasting and hydropower production, help support sustainable agriculture, and improve our ability to monitor and conserve biodiversity. For example, cryosphere information is required for infrastructure design in cold climates, improved management and protection of terrestrial, coastal and marine ecosystems, and an improved understanding of environmental factors affecting human health and wellbeing.
- WMO Congress decided to engage in the pre-operational phase of WIGOS with five priorities: (1) complementing the WIGOS Regulatory Materials with the necessary guidance material, (2) further development of the WIGOS Information Resource with special emphasis on OSCAR, (3) development and implementation of the WIGOS Data Quality Monitoring System, (4) concept development and initial establishment of Regional WIGOS Centres, and (5) national WIGOS implementation.

- WIGOS and most of the WMO priority activities, including the WIGOS pre-operational phase priorities are relevant to the work of GCW, and development of CryoNet in particular. Indeed, Congress decided that the GCW surface-based measurement sites referred to as “CryoNet” would be one of the four WIGOS component observing systems.

1.1.4. The following key accomplishments of GCW since the first CryoNet Asia Workshop (Beijing, China, 3-5 December 2013) were noted:

- (i) adoption of the GCW Working Structure, and initiation of the implementation phase (2016-2019) of GCW;
- (ii) GCW Regulatory Materials have been included in the WMO Technical Regulations and WIGOS Manual;
- (iii) the inventory of the Snow Watch products, which is available on the GCW website has been developed;
- (iv) good progress with regard to the development of the CryoNet whereby Design Principles consistent with WIGOS have been developed, Sites/Stations concept and procedure for site selection have been proposed, including evaluation criteria, and minimum requirements for CryoNet Sites have been proposed ([Annex 8](#)); Thirty-Six (36) CryoNet Sites have been identified for pre-operational testing and are undergoing evaluation;
- (v) the GCW Portal is progressing, and metadata from 6 sites are routinely harvested. A GCW Portal Interoperability Guidelines document and a GCW Portal Operations Manual have been drafted;
- (vi) on terminology, the GCW Glossary has been developed and is routinely being updated with new terms. There are now over 2900 terms, with 1600 being unique, from 21 different sources; and
- (vii) the GCW Website is completed, and includes comprehensive information on GCW.

1.1.5. There are key activities and challenges that the workshop is invited to discuss this week:

- Operationalizing GCW and establishing closer links between the operational and research communities in particular in Regional Association II;
- Proposals with regard to establishment of a GCW working structure at the regional level;
- Progress with regard to CryoNet Site selection in Asia;
- Contributions of Asian countries with regard to the development of GCW agreed practices, including at the regional level if needed;
- Contributing to the developing GCW terminology;
- Facilitating access to data (not just metadata) through the GCW Portal;
- Provision of CryoNet Sites/Stations metadata to OSCAR/Surface;

- Proposing mechanisms for assuring GCW contribution to the WIGOS Quality Monitoring System.

1.1.6. On behalf of the Organizing Committee, the Chair of the GCW Observations Working Group, Prof Wolfgang Schöner (Austria) welcomed all participants to the workshop, and expressed his appreciation for the commitment of the participants. He then conveyed his sincere appreciation to the Russian Federation Government, AARI and the Roshydromet, and YaNAO for preparing, hosting and organizing the Workshop.

1.1.7. Prof Schöner recalled the main objectives of the Workshop, i.e. to develop practical aspects of the implementation of CryoNet in Asia (WMO Regional Association II) based on the decisions of the Seventeenth World Meteorological Congress (Geneva, Switzerland, 25 May – 12 June 2015) and the GCW Implementation Plan. This includes, among others, (a) identifying new stations/sites that could become CryoNet or GCW contributing stations/sites in both terrestrial and marine environments in Asia; (b) compilation of national and regional cryospheric observing guidelines, practices and standards being used at proposed CryoNet Asia sites and stations; (c) examining advances in measurement techniques; and (d) discussing data policies.

1.1.8. The workshop noted that its recommendations can be submitted to the WMO Regional Association II Session in China in late 2016; and to the WMO Executive Council through the GCW Steering Committee (GSC) and the EC-PHORS, which will have its next meeting in early 2017.

1.1.9. The workshop was chaired by Prof. Schöner.

1.2. Adoption of the Agenda

1.2.1. The workshop adopted its Agenda, which is reproduced in [Annex 1](#).

1.3. Working arrangements, information for participants and material arrangements

1.3.1. The local organizer for the workshop outlined various local arrangements. The workshop agreed on its working hours and adopted a tentative work plan for consideration of the various agenda items.

1.4. Round-table introduction of participants

1.4.1. There were 38 participants, including GCW experts, and from 10 Members of WMO Regional Association II (RA-II), at the workshop. The participants introduced themselves, indicating their national duties and role in GCW as appropriate.

1.5. Introduction of local scientific activities

1.5.1. Mr Alexey Titovsky (Russian Federation) provided an overview of local scientific activities undertaken in the Salekhard region. In the light of dynamic industrial development of the region, science in YaNAO become of particular importance. Great attention is given to the development of local scientific basis, participation in the international projects, building up research teams, and realization of joint projects in cooperation with the Russian Academy of Science as well as universities.

1.5.2. Crucial parts of scientific activities in YaNAO are research expeditions and fieldwork. In order to create good conditions for carrying out field explorations and monitoring in remote sides of Yamal the network of scientific research stations is in the process of being established. The network includes research station on the Belyi Island, Bovanenkovo research station, Gydan research station, Sabetta research station, and also Nadym research station. Another aim is to modernize existing material and the technical base of scientific infrastructure in order to implement complex inter-disciplinary studies with the participation of foreign research teams. In general, further development of scientific infrastructure will open new gates for the scientific studies in the Russian Arctic.

1.5.3. The workshop noted with appreciation YaNAO's support with regard to the proposal to include Belyi island scientific station to the CryoNet (see also item 5.4, and [Annex 10](#)).

2. STATUS OF THE DEVELOPMENT OF GLOBAL CRYOSPHERE WATCH (GCW)

2.1. GCW Overview

2.1.1. Dr Key reported on the status of GCW implementation. The overview included GCW history, current activities, and status. Although there was no single program or project that led to the GCW proposal to the World Meteorological Congress in 2007, perhaps the one project most attributable to the "birth" of GCW was the Integrated Global Observing Strategy (IGOS) Cryosphere Theme. In any case, the 16th World Meteorological Congress (2011) decided to embark on the development of GCW as an IPY legacy, and the 17th Congress (2015) decided to mainstream and implement GCW in WMO Programmes as a cross-cutting activity.

2.1.2. The workshop noted that over the past few years the GCW framework has been refined, with a Steering Group, Working Groups, and Task Teams. See agenda item 2.2 for details. GCW is engaged in a number of activities, notably the development of the core surface observation network, CryoNet, examining measurement practices and observational requirements, inter-comparing products by the Snow Watch Team, and building a cryosphere glossary. The GCW Data Portal (<http://gcw.met.no>), developed and operated by the Norwegian Meteorological Institute, is currently in a "pre-operational" phase. The GCW website (<http://globalcryospherewatch.org>) is fully functional, providing information about GCW, information on the state of the cryosphere, and access to the glossary and other tools and databases.

2.2. Role and status of the GCW Steering Group

2.2.1. Dr Key also reported on the role and status of the GCW Steering Group (GSG), which is chaired by Árni Snorrason (Iceland), and vice-Chaired by Dr Barry Goodison (Canada). The GCW Steering Group (GSG) provides high-level guidance on the GCW development and implementation. It advises on the activities of its Working Groups and Task Teams. Furthermore, the GSG liaises with the GCW focal points and partner organizations, coordinates GCW activities in collaboration with the WMO Technical Commissions (TC), Regional Associations (RA) and Programmes, and reports annually to EC-PORS, including recommendations for GCW development and implementation for consideration by the WMO Executive Council and the WMO Congress.

2.2.2. The GSG is comprised of experts from the WMO Executive Council (EC)

Expert Panel on Polar and High Mountain Observations, Research, and Services (EC-PHORS), relevant WMO Programmes, Technical Commissions and co-sponsored programmes, and from partners and contributors. The fields of expertise of GSG members will encompass all the components of the cryosphere as well as ground observation, remote sensing and modelling communities. There are currently 15 GSG members from 15 countries. Members are listed on the GCW website at <http://globalcryospherewatch.org/about/gsg.html>.

2.2.3. The Global Cryosphere Watch has three Working Groups (figure 1):

- the **Observations Working Group**,
- the **Integrated Products Working Group**, and
- the **Information and Services Working Group**.

2.2.4. It was noted that Working Groups can establish Teams, as needed, to address the priority tasks defined in the work plans of the Groups. Initially, the Observations Working Group includes the CryoNet Team, the Best Practices Team, and the Solid Precipitation Team. The Integrated Products Working Group includes the Snow Watch Team, the Sea Ice Team, and the Glacier Team. The Information and Services Working Group contains the Portal Team, the Terminology Team, and the Website and Outreach Team. More information on working groups and teams is available at <http://globalcryospherewatch.org/about/teams.html>.

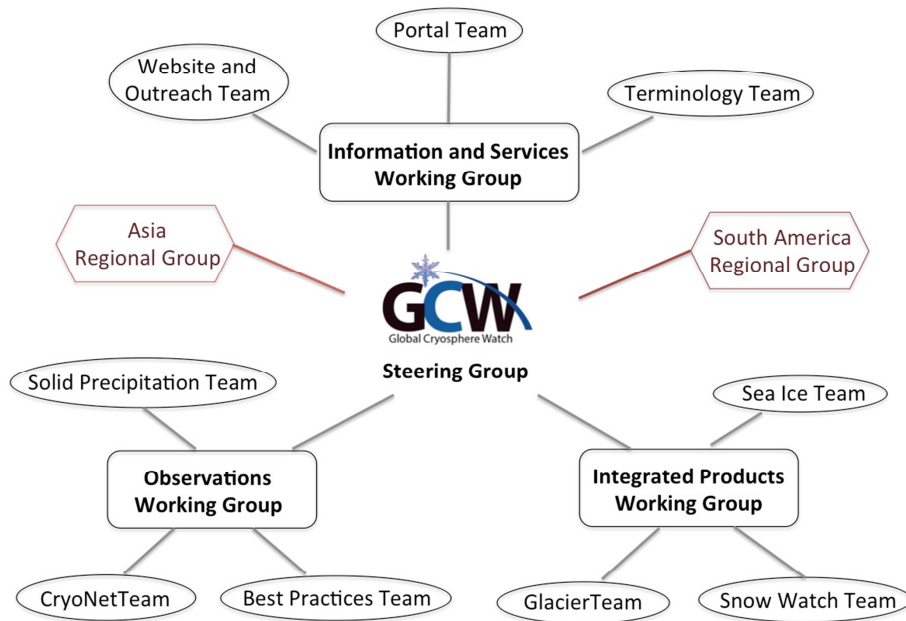


Figure 1: The GCW Working Structure.

2.3. Status report on CryoNet

2.3.1. Prof. Schöner gave an overview on CryoNet and the current status of the network. The key objectives of CryoNet were highlighted and the timeline of previous CryoNet meetings were shown. The following key tasks of CryoNet were discussed in detail:

- The concept of CryoNet stations and sites
- The GCW station proposal (see item 4.2 for details)
- The minimum requirements for CryoNet stations
- The initial list of CryoNet sites for the pre-operational testing
- Due to the complex structure of the cryosphere, the definition of the station/site concept and minimum requirements has been a long process. Thus the list of CryoNet stations/sites is initial and will be evaluated (based on the procedure described in the document of GCW station proposal) by the CryoNet team in 2016/ Q2-Q3. After that, the list, suggested by the CryoNet team, will go to GCW-SG, EC-PHORS and EC for final approval.

2.3.2. Prof. Schöner clarified the funding of the GCW, i.e. that implementation is funded on the national level, and that Secretariat support is provided by the WMO from its Regular Budget and from Voluntary contributions of WMO Members.

2.3.3. The workshop noted that the current 36 Sites under evaluation are not entirely representative of the global cryosphere, and more efforts are needed to identify additional Sites and Stations that will allow the improve such representativeness (e.g. bring more permafrost stations in CryoNet). Participants interested in proposing additional CryoNet stations were invited to fill in the Questionnaire on the GCW Website in order to have them evaluated and considered by the CryoNet Team and the GCG.

2.3.4. The meeting recommended that the CryoNet Team should proof if extended information, including data delivery mode, of the Cryonet Stations (see also discussion under 8) could be displayed on the Cryonet map (**action; CryoNet Team; December 2016**).

2.3.5. The meeting recalled the importance of the GCW, its purpose and objectives as detailed in the GCW Implementation Plan, which is available on the GCW Website.

2.4. GCW Data Portal

2.4.1. Dr Øystein Godøy (Norway) provided an overview of the purpose and current status of the GCW Portal. The workshop noted with appreciation that the GCW data portal is available at <http://gcw.met.no/> in pre-operational form. Harvesting of metadata from 6 data centres was achieved, and the development of a WMO Information System (WIS) Data Collection and Production Centre (DCPC) is underway. Accessibility of data from 3 CryoNet sites was also initiated. Workshop participants holding cryosphere data-sets were invited to collaborate with the Portal Team with the view to make such data-sets discoverable via the GCWP Data Portal if that is not already the case (**action; participants; ongoing**).

2.4.2. First draft versions of the GCW Portal Interoperability Guidelines, and GCW Portal Operations Manual have been developed and were circulated within the GSG and Portal Team before they can be made available to the GCW community.

2.4.3. The present version the GCW Portal is focusing on WIS type metadata, WIGOS type metadata interaction is under development, but implementation is pending development of machine interfaces/encoding (OSCAR/Surface – oscar-wmo.int – will become the official repository of WIGOS metadata as of May 2016). The current human interface was presented along with listing of data repositories with interfaces working or under development. Main challenges encountered include the availability of standardized interfaces to metadata, semantic annotation within metadata and interoperability at the data level. In order to progress on metadata ingestion, semantic capabilities are being developed. To meet the GCW requirements, data brokering capabilities are under development.

2.5. Outcome of the 1st CryoNet Asia Workshop

2.5.1. Prof. Cunde Xiao (China) reported on the outcome of the first GCW CryoNet Asia Workshop, which was hosted by the Chinese Academy of Sciences (CAS) and the China Meteorological Administration (CMA) in Beijing, China, from 3 to 5 December 2013. The meeting was organized by the CryoNet Team of the GCW Observing Systems Working Group and co-led by Prof. Xiao, Dr Key and Prof. Schöner. Seven experts from the China Meteorological Administration (CMA), 23 experts from the Chinese Academy of Sciences (CAS), and 17 international experts from 14 countries attended the workshop.

2.5.2. To stimulate initial thinking about the GCW CryoNet Asia prior to the workshop and to share participants' thoughts on the purpose and benefits, structure and scope of the network, participants were asked to answer a list of basic questions. Such as: (1) what is the goal of GCW? (2) what are the methodologies? (3) duplication and gaps: what is missing? and (4) how data will be made available?

2.5.3. Presentations were divided into 5 sessions: (1) CryoNet Asia: Objectives and Benefits; (2) Potential GCW Stations; (3) Potential GCW Stations in High Elevation Central Asia; (4) Potential GCW Stations Over High Latitudes of Asia; and (5) Observation / Measurements / Data.

2.5.4. Six station/sites in China were proposed for CryoNet, many other stations/sites of the Third Pole region outside China also expressed the willingness of being part of CryoNet.

2.5.5. There has been discussion about whether the Asia CryoNet group should be only limited to third pole region, or whether it should be for the whole WMO Regional Association II. Most participants agreed that Asia CryoNet should include both high latitudinal and high altitudinal stations/sites.

2.5.6. The Salekhard workshop expressed concerns that not all countries with potential interest in GCW were represented in the first and the second CryoNet Asia workshops (e.g. Iran). The workshop invited participants to make direct contacts with those countries in the view to have national focal points nominated (**action; participants; asap**). The Secretariat will then assist as needed for contacting the Permanent Representatives of those concerned countries with the WMO.

2.6. Outcome of the 1st CryoNet South America Workshop

2.6.1. Prof. Schöner reported on the outcome of the first CryoNet South America Workshop, which was held in Santiago, Chile, from 27 to 29 October 2014, with the attendance of 65 participants from 16 countries. GCW and CryoNet sessions were held during Days 1 and 2 with presentations from experts of all participating countries. On Day 3 field work was conducted at Valle Nevado and El Colorado ski resorts, 60 km east of Santiago, visiting snow and meteorological stations operated by University of Chile and DMC, and learning practical experiences of snow cover characterization.

2.6.2. The main objective of the 1st CryoNet South America Workshop was to identify stations/sites that could be selected for CryoNet in South America, discuss practices that should be applied and to foster the development of cryospheric activities in the region.

2.6.3. A final session on Day 2 was dedicated to the review of environmental regulations related to glaciers and the periglacial environment within the different countries represented in the Workshop, a topic of particular relevance to Chile in view of the glacier law initiative currently being discussed in Congress. The need for adequate cryospheric definitions was stressed in view of their legal implications.

2.6.4. The workshop noted the following agreements and action points that were concluded by the first CryoNet South America Workshop:

1. There is high interest in the region to contribute to the CryoNet initiative.
2. National Representatives of CryoNet South America will be initially selected among the invited participants, in coordination with the national IACS correspondents.
3. Gino Casassa, National Representative for Chile, will follow up on item 2.
4. Each National Representative will contact the respective agencies, institutions and colleagues to remind them to complete the site questionnaire before 25 November 2014.
5. A Regional Group will be formed by consensus from the National Representatives.
6. Mexico will be included in the group, and the name CryoNet Latin America will be proposed.
7. Potential collaboration with the Latin America and the Caribbean (LAC) regional section of the International Hydrological Programme (IHP) of UNESCO will be proposed to the Snow and Ice Working Group of LAC.
8. A 2nd South America meeting is proposed to be held in the 2nd half of 2015.
9. The Regional Group will follow up on items 6, 7 and 8.

2.6.5. The discussion of potential stations of CryoNet South America concentrated on the following topics:

- Should we focus on the Andes as one region, or by three climate zones – tropical, dry, and wet Andes?
- Should Antarctic stations/sites operated by South American countries be part of South American CryoNet or Antarctic CryoNet?

- Is Mexico part of this region or part of North American region?
- Is South American boundary equivalent to WMO RA II countries (like Asia)?

2.6.6. The participants proposed Eighteen (18) stations and sites for inclusion in CryoNet.

2.6.7. Further discussion points included data archiving, data policy and data sharing, the further building of CryoNet South America, and the management of the CryoNet South America.

3. CRYOSPHERIC ACTIVITIES IN ASIA

3.1. Presentations by participants from Asia

3.1.1. National and province representatives were invited to prepare and present a brief report about the state of the cryosphere observations in their home country or province, including information on the past and current observations and research such as:

- (a) Meteorological and synoptic observations at high altitudes above 2000 m a.s.l. - data from long-term meteorological stations operated in past and currently active; the list of measured parameters; the frequency of observations (i.e., every second, every minute, every hour, every three hours, etc.)
- (b) Monitoring of seasonal snow cover - snow depth, snow density, and snow water equivalent, changes in snow area during a year (dynamics of snow line) from the date of snow appearance and disappearance. This applies to the data from meteorological stations, avalanche stations, monthly ground snow surveys, aerial (helicopter) snow surveys, and the modern satellite monitoring data, etc.
- (c) Monitoring the state of permafrost (cryolithic zone), changes in the area, fluctuation of temperature and the active layer thickness, etc.
- (d) The area of glacier changes obtained from high resolution topographic maps, aerial photography, photogrammetry and geodetic surveys in the past, and measurements based on modern high resolution satellite images georeferenced with the ground control points (GCPs), measured glacier mass balance (ablation and accumulation), glacier surface velocity and glacier surface elevation changes

3.1.2. The information presented was useful for the programme to further develop and for the planning of new observations in Asian and the other regions of the world in a framework of GCW. Written reports have been submitted in advance of the Workshop by Japan, Mongolia, Nepal, Pakistan, and Uzbekistan.

3.1.3. This national and province reporting session was chaired by Prof. Cunde Xiao (China). Ten oral presentations were made by:

- China (presentation by Prof. Cunde Xiao)
- Japan (presentation by Dr Katsuhisa Kawashima).
- Kazakhstan (presentation by Ms Larissa Kogutenko).

- Kyrgyzstan (presentation by Mr Ryskeldi Asankhodzaev).
- Mongolia (presentation by Dr Gombo Davaa).
- Nepal (presentation by Mr Bikram Shrestha Zoowa).
- Pakistan (presentation by Mr Kamal ud Din).
- Russian Federation (presentation by Dr Vasily Smolyanitsky)
- Tajikistan (presentation by Mr Taghoybekov Abdurashid).
- Uzbekistan (presentation by Mr Klimentiy Valiev)

3.1.4. The workshop noted that negative mass balance of many glaciers has been observed in Asia in the last few decades. It stressed that specific focus should be placed on the Third Pole region because of the potential impact of cryosphere (snow and glaciers) changes on water resources due to climate change and because of impact of cryosphere changes on atmospheric circulation and thus weather patterns in the region. GCW data should eventually be useful to facilitate adaptation measures. The GSG was invited to address this issue (**action; GSG; asap**).

3.1.5. The workshop also stressed that access to cryospheric data from the region is essential for many applications and products (e.g. weather forecast, hydrological forecast), and invited the participants to discuss nationally in the view to facilitate the free and unrestricted exchange of cryospheric data (**action; participants; asap**).

3.1.6. The workshop thanked all presenters for the valuable information contributed to this event.

3.2. Presentation on Russian national best practices for cryospheric measurements

3.2.1. Dr Vasily Smolyanitsky introduced the Russian national best practices for cryospheric measurements and briefed AARI activities for the coastal and marine observations. He noted that for the last summer seasons AARI continued to operate the seasonal “North Pole” drifting station as an integrated CryoNet station with instrumental measurements of sea ice, snow, hydrosphere, surface and upper atmosphere. A similar year-round instrumental set is in operation at Cape Baranova station extended by river, lake ice and glacier measurements. The latter are complemented by the remote sensing imagery from Landsat-8, Sentinel satellites and the unmanned aircraft vehicles (UAV). Various UAVs of different construction and instrumentation, operated by AARI since 2008, are successfully complementing the ground-based observational segment in the high Arctic providing centimeter-resolution visible and IR georeferenced imagery and meteorological measurements. Georadar profile measurements with a portable PIKOR-LED model (<http://kbor.ru>) operating at 1-4GHz frequency are gradually advancing for fresh water ice and snow at Cape Baranova station. In conclusion, Dr Smolyanitsky noted that PIKOR-LED Georadar will be a part of field work during the third day of the workshop (see item 6).

Observations and modeling of active layer thickness variability at Tiksi and Cape Baranova stations

3.2.2. Dr Piotr Bogorodsky (AARI St. Petersburg, Russian Federation) provided an overview of the Russian best practices in the field of modeling the permafrost

dynamics using observations of the permafrost active layer properties at the CryoNet stations Tiksi and Cape Baranova. He noted that direct measurements of soil temperature were started at the Tiksi station in 2009 in a framework of studies of the energy and mass balance exchange between the atmosphere and underlying surface. Up to the present, observations are conducted on three observation sites with various soil and vegetation types. Measurements are carried out at 10 levels up to the depth of 3.2 m using thermometric apparatus AMT-5 (manufacturer "Typhoon", Russia) and two thermistor strings GP5W-Shell (manufacturer "GeoPrecision", Germany). The stated measurements in the soil are complemented by the observations in the atmospheric boundary layer to support the IASOA and BSRN Programs, as well as routine meteorological observations (started at Tiksi in October 1932, which give important information for understanding the processes of permafrost evolution.

3.2.3. Dr Bogorodsky further noted that the length of the meteorological data series provides an opportunity to assess changes of the seasonal thawing depth using mathematical modeling. To achieve that, version of the stationary model of the Geophysical Institute, University of Alaska, using the well-known Kudryavtsev's approach and based on the assumption of exponential decay of the periodic variations of temperature amplitude with depth, has been implemented at AARI to study permafrost dynamics in Tiksi and Cape Baranova stations. Despite a number of simplifications for the real processes in the above approach, such models allow taking into account the characteristics of the vegetation and the snow cover, therefore they are widely used for analysis of active layer dynamics and give satisfactory results at more than modest requirements to computing resources.

Russian practices of the permafrost monitoring and data base development within the GTN-P

3.2.4. Dr Dmitriy Drozdov (ECI SB RAS, Tyumen, Russian Federation) presented extended information on the Russian practices of the permafrost monitoring within the continental Russia and Arctic coastal environment. He noted that monitoring of the permafrost zone is a unified system of observations and forecasting of permafrost changes under the influence of natural and anthropogenic factors.

3.2.5. Most of the international and Russian studies, now conducted within the Circumpolar Active Layer Monitoring (CALM) and Thermal State of Permafrost (TSP) programs and similar projects, revealed an urgent need to combine studies of the near-surface permafrost and adjacent geospheres under the "umbrella" of common ideas and organizational efforts. A new level of international cooperation and support to permafrost studies was achieved after the International Permafrost Association (IPA) launched the project GTN-P (Global Terrestrial Network – Permafrost) with its Strategy and Implementation Plan accepted in May 2013.

3.2.6. Dr Drozdov underlined that implementation of the semi-isolated Russian branch of the GTN-P database ought to consolidate national studies and overcome methodological ambiguities including that for the data in formats not compliant with the GTN-P templates. Close interaction with the weather services is a huge resource to empower GTN-P databases by adding measurements on surface atmosphere and underlying soil. In a practical way it may be done by extending the soil temperature measurements at the WMO weather stations up to a 15-20 m depth and including them into the regular meteorological reports. Such proposal could be implemented within the framework of the GCW CryoNet project. Simultaneously the majority of the existing and developing GTN-P stations and polygons / CALM and TSP sites should be involved into the CryoNet with the benefits of integrating data and possible

additional funding. The workshop recommended and invited the GCW Observations Group, to promote the idea of extending WMO soil temperature observations to 15-20m depth at weather stations with permafrost (**action; GCW Obs. Group; ongoing**).

3.2.7. More information about Dr Drozdov's presentation is provided in [Annex 11](#).

3.3. Cooperation with IAEA

3.3.1. A short description of the International Atomic Energy Agency (IAEA) Interregional technical cooperation (TC) Project "Assessing the Impact of Climate Change and its Effects on Soil and Water Resources in Polar and Mountain Regions" (INT5153, 2014-2017) was presented by Dr Sergey Verkulich (AARI, St. Petersburg, Russia). The project includes 23 countries, 13 selected benchmark sites (some of which are CryoNet stations/sites, too) for research activity over the world and is aimed to improve the understanding of the impact of climate change on polar and mountainous ecosystems at the local and global scale for their better management and conservation.

3.3.2. The project is concentrated on interregional, multidisciplinary study of the impact of long-term and current climate change on cryosphere (glacier - snow cover - permafrost), soil and soil organic carbon, water availability and soil-sediment redistribution processes in polar and mountainous regions with using isotope and related techniques.

3.3.3. Concluding the presentation Dr Verkulich noted the existence of overlap between the INT5153 project and CryoNet for i) one the main objects for study - cryosphere and ii) several expected outcomes (developing standards and methodologies for monitoring, developing interregional network of institutions, improved understanding of the effects of climate change, a platform or database with global access, etc.) which provides a potential for cooperation between the WMO GCW/CryoNet and the IAEA.

4. PROCEDURE FOR SELECTION OF CRYONET STATIONS IN ASIA

4.1. CryoNet Asia Sites Questionnaire & Responses

4.1.1. Dr Key provided an overview of the CryoNet Sites Questionnaire available from the GCW Website, and explained the type of information that must be entered in the questionnaire for candidate CryoNet Sites and Stations.

4.1.2. The workshop noted that the GCW station and site questionnaire was recently updated (January 2016) to reflect changes in the station/site structure. Station and site definitions were simplified at the CryoNet Team meeting in Boulder, December 2015. Stations and sites may each have particular attributes, which are reflected in the online questionnaire. A preview of the "application" for a station or site to become part of CryoNet is available on the questionnaire web page at <http://globalcryospherewatch.org/cryonet/questionnaire/>.

4.1.3. When an application is submitted via the online questionnaire process, the station is listed on the GCW website as "candidate". It is not yet part of the GCW surface network. When the GCW Steering Group recommends stations for inclusion in the surface network, for all practical purposes they are part of the GCW network and will be listed on the website accordingly. They are not, however, officially part of

the network until approved by EC.

4.1.4. Participants in the Salekhard workshop were encouraged to complete and submit questionnaires for the stations they proposed (**action; participants; ongoing**).

4.1.5. The workshop requested the Secretariat to provide Ms Larissa Kogutenko (Kazakhstan), and other interested participants (they are invited in this case submit a request to echarpentier@wmo.int) with copy of the letter that was sent to the PRs inviting them to submit applications for CryoNet sites (**action; Secretariat; asap**).

4.2. Procedure for Selection

4.2.1. Prof. Schöner reported on the GCW Site evaluation and approval process. The GCW document on „ the procedure for selection” (see [Annex 6](#)) was presented to the participants of the workshop. The minimum requirements for including a station in CryoNet, in particular the long-term commitment, free access to meta-data as well as data and the compliance with agreed practices were discussed. There was some discussion on item 3 of the document on the need for stations that are operated by other national entities than the NHMs, for a written agreement between that entity and the PR (or for stations that are located in another country where an agreement between the parties in these countries should be available for information).

4.2.2. The workshop requested the Secretariat to revise the paragraph of item 3 of the document for WMO compliance and to consider the case of Antarctica (**action; Secretariat; asap**).

4.3. Connection of CryoNet stations to the GCW data portal

4.3.1. An introduction to the two types of metadata that GCW CryoNet stations have to contribute was provided. Several exchange mechanisms and documentation standards were presented along with recommendations on preferred solutions in short and long term. Data brokering and integration across domains and institutions is simplified through the application of a generic data model like the Common Data Model and the requirement for standardization was strongly emphasized to achieve a cost effective and sustainable system. The current status of GCW interoperability guidelines and operations manual and procedure for further development was also communicated.

4.4. Discussion on observational gaps by components

4.4.1. Mr Etienne Charpentier provided an overview of the WMO Rolling Review of Requirements (RRR), and of the Observing System Capability Analysis and Review tool (OSCAR¹). He recalled that GCW is not a WMO Application Area as such but is regarded as a cross cutting theme whereby certain variables (e.g. snow depth) can be tagged as belonging to this theme. However, GCW was invited to consider whether there are any observational user requirements which are independent from other WMO Application Areas. In that case (i) a new Application Area would have to be created, (ii) specific observation observational user requirements for that Application Area would have to be collected and record in the OSCAR/Requirements database.

¹ <http://oscar.wmo.int>

4.4.2. Dr Smolyanitsky reported on observational gaps by component (snow, glaciers and ice caps, ice sheets, permafrost, sea ice, lake ice, solid precipitation). He indicated that there are currently 11 core stations operated in RA-II (China: 7, Russia:2, Japan: 1, other international: 1). Among these stations there are 8 in high mountain regions (China, Russia), 2 in the Arctic, and 1 station in the sub-Arctic region. Observations at those sites are fragmented in terms of the measurements that are made (see tables 1 and 2 below). The identified gaps were used to contribute to the discussion under item 5 below.

#	Name	Country	Type ²	S ₃ Ice	R ₄ ,L ₄ Ice	Snow	Glacier	Permafrost
4	Qilianshan	China	High M.				*	
6	Qilian	China	High M.			*	*	*
7	Tanggula 1	China	High M.			*	*	*
23	Xidatan	China	High M.					*
24	Tanggula	China	High M.			*		*
25	Tiksi	Russia	Arctic	?		*		*
26	Baranova	Russia	Arctic	*	*	*	*	*
30	Tianshan	China	High M.			*	*	*
32	Koxkar	China	High M.			*	*	
36	Yakutsk	Jp/Ru	SubA			*		*
32	www.asiacry oweb.com	Reg	High M.				*	

Table 1: Core CryoNet Stations in Asia and the cryosphere components that they measure⁵ (see footnotes for meaning of columns' heading).

2 HiM-PT: High Mountain Pamir-Tyan Shan; HiM-T: High Mountain Tibet; HiM-H: High Mountain Himalaya (HiM-H), HiM-AS: High Mountain Altai/Sayan

3 Sea ice

4 River and lake ice

5 Question mark (?) means "to be checked or confirmed by operator(s)"

	Country	Type⁶	Slice³	R,Lice⁴	Snow	Glacier	Permafrost
GTSWIS	Int'l	Global	(*)	(*)	(*)		(*)
GTN-P	Int'l	SubA					*
WHOS	Int'l	Global		(*)	(*)		
IABP (IMB)	Int'l	Arctic	*		*		
IICWG	Int'l	Arctic	*			(*)	

Table 2: Networks and programmes contributing to CryoNet Asia⁷.

4.4.3. Prof. Vladimir Aizen (USA) reported on gaps in high mountain regions in RA-II. He explained that there is currently only very sporadic meteorological and cryospheric information available from high elevation regions for elevations over 4000-5000 m a.s.l. [Siberian Altai, Tien Shan (both Chinese and Kyrgyzstan territory), Pamir (Tajikistan)]. He suggested establishing between 10 to 15 new AWS including cryospheric measurements (precipitation and snow accumulation, snow density and depth snow/firn temperature, changes in glacier surface elevation and glacier surface velocity) at an altitude over 4000-5000 m a.s.l.. All stations should be equipped with satellite data transmission system. There would be a need to define how such stations could be operated and maintained on the long term through a regional group to be set up for that purpose. WMO was invited to explore the possibility of getting financial support for this Asian High Elevation Cryosphere Observation (AHECO) project through the international financial institutions cooperating with the WMO (**action; WMO; end 2016**).

4.4.4. The Workshop proposed to set up an *ad hoc* Steering Group to set up the AHECO project, in strong cooperation with GCW, chaired by Vladimir Aizen with representatives from RA-II and beyond. The *ad hoc* Steering Group will be tasked to make the case for the Project and provide the necessary supporting documentation to the WMO for promoting the project. The Workshop requested Prof. Aizen to propose membership and terms of reference of the steering group, in the view to have them adopted by the GSG (**action; V. Aizen; 31 Mar. 2016**). See also [Annex 15](#) for more detail.

5. POTENTIAL STATIONS OF CRYONET ASIA

5.1. Experiences from a large scale automatic monitoring network

Danish programme for the monitoring of the Greenland ice sheet

5.1.1. Michele Citterio (Denmark) provided a brief overview of the Danish Programme for the monitoring of the Greenland Ice Sheet (PROMICE), to provide an example of CryoNet stations relying primarily on automatic instrumentation (AWS). The overall design of the PROMICE on-ice climate network is composed of AWS transects along the altitudinal gradient in 8 sectors of the ice sheet margin. Other in-situ cryospheric observations using GPS trackers on outlet glaciers as validation of

⁶ SubA: Sub-Arctic

⁷ (*) : partially measured (not meeting the minimum requirements at the moment).

remotely sensed surface velocities were also mentioned.

5.1.2. The technical details of the GEUS AWS were provided, in particular regarding the meteorological and glaciological sensors, and those required for operation on changing surfaces like a melting glacier such as the measurement of radiometers tilt. The near-real time data transmission was illustrated, as well as examples of data plots, metadata, and full data access through the promice.org website.

5.1.3. In the last part of the presentation, lessons learned and practical tips about the design, construction and operation of on-ice AWS were illustrated through several pictures. Institutions committing to CryoNet's open-data policy will be have free access to the construction details of the standard GEUS AWS.

Long term mass and energy balance monitoring of Himalayan glaciers

5.1.4. Mr Yves Arnaud (France) reported on long term mass and energy balance monitoring of Himalayan glaciers (some results for Khumbu area in Nepal). He noted that at the moment there is no Himalayan glacier included in Global Cryosphere Watch/CryoNet network. In order to partly fill this gap, Mr Arnaud explained that they would like to propose in collaboration with their Nepalese partners (DHM, ICIMOD, NAST) at least one Nepalese site to be included in Global Cryosphere Watch/CryoNet-Asia.

5.1.5. Mr Arnaud explained that the GLACIOCLIM (Les GLACIers, un Observatoire du CLIMat) is an Observatory for Research on the Environment dealing with Glaciers and Climate operated by France in collaboration with local partners in different countries. Four components are included in this network: GLACIOCLIM-ALPS, GLACIOCLIM-ANDES, GLACIOCLIM-HIMALAYA and GLACIOCLIM-ANTARCTIC with the aim of producing long-term mass and energy balance monitoring suitable for studying interaction between climate and mass balance. Several glaciers in the Alps, Andes and Antarctica monitored under the GLACIOCLIM and following the same glaciological procedure are already included in GCW/CryoNet network.

5.1.6. The candidate is Mera glacier (5 km²) situated in Khumbu region of Nepal (27°42'N 86°52'E) and mainly influenced by monsoon. Three Automatic Weather Station (AWS) are currently installed in different locations of the glacier (1 almost at the top of the glacier, 1 on the glacier tongue and 1 on the moraine). These AWS let us study the different processes controlling glacier melt. A glaciological network composed of around 30 ablation stakes and 5 accumulation drilling is surveyed since 2007 and let us assess the mass balance. He proposes a minimal network composed of 20 ablation stakes, 2 accumulation pit and 1 AWS suitable in order to perform a long-term monitoring suitable for the study of the response of glaciers to climate change.

Glaciers in the Polar Urals mountains

5.1.7. Dr Anton Sinitsky (Scientific center of Arctic Research, Salekhard, Russian Federation) reported on the Glaciers in the Polar Urals mountains, a joint study with the Moscow Lomonosov University. He noted that the special character of relief and climate created conditions for existence of 75 cirque and slope glaciers in the Polar Urals, founded in 1929-1930, with mainly eastern orientation. Areas of research include processes of accumulation and ablation, diagnosis of snow cover, water, heat and mass balance, glacial tectonic etc. Rapid shrinking of the glaciers is typical for recent years with more than 20 glaciers disappeared (figure 2). Location of the glaciers is a couple of hours – half a day trip from Salekhard in summer time. Dr

Sinitsky concluded by underlining the necessity to continue direct field observations of glacier fluctuations using modern remote sensing methods and technologies.

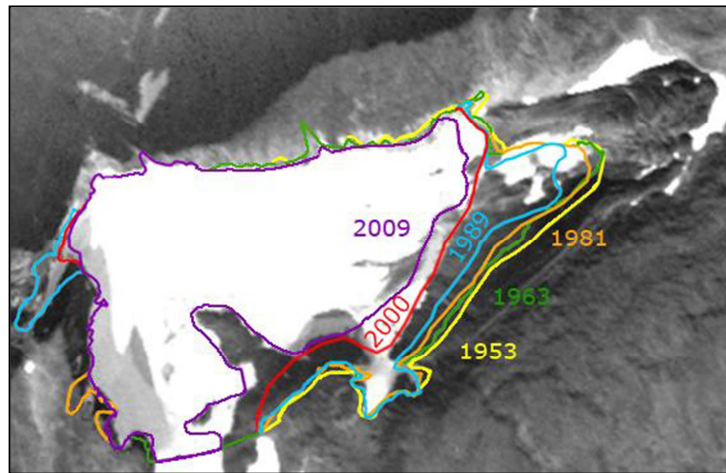


Figure 2: Dynamics of glaciers of the Polar Ural

Central Asia Elevation International Geophysical (HEIGE) Project

5.1.8. Dr Vladimir Aizen (USA) reported on the Central Asia Elevation International Geophysical (HEIGE) Project. The goal of the project is to synthesize and integrate multiple disciplines to develop fundamental understanding the interaction between climate and alpine cryosphere in the high central Asia: the past, present and possible future variability contributed to water resources of the world largest endorheic basin. Dr Aizen noted that the modern satellite information cannot fulfill the gap without the results calibration and validation with the ground observational data. To fulfill the gap, the automatic meteorological stations with cryospheric components of measurements have to be installed at high elevations (over 4000-5000 m a.s.l) in Asian mountains. Details about the HEIGE project are in [Annex 5](#).

5.1.9. The workshop agreed that GCW should investigate opportunities to support HEIGE for meteorological measurements (AWS), and seek funding sources to address the gaps, and partner organizations to implement it. The workshop invited the GSG to address this issue (**action; GSC; end 2016**).

5.1.10. The workshop invited the participants with experience with regard to the implementation of cryospheric observational guidelines, and who have developed national practice documents to provide such documents to the Chair of the GCW Best Practice Team so that they can contribute to the CryoNet best practices under development (**action; participants; mid-2016**).

5.2. Session 1: Potential Station/Sites in the Arctic and sub-arctic

5.2.1. Dr Smolyanitsky Chaired the Session. A breakout group was formed during the workshop to discuss which additional existing Sites could be considered for inclusion in the CryoNet in the Arctic and sub-Arctic region in RA-II.

5.2.2. Regarding the geographical domain to be considered, the group proposed (i) to consider the sub-Arctic as being within RA-II area but excluding the high-mountain areas (Figure 3 below) with exception of Altai; and (ii) to use an approach to the Arctic as a whole without distinct sub-division into RA-II, IV or VI, i.e. the same as proposed

for the Arctic PRCC-Network based on AMAP definition.



Figure 3: Proposed geographic domain for the sub-Arctic.

5.2.3. The workshop concurred with the recommendations of the breakout group, and proposed to add the sites listed in Table 3 below:

#	Name	Country	Type	Slice	R,Lice	Snow	Glacier	Permafrost
1	Beliy	Russia	Arctic	*	*	*		*
2	Svalbard	NO/RU	Arctic	*		*	*	*
3	Tavan Bogd	Mongolia	HiM/Altai			*	*	
4	Chersky	Int'l/Ru	SubA					*
5	PEEX	Int'l/	SubA			(*)		*
6	INTERACT	Int'l/	SubA			(*)		(*)
7	IMB	USA	Arctic	*				

Table 3: Summary of Sites proposed for inclusion in the CryoNet in the Arctic and sub Arctic region of RA-II⁷.

5.2.4. See also action proposed under item 5.3 below.

5.3. Session 2: Potential Station/Sites in High Mountain and other cold regions

5.3.1. Dr Valdimir Aizen chaired the Session. The workshop agreed that the number of additional Sites/Stations to be proposed at this point in the CryoNet should be limited and focus on high quality sites and focus on the mountain sites that are representative to the particular mountain system or large mountain range by the climatic and cryospheric conditions.

5.3.2. A breakout group was formed during the workshop to discuss which additional existing Sites could be considered for inclusion in the CryoNet in the High Mountain and other cold regions of RA-II.

5.3.3. After seeing the recommendation of the breakout group, the workshop agreed and proposed to add the stations/sites listed in Table 4 below:

#	Name	Country	Type	Slice	R,Lice	Snow	Glacier	Permafrost
1	Yala	Nepal	HiM			*	*	
2	Mera	Nepal	HiM			(*)	*	
3	Tuyuksu	Kazakhstan	HiM			*	*	
4	Big Almaty Lake	Kazakhstan	HiM			*		
5	Mynzhilki	Kazakhstan	HiM			*		
6	Jasaly Kezen	Kazakhstan	HiM			(*)		*
7	Khama Bagrot	Pakistan	HiM			*	*	
8	Dammay Bagrot	Pakistan	HiM			*	*	
9	Passu	Pakistan	HiM			*	*	
10	Altai	China	HiM			*	*	*
11	Chimgan	Uzbekistan	HiM			*		
12	Minchukur	Uzbekistan	HiM			*		
13	Mykhura	Tajikistan	HiM			*		
14	Navabad	Tajikistan	HiM			*		
15	Khorog	Tajikistan	HiM			*		
16	Fedchenko Glacier 5600 m a.s.l.	Tajikistan	HiM			*	*	
17	Ala-Archa Golubina glacier	Kyrgyzstan	HiM			*	*	
18	South Inylchek Glacier	Kyrgyzstan	HiM			*	*	
19	Abramova	Kyrgyzstan	HiM			*	*	

#	Name	Country	Type	Slice	R,Lice	Snow	Glacier	Permafrost
	Glacier							
20	Chon-Ashuu	Kyrgyzstan	HiM			*	*	
21	Tian-Shan-Kumtor	Kyrgyzstan	HiM			*	*	
22	Sarytash	Kyrgyzstan	HiM			*	*	
23	Nagaoka	Japan	other cold regions			*		
24	Shinjo	Japan	other cold regions			*		
25	Tokamachi	Japan	other cold regions			*		
26	Monbetsu	Japan	other cold regions	*				

Table 4: Sites proposed for inclusion in the CryoNet in the High Mountain and other cold regions of RA-II⁷. See further information about some of these stations/sites in [Annex 13](#).

5.3.4. The workshop requested the WMO Secretariat to liaise with the participants of the workshop as appropriate in the view to write to the Permanent Representatives of the corresponding countries if needed (tables 2 and 3) to invite them to indicate whether they concur to include the proposed Sites/Stations in the CryoNet under evaluation (**action; Secretariat; 31/5/2016**).

5.4. Presentation by YaNAO experts on ‘Beliy Island’ observatory as a potential CryoNet station/site

5.4.1. Mr Vladimir Pushkarev (Russian Federation) and Dr Dmitry Drozdov (Russian Federation) presented an overview of the proposal for establishing the Beliy Island as a new CryoNet Site. Details about the Site are provided in [Annex 10](#).

5.4.2. The workshop noted the efforts of YaNAO for developing the Beliy Island observatory as a candidate CryoNet Site with appreciation. Formal application for this CryoNet Site will be submitted by Roshydromet with the assistance of the Arctic and Antarctic Research Institute (AARI) in collaboration with the Russian Academy of Science and YaNAO Administration.

6. OBSERVATIONS & MEASUREMENTS

6.1. Fieldwork at a site on river Ob

6.1.1. Fieldwork at a site on the river Ob was organized on Thursday 4 February morning with the participants. The work was focusing on measurement of fresh water river ice, and snow.

6.1.2. An introduction and three practical demonstrations of instrumental measuring techniques used for snow and glacier monitoring were given in the field.

6.1.3. The first instrument demonstrated is the portable Georadar PIKOR-LED developed by the KBOR, Moscow (<http://kbor.ru>) for various field applications in cold regions and currently being introduced into practice by the AARI at Cape Baranova station. The very cost-effective PIKOR-LED Georadar is operating at frequencies 1-4 GHz, is capable to continuously record structural heterogeneities (multi-layer profiles) for fresh water ice up to ~2 m (or up to ~3 m for snow) and can be powered and controlled by any tablet computer. It was shown that key importance for correct measurements is the knowledge of the dielectric properties of the studied media including temperature and salinity (in case of possibility of sea ice inclusions) profiles. GPS connection to a tablet provides possibility of a 3D survey.

6.1.4. The second instrument demonstrated is the hydraulic ice ablation meter developed by the Geological Survey of Denmark and Greenland (GEUS) currently used extensively on the Greenland Ice Sheet. For practical reasons, a scaled-down demonstration version of the sensor was used to illustrate the operating principle and, involving the help of some of the participants, to show some instantaneous measurements by simulating manually the elevation change of a hypothetical melting surface and reading the corresponding signal on a voltmeter.

6.1.5. The third instrument demonstrated was a 2-axes tilt meter such as is used to monitor the tilt of radiometers at automatic weather stations operating on ablating ice surface and to correct their incoming solar radiation measurements. The key importance of this correction was also discussed, stressing that the cost of such tilt meters is negligible when compared to the cost of the radiometers. Instantaneous measurements were demonstrated with the help of some of the participants and visualized on a voltmeter.

6.1.6. Finally, some of the major applications of differential GPS in snow and glacier observations were illustrated, such as: the measurement of snow depth by subtracting known snow-free ground elevation from elevation profiles of the snowpack surface; the determination of surface velocity by repeated measurements of stakes; the measurement of glacier surface elevation change by repeated profiling. Basic elements of GPS surveying were introduced, including the concept of base and rover receivers, baseline processing, the use of data from local permanent reference stations, the different accuracies achievable by carrier phase vs. code differential techniques, and some practical consideration on different types of receivers.



Picture 1: Dr Vasily Smolyanitsky explaining about portable Georadar, which provides measurements of multiple layers profiles



Picture 2: Dr Michele Citterio explaining about use of phase differential GPS for measuring snow depth



Picture 3: Prof. Vladimir Aizen explaining about snow properties



Picture 4: The observing Site at Ob river

7. OBSERVATIONS & MEASUREMENTS (PRACTICES APPLIED IN ASIA)

7.1. Standards and best practices for cryospheric measurements used by GCW – A work in progress

7.1.1. Prof. Schöner reported on status of development of standards and best practices for cryospheric measurements used by the GCW. He recalled that Charles Fierz (WSL Institute for Snow and Avalanche Research SLF, Switzerland) is chairing the GCW Best Practices Team, which is compiling an inventory of existing best practices for specific cryosphere elements (snow, glaciers, ice sheets, ice caps, sea ice, solid precipitation, permafrost, etc.). Some information is already available from the GCW Website.

7.1.2. The workshop noted with appreciation that a draft of the structure of a new GCW guide to cryospheric practices is planned for completion in June 2016.

7.1.3. The workshop agreed that it was critical to receive feedback from GCW members regarding the standards and best practices used by all countries. It invited the participants to provide information to the Chair of the Best Practices Team on the practices and standards they believe ought to be included in the inventory (**action**;

participants; June 2016).

7.1.4. The workshop noted that efforts ought to be made in two directions equally important (i) develop GCW agreed best practices and standards, and (ii) WMO Technical Regulations. It was noted that one of the advantages of the Technical Regulations was that (i) they include practices that WMO members are mandated (e.g. Members shall ...) to do, and (ii) they are translated in WMO languages and can therefore better reach all Members. When mature enough, parts of the GCW standards and best practices could be elevated to the WMO Technical Regulations level.

7.2. Current methods of measurement of the cryosphere in Asia – consistency and issues

7.2.1. Dr Dongqi Zhang (China) reported on the current methods of measurement of the cryosphere in Asia. He essentially referred to measurement methods and parameters listed in the IGOS Cryosphere Theme Report 2007 for snow cover, glaciers, sea ice, river and lake ice, solid precipitation, permafrost and seasonally frozen ground, as well as cryosphere related measurements for meteorology, hydrology, and ecology. Details are provided in [Annex 12](#).

7.2.2. The workshop noted that snow water equivalent of snow cover is a complex and difficult variable to measure. The workshop agreed that the uncertainty of such measurements under different practices should be evaluated and reported, and it invited the Best Practices Team to address this issue (**action; BP Team; asap**).

7.3. New measurements techniques

7.3.1. Prof. Xiao presented an overview of new measurement techniques, including for example Eddy covariance on glaciers, InSAR, Integrated observation system, Wireless monitoring network, 3D Laser Scanner, and Glacier watch tower.

7.3.2. The workshop agreed that it was critical to collect information on new measurement techniques worldwide on both in situ and remote sensing techniques. One of the goals is to eventually reduce the cost of sensors and instruments. Developed countries/regions should lead this, and share information and techniques. The workshop therefore invited the Dr Key to investigate the opportunity to establish a “Cryotech” (the proposed name) mailing list, or some other web-based mechanism (e.g. Wiki) for sharing information on new measurement techniques (**action; J. Key; Sep. 2016**).

7.4. Automatic glacier ablation measurement instruments

7.4.1. Dr Citterio made a presentation on automatic glacier ablation measurement instruments. The scope of this presentation was widened to include a demonstration of real datasets acquired using the instruments and techniques illustrated during the field excursion (see item 6), as well as to answer some recurring questions from several participants during the previous days of the workshop.

7.4.2. A typical record of ice ablation from the Greenland ice sheet as measured using the hydraulic ablation meter design demonstrated in the field excursion was shown, together with the nearly identical validation dataset provided from a conventional sonic ranger and with the formulas to calculate ice melt from the raw sensor measurements. The advantage of the hydraulic ablation meter capable of unattended operation for several years was discussed with reference to an actual

multi-year example.

7.4.3. A typical record of radiometer tilt from a station in Greenland was then discussed, showing that over 6 years of uninterrupted measurement the station tilt was limited to within about +/- 5 degrees from the local slope of the glacier surface. To illustrate one application of carrier phase differential GPS, the elevation change along the central flowline of a Greenlandic glacier was shown, together with links to the very good free open source post-processing software RTKlib by Tomoji Takasu (Tokyo University of Marine Science and Technology). Finally, some frequent questions were addressed with real world estimates of electric power consumption, cost and reliability of satellite data telemetry, and the operation of automatic weather stations in the accumulation zone of glaciers.

7.5. New sensor techniques for cryospheric measurements

7.5.1. Prof. Aizen (USA) made the following presentations on new sensor techniques for cryospheric measurements:

- New sensor techniques for cryospheric measurements on behalf of Mark Bennett (Campbell Scientific). The presentation included techniques for fixed and mobile monitoring stations, information on standard meteorological measurements, and on additional standard measurements such as snow depth and level, four-component net radiometer, temp profile within glacial ice, ice movement, accumulated snow water equivalent, and trail cam. See [Annex 14](#) for details.
- Ice-coring and other field glaciological research in central Asia. The presentation included information on ice-coring and other field glaciological research in Central Asia performed by the International team of glaciologists under the UNESCO HEIGE IGCP Project auspices. The results of the last 15 years research were presented. The presentation also included information regarding the proposal to establish a high elevation monitoring project in central Asia, with indication of how the project should be promoted by the GCW, and a first overview of the Asian High Elevation Cryosphere Observation (AHECO) project development plan (see also paragraph 4.4.3). See [Annex 15](#) for details.

7.6. Consolidation of a list of the GCW standards for RA-II

7.6.1. The workshop reviewed the cryosphere measurement standards used nationally by RA-II participants regarding sea-ice, fresh-water ice, glaciers, snow, permafrost, etc. Participants were invited to review the list consolidated by the workshop by 19 February 2016 (**action; participants; 19 February 2016**). The final list of standards resulting from this discussion and further review of the participants is provided in [Annex 7](#).

8. SUMMARY & WAY FORWARD FOR CRYONET ASIA

8.1. Summary of Sessions 1 to 3

8.1.1. Dr Smolyanitsky summarized the outcome of Sessions 1 and 2 under items 5.2 and 5.3 respectively (see details under these sections).

8.2. Discussion on data archiving, further building of CryoNet Asia, and

management of CryoNet Asia

8.2.1. Dr Øystein Godøy (Norway) led a discussion on data archiving, data policies and data sharing. Contributions to the discussion were made by Nepal, Pakistan, Kazakhstan and Uzbekistan. Concerning data policies, the situation in these countries was relatively similar, although apparently a bit more restrictive for a couple of countries.

8.2.2. The norm is that access to data is restricted and not free and open as requested by the CryoNet requirements. These countries generally require bi-lateral agreements to share data. This is not a feasible form for GCW.

8.2.3. Concerning interoperability interfaces to metadata and data, this is usually not present. Data are, if available online, usually presented on web pages using interactive data access mechanisms. Sometimes data are not available in digital form. Also when it comes to data preservation, there are issues to address. However, all contributors to the discussion expressed interest for contributing to GCW and sharing data. Issues on data policies, and interoperability will have to be addressed.

8.2.4. The workshop requested the Secretariat to provide guidance on the process of addressing these issues (**action; Secretariat; 30 June 2016**).

8.3. Data archiving, data policy and data sharing

8.3.1. The workshop reviewed data policies, and data sharing and archiving practices in Asia with regard to cryospheric data. The workshop stressed that the data needed to be accessible in order to be utilized.

8.3.2. The workshop also noted that following the latest GCW surface observing network criteria, stations that are now inactive but have valuable data records can be GCW contributing stations. The workshop suggested investigating additional mechanisms for inclusion of such stations into the GCW surface network. (**action: CryoNet Team; Sept. 2016**).

8.4. Formation of regional CryoNet-Asia Working Group

8.4.1. The workshop discussed the formation of a regional CryoNet-Asia Working Group (WG/CryoNet/Asia).

8.4.2. The workshop agreed that the WG/CryoNet/Asia should be providing an overall coordination function for all CryoNet activities in Asia, and should particularly be addressing regional best practices, help identifying gaps and potential new stations in Asia, liaising with other regional working groups (e.g. South America), and reporting to WMO Regional Association II (RA-II) and the GCW Steering Group (GSG).

8.4.3. The Workshop agreed that the membership of the Working Group should include representatives of the Arctic, sub-Arctic, High Mountain/Tibet, High Mountain/Tibet/Pamir, and High Mountain/Himalaya.

8.4.4. The Secretariat was tasked to finalize the Terms of Reference and annex them to the final report of the Workshop, with the view to submit them to the Regional Association II and the GSG for their approval. The proposed Terms of Reference for the WG/CryoNet/Asia are provided in [Annex 9](#).

8.4.5. GCW Focal Points of RA-II, and the workshop participants (in liaison with the Focal Points of their country as appropriate) were invited to propose nominations no later than 19 February 2016 for the membership of the Regional Working Group being set up (**action; RA-II FPs; asap**). The GSG is invited to discuss and propose the governance for approving membership and Chair of the Working Group (**action; GSG; end 2016**).

9. CLOSURE OF WORKSHOP

9.1. Mr Alexey Titovkij, director of the YaNAO Government department for science and innovations addressed the meeting for the closing remarks. He thanked all participants for their contributions to the discussion. He recalled that the Governor of the region formulated that science in the Arctic was necessary for industrial development. International and inter-regional cooperation will therefore strengthen, and new stations are planned, or will be upgraded. He noted that the proposal to include Belyi Island in CryoNet will be of mutual benefit to the local government and the GCW and WMO. Finally, he thanked the organizing committee, including Prof. Schöner, Dr Jeff Key, and the Secretariat for assisting with the organization of the workshop. He welcomed all the participants to the social event in the evening and was looking forward to future cooperation with the GCW.

9.2. The representative of Roshydromet and AARI, Dr Smolyanitsky addressed the meeting and indicated that he had enjoyed organizing in such nice venue. He was pleased to note progress with regard to the study of permafrost, as there are now more stations dealing with this issue, and there is an enhanced cooperation with YaNAO. He therefore wished to thank YaNAO, its department for science and innovations, the Russian Center of Arctic exploration and the participants for their respective contributions.

9.3. In closing the session, the WMO Secretariat representative, Mr Etienne Charpentier once again thanked the YaNAO for co-organizing the workshop and providing such nice facilities, support and hospitality for the workshop, and the Arctic and Antarctic Research Institute (AARI) of Roshydromet for co-organizing the Workshop. The excellent facilities, support and hospitality that had been provided for the workshop had indeed contributed substantially to its success. He also thanked the staff of YaNAO and AARI who has contributed to the organizing of the Session, and for their support during the Session, and particularly Dr Vasily Smolyanitsky. Finally, he thanked all the participants for their active and positive contributions to the workshop and to the work of the GCW, which allows to build the Cryosphere community, and the CryoNet in Asia.

9.4. The list of action items arising from the Workshop is provided in [Annex 3](#).

9.5. The second CryoNet/Asia workshop closed on Thursday 5 February 2016 at 18:00.

ANNEX 1

WORKSHOP PROGRAMME

VENUE:

(a) Conference Hall (prospect Molodezhi, 9, room 332), YaNAO Administration, Salekhard, Russian Federation (plenary sessions)

(b) Ob' river between the towns of Labytnangi and Salekhard (fieldwork)

Tuesday, 2 February 2016

08:00-09:00 Participants registration

09:00-10:30

1 ORGANIZATION OF THE SESSION (Chair: V. Smolyanitsky)

1.1 Welcome and opening of the session (YaNAO administration, WMO)

1.2 Adoption of the Agenda

1.3 Working arrangements, information for participants and material arrangements

1.4 Round-table introduction of participants

1.5 Introduction of local scientific activities

10:30-11:00 Coffee break and group photo

11:00-12:30

2 STATUS OF THE DEVELOPMENT OF GLOBAL CRYOSPHERE WATCH (GCW)

2.1 GCW Overview (15 min) (J. Key)

2.2 Role and status of the GCW Steering Group (15 min) (J. Key)

2.3 Status report on CryoNet (15 min) (W. Schöner)

2.4 GCW Data Portal (15 minutes) (Ø. Godøy)

2.5 Outcome of the 1st CryoNet Asia Workshop (15 min) (C. Xiao)

2.6 Outcome of the 1st CryoNet South America Workshop (15 min) (W. Schöner)

12:30-14:00 Lunch break in Yuribey hotel

14:00-18:00 (including coffee break 15:30-16:00)

3 CRYOSPHERIC ACTIVITIES IN ASIA (15 min each)

3.1 Presentations by participants from Asia

3.2 Presentation on Russian national best practices for cryospheric measurements

3.3 Cooperation with IAEA (S. Verkulich)

18:00 End of the Day

18:30 – 20:30 Reception by YaNAO Administration

Wednesday, 3 February 2016

09:00-10:00

4 PROCEDURE FOR SELECTION OF CRYONET STATIONS IN ASIA

4.1 CryoNet Asia Sites Questionnaire & Responses (10 min) (J. Key, W. Schöner)

4.2 Procedure for Selection (15 min) (W. Schöner)

4.3 Connection of CryoNet stations to the GCW data portal (20min) (Ø. Godøy)

4.4 Discussion on observational gaps by components (snow, glaciers and ice caps, ice sheets, permafrost, sea ice, lake ice, solid precipitation) (15 min) (V. Smolyanitsky, E. Charpentier)

10:00-10:30 *Coffee break*

10:30-12:30

5. POTENTIAL STATIONS OF CRYONET ASIA

5.1 Experiences from a large scale automatic monitoring network (20 min) (M. Citterio)

5.2 Session 1: Arctic and sub-arctic stations/sites (Chair: V. Smolyanitsky)

12:30-14:00 *Lunch break in Yuribey hotel*

14:00-18:00 (including coffee break 15:30 – 16:00)

5. POTENTIAL STATIONS OF CRYONET ASIA (Cont'd)

5.2 Session 2: Other cold regions stations/sites (Chair: V. Aizen)

5.3 Session 3: High Mountain stations/sites

5.4 Presentation by YaNAO experts on 'Beliy Island' observatory as a potential CryoNet station

18:00 *End of the Day*

Thursday, 4 February 2016 (following weather conditions may be shifted to +/- day)

08:00-12:00 (Including Coffee break 10:00-10:30)

6 OBSERVATIONS & MEASUREMENTS (V. Smolyanitsky)

6.1 Fieldwork at a site on river Ob (focusing on fresh water river ice, snow).

12:00 – 13:30 *Cultural program (Review excursion in Salekhard town and visit to [Obdorskiy burg](#))*

13:30-14:30 *Lunch break in Yuribey hotel*

15:00 – 18:00 *Cultural program (visit to Yamal-Nenets museum)*

Friday, 5 February 2016

09:00-13:00 (including coffee break 10:30 – 11:00)

7 OBSERVATIONS & MEASUREMENTS (practices applied in Asia) (20-35 minutes each)

7.1 Standards and best practices for cryospheric measurements used by GCW – A work in progress (W. Schöner)

7.2 Current methods of measurement of the cryosphere in Asia – consistency and issues (D. Zhang, V. Aizen, W. Schöner)

7.3 New measurements techniques (C. Xiao, C. Xiao, V. Aizen, W. Schöner)

7.4 Automatic glacier ablation measurement instruments (M. Citterio)

7.5 New sensor techniques for cryospheric measurements (M. Bennett)

7.6 Consolidation of a list of the GCW standards for RA-II

13:00-14:00 *Lunch break in Yuribey hotel*

14:00-18:00 (including coffee break 15:30 – 16:00)

8 SUMMARY & WAY FORWARD FOR CRYONET ASIA (Chair: J. Key)

8.1 Summary of Sessions 1 to 3 (40 min) (V. Smolyanitsky, V. Aizen, C. Xiao)

8.2 Discussion on:

- Data archiving, data policy and data sharing (Ø. Godøy) (30 min)
- Further building of CryoNet Asia (V. Smolyanitsky) (30 min)
- Management of CryoNet Asia (V. Smolyanitsky, C. Xiao) (30 min)

8.3 Formation of regional CryoNet-Asia WG

9 CLOSURE OF WORKSHOP (YaNAO administration, WMO)

18:00 End of the Meeting

18:00 – 20:30 Cultural program (visit to cultural – ethnographic facility “[Gornoknyaz'evsk](#)” ([also this link](#)) with no-host “local cuisine” dinner – 2500 RUB - ~ 35 USD)

ANNEX 2

LIST OF PARTICIPANTS

(CryoNet Asia Workshop, Salekhard, Russian Federation, 2-5 February 2016)

#	Name	Country, City	Position, Affiliation, address	tel., fax, e-mail
1.	Prof. Wolfgang Schöner	Austria, Graz	Professor, University of Graz, Department of Geography and Regional Science Heinrichstrasse 36, 8010 Graz, Austria	Tel: +43 (0)316 380 8295 e-mail: wolfgang.schoener@zamg.ac.at
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ANNEX 3

List of action items arising from the Workshop

No.	Ref.	Action item	By whom	Deadline
1	2.3.4.	to proof if extended information, including data delivery mode, of the Cryonet Stations could be displayed on the Cryonet map	Cryonet Team	31 Dec. 2016
2	2.4.1.	Workshop participants holding cryosphere data-sets were invited to collaborate with the Portal Team with the view to make such data-sets discoverable via the GCWP Data Portal if that is not already the case	participants	ongoing
3	2.5.6.	to make direct contacts with the Asian countries which did not participate at the CryoNet Asia workshops in the view to have national focal points nominated	participants	asap
4	3.1.4.	to address the issue that specific focus should be placed on the Third Pole region because of the potential impact of cryosphere (snow and glaciers) changes on water resources due to climate change, and because of impact of cryosphere changes on atmospheric circulation and thus weather patterns in the region	GSG	asap
5	3.1.5.	to discuss nationally in the view to facilitate the free and unrestricted exchange of cryospheric data	participants	asap
6	3.2.6	to promote the idea of extending WMO soil temperature observations to 15-20m depth at weather stations with permafrost	GCW Observations Group	ongoing
7	4.1.4.	to complete and submit questionnaires for the stations they proposed	participants	ongoing
8	4.1.5.	to provide Ms Larissa Kogutenko (Kazakhstan), and other interested participants (they are invited in this case submit a request to echarpentier@wmo.int) with copy of the letter that was sent to the PRs inviting them to submit applications for CryoNet sites	Secretariat	asap
9	4.2.2.	to revise the paragraph of item 3 of the document for WMO compliance and to consider the case of Antarctica	Secretariat	asap
10	4.4.3.	to explore the possibility of getting financial support for the proposed project for high elevation cryospheric regions from elevations over 4000-5000 m a.s.l. in Asia through the international financial institutions cooperating with the WMO	WMO	end 2016
11	4.4.4.	to propose membership and terms of reference of the steering group for the	V. Aizen	31 Mar. 2016

No.	Ref.	Action item	By whom	Deadline
		proposed project for high elevation cryospheric regions from elevations over 4000-5000 m a.s.l. in Asia, in the view to have them adopted by the GSG		
12	5.1.9.	to investigate opportunities to support HEIGE for meteorological measurements (AWS), and seek funding sources to address the gaps, and partner organizations to implement it. The workshop invited the GSG to address this issue	GSC	end 2016
13	5.1.10.	participants with experience with regard to the implementation of cryospheric observational guidelines, and who have developed national practice documents to provide such documents to the Chair of the GCW Best Practice Team so that they can contribute to the CryoNet best practices under development	participants	mid-2016
14	5.3.4.	to liaise with the participants of the workshop as appropriate in the view to write to the Permanent Representatives of the corresponding countries if needed (tables 2 and 3) to invite them to indicate whether they concur to include the proposed Sites/Stations in the CryoNet under evaluation	Secretariat	31/5/2016
15	7.1.3.	to provide information to the Chair of the Best Practices Team on the practices and standards they believe ought to be included in the inventory	participants	June 2016
16	7.2.2.	to evaluate and report on the uncertainty of snow water equivalent of snow cover measurements under different practices	BP Team	asap
17	7.3.2.	to investigate the opportunity to establish a "Cryotech" (the proposed name) mailing list, or some other web-based mechanism (e.g. Wiki) for sharing information on new measurement techniques	J. Key	Sep. 2016
18	7.6.1.	to review the list of cryosphere measurement standards used nationally in RA-II regarding sea-ice, fresh-water ice, glaciers, snow, permafrost, etc.	participants	19 February 2016
19	8.2.4	to provide guidance on the process of addressing issues on data policies, and interoperability	Secretariat	30 June 2016
20	8.3.2	to investigate additional mechanisms for inclusion as GCW contributing stations, those that are now inactive but have valuable data records into the GCW surface network	Cryonet Team	Sep. 2016
21	8.4.5.	to propose nominations for the membership of the CryoNet Asia Working Group	RA-II FPs & participants	19 February 2016
22	8.4.5	The GSG is invited to discuss and propose the governance for approving membership and Chair of the Working Group	GSG	End 2016

No.	Ref.	Action item	By whom	Deadline

ANNEX 4

Opening Remarks of Dr Aleksandr Mazharov *(deputy governor of YaNAO, Russian Federation)*

Dear conference participants!

I am glad to welcome you in Salekhard – the capital of the Yamal-Nenets autonomous district. Our region is world-wide famous due to large hydrocarbon reserves, industrial exploitation of which has begun in the second half of the 20th century and continues till today.

Modern gas and oil-producing plants, pipeline system, transport and social infrastructure, new towns and workers' camps for fly-in fly-out personnel was constructed in the harsh climate circumstances during the last fifty years. In the coming years a new plant Yamal LNG will start operating. It will be the biggest northern industrial company to produce liquefied natural gas. A new Arctic port Sabetta and a Northern latitudinal railway will be placed next to the Yamal LNG. The railroad will help the North-West Russian regions, the Urals and Siberia to access global markets via the Northern Sea Route. From being a provincial northern district with economy based on raw materials, Yamal currently transforms into a strong center of industrial, infrastructural and socio-economic development in the North. And we understand a great responsibility that rests on our shoulders due to on-going and future activities in the Arctic.

Cryosphere has played an important role in forming unique polar landscape, flora and fauna of the Arctic. It contains enormous reserves of fresh water. Many meters of the underground ice (permafrost) has been a strong foundation material on which industrial and civil buildings have been constructed. Without knowing all the risks resulted from anthropogenic impacts and global climate change, without understanding as the consequences for cryosphere we may end up with the global ecological and economic problems instead of global projects in the Arctic and the rest of the world.

Therefore, the President of the Russian Federation and the Russian Government has set the following priorities when it comes to the industrial development of the North. Firstly, we need an accurate knowledge about environmental potential of the Arctic, based on which we can evaluate feasibility of future decisions and actions. Secondly, we shall follow ecological standards and put into practice environmental protection measures. Thirdly, it is important to cooperate with the scientific community.

The same stations will be established in the industrial areas of the Yamal Peninsula, near the town of Nadym, and on the unpolluted territories of the Gydan Peninsula. The scientists, who will come to the Gydan Peninsula earlier than oil and gas companies, can get a unique possibility to follow the impact of the industrialization and assist to avoid the mistakes of the manufacturing plants.

There are more than 15 field groups from the Russian Academy of Science and other Russian Institutes operate on the territory of the region each year. They provide us with update information about the ecological situation in Yamal, the cryogenic processes, which take place on the territory of the region, and their impact on the industrial facilities, and the influence of climate change on the population of the Arctic animals and birds.

But even having the deep knowledge we can't have a complete picture of what is happening with nature, if these knowledge are not supported by the data from other territories. Especially in the Arctic, where everything is interconnected. It's the reason why we have responded to the initiative to provide the International seminar CryoNet in Salekhard. We are ready to make our contribution into the network development of the cryosphere condition. I'm sure that here, in Yamal, your researches will find support and understanding. And this seminar will be a beginning of the long-term and productive

collaboration between the World Meteorological Organization and the Yamal-Nenets autonomous district.

I wish you successful and efficient work!

ANNEX 5

Central Asia High Elevation International Geophysical Project (HEIGE)

Dr Vladimir B. Aizen, the project leader University of Idaho, USA

The Central Asia High Elevation International Geophysical Project (HEIGE) started in 2015 under financial support of the National Science Foundation (USA), University of Heidelberg and the Bavarian AS Glaciological Commission (Germany), the Nagoya and Chiba Universities (Japan), the Joseph Fourier University (France), and Cold and Arid regions Environment Engineering Institute in Lanzhou, PR of China, and assistance in the organization of the project by the Government of Tajikistan and the International Geoscience Programme (IGCP UNESCO).

The HEIGE Goal: to Synthesize and integrate multiple disciplines to develop fundamental understanding the interaction between climate and alpine cryosphere in the high central Asia: the past, present and possible future variability contributed to water resources of the world largest endorheic basin.

- *Will climate thresholds be crossed that change the current state of water resources, and if so where, how fast, and how much?*
- *How will local and regional changes in climate, snow cover, glaciers, and permafrost impact the regional hydrology, water quality, land degradation, bio-ecology, food production and human health?*

Presented information based on the central Asia meteorological and cryospheric observations completed before 1991 and the modern remote sensing data. All data has been processed through the method of finding of random errors and comprehensive statistical analysis and scientific interpretation. The data analysis includes: the long-term meteorological observations on the territory of all central Asia between Mongolia and Caspian Sea and between the western Siberia and Tibetan Plateau; the observations on seasonal snow covered area changes, based on the ground snow observations and remote sensing data, the glacier area and glacier ice volume changes during the last 70 years. The data analysis and interpretation has been completed by the glacio-climatic group of the University of Idaho. The results has been presented as an example of high mountains cryospheric data set that could be developed for the Asian regions and contributed to GCW Program. It was noted that the major data gap is in the absence of information from high mountain areas above 4000-5000 m. The snow/firn/ice accumulation areas , which are the natural storages of the Asian fresh water.

Author of presentation has noted that the modern satellite information cannot fulfill the gap without the results calibration and validation with the ground observational data. To fulfill the gap, the automatic meteorological stations with cryospheric components of measurements have to be installed at high elevations (over 4000-5000 m a.s.l) in Asian mountains.

ANNEX 6

Procedure for CryoNet Site selection

1. GCW Station Proposal Process

GCW seeks to design a network that advances the scientific and operational objectives of WMO and its partners. The process of evaluating a station or site for inclusion in the GCW surface network is described below. It is the same for CryoNet stations, contributing stations and CryoNet sites, except as indicated below.

1. A representative of the station or site (hereafter, the “applicant” and the “station”) completes and submits the station questionnaire (the “application”) on the GCW website (globalcryospherewatch.org/cryonet/questionnaire).
 - It is recommended, though not required, that the applicant present the station at a GCW meeting before beginning the application process.
 - By submitting the application for a CryoNet station, the applicant is implicitly agreeing that the station meets the CryoNet Minimum Requirements. A commitment to longevity, data quality, and data distribution is particularly important.
2. CryoNet sites must also submit a site concept paper.
3. For stations that are operated by the WMO Member’s NHMS, the WMO Permanent Representative (PR) of the station’s operating country sends a letter of endorsement to WMO. For stations that are operated by other national entities, there must be a written agreement between that entity and the PR. For stations that are located in a country other than that of the proponent, the agreement to operate in that country and to share data as per GCW requirements must be provided. The PR of the country in which the station is located must be informed that the station could become part of CryoNet. For the mobile platforms operating in international waters by an international consortium, endorsement is done by the designated PR of the concerned countries with concurrence by the chair of the relevant consortium.
4. The application is examined by the WMO Secretariat for completeness.
5. The GCW CryoNet Team, in consultation with relevant experts, evaluates the application. This is normally done annually, but may be expedited in some situations. There are no site visits. Applicants may suggest relevant experts.
6. If the Team recommends that the station **not** be included in the GCW surface network, feedback is provided to the applicant. The application can be modified and resubmitted at any time.
7. If the Team recommends that the station be included in the network, the GCW Steering Group (GSG) makes its determination. This is normally done at GSG annual meetings. If the GSG recommends that the station **not** be included in the GCW surface network, feedback is provided to the applicant.
8. If the GSG recommends the station for inclusion in the network, the station is conditionally accepted and enters a one-year trial period. CryoNet stations and sites shall operate according to the Minimum Requirements.
9. If the GSG recommends the station for inclusion in the network, the final approval is made by the WMO Executive Council (EC). EC meets annually.

Each CryoNet station will be evaluated by the Team every four years to ensure that it continues to meet the Minimum Requirements. If it does not, a timeline for correcting

deficiencies will be mutually agreed upon by the Team and the station representatives. If no agreement can be reached, the station will be removed from the CryoNet network or, by mutual agreement, will become a contributing station.

A change in the station type, CryoNet or contributing, requires reapplication. This entails a modification to the original application, resubmission, and re-evaluation by the Team and GSG.

Stations may be withdrawn from the GCW surface network at any time by request, in writing, of the station owners/operators. In such case stations may be listed as discontinued.

When an application is submitted via the online questionnaire process, the station is listed on the GCW website as “candidate”. It is not yet part of the GCW surface network. When the GCW Steering Group recommends stations for inclusion in the surface network, for all practical purposes they are part of the GCW network and will be listed on the website accordingly. They are not, however, officially part of the network until approved by EC.

2. CryoNet Station/Site Questionnaire

A preview of the “application” for a station or site to become part of CryoNet is shown below. The questionnaire is online at:

<http://globalcryospherewatch.org/cryonet/questionnaire/>

ANNEX 7

Cryosphere measurement standards used in Regional Association II

The workshop identified the following cryosphere measurement standards used in WMO Regional Association II:

- Russian Federation (Vasily Smolyanitsky): Sea ice, WMO Sea-Ice Nomenclature, Manual for air reconnaissance, Manual for coastal obs, Roshydomet
- Austria (Wolfgang Schöner): glacier, WGMS and UNESCO guide on mass-balance, for snow the WMO guide
- China (Cunde Xiao): glacier – same as Austria, snow – WMO guide, sea ice – WMO standard, permafrost – largely based GTN-P standard, Chinese manual
- Pakistan (Kamal ud Din): snow and glacier: snow and glacier mass-balance national guide, snow in acc. to WMO tech.
- Kazakhstan (Larissa Kogutenko): glacier and snow - same as Austria, permafrost; glacier mass balance – WGMS and UNESCO standard; *glacier inventories* - GTN-G, GLIMS standard, Vinogradov ON, Krenke AN, Oganovskiy PN. 1966. Rukovodstvo po sostavleniyu kataloga lednikov [Guide on compilation of catalogue of glaciers]. Leningrad: Gidrometeoizdat, p. 154. Russian; Paul F., R.G. Barry, J.G. Cogley, H. Frey, W. Haeberli, A. Ohmura, C.S.L. Ommanney, B. Raup, A. Rivera, M. Zemp (2009) Recommendations for the compilation of glacier inventory data from digital sources. *Annals of Glaciology* 50(53) 119-126; Racoviteanu, A.E., Paul, F., Raup, B., Singh Khalsa, S.J. & Armstrong, R. (2009). Challenges and recommendations in mapping of glacier parameters from space: results of the 2008 Global Land and Ice Measurements from Space (GLIMS) workshop, Boulder, Colorado, USA. *Annals of Glaciology* 50(53) 53–69 ;; snow cover - WMO standard; permafrost – GTN-P standard.
- Mongolia (Gombo Davaa): permafrost, glacier: glacier – same as Austria, snow – WMO guide, permafrost – GTN-P guide, fresh water ice – WMO and Russian standards
- Japan (Katsuhisa Kawashima, Japan): snow: Fierz et al. (2009) and JSSI classification for snow cover*
 - * Japanese Society of Snow and Ice, 1998, JSSI classification for snow cover. *Seppyo* (Journal of the Japanese Society of Snow and Ice), Vol. 60, No. 5, 419-436. (in Japanese)
 - glacier: WGMS and UNESCO guide on mass-balance
 - permafrost: GTN-P standard
 - sea ice: WMO Sea-Ice Nomenclature, SCAR/ASPeCt protocol**
 - ** Antarctic Sea Ice Processes and Climate (ASPeCt, established in 1996) is an expert group on multi-disciplinary Antarctic sea ice zone research within the SCAR Physical Sciences program.
- Nepal (Bikram Shrestha Zoowa): glacier: glacier and snow – WGMS and UNESCO guide, permafrost - ?, snow - ?
- France (Yves Arnaud): glacier: glacier - WGMS and UNESCO guide, permafrost - ?, snow – WMO standard
- Denmark (Michele Citterio): glacier: glacier - WGMS and UNESCO guide, snow – WMO standard, permafrost – (GTN-P), ice shelf - adapted from WGMS
- Tajikistan (Abdurashid Tagoybekov): glacier – Russian guideline, snow – WMO
- Russian Federation (P.Orekhov, D.Drozhdov): permafrost, snow: permafrost – GTN-P, snow – WMO guideline + Roshydroomet guide for hydrological posts, permafrost also 'SNIP'

- Kyrgyzstan (Ryskeldi Asankhodzhaev): snow – WMO standards, glacier – partly Swiss Meteo Bureau, partly WMO standards, permafrost (Kyrgyzstan Institute for Geology) – TBD
- Uzbekistan (Klimentiy.Valiev): For stations, snow and meteorological measurements are done - according to WMO standards/guideline,

Others: Snow measurement guidance in Mountains (Руководство по снегомерным работам в горах РД 52.25.261-90, Госкомгидромет, Москва 1991), instructional lines on organisation and conducting airborne snow cover observation in mountains (Методические указания по организации и проведению авианаблюдений над снежным покровом в горах, САРНИГМИ, Ташкент 1979), Guidance on operation for avalanche protection (Руководство по снеголавинным работам (временное), Гидрометеорологическое издательство, Ленинград 1965)

Note: List above updated by workshop participants after the meeting and by 19 February 2016.

ANNEX 8

CRYONET STATION REQUIREMENTS – Proposed Revisions *(as proposed by the GCW Steering Group, Boulder, USA, December 2015)*

In order for a surface station to be included in the core part of the GCW network, CryoNet, it must meet certain criteria. The current minimum requirements are posted on the GCW Website. If a station meets these requirements, additional information can be provided for further evaluation through the GCW Station/Site Questionnaire. Contributing stations, which are part of the GCW surface network, but not part of CryoNet, only need to meet the data sharing requirement, although they would be encouraged to meet as many of the requirements as possible.

Discussion at the CryoNet meeting resulted in a suggested revision and update to the minimum requirements, as given below. When finalized by the CryoNet Team, and approved by the GSG, these will become the minimum requirements for a CryoNet station.

Revised Minimum requirements of CryoNet Station (to be finalized by CryoNet Team)

1. Meeting Core CryoNet Measurement Requirements

The station shall measure at least one of the major cryosphere components and variables (i.e. snow, solid precipitation, lake and river ice, sea ice, glaciers and ice caps, ice sheets, permafrost and frozen ground). The station location is chosen such that cryospheric measurements are representative of the surrounding area, and such representativeness needs to be clearly described by the applicant.

2. Commitment of Operational Continuity

The station must be active. The responsible agencies are committed, to the extent reasonable, to sustaining long-term observations of at least one cryosphere component. There must be a commitment to continue measurements for a minimum of four (4) years.

3. Metadata Up-to-Date and Available

The station metadata (including all needed metadata describing the station characteristics and observational programme information) are kept up-to-date and available in the GCW station information database, and through the GCW Portal, the WIGOS Information Resource (WIR).

4. Compliance with Agreed Regulatory Practice

The station observational procedures, the instruments and method of observations, quality control practices, etc., should follow GCW endorsed regulations, manuals, guides and to the extent possible the recommended GCW best practices.

5. Data and Ancillary Data Freely Availability

Data shall be made freely available, whenever possible in (near-) real time, or otherwise for the agreed timelines (for some special observations which have no real or near real time nature); in-situ ancillary meteorological observations, as required in the CryoNet best practices, should also be available with documented quality.

6. Competency of Staff

Personnel must be trained in the operation and maintenance of the station.

ANNEX 9

Proposed Terms of Reference of the CryoNet/Asia Working Group

(as proposed by the Second CryoNet Asia workshop, Salekhard, Russian Federation, 2-5 February 2016, and to be proposed to Regional Association II, and the GCW Steering Group for their consideration)

The CryoNet-Asia Working Group shall:

1. Provide an overall coordination function for all cryospheric observing activities in Asia;
2. Collect and compile information on regional best practices for cryospheric measurements, and assist in producing sets of measurement standards and practices for Asia recognized by GCW and the WMO;
3. Help identifying gaps and potential new cryospheric stations in Asia, including new potential CryoNet Sites and Stations;
4. Liaise with other regional working groups (e.g. South America) as appropriate; and
5. Report to WMO Regional Association II (RA-II) and the GCW Steering Group (GSG).

The membership of the Working Group shall include representatives of Regional Association II for the following areas:

- Arctic,
- Sub-Arctic,
- High Mountain/Altai-Sayan
- High Mountain/Tibet,
- High Mountain/Tan Shan/Pamir
- High Mountain/Himalaya.

Expertise of the nominated representatives shall cover all components of the cryosphere, i.e. sea ice, river ice, lake ice, snow, permafrost and glaciers.

Nominated members:

- Abdurashid Tagoybekov, Head Center glaciology Agency of hydrometeorology, Tajikistan, expertise: glacier, snow for High-Mountain/Pamir, E-mail: tagoibekov@inbox.ru
- Klimentiy Valiev, Engineer of Service of Monitoring of the Hazardous Hydrometeorological Phenomena, Uzbekistan, E-mail: : klmnvly@gmail.com
- Dr Hironori Yabuki, Department of Environmental Geochemical Cycle Research, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), E-mail: yabuki@jamstec.go.jp
- Dr Feiteng Wang, Cold and Arid Regions Environmental and Engineering Research Institute (CAREERI), Chinese Academy of Sciences (CAS), China, E-mail: wangfeiteng@lzb.ac.cn
- Dr Dongqi Zhang, China Meteorological Administration (CMA), China, E-mail:

zhangdq@canscma.cn

- Ms Larissa Kogutenko, Laboratory of Glaciology, Institute of Geography, Ministry of Science and Education, Kazakhstan, E-mail: kogutenko_larissa@mail.ru (cc Igor Severskiy, iseverskiy@gmail.com)
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ANNEX 10

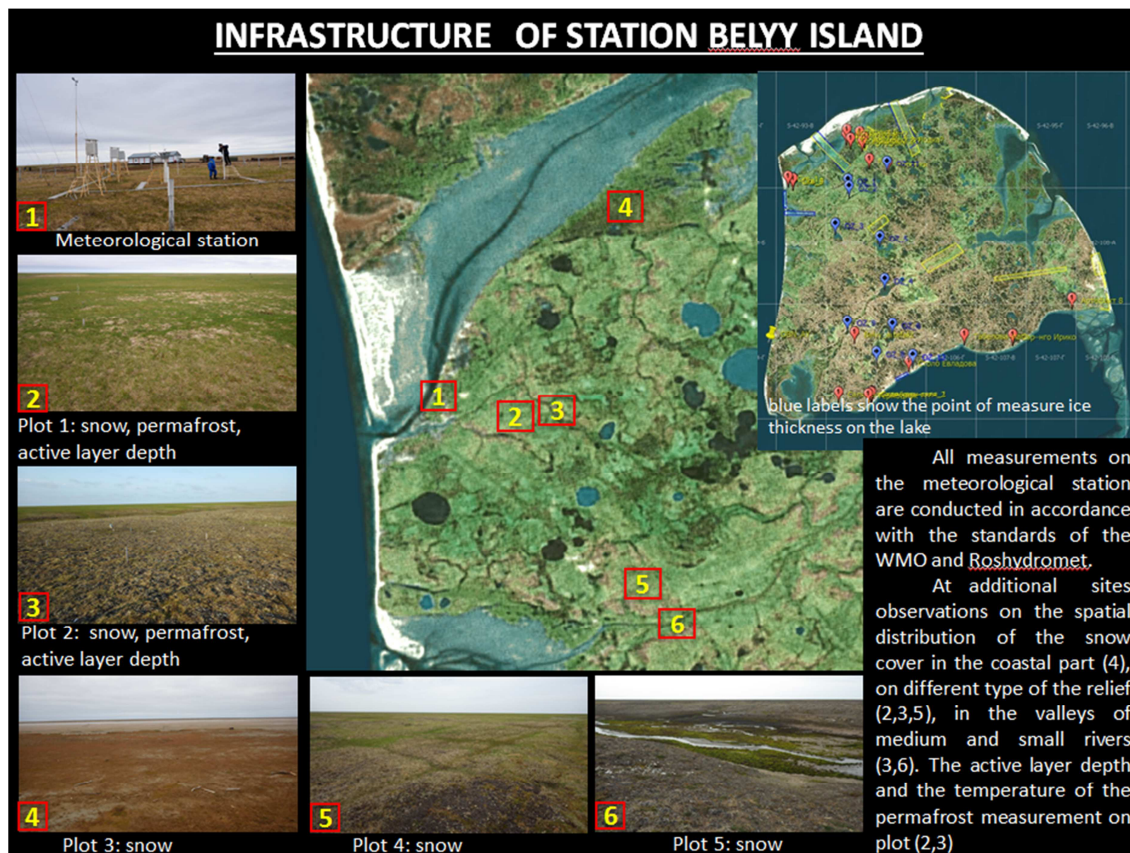
Natural Conditions and Permafrost Measurements at Belyi Island Permafrost Station, Kara Sea coast, Western Siberia

Orekhov P.T., Slagoda E.A., Drozdov D.S

Earth Cryosphere Institute SB RAS (ECI SB RAS), Tyumen, Moscow, Russia

Belyi Island located north of the Yamal Peninsula in the Kara Sea is a terraced coastal plain rising in steps from the beach and layda level at 0-3m a.s.l. to terraces I (3-7 m a.s.l.) and II (6-12 m a.s.l.). The terraces with numerous lakes are cut by creeks and gullies. The island is divided into halves by a system of two rivers flowing in the NE and SW directions. The surface of terrace I is wet and marshy in its rear part and well drained near the edge.

The climate is severe with long winters, short and cool summers, and brief transitional seasons in spring and autumn. The annual temperature variations lack a prominent winter minimum because of warm air transport with western cyclones and heat emission from the Kara Sea. According to reports from the M.V.Popov weather station, the long-term mean annual air temperature is -10.6°C ; the monthly means vary from -20.2 to -24.4°C from December to March, reach positive values in mid-June, rise to $+5.3^{\circ}\text{C}$ in August, and turn to below zero in late September. The total annual moisture is 258 mm: 87 mm from November to March and 171 mm precipitation between April and October. The snow depth increases smoothly from 11 cm in mid October to 50 cm in early May. Snow starts melting about 10 June, but some snow fields hold in topographic lows as long as August. The mean annual wind speed is 5.7 m/s. Winds are mostly of southern directions in November-February, while northern and northeastern winds predominate in summer. The wind transport controls snow cover patterns.



Beliy Island lies in the northern subzone of the Arctic tundra, subzone “B” (CAVM Team, 2003; Yu et al., 2012). Its vegetation is less diverse and taxonomically poorer than the northern Yamal tundra (Rebristaya, 1995) and consists mostly of Poaceae, Cyperaceae and Ranunculaceae, with graminoid, cottongrass, and sphagnum assemblages in bogs and graminoid, cottongrass, and moss tundra assemblages in better drained zones. Graminoid-willow-sedge-cottongrass-moss tundra vegetation grows on drained sand watersheds while mottled tundra occupies the margins of sand ridges. Halophytic meadow plant communities grow mostly on the flood layda and in river deltas and banks (Orekhov et al., 2010).

Measurements in the 1970s showed permafrost temperature to be -12.2°C in elevated areas with snow depths from 0 to 10 cm and -8.7°C in areas of thicker snow of 50-60 cm (Trofimov et al., 1975). In 2012 ground temperature here became -8° and -4°C . The permafrost thicknesses calculated from these values are 240 m in upper marine terrace II, 65 to 165 m in marine terrace I, 50-80 m in the layda (back parts) to 2-10 m in the beach (Trofimov et al., 1987).

Active layer thickness, snow thickness and density, lake and marine ice thickness annual measurements and cryogenic process monitoring are started by ECI SB RAS in 2009.

ANNEX 11

Russian Permafrost Monitoring and Database: GTN-P Project to GCW initiative

Drozdov D.S.*, Malkova G.V.*, Romanovsky V.E.*****, P.Orekhov*, Abramov A.A.**,
Konstantinov P.Ya.***, Sergeev D.O.****, Kholodov A.L.*****

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*** *Melnikov Permafrost Institute SB RAS (MPI SB RAS), Yakutsk, Russia*

**** *Institute of Environmental Geoscience (IEG RAS), Moscow, Russia*

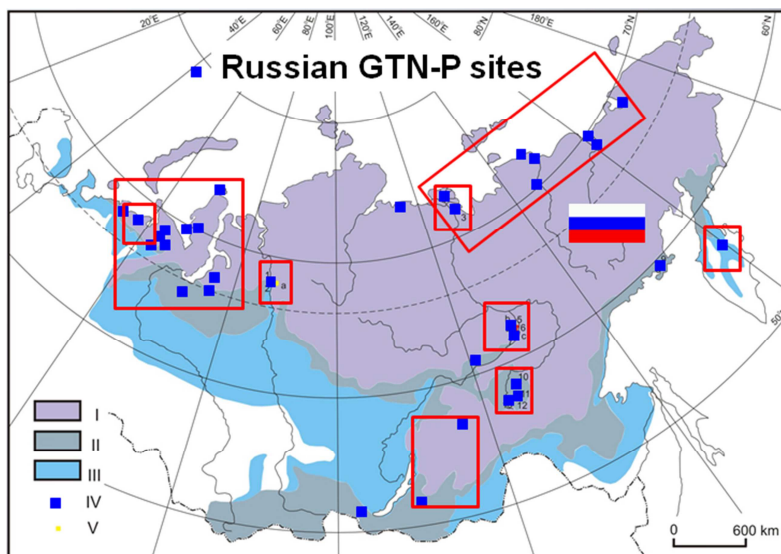
***** *Geophysical Institute, University of Alaska Fairbanks, USA*

Monitoring of the permafrost zone is a unified system of observations on the permafrost, assessment, monitoring and forecast of its change in time and space under the influence of natural climatic and anthropogenic factors.

A unique data of long-term geocryological monitoring which have been held at a number of special sites all over the World allows to learn cyclical and trend components of change in the active-layer features and the frozen ground temperature, as well as the rate and rhythm of cryogenic processes. These data characterize permafrost response to global warming and technogenesis.

International and Russian studies on CALM and TSP programs and numerous similar projects revealed the urgent need to combine studies of the near-surface permafrost in its interaction with adjacent geospheres under the "umbrella" of common ideas and organizational efforts. The fact that many key-sites already are complex and examined by experts involved in various ongoing programs indicates the presence of good prospects in this direction.

A new level of international cooperation and technological support regime study of permafrost was achieved after the International Permafrost Association (IPA) launched the project GTN-P (Global Terrestrial Network – Permafrost). In May 2013 at the WMO Headquarters in Geneva is was discussed and accepted the GTN-P Strategy and Implementation Plan. National Correspondents from the countries participating in GTN-P formulated the problems concerning worldwide database on the near-surface permafrost properties and there spatiotemporal variability.



While implementation of the project, the Russian participants of GTN-P realized that at the initial stage of the project the semi-isolated Russian branch of the GTN-P database

could serve to bring together various institutions, individual researchers and enthusiasts to overcome methodological ambiguities and complexities. It concerns first of all data which exist in formats not covered by GTN-P templates for subsequent mating with GTN-P and testing the effectiveness of these advanced formats in terms of the future development of GTN-P project.

It should be noted that close interaction with the weather service is a huge resources to empower GTN-P databases for the purposes of assessment of the permafrost spatiotemporal variability both generally of the spatiotemporal variability of the atmosphere / surface interface. So it seems appropriate to turn to the WMO and the National Meteorological Services with a proposal to include air and ground temperature measurements (to 15-20 m depth) at landscapes surrounding weather stations in the regulation of meteorological observations.

We hope this idea could be realized within (or nearby) a framework of the GCW-project (Global Cryosphere Watch) initiated by WMO. But we have to insure the evidence of the fact that a couple of GCW-station for the territory of Russia ore North America is too pore. We think that the majority of GTN-P stations and polygons could be involved somehow into GCW-project to integrate data and funding for common benefits.

ANNEX 12

Consistency and Issues with regard to the current methods of measurement of the cryosphere in Asia

Table 1: Consistency and issues regarding cryospheric measurements

<i>Cryosphere component</i>		<i>Consistency</i>	<i>Issues</i>
Snow (cover)	methods	terrestrial gamma radiation from low-flying aircraft, visible and infrared radiance from aircraft, low Earth-orbit (LEO) , geostationary (GEO) satellites, observations of microwave emissions and backscatter using passive and active sensors on aircraft and LEO satellites	Algorithm, graduated probes and stakes acoustic snow- depth sounders snow coring devices snow pillows (pressure transducers), snow pits
	platforms	Airborne and spaceborne	surface
	parameters	snow cover, water equivalent, depth and albedo	snow density, temperature, microphysical properties, chemistry
Glaciers	methods	WGMS (2012) guideline, Hi-res optical, InSAR, DEM	
	parameters	Area	glacier inventory, Glacier mass balance data, glacier topography database, thickness, velocity, accumulation
	platforms	Airborne, Landsat	surface
Sea ice	methods	Submarine sonar observations, Electromagnetic (EM) sensors, Satellite-borne visible/infrared sensors, Satellite-borne dual-polarized, multi-frequency passive microwave radiometers	

Cryosphere component		Consistency	Issues
	parameters	concentration/ extent, thickness distribution, motion, melt, albedo, Leads/polynyas, Stage of Development, Ridge Height	thickness, Snow Depth on Ice, Surface Characteristics (albedo, meltpond, dust, snow properties, temperature), small-scale properties
	platforms	airborne, spaceborne systems	Surface, Ship, near-surface
Solid precipitation	methods	precipitation gauge network, satellite remote sensing, and ground radar	sparseness and decline of the precipitation observation networks, uneven distribution, spatial and temporal discontinuities, biases in gauge measurements
	parameters	Precipitation type, Precipitation/Snowfall rate, Snowfall amount	Snow water equivalent
	platform	surface	Airborne and spaceborne
Permafros and seasonal frozen ground	methods	SMMK and SSM, D-InSAR, AMSR-E	
	parameters	Annual surface elevation change, Active layer depth, Soil temperature, Surface temperature, Duration of thaw, Onset of seasonal freezing, Depth of seasonal freezing, Duration of freeze, Distribution of seasonal freezing, freeze/thaw depth	Thickness, Ground ice volume, soil thermal regime, distribution
	platform	Surface	Spaceborne systems
River(lake) ice	method	NOAA AVHRR (1.1 km),RADARSAT ScanSAR (100 m) imagery, ICESat	algorithm
	platform	surface-based observation	spaceborne systems

<i>Cryosphere component</i>		<i>Consistency</i>	<i>Issues</i>
	parameters	Ice concentration, Ice areal extent, Freeze-up and break-up dates, Aufeis, Areal extent of floating and grounded ice, River ice jams and dams	Snow depth on ice, Thickness,

Table 1: Consistency and issues regarding other cryospheric related measurements

	consistency	Issues
<i>Meteorology</i>	WMO guidelines	Sites distribution Parameter uneven
<i>Hydrology</i>	WMO guideline	
<i>Ecology</i>		

ANNEX 13

INFORMATION ON SOME CRYOSPHERIC OBSERVING STATIONS IN ASIA

1. DETAIL OF AWS INSTALLED IN CRYOSPHERIC ZONE OF PAKISTAN

Stations Detail	Passu AWS (Passu glacier)	Khamma Bagrot AWS (Hinarchie glacier)	Dammay Bagrot AWS (Chira glacier)	Bitrakh Bindogol, Chitral AWS	Kirchili Golain, Chitral AWS	Roghali, Golain, Chitral AWS
Latitude and Longitude	36.48°N 74.79°E	36.06°N 74.564°E	36.015°N 74.588°E	36.25°N 72.0546°E	36.025°N 72.172°E	35.8171°N 71.9917°E
Date of Installation	10-06-2011	August 2013	July 2013	17 June 2014	November 2014	August 2015
Elevation	4400 m.a.s.l.	3260 m.a.s.l.	4140 m.a.s.l.	4200 m.a.s.l.	3800 m.a.s.l.	3900 m.a.s.l.
Details of sensors	Air temperature, Humidity, Solar Radiation, Wind speed and direction, Rain	Air temperature, Humidity, upper and lower pyranometer, Upper and lower pyrgeometer, Wind speed and direction, Rain, snow scale,	Air temperature, Humidity, upper and lower pyranometer, Upper and lower pyrgeometer, Wind speed and direction, Rain, snow scale,	Air temperature, Humidity, upper and lower pyranometer, Upper and lower pyrgeometer, Wind speed and direction, Rain, snow scale,	Air temperature, Humidity, Solar Radiation, ultrasonic snow height, Wind speed and direction, Rain	Air temperature, Humidity, upper and lower pyranometer, Upper and lower pyrgeometer, Wind speed and direction, Rain, snow scale,
Data Communication Mode	No Communication	Satellite Communication	GSM Communication	Satellite Communication	Satellite Communication	Satellite Communication

ANNEX 14

NEW SENSOR TECHNIQUES FOR CRYOSPHERIC MESAUREMENTS

(Mark Bennett's presentation, Campbell Scientific)

Fixed and Mobile Monitoring Stations

At any given proposed site for automated, glacial monitoring, both a fixed monitoring station (located on firm ground/rock adjacent to the glacier) and a mobile monitoring station (located on the glacier itself) could be employed to measure and collect various and specific types of meteorological and glacial data. In concept, the mobile station located on the glacier, with its various sensors and datalogger, would send its collected data via short-distance, low-power, spread-spectrum radio to the nearby fixed station. The datalogger at the fixed station would then incorporate this data from the mobile station into its own data structure and memory. All data could then be transmitted via satellite modem.

For data transmission vis satellite, two viable options include the Meteosat transmitter or the HughesNet modem. Campbell Scientific's offering based on Meteosat is shown here <https://www.campbellsci.com/tx320> , while its offering based on the HughesNet is shown here <https://www.campbellsci.com/hughes9502> .

With HughesNet, two-way, IP communications are available. This facilitates not only data transmission to the End User's server anywhere in the world, but also communications back to the datalogger. The latter capability is useful, for example, when a datalogger program must be altered or the datalogger's health and status must be checked for purposes of trouble shooting. Meteosat, on the other hand, offers only one-way data transmission. Meteosat is essentially free of charge. The HughesNet option would require a monthly fee comparable to, or slightly higher than a standard cellular data plan.

A fixed station could primarily provide standard meteorological measurements ... such as (a) wind speed, (b) wind direction, (c) ambient air temperature, (d) relative humidity, (e) barometric pressure, and (f) short-wave solar radiation. A mobile station could provide glacial measurements such as (f) vertical temperature profile within glacial ice, (g) snow depth/level, (h) four-component solar radiation for energy balance, and (i) ice movement. More problematic to obtain, but very much needed, is (j) snow-water equivalent (SWE) of accumulated hard precipitation. As research objectives may dictate, any of the above-mentioned parameters could be used or replicated at either the fixed and/or the mobile station.

Standard Meteorological Measurements

Refer to the above-described items (a) through (f). These parameters are easily measured with standard, low-power, research-grade instrumentation available through Campbell Scientific.

Additional Standard Measurements

Snow Depth/Level

During periods of relative calm, when snow is not falling or being blown about, the distance between (a) the surface of accumulated snow and (b) a sonic distance sensor (mounted on cross-arm, attached to tripod) is readily and easily be obtained. See Campbell Scientific's SR50A "Sonic Ranging Sensor," where either non-heated or heated is available.

- Non-heated: <https://www.campbellsci.com/sr50a>
- Heated: <https://www.campbellsci.com/sr50ah-l>

Four-component Net Radiometer

With a properly mounted, 4-component net radiometer, both incoming and reflected short-wave and long-wave components can be accurately measured. Albedo can be calculated, etc. Examples of sensors that could be used, and that are compatible with Campbell dataloggers, are:

- Kipp & Zonen CNR4 4-Component Net Radiometer <http://www.campbellsci.ca/cnr4-l>
- Apogee Net Radiometer: <http://www.apogeeinstruments.com/net-radiometer/>

Non-standard Glacial Measurements

Temp Profile within Glacial Ice

Campbell Scientific's CS225 Temperature String is used for developing a temperature profile with soil, permafrost, or potentially within ice. See <http://www.campbellsci.ca/cs225> For the latter application, we anticipate that the empty volume resulting from an ice core could house the temperature string in a suspected position. The annular space at the surface would be sealed off from thermal communication with atmosphere. After installation, the sensor should likely be considered "sacrificial," as the movement and shifting of ice may render the sensor irretrievable. It should also be understood that the sensor may be destroyed by such dynamic conditions during or after its first season of use.

Ice Movement

There appears to be few, if any, practical, affordable methods for measuring movement of a point on a glacier. Standard optical, geodetic monitoring could be used for such an application, but high cost and remote siting of advanced, tripod-mounted equipment would make this option impractical. (See <http://leica-geosystems.com/products>) If a practical solution can be developed, it would likely include finding and using a high-resolution, low-temp, GPS sensor mounted on a self-"verticalizing" elevated pole. Such devices can achieve approximately 10 cm-level resolution, in all directions ... X, Y, Z.

Accumulated Snow Water Equivalent (SWE)

This is an extremely difficult measurement to make in harshly cold, remote locations. To do it properly, one would typically use a weighing rain gauge, with heated rim. A heated rim is needed to reduce/prevent the formation of ice on the rim of the funnel, which can otherwise progressively build until the funnel opening is partially or completely sealed over with ice. This approach is workable, however, heating elements require a significantly increased power supply in the form of larger solar panel(s) and/or high-capacity (100 amp-hour), deep-cycle, rechargeable batteries.

- SWE Alternative Option #1: One possible option to pursue would be designing and using a precipitation stand-pipe, fitted with pressure transducer. Such stand pipes are in wide-spread use within the SNOTEL network operated by U.S. Natural Resources Conservation Service (NRCS) with the western United States. See <http://www.wcc.nrcs.usda.gov/snow/> Such a device should be sized to contain all

precipitation for an entire season, and must use a glycol/alcohol antifreeze mixture to melt hard precipitation. Such a mixture, with a specific density of 1.0, would “weigh out” as water. This option should also include structural design features to allow for self-“verticalizing” of the standpipe.

- SWE Alternative Option #2: Campbell Scientific offers its CS725 Snow-Water Equivalent (SWE) Sensor. See <https://www.campbellsci.com/cs725> To determine SWE, this device measures the attenuation of naturally occurring gamma radiation emitted from soil, which radiates upward through the snow pack to the device mounted above the highest anticipated snow level. While the CS725 has demonstrated excellent performance in soils-based applications, it has not yet been fully proven in glacial applications. (Note: academic research is currently in process for such an application, where, instead of naturally occurring gamma radiation from soil, the radiation is derived from potassium-seeding within an enclosed container located at the base of the measurement area.)

Trail Cam

We suggest the use of one or more “trail cameras,” focused on key instruments, to record environmental conditions which otherwise would not be known. For example, a trail camera focused on the funnel opening of a precipitation gauge or stand-pipe could show potential ice build-up and possible need to account for this condition when evaluating reported data. This trail camera would be turned on prior to departure of installation team. The camera would operate for many months ... presumably well into the winter season ... until the battery went dead. At the next site visit, the camera would be retrieved ... perhaps replaced by a new camera ... and the images obtained could prove to be invaluable for reviewing conditions at the monitoring station.

ANNEX 15

ICE-CORING AND OTHER FIELD GLACIOLOGICAL RESEARCH IN CENTRAL ASIA

(Vladimir Aizen presentation)

Ice-coring and other field glaciological research in Central Asia performed by the International team of glaciologists under the UNESCO HEIGE IGCP Project auspices and financial support of the NSF (**US**), University of Heidelberg and Commission for Geodesy and Glaciology Bavarian Academy of Sciences (**GERMANY**), Nagoya University and Chiba University (**JAPAN**), University of Grenoble (**FRANCE**) and Cold and Arid Region Environmental Engineering Research Institute (**CHINA**)

- Ice-coring paleoclimatic and glaciological research in Central Asia focuses on the development of well dated, multi-parameter, high resolution paleo-climatic records for the last thousands years through the chemical and physical analysis of ice cores recovered from accumulation areas of the Asian glaciers (*Tien Shan, Altai, Tibet Pamir and Himalayas*).
- The project is aimed to fill a substantial knowledge gap in global change processes as it relates to our understanding of climate change effect on the alpine cryosphere and snow/ice/water resources at high Asia. The research is conducted with emphasis in study of the ecological consequences of global climatic change impact on natural and human-influenced systems, e.g., atmosphere/cryosphere/land surface hydrological and chemical cycling in the Asian alpine river basins.
- Time-series developed from the physical (e.g., visible stratigraphy, microparticle concentrations) and chemical (trace elements, major ions, and stable isotopes) analyses of the ice cores. This research also includes detailed meteorological and glaciological measurement at high mountains in Asia. The observational data received through the research allow to describe and assess the variability in the Earth's climate system (e.g., temperature, precipitation/snow accumulation, atmospheric circulation dynamics, glacier's mass balance, glacier area and glacier ice volume changes, etc). The unique data developed using this complex approaches allow to obtain more comprehensive understanding the physical and chemical processes that drive regional climate and hydrologic changes over the past several thousand years. Both, the ice-core paleo-climate reconstruction and modern observational data will be used to validate the GCMs. Most of the data stored at the University Idaho (US) will be public available through a renewed AsiaCryoWeb data base.

To assess, model, and predict climate and hydrological consequences of accelerated cryospheric changes in future, the international research team also use the modern remote sensing and the last 50-80 years in-situ observational data collected over the high Asia. The collected data and comprehensive computational analysis will (?) allow developing several end- cryospheric products used in Snow-Glacier-Runoff (SGR) model and potential ready to use in the Global Circulation Model. The ice-cores paleo-climatic data calibrated with the modern climate-cryosphere data are unique proxy data, which can be used to improve and validate a Climate Prediction Model and evaluate the consequences of high mountains cryosphere degradation on water resources in Asia.

The results of the last 15 years research presented in:

- Fifty to eighty years of daily, monthly, and annual meteorological records from 452 meteorological stations and hydrological gauges throughout the central Asia (51° – 113°E ; 56° – 32°N). All data has been checked for homogeneity and random errors

according to the method of *Fotheringham and others, 2002; Brunsdon and others, 2001*. Continuous spatial fields of central Asia climate change characteristics, i.e., differences in means for two 35-year periods 1975-2015 and 1935-1975, acceleration in changes, and differences in standard deviations, generated and validated using geographically weighted regression interpolation method. Changes in sums of annual, and seasonal precipitation, and means of annual and seasonal air temperatures of listed characteristics computed and mapped in GIS format (*Aizen and others, 1997; 2000; 2001; 2011; 2016*). All data collected and stored in *AsiaCryoWeb data base at the University of Idaho*.

- The central Asia each 8-day, 500 m grid resolution cloud-free (method of *Gafurov and Bardossy, 2009*) long term **snow cover extent dataset** from AVHRR and MODIS data (1975 – 2015) covered territory 51° – 113°E; 56° – 32°N (*Zhou and others, 2011; 2016*). Data collected and stored in *AsiaCryoWeb data base at the University of Idaho*.

The central Asia snow observational data that included end of each month snow depth, snow density and snow water equivalent from 1950s through 1991 is available from NSIDC (<https://nsidc.org/data/q01171/metadata>)

- Two glacier area change inventories developed for the entire Siberian Altai, Tien Shan and Pamir mountains: one for the beginning of 1970s and the second one for 2010s using Corona/Hexagon and Alos-Prism high resolution images. All images were co-registered using Ground Control Points (GCP) collected in the field and from Quickbird high resolution imagery and orthorectified using the DEMs. Glacier boundaries were derived using multispectral classification of ETM+/ASTER images and manual digitizing of KH-9 images. The USSR historical aerial photography applied to interpret and adjust glacier boundaries in 1970s (*Aizen and others, 2006; 2007; 2009; 2016; Surazakov and Aizen, 2007; 2010*). More detailed high resolution analysis of glacier area and glacier surface elevation changes completed for two largest glacier massifs in Central Tien Shan and Central Pamir based on IceSat and CryoSat radar altimetry data calibrated and with field high resolution GPS and measurements in 2009, 2011 and 2015 (*Lambrecht and other, 2014; Aizen and other 2016*).

All data collected during our research, including the ice-cores isotope-chemistry data, stored in *AsiaCryoWeb data base at the University of Idaho*.

The research results planned for publication by Springer Publisher in ~2017 or 2018 upon funds availability for the editorial work (*Aizen and Aizen. The Cryosphere of Central Asian Endorheic Basins*)

Currently, field research of the International Project team in central Asia (in 2015 and 2016) includes hourly meteorological monitoring with Campbell Sci AWS at elevation of 5600 m on the Fedchenko Glacier in Central Pamir (*data transmitted through satellite system to University of Idaho*). From 2016 this monitoring is planned to include the measurements of snow accumulation rate, snow density, snow temperature in the glacier active layer and from surface to the bedrock, the glacier surface elevation changes, and glacier surface velocity.

Information regarding the proposal to establish a high elevation monitoring project in central Asia, with indication of how the project should be promoted by the GCW (e.g. recommendation to be made to the GCW Steering Committee) by Vladimir Aizen

The problem

Changes in air temperature and moisture income influence high mountain regions differently at the macro- and meso-scale level. For example, glaciers in the European Alps, South and

North America are more vulnerable, and retreat faster than Himalayan, Karakoram, Pamir, or Tien Shan, glaciers due to their lower absolute elevations (*Paul and others, 2004; Naftz and others 2002; Franco and others, 2003, Aizen and others, 1997; 2011; 2016*). Climate change in different mountain systems affects the cryosphere regime differently at high mountains. The Himalaya, Karakoram, Pamir, Tien Shan and Altai are also natural barrier, which playing one of the major role in transformation of atmospheric processes over the vast Asian continent. Large scale mountain systems dynamically change the routes of the jet-stream and induce unique synoptic patterns in the leeward. Meridional shift of the location of the subtropical jet driven as a part of local-Hadley and sub-polar jet in the baroclinic zone is changing year-by-year, altering the seasonal timing of mountain impacts on local weather the snow cover and glacier mass balance. Weakening of upper jet-stream causes the activation of local deep convections and enhances diurnal signals.

Being part of the global cryosphere system, the Himalaya, Karakoram, Pamir, Tien Shan and Altai preserve approximately 12,000 km³ (*World Atlas of Snow and Ice Resources, 2011*) of fresh water in glacier ice that supply water to more than 2.5 billion people in the most populated part of the world. The global climate change may affect high mountains cryosphere and water resources of Asia dramatically, which can lead to a natural disaster and humanitarian catastrophe that has never been known in the history of humankind. The glacier mass accumulation areas located at elevations over 5000 m a.s.l. in Asian high mountains. We have little knowledge about the cryosphere processes in these areas, while this knowledge is critical to understand the consequences of the global warming impact on water resources of the mid- low latitudes of Asia. The development of cryosphere monitoring network at high mountains of mid- low latitudes of Asia will deliver a novel information about the high elevation cryospheric processes for calibration and validation of the physical based mathematical models. The new proxy results will give an assurance in development of the best possible strategy for mitigation and adaptation of the impact of global climate change on cryosphere/ water resources at mid- low latitudes of Asia in future.

High elevations cryosphere

Snow cover

Seasonal snow contributes up to 60% of snowmelt runoff from high mountain basins (*Aizen and others, 1996*). Seasonal snow is the most important source of melt water in high elevated mountain areas. Over the mountains, energy used for snowmelt amounted to 30x10¹² MJ yr⁻¹ with a maximum from the end of spring to the middle of summer. The annual air volume cooled 5 °C by snowmelt amounted, on average, to 0.9x10⁷ km³ yr⁻¹. The heat loss from snowmelt in mountains amounted to about one third of heat loss in the plains, and air volume cooled by snowmelt in mountains amounted to about one half of air volume over plains. The difference in the proportions occurred as a result of lesser air thickness in mountains than over plains, which allowed the cooling of a larger air volume in mountains under the same amounts of heat losses. The process of snow ablation and atmospheric cooling in mountains due to snowmelt occurs more slowly and without the abrupt changes observed on the plains, and the energy losses in mountains smooth the general process of atmospheric cooling prolonging it until the beginning of autumn, which create better condition for cryosphere existence at high elevations (*Aizen et al., 2000*). The study of seasonal snow cover extension and the energy spent during snowmelt are important in development of regional and global climatic models in a frame of the GCW (Asian Cryo-net) Program.

Glaciers

Glaciers integrate climate variations over a wide range of timescales, making them natural sensors of climate variability and providing a visible expression of climate changes, preserving climatic signatures that can be used to reconstruct past climatic and environmental records through isotope/chemical analyses of glacier ice-cores. Glaciers in Himalayas, Karakoram, Pamir and Tien Shan may be more stable than the glacier of the Alps or northern America, and may even advance (*Bahadur and Naithani, 1999; Ageta and others, 2001; Fujita and others., 2001; Aizen and others, 2006; 2011; 2016; Liu and others,*

2006; Narama and others, 2006). However, the shift between predominant atmospheric circulation patterns determine glacier dynamics and river runoff regime in the short- and long-term, as it may change the contribution of moisture (snow) to the glacier accumulation process and change the glacier surface albedo during the ablation period.

For instance, Altai and Pamir high mountains revealed an increase in annual precipitation in areas over 3000 m a.s.l. up to 8.1 mm yr^{-1} for the period ??? and increase in summer air temperatures of $0.03 \text{ }^{\circ}\text{C yr}^{-1}$ (Surazakov and others, 2007; Finaev, 2007; Aizen and others 2007; 2011, 2016)

Unlike the Pamir and Altai, precipitation in Tien Shan has increased mainly at the western and northern part of the mountain system, while air temperature has increased significantly at elevations below 3000 m ($0.02 \text{ }^{\circ}\text{C yr}^{-1}$). The difference in climate regime determined by changes in atmospheric processes contribute to the differences in glacier dynamics in Asian high mountains. The advancement of surging glaciers observed in Himalayas, Karakorum and Pamir in the last decades, while Tien Shan has no one advanced glacier (WWF program Report, 2005; Bolch and others, 2010; Aizen and others, 2016)

Conclusion

Scarcity of information about the processes of climate and cryosphere dynamics at the high mountains of Asia, at altitudes above 4000 - 5000 m a.s.l. does not allow proxy simulation of the possible future climate change impact on the cryosphere snow/ice water resources in Asia where life of people entirely depend on water from snow and glaciers melt water. One of the priority of the Global Cryosphere Watch (Asian Cryo-net) Program should be the development of high elevation observational cryosphere network over 4000 -5000 m a.s.l. in Himalayas, Karakoram, Pamir, Tien Shan and Altai mountains.

A first overview of the Asian High Elevation Cryosphere Observation (AHECO) project development plan

- AHECO project has been discussed during the 2nd GCW (Asian Cryo-net) Meeting in Salekhard, Russia in February 2016 and supported by the meeting participants and the GCW steering Committee
- The Glacier-climatic group of the University of Idaho will develop project-proposal to WMO to apply for the financial support through international monetary institutions for initial 5 years research of the project
- AHECO project can be developed on the basis of the regional hydrometeorological organization and academic institutions of Nepal (Himalayas), Pakistan (Karakorum), Tajikistan (Pamir), Kyrgyzstan (Tien Shan), Kazakhstan (Tien Shan) and Russia (Altai) by creating of small AHECO monitoring and technical support group (2-3 people in each country) that will maintain (serving) automatic observation equipment at high elevation one time a year. The financial support for every year field campaign in each country should be included in the AHECO budget
- Campbell Scientific Co, is willing to supply and install 2-3 automatic monitoring station for high elevation observations in Himalayas, Karakoram, Pamir, Tien Shan and Altai with the data satellite transmission system. The following the list of recorded parameters for each high elevation monitoring station: Air temperature, air humidity, atmospheric pressure, wind spread, wind direction, solar radiation (short and long wave), snow accumulation thickness dynamics, snow density, temperature in the glacier annual active layer ~30 m from surface to bottom), changes in glacier surface elevation and glacier surface velocity). The sensors technical characteristics and other technical/engineering issues will be discussed with the Campbell Sci Co engineers. The Campbell Sci Co engineers or technicians will be obligated to

participate in some field surveys and the net-work remote monitoring management and support in according with an agreement between GCW Programme, the Campbell Sci Co, and the University of Idaho, the lead scientific institution of AHECO project

- The AHECO regional service groups will learn how to work and maintain automatic equipment and sensors during a training class (seminar), that Campbell Sci. engineers will organize in one of the Asian country or in US (depending on the project budget level)
- The data from each Cryo-net automatic monitoring station will be collected in data loggers locally (at each station) and transmitted through satellite system to University of Idaho Group for analysis and interpretation one time a day. All data will be collected and stored at the GCW AsianCryoWeb data base and will be available for the international research community
- The Glacier-climatic group at the University of Idaho will apply for an additional science (?) grant to NOAA or NSF, or US AID to support this project at University of Idaho and to organize the cryosphere monitoring and data analysis seminars in Asian countries. We suppose that these student will be involved in future maintenance and management of the Asian High Elevation Cryosphere Observation project and data analysis