WORLD METEOROLOGICAL ORGANIZATION

GLOBAL CRYSOPHERE WATCH

FIRST IMPLEMENTATION MEETING
Geneva, Switzerland
21 – 24 November 2011

Final report

Observing Systems Division
WMO Integrated Global Observing System Branch
Observing and Information Systems Department

WORLD METEOROLOGICAL ORGANIZATION

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GCW Report-1

EXECUTIVE SUMMARY

1. The cryosphere collectively describes elements of the Earth System containing water in its frozen state and includes solid precipitation, snow cover, sea ice, lake and river ice, glaciers, ice caps, ice sheets, permafrost, and seasonally frozen ground. The cryosphere is global, existing at all latitudes and in approximately 100 countries. Recognizing the growing demand for authoritative information on past, present and future state of the world's snow and ice resources, WMO Congress decided in 2007 to embark on the development of the Global Cryosphere Watch (GCW), in collaboration with other WMO programmes and international partner organizations and programmes. In 2011, the Sixteenth WMO Congress decided to implement GCW. The First Implementation Meeting of the Global Cryosphere Watch (GCW) was held at WMO Headquarters, Geneva, Switzerland 21-24 November 2011.

2. The GCW Implementation Strategy (IS) approved by WMO Congress in 2011 formed the basis for discussion at this first implementation meeting. The IS provided the GCW background, an overview of user needs, GCW mission and objectives, and suggested a GCW implementation process, including suggested initial tasks. This meeting was structured to engage participants and to maximize the benefits of existing activities and ideas for new collaboration presented by partners and other organizations in order to determine specific directions, tasks, services, products, contributions, and initial management structure for GCW which would contribute to the development of the GCW Implementation Plan. Documents and presentations can be accessed and downloaded through the GCW Documentation Plan prepared for the meeting (see: http://www.wmo.int/pages/prog/www/OSY/Meetings/GCW-IM1/DocPlan.html).

3. Although GCW is global in scope, participants emphasized the need for activities at all scales, including at regional, national and local levels. Early in the meeting, participants provided their perspective on the implementation of GCW and answered a set of questions in advance of the meeting which provided very valuable information and insight which was used in subsequent discussion of activities and needed actions. All participants emphasized the importance of the cryosphere in addressing national and international issues related to climate, water and weather and other environmental matters and how GCW, through existing and new activities, could provide a more cohesive and integrated effort with respect to observation, monitoring, assessment, product development, prediction, and research. Responses are appended to this report.

4. It is essential for GCW to understand users' needs for data and information so that GCW can be designed to address these needs, including the design and implementation of the GCW portal that would facilitate meeting these needs. A synthesis of user needs identified by participants and breakout group discussion identified five categories of use:

1. Long-term, sustained, high quality monitoring of cryospheric parameters at key sites/networks to meet particular ***strategic needs*** e.g. water security, hazards, building codes
2. Real-time cryospheric information for assimilation into ***operational forecasting***
3. ***Research datasets*** for improved understanding and process and climate model validation
4. Public and media
5. **Future scenarios** for long-term planning and adapting to a changing cryosphere (needed for 1 and 4) to meet the needs of decision and policy makers

5. There were several needs and gaps that participants felt were not being adequately met, and offered the following recommendations on how these might be addressed:

- Sustained monitoring activities at long-term reference sites are needed. It was noted that some key sites are being lost. **"GCW-endorsed" long-term sites would help to protect key sites**

- There are gaps in *in-situ* observations in some polar regions, such as northern Canada, Alaska, Siberia, limiting NWP forecasting capabilities for such areas. **GCW needs to engage the modelling and monitoring communities to determine what and where there are key gaps and for which variables.** It was acknowledged that there is a need to optimize monitoring in face of declining budgets.

- GCW needs to have a good grasp on what cryospheric data and products currently are available and to know where there are gaps. **GCW should initiate a "gap analysis" process,** recognizing that this needs to be balanced to avoid ending-up as just a wish list for more resources. The gap analysis **could be linked to important "hot topics"**.

- It was felt that scientific community collaboration in core monitoring is essential to maintain a robust system. **GCW should play role in strengthening collaboration between partners.**

- Lack of new young scientists in cryospheric sciences is considered a critical gap. **GCW should look at ways to entrain new expertise as part of its capacity development effort**.

6. There will be a wide range of users, both internal and external. However, the workload to satisfy their needs could be very different. The following considerations were presented:

- GCW needs to look carefully at the ***"value chain"*** from raw data to different levels of information relevant to different user groups to have a clearer understanding of who are the clients, and what their needs are.
- GCW needs to make sure that the connections can be made between the data and the decision ***(a "decision support" role*****)**
- GCW should go out and meet users at their table.

7. The Norwegian Meteorological Institute (METNO) has taken the lead in developing the information portal for GCW. The portal, as a part of the WMO Information System (WIS), will allow for rapid exchange of data, metadata, information, and analyses. GCW will use **distributed data management** in practise in order to utilise existing infrastructure and efforts, avoid duplication of data, integrate existing infrastructure through machine interfaces to metadata and data and the exchange of metadata. A demonstrator prototype portal has been established. It currently contains information on IPY datasets documented in Norway (through metadata exchange between institutes), on EU FP7 DAMOCLES and EUMETSAT OSISAF datasets and datasets at NSIDC. Next steps include a regular harvest from the Canadian Cryosphere Information Network (CCIN) as well as examination of interoperability with British Antarctic Survey (BAS), International Permafrost Association (IPA), and the World Glacier Monitoring Service (WGMS). For the GCW portal, participants identified two levels of **required information – data and the higher level "watch" information.** Discussion identified two key issues - **"Who is responsible for editorial information?" and "What/who is an authoritative source of information? It was recommended** that there needs to be a product review mechanism to provide QA and accountability for GCW datasets [*e.g. GCW expert teams*]. Participants suggested that:

- *GCW should initially focus on the key cryosphere datasets;*
- *there needs to be an inventory with which to start in order to determine what is available;*
- *there should be free and open access;*
- *there is a role for GCW in data comparison and development of integrated datasets/integration, e.g. with respect to different sea ice extent products.*

8. The GCW IS had proposed initiation of a comprehensive **cryosphere observing network called "CryoNet",** a network of reference sites or "supersites" in cold climate regions, on land or sea, operating a sustained, standardized programme for observing and monitoring as many cryospheric variables as possible. CryoNet would provide reference sites for validation of satellite and model outputs. Initially, it would build on existing cryosphere observing programmes or add standardized cryospheric observations to existing facilities. Some potential sites covering different regions and cryospheric conditions were presented (Finland, China, Austria, Antarctica), which set the stage for discussion in the breakout session. Participants strongly endorsed establishment of such a specialized network and **recommended that GCW should establish a team to initiate the task on defining and identifying supersites and reference sites** for integrated, multidisciplinary environmental monitoring. A small initial task group was established to initiate the task.

9. Participants strongly supported the recommendations presented by WMO on guidelines, standards and best practices. These are provided in the report. It was recommended that GCW needs to establish small task groups to **initiate the compilation of current guidelines, standards and best practice in use in the cryosphere community**. Contributors who could start the process were identified.

10. It was acknowledged that there are many sources of **cryosphere terminology** available, possibly in different languages, often having different definitions for the same term depending on the source and community of use. It was **recommended** that GCW should **establish a small team** from the different communities (e.g. IACS, WGMS, WMO, UNESCO and countries with national glossaries) **to compile the lists of existing publications of cryospheric terminology/vocabulary** and then **outline the next steps to consolidate** a list of terms based on existing sources. Ultimately the **terms should be available in multiple languages.**

11. Participants unanimously agreed that **partnering is essential** for GCW to be successful. This involves engaging government agencies and institutions that measure, monitor, or archive cryosphere data and information from in-situ and satellite research and operational networks and model sources, and international research organizations. Several international organizations (IACS, IASC, IPA, GTN - P, WCRP, WGMS/GTN-G) and national organizations and programmes (GlobSnow, CryoClim, NSIDC) made presentations on what they do and on collaborating and partnering in the GCW initiative for mutual benefit. Partnering was also acknowledged as an essential ingredient for achieving an integrated perspective of the cryosphere. GCW offers the unique opportunity to look at the cryosphere as a whole and to look at regional aspects of the cryosphere and its components. Presentations on experiences in Canada (CRYSYS), Nordic countries (SVALI) and in Svalbard Norway (SIOS) provided valuable insight in identifying opportunities for pilot and demonstration projects within GCW. The Pilot/Demonstration Projects break-out session provided an extensive list of actions, activities and deliverables, and suggested contributors to the potential task(s) being discussed. This provided many concrete suggestions which could be subsequently used by GCW task teams.

12. Providing **authoritative information** is considered as a key attribute of GCW. Presentations on satellite products, instrument intercomparisons and production of authoritative products provided participants with valuable information for consideration in their discussions. The GCW Products break-out session included discussion of both *in-situ* and satellite data and information products. It was suggested that the **types of products** could be categorized by cryospheric element and should consider both research and operational products for both real/near-real-time and climate scales. There were three levels envisaged: **data products, information products and higher-level aggregated products.** Examples of each are provided. There was discussion on creation of a data products inventory and what it might contain. The group felt it should include subsets of a main data product inventory, include data on format and recommendations on the use of the data products and include

cryospheric data from established models. In all cases it is essential to build on what is already available. The process must allow for user feedback to ensure products will meet user needs.

13. Communication, outreach, capacity development and resource mobilization were considered collectively and several suggestions from WMO were offered to the group. The first hurdle was to explain clearly "what is the cryosphere". Communications has to reach funders and decision makers, in terms they understand and this approach should be embedded in GCW from the beginning. Good communication will need to ensure a consistent response to issues and GCW efforts will be aimed at complementing, not duplicating, others' efforts. GCW must develop an effective capacity development strategy. Capacity development will initially be coordinated with existing WMO efforts and will take advantage of mechanisms established by WMO Programmes and co-sponsored programmes, RAs, TCs, and GCW partners. Aspects which GCW should consider as part of its capacity development efforts were discussed and are given in the report. It was emphasized that GCW needs to show how and why the cryosphere is important to a nation since a key for capacity development is national commitment. Likewise for resource mobilization, there is a need to demonstrate the relevance of the cryosphere within weather, climate and water to get large funders interested in cryosphere.

14. Parallel breakout sessions were held on the last day to discuss how GCW should be structured, managed, and work with partners. The breakout groups were asked to suggest how GCW could effectively operate and interact and addressed the topics:

- *What expert teams are needed for GCW?*
- *Describe the activities and roles of the teams and suggest who should be involved.*

Participants were guided by the Implementation Strategy, including the initial framework, or conceptual model, for GCW and by discussion on activities at this meeting. Different, but complementary, perspectives came from three groups, which were then used to recommend a structure for GCW and its activities. The initial structure was further refined at the EC-PORS GCW Task Team meeting whose deliberations are included in this report.

15. A GCW **operating structure,** including objectives, tasks and co-leads were defined as:

1. Observing Systems Working Group (co-leads: Jeff Key and Wolfgang Schoener)

(a) CryoNet Team

(b) Requirements and Capabilities Team

(c) Infrastructure and Practices Team

2. Products and Services Working Group (co-leads: Jim Abraham and Walt Meier)

(a) Portal Team

(b) Products Team

-Terminology Sub-Group

(c) Outreach Team

Tasks and roles were identified for the GCW focal points and for the Secretariat. A GCW Implementation Plan is being drafted. It will build on the Implementation Strategy and include the ideas for working structure suggested at this first GCW Implementation Meeting. A revised GCW structure will be presented in the IP and the responsibilities of the various components will be defined. Initially it was suggested that the EC-PORS should have initial oversight of GCW.

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1. OPENING OF THE WORKSHOP

1.1 The First Implementation Meeting of the Global Cryosphere Watch (GCW) was held at WMO Headquarters, Geneva, Switzerland 21-24 November 2011. The meeting was jointly organized by the GCW Task Team of the WMO Executive Council Panel of Experts on Polar Observations, Research and Services (EC-PORS) and the Observing and Information Systems Department of WMO. Mr Jim Abraham, co-chair of the EC-PORS Observations Task Team, served as General Chairperson for the meeting.

1.2 Dr Barbara Ryan, Director, WMO Space Programme, officially opened the meeting, welcoming the participants to WMO and the GCW meeting. Dr Ryan noted that participants were from many different countries, represented different organizations having a wide range of interests over a wide range of time and space scales, and brought decades of experience in cryospheric studies. She noted that cryosphere is a “hot topic” which impacts not only nations where the cryosphere occurs but also other nations, often developing ones, where cryosphere is not present. She pointed out that engagement of users of cryospheric information is important so GCW understands what the user needs are in order to make information easily available, while ensuring it is authoritative, based on the best observations, measurements, products and models that we have from all countries, organizations and investigators. GCW needs to be an authoritative voice as is the Global Atmosphere Watch (GAW). She emphasized that GCW needed participants’ extensive experience for its successful development and implementation. It is the collaboration of the broad community that will in fact make it successful. Dr Ryan invited participants to be partners in this new WMO initiative – Global Cryosphere Watch.

2. ORGANIZATION OF THE SESSION

2.1 The programme for the workshop was adopted with minor amendments, in order to accommodate last minute changes in individual travel schedules. The final programme is attached as **ANNEX 1**.

2.2 Participants briefly introduced themselves and identified their interests and background relevant to the themes of the session (see also **ANNEX 5**). The final List of Participants is attached as **ANNEX 2**.

2.3 Dr. Goodison provided the required logistic details during the period of the workshop and outlined working arrangements.

2.4 The meeting was organized to maximize discussion and interaction among participants on key issues using breakout sessions which were supported by background documents and presentations. The breakout sessions were designed to identify activities and related actions for GCW. This will contribute to the development of GCW Implementation Plan to be considered at the next EC-PORS session in Finland in February 2012. All written documents prepared for the meeting and all presentations (pdf format) can be accessed and downloaded through the GCW Documentation Plan prepared for the meeting (see: http://www.wmo.int/pages/prog/www/OSY/Meetings/GCW-IM1/DocPlan.html). These documents will be kept available through the GCW website.

3. GCW: HERITAGE AND CURRENT STATUS

This session provided background information, focussing on the development and evolution of GCW.GCW cuts across all WMO Programmes, has links to all Technical Commissions, and engages partners external to WMO. Its scope is global. Implementation will be both exciting and challenging.

3.1 EC Panel of Experts on Polar Observations, Research and Services (EC-PORS)

3.1.1 The EC-PORS was established by WMO in 2008 and one of its major activities is to provide guidance and oversight for the development of GCW. EC-PORS established a Task Team to develop and implement the GCW. A. Snorrason, a member of EC-PORS and its GCW Task Team, presented an overview of the activities of EC-PORS. "Services" is a key driver that anchors the work of WMO Polar Activities, including GCW. It was emphasized that although the Panel has a "polar" emphasis, GCW is truly global in its scope.

3.1.2 EC-PORS brings observations, research and services together allowing WMO to maximize the value of its and its partners' investments in Polar Regions. Partnerships are critical for EC-PORS and GCW to be effective. Not only does PORS coordinate internally within WMO, but also externally with relevant organizations and scientific bodies to coordinate and implement WMO's cross-cutting polar activities. These linkages have also been essential in the development of GCW. EC-PORS currently has 32 experts nominated by 21 WMO Members (countries) and partner organizations. Members of its GCW Task Team included: Jeff Key (lead, USA), Eric Brun (France), Hans-Wolfgang Hubberten (Germany), Arni Snorrason (Iceland), Xiao Cunde (China), Karl Erb (USA). Support to this Task Team is provided by WMO Secretariat (Barry Goodison). Further information on EC-PORS activities can be obtained at http://www.wmo.int/pages/prog/www/polar/index_en.html.

3.2 WMO Integrated Global Observing System (WIGOS) and WMO Information System (WIS)

3.2.1 Two major activities of WMO influencing GCW development are the WMO Integrated Global Observing System (WIGOS) and the WMO Information System (WIS). Through WIGOS and WIS, GCW will provide a fundamental contribution to the Global Earth Observation System of Systems (GEOSS).

3.2.2 WIGOS is not a new observing system, but is an improvement and evolution of the present WMO global observing systems into an integrated, comprehensive, coordinated, cost-effective and sustainable system. It will provide a framework using defined and implemented mechanisms, processes, standards and best practices. WIGOS observations would be compatible, quality-assured, quality-controlled, well-documented (metadata), continuous, long-term and based on standard procedures and best practices. WIGOS will work through cooperation and partnership for coordinated evolution of observing systems and practices to provide operational availability and to support migration from research to operations, where appropriate, of some research-based observing systems. It will provide a mechanism for integration of research observations and handling of "third party" data (i.e. outside of WMO and NMHSs). GCW will contribute to WIGOS as an integrated cryosphere network. For more information, see www.wmo.int/wigos.

3.2.3 WIS aims to increase data visibility, broaden data access and simplify data use. WIS is intended to build on the success of the GTS, adding new Discovery Access and Retrieval (DAR) function and communications technologies based on the international standards to those of the GTS. There are technical and procedural constraints that centres operating as information providers within WIS have to meet that can be found at http://www.wmo.int/pages/prog/www/WIS/index_en.html. Data formats are more flexible than for the GTS with NetCDF currently being the core format, and with exchange in XML being expected in the near future. A key element of WIS is the creation of a metadata catalogue that allows users to find and access data. Preparing and submitting good metadata is essential in WIS. Outside users are being encouraged to make use of this interoperability and data exchange. The GCW portal is being developed so that it is WIS compliant. GCW offers an excellent opportunity to test WIS.

3.3 Global Framework for Climate Services

3.3.1 A major new initiative of WMO and partners is the Global Framework for Climate Services (GFCS). GCW would contribute to this evolving initiative. The goal of GFCS is to enable better management of the risks of climate variability and change and adaptation to climate change at all levels, through development and incorporation of science-based climate information and prediction into planning, policy and practice. GFCS is a global collective effort being built in collaboration with the UN family, partners and stakeholders and consultations with users and providers are intended to ensure the engagement of Members and stakeholders early in the process of the development of the draft Implementation Plan of the GFCS (GFCS-IP). Further details can be found at: http://www.wmo.int/pages/gfcs/consultations_en.php. All socio-economic sectors are to be tackled but in the first four years, the GFCS is proposing giving priority to water, agriculture, disaster risk reduction, and health. GCW would contribute to this evolving initiative through its capabilities related to observation and monitoring, research and prediction, and would link to the GFCS user interface platform (UIP). The GCW Implementation meeting was informed on the preparation of the Observations and Monitoring Annex of the GFCS-IP and participants provided valuable contributions to its preparation.

3.4 GCW: Mission, Objectives, Expected Outcomes, Implementation

3.4.1 The cryosphere occurs globally, existing in various forms spanning all latitudes and occurring in approximately one hundred countries, in addition to the Antarctic continent. Recognizing the growing demand for authoritative information on past, present and future state of the world's snow and ice resources WMO embarked on the development of the Global Cryosphere Watch, in collaboration with other WMO programmes, international partner organizations and programmes, with the aim of an operational GCW. Partnering and collaboration are essential in the development of GCW and in ensuring its success. This meeting was structured to engage participants and to maximize the benefits of existing activities and ideas for new collaboration presented by partners and other organizations.

3.4.2 The GCW Implementation Strategy **(ANNEX 3)**, approved by the Sixteenth WMO Congress in May 2011, formed the basis for discussion throughout the meeting. This document provided the GCW background, an overview of user needs, GCW mission and objectives, and outlines GCW implementation, including suggested initial tasks. It outlines the importance of collaboration and partnership, suggests possible management options, and provides an initial timeline for suggested tasks. All participants were familiar with the Implementation Strategy and used it in proposing subsequent activities and actions.

3.4.3 WMO Members have responded strongly and positively to GCW and with more than 30 Members from all WMO Regions nominating GCW focal points. These focal points will be involved in the development of GCW and will help integrate the global initiative with their national plans. In addition to Members with specific national or regional activities in the Polar Regions, interest was expressed by Members (e.g. Maldives, Thailand, Malaysia) who are concerned about changes in the cryosphere and the potential impact on their country. More than one person could be nominated and the Individual could be from outside the NMHS, as appropriate, recognizing that cryospheric activities commonly extend beyond the mandate or responsibility of the NMHS. Draft Terms of Reference for Focal Points and the current list of focal points (by country and WMO region) are given in **ANNEX 4.**

3.4.4 The meeting was structured to determine specific directions, tasks, services, products, contributions, and initial management structure for GCW. Participants' ideas on these issues were essential to expand implementation from the strategy to an **Implementation Plan (IP)** which would provide the basis for subsequent activities and actions. An outline for the Plan was presented to the meeting. A draft IP will be presented to the EC-PORS for consideration in February 2012.

4. ROUNDTABLE DISCUSSION

4.1 The meeting engaged participants from several different organizations, agencies, and institutions and from many countries. Perspectives on the implementation of GCW could be quite wide ranging. In order for all participants to have some background information about each other and for the different agencies and institutions, participants were asked to provide in advance of the meeting short answers to the following questions:

- What is your personal area of interest in the cryosphere?
- What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?
- What are the needs of users in your institute/country/region for cryosphere data and information?
- How could GCW help meet your national, regional or global interests?
- What could you or your organization contribute to the implementation of GCW?

4.2 The responses of participants were excellent and provided very valuable information and insight which was used in subsequent discussion of activities and needed actions. Participants provided a short verbal summary to highlight issues which should be discussed further in breakout sessions. All participants emphasized the importance of the cryosphere in addressing national and international issues related to climate, water and weather and other environmental matters and how GCW, through existing and new activities, could provide a more cohesive and integrated effort with respect to observation, monitoring, assessment, product development, prediction, and research.

4.3 Participants' unedited replies are given in **ANNEX 5** and are not summarized further in this report.

5. PERSPECTIVES ON CRYOSPHERIC ISSUES AND GCW CONTRIBUTION

5.1 The GCW is building on accomplishments of the global cryosphere community. One key contribution of the community was preparation of the IGOS Cryosphere Theme (CryOS) Report (http://igos-cryosphere.org), published in 2007, which provides a firm basis for developing and implementing GCW. The CryOS report was the culmination of effort by the worldwide cryospheric science community, initiated in 2004 by the World Climate Research Programme (WCRP) Climate and Cryosphere (CliC) project and by the Scientific Committee for Antarctic Research (SCAR) on behalf of the Integrated Global Observing Strategy (IGOS) partnership. The Report contains more than 100 recommendations for all elements of the cryosphere and **ANNEX 6** provides a simple compilation of those recommendations. Additional background information can be obtained from the CryOS Report.

5.2 One of the outcomes of this meeting was to identify in the GCW Implementation Plan how GCW will build on these recommendations to ensure a comprehensive, coordinated and sustainable system of observations and information to allow for a full understanding of the cryosphere and its changes. It was agreed that GCW would subscribe to the GCOS Climate Monitoring Principles for *in-situ* and satellite observations (see **ANNEX 7**).

5.3 GCW is global, but there needs to be activities which not only address the global scale, but also regional, national and local scales. Several participants offered to discuss their more "regional" or national activities and issues with respect to cryosphere, and to indicate how these could contribute to GCW and how GCW could help meet their needs. Again, these presentations provided background information for discussion in the breakout sessions and many offered specific suggestions for action by GCW.

5.4 There are some points raised in these talks which were particularly relevant in subsequent discussions, including:

- The need to establish a **network strategy for the proposed CryoNet**;
- The value of **supersites** for detailed integrated monitoring and of regular reference sites with a more "relaxed monitoring programme" which focus on key cryospheric variables. Pallas-Sodankylä was offered as a high latitude supersite;
- The need for supersite(s) in alpine regions, the Southern Hemisphere and Antarctica;
- The **importance of both satellite and in-situ data** for product development was emphasized by several presenters, noting the important role of reference/supersites for calibration/validation and satellite and model outputs.
- The **need for regional information in the Southern Hemisphere,** not just in the Northern Hemisphere.
- The essential link between **cryosphere and water resources** in all regions of the world; the rapid **degradation of glaciers** in several regions highlighted their importance to water resources;
- The importance of **long term data** records, the re-establishment of observing sites in often remote but economically important regions, the increased use of auto-stations, and data sharing was highlighted by several presenters.
- Tajikistan emphasized the challenge of **data sharing as it is often viewed as a political issue** when related to water resources. Would the sharing of data be different if viewed as a hazard issue?
- The need for **co-ordination of work among institutes both within and between countries** to maximize the value of information collected; often difficult to coordinate work between countries but GCW offers countries an opportunity to organize themselves, e.g. in Region III (South America).
- The significant contribution of the SCAR (Scientific Committee on Antarctic Research) project called **READER** (REference Antarctic Data for Environmental Research) which has produced the best dataset of Antarctic surface and upper air temperature data.
- All Antarctic **data must be shared**
- What will or should GCW's **role be with respect to ice cores**; how could it work with PAGES on this issue?
- The need for improving measurement of **precipitation amount in Antarctica**, since most of it falls as snow and is an important component of the cryosphere. This is a very hard parameter to measure but would be a very useful dataset.
- The need to have better **seasonal forecasting of sea ice** to help with planning of ship operations; better knowledge of sea ice conditions contributes directly to improved ship safety and efficiency
- The **lack of young scientists** engaged in field work was identified as a challenge for GCW and the cryosphere community.

5.4 The chairperson provided an excellent perspective of the wide ranging discussion and provided a high-level summary of key points as assets that participants, institutes and partners bring to GCW and needs that GCW can help meet. It is clear that collaboration and co-operation will benefit everyone.

Assets	Needs
• Data, archives, products, services • Portal, gateway and telecom distribution systems • Standards and best practices • “supersite” infrastructure • Expertise • Connections to partners and relevant activities • Validation • Modelling and data assimilation systems • Documented and assessed impacts • Research, educational and outreach activities • Gatherings • Antarctic activities • Resources ($$)	• Observations (including sustained & real-time) • Data - common standards, metadata, sharing policy • Dedicated web portal • Products • research, process understanding • Services to meet needs of variety of users • Sustainable management of resources • Validation • Modelling and data assimilation systems • Understanding of impacts • Educational and outreach activities • Antarctica • Resources ($$)

6. ADDRESSING USER NEEDS

The GCW strategy is to provide information to Members and the wider user community for informed decision making and policy development related to climate, water and weather, for use in real time, for climate change adaptation and mitigation, and for risk management. Over time, this information would become more service-oriented. The challenge is to truly understand users’ needs for data and information so that GCW can be designed to address these needs, including design and implementation of a GCW portal that can facilitate meeting these needs. Valuable insight for the discussion in the Breakout Session on User Needs was provided by the presentations made by participants, the GCW Implementation Strategy (Annex 3), and a synthesis of written responses from participants (Annex 5). The presentation and subsequent discussion on the prototype GCW portal provided some clear insights into how these needs might be effectively met.

6.1 Needs of Users: Synthesis of Participants’ Responses

6.1.1 Based on the responses to the question “*What are the needs of users in your institute / country / region for cryosphere data and information*”, a synthesis by Ross Brown (Canada) found that users fell into five main categories:

6. ***Long-term, sustained, high quality monitoring of cryospheric parameters at key sites/networks to meet particular national needs*** (e.g. snow depth monitoring networks in Austria and Switzerland, avalanche forecasting in France, glacier mass balance in Norway for hydro-electric power (HEP) management, snowfall monitoring in Andes for water resource management, glacier runoff in Tajikistan…) with strong strategic aspects to these networks for

operations, economy and long-term planning (e.g. building snow loads, agriculture, HEP, water security, transport, tourism, public security, natural hazards etc).

7. ***Real-time information for operational forecasting*** (timeliness, quality and good spatial coverage are important; need estimates of uncertainty for 4Dvar assimilation).

8. ***Research datasets for process and climate model validation*** (high quality, high spatial resolution, uncertainty estimates, ancillary information (temp, precip, U, RH, Q↓); longevity was less an issue, but homogeneity was important).

9. ***Public and media*** (information, education, outreach etc) Main issues are credibility (accuracy, accountability), up-to-date information, quick access, ability to monitor and respond to cryosphere "anomalies" that become media events for 15 minutes.

10. ***Future scenarios for long-term planning strategies, policy development*** (e.g. HEP, water resource security).

6.2 Modellers Needs

6.2.1 The needs of modellers are of particular importance and those needs were discussed by Gianpaolo Balsamo (ECMWF) and Eric Brun (MeteoFrance). Several important points were identified, including:

- The benefits of snow **data from supersites**, notably Sodankylä, for model development and validation
- The benefits of using both ***in-situ*** **and satellite products** of snow depth and snow cover in the assimilation process
- The need to **exchange** snow depth data in real-time for assimilation into the model
- The importance of good snow analyses for **improving forecasts** in eastern and southern Asia, especially for 500Hp
- The **problems** of *in-situ* snow depth observation (automation, representativeness, reporting) and the need for better quality control of snow depth data

6.2.2 **Suggested Actions for GCW**:

- ***A GCW initiative to foster and sustain new observing facilities, such as reference and supersites would be welcomed***
- ***Transmit zero snow depth when there is no snow on the ground***
- ***Promote local SWE measurements***
- ***Facilitate a demonstration project in regions of the world on data assimilation of snow cover, using agreed metrics and a validation data set***

6.2.3 The recent ECMWF newsletters provide useful and timely background on the modelling needs of users. For surface modelling, this may be accessed at http://www.ecmwf.int/publications/newsletters/pdf/127.pdf. The recent revisions of cloud and precipitation provide elements for the discussion on the atmospheric modelling needs. See for instance the article by Forbes and Thompkins in: http://www.ecmwf.int/publications/newsletters/pdf/129.pdf.

6.3 Role of the GCW Portal

6.3.1 The Norwegian Meteorological Institute (METNO) has taken the lead in developing the information portal for GCW. Building on other related activities, this effort has been a tremendous contribution to the initiation of GCW in a timely and logical manner. WMO greatly appreciates this contribution and leadership.

6.3.2 There are **preliminary functional requirements** for the portal, a primary one being that users of cryospheric data, products and information should be able to easily find what they need. The portal should support both human and machine interfaces. The GCW web portal will make GCW data and information and metadata available to WMO Members, their partners, and users while providing the ability to exchange data and information among a distributed network of providers of data and products. The portal, as a part of WIS, will allow for rapid exchange of data, metadata, information, and analyses.

6.3.3 There are two **main components** – editorial and catalogue. The editorial component is concerned with editorial content prepared by the community; it is distributed by its nature and community contributions allow for "pushing" data through. The catalogue component is focused on metadata that can be obtained from various catalogues, preferably linking directly to data. It is also, by its nature, distributed as one can harvest or use a distributed search across relevant existing catalogues to "pull" information through. Currently, there is a fragmented system with multiple catalogues/portals to check, often with limited data online. There is often multiple or even incompatible file formats/interfaces for products and highly variable documentation standards, e.g. positioning information, quality information or traceability.

6.3.4 **Data management** is important for GCW. GCW aims to improve exchange of observations and products, access to observations and products, and utilization of observations and products from WMO and other observing systems. Establishing interoperability between data management systems supporting cryospheric data directly addresses GCW objectives. GCW will link infrastructure and aims to utilise relevant information no matter where it is located by linking and bridging existing infrastructure. GCW will not "reinvent" anything. GCW will use **distributed data management** in practise in order to utilise existing infrastructure and efforts, avoid duplication of data, integrate existing infrastructure through machine interfaces to metadata and data and the exchange of metadata. This is seen as a sustainable solution as datasets are maintained by owners/creators, information on datasets and are maintained by owners/creators and the subsystems work.

6.3.5 Achieving a successful, sustainable distributed data management system, however, does **require certain conditions**, including:

- Standardisation of documentation, file formats/access mechanisms etc supporting system interoperability
- Implementation of interfaces supporting the standards
- Willingness to utilise standards
- Willingness to properly document data
- Willingness to properly share data and information
- Translation between various interoperability standards/dialects
- Establish rules of operation

6.3.6 The GCW portal is **collecting information** from a set of distributed data management systems. It collects metadata, not data and prepares this for discovery, enabling users to perform a dedicated search for cryosphere related data without entering a multiple of systems. The idea is that GCW should present information contained within WIS centres, World Data System centres (e.g.

NSIDC) and other types of data centres. GCW will be based upon the interoperability framework defined through WMO Information System, but in order to integrate information from various sources not belonging to WIS, a certain level of pragmatism is required for the interoperability standards.

6.3.7 While discovery and access to data is the primary functionality of any portal, experience shows that users soon request more advanced functionality, such as visualisation, transformation, reformatting, and re-projection of datasets. Given the open data space of GCW, enabling higher order functionality like distributed visualisation and transformation would require some harmonisation of protocols. This would have to be enabled on a dataset basis through proper description of interfaces to the datasets and implementation of layers accessing the data. However, **the first priority is enabling data discovery across the data centres contributing to GCW**.

6.3.8 There are **technological considerations** for catalogue interoperability, involving exposing metadata using standard interoperability interfaces and documentation standards (e.g. OAI-PMH, OGC CSW, ISO23950, **ISO19115**, GCMD DIF). It is preferable to keep data online. There are relevant frameworks for catalogue interoperability including WMO Information System (WIS), ICSU World Data System (WDS), and Group on Earth Observation (GEO). There are regional frameworks, such as INSPIRE and domain specific frameworks that includes the Global Change Master Directory, International Permafrost Association and IPYDIS.

6.3.9 There will be **challenges** in developing the GCW portal from content management for editorial information to deciding what a GCW dataset is. What interoperability standards should be employed? How does GCW achieve a sustainable solution to ensure the future relevance of GCW?

6.3.10 There is a **demonstrator prototype portal** available at: http://gcwdemo.met.no/. It addresses only the catalogue component of the GCW portal. It currently contains information on IPY datasets documented in Norway (through metadata exchange between Norwegian Polar Institute, Institute of Marine Research and Norwegian Meteorological Institute), EU FP7 DAMOCLES and EUMETSAT OSISAF datasets and at NSIDC.

6.3.11 Preliminary plans for the demonstrator include updating the software, improving filtering, moving the demonstrator to a new computer and database, and linking with METNO WIS nodes. A regular harvest from the Canadian Cryosphere Information Network (CCIN) will be implemented after testing ingestion into the database. Examination of interoperability with British Antarctic Survey (BAS), International Permafrost Association (IPA), potentially the World Glacier Monitoring Service (WGMS) and sustainable visualisation and transformation of remote datasets are planned to be investigated. There is much that can be done, but development will be related to available resources and associated cost-benefit analyses for meeting desired functionality of the portal.

6.4 Outcomes from User Needs Breakout Discussion

The break-out session addressed several questions that were identified for discussion. Those questions and the group's associated recommendations follow.

6.4.1 Who are the users and what are the categories of use?

6.4.1.1 The group identified five categories of use, based primarily on review of GCW questionnaire responses in 6.1:

1. Long-term, sustained, high quality monitoring of cryospheric parameters at key sites/networks to meet particular ***strategic needs*** e.g. water security, hazards, building codes

2. Real-time cryospheric information for assimilation into ***operational forecasting***
3. ***Research datasets*** for improved understanding and process and climate model validation
4. Public and media
5. **Future scenarios** for long-term planning and adapting to a changing cryosphere (needed for 1 and 4) to meet the needs of decision and policy makers

6.4.1.2 For the **GCW portal** they felt that there are **two levels of information required - data, and the higher level "watch" information.** Mechanisms exist to clearly document data via metadata (origin, attribution, methods, units etc), but it was not quite so clear for higher-level information. **Two specific issues were "Who is responsible for editorial information?" and "What/who is an authoritative source of information?"**

> **Recommendation:** Need a product review mechanism to provide QA and accountability for GCW datasets [*e.g. GCW expert teams*]

6.4.2 Which needs are not being met (gaps?)

There were several needs and gaps that the group felt were not being adequately met, and offered recommendations on how these might be addressed.

- Sustained monitoring activities at long-term reference sites are needed. It was noted that some key sites are being lost.
  > **Recommendation:** "GCW-endorsed" long-term sites would help to protect key sites

- There are gaps in *in-situ* observations in some polar regions, such as northern Canada, Alaska, Siberia, limiting NWP forecasting capabilities for such areas.
  > **Recommendation:** GCW needs to engage the modelling and monitoring communities to determine what and where there are key gaps and for which variables. It was acknowledged that there is a need to optimize monitoring in face of declining budgets.

- GCW needs to have a good grasp on what cryospheric data and products currently are available (***the assets***) and to know where there are gaps. For example, are there near real-time cryospheric data streams that are not being tapped (e.g. snow course, snow pillow data)?
  > **Recommendation:** GCW should initiate a "gap analysis" process, recognizing that this needs to be balanced to avoid ending-up as just a wish list for more resources. The gap analysis could be linked to important "hot topics" to avoid this trap.

- It was felt that scientific community collaboration in core monitoring is essential to maintain a robust system. As an example, the international scientific community reaction to proposed cuts to the Canadian ozone monitoring network had an impact. The Global Atmosphere Watch (GAW) could serve as an example of how networks are structured to meet user needs.
  > **Recommendation:** GCW should play role in strengthening collaboration between partners.

- Lack of new young scientists in cryospheric sciences is considered a critical gap.
  > **Recommendation:** GCW should look at ways to entrain new expertise as part of its capacity development effort.

6.4.3 Who are internal / external clients?

There will be a wide range of users. Sometimes the users will be more internal, while at other times they will be more external. However, the workload to satisfy their needs could be very different.

Recommendation: There is a need to look carefully at the ***"value chain"*** from raw data to different levels of information relevant to different user groups to have a clearer understanding of who are the clients, and what their needs are.

There was debate about whether GCW should provide information for policy makers. It was felt that the IPCC process was better-equipped to handle this, **BUT** the IPCC is not timely enough for the fast-changing components of the cryosphere. It was agreed that policy-relevant information and the information for decision-makers should flow naturally from a strong science base and data.

Recommendation: GCW needs to make sure that the connections can be made between the data and the decision ***(a "decision support" role*)**

It was noted that many people currently use Wikipedia as an authoritative source for information on the cryosphere. This was not deemed to be a great situation, but it might be a potential vehicle to promote GCW. However, there is a definite need to engage users.

Recommendation: GCW should go out and meet users at their table.

6.4.4 What data should be available?

6.4.4.1 The group asked the question of whether this should include only cryosphere data or also other related data. This question had also been raised by NSIDC during early GCW consultations. The discussion suggested the following:

- GCW should initially focus on the key cryosphere datasets;
- There needs to be an inventory with which to start in order to determine what is available;
- There should be free and open access (no registration); it was noted, however, that registration is useful for follow-up with users when specific datasets are updated;
- There is a role for GCW in data comparison and development of integrated data sets/integration, e.g. with respect to different sea ice extent products. It is recognized that such an activity takes human resources.

6.4.5 Feedback from the plenary discussion

6.4.5.1 There was further discussion during the plenary on user needs, which raised a couple of additional considerations. An important point that applies to all GCW issues is that GCW has to be concerned with all time scales, not just the longer climate time frame. Likewise, the space and time scales relevant to hydrological users must be determined. It was also noted that when there is an anomalous or sudden change in cryospheric conditions there has to be a mechanism for an authoritative source to inform policy and decision makers. Communication within and by GCW will be essential to respond to such a situation.

In summary, GCW can provide "solutions" to meet the needs of users and fill gaps. This would involve many aspects, including the portal, the establishment and operation of reference sites/supersites, the development and use of agreed upon standards and best practices, and engagement of partners. GCW must be based on sound science.

7. CRYONET

The GCW Implementation Strategy proposed initiation of a comprehensive **cryosphere observing network called "CryoNet",** a network of reference sites or "supersites" in cold climate regions, on land or sea, operating a sustained, standardized programme for observing and monitoring as many cryospheric variables as possible. CryoNet would provide reference sites for validation of satellite and model outputs. Initially, it will build on existing cryosphere observing programmes or add standardized cryospheric observations to existing facilities to create supersite environmental observatories.

> **Recommendation: It was proposed that Members, through their cryosphere focal points, would be asked to recommend suitable sites.**

7.1 Best Practices, Guidelines and Standards for Cryosphere Measurements and Observations

7.1.1 A critical component in the development of CryoNet is the effort to establish **best practices, guidelines and standards** for cryospheric measurements. This would include consideration of data homogeneity, interoperability, and compatibility of observations from all GCW constituent observing and monitoring systems and derived cryospheric products. Miroslav Ondráš presented essential background on these issues as a basis for discussion in the breakout (http://www.wmo.int/pages/prog/www/OSY/Meetings/GCW-IM1/Doc7.1_BestPractices.pdf). WMO regulatory material (guides, manuals, technical regulations), much of which is now online, was summarized. Manuals provide the standard practices, while guides provide recommended practices.

7.1.2 Of particular note are the Manual on the Global Observing System and the Guide to Meteorological Instruments and Methods of Observation (CIMO Guide). The breakout session was asked to consider the need for a **review of existing GCW practices and whether there should be a "GCW Manual".** There is also the consideration for CryoNet and other GCW Networks being included in the new Manual on WIGOS. As a first step, it was suggested that **GCW review existing instrument & observing methods and practices for cryosphere in the CIMO Guide** and consider whether the CIMO Guide should be expanded to include instruments for the cryosphere. In this context, the importance of **instrument intercomparisons** was noted. Formal intercomparisons are conducted to determine and intercompare performance characteristics of instruments under field or laboratory conditions and to link readings of different instruments – data compatibility & homogeneity. The current **WMO Solid Precipitation Intercomparison** (SPICE), including snowfall & snow depth, is of direct relevance to GCW, and is considered as a contribution to GCW. Potential GCW reference sites might be suitable sites for inclusion in this intercomparison. **Are there other intercomparisons of cryospheric measurements, such as this, which should be conducted?**

7.1.3 The breakout was also asked to discuss **standardized terminology for the cryosphere**. WMO has compiled an International Meteorological Vocabulary aimed at standardizing the terminology used in this field and facilitating communication between specialists speaking different languages. METEOTERM is online and has 34662 terms in six languages, including International Meteorological Vocabulary, the International Glossary of Hydrology, and terms from related sciences that appear in WMO documents. There would be a benefit in having a **collated cryospheric vocabulary**.

7.1.4 The following recommendations were presented for consideration in the breakout session for GCW action and inclusion in its Implementation Plan:

1. Standardization of Practices (networks, observations, instruments, data exchange & policy, products):
    - Review **existing** GCW practices and develop an **inventory**; identify differences and inconsistencies
    - Identify a need for **new** standard/best practices, identify priorities and develop new standard/best practices
    - Develop Cryospheric **Vocabulary**
    - Identify standard/practices that may be promoted to **ISO** standards?
    - Develop "**GCW Manual**"; provide input to WIGOS Manual, CIMO Guide
2. Register user requirements in WMO Rolling Review of Requirements (RRR) data base:
    - Propose a new application area – Cryosphere
    - Identify **focal points** for Cryo different application areas and observing system capabilities
    - **Verify existing** variables and add **new (key)** cryospheric variables in RRR database

3. Establish Centres of Excellence from among GCW Reference sites:
    - e.g., **Instrument Centres** and **Testbeds** responsible for maintaining a set of standard instruments, calibration, intercomparison, traceability, compatibility, integration of RS and *in-situ* observations
4. Instrument Intercomparisons:
    - Identify needs
    - Participation in WMO Solid Precipitation Intercomparison (**SPICE**)

7.2 Establishment of Reference Sites

Some potential reference or supersites covering different regions and cryospheric conditions were presented, which set the stage for discussion in the CryoNet breakout session. The network of monitoring stations ("CryoNet") is proposed to include supersites as well as regular sites with more limited monitoring capabilities.

7.2.1 Finland (Finnish Meteorological Institute - Boreal Forest Region)

7.2.1.1 The Finnish Meteorological Institute (FMI) provided suggestions on observations for the case of seasonally-snow covered, terrestrial (non-mountainous) cryosphere (boreal forest and sub-arctic zones) **(ANNEX 8)** which could be used as a basis for discussion. In addition to the parameters to be measured, they raised other considerations. Measurements especially at supersites should be performed by well established reference methods/instruments (even with identical instrumentation when possible). Supersites may also need to have infrastructure for the validation and calibration of methods/instruments used at the regular sites. Both supersites and regular sites should facilitate free and open data distribution and archiving. Any other issues needed to guarantee the transferability of measurements and comparability of data should be considered. These considerations are in line with the concept of Centres of Excellence in support of calibration, traceability, data compatibility and integration which Miroslav Ondráš suggested as an approach that could be employed at GCW Reference sites/Supersites. Finland offered **Sodankylä-Pallas as a supersite**; the site is already a key reference station for satellite and model cal/val activities in northern boreal forest, a GAW station, and a synoptic surface and upper air station.

7.2.2 China (State Key Laboratory for Cryospheric Sciences -“Third Pole”: Tibetan Plateau-Himalaya)

7.2.2.1 China focused on the Upland Asian Cryosphere, especially the Third Pole region. It was noted that the main issues for regional sustainable development are cryospheric, notably glaciers, permafrost and snow cover, and should be addressed by the Global Cryosphere Watch (GCW).

7.2.2.2 China’s observing network is linked to applications, with water being the most important for this region, as it is the source region for many major rivers. Hence there was a need to improve high-altitude climate monitoring. Their re-designed High Asian cryosphere network includes 7 supersites, some of which have up to 20 years of record. During the past 5 years, the Himalayan network has been expanded, yet there are still many gaps. There is a gap in the Tibetan Plateau region as there are few met stations and no cryosphere stations above 4000m, and none above 5000m. Many snow cover observations are missing.

7.2.2.3 The snow, freshwater ice, glacier and permafrost components were linked to GCOS Essential Climate Variables. They have identified the possible methods of measurement (manual/automatic), the associated accuracy, and recommended the standard method currently used for measuring each ECV (see, ANNEX 8 for an example and http://www.wmo.int/pages/prog/www/OSY/Meetings/GCW-IM1/Doc7.2.1_China.pdf).

7.2.2.4 Likewise, they have identified associated gaps in measured cryosphere ECVs (see ANNEX 8 for a freshwater ice example). They raised some critical questions for GCW to consider:

- Since measurement of ECVs may vary by region, there may need to be regional ECVs to meet the different needs. GCW could help establish these, i.e. set regional standards. There would be a need to determine which ECVs should be international standards, and which should be regional?
- There is a need to define reference sites and supersites, as noted by Finland
- There is need for regional coordination of data from countries around China – this is an issue common to other regions.

7.2.3 Austria - Alpine Perspective for CryoNet

7.2.3.1 GCW needs to address how to define a supersite and reference site for CryoNet. One possibility for identifying a supersite is either to look for sites already measuring relevant variables of the atmosphere and the cryosphere, e.g. glacier mass balance, energy balance at the surface, borehole temperatures, snow height, or to define monitoring/research questions (user needs) to be solved, e.g. reaction of glaciers to climate or relevance of glaciers to water resources. **Sonnblick,** at 3100m, offers measurements of glaciers, permafrost, snow cover and the atmosphere, including chemistry (it is a GAW station). The observatory is on a main alpine divide which provides strong climate gradients, especially for precipitation. The surrounding cryosphere networks provide excellent complementary measurements, hence increasing spatial coverage which is especially useful for satellite and model validation in a rugged alpine area. Data from such cryospheric monitoring at supersites would also be valuable for other users (e.g. atmospheric deposition, stable isotopes for paleoclimate reconstructions, etc.).

7.2.3.2 This observatory conducts an extensive snow/atmosphere chemistry program, and this raised the question whether there **should be a snow chemistry component within in GCW**. As **many supersites may be GAW stations** as well, this issue needs further discussion. It was not explicitly mentioned in the implementation strategy, but a joint effort with GAW could fill a gap and provide increased information on the fate contaminants from atmospheric deposition, which impact hydrology and ecology, as well the food web. In this discussion, the question of how we delimit GCW was raised.

7.2.4 Antarctic/Concordia Station

Concordia is a French-Italian station, in the heart of Antarctica – Dome C. Winter-over staff allows for year long continuous operations and instrumental maintenance. This includes a radiosonde launch per day and surface (2-m, 10-m) standard automatic weather station observations, the data of which are all put on the GTS. Concordia station is a BSRN (Baseline Surface Radiation Network) monitoring site. Meteorological instruments along a 45-m tower ensure continuous observation of the surface boundary layer which is characterized by extreme inversions. Temperature profile below the surface is also continuously monitored, and the characteristics of the surface snow (density, grain size) are regularly sampled. Polar-orbiting satellites miss the South Pole, but they frequently overpass Concordia-Dome C. Could Dome C and Concordia be a GCW Reference site? Stations in Antarctica are needed as part of CryoNet, even though it is a challenging environment for cryospheric measurements. Concordia has major, well supported infrastructure, including an ice-core programme. Concordia does provide access to an extreme that could fill a need in CryoNet.

7.3 Outcomes from CryoNet Breakout Discussion

7.3.1 Guidelines, standards, best practice

7.3.1.1 The participants in this session considered the **recommendations presented in 7.1 above**. These were **strongly supported** and hence the subsequent discussion focussed on “next steps” to initiate action on them. The first step in the process is to determine what is currently being measured, how it is being measured and which best practices, guidelines or standards are being followed and who are conducting or co-ordinating the measurements. Once this compilation is available, then the different practices, methods, standards could be compiled and compared as a first step in ultimately preparing a comprehensive manual on the topic. Gaps could be identified and addressed. As guidelines, standards and best practice will likely vary for each component of the cryosphere, the establishment of small “task groups” were recommended. The WMO focal points and members of partner organizations should also be engaged in this task. It was realized that a list of the participants and their expertise would be useful to help set the context of all breakout discussions.

> **Recommendation:** GCW needs to establish small task groups to initiate the compilation of current guidelines, standards and best practice in use in the cryosphere community, as recommended below.

7.3.1.2 GCW Secretariat is asked to initiate the formation of these task groups. The initial list of contributors was based only on those attending this breakout session and the list will be expanded.

- Glaciers and ice sheets - Head, IACS Division on Continental Glaciers and Ice Sheets; Vasily Smolyanitsky
- Sea Ice - Vasily Smolyanitsky in co-ordination with International Ice Charting Working Group (IICWG) and JCOMM expert team on sea ice.
- Permafrost –Hans Hubberten with IPA and GTN-P; Oleg Anisimov
- River and Lake Ice - Xiao Cunde
- Seasonal snow cover - Kari Luojus
- Alpine snow cover – Charles Fierz

7.3.1.3 The role of satellites should also be included and the current efforts of WMO and other satellite based cryosphere projects will need to be checked as part of this effort. It was noted that satellite coverage could be an issue for some countries (such as New Zealand) due either to their position regarding a satellite or their geographical characteristics.

7.3.2 Supersites and Reference Sites

7.3.2.1 The presentations and associated written submissions identified in 7.2 provided an excellent basis for the discussion. It was recognized that there are some existing reference and/or supersites which could serve as a solid foundation for describing a network of such sites and the establishment of CryoNet.

7.3.2.2 Issues which will need to be identified include measurements to be made, measuring capabilities, minimum requirements, minimum accuracies allowed, redundancy, traceability, reliability, calibration, as well as continuity and sustainability. Again this would have to be done for each cryospheric parameter to be measured. As Finland noted, there could be different requirements and measurements at supersites and reference sites. Hence, should CryoNet be a tiered network, perhaps along the lines originally suggested for levels of GCOS stations?

7.3.2.3 In addition to the sites mentioned above, other sites need to be investigated, including Svalbard, Barrow/Fairbanks Alaska, the Antarctic Peninsula or West Antarctic, Greenland Summit, and the Russian North Pole drifting station 39. It was recommended that satellite data be archived for areas over and around supersites (like the WCRP/CEOP initiative). A practical question for stations that already would qualify as reference or supersites is when their period of record would start. Would historical data be part of the archive?

7.3.2.4 The group identified a small initial task group to address the many issues related to this topic. Dr. Wolfgang Schoener offered to serve as initial lead.

> **Recommendation:** GCW should establish a team to initiate the task on supersites and reference sites for integrated, multidisciplinary environmental monitoring.

7.3.2.3 Eric Brun, Kari Luojus, Wolfgang Schoener, Tetsuo Ohata and Xiao Cunde offered to participate in this effort. As a first step, it was recommended they prepare a short document on their existing program at the sites offered to be part of this network to serve as a basis for establishing requirements for CryoNet.

7.3.3 Cryosphere Terminology/Vocabulary

7.3.3.1 It was acknowledged that there are many sources of cryosphere terminology available, possibly in different languages, and often having different definitions for the same term, depending on the source and community of use. In addition to METEOTERM, the International Association of Cryospheric Sciences has worked with UNESCO on publishing a glossary for glaciology. At the national level, China is in the process of publishing an updated glossary of Chinese-English terminology as often translation of existing terms is not always accurate or satisfactory. It was noted that Springer has recently released an Encyclopaedia of Snow, Ice and Glaciers with over 1000 entries. The need for terminology compatible in different languages was acknowledged to be important by the group. It was also acknowledged that multiple definitions for the same term could be acceptable. All sources of these definitions would be referenced.

<u>Recommendation</u>: GCW should establish a small team from the different communities (e.g. IACS, WGMS, WMO, UNESCO and countries with national glossaries) to compile the lists of existing publications of cryospheric terminology/vocabulary and then outline the next steps to consolidate a list of terms based on existing sources. Ultimately the terms should be available in multiple languages.

8. CO-OPERATION BETWEEN GCW AND PARTNERS

WMO Members have responded strongly and positively to GCW as noted above, but cryospheric partnerships go well beyond just WMO, its programmes, co-sponsored programmes, WMO Technical Commissions, and Regional Associations. GCW partnerships are being identified, including government agencies and institutions that measure, monitor, or archive cryosphere data and information from in-situ and satellite research and operational networks and model sources, and international research organizations. Several international organizations and national organizations and programmes made presentations on what they do and on collaborating and partnering in the GCW initiative for mutual benefit.

8.1 International Organizations Involved in the Cryospheric Sciences

There are many international cryospheric organizations, each with their interests, activities, and responsibilities developed over many years, including (in alphabetical order):

- Association of Polar Early Career Scientists, APECS
- Cryosphere Research Focus Group, American Geophysical Union, AGU
- Division on Cryospheric Sciences, European Geosciences Union, EGU
- International Arctic Science Committee, IASC
- International Association of Cryospheric Sciences, IACS
- International Commission on Snow and Ice Hydrology, ICSIH
- International Glaciological Society, IGS
- International Permafrost Association, IPA
- Permafrost Young Researchers Network, PYRN
- Scientific Committee on Antarctic Research, SCAR
- World Climate Research programme – Climate and Cryosphere Project (WCRP/CliC), and in addition, the
- World Glacier Monitoring Service (WGMS), which is a service under the umbrella of IACS/IUGG/ICSU

All of these organizations have signed a MoU to better co-ordinate their activities. GCW has had interaction with most of these, and partnership for mutual benefit is essential for GCW to be effective. At this meeting, there were presentations from IACS, IPA and IASC (presentations are available on website).

8.1.1 International Association of Cryospheric Sciences

IACS is young (2007) in its current form as an association of IUGG/ICSU, but has a heritage back to 1894. Two particularly relevant objectives related to GCW are to: *encourage research in the above subjects by members of the cryospheric community, national and international institutions and programmes, and individual countries through collaboration and international co-ordination; and, facilitate the standardisation of measurement or collection of data on cryospheric systems and of the analysis, archiving and publication of such data.* Their work complements other organizations (e.g. IGS, AGU, EGU) and their success is also through partnering. Two publications of particular relevance are the “**International Classification for Seasonal Snow on the Ground**” and “**Glossary of Glacier Mass Balance and Related Terms**“. The IUGG urges snow and ice scientists, practitioners, and scientists from related disciplines to adopt these new schemes as standards. These will be important documents in developing GCW’s proposed Terminology/Vocabulary activity.

8.1.2 International Arctic Science Committee

IASC is a non-governmental, international scientific organization established in 1990. The mission of IASC is to encourage and facilitate cooperation in all aspects of Arctic research, in all countries engaged in Arctic research and in all areas of the Arctic region. IASC promotes and supports leading-edge multi-disciplinary research in order to foster a greater scientific understanding of the Arctic region and its role in the Earth system. IASC is an International Scientific Associate of ICSU and observer on the Arctic Council. The scientific foci of its Cryosphere Working Group includes: the cryosphere as an indicator of climate change; the cryosphere as a climate amplifier, feedback effects; the role of the cryosphere in Arctic hydrology; Arctic land ice and sea level; the biology and biogeochemistry of icy environments; representation of the cryosphere in climate and earth system models; and, impacts on human activity in the Arctic. As a collaborator with GCW, the WG suggested some cross-cutting issues could include maintenance of observing networks and systems, including satellite observations, improving input to climate change assessments and policy making, and rapid public dissemination of information about cryosphere change. Now the task is to identify how we interact to achieve these.

8.1.3 International Permafrost Association (IPA) and the GTN-P

8.1.3.1 The Global Terrestrial Network for Permafrost (GTN-P) is the primary international programme concerned with monitoring permafrost parameters. It was developed in the 1990s by the IPA under GCOS and GTOS. It monitors active layer and permafrost temperature, two Essential Climate Variables (ECVs) of GCOS and GTOS. There are two international monitoring components: Thermal State of Permafrost-TSP; and, Circumpolar Active Layer Monitoring-CALM. More than 700 boreholes and 300 active layer monitoring sites were used for the snapshot of the International Polar Year. However, GTN-P had been run on a voluntary basis, with no established governance or management structure and very little institutional support. IPA addressed this recently by developing a document outlining the GTN-P strategy (including management and governance) in cooperation with major international partners (including GCOS, GTOS, WMO, and GCW).

8.1.3.2 The strategy would include a permanent permafrost observing network to provide timely information to the scientific community and to society on the state of permafrost. It would focus on its core products, that is, the monitoring of the ECVs, to collect standardized data on permafrost temperature evolution and active layer thickness and to publish those on a regular basis. It would manage and upgrade the existing TSP and CALM networks and build upon its data management system. It would periodically assess changes, and contribute to relevant assessments on the state of permafrost. This requires efficient governance and management and development of a robust data management framework. GCW has been part of the development of the strategy and sees IPA and GTN-P taking a leading role in developing the GCW permafrost component. **One need that was identified** for further discussion was the operationalizing of the permafrost temperature network and the installation of sites at meteorological stations where permafrost occurs, hence strengthening the operational aspect of permafrost monitoring.

8.1.4 World Climate Research Programme

8.1.4.1 WCRP has been transitioning to defining its Grand Challenges. One key focus is a polar climate predictability initiative which inherently involves the cryosphere. The questions include understanding and predicting the rate of Arctic sea ice loss and understanding the drivers of change in the Antarctic, including connections to ocean circulation, carbon uptake, and ice shelves. It will require improved models while identifying measurement needs, both for initialization and for monitoring variability and long-term changes. WCRP and its Cryosphere and Climate project (CliC) identified common interests with GCW, including:

- Prediction of the cryosphere
- Science-based cryospheric products:
  - more rigor in and responsibility for QA of existing products
  - new products, e.g. snow on sea-ice
- Pool of cryospheric expertise
- “One-stop shop”
- Scientific assessment of the state of cryosphere, reanalysis
- Process understanding, model development and implementation of cryospheric modules into Earth System models

8.1.4.2 WCRP/CliC and GCW are expected to have a strong working relationship as both programmes continue to develop.

8.1.5 World Glacier Monitoring Service (WGMS), University of Zurich

8.1.5.1 WGMS fostered a very useful discussion on GCW and the partnering with other organizations, in this case on contributions from, and expectations of, the internationally coordinated glacier monitoring of WGMS. WGMS uses a multi-level, integrative strategy combining: local process understanding with global coverage, in-situ measurements with remote sensing, and traditional observations with new technologies using an integrated/tiered strategy. GCW aims to provide authoritative information and WGMS can contribute its long-term experience in coordinating the international glacier monitoring and data and information on glacier distribution and changes. Toward the development of CryoNet, WGMS can contribute long-term experience in coordinating the international glacier monitoring of 37 ‘reference’ glaciers with long-term and continuous mass-balance monitoring programmes. In both cases there would be practical issues to be addressed in implementing a partnership.

8.1.5.2 In summary, it was noted that organizations which contribute to GCW also have expectations of GCW:

Potential contributions from the WGMS and GTN-G to GCW:

- long-term experience in coordinating international glacier monitoring
- representation of the glacier monitoring community
- data and information about glacier distribution and changes

WGMS expectations of GCW:

- well-elaborated implementation plan that is feasible in light of available resources
- clear positioning within other international organizations
- close collaboration with authoritative data services

8.2 Examples of National and Regional Cryosphere Contributions

8.2.1 GlobSnow

8.2.1.1The ESA-GlobSnow project "Production of novel hemispherical snow extent (SE) and snow water equivalent (SWE) climate data records" is generating a long time-series employing FMI supercomputing facilities at Helsinki. Daily, weekly and monthly maps of SE and SWE for northern hemisphere for 15 and 30 years of snow cover information are produced at coarse resolution (25km) SWE and SE for 1979 – 2011 and medium resolution (1km) SE for 1995 – 2011. The near-real-time GlobSnow processing system and data archives located in Sodankylä will allow continuing operational production. Details and products are available at www.globsnow.info. All GlobSnow products are available free through their website. It was recommended that these products be considered as a contribution to GCW.

8.2.1.2 The presentation generated a good discussion on the production and use of these products. It does involve the use of satellite and *in-situ* data, so the changes in measurement of snow depth with automation should be considered. This links to CIMO SPICE project noted in 7.1 above. ECMWF noted their need for information in shallow snow regions, such as the Arctic; however, validation data are limited in these regions. Oleg Anisimov noted that Russian data are freely available from meteo.ru (in English) and would be of use in such validation.

8.2.2 CryoClim

8.2.2.1CryoClim is a Norwegian initiative to develop an operational and permanent service for cryospheric climate monitoring (http://www.cryoclim.net). It would be a national contribution to GEOSS and GCW following GCOS monitoring principles and GMES, GEOSS and WMO recommendations and standards. It aims to monitor sea ice (global), seasonal snow (global), glaciers (Norway) for the longest possible time series based on earth observation data. They are also producing products that serve as climate change indicators, e.g. length of snow season, last day of sustained snow cover. Their work is designed to respond to user needs, e.g. the European Environment Agency (EEA). The need to intercompare products was noted.

8.2.2.2 Access to data and products would be free of charge through a web service and web portal for searching, browsing and ordering. A key is that it would be run by mandated, operational organizations (METNO, NVE, NPI) as a network of automated nodes. As for GlobSnow, CryoClim is also deemed as part of GCW. It is seen to be a fully operational service from summer 2013, although first products are available now. It is important to acknowledge that the experiences gained in developing their portal and web service are being used in GCW portal development.

8.2.3 U.S. National Snow and Ice Data Center (NSIDC)

8.2.3.1 NSIDC provided an overview of its research, science, archive, data management, access and educational offerings developed over many years. It is of course more than a national centre with long-term responsibilities as a World Data Centre for Glaciology. They now have more than 600 data and information products with most being freely available online. An important component is the NSIDC User Services Office which provides expert and timely assistance in selecting and obtaining data. **As GCW evolves, there will have to be thought given on how to help users meet their needs**. NSIDC is a data and information service. It is an archive. A new initiative is the Advanced Cooperative Arctic Data and Information Service (ACADIS) which will manage Arctic data for NSF and develop prototype integrated/value added products. Effective data management is a key ingredient in the long-term success of NSIDC. GCW does not see itself being an archive, but will want to access metadata/data of centres like NSIDC. **NSIDC was the first data centre to be interoperable with the GCW prototype portal**. These connections have been extremely valuable in the development of the GCW portal and meeting the need to make cryospheric data more readily accessible and in our thinking of how to develop the portal.

8.2.3.2 Rather than a one-stop shop, NSIDC's Mark Parsons suggested that a better metaphor could be a marketplace or bazaar—a virtual space where all data can be found, but specialist portals provide the expertise, information, and referrals necessary to identify and understand data within a specific disciplinary context. At a practical level this implies that disciplines and research or decision focus areas need to develop portals to meet their needs. It also means that data centres need to expose their data and metadata through multiple protocols that allow these different systems to automatically identify and acquire the information to be presented in ways that are meaningful to their designated user communities. IPY has had initial success creating a union catalogue where multiple data centres expose their metadata through the Open Archives Initiative Protocol for Metadata Harvesting. He notes that the GCMD served as an overall authority catalogue in this initial system and harvests all available metadata, but, more importantly, individual archives can choose to harvest and expose only select data in ways relevant to their users. Evolving examples of these specialized portals range from a global cryospheric portal to a portal offering a local and traditional knowledge perspective of biodiversity change. The GCW portal is drawing on these thoughts in its development.

8.3 Partnering for an Integrated Perspective of the Cryosphere

GCW offers the unique opportunity to look at the cryosphere as a whole and to look at regional aspects of the cryosphere and its components. This is a short session to stimulate our thinking on how we look at the cryosphere and its components while thinking about what is causing the changes that are occurring.

8.3.1 CRYSYS: Lessons Learned (Canada)

8.3.1.1 CRYSYS (Cryosphere SYStem in Canada) was a NASA/EOS Inter-Disciplinary Science (IDS) Project from 1990-2006 involving collaboration and partnering of Canadian researchers from universities, federal agencies and the private sector. Its goals were to:

- Monitor and understand ***variability and change in the cryosphere system*** in Canada, and its interactions with the climate system
- Develop capabilities for ***improved satellite-based measurement****,* monitoring and understanding of cryospheric variables over a range of spatial and temporal scales
- Contribute to ***development and validation*** of local, regional and global models of climate-cryospheric processes and dynamics, and to improve understanding of the role of the cryosphere in the climate system
- Assemble, maintain and analyze key historical, operational and research ***cryospheric data sets*** for climate monitoring, model development and validation, and change analysis

8.3.1.2 Further background is given in the presentation by Ross Brown. His list of lessons learned, which could be applicable to both GCW and to a national contribution to GCW, were useful in subsequent breakout discussions:

- The success of the enterprise was due in large measure on ***the ability of the PI to secure funding and keep CRYSYS "connected" to national and international activities*** e.g. Climate Monitoring, GCOS, WCRP/CliC, IPY *[need a champion(s), need relevance, need funding]*

- Most of the ***success stories were from small focused groups with key expertise and strong research programs*** e.g. GLIMS Centre at U. Alberta *[invest in sure bets]*
- ***Annual science meetings played a very important role*** in networking and mentoring (CRYSYS covered the travel costs of Co-I's*) [need some mechanism to build identity and keep momentum]*
- The CRYSYS network contributed to an integrated vision of the Canadian Cryosphere, and ***helped break-down institutional silos****. [developing an integrated vision of the cryosphere takes work as some of the connections are not obvious... takes more than getting people around the same table]*
- For various reasons the ***value-added aspects of CRYSYS*** (e.g. Canadian Cryospheric Network) ***did not reach initial expectations*** *[need to monitor cost/benefits closely for value-added activities]*
- Operating an enterprise like ***a Cryospheric Information Network takes a special blend of human resource skills*** *[attracting and retaining skilled people is a major challenge in the value-added domain]*
- ***Cost recovery potential is not promising*** – CRYSYS commissioned a number of surveys that showed that while there is strong industry demand for cryospheric products and information, the potential for cost-recovery in supplying these needs is LOW

8.3.2 Stability and Variations of Arctic Land Ice - SVALI (Nordic Centre of Excellence)

8.3.2.1 SVALI is one of three projects under the Nordic Centre of Excellence Programme on Interaction between Climate Change and the Cryosphere. All Nordic countries are affected by the cryosphere which is especially important for industries like hydropower, forestry, fishing, transport, exploration and tourism. However, it has been found that IPCC models perform badly for the cryosphere. Arctic glaciers are particularly vulnerable to climate change. Details on SVALI can be found at: http://www.ncoe-svali.org/.

8.3.2.2 SVALI brings together a consortium of 17 institutions (partners) from 5 countries plus Greenland with a wide range of expertise and experience in collaboration in studying the cryosphere. This collaboration and expertise can be useful for GCW. Their data policy follows the IPY data policy. SVALI data are made available fully, freely, openly, and on the shortest feasible timescale and projects should promptly provide basic descriptive metadata. The GCW portal could be interoperable with their data. As a contribution to GCW they have suggested:

- Nordic reference sites
- Data provider
- Testbeds for: measurement strategies; measurement methodologies,analysis-reporting; scenarios and assessments

As GCW evolves, there are logical links to their efforts/expertise with the their collaborative network of Nordic institutes involved with cryosphere research and monitoring; development of co-ordinated long-term measurement strategies, use of standardised measurement methodologies and harmonized and authentic reporting. SVALI and GCW have common needs in this regard. With respect to training and capacity development,the Nordic graduate school in cryosphere science and Earth Systems Modelling could be a very useful resource for GCW and its participants.

8.3.3 SIOS (Svalbard Integrated Arctic Earth Observing System) - Remote Sensing Strategy (Norway)

8.3.3.1 The main goal of SIOS is to establish an (Arctic) Earth System Observing Facility on and around Svalbard that covers meteorological, geophysical, hydrological, cryospheric and biological processes from a set of platforms matching Earth System models (ESM). It could serve as a hub in

SAON. Svalbard has extensive existing research facilities and associated infrastructure. Norway, with EU support, wishes to establish the formal framework needed to operate a geographically distributed multinational research infrastructure across Svalbard and provide a research node to contribute effectively to future circum-Arctic monitoring.

8.3.3.2 Many of the key topics for SIOS relate to the cryosphere. Under this framework a remote sensing strategy is being developed that will enable the SIOS infrastructure and, in a more general sense, Svalbard to gain a leading role in providing quality controlled remote sensing data for polar research. SIOS will be ideally suited to validate and promote use of satellite and other remote sensing products over land, sea, cryosphere and atmosphere/space for research and monitoring in the Arctic. GCW needs to be engaged with SIOS as so many of its activities could contribute directly to GCW activities.

8.4 Outcomes from Pilot and Demonstration Activities Break-out Session

8.4.1 The Pilot/Demonstration Projects break-out session outlined actions, activities, and deliverables and suggested contributors to the potential task(s) being discussed. Demonstration projects would focus on regional or national contributions to standardization, integration and interoperability. Projects will involve contributions of WMO Members, Programmes and TCs, and contributing partners. The aim of pilot projects is to achieve quick wins. The group suggested the following (contributors in brackets – list can be expanded):

(a) The types of data and information that GCW could provide for cryosphere components globally, regionally and nationally;

- Reanalysis tools to describe state of Cryosphere in the past (including data rescue) (G. Balsamo, T. Ohata)
- GTN-P and GTN-G data to be integrated by GCW for scientific use and dissemination (IACS)
- Involvement and integration of international organizations, e.g. IPA, IACS, IASC (GCW)

(b) How GCW could build on existing efforts by the cryospheric community;

- SVALI (standards, regional/national) (J-O Hagen)
- GTN-P (IPY output with permafrost outputs) State of the Permafrost report every 2-3 years?, GTN-P, GTN-G, GTN-H (IPA/H-W Hubberten)
- Cryosphere product integrated in existing project (e.g. WHYCOS) (J. Abraham, A. Snorrason)
- Linking of the community (e.g. hydrological, arctic, glacial,…), and needs to bring together IPA, IASC, IACS; there needs to be good co-operation between operational and research communities(C. Fierz, B. Goodison)
- Link Research and Operational sites, network design and optimisation and associated issues (e.g. maintenance, data download, sharing services,…) (G Balsamo)
- WMO telecom system handling different type of data (GTS integrated with WIS) (IPA, H-W. Hubberten, B. Goodison)

(c) The time and resources required to create a fully functional integrated cryosphere information system;

- Overview provided by O. Godoy – details provided above

(d) How to document standards and best practices for observing and product development;

- Sharing information between countries (GCW)

- Integrate Best Practice from Research community (IACS, GCW)
- Use existing work done by other working groups (e.g. IACS, snow and ice glacier glossary, UNESCO) (IACS, GCW)
- Common activities for further cooperation and development (e.g. dictionary, standards,..) (IACS, GCW)

(e) Challenges/gaps/needs that GCW could address

- Global vs. regional (SVALI)
- Sharing of activity between countries (linking sites that have been developed for different purpose) (O. Anisimov)
- Himalaya Cryosphere – Lot of data available for further study – International collaboration with neighbouring countries (C. Xiao)
- Involvement of modellers for pilot studies (GCW and GIPPS) for data assimilation, network analysis , network optimisation, model validity for forecast (G. Balsamo- T. Ohata)
- Reference sites vs. supersites (W. Schoener)
- Communication between community (operational/research), internal/external groups, national/international (C. Fierz)
- Long term goal: joint GCW and modelling for cryospheric re-analysis

8.4.2 GCW will build on existing programmes and projects, but other **pilot and demonstration projects need to be established in different regions**, including alpine areas, central Asia (notably the "Third Pole"), the tropics, and Antarctica. Suggestions for location/projects were:

- SVALI (Iceland, ….)
- CryoClim could demonstrate their services to demonstrate added value
- National level collaboration: Permafrost in Russia ,including demonstration of operationalizing the permafrost network in Russia and the development of a Russian permafrost site on the internet (in Russian) (O. Anisimov)
- Organisation of work in South America (Argentina- J-M. Hörler)
- WTPS integration with WIS to handle permafrost data
- Best practices demonstration site in Ice pilot (Norway)
- Data assimilation (e.g. snow cover) – Develop basin assimilation techniques for surface condition (e.g. Japan) which would require involvement of modellers e.g. ECMWF Community interaction through workshop for national/regional/global
- Contribution of different organisations/initiatives
- Synergy and communication of different working group (e.g. IACS, Permafrost,….), sharing of knowledge/resource
- Develop an effective focal point network to improve communication at national and international level, and between research and operational communities; ensure national focal points are informed of national/regional contacts of other associations
- Identify scientists who can answer questions online about specialized issues (O. Anisimov)

8.4.3 An example of a national pilot project targeted at aggregation, analysis and dissemination of available permafrost data in Russia is given in **ANNEX 9.** This project is seen as a contribution to GCW already.

9. PRODUCT INTERCOMPARISON: PRODUCING AUTHORITATIVE INFORMATION

The vision of WMO is to provide world leadership in expertise and international cooperation in weather, climate, hydrology and water resources and related environmental issues and thereby contribute to the safety and well being of people throughout the world and to the economic benefit of all nations. GCW will contribute to this vision. Providing authoritative information is a key ingredient in achieving this. Presentations on satellite products, instrument intercomparisons and production of authoritative products provided participants with considerations for the breakout session on GCW products. One task already identified involves developing an inventory of candidate satellite products for GCW which are mature and generally accepted by the scientific community. This includes an intercomparison of products to assess quality and to ensure an authoritative basis.

9.1 Satellite sea ice products

9.1.1 Sea ice products derived from satellite data, particularly for the Arctic, have arguably had the longest period of development and assessment of any satellite derived cryosphere product. Walt Meier provided a summary of satellite sea ice products which currently are produced and available. Most are derived from passive microwave data. There are currently seven agencies producing "research" products which are being used to produce time series ice extent, area and concentration. In addition there are the operational sea ice products produced largely by National Ice Services. In the end there are 17 sources offering sea ice concentration/extent products. Intercomparisons have shown that there can be significant differences among the products.

9.1.2 Meier's presentation provides a valuable summary of the challenges of having different products and the effort to build Climate Data Records (CDRs) from the existing products. An initial satellite derived sea ice products workshop in 2011 produced several key recommendations, many related to better definition of the uncertainty of the products. In the end, the question is whether all sea ice products should be considered equal. The following requirements were suggested for climate products:

- Use validated, peer-reviewed methods
- Demonstrate long-term consistency
    - Operational products can provide targeted information for real-time users as well as validation for climate products
- Bear a reasonable resemblance to reality and a confidence level in that resemblance to reality (i.e., data quality/error information)
- Processing is transparent and reproducible
- Archived in a self-describing format, but distributed in a variety of usable formats (e.g., GIS, KML, GeoTIFF, browse, etc.)

Currently it was felt only three products meet these requirements: OSI-SAF, NOAA/NSIDC, MASIE.

9.1.3 This is a very important issue if GCW is to make available "authoritative" data, products and information. It was suggested that GCW could provide a forum for reviewing different approaches and the review of algorithms and products.

9.2 WCRP/GCOS/WOAP Intercomparison Workshop

The WCRP Observation and Assimilation Panel (WOAP) held a workshop on essential climate variables (Frascati, Italy, 2011). A structure for an inventory of satellite and *in-situ* ECV products was proposed and examples were developed. The inventory will contain information on product maturity, accuracy, users, applications, and adherence to the GCOS guidelines for ECV datasets. The proposed inventory elements are given in **ANNEX 10**. GCW might consider such an inventory for its products. Intercomparisons may not be straightforward, yet inventories and self-assessments can be very useful.

9.3 CIMO Instrument Intercomparisons: Solid Precipitation (SPICE)

9.1.3.1 The WMO/CIMO Solid Precipitation Intercomparison Experiment (SPICE) is a GCW priority activity and should be considered as a demonstration project. The experiment has several objectives but essentially the main goal is to assess/characterize automatic systems used in operational applications for the measurement of total precipitation (especially solid precipitation), snowfall and snow depth. GCW has an important role to play in extending the results beyond WMO Members and in ensuring recommended improvements in solid precipitation are implemented. GCW can promote participation in SPICE by the cryospheric community through its focal points. Consideration of an Antarctic intercomparison site should be promoted, possibly at Rotheray. The intercomparison must be conducted under a wide range of geographic and climatic conditions.

9.4 Global Precipitation Climatology Centre (GPCC)

9.4.1 The Global Precipitation Climatology Centre (GPCC) was established by WMO in 1989 and is operated by DWD (Germany). It contributes to thousands of users worldwide and to programs such as GCOS and WCRP. Details on its data collection and provision of products were provided in the presentation. It has more than 85,000 stations, with 65,000 having at least 10 years of record. GPCC serves as a data collection and production centre (DCPC) within WIS. It provides quality control of data and produces a range of products, including some in near-real time. GPCC has developed procedures for adjusting the daily precipitation data (solid) for systematic errors based on results of the First Solid Precipitation Intercomparison. The results of SPICE will be very useful in updating and reefing procedures for automatic gauges.

9.4.2 GPCC/DWD summarized its potential contributions to GCW as follows:

- **Provision of RA VI RCC Data:** Range 10W, 50E, 70N, 35S via WebWerdis Web Interface http://werdis.dwd.de/werdis/start_js_JSP.do. This functionality will migrate to GISC as part of WIGOS
- **Gridded number of snow days and snow depth on a 0.1x0.1 degree grid** derived from SYNOP data, provided by WMO RA VI Regional Climate Centre (RCC) on Climate Monitoring WMO-RA6-RCC-CM
- GPCC can offer **experiences from the ACSYS-APDA** project and should be available for cross-comparison of arctic precipitation measurements. However, **GPCC has currently no additional DWD in-house resources for further studies**. Efforts of this kind would need to watch out for soft money to fund extra project posts.
- GPCC would like to join in **development and validation of time variable systematic error** correction functions if that is of interest to other partners
- **Sharing GPCCs original precipitation data is problematic**, as GPCC cannot claim the copyright on the data from its suppliers. However GPCC is open to solutions that would not require to give away the data, e.g. by hosting experts
- GPCC would join a **re-examination of the quality and reliability of historic solid precipitation measurement**s

Quite appropriately, GPCC/DWD look to GCW to help it meet its mission:

- To generate **new momentum** for **high altitude data availability**
- To establish **modern station Metadata catalogues**. Current Issue: Countries with too small a number of station IDs (e.g. Canada) are forced to make too quick re-use of station IDs from

suspended stations leading to synchronization issues with WMO documents and GPCCs metadata base.

- A **reliable watch function** providing **high quality GTS messages on snowfall and snow depth** that allow for early warning on flash floods and calculation of water budgets and river basin specific precipitation to drive or verify runoff models.

9.4.3 These suggestions are very constructive and provided valuable information for subsequent discussion and action. It was noted that GCW could also help in getting data from some countries where submission has been slow. For adjustments to be made and accurate (authoritative) products to be produced, accurate and up-to-date metadata are essential. GCW could stimulate countries to improve this situation.

9.5 Outcomes from GCW Products Break-out Session

9.5.1 The GCW Products break-out session included discussion of both *in-situ* and satellite data and information products. The types of products could be categorized by cryospheric element and should consider both research and operational products for both real/near-real-time and climate scales. There were three levels envisaged, data products, information products and higher-level aggregated products, as summarized below.

9.5.2 Types of Products:

- Data products (operational vs. climate)
    - Sea ice and icebergs
    - Lake and River Ice
    - Glaciers
    - Ice sheets & shelves
    - Frozen Ground
    - Snow
    - Solid Precipitation
- Information products
    - News ticker/letter, Blog, traditional knowledge
    - Points of contact, Services, Acronym list
    - Terminology, glossary, vocabulary, ontology, Cryopedia?
- Higher-level, aggregated products?
    - Atlas-type information, links to model output?

9.5.3 The group made several general recommendations. It was recommended to:

- start with low-level activities, make them work, allow user feedback, and then improve/extend the products
- put all ideas into a plan for later implementation
- build upon what is already there (more easy to implement), e.g. sea ice from NSIDC
- include a user feedback possibility to find out what they want

9.5.4 There was discussion on a data products inventory. This should include subsets of a main data product inventory, including data on format and recommendations on the use of the data products. It should include cryospheric data from established models. The data providers could help in the creation of such an inventory (per cryospheric element) and it was suggested that IPCC lead authors could be approached to help in this task. The group suggested some ideas on how to select data products. There should be a pre-selection of available products through a peer-review process/intercomparison in order to be authoritative. This process needs to be established. Then, provide sufficient information for those data sets remaining, so that the users can decide which would be the most appropriate for their purpose. This should include a user feedback option to help find out what they really want. Proper credits to data providers (e.g. imbed in the image) must be provided. The process must be clear on which version of a product is being used and allow for updating. WGMS indicated that they provide a link to previous data reports to track changes of the data sets. As well, a general disclaimer needs to be added for being not responsible of wrong use of the data product. Some users will be more interested in higher-level products. The question was raised, but not answered, whether GCW should provide regularly updated summary information (e.g. sea ice cover with a nice figure and statistics) or only the link? **ANNEX 11** provides an example of tables of data products with some basic metadata that GCW might prepare and make available. The aim is to help users find appropriate data products.

9.5.5 In general discussion the question was raised about related data and products, for example those that would help explain the current state and related variation and change in the cryosphere. For supersites/reference sites the related meteorological data should be linked to allow complete analysis. It was also noted that outputs of a demo project on re-analysis links to this topic on products.

10. COMMUNICATION, OUTREACH, CAPACITY DEVELOPMENT, RESOURCE MOBILIZATION

10.1 Capacity Development

10.1.1 GCW must develop an effective capacity development strategy. A coordinated capacity development effort should respond to the needs at national and regional levels, as identified by Members, which would assist all countries in improving and sustaining observation and exchange of cryospheric data and information. For developing and the least developed countries there is a need to ensure access to, and effective utilization of, observations, data and products, related technologies and new knowledge. For example, information on potential sea level rise, loss of mountain (including tropical) glaciers, and improved understanding of the impact of cryospheric changes in the Antarctic on extreme weather and climate in tropical and sub-tropical regions has been identified by Members as a need to which GCW can contribute. Capacity development will be coordinated with existing WMO efforts and will take advantage of mechanisms established by WMO Programmes and co-sponsored programmes, RAs, TCs, and GCW partners.

10.1.2 Discussion identified several aspects which GCW should consider as part of its capacity development efforts, including:

- a key for capacity development is national commitment
- the need to show how the cryosphere is important to a nation
- the need to show how the developing world fits into GCW, and the need for developing countries to include in their plans the development of science capacity to understand what changes in the cryosphere mean to them
- the transfer of cryospheric research into operations is perhaps the biggest challenge
- can WMO help to build the institutional framework in regions to facilitate transfer of knowledge from research institutes to operational agencies
- WMO is updating the manuals on the role of meteorological services, but there is currently nothing on cryosphere in the manual; since hydrological agencies are often responsible for the cryosphere, their role should be considered in such an update
- It was noted that water and food production are key issues for many countries and that the impact of the cryosphere on water supply and water resources was an essential component
- Engaging the indigenous peoples of the north would help build knowledge and capacity with

respect to the cryosphere, although this opportunity and need is often overlooked when these peoples are in developed countries; capacity development should include this aspect.

- Could WMO leverage funding to support the development of cryospheric courses in developing countries as part its education and training initiatives?

10.2 Resource Mobilization

10.2.1 As part of this effort, GCW should look at all options for resourcing activities, particularly at regional scales. Participants need to understand what options may exist, and how GCW should be prepared for opportunities that may arise at short notice. Presentations/discussion by WMO programmes on capacity development and resource mobilization will aim to help GCW understand these issues for future planning/implementation.

10.2.2 Resource mobilization is often done with big funding groups and there is a need to demonstrate the relevance of the cryosphere within weather, climate and hydrology. There is a need to get all funders interested in the cryosphere. This will require strategic thinking and effort from the GCW community. Current funding partners of WMO capacity development include the World Bank, the EU, other UN agencies and the Rockefeller Foundation, etc.

10.3 Communication

10.3.1 GCW will have numerous, diverse stakeholders both within WMO and with its partners. GCW will establish an effective communication, advocacy and outreach, and education strategy in collaboration with WMO Members, Programmes, RAs and TCs. It will take advantage of outreach programmes developed and effectively deployed through IPY and with organizations such as the Association of Polar Early Career Scientists (APECS). .

10.3.2 WMO Communications gave an overview of communication issues in WMO as they may relate to GCW. The first hurdle was suggested to be explaining clearly "what is the cryosphere". Communications has to reach funders and decision makers, in terms they understand (e.g. we use "uncertainty", donors use "risk") and this should be embedded in GCW from the beginning. Good communication will need to ensure a consistent response to issues. It was noted that WMO uses Facebook as a social media tool to reach out to students and professors in developing countries. However, DWD has found that they had trouble responding in a timely manner as this takes resources. It was also pointed out that "speed" and "solid science" can in fact be competitive. Yet, WMO is often asked for comments on issues and GCW will have to decide how best to proceed on contributing to cryospheric communication issues. GCW efforts will be aimed at complementing, not duplicating, others' efforts

11. PARTNERSHIPS AND GCW STRUCTURE

11.1 Background

11.1.1 There were three breakout sessions which met in parallel, all addressing the same topic: **Partnerships and GCW Structure**. The aim was to get the opinions from different groups on how GCW should be structured, managed, and work with partners. The breakout groups were asked to suggest how GCW could effectively operate and interact. Participants were guided by the Implementation Strategy (Annex 3), including the initial framework, or conceptual model, for GCW given in Figure 2 in the Implementation Strategy. It illustrates the "why, what, and how" of GCW operation. "The thinking to date was that GCW's organizational, programmatic, procedural governance would be based on WMO structures and interfaced with those of partner organizations. Cryospheric data, information, products and knowledge will be provided not only from National Meteorological and Hydrological Services (NMHSs), but also from national and international partner organizations, agencies and the scientific community. Collaboration and cooperation through partnering was recognized by all to be essential. In essence, how should GCW be organized to be most effective, while being accountable to WMO and partners?

11.1.2 The outcomes from the three independent sessions identified some similarities, but also reflected different approaches. These ideas were then discussed in plenary to provide more cohesive suggestions on a working structure for GCW that ensures engagement of all partners. The GCW Task Team would then discuss the recommendations further and develop a working structure for consideration by EC-PORS. All three groups were asked to answer the following questions:

- *What expert teams are needed for GCW?*
- *Describe the activities and roles of the teams and suggest who should be involved.*

11.2 Outcomes from Break-out Session 1

11.2.1 The group suggested the following with respect to the **formation of task teams**:

- **Don't create** parameter teams (e.g., sea ice, snow, etc.), but teams to address specific needs
- Each team should have some representation and/or contact point for each parameter
- Use existing infrastructure (e.g., IICWG, CliC, IPA, etc.) to provide basis/resource for teams
- Recruit potential participants through mechanisms including::
    - Cryolist, etc.
    - APECS for incorporating early-career scientists
    - Recruitment at science conferences - could there be a GCW booth at AGU, EGU, etc.?

11.2.2 The group recommended the following **teams,** noting that some could be consolidated as sub-teams within other teams: Terminology, Bridging, Observing System Development, Outreach, Assessment, Products and Services (Bazaar). The teams' functions could include activities such as identified below:

Terminology Team

- Develop/evaluate terminologies, glossaries, vocabularies, ontologies, CryoPedia (?)
- Define 'supersite' vs. 'reference site' vs. other observation sites

Bridging Team

- Make scientific and operational communities aware of each other
- Facilitate interaction and collaboration between the two communities

Observing System Development Team

- Help establish reference sites/supersites
- Evaluation of site requirements and consider non-supersite locations (labs vs. automated sites, single parameter sites)
- Periodically update/review observing system requirements and capabilities

Outreach Team

- Available on request to speak to media, policymakers, etc.
- Provide guidance for 'outreach' products to provide to public and policymakers (on request?)
- Provide **authoritative voice** on cryosphere issues (e.g., Times Atlas imbroglio)
- Scientists will be source of information

- Communication/public affairs personnel to assist (coordination, copy editing material)
    - Facilitate training of students and early career scientist and incorporation of them into the cryosphere community
- Potential activities:
    - Press releases? – but can't step on toes of existing organizations
    - Quarterly/semi-annual newsletter compiling interesting/important info about entire cryosphere
    - Blog? Social media (Facebook/Twitter)?

Assessment Team (under another team?)

- Provide cryosphere contribution to WMO State of the Climate report
- Decadal and multi-decadal surveys of state of the cryosphere (either produce, facilitate production, or collate assessments produced by others)

Products and Services Team (Bazaar Team)

- Clearinghouse for potential products/services
- Select/recruit various products (portal products and related services)
- Evaluation of candidate products (from various organizations)
- Facilitate harmonization of products (e.g., sea ice estimates)
- Outreach team could be a sub-team within this team?

11.3 Outcomes from Break-out Session 2

11.3.1 This session was chaired by Jim Abraham, with Øystein Godøy as rapporteur. The group discussed "*What expert teams are needed for GCW*", and considered that the teams could be identified by outcome, project, cryosphere element, information content or by other elements. The group discussed the activities and roles of the teams as well as who could be involved.

11.3.2 The starting point for the discussion was that **contact points** in the various components of the cryosphere are needed in order to establish the cross-cutting activities. It was noted that some areas are well covered by existing communities (e.g. Glaciers and Permafrost) while others lack a well identified network (e.g. snow and sea ice).

> ***Recommendation:*** It was recommended that an initial list of activities, points of contact and cross-cutting issues to be addressed is required.

11.3.3 Some preliminary steps required to fully address the **cross-cutting activities** were identified. An inventory identifying stakeholders is required that should address the following elements:

- An assessment on relevant existing activities/groups
- A cost benefit analysis on which areas to give priority (Go first for the "low hanging fruits")
- How to involve/link to relevant existing activities/groups

11.3.4 **The web portal was identified as an important** first step to raise the awareness of GCW as well as to be able to link to the relevant communities and to plan the work ahead. However, in order to establish a web portal the following issues have to be addressed:

- Need to establish initial relevant priorities for the development as not everything can be done at once.

- The stakeholders' requirements have to be collected. These requirements have to be subject to a cost benefit analysis determining which requirements that can be addressed in which time frame.

- To ensure visibility of GCW within relevant communities, the portal should link to the *cryolist* email list.

- It was acknowledged, that the editorial component of a portal will require some dedicated resources in order to undertake the editorial responsibility including filtering of information and quality control.

- The need for thematic pages addressing, for example, snow was identified. In order to support this, the portal solution should include an open design and content management system that allows the community to actively contribute to the portal content.

11.3.5 **Points of contacts** within various communities were identified by the group:

- The preliminary contact points identified within GCW relevant communities were:
  - Snow - Ross Brown and K. Luojus
  - Glaciers and ice caps - M. Zemp (GTN-G).
  - Permafrost - Hans W. Hubberten (GTN-P) and Oleg Anisimov.
  - Sea ice - Walt Meier and someone from EUMETSAT Ocean and Sea Ice SAF
  - IPCC Liaison - F. Paul
  - Ice sheets - K. Steffen, J. Bamber, and M. Tedesco

Not all the persons listed above have been asked, but these were the names that were identified during discussion.

It was also noted that:

- WMO commitment to secretariat resources is essential for central parts of the process to function (at least initially).
- a critical mass is essential to show the benefit and to achieve community support for GCW

11.3.6 Some **cross cutting issues** were identified for further discussion:

- The GCW community should contribute to the IPCC review of cryospheric information.

- GCW should **establish a preliminary inventory of "supersites".**
  - including documentation of criteria for identification of such "supersites".
  - including documentation of the "supersites" (methodologies and standards used)
  - including information on how data are shared.

- The **web portal** was identified as a cross-cutting activity.
  - to link between communities which usually are separate.

- **Outreach** is a key cross-cutting activity as it is important to reach young scientists. Specific outreach tools that were mentioned were:
  - a newsletter to raise awareness
  - a glossary to help interpret information
  - a "cryopedia" to convey quality assured information

This was identified on the basis that Wikipedia is an “authoritative” source for information for many users. GCW could establish a “cryopedia” or, as public behaviour is hard to change, could contribute through Wikipedia as well. The important issue is that correct information is provided to the public. It was acknowledged that the expert teams should decide on who should engage in outreach

- **Impacts** were the final cross-cutting issue addressed:
    - Impacts can be related to climatic impacts or vulnerability, but can also be related to hazards (e.g. avalanches). The discussion centred on vulnerabilities which were related to climatic processes and hazards that related more to forecasting processes.
    - O. Anisimov volunteered to liaise with the climate modelling community in order to address change and vulnerability due to climate processes.
    - Concerning hazards, GCW should involve Glacier and Permafrost Hazards in Mountains (GAPHAZ).

11.4 Outcomes from Break-out Session 3

11.4.1 This group differed from the first two groups as it felt that it was necessary to set-up thematic teams or enlist an expert panel which would act as a resource when GCW needs reliable information on specific components of the cryosphere. This provided another perspective compared to the other groups. Possible teams, composition and activities are given below:

Portal:
- Type of team: cross-cutting , standing-Committee
- Composition: IT experts, editorial board
- Activities:
    - links with relevant Web services
    - Web service
    - Data storage
    - Interfaces
    - Meta data

Permafrost:
- Type of team: thematic
- Composition: IPA representative, CBS representative, PYRN representative., ...
- Activities:
    - links with GTN-P
    - Recommendations (standardization, networks, ...)
    - promotion of synoptic obs of ground surface temperature
    - expert resource for editorial board
    - links with relevant other external groups

Sea Ice:
- Type of team: thematic
- Composition: NSIDC rep., CliC rep., OSI-SAF rep., ...
- Activities:
    - expert resource for editorial board
    - links with relevant external groups
    - Recommendations (standardization, networks, ...)

Glaciers and Ice Sheets:

- Type of team: thematic
- Composition: WGMS GTN-G, CliC rep, IASC-CWG, IACS, APECS, ...
- Activities:
  - Expert resource for editorial board
  - links with relevant external groups
  - Recommendations (standardization, networks, ...)

Snow:

- Type of team: thematic
- Composition: remote-sensing expert, CBS rep, ...
- Activities:
  - solid precipitation
  - Expert resource for editorial board
  - links with relevant external groups
  - Promotion of « 0 cm snow depth » in messages

Cryosphere Remote Sensing:

- Type of team: cross-cutting
- Composition: Space agencies reps., CliC, SCAR, ...
- Activities:
  - links with relevant external groups

Infrastructure and Sites:

- Type of team: cross-cutting
- Composition:
- Activities:
  - reference sites, supersites
  - links with relevant external groups

Data:

- Type of team: cross-cutting
- Composition: modellers, ...
- Activities:
  - data rescue
  - Monitoring of climate parameters
  - Integration with modelling
  - provide validation data sets

12. TASK PLAN AND DELIVERABLES

12.1 This session reviewed the many recommendations and suggestions made during the meeting with a particular emphasis on defining the GCW working structure, identified near and mid-term tasks and deliverables, including the identification of persons or organizations that will lead and/or contribute to their initiation.

12.2 G. Balsamo (ECMWF) raised an issue that had not been discussed – what about GCW **establishing a field campaign**? It was noted that CliC had discussed a floating sea-ice site, and one group discussed infrastructure for both research and monitoring. This should be considered further by the observing task group.

12.3 Plenary discussion initially suggested three expert teams:

1. **Observing Systems** (and Infrastructure) – to provide leadership in monitoring (including guidelines, ref sites, etc.)
2. **Portal** – activities, products and services and outreach could go into this, but this is yet to be fully defined. Should it just be primarily technical (interoperability, metadata) or also include the products and services, and access to data and metadata?
3. **Products and Services** and priorities within it. Access to products is the first priority and a group would be needed to select what products should be used as a source. This would need a representative from each cryosphere component and would need operational and research products and people (see 12.1, Bazaar Team)

12.4 It was then decided to modify the structure to **two teams: Team on Products and Services and Team on Observations.** Leads and members, activities and objectives were identified. Other issues identified for subsequent development included the role of focal points, identification of contact points with WMO technical commissions, articulation of how to engage users, e.g. ECMWF, development of a strategy for advising national governments. For governance it was recognized that an Advisory Board (oversight group) was needed and that team co-chairs would be responsible to receive comments from the Board. Partners need to have a clear role to reflect their important contribution to observing and products. The role of EC-PORS in guiding activities needs to be clarified.

12.5 The **next meeting for implementation** should be spring 2013 at the earliest. Initially the sub groups can get started planning by email and then team meetings could be held to move forward.

13. GCW Task Team Meeting (Friday, November 25)

13.1 Background

The EC-PORS GCW Task Team and a few additional participants (including Key, Abraham, Xiao, Godoy, Hubberten, Snorrason, Ondráš, Smolyanitsky, Brown, and Goodison) met to consolidate GCW structure, activities and identify next steps, including:

- Finalization of the outcomes of break-out sessions
- Definition of Task Teams and associated activities,
- Discussion of GCW Structure
- Discussion of need and options for GCW Project Office
- Identification of items for EC-PORS approval and follow-on action: IP including structure, advisory group, secretariat
- Discussion on updating GCW Implementation Plan

13.2 Proposed Initial Operating Structure

An **operating structure** was agreed as summarized below:

1. Observing Systems Working Group (co-leads: Jeff Key and Wolfgang Schoener)

Objectives:

- Help establish sites/ reference sites/supersites
- Compile best practices, guidelines, standards,
- Evaluation site requirements and consider non-supersite locations (labs vs. automated sites, single parameter sites)
- Periodically update/review of observing system requirements and capabilities
- Assess user needs
- Inventory of current network, including infrastructure and practices
- What should be measured?
- Make scientific and operational communities aware of each other. Facilitate interaction and collaboration between the two communities.

Task teams within the WG would be established: CryoNet, Requirements and Capabilities, Infrastructure and Practices.

1 (a) CryoNet Team

- Members: Schoener (lead), Xiao (China), Pulliainen (Finland), Brun/Genthon (Concordia, Antarctic), Ohata (Japan in E Asia and Mongolia and CEOP), Herland (Svalbard), Smolyanitsky (Russian ESIMO&NP)
- Tasks:
  - Definition of site types: supersites, reference sites, tiers
  - What should be measured
  - Data availability
  - Formal procedures for identifying this GCW network
  - Determine potential supersites

1 (b) Requirements and Capabilities Team

- Members:
- Tasks:
  - Assess user needs

- Periodically update/review of observing system requirements; record/insert into WMO RRR database
- Link to Polar Space Task Group (PSTG)

1 (c) Infrastructure and Practices Team

- Members:
- Tasks:
  - Inventory of current network, including infrastructure and practices
  - Standard practices, suitability for validating models and remote sensing (engaging experts to advise)
  - What should be measured

2. Products and Services Working Group (co-leads: Jim Abraham and Walt Meier)

Access to products is one priority; selection of products is another. Representatives from each cryosphere component, including operational and research, would be needed in assessing products. Hence, Task Teams within the WG would be established, including teams on Portal, Products (including Terminology), and Outreach.

2 (a) Portal Team

- Members: Øystein Godoy (lead), Mark Parsons, BAS (Steve Colwell), WIS, IPA
- Tasks:
  - Met.no to prepare initial plan for further development: including, linking contributors, testing by partners, involvement of GCW "meeting participants" or focal points, documentation needed for outside use, timeline, updates on progress,, including successes and setbacks, development of WIS demonstration (e.g. permafrost data)……….
  - Interoperability with NSIDC, CCIN, BAS (metReader and Polarview), GTN-G/WGMS, GTN-P/Arctic Portal, Ice Portal?, Russian permafrost (Anisimov),
  - Editorial component

2 (b) Products Team

- Members: Many identified throughout the meeting
- Tasks:
  - Clearinghouse for potential products/services
  - Select/recruit various products (portal products and related services)
  - Evaluation of candidate products (from various organizations), including met data products (Steve Colwell for Antarctic met data)
  - Facilitate harmonization of products (e.g., sea ice estimates) and develop high-level monitoring products
  - Make scientific and operational communities aware of each other. Facilitate interaction and collaboration between the two communities.
  - Data policies for GCW, including data exchange by WMO Members
  - Identify new satellite products, with PSTG
  - Organize specialized product teams, especially for snow-climate links, recognizing that snow is less organized than other communities (e.g. Snow-climate and the link to operations would be led by Brown and Luojus and would engage other snow specialists, including Robinson (Rutgers), Solberg

(CryoClim), Pulliainen/Luojus (GlobSnow), CMC, ECMWF and others, such as a mountain snow specialist.

Terminology Sub-Group:

- Members: Secretariat, Fierz (IACS), Xiao (China), Mishra (UNESCO), Smolyanitsky (ETSI)
- Tasks:
  - Identify current cryosphere glossaries and determine next steps
  - Develop/evaluate terminologies, glossaries, vocabularies, ontologies, CryoPedia(?)
  - Define ‘supersite’ vs. ‘reference site’ vs. other observation sites
  - Areas of focus suggested – snow (Brown), ice sheets (some suggested), glaciers (Zemp), Permafrost (Hubberten), impacts and climate modelling (Anisimov)

2 (c) Outreach Team

- Members: TBD
- Tasks:
  - Available on request to speak to media, policymakers, etc.
  - Provide guidance for ‘outreach’ products to provide to public and policymakers (on request?)
  - Provide authoritative voice on cryosphere issues (e.g., Times Atlas imbroglio)
  - Scientists will be source of information
  - Communication/public affairs personal to assist (coordination, copy editing material)
  - Facilitate training of students and early career scientist and incorporation of them into the cryosphere community
  - Press releases? – but can’t step on toes of existing organizations
  - Quarterly/semi-annual newsletter compiling interesting/important info about entire cryosphere
  - Blog? Social media (Facebook/Twitter)?

13.3 GCW Secretariat

13.3.1 Currently, WMO Members have supported a part-time staff member to support initial development of GCW leading to its acceptance as a project by WMO Congress. As GCW moves forward, the need for more secretariat support is recognized. The Secretariat could be at WMO, hosted by a country, or dispersed. For example the IPA and IASC secretariats are hosted by Germany and funded by the German Science Foundation. The issue of a GCW Project Office was briefly discussed. Initially, could the two working groups have support near the leads that could reduce secretariat support? A letter should also be sent to selected countries concerning support of a “secretariat” or project office.

14.3.2 There were several issues which the GCW Task Team identified for which the Secretariat should take the lead. The Secretariat’s role initially would include coordination, engagement, facilitating, report preparation, inventory of best practices and preparation of regulatory material. Suggested **tasks** are given below:

Focal Points

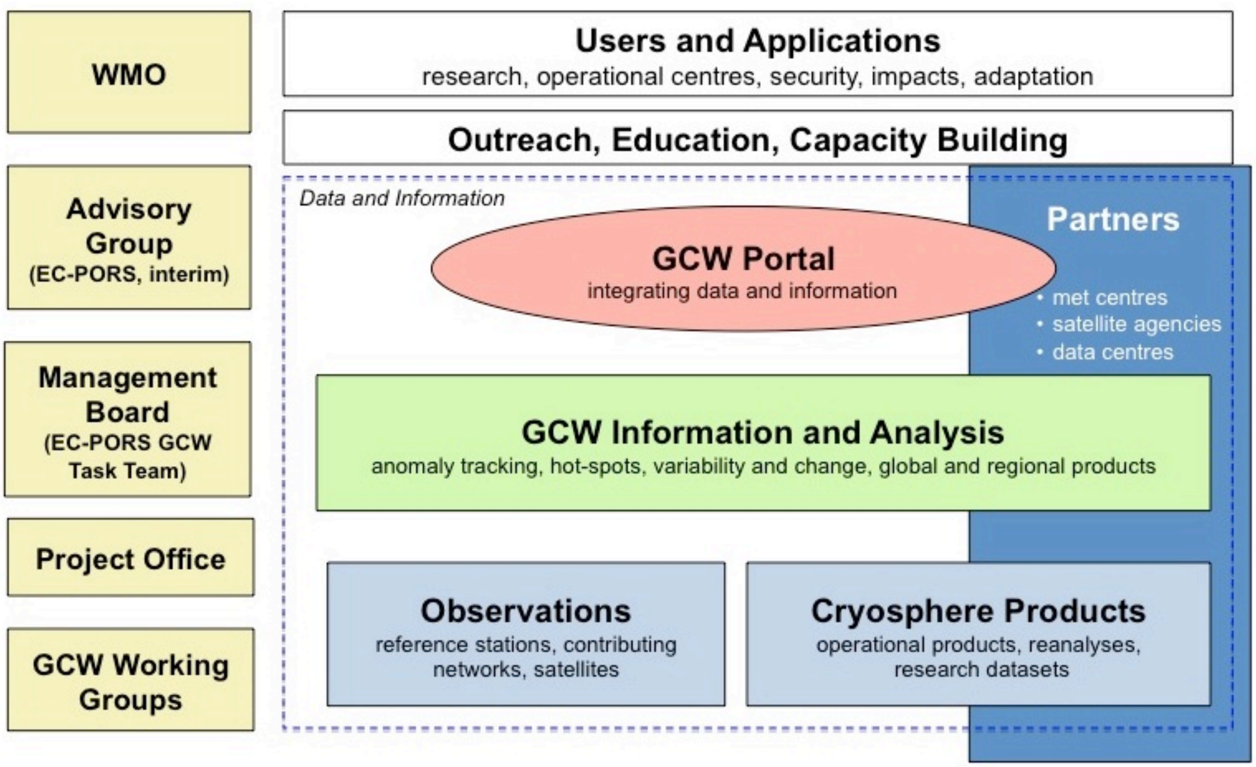
- Finalize terms of reference and update current list of focal points
- Share names with other focal points and GCW members
- Get national contacts from IASC, IACS, WGMS, IPA….. And share with GCW contacts
- Letter to PRs seeking new focal points, including ToR
- Region III co-ordination (Hörler)
- Development of national GCW activities

Other Actions

- Liaise with WMO on capacity development, resource mobilization, communication
- Liaise with UNESCO
- Co-sponsorship (?) – relates to governance
- Funding opportunities
- Report to EC-PORS
- Implementation Plan development (with teams)
- Liaise with WIGOS/WIS as needed

13.4 GCW Structure

A GCW Implementation Plan is being drafted. It will build on the Implementation Strategy and include the ideas for working structure suggested at this first GCW Implementation Meeting. A revised GCW structure will be presented in the IP and the responsibilities of the various components will be defined. Initially it was suggested that the EC-PORS should have oversight of GCW. A draft structure is suggested below. This will be updated in the GCW Implementation Plan and modified as appropriate as discussion with partners and contributors proceed.



ANNEX 1

PROGRAMME

MONDAY 21 NOVEMBER

VENUE: **World Meteorological Organization (WMO) Headquarters**
Geneva, Switzerland. Salle C1

09:00-09:30

1. ORGANIZATION OF THE SESSION (CHAIR: J. ABRAHAM)

1.1Welcome, opening *(B. Ryan)*
1.2 Introduction of participants
1.2 Adoption of the agenda
1.3 Working arrangements *(B. Goodison)*

09:30-10:30

2. GCW: HERITAGE AND CURRENT STATUS (CHAIR: J. ABRAHAM)

2.1 EC-Panel on Polar Observations, Research and Services (EC-PORS) *(A. Snorrason)*
2.2 WMO Integrated Global Observing System (WIGOS) *(I. Zahumenský)*
2.3 WMO Information System (WIS) *(S. Foreman)*

10:30-11:00 HEALTH BREAK

11:00-12:15

2.4 Global Framework for Climate Services (GFCS) *(F. Lucio)*
2.5 GCW: Mission, Objectives, Expected Outcomes, Implementation *(B. Goodison, J. Key)*

3. ROUNDTABLE INTRODUCTION AND DISCUSSION (CHAIR: B. GOODISON)

3.1 Participants present summary of key points of their written submission to GCW questions

12:15-13:30 LUNCH

13:30-15:20

3.1 Participants present summary of key points of their written submission to GCW questions (continued)
3.2 Discussion of roundtable presentations

4. PERSPECTIVES ON CRYOSPHERIC ISSUES AND GCW CONTRIBUTION (CHAIR: B. GOODISON)

4.1 IGOS Cryosphere Theme (CryOS) Recommendations *(J. Key)*
4.2 Regional Activities and Perspectives on GCW
4.2.1 Finland *(J. Pulliainen)*

15:15-15:45 HEALTH BREAK

15:45-17:15

4.2.2 New Zealand *(C. Zammit)*
4.2.3 Central Asia *(A. Kayumov)*
4.2.4 Argentina/South America *(J.M. Hörler)*
4.2.5 Antarctica *(S. Colwell)*
4.2.6 Japan activities *(T. Ohata)*
4.2.7 Switzerland – SLF/Davos *(C. Fierz)*

5. SUMMARY OF THE DAY (CHAIR: J. ABRAHAM)

END OF DAY (1715)

TUESDAY 22 NOVEMBER

09:00-10:30

6. MEETING USER NEEDS (CHAIR: H-W. HUBBERTEN)

6.1 UNESCO International Hydrological Programme (IHP) *(unable to participate)*
6.2 Modelling Needs (ECMWF) *(G. Balsamo) (20 min, with questions)*
6.3 Importance of synoptic snow depth observations *(E. Brun) (15 min)*
6.4 Hydrometeorological support for marine activity in the Arctic *(V. Smolyanitsky) (15 min)*
6.5 Synthesis of written submissions from participants *(R. Brown) (10 min)*
6.6 GCW web portal: structure and demonstration *(O. Godoy) (30 min, with questions)*

10:30-10:50 HEALTH BREAK

10:50-12:10

7. CryoNet (CHAIR: H-W. HUBBERTEN)

7.1 Best practices, Guidelines and Standards *(M. Ondráš)*
7.2 Establishment of Reference Sites
7.2.1 China *(C. Xiao)*
7.2.2 Austria-Alpine perspective*(W. Schoener)*
7.2.3 Antarctica-Concordia Station *(C. Genthon/E. Brun)*

1210-1330 LUNCH

13:30-15:15

8. BREAK-OUT SESSION 1 (Note: 8.1 and 8.2 will be held in parallel)

8.1 CryoNet *(Chair: B .Goodison; Rapporteur: S. Colwell)*

8.2 User Needs *(Chair: A. Becker; Rapporteur: R. Brown)*

15:15-15:45 HEALTH BREAK

15:45-17:30

9. CO-OPERATION BETWEEN GCW AND PARTNERS (CHAIR: C. XIAO)

9.1 International Association of Cryospheric Sciences (IACS) *(C. Fierz)*

9.2 International Arctic Science Committee (IASC) Cryosphere WG *(J-O Hagen)*

9.3 World Climate Research Programme (WCRP) *(V. Ryabinin)*

10.SUMMARY (CHAIR: J. ABRAHAM)

10.1 Rapporteurs' Summary of first break-out sessions; Identification of Actions; Recommendations

10.2 Summary of the Day

END OF DAY (17:30)

WEDNESDAY 23 NOVEMBER

09:00-10:40

11. CO-OPERATION BETWEEN GCW AND PARTNERS (Contd.)
(CHAIR: E. BRUN)

11.1 GlobSnow *(K .Luojus)*

11.2 CryoClim *(R. Solberg)*

11.3 GTN-G, World Glacier Monitoring Service (WGMS) *(M. Zemp)*

11.4 GTN-P, International Permafrost Association (IPA) *H-W. Hubberten)*

11.5 National Snow and Ice Data Center (NSIDC) *(W. Meier)*

10:40-11:05 HEALTH BREAK

11:05-12:25

12. PRODUCT INTERCOMPARISON: PRODUCING AUTHORITATIVE INFORMATION
(CHAIR: E. BRUN)

12.1 Satellite sea ice products *(W. Meier) (20 min, with questions)*

12.2 WCRP/GCOS/WOAP Intercomparison Workshop
(J. Key)
12.3 CIMO Instrument intercomparisons: Solid Precipitation (SPICE)
(J. Abraham)
12.4 Global Precipitation Climatology Centre (GPCC)
(A. Becker)

12:25-13:45 LUNCH

13:45-16:45 (Including Health Break)

13. AN INTEGRATED PERSPECTIVE OF THE CRYOSPHERE (CHAIR: M. ONDRAS)
13.1 CRYSYS: Lessons learned (Canada) *(R. Brown)*
13.2 SVALI (Nordic Centre of Excellence)
(J-O. Hagen)
13.3 Svalbard Integrated Arctic Earth Observing System (SIOS)
(E.A. Herland)

14. BREAK-OUT SESSION 2 (Note: 14.1 and 14.2 will be held in parallel)
14.1 Pilot and Demonstration Activities
(Chair: A. Snorrason; Rapporteur: C. Zammit)
14.2 GCW Products *(Chair: J. Key; Rapporteur: F. Paul)*

16:30-17:35

15. SUMMARY (CHAIR: J. ABRAHAM)
16.1 Rapporteurs' Summary of second break-out sessions; Identification of Actions; Recommendations
16.2 Summary of the Day

END OF DAY (1735)

THURSDAY 24 NOVEMBER 24

0900-10:20 (CHAIR: A. SNORRASON)

16. BREAK-OUT SESSION 3 (Note: 3 parallel sessions will all discuss 17.1)
16.1 Partnerships and GCW Structure
#1: Chair: J. Key; Rapporteur: W. Meier
#2: Chair: J. Abraham; Rapporteur: O. Godoy
#3: Chair: H-W. Hubberten; Rapporteur: E. Brun

10:20-10:40 HEALTH BREAK

10:40-12:15

17. CAPACITY DEVELOPMENT/RESOURCE MOBILIZATION/COMMUNICATION

17.1 Capacity development *(R. Masters)*
17.2 Resource Mobilization *(TBC)*
17.3 Communication and Outreach *(C. Nullis)*

18. BREAKOUT SESSION SUMMARY

18.1 Rapporteurs' Summary of third break-out sessions; Identification of Actions; Recommendations

12:15-13:30 LUNCH

13:30-15:00

19. TASK PLAN AND DELIVERABLES (CHAIR: J. ABRAHAM)

19.1 Revisit topics as necessary, including: GCW web site, CryOS Recommendations, Role of GCW Focal Points
19.2 Near-term and mid-term tasks and deliverables for Implementation Plan

15:00

20. ADJOURN MEETING

The EC-PORS GCW Task Team will begin their deliberations after the conclusion of the meeting, and continue Friday November 25 until 1500.

Tentative Agenda includes:

- Finalization of the outcomes of break-out sessions
- Definitions of Tasks and Task Teams, including priorities, cost, responsibility and time for implementation activities
- Discussion on draft GCW Implementation Plan
- Discussion on draft Annex on Observations & Monitoring: Cryosphere(GFCS Implementation Plan)

ANNEX 2

LIST OF PARTICIPANTS

NAME	INSTITUTION	E-MAIL
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ANNEX 3

GLOBAL CRYOSPHERE WATCH (GCW)

GCW IMPLEMENTATION STRATEGY

1.0 BACKGROUND:

The cryosphere collectively describes elements of the Earth System containing water in its frozen state. It includes solid precipitation, snow cover, sea ice, lake and river ice, glaciers, ice caps, ice sheets, permafrost, and seasonally frozen ground. The cryosphere is global, existing not just in the Arctic, Antarctic and mountain regions, but at all latitudes and in approximately 100 countries. Frozen water and its variability and change in the atmosphere, on land, and on the ocean surface has direct feedbacks within the climate system, affecting energy, moisture, gas and particle fluxes, clouds, precipitation, hydrological conditions, and atmospheric and oceanic circulation. The cryosphere provides some of the most useful indicators of climate change, yet is one the most under-sampled domains of the Earth System. Improved cryospheric monitoring is essential to fully assess, predict, and adapt to climate variability and change.

All of these issues require a coordinated international and cross-disciplinary mechanism, thus the proposal for the establishment of an operational Global Cryosphere Watch (GCW).

2.0 GCW Meets User Needs

GCW will provide data, information and products that will help Members and the wider user community reduce the loss of life and property from natural and human-induced disasters, improve management of energy and water resources, contribute to a better understanding of environmental factors affecting human health and well-being, understand, assess, predict, mitigate and adapt to climate variability and change, improve weather forecasts and hazard warnings, aid in management and protection of terrestrial, coastal and marine ecosystems, and support sustainable agriculture.

GCW will provide information for informed decision making and policy development related to climate, water and weather, for use in real time, for climate change adaptation and mitigation, and for risk management. Over time, this information will become more service-oriented. During GCW consultation, Members emphasized the national and global impact of the cryosphere, particularly:

- Sea level rise threatens vital infrastructure, settlements and facilities of small island states and low-lying coastal zones;
- Changes in sea-ice affect access to the polar oceans and surrounding seas, in turn affecting economic development, accessibility to resources, navigation, tourism, marine safety and security. Declining summer sea-ice may also impact ocean circulation and weather patterns in the mid-latitudes;
- Permafrost thawing impacts infrastructure and is a potential major source of methane, a greenhouse gas;
- Changes in the cryosphere have major impacts on water supply, food production, availability of potable water, freshwater ecosystems, hydropower production, and the risk of floods and droughts;
- Natural hazards such as icebergs, avalanches and glacier outburst floods create risks for transportation, tourism and economic development;

- Cryospheric data and information are required for improved numerical weather prediction and climate monitoring and prediction in polar and alpine regions as well as globally;
- Changes in large scale dynamics such as the Arctic Oscillation (AO) Index have major and currently not well predicted impacts on climate in North America, Europe and Asia.

3.0 Mission and Objectives

GCW will be an international mechanism for supporting all key cryospheric in-situ and remote sensing observations, from research and operations, and for implementing the recommendations of the Integrated Global Observing Strategy Partnership (IGOS-P) - Cryosphere Theme (hereinafter "CryOS").

To meet the needs of WMO Members and partners in delivering services to users, the media, public, decision and policy makers, GCW will provide authoritative, clear, and useable data, information, and analyses on the past, current and future state of the cryosphere. In its fully developed form, GCW will include observation, monitoring, assessment, product development, prediction, and research. It will provide the framework for reliable, comprehensive, sustained observing of the cryosphere through a coordinated and integrated approach on national to global scales and deliver quality-assured global and regional products and services. GCW will organize analyses and assessments of the cryosphere to support science, decision-making and environmental policy. To meet these objectives, GCW will encompass:

- *Requirements:* Meet evolving cryospheric observing requirements of WMO Members, partners, and the scientific community, by making CryOS a living document and contributing to the WMO Rolling Review of Requirements (RRR) process;
- *Integration:* Provide a framework to assess the state of the cryosphere and its interactions within the Earth System, emphasizing integrated products using surface- and space-based observations, while including a mechanism for early detection of, and support for, endangered long-term monitoring series, aimed at optimizing knowledge of environmental conditions and exploiting this information for predictive weather, climate and water products and services, thus contributing to the proposed WMO Global Integrated Polar Prediction System (GIPPS) and Polar Regional Climate Centres;
- *Standardization:* Enhance the quality of observational data by improving observing standards and practices for the measurement of cryospheric variables, by addressing differences and inconsistencies in current practices used by Members, partner organizations and the scientific community;
- *Access:* Improve exchange of, access to, and utilization of observations and products from WMO observing systems and those of its partners;
- *Coordination:* Foster research and development activities and coherent planning for future observing systems and global observing network optimization, especially within the WMO Integrated Global Observing System (WIGOS), by working with all WMO Programmes, technical commissions (TCs), regional associations (RAs), partner organizations and the scientific community.

GCW will be an essential component of WIGOS and will coordinate cryospheric activities with the Global Climate Observing System (GCOS), which includes the climate-related components of the Global Ocean Observing System (GOOS) and the Global Terrestrial Observing System (GTOS), enhancing GCOS support to the UNFCCC. GCW will strengthen the WMO contribution to the Global Framework for Climate Services (GFCS). Through WIGOS and the WMO Information System (WIS), GCW will also provide a fundamental contribution to the Global Earth Observation System of Systems (GEOSS).

4.0 GCW and the WMO Strategic Plan

The cryosphere, by its nature, is intrinsically interdisciplinary. GCW, in the context of the WMO Strategic Plan 2012-2015, is a crosscutting activity contributing to all five priority areas and to achieving the expected results of all Strategic Thrusts. It cuts across all the WMO technical departments (Observing and Information Systems, Research, Climate and Water, Weather and Disaster Risk Reduction Services), joint sponsored activities (e.g. WCRP, GCOS) and WMO TCs. GCW will

- Enhance capabilities to produce better climate predictions and assessments, hydrological forecasts and assessments, weather forecasts and warnings;
- Provide the mechanism to integrate the atmospheric, terrestrial (including hydrology) and marine cryosphere Essential Climate Variables (ECVs) within GCOS;
- Coordinate cryospheric observations of WMO and other agencies and organizations;
- Be part of the WIGOS and WIS.

5.0 GCW Implementation

5.1 Phases

GCW Definition Phase (2007 - 2011)

Following a review of the feasibility study for developing and implementing GCW within WMO, EC-LXI endorsed the next steps for developing GCW with the guidance of its EC Panel of Experts on Polar Observations, Research and Services (EC-PORS). Extensive consultation contributed to developing the rationale, concept, principles and characteristics of GCW as well as the engagement of WMO Programmes and TCs, key partners from other agencies, institutes and organizations, and the scientific community who could contribute to the development and implementation of GCW. Pilot and demonstration projects are being identified to test GCW implementation. The Secretariat has provided support for initial GCW development through the EC-PORS Trust Fund.

GCW Implementation phase (2012-2019)

The Implementation phase, to be undertaken between 2012 and 2019, will be coordinated by WMO and its partners. It will focus on developing and implementing GCW through tasks and activities that will form the GCW Implementation Plan. Initial timelines and deliverables are given in Figure 1.

GCW Operational Phase (2020 onward)

Once the framework is established, GCW enters its Operational Phase. It will continue to evolve to improve service delivery and support decision-making in response to the needs of users and technological opportunities.

5.2 Tasks

Based on the feasibility study and continuing consultation with WMO Members and potential partners by the EC-PORS GCW Task Team, initial key tasks were identified for implementation:

1. Implement recommendations of CryOS;
2. Initiate pilot and demonstration projects;
3. Establish cryosphere reference sites;
4. Develop an inventory of satellite products for GCW;
5. Develop a web portal and interoperability for cryosphere users and providers;
6. Capacity building;
7. Communication and outreach;
8. Monitor scientific progress.

GCW Expert and Technical Teams will be established to lead these activities with experts from WMO and its partners. A summary of the initial tasks follows.

Implementation of CryOS recommendations

CryOS provides a framework for developing and implementing GCW. Developed through widespread consultation and review within the global cryosphere community, it details observational capabilities and requirements, and gives recommendations for filling gaps. It proposes measures to develop and coordinate cryospheric components of the WIGOS, GCOS/GOOS/GTOS and other systems, so that cryospheric products will meet most user requirements within approximately 10-15 years. It describes arrangements to ensure that existing cryospheric data and products are openly accessible to users in a timely and interoperable manner. It highlights the need for the identification and coordination of resources to continuously improve observations as requirements and technology evolve, and reiterates the need for commitment by observing system operators to sustain and augment cryospheric observations and products. GCW will build on these recommendations to ensure a comprehensive, coordinated and sustainable system of observations and information to allow for a full understanding of the cryosphere and its changes.

Pilot and Demonstration Projects

Pilot projects will be implemented to demonstrate: (a) the types of data and information that GCW could provide for cryosphere components globally, regionally and nationally; (b) how GCW could build on existing efforts by the cryospheric community; (c) the time and resources required to create a fully functional integrated cryosphere information system; (d) how to document standards and best practices for observing and product development; and (e) challenges/gaps/needs that GCW could address. Demonstration projects would focus on regional or national contributions to standardization, integration and interoperability.

Projects will involve contributions of WMO Members, Programmes and TCs, and contributing partners. Potential projects which can contribute to demonstrating GCW's operation include CIMO's intercomparison of measurement of solid precipitation, snowfall and snow depth; Norway's CryoClim initiative to develop new operational services for long-term systematic climate monitoring of the cryosphere; ESA's "Global Monitoring of Essential Climate Variables" programme (Climate Change Initiative) for the cryosphere; the World Glacier Monitoring Service (WGMS), University of Zurich, Switzerland, which is operated under the auspices of the International Council for Science World Data System (ICSU/WDS), International Association of Cryospheric Sciences of the International Union of Geodesy and Geophysics (IUGG/IACS), UNEP, UNESCO and WMO; Nordic Centre of Excellence (NCoE): SVALI - Stability and Variations of Arctic Land Ice; USGS Benchmark Glacier Programme and the IPY Data and Information Service (IPYDIS) global partnership of data centres, archives, and networks creating interoperability between cryosphere data centres in Norway, USA, Canada and the UK. GCW will build on existing programmes and projects, but other pilot and demonstration projects need to be established in different regions, including alpine areas, central Asia (notably the "Third Pole"), the tropics, and Antarctica.

Reference Sites

GCW will initiate a comprehensive cryosphere observing network called "CryoNet", a network of reference sites or "supersites" in cold climate regions, on land or sea, operating a sustained, standardized programme for observing and monitoring as many cryospheric variables as possible. CryoNet will provide reference sites for validation of satellite and model outputs. Initially, it will build on existing cryosphere observing programmes or add standardized cryospheric observations to existing facilities to create supersite environmental observatories. As encouraged by GCOS, GCW will facilitate the establishment of high-latitude supersites with co-located measurements of key variables, especially permafrost and snow cover, thus enhancing GCOS/GTOS Networks for Permafrost (GTN-P), Glaciers (-G) and Hydrology (-H) and including the measurements of solid precipitation. GAW stations and WCRP/Coordinated Energy and Water Cycle Observations Project (CEOP) reference sites in cold climates are potential candidates.

Members, through their cryosphere focal points, are being asked to recommend suitable sites. China has established supersites in the "Third Pole" region where the High Asian cryosphere (HAC) serves as the Asian "water tower" for over a billion people. They would like to merge into the proposed GCW network and help lead the development of standardized cryosphere observing programmes. Another proposed contribution is the Sodankylä-Pallas supersite in the boreal forest of northern Finland. Its infrastructure is designed for integrated monitoring of soil-snow-vegetation-atmosphere interaction and provides reference measurements for satellite sensors on a continuous basis.

Reference sites will lead in the effort to establish best practices, guidelines and standards for cryospheric measurement. This will include consideration of data homogeneity, interoperability, and compatibility of observations from all GCW constituent observing and monitoring systems and derived cryospheric products.

Inventory of Satellite Data Products

This task involves developing an inventory of candidate satellite products for GCW which are mature and generally accepted by the scientific community. It includes an intercomparison of products to assess quality and to ensure an authoritative basis. The Polar Space Task Group of EC-PORS, with its direct connection to Space Agencies, will work with GCW to identify new satellite products to support GCW pilot projects and services.

Currently, the WCRP/SCAR/IASC Climate and Cryosphere Project (CliC) is sponsoring a workshop on the evaluation of satellite-derived sea ice extent and concentration products. This task was identified as a pilot project in the GCW feasibility study. The results of the intercomparison will provide valuable information to GCW on the many available products and on the process for determining "authoritative" information. The WCRP Observation and Assimilation Panel (WOAP) is organizing a workshop on essential climate variables (ECVs), where an inventory of satellite and in situ ECV products will be compiled with information on product maturity, accuracy, users, applications, and adherence to the GCOS guidelines for ECV datasets. For example, the United States National Oceanic and Atmospheric Administration (NOAA) is supporting work on satellite-derived climate data records (CDRs) for snow and ice, and the European Space Agency (ESA) Climate Change initiative will provide ECVs that meet GCOS requirements, and will support efforts to validate and improve current methods for extracting cryospheric geophysical parameters from satellite data.

GCW Web Portal

The GCW web portal will make GCW data and information available to WMO Members, their partners, and users while providing the ability to exchange data and information among a distributed network of providers of data and products. The portal, as a part of WIS, will allow for rapid exchange of data, metadata, information, and analyses. The concept for the flow of information to the portal is given in Figure 2.

The portal and associated data and information will be capable of including all elements of the cryosphere at national, regional and global scales. It will provide access to data and information on past, present and future cryospheric conditions, and be able to draw on operational and research-based observation and monitoring and modelling. GCW will ensure access to real time, near-real time and historical cryospheric data and products through WIS. GCW will respect partnership, ownership and data-sharing policies of partners. It will allow new types of information to be widely distributed, such as real-time cryospheric "hot news" (e.g. extremes, physical or socio-economic impacts, new research results).

A prototype GCW web portal for GCW is being developed by the Norwegian Meteorological Institute (METNO), building on their web-based tool for searching data. IPY data centres/portals, such as METNO, Canadian Cryosphere Information Network (CCIN), British Antarctic Survey (BAS), and US National Snow and Ice Data Centre (NSIDC) are already interoperable. This approach will facilitate seamless access with NMHSs and external data centres holding relevant cryospheric data and information at the national or global scale.

Capacity Building

GCW must develop an effective capacity building strategy. A coordinated capacity building effort should respond to the needs at national and regional levels, as identified by Members, which would assist all countries in improving and sustaining observation and exchange of cryospheric data and information. For developing and the least developed countries there is a need to ensure access to, and effective utilization of, observations, data and products, related technologies and new knowledge. For example, information on potential sea level rise, loss of mountain, including tropical, glaciers, and improved understanding of the impact of cryospheric changes in the Antarctic on extreme weather and climate in tropical and sub-tropical regions has been identified by Members as a need to which GCW can contribute.

Capacity building will be coordinated with existing WMO efforts and will take advantage of mechanisms established by WIGOS and other WMO Programmes, RAs, TCs, and GCW partners.

Communications and Outreach

GCW will have numerous, diverse stakeholders both within WMO and with its partners. GCW will establish an effective communication, outreach and education strategy in collaboration with WMO Members, Programmes, RAs and TCs. It will take advantage of outreach programmes developed and effectively deployed through IPY and with organizations such as Association of Polar Early Career Scientists (APECS) and the Global Learning and Observations to Benefit the Environment program (GLOBE) program. The GCW portal will provide relevant information on communication, outreach and capacity building, aimed at complementing, not duplicating, others' efforts.

6.0 Collaborations, Partnerships, Sponsorship

WMO Members have responded strongly and positively to GCW and, so far, over 30 Members from all WMO Regions have nominated GCW focal points. These focal points will be involved in the development of GCW and will help integrate the global initiative with their national plans. In addition to Members with specific national or regional activities in the Polar Regions, interest was expressed by Members (e.g. Maldives, Thailand, Ethiopia, Tajikistan) who are concerned about changes in the cryosphere and the potential impact on their country.

GCW will engage WMO co-sponsored programmes, TCs, RAs, and other organizations that have cryospheric responsibilities. GCW partnerships are being identified, including government agencies and institutions that measure, monitor, or archive cryosphere data and information from in-situ and satellite research and operational networks and model sources. International bodies, such as International Permafrost Association (IPA), World Glacier Monitoring Service (WGMS), Global Precipitation Climatology Centre (GPCC), and national institutions, such as the US National Snow and Ice Data Center (NSIDC) have already indicated their willingness to support GCW.

WMO’s co-sponsored programmes are essential partners. WCRP/CliC coordinated the development of the GCW feasibility study and co-led with SCAR the development of CryOS. The WMO-IOC-UNEP-ICSU Steering Committee for GCOS endorsed the creation of GCW as a mechanism for integrating cryospheric observations.

Potential co-sponsorship is being investigated. The IOC of UNESCO, which has been engaged in the GCW process from the beginning, has already indicated its interest in being a co-sponsor. Memorandum of understanding or agreements would be established between all sponsors.

EC-PORS and its GCW Task Team will lead the discussion with partners.

7.0 GCW Management and Governance

7.1 *Conceptual Framework for GCW*

GCW’s organizational, programmatic, procedural governance will be based on WMO structures and interfaced with those of partner organizations. Cryospheric data, information, products and knowledge will be provided not only from National Meteorological and Hydrological Services (NMHSs), but also from national and international partner organizations, agencies and the scientific community. Collaboration and cooperation through co-sponsorship and partnership is essential. GCW will include an effective interface with the user community. Capacity building and training will be included in all aspects of the GCW framework. Expert, technical and regional task teams would be responsible for developing, implementing and managing the GCW tasks. A GCW Advisory Committee will initially steer activities, tasks, and the establishment of teams within the available resources. An initial framework, or conceptual model, for GCW is given in Figure 2. It illustrates the “why, what, and how” of GCW operation.

7.2 *Deliverables and Milestones*

Upon approval and within available resources, GCW will address tasks associated with the key deliverables and milestones. Figure 1 shows the key milestones and timelines. The aim is to begin now to implement tasks, recognizing the complexity of engaging NMHSs and their national partner agencies, national and international institutes and the scientific community.

7.3 Resources

The successful launch of GCW depends directly on the availability of resources. Support of the definition phase has been through funding by Members to the GCW and EC-PORS Trust Funds (namely, part-time temporary staff and consultative meetings), supplemented by in-kind contribution from Members for technical expertise. However, additional resources will need to be provided through the WMO Secretariat for both staff and non-staff costs for the implementation and coordination that goes beyond the programmatic activities of the Secretariat to date. One full staff position would be needed in the WMO Secretariat for GCW implementation activities and should be funded jointly by the WMO regular budget and other sources, including:

- GCW and EC-PORS Trust Funds to supplement the WMO regular budget;
- In-kind contributions, e.g. Task Office/activity funded by a Member(s);
- Staff secondments;
- Project Compendium that includes a request for GCW funding from voluntary contributions (seeking contributions totalling CHF2.4M for implementation of EC-PORS activities over four years, including GCW to support the advisory committee and expert teams in implementing GCW and provide some Secretariat support for GCW development, coordination and implementation).

7.4 *Governance within WMO*

GCW requires cooperation, collaboration and coordination within WMO and with external partners, for which working arrangements between WMO and partners would be established. WMO provides a legitimate, valued and unique entry point on cryospheric issues related to weather, climate, water and other environmental matters in 189 countries.

A GCW Secretariat (Project Office) will be established in the WMO Secretariat to support all GCW activities, including coordination with partners, monitoring of implementation, reporting and follow-up actions. It will also provide support to national focal points and activities.

GCW is a truly cross-cutting activity. However, at the beginning of the Implementation Phase observational aspects (e.g. reference sites, observing practices, data compatibility, interoperability, etc.) may prevail. This would likely shift later in the Implementation Phase, as services become more prominent. At the beginning, the links would be strongest with WIGOS and WIS, several of the TCs, and co-sponsored programmes. Hence, the Executive Council, through its EC-PORS, would be best positioned to oversee GCW's initial development and implementation, recognizing that the structure of the Secretariat will have to adapt, as and when appropriate, to ensure optimal management of, and support to, the initiative.

Figure 1: GCW Milestones and Deliverables

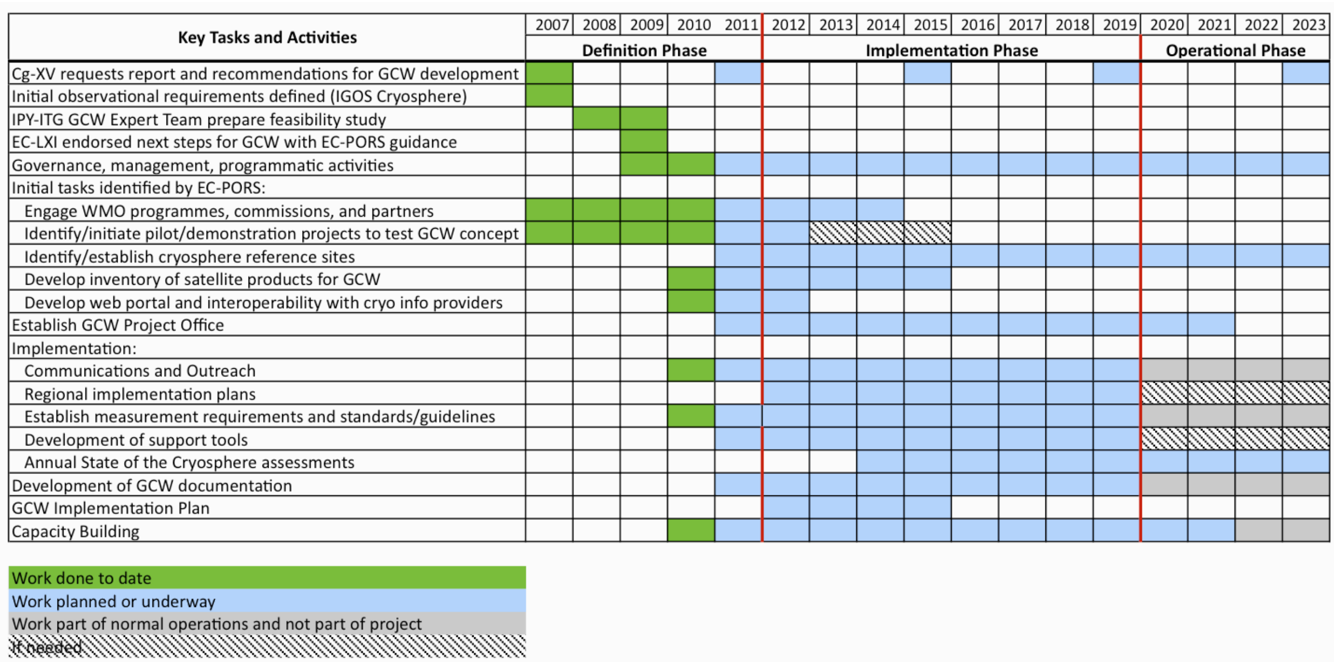
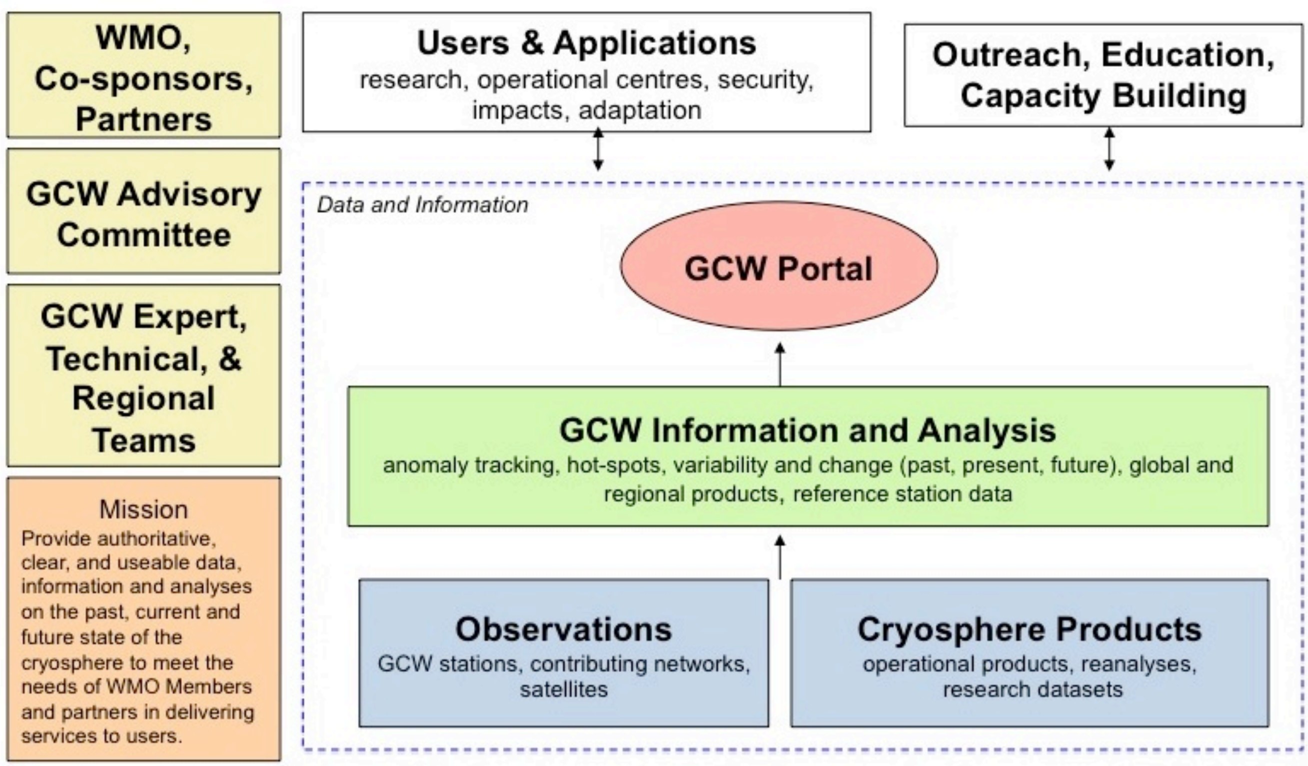


Figure 2: Conceptual Framework for GCW Operation



ANNEX 4

GLOBAL CRYOSPHERE WATCH (GCW) FOCAL POINTS

DRAFT TERMS ON REFERENCE

GCW focal points are formally nominated by the Members' Permanent Representatives with WMO. There may be more than one contact in a country. Focal points may be from outside the Member's national meteorological and hydrological service (NMHS), recognizing that other bodies may have operational and/or research responsibilities for the cryosphere. This could differ by country. The focal point(s) will liaise with the GCW management group (to be determined). In order to minimize GCW operating costs, the working language of the management group will be English. The focal point(s) will have the following responsibilities:

1. Serve as the national contact(s) for, and contribute to, the development and implementation of GCW and its activities locally, nationally, regionally and globally.

2. Liaise with national bodies that have responsibilities for observation, monitoring, development and provision of information products and services, prediction and research related to the cryosphere for implementation of GCW.

3. Engage national representatives of international organizations partnering with GCW (e.g. International Arctic Science Committee (IASC) Cryosphere Working Group, International Association for Cryospheric Sciences (IACS), International Permafrost Association (IPA), Scientific Committee for Antarctic Research (SCAR), World Glacier Monitoring Service (WGMS)), in furthering GCW nationally and regionally.

4. Identify national and regional cryosphere-related issues, needs and gaps that should be considered in GCW action plans.

5. With other focal point(s) in their WMO Region, engage their WMO Regional Association to foster, promote and further develop GCW products, services, and information.

6. Actively engage the national representatives of Technical Commissions and WMO co-sponsored programs, particularly Global Climate Observing System (GCOS) and World Climate Research Programme to foster, promote and further develop GCW activities.

7. Where possible, establish a GCW national committee, engaging representatives of national and international bodies, to co-ordinate and initiate a national GCW programme.

8. Identify needs and opportunities for capacity building related to GCW activities.

9. Identify opportunities for resource mobilization to support GCW implementation or operation.

WMO/GCW FOCAL POINTS
(Nominated by WMO PRs, as of 21November 2011)

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Netherlands (the)	VI	Dr.ir.A (AD) C.M. Stoffelen	stoffele@knmi.nl	Royal Netherlans Meteorological Institute
Norway	VI	Mr. Oystein Godoy	o.godoy@met.no	Norwegian Met Institute
Russian Federation	VI	1.Ivan Yevgenyevich Frolov; 2. Vladimir Mikhailovich Kotlyakov	frolov@aari.nw.ru direct@igras.geonet.ru	1. Director, Roshydromet Arctic and Antarctic Institute; 2. Geographical Institute of the Russian Academy

				of Sciences
Sweden	VI	Mr. Amund Lindberg	amund.lindberg@smhi.se	SMHI
Switzerland	VI	Dr. Gabriela Seiz	Gabriela.Seiz@meteoswiss.ch	Head of Staff Office Climate Domain
United Kingdom of Great Britain and Northern Ireland	VI	Dr. Jon Shanklin; Mike Molyneux	j.shanklin@bas.ac.uk; mike.molyneux@metoffice.gov.uk	British Antarctic Survey; UK Met Office

ANNEX 5

PARTICIPANT RESPONSES TO GCW QUESTIONS
(Alphabetical by Participant)

Participants were asked to address the following five questions to help focus discussion during the roundtable and in the breakout sessions.

> ***What is your personal area of interest in the cryosphere?***
> ***What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?***
> ***What are the needs of users in your institute/country/region for cryosphere data and information?***
> ***How could GCW help meet your national, regional or global interests?***
> ***What could you or your organization contribute to the implementation of GCW?***

Participants' responses are included below.

1. Oleg Anisimov (Roshydromet, oleg@oa7661.spb.edu)

What is your personal area of interest in the cryosphere?

- Permafrost observations and modelling in relation to climate change.
- Identification of critical climate thresholds governing the response of permafrost to climatic change.
- Impact of thawing permafrost on infrastructure and carbon cycle (greenhouse gas emissions, particularly methane).
- Permafrost-related information services, i.e. dedicated web portal etc.
- Regionalization of permafrost with respect to susceptibility to climate change.

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

Roshydromet is in charge of monitoring hydrometeorological conditions in Russia. It includes sea, river and lake ice, snow, and permafrost. Glaciers are not in this list since they are monitored occasionally by the Russian Academy of Sciences.

What are the needs of users in your institute/country/region for cryosphere data and information?

Russia is a northern country and cryospheric information is highly demanded on the operational level for ice roads, sea and river navigation, in particular along the Arctic coast. Snow information is crucially important for transport operations, management of buildings and infrastructure; it also has direct implications in agriculture and hydrology (spring flood forecasting). Permafrost data are important for preventing damage to infrastructure and for development planning in the northern lands. Scientific community requires various cryospheric data for modelling.

How could GCW help meet your national, regional or global interests?

Establishing GCW will facilitate implementation of several tasks Roshydromet is charged with, see the list above.

What could you or your organization contribute to the implementation of GCW?

Personally, I may serve as a focal point for integrating the Russian permafrost data from both observations and modelling. Roshydromet can provide data on river, lake and sea ice, as well as snow data from weather stations.

2. Gianpaolo Balsamo (ECMWF, pad@ecmwf.int): Modelling and Data Assimilation needs for the Cryosphere at ECMWF

What is your personal area of interest in the cryosphere?

My main research interests are in: (1) Land surface modelling and data assimilation in Numerical Weather Prediction (2) The links between water, energy, carbon cycles in Earth System Science, and (3) land-related predictability.
My current research with an up-to-date list of publications is available on:
http://www.ecmwf.int/staff/gianpaolo_balsamo/

What are your organization/agency current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

The European Centre for Medium-Range Weather Forecasts (ECMWF, the Centre) is an intergovernmental organisation supported by 34 States, based in Reading, west of London, in the United Kingdom. Extensive information is published on the ECMWF web-site:
http://www.ecmwf.int/

The main mission of ECMWF is the development and operation of global models and data-assimilation systems for the dynamics, thermodynamics and composition of the Earth's fluid envelope and interacting parts of the Earth-system, with the mandate to:

1. Prepare forecasts by means of numerical methods;
2. Provide the best initial conditions for the forecasts; and
3. Contribute to monitoring the relevant parts of the Earth-system.

In achieving these ambitious goals the ECMWF benefits for the support of the World Meteorological Organization and of a large number of cooperation agreements with European and World-wide organizations:
http://www.ecmwf.int/about/cooperation/

ECMWF is carrying out scientific and technical research directed towards improving the quality of these forecasts, made available to the Member States, in the most appropriate form, so that the results provide assistance in implementing programmes of the World Meteorological Organization.
ECMWF also provides advanced training to the scientific staff of the Member and Co-operating States in the field of numerical weather prediction, and makes the data from its extensive archives available to outside bodies. ECMWF delivers a large range of forecast products, including high-resolution deterministic prediction up to 10 days, a 51-member ensemble prediction system (EPS) up to 15 days (both issued twice daily). Monthly and a Seasonal forecasting and retrospective reanalyses over multiple decades (e.g. ERA-40, ERA-Interim) are also among the ECMWF's range of key products:
http://www.ecmwf.int/products/

What are the needs of users in your institute/country/region for cryosphere data and information?

The Polar regions and cold remote areas represent a real challenge for the three main components of the integrated Forecasting System (IFS) at ECMWF:

Data availability and data monitoring:
Few in-situ data exists in polar regions and generally in remote cold-regions. This is exacerbated if we consider data with Near-Real-Time accessibility that can be useful for operational weather forecasting. The daily data availability is monitored at ECMWF and available at:
http://www.ecmwf.int/products/forecasts/d/charts/monitoring/coverage/dcover/
The availability of isolated observations implies that quality control methods that are operating in observationally dense areas may reject valuable observations in remote regions.
Polar orbiting satellites do guarantee frequent overpasses at high latitudes but the retrieval of atmospheric profiles can be problematic due to difficulties in the separation of the signals from cold surfaces and clouds. Therefore there is a need of high quality observations for process studies (e.g. by field campaigns such as SCHEBA over the Arctic sea-ice and CONCORDIASI over Antarctica) and for operational use in Numerical Weather Prediction and retrospective Re-Analyses.

Cold-processes modelling:

Modelling snow, ice, and liquid water hydrometeors in the atmosphere of polar regions is a particularly complex task as the temperature range determine a large sensitivity to tiny amounts. For instance the presence of super-cooled liquid water in clouds appears essential to characterize long-wave shielding effect of clouds overnight at high latitudes. The optical properties of polar clouds are peculiar and represent a challenge for NWP parameterizations.
Snow and Ice over flat-land and sea represent a comparable challenge as the amount of snow overburdening the ice-sheet cannot easily be inferred by remote sensing. This is due to the complexity of radiative emission of the snowpack.
Finally glaciers and snow over orographic areas are parameterized with drastic approximations, neglecting many important processes related to aspect and elevation differences.

Data assimilation:
With the shortage of observations from in-situ and well know aliasing problem in separating clouds from cold surfaces, the atmospheric data assimilation faces a challenge in using the remote sensing data over the Poles and over large orographic regions.

How could GCW help meet your national, regional or global interests?
The actions undertaken under the WMO programme related to the Cryosphere (named Global Cryosphere Watch) can have large impact by improving and extending the in-situ network (e.g. SYNOP stations). Important variables are the snow depth, the snow density (if possible) and the precipitation.
Fostering new field campaign and coordinating high latitude observing stations to enhance the observation capabilities (e.g. towards the so-called supersite configuration) would be beneficial.
More comprehensive vertical soundings (by balloon-radiosondes and drop-sondes), would also represent a big step forward.

What could you or your organization contribute to the implementation of GCW?
ECMWF will contribute to the GCW by monitoring and assimilating all available data in the atmospheric 4-dimensional variational assimilation system (4D-VAR) and in the dedicated land data assimilation system (LDAS).This will generate a benefit to the ECMWF products' accuracy both in real-time operations and in retrospective re-analyses. Such products are widely used also by the cryosphere community.

On the land surface aspects a new snow analysis, based on the spatial Optimum Interpolation method applied at the Canadian Meteorological Centre has been recently introduced operationally. This method is able to ingest in-situ and satellite-based snow-cover products and the availability of new ground based observations will result in a better handle of model-errors (e.g. related to snowfall and snow metamorphism).

From the scientific point of view, the cryosphere is of high interest at ECMWF and a recent workshop dedicated to the meteorologically stable cases and co-organized with the GEWEX-GABLS panel, highlighted the importance of representing correctly the interaction between turbulent fluxes and radiation at the surface in Earth System models. See:
http://www.ecmwf.int/newsevents/meetings/workshops/2011/GABLS/index.html

In the long term strategy of development, the interaction of surface with the atmosphere and cold-processes anomalies (e.g. anomalous snowfall episodes, and long-term anomalies as those detectable by re-analyses) are highlighted as belonging to the core activities of ECMWF, in the programmatic documents:
http://www.ecmwf.int/about/programmatic/strategy/index.html

3. Andreas Becker (DWD and GPCC, Germany, Andreas.Becker@dwd.de)

What is your personal area of interest in the cryosphere?
Primary personal interest in my role as Head of GPCC and the Precipitation Monitoring Unit of Deutscher Wetterdienst is to improve on the quality, quantity and availability of solid precipitation observations in all cryospheric regions. In doing so I am interested to learn about the country specific status quos, and GCWs potential to improve on them.

I am always interested in exchange on recent developments with regard to in-situ and remotely sensed solid precipitation including automated gauges and radar based dual pol. Technologies, and GCW might serve a platform for new information on this.

GPCC would appreciate a re-examination of the quality and reliability of historic solid precipitation measurements

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

The Deutscher Wetterdienst (DWD), which was founded in 1952, is as National Meteorological Service of the Federal Republic of Germany responsible for providing services for the protection of life and property in the form of weather and climate information. This is the core task of the DWD and includes the meteorological safeguarding of aviation and marine shipping and the warning of meteorological events that could endanger public safety and order.

DWD hosts the Global Precipitation Climatology Centre in charge of collecting world-wide precipitation data in online and offline mode, including the tedious task of QC on the data collected globally. This is done as a contribution to WCRP and GCOS. Solid state precipitation imposes a particular challenge with regard to systematic error and with regard to quality and availability of data.

Therefore, the Arctic Precipitation Data Archive (APDA) was installed in 1996 within the Global Precipitation Climatology Center (GPCC, German Weather Service, in Offenbach/Main, Germany). It is a subproject of the Arctic Climate System Study (ACSYS) which was established by the World Climate Research Programme (WCRP, WMO/WCRP, 1997).

The WCRP decided in 2000 to expand ACSYS into a global project Climate and Cryosphere (CliC) that investigates the role of the entire cryosphere in the global climate. The head of the German Weather Service agreed that APDA become integral part of the Global Precipitation Climatology Center (GPCC) and that the APDA activities would continue regardless of the end of the German ACSYS-Project in 2005.

The Hydro-Meteorological Department of DWD runs the model SNOW (www.dwd.de/SNOW) for the sake of providing water resources management authorities at the regional and national level with the needed precipitation supply data (i.e. the amount of snow melt and rain water) for the purposes of operational flood forecasting. The model performs very well for the central European river basins relevant to Germany but has certain requirements on the input data that might not be easy to be satisfied globally.

Overall DWD's engagement on the cryosphere is comparatively small. In Germany the Alfred-Wegner Institut (AWI) is an important and active player in the field

What are the needs of users in your institute/country/region for cryosphere data and information?

High quality SYNOP messages including RR group. High quality messages on snowfall and snow depth for early warning (Watch Function!) on dew weather (rapid snow melt!) and calculation of water budgets and river basin specific precipitation to drive run-off models

Our marine weather forecasters in charge to consult on ship routing would benefit from sea-ice data at a high update frequency and with the parameters (Concentration, Thickness, Type of Ice-Edge, Drift-Velocity of Icebergs and type of Ice). Overall a well updated watch on Iceberg occurrences to assess their potential hazard to navigation and marine safety is highly welcome

How could GCW help meet your national, regional or global interests?

GCW should act catalytic for a fast international exchange of data and Information including temporary data sources alike those related to research expeditions and missions. This would be beneficial for many purposes, e.g. to improve initialization of NWP models with a more accurate sea – ice distribution being beneficial for the forecasts

What could you or your organization contribute to the implementation of GCW?

Provision of RA VI RCC Data: Range 10W, 50E, 70N, 35S via WebWerdis Web Interface
http://werdis.dwd.de/werdis/start_js_JSP.do

- Maps of Snow days : Number of snow days Maps and grids of number of snow days on a 0.1x0.1 degree grid derived from SYNOP data, provided by WMO RA VI Regional Climate Centre (RCC) on Climate Monitoring WMO-RA6-RCC-CM,
- Maps of snow depth on a 0.1x0.1 degree grid derived from SYNOP data, provided by WMO RA VI Regional Climate Centre (RCC) an Climate Monitoring
- An account on the WebWerdis Interface could be provided. However, this functionality will soon be covered by GISC as part of WIGOS.
- GPCC can offer experiences from the ACSYS-APDA project and should be available for cross-comparison of arctic precipitation measurements. However, GPCC has currently no additional DWD in-house resources for larger studies. Efforts of this kind would need to watch out for soft money to fund extra project posts.
- GPCC would like to join in development and validation of time variable error correction functions if that is of interest to other partners
- Sharing GPCCs precipitation data is problematic, as GPCC cannot claim the copyright on the data from its suppliers. However GPCC is open to solutions that would not require to give away the data, e.g. by hosting experts.
- This list is surely not comprehensive; I assume the 1st GCW implementation meeting will provide inspiration for further potential ways of DWDs contribution.

4. Ross Brown (Environment Canada, brown.ross@ouranos.ca)

What is your personal area of interest in the cryosphere?

- Documenting and understanding variability and change in snow cover at regional, national and hemispheric scales;
- Evaluation of snow cover datasets from various sources (e.g. satellite, in situ, reanalyses);
- Validation of snow processes and feedbacks in climate models.

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

Environment Canada has responsibilities to provide Canadians with high quality information for decision-making over short (e.g. weather forecasting) to longer (e.g. climate model scenarios) time-scales. This involves monitoring, research, weather forecasting and climate prediction. The main elements of the cryosphere included in these activities are: solid precipitation, snow cover (areal coverage, depth, snow water equivalent), sea ice (concentration, type, and amount), lake and landfast ice thickness. Environmental Prediction coupled atmosphere-ocean-ice and atmosphere-land surface-hydrology modelling and prediction efforts all rely on cryospheric data for assimilation. Enhanced assimilation of cryospheric information from additional data and improved data assimilation strategies (e.g. CaLDAS - Canadian Land Data Assimilation System) will improve our weather prediction initiatives in the Arctic and in our recently assumed responsibilities for MetAreas. All aspects of the cryosphere including frozen ground and land ice processes are considered in the land surface and climate models developed and used by Environment Canada.

Monitoring of daily snow depths is carried out at climate stations nationally in support of weather forecasting (e.g. initialization of NWP model), climate monitoring and various applications. A large fraction of these data are contributed in real-time to the WMO Information System (WIS). Satellite snow products are developed and evaluated in the Climate Research Division (CRD) for use in climate monitoring, operational forecasting and evaluation of climate models. Meteorological Research Division use satellite and in situ snow cover information in CaLDAS (the Canadian Land Data Assimilation System) for high resolution (100-m) prediction of snow cover in mountainous terrain.

Environment Canada's Canadian Ice Service (CIS) prepares weekly ice concentration and type charts for Canada's Arctic, Hudson Bay, East Coast, and Great Lakes are based primarily on RADARSAT and

ENVISAT satellite data supplemented by air reconnaissance and ship-based ice specialists. This information contributes to global sea ice charting through the U.S. National Ice Center which partners with CIS in the North American Ice Service. CIS also maintain historical digital databases of sea ice conditions in Canadian waters back to the 1950s in support of applications and R&D.

More details about EC's contributions to cryospheric monitoring in Canada are provided in the Canadian National GCOS reports compiled in 2002 and 2008.
http://unfccc.int/resource/docs/gcos/cangcose.pdf
http://unfccc.int/files/methods_and_science/research_and_systematic_observation/application/pdf/canada.pdf

What are the needs of users in your institute/country/region for cryosphere data and information?

Sea ice: shipping operations, over-ice transport, coastal engineering studies, climate monitoring, R&D
Snow depth: ski operations, snow clearing, snow load calculations, ground frost, R&D
Snow water equivalent: water resource management (flood forecasting, hydro-power operations), climate monitoring, R&D
Snowfall: avalanche forecasting, snow clearing, ski operations, traffic management, aircraft de-icing
Research: climate monitoring, process studies, model evaluations
Forecasting: real-time obs of snow depth and sea ice needed for operational forecasting

How could GCW help meet your national, regional or global interests?

Increased sharing of real-time snow depth data would improve the quality of snow analysis products e.g. China does not currently contribute snow depth obs to WIS in real-time.

Support for developing a global in situ snow database would greatly assist climate monitoring and R&D activities requiring historical information on snow depth and SWE. This would greatly benefit reanalysis activities as all reanalyses would have access to the same QC'd in situ snow data.

Sponsorship of measurement and model intercomparison projects related to cryospheric variables e.g. solid precipitation, automated snow depth sensors.

What could you or your organization contribute to the implementation of GCW?

- contribute supersite for CryoNet
- contribute to WMO solid precip intercomparison project (SPICE)
- contribute to development of Cdn GCW portal
- contribute authoritative cryospheric products to GCW particularly snow
- participate in Cdn GCW advisory group

5. Eric Brun (Meteo-France, eric.brun@meteo.fr)

What is your personal area of interest in the cryosphere?

- detailed numerical modelling of snow cover and study of snow-climate interactions
- assessment of the impact of climate change on snow climatology

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

Météo-France is involved in many aspects of cryosphere monitoring and research:
- operational monitoring of the state of the snow cover in France is part of its core missions, mainly for avalanche forecast but also for the survey of water resources. A specific snow-weather network is operated in winter.
- operational monitoring and forecast of snowfalls in plains and mountains
- research on snow cover and avalanches is the core mission of the Centre for snow research (CEN) , which is a lab of CNRM, the research center of Météo-France (a joint lab between Météo-France and CNRS). The development of detailed snowpack models is part of this research.
- study of snow/atmosphere interactions

- snow and cryosphere modelling for the Earth Climate system of Météo-France and for its NWP systems.
- study of the impact of climate change on snow cover, avalanche risk, alpine river discharges and water resources

What are the needs of users in your institute/country/region for cryosphere data and information*?*
There are both operational needs (real-time snowpack survey for avalanche forecast and hydrological survey, real time snowfall detection for weather nowcasting) and research needs (climate studies, climate change attribution, water cycle studies, ...).

How could GCW help meet your national, regional or global interests?
The promotion of an easy access to cryosphere observations would be very beneficial for the research on the interactions between the cryosphere and the climate. WMO should promote the best practices for continuous long-term in-situ observations of the snow cover.

What could you or your organization contribute to the implementation of GCW?
- Contribution to the long-term monitoring of the snow cover over the French Alps
- Development of global modelling systems to survey the snowpacks, based on snow modelling and data assimilation

6.Charles Fierz (The International Association of Cryospheric Sciences (IUGG), WSL Institute for Snow and Avalanche Research SLF, fierz@slf.ch)

What is your personal area of interest in the cryosphere?
Snow and avalanches, that is, I am mainly interested in snow-cover modelling with regards to avalanche formation. This also implies getting some knowledge, for example, in micrometeorology as well as in crystal growth (snow metamorphism). Such work can also lead to valuable modelling excursions reaching as far as Antarctica. After starting working at the WSL Institute for Snow and Avalanche Research SLF in Davos, Switzerland, some twenty years ago, I very soon heard from the International Commission on Snow and Ice ICSI and became engaged in the birth and first years of IACS since 2005.

What are your organization current interests or responsibilities with respect to the cryosphere (within and beyond your country)?
The International Association of Cryospheric Sciences IACS is the youngest of eight scientific associations within the International Union of Geodesy and Geophysics IUGG, which in turn is member of the International Council of Science ICSU.
Two of IACS goals are listed below
1. *to encourage research in Cryospheric sciences by members of the cryospheric community, national and international institutions and programmes, and individual countries through collaboration and international co-ordination*
2. *to facilitate the standardisation of measurement or collection of data on cryospheric systems and of the analysis, archiving and publication of such data.*

What are the needs of users in your institute/country/region for cryosphere data and information?
IACS sees itself more as a co-ordinator and promoter than a user.
Regarding Switzerland, there is a need for continued and sustained long term high qualitydata series on snow (Weissfluhjoch), permafrost (PERMOS) and glaciers (Swiss Glaciers Monitoring Network).

How could GCW help meet your national, regional or global interests?
IACS is a long standing but nevertheless “young” partner in the Cryospheric community. Participating in GCW will help IACS meet some of its main goals (see above).
Swiss research institutions in the field of cryosphere would gain support in securing funds and resources to maintain the level of the above data series that are very valuable for cryospheric research and risk management in alpine environments.

What could you or your organization contribute to the implementation of GCW?

Goals of IACS (see above) match many of GCW aims. As a partner, IACS can provide abridge to the scientific community. The simple organizational structure of IACS allows for "neutral"and short term Working Groups to tackle dedicated topics. Standing Groups like the GTNGsteering committee (see WGMS) or GAPHAZ (Glacier And Permafrost HAZard in mountains, jointly with IPA) provide advice and continuity in important aspects relevant to the whole Cryospheric community.

International Association of Cryospheric Sciences: http://www.cryosphericsciences.org

The objectives of IACS

3. – *to promote studies of cryospheric subsystems of the Earth solar systems*
4. – *to encourage research in the above subjects by members of the cryospheric community, national and international institutions and programmes, and individual countries through collaboration and international co-ordination*
5. – *to provide an opportunity on an international basis for discussion and publication of the results of the above research*
6. – *to promote education and public awareness on the cryosphere*
7. – *to facilitate the standardisation of measurement or collection of data on cryospheric systems and of the analysis, archiving and publication of such data.*

We encourage all members of the cryospheric community to contribute towards these goals.

7. Øystein Godoy (MET.NO, o.godoy@met.no)

What is your personal area of interest in the cryosphere?

I have been working with snow and sea ice detection using optical sensors on meteorological satellites for several years. These activities have been organised through both internal and external projects. Internal project have focused on cloud classification while external projects on the snow and sea ice information. The main methodology used have been Bayesian classification of weather phenomena, clouds, snow and sea ice. One particular challenge have been how to distinguish between clouds and snow/sea ice in a reliable manner in operational processing chains and under suboptimal conditions for classification schemes.

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

The Norwegian Meteorological Institute (METNO) is responsible for the national sea ice service. We do also perform snow mapping as cryosphere information is essential for the performance and reliability of our operational numerical weather prediction models as well as our numerical ocean models and radiative transfer models providing forecasts of UV-radiation.
Concerning externally funded activities, METNO is managing the High Latitude processing centre of the EUMETSAT Ocean and Sea Ice Satellite Application Facility (SAF). We do also manage the MyOcean Sea Ice and Wind Thematic Assembly Center (TAC).

What are the needs of users in your institute/country/region for cryosphere data and information?

Cryosphere in situ information is used for validation of cryosphere products derived from remote sensing sensors and numerical models. The numerical modelling community at METNO require high quality snow and sea analyses combining in situ and remote sensing data. In order to effectively utilise this information, proper documentation of the data, collection procedures, availability etc are required. One important issue to consider is the inclusion of uncertainty estimates in all products, whether observation or derived product. General users in Norway usually are interested in snow and sea ice maps at the national level. More advanced users require time series of maps or at positions in support of their analysis work. Generally, user needs starts with discovery, then access and finally higher order services including transformations to the state needed for their analysis.

How could GCW help meet your national, regional or global interests?

Among the main problems working with cryosphere products derived from remote sensing sensors are the

lack of in situ validation data. METNO derives such products at national, regional and are working towards global coverage for some products. At the national level knowledge and access to validation data is acceptable, but this is a major challenge at regional and global level. Access, set aside, procedures collecting and describing cryosphere information differs as well.
GCW would help identify potential validation data as well as other products available that could be used in our activities. The current situation is that the data overview is fragmented and that little data is available online. GCW could help promoting standardisation, interoperability, and data exchange. GCW could also demonstrate the mutual benefit of free exchange of data to the community and through this possibly influence existing data policies for cryosphere data.

What could you or your organization contribute to the implementation of GCW?
METNO would contribute to the GCW data management system and portal solution. All METNO data are freely available and our institution undertakes currently an effort to document and make all data discoverable and available online through interoperable interfaces (including WIS and INSPIRE compliant interfaces).

8. Jon Ove Hagen (Norway, IASC WG Cryosphere, j.o.m.hagen@geo.uio.no)
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What is your personal area of interest in the cryosphere?
I will represent the IASC WG on Cryosphere and Norway in the GCW implementation meeting. My main personal focus and interest is the Glaciers and Ice caps in the Arctic. I have worked on glacier mass balance changes in the Arctic over the last 25 years within the Svalbard archipelago. During the IPY and beyond we have focused our activity on the large ice cap Austfonna. We have studied the ice cap by field investigations, remote sensing and modelling.

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?
The IASC Cryosphere WG will work within in all aspects of terrestrial and marine cryosphere in the Arctic. The scientific scope of the Cryosphere Working Group shall include any scientific or engineering research relating to the Arctic and sub-Arctic cryosphere, including its interactions with the climate, oceans, and biosphere. The main aims are to develop, encourage and initiate cryosphere research activity. Thus GCW will be an important tool to be able to achieve the aims of IASC, and the IASC WG Cryosphere will also be a help for GCW in the Arctic.
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What are the needs of users in your institute/country/region for cryosphere data and information?
Norway is a country where the cryosphere is very important in all aspects of the cryosphere. We have a hydro-power industry that need long term monitoring of glacier mass balance and snow in their reservoir calculations, in flood calculations and predictions. Permafrost thawing may have impacts on geohazards and currently there are monitoring sites in steep rock walls in Norway to be able to predict possible rock falls caused by thawing permafrost.
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How could GCW help meet your national, regional or global interests?
The main help will be to support to maintain long term monitoring of many parameters of the cryosphere. Secondly, the planned portal of GCW will be a tool to get easy access to world-wide data about the cryosphere.

What could you or your organization contribute to the implementation of GCW?
I am personally at University department so our main interest is focused research projects. These are by nature temporary or short term projects. However, we always need long term data as input and background data. In Norway we have institutions responsible for long term monitoring of glacier, snow and meteorology in the mountains; on mainland Norway these are The Norwegian Water resources and energy Administration, The Norwegian Meteorological Institute (met.no) and in Svalbard Norwegian Polar Institute and met.no. These institutions maintain monitoring stations and serve as local and national data bases. They should all have a key role in the implementation of GCW.

9. Juan Manuel Hörler (Servicio Meteorológico Nacional, Buenos Aires, Argentina, jhorler@smn.gov.ar)

What is your personal are of interest in the cryosphere?

Impacts in snow accumulation and glaciers are important as available water in Argentina. The increased height of the snow line in the central Andes of Chile is one effect that has begun to observe in recent decades and future scenarios of XXI century climate change associated with a rising trend. Different studies have been conducted in glacier retreat and mass balance in the Chilean Patagonia and central Andes, as well as their contribution to rising sea level as a result of climate change.

What are your organization/agency´s current interests or responsibilities to the cryosphere?

Accurate determination of precipitation, including the solid component, is essential to assess the global water cycle, in particular over The Andes Mountains, Argentina's west boundary (from 21°S to 55°S). The observational network of the NWS constitutes the basis of climate studies for all meteorological variables and some hydrological ones in the country. The lack of a denser network for cryosphere data prevents for assessing the real impacts of weather regimes and climate variability or climate change.

What are the needs of users in your institute/country/region for cryosphere data and information?

Snow- and glacier-melt are critical sources of water for agricultural, domestic and industrial water supply and hydropower production, and directly contribute to flood and drought hazard conditions. Our users, mainly from the Energy section, needs to quantify the solid precipitation, accumulated snow and melting rate in many time scales over The Andes Mountains, near major river basins (Comahue, Limay, etc). Other small river basins serve a water supply for the community or agriculture in other places along de barrier.
Other important users needs are those related to decision making and formulation of environmental policy

How could GCW help meet your national, regional or global interests?

Enhance the capability for providing quality assured regional products on the state of cryosphere. It will facilitate assessments of the cryosphere and its components on regional scale to support user's needs and provide information for the climate change community and decision making and formulation of environmental policy.

What could you or your organization contribute to the implementation of GCW?

Argentina can coordinate Reg. III Cryospheric activities, and implement a Data Base to send in real time all collected cryospheric observations.

10. Abdylkhamid Kayumov (State Administration for Hydrometeorology Committee of Environmental Protection under the Government of the Republic of Tajikistan, abdkaumov@mail.ru)

What is your personal area of interest in the cryosphere?

Since 2007 I am scientific secretary of the Committee on the implementation of the International Polar Year in Tajikistan. I study the impact of climate change on glaciers in Tajikistan. In 2011, with the support of the RT Government and UNDP, organized the first comprehensive international expedition to assess the state of glaciers in the upper reaches of the Vakhsh and Panj rivers. I was chief of the expedition.
In 2008, with the support of the Russian Antarctic Expedition, organized the first Tajik Antarctic Expedition (2008-2009). I have several publications on the subject. Reports on a comparative analysis of the state of glaciers on the Pamir and Antarctica was speaking at the Conference of Parties on Climate Change COP-15 (Copenhagen, 2009) and COP-16 (Mexico 2010) and other international and national conferences. I took part in Antarctic expeditions: 29 Soviet Antarctic Expedition (1983-1984). 54 Russian Antarctic Expedition (2008-2009).

What are your organization / agency current interests or obligations with respect to the cryosphere (within and outside your country)?

The State Administration for Hydrometeorology Committee of Environmental Protection under the Government of the Republic of Tajikistan is the authorized body for the study and monitoring of meteorology, hydrology and glaciers. Our organization is the main contractor of the State Program for the Study of glaciers in Tajikistan for the period 2010-2030 gg. Conducting aerial and field work to monitor the state of glaciers in Tajikistan. Areas of interest also are the glaciers of Antarctica.

What are the needs of users in your institution / country / region, cryospheric data and information?

Our experts will need to be methodological, consulting and technical assistance, and strengthening human resource capacity.

How can the GCW meet your national, regional or global interests?

For a realistic assessment of the trends and dynamics of the degradation of glaciers in Tajikistan to data on regional and global level. Tajikistan may obtain such information only on the basis of the implementation of HSCs. The comparative analysis allows our experts to identify similarities and differences of degradation of glaciers in Tajikistan against global warming. In Tajikistan, 60% of the water formed the Amu Darya. Water supply to more than 60 million people CAR depends on the glaciers of Tajikistan.
Implementation of the GCW in Tajikistan can focus on the glaciers and snowfields in mountain regions. That depends on water security at the regional and global level. Water security is the foundation of food security and sustainable development of any region in the world.

What would you or your organization contributes to the GCW?

In Tajikistan, there are more than 8000 glaciers, the largest glaciers in the former Union of Independent States (CIS) are in the Pamir Mountains, one of them Fedchenko (length 70 km). For the glaciers are monitored with 30 of the last century, the database is located in the State agency for hydrometeorology. In accordance with the Government on the basis of the Hydromet has a Committee on the implementation of the IPY in Tajikistan since 2007. All of this allows our organization to successfully implement the GCW in Tajikistan.

11. Kari Luojus and Jouni Pulliainen (Finnish Meteorological Institute, Helsinki, Finland, Kari.Luojus@fmi.fi and jouni.pulliainen@fmi.fi)

What is your personal area of interest in the cryosphere?

Prof. Pulliainen: Prof. Pulliainen was a professor of space technology at the Helsinki University of Technology from 2001 to 2006, specializing in remote sensing. He is currently a research professor at the Finnish Meteorological Institute (FMI) and head of the Arctic Research of FMI. His research interests include direct and inverse modelling in remote sensing, and additionally, remote sensing data assimilation and application development e.g. for the needs of cold regions hydrology and climate change investigations. Recently, his work has focused on the active and passive remote sensing of boreal forests and snow cover applying both microwave and optical data. Prof. Pulliainen has been a principal investigator or project manger for several nationally funded and international research projects, including several ESA and EC contracts.

Dr. Luojus: Dr. Luojus has been working with remote sensing of snow cover and monitoring of Cryosphere in the context of investigating and generating long-term records on snow cover properties within the ESA GlobSnow initiative. Dr. Luojus has worked extensively with SAR-based snow cover monitoring for the boreal forest zone and was recently the project manager for GlobSnow, which has been scientifically led by Prof. Pulliainen.

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

The research, monitoring, assessment and prediction of climate and environment changes of the cryosphere (focusing to northern latitudes) is one of primary work areas of FMI. FMI has been working with remote sensing and monitoring of Cryosphere for several decades. FMI operates a well-developed cryosphere monitoring station and a satellite receiving station in Northern Finland in Sodankylä. FMI have worked with generating of long-term records on snow cover properties (e.g. ESA GlobSnow), are involved with the preparation of ESA Earth Explorer CoReH20 mission and are operating several Earth Observation (EO) cal-val instruments at Sodankylä (e.g. ESA Elbara - SMOS cal/val instrument, ESA SnowScat X-Ku band scatterometer simulating CoReH2O measurements, Radiometer system with frequencies coinciding with AMSR-E and SSM/I i.e. X, K-, Ka, W-bands).

What are the needs of users in your institute/country/region for cryosphere data and information?

We are interested in providing and gaining access to both ground based measurements and satellite-based data that can be utilized for monitoring the state of cryosphere for hydrological purposes, climate monitoring and utilization of data for NWP needs.

How could GCW help meet your national, regional or global interests?

We expect that the GCW could be help in providing a framework for collaboration, exchange of data and common practices relevant for the monitoring of cryosphere. Improved access to cryosphere data would assist FMI in carrying out the research and monitoring activities of northern latitudes.

What could you or your organization contribute to the implementation of GCW?

We are willing to provide access to data collected at Sodankylä cryosphere measurement site. We are also willing to provide the long-term records (and tools for exploitation of them) we've been generating within several international projects we have participated on. One of the more well known being the ESA GlobSnow, which data we are currently producing and distributing through our facilities in Sodankylä. The data centre of Sodankylä with data archiving, processing and distribution infrastructure could be further utilized for hosting of additional cryosphere data. We are also willing to host and facilitate experimental campaigns (related to cryosphere) in Sodankylä, where we are already operating cryosphere focused cal-val instrumentation and a wide array of continuous measurements on cryosphere relevant parameters.

12. Walt Meier (NSIDC Response, walt@nsidc.org)

What is your personal area of interest in the cryosphere?

I am primarily interested in remote sensing of sea ice, particularly from passive microwave sensors. I also am involved in creating sea ice Climate Data Records, which will provide full documentation of provenance information, metadata, processing methods.

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

NSIDC is primarily a data center and the largest component is archival of datasets within the NASA Distributed Active Archive Center (DAAC), which archives the NASA Earth Observing System (EOS) and other NASA cryosphere products. In addition to satellite products, NSIDC also archives in situ data, aircraft, submarine, and other data. For sea ice, operational ice chart data and pre-satellite sea ice information is archived, including submarine ice draft measurements. NSIDC is now archiving NASA IceBridge aircraft data. NSIDC also has an active research component, with ~12 scientists working on various research aspects of the cryosphere, including: sea ice, ice shelf/ice sheet processes, glaciers, snow, permafrost/frozen ground, cryospheric carbon cycle, etc. NSIDC has also been involved in numerous education and outreach initiatives, both formally and information (e.g., http://serc.carleton.edu/eet/seaice/). Finally, NSIDC has several informatics initiatives to develop improved metadata databases, enhanced search and discover tools, etc.

What are the needs of users in your institute/country for cryosphere data and information?

NSIDC users span a broad range of categories. NSIDC's primary support is for the DAAC to archive, distribute NASA cryospheric data and support users of that data. The main user group has historically been scientists interested in using that NASA data. However, a much wider range of users is now coming to NSIDC. Data has been provided to a broader range of scientists, such as biologists investigating the status of polar bear and other marine mammal populations. NSIDC has consulted with U.S. Department of Defence personnel to provide data on changing Arctic conditions to aid in long-term strategic planning. A variety of news media have requested data (e.g., National Geographic, New York Times, etc.) and information about Arctic climate. NSIDC data has been involved in several educational modules, e.g., the Earth Exploration Toolkit (http://serc.carleton.edu/eet/seaice/). Data and information has been provided directly to educators and students. And NSIDC often receives requests from the general public about various data products. Sea ice data has been particularly sought after in recent years because of the large decline seen in the data.

How could GCW help meet your national, regional, or global interests?
GCW could be a valuable tool to share access to data both nationally and internationally and help set standards for data and metadata. GCW should facilitate advertising and sharing of standardized metadata through open web services to enable broad data discovery across organizations. In addition standardizing the presentation of data could be useful. For example, several groups provide estimates of sea ice extent from passive microwave (and other data), but these data are not standardized in terms of: map projection, grid size, land mask, minimum concentration threshold, providing error estimates, etc. An international body could help set such standards, with input from participating groups. Finally, GCW could promote communities of practice who work to agree on standard data collection protocols and data formats within their discipline.

What could you or your organization contribute to the implementation of GCW?
All NSIDC data is freely available and thus could be shared with GCW. As mentioned above, NSIDC developing metadata databases that conform to evolving international standards and NSIDC has an interest in having these standards adopted and uniformly applied. NSIDC could provide information to GCW to implement these standards and/or help GCW implement them. NSIDC is also interesting in developing data search and discover tools, on-the-fly processing tools, etc. and these could be adapted by GCW. Most of these efforts would require resources, but NSIDC would be interested in contributing to whatever extent we are able.

13. Anil Mishra (International Hydrological Programme (IHP), Division of Water Sciences, UNESCO**,** a.mishra@unesco.org)

What is your personal area of interest in the cryosphere?
I am coordinating UNESCO'S International Hydrological Programme (IHP) activities on climate change impacts on water resources. Particularly I am coordinating global activities related to melting glaciers and snow and impacts on water resources within the framework of IHP.

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?
UNESCO's mission under IHP–VII (2008-2013) 'Water Dependencies: Systems under Stress and Societal Responses' is to strengthen scientific understanding of the impacts from global changes on water systems, and to link scientific findings to policies for promoting sustainable management of water resources.
IHP has been coordinating glacier mass balance studies, research, training and capacity building programmes in different mountain regions: Himalayas, Central Asia, European Alps and Latin America/Caribbean with the following scope:

- Reviewing ongoing studies on the hydrological impacts of glaciers, snow and permafrost, and formulating further research needs;
- Developing regional networks of benchmark basins based on existing research and monitoring sites;
- Improving capacity of the scientists and institutions of the region to apply advanced methods and technologies (including use of satellite images) in assessing the status of snow and glaciers, and the impact of climate variability on them; and
- Awareness-raising programme for policy-makers at the national level on the predictions and risks related to melting mountain glaciers.

What are the needs of users in your institute/country/region for cryosphere data and information?
I think member states need to be supported on the long-term capability to assess and monitor changes in snow, glacier and permafrost conditions in the different region.

How could GCW help meet your national, regional or global interests?

- Develop programme linkages with ongoing efforts

- Improve coordination and exchange of information between the different organizations involved in monitoring glaciers, snow and permafrost in different regions

What could you or your organization contribute to the implementation of GCW?
Exchange of information and develop programme linkages and joint programme initiatives.

14. Tetsuo Ohata (JAMSTEC, ohatat@jamstec.go.jp)

What is your personal area of interest in the cryosphere?
- How cryosphere need to be organized into the future projection of climate and environment change of earth.
- Specifically, change of cryosphere components in the Arctic and Asian Regions. Better relation between observation and modelling.

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?
- In my Institute (JAMSTEC), the understanding the present and future of Arctic Environment System, through observation (Research vessel Mirai and terrestrial network in northern Eurasia and Alaska) and modelling.
- In the newly established JCAR (Japan Consortium for Arctic Environmental Research since 2011; Ohata, Chairman), direction and strategy of Arctic Research of Japan, including cryosphere is being discussed.
- Japanese Society for Snow and Ice (JSSI) is strengthening its activity to correspond to GCW direction, in collaboration with Japan Meteorological Agency (JMA).

What are the needs of users in your institute/country/region for cryosphere data and information?
- For the water resource agricultural management in Japan.
- Data for earth and climate system modelling, Arctic sea ice prediction.

How could GCW help meet your national, regional or global interests?
- Organized global data archive easy to access and use.
- Availability of regional and experimental cryosphere data, without need to interact with the data owner.

What could you or your organization contribute to the implementation of GCW?
- Better data archive system with inclusion of Japanese data.
- Reference sites (Japan: Siberia, Alaska, Himalaya, Patagonia, Antarctica)
- Pilot studies

15. Frank Paul (University of Zurich, frank.paul@geo.uzh.ch)

What is your personal area of interest in the cryosphere?
- Research related to past, ongoing and future glacier change (focus Alps)
- Monitoring of the ECV glaciers and icecaps from space

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?
- I am GLIMS representative in WGMS (contributing the remote sensing issues)
- I am scientific leader of the ESA project Glaciers_cci that aims to implement a long-term strategy for space-borne glacier monitoring
- I was responsible for the ESA project GlobGlacier
- I am actively involved in implementing data standards for remote-sensing products (in collaboration with WGMS and GLIMS)
- I gave lectures at the University/ETH on glacier remote sensing

What are the needs of users in your institute/country/region for cryosphere data and information?

- up-to-date glacier extents with topographic information for each entity to facilitate water resources assessment and modelling (e.g. hydrological -> CCHydro, NFP61, in RCMs -> EU FP7 High Noon, or for global sea-level-rise -> EU FP7 ice2sea, IPCC)
- periodic assessment of overall glacier changes to supplement ground-based observations

How could GCW help meet your national, regional or global interests?

- having an overview of all activities related to cryospheric monitoring (operational and project like) on a country to global scale
- manage a frequently updated list of all conferences, meetings and events related to cryosphere
- provide a news portal with latest reports, videos, blogs etc. on the cryosphere
- anounce publications on cryospheric topics that appear in non-cryospheric journals
- make clear to politicians/funding organisations etc. that monitoring is (1) a long-term commitment that (b) needs long-term financial support

What could you or your organization contribute to the implementation of GCW?

- prepare data sets requested by the community
- participate actively in the required reporting to get the overview mentioned above
- promote GCW during public outreach
- know-how and expertise on remote sensing based glacier maping and monitoring
- a global network of colleagues that are always supportive

16. Jouni Pulliainen (FMI, See Kari Luojus above)

17. Vladimir Ryabinin (WCRP, VRyabinin@wmo.int)

What is your personal area of interest in the cryosphere?

Acronyms

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

Seriously: To observe, assess and predict the cryosphere as a part of the climate system and to assess the impact of changes in it on various aspects of life support (e.g. water resources, sea level, etc.)

What are the needs of users in your institute/country/region for cryosphere data and information?

Hydrology people - need SWE
Modelling people - need validation data
Prediction people – need near-real time initial conditions for ice concentration and thickness, snow on land and on ice
Sea level people - mass balance of terrestrial cryosphere
Need albedo data for models, too.
Need surface fluxes via surface covered completely or partially with snow and ice
Need carbon stocks in permafrost broken down for types, depths, and with high horizontal resolution
Need permafrost temperatures

How could GCW help meet your national, regional or global interests?

Give me what I want!

What could you or your organization contribute to the implementation of GCW?

WCRP: help to specify requirements, advocate for the resources and national commitments.
Need to clearly define synergistic opportunities.

18. Wolfgang Schöner (Central Institute for Meteorology and Geodynamics, AUSTRIA, wolfgang.schoener@zamg.ac.at)

What is your personal area of interest in the cryosphere?

Glacier-climate relationship, permafrost-climate as well as snow cover-climate relationship in mountain regions (in particular the Alps) and in the Arctic (NE-Greenland). Our research group is not only running an extensive monitoring (glacier mass balance, glacier dynamics, glacier hydrology, permafrost temperature, physical and chemical snow cover properties) but also modelling studies.

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

ZAMG is the national weather service of Austria with high interest on snow observations and snow forecast (Alps). ZAMG is also responsible organisation for running the Sonnblick Observatory with its wide range of monitoring and research projects on glaciers, permafrost and snow cover. Recently, Sonnblick Observatory prepared a research plan for 2011-2015 with an important focus on the cryosphere. This research focus is highly linked to the atmospheric monitoring (e.g. radiation, aerosols, gases, water vapour) at Sonnblick. A third and new major research area is focussing on the biosphere, also well linked to changes in the atmosphere and cryosphere. In situ observations (not only at the observatory, but also at a spatial distributed network of stations) is complemented by satellite observations. Sonnblick has atmospheric and cryospheric observations back to 1886. Consequently, the site is an ideal place to study the reaction of the cryosphere on climate change (which is a major interest of ZAMG research). In 2012 ZAMG will start with a new snow modelling initiative covering the entire region of Austria using also extensive satellite data products.

What are the needs of users in your institute/country/region for cryosphere data and information?

There is very high interest on snow in Austria (because of commercial relevance for tourism, water management, traffic maintenance etc.). Permafrost distribution and its changes are relevant for building activities and road maintenance. Information on glaciers is asked mainly from hydrology, water management and tourism. All cryospheric data are highly relevant in public discussion (media) on climate change.

How could GCW help meet your national, regional or global interests?

GCW could provide an international framework emphasizing and promoting the high importance of the cryosphere with respect to global climate change. Giving GCW an active and important role in GCOS (as e.g. GAW) would support the funding situation for the cryospheric monitoring at the national and international level. Additionally, GCW could help to increase the international recognition of cryospheric monitoring activities. Inter-comparison studies for measurements could increase data quality and data standardization.

What could you or your organization contribute to the implementation of GCW?

ZAMG could support implementation of GCW by active work, in particular contributing to the definition of CryoNet supersite concept, to the definition of relevant cryospheric variables, to data standardization (and ev. homogenisation). Results from ZAMG ongoing cryospheric monitoring activities could be provided for the GCW website in order to show the potential of GCW at an established level in the future. ZAMG could also perform and host working group meetings, training courses for cryospheric measurements, data quality control or data standardization.

19. **Arni Snorrason** (Icelandic Meteorological Office, arni.snorrason@vedur.is)

What is your personal area of interest in the cryosphere?

The reply covers the interests and experience of glaciology group members at the Icelandic Meteorological Office (IMO), who have interest and experience in various fields of glaciology, including:

- glacier and ice-cap margin observations
- aerial photography of glaciers
- mass balance measurements
- studies of glacial runoff
- research on glacier dynamics
- modelling the impacts of climate changes on glacier mass balance and glacier dynamics
- ice drilling techniques (hot water drilling, ice core drilling)
- subglacial lake studies
- research on jökulhlaup (= glacial outburst flood) mechanisms

- LIDAR-mapping of glacier/ice-cap surfaces
- snow avalanche dynamics
- snow avalanche hazard zoning
- protection measures against snow avalanches
- lecturing on glaciology-related studies in University courses and summer/winter schools
- participation in the activities of the Icelandic Glaciological Society and the International Glaciological Society

Most of the above mentioned studies are done in cooperation and/or coordination with the glaciology group at the University of Iceland.

Other interests include:

- the history of glaciological observations and studies
- glaciology of the polar regions and the Himalayas (the “Third Pole”)
- studies of ice on Mars and other bodies of the Solar System.

What are your organization/agency’s current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

IMO has the responsibility to monitor various components of the natural environment in Iceland, including the cryosphere.

IMO employees measure the winter and summer mass balance of two of the five largest ice caps in Iceland and participate in the monitoring of a third ice cap. The mass balance studies were started in 1988. Glacier margin positions at 60 locations all over the country have been recorded in cooperation with volunteers since 1930.

The discharge and sediment transport of several glacial rivers originating in the country´s ice caps has been recorded since the 1940´s and by now many hydrometric stations deliver data in real-time. Some of the stations form part of an early warning system that monitors subglacial volcanoes. Monitoring of jökulhlaups and regular reporting of their occurrence forms part of IMO´s responsibilities.

LIDAR mapping of glacier and ice-cap surfaces in Iceland was initiated in 2008 as an Icelandic contribution to the IPY and will likely be completed in 2012. The project will provide an accurate reference data set on glacier/ice-cap surfaces against which future changes may be measured.

Snow thickness and snow cover are recorded at many manned weather stations in the station network of IMO.

IMO is responsible for avalanche warnings and hazard zoning and advices the government on avalanche protective measures. The office employs snow observers in the most important villages in avalanche-prone areas and maintains a database for avalanches.

Observations of river ice and lake ice thickness are made, but not on a regular basis.

International responsibilities and activities include:

- leadership in several Nordic projects focussing on the impacts of climate change on renewable energy sources, with emphasis on hydropower utilization in glaciated regions
- annual delivery of data on glacier mass balance and glacier front variations to the World Glacier Monitoring Service
- regular membership on the board and committees of the International Glaciological Society
- editorial assignments (Journal of Glaciology, Annals of Glaciology (special issues)
- organizing of international glaciology conferences and workshops

IMO participates in the Nordic Centre of Excellence (NCoE) "Stability and Variations of Arctic Land Ice" (SVALI, 2011–2015) together with 16 other Nordic research institutes and universities. SVALI is a comprehensive joint Nordic research programme to study basic cryospheric processes using remote sensing, airborne and in-situ measurements and carry out advanced Earth Systems Modelling with focus on glaciers in the Arctic/N-Atlantic area. SVALI will constitute a platform for joint process studies, analyses, sharing of methods, researcher training and outreach activities and for reporting of scientific results regarding the impact of climate change on terrestrial ice.

What are the needs of users in your institute/country/region for cryosphere data and information? and
How could GCW help meet your national, regional or global interests?

Iceland is situated within the North Atlantic Ocean and harbours large glaciers and ice caps that are highly sensitive to climate variations. Presently, the glaciers cover 10% of the country and they are modelled to essentially disappear within the next 100–200 years under current IPCC scenarios of future climate change. This will lead to other drastic changes in the natural environment, with considerable societal implications. Thus careful monitoring, modelling and regular assessment of cryosphere conditions will be needed as part of IMO´s activities. A few key points are outlined below:

- Discharge of glacial meltwater has increased since 1995 and a further increase is projected over the coming decades. Discharge will return to previous levels when the ice caps have receded greatly. Hydropower plants may need to be adapted to these changes.
- Shifts in glacial river courses due to glacier retreat are already occurring. Road infrastructure design, operation and maintenance must adapt to these changes, as well as to changes in the timing and extent of freeze-thaw cycles and changes in snow cover.
- Global sea level rise calls for revised design protocols for harbours, breakwaters and onshore coastal protections**.** In Iceland, plans must take into account not only the effects of rising sea levels, but also those of rising land, due to the reduced weight of glacier ice cover. These effects will vary regionally.
- Flood-risk criteria must be re-assessed. This refers both to *jökulhlaups* (glacial outburst floods, often due to subglacial volcanism), which are very common in Iceland, and floods due to rapid snowmelting.

The situation in Iceland invites the question whether the country could form a test bed for the development of glaciological monitoring and research programs within the framework of the Global Cryosphere Watch. The glaciers are easily accessible from the road network and a well-developed system of expedition logistics is in place.

What could you or your organization contribute to the implementation of GCW?

- The Icelandic Meteorological Office could provide data about cryospheric changes in Iceland to international data centres operated by or affiliated with the GCW and could function as a national GCW representative for Iceland in this context.
- The IMO will also collaborate with related institutes in the other Nordic countries on reporting cryospheric changes in the Nordic/N-Atlantic area in a systematic manner and will within the SVALI collaboration work towards establishing a Nordic entity that will formally be responsible for such activities towards the GCW.
- The IMO is prepared to participate in the practical implementation of the GCW by attending preparatory meetings and providing input to strategic plans for the activities of the GCW.

20. Rune Solberg (Section for Earth Observation, Norwegian Computing Center (rune.solberg@nr.no)

What is your personal area of interest in the cryosphere?

- R&D of remote sensing retrieval algorithms, in particular for snow
- The cryosphere's response on climate change
- Quantification of global, regional and local climate change by analysis of earth observation data time series
- Development of monitoring systems for changes in the cryosphere

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

- Much the same as above
- One of the R&D disciplines is methodology for retrieval of cryospheric variables from earth observation data
- We have currently R&D related to fractional snow cover, snow surface wetness, snow surface temperature, snow grain size, snow reflectance and black carbon in snow
- We can draw on other groups in our organization for statistical analysis of time series and information technology for climate monitoring system development
- We deliver anything from basic research results and algorithms to prototypes and operational systems (not off-the-shelf products and operational services)

What are the needs of users in your institute/country/region for cryosphere data and information?

- Norway as a northern, mountainous country is affected by the cryosphere all year around
- Any changes in the cryosphere might have concrete impact on the society (like infrastructure, water supply and energy supply)
- All available observations are of interest for improved understanding of the geophysical system and refinements of models for improved forecasting/projections of the future climate

How could GCW help meet your national, regional or global interests?

- Simple access to standardized data (products) and documentation
- Longest possible time series
- Quality assurance of the data
- Coordinating a long-term focus for measurements
- Coordinating reprocessing of the observational data as algorithms improve

What could you or your organization contribute to the implementation of GCW?

- Retrieval algorithms
- Time series of cryospheric variables retrieved from earth observation
- Components of the IT system for processing, handling, storing and distributing cryospheric data (including web service and web portal)

21. Christian Zammit (including NEW ZEALAND Investigators) (NIWA, c.zammit@niwa.co.nz)

What is your personal area of interest in the cryosphere?

- Establishment of long term monitoring site for estimation of snow storage across New Zealand Alps and modelling purpose
- High altitude climate and snow monitoring stations at 12 locations (11 in the South Island, 1 North Island).
- Modelling of snow processes integrated with NIWA hydrological model (TopNet) and University of Wellington Glacier Mass Balance model.
- Estimation of climate change impact on water resources and flood in alpine catchments for hydro-electricity purpose.
- Determination of seasonal snow cover through monitoring (End of Summer Line) and remote sensing products.

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

Monitoring: High altitude climate and snow monitoring stations at 12 locations (11 in the South Island). Modelling of snow processes integrated with NIWA hydrological model (TopNet). Estimation of climate change impact on water resources and flood in alpine catchments for hydro-electricity purpose. Determination of seasonal snow cover through monitoring and remote sensing

Glacier: Impact of climate change in glacier mass balance. End of summer snow line monitoring to estimate glacier mass balance and changes in ice volume to allow reconstruction past climatic information.

Sea Ice: Estimation of sea ice thickness

- Purdie: My research interest focuses on relationships between glacier mass balance and climate on glaciers in the New Zealand Southern Alps. I am interested in the variability of such relationships over temporal scales ranging from decades to centuries. In particular, I have been looking at patterns in snow accumulation on glaciers in relation to atmospheric circulation patterns like the El Nino Southern Oscillation and Southern Annular Mode.
- Ralf: During the past years a got more and more involved into sea ice research. My collaborators are the University of Otago, NIWA, and the University of Alberta. We use a helicopter instrument to measure sea ice thickness. This is not reflected on my website.
- Sirguey: Remote sensing of the seasonal snow cover, assimilation into hydrological model Glacier mapping from via remote sensing (outlines, velocity)

Photogrammetry

- Lorrey: maintain an end of summer snowline monitoring overflight for dozens of index glaciers in the southern alps of New Zealand, calculate mass balance and changes in total ice volume for that region of New Zealand. Enable reconstruction of longer term records of past glacial changes. Detection and attribution of glacier changes on modern scales to climate variability and climate drivers.

Behaviour of Mountain Glaciers and Ice Sheets, modern linkages of ice response to synoptic circulation changes, glacial history reconstructed using landforms, impacts of warming on glaciated environments

- Lorrey: translation of glacier and snowmelt to inflows utilised for agriculture and power generation schemes as well as the tourism industry

What are the needs of users in your institute/country/region for cryosphere data and information?

High resolution data and information at low or no cost such as:

- Low cost information as New Zealand is not part of a space agency
- Remote sensing information (optical or radar) or imagery to estimate sea ice property (MODIS, ASAR, SSMI, AVHRR) or Snow on land extent
- CryoSat products to estimate thickness of the sea ice.

Local information:

- Snow measurements (snow depth, snow density, snow water equivalent) at local points at low and high altitude

Glacier information:

- Mass Balance information in New Zealand and around the world

Topographical

- High resolution DEM

Climate

- Good quality climate information such as Sea Surface Temperature Atmospheric circulation indices such as IPO and SAM

Anderson: The other major industry user is tourism, and they are interested in either very specific information about glaciers to guide their interpretation and management (e.g. Franz Josef Glacier Guides, Fox Glacier Guides, Glacier Explorers (boats on Tasman Glacier lake)), or general changes to the mountain environment. The Department of Conservation is also an interested user of glacier information, especially regarding hazards. And of course the general public have an interest in glaciers as an 'iconic' and dynamic part of our landscape.

How could GCW help meet your national, regional or global interests?

- Ralf: Facilitating collaboration with partners in other countries, like the US, Europe, and Asia, e.g. by travel grants, and student support/scholarships. Another possibility would be support for airborne measurements like for sea ice thickness in Antarctica, in terms of costs and instrument development.

- Sirguey: Funding, collaborations, data sharing, access to imagery databank repository
- Lorrey: Promote opportunities for scientists studying the cryosphere to meet and exchange ideas, perhaps develop a repository of several key glacial data sets for different areas of the globe

What could you or your organization contribute to the implementation of GCW?

New Zealand can contribute to the implementation of GCW

- Purdie: As I understand it, the WMO are interested in improving the downscaling of GCM's to better reflect regional variability. Therefore improved regional knowledge of the cryosphere can assist those working on predictive models of the response of glaciers and ice sheets to future climate change.
- Ralf: Because we have excellent access to Antarctica via the NZ Antarctic Program, we can contribute validation data for satellite measurements in Antarctica. We currently do this for ESA's CryoSat project.
- Lorrey: We can provide annual data on the end of summer snowline changes and mass balance changes for the Southern Alps of New Zealand...(in fact, we plan on publicising this greatly as we move ahead). WE can provide members and critical interest in terms of support for the global concept, and possibly serve as a host for future group meetings.

22. Michael Zemp (World Glacier Monitoring Service, Zurich, Switzerland, michael.zemp@geo.uzh.ch)

What is your personal area of interest in the cryosphere?

- research and monitoring of glaciers and ice caps

What are your organization/agency's current interests or responsibilities with respect to the cryosphere (within and beyond your country)?

- World Glacier Monitoring Service; we are in charge of the Global Terrestrial Network for Glaciers in close collaboration with the U.S. National Snow and Ice Data Center and the Global Land Ice Monitoring from Space initiative

What are the needs of users in your institute/country/region for cryosphere data and information?

- we are a data and information service, compiling data and information about glacier distribution and changes through our worldwide scientific collaboration network

How could GCW help meet your national, regional or global interests?

- provide an overview of the authoritative organizations that are in charge of the monitoring of the cryosphere
- bundle resources and capacities towards these authoritative organizations
- lobby for an improved visibility and funding of long-term monitoring of the cryosphere and related data management

What could you or your organization contribute to the implementation of GCW?

- knowhow and expertise from more than one century of successfully running the internationally coordinated glacier monitoring
- key datasets on glacier distribution and changes
- well developed and reflected monitoring strategy
- link to monitoring-reality

ANNEX 6

A COMPILATION OF RECOMMENDATIONS FROM THE IGOS CRYOSPHERE THEME REPORT (2007)

RECOMMENDATIONS FROM THE EXECUTIVE SUMMARY

Near Term (2007-2009):

Adopting these recommendations will ensure that IPY legacy data sets are available as benchmarks for gauging future climate change, that important in situ observational networks are reinvigorated, that plans are made for follow-on programs for key spaceborne sensors (e.g., passive microwave imaging systems), and that innovative data management systems deliver data and GIS services to the science community, policy makers, and the public.

- Ensure coordinated interagency planning of the IPY Polar Snapshot (particularly Synthetic Aperture Radar (SAR) and Interferometric SAR (InSAR); high-resolution visible and InfraRed (Vis/IR); and optimization of coverage in respect to ICESat laser cycles). Coordinate near-surface, high-resolution remote sensing activities from aircraft, Unmanned Aerial Vehicles (UAVs) and Autonomous Underwater Vehicles (AUVs) with satellite and in situ experiments during the IPY. Achieve better continuity in higher-level polar data products from existing satellites, for IPY legacy dataset.
- Supplement sparse and sporadic basic in situ observation networks for precipitation, snow water equivalent, permafrost borehole temperatures, ice sheet core properties, met/ocean/ice mass balance tracked buoys, and mountain glaciers, and plan selection and augmentation of at least 15 reference “Supersites” with suites of relevant cryospheric measurements (e.g., by augmentation of existing Coordinated Enhanced Observing Period (CEOP) sites and/or Global Terrestrial Network (GTN) sites).
- Begin implementing a CEOP-oriented integrated approach for production of integrated cryosphere-related data products. Develop tools for integrating diverse and geographically distributed data including in situ measurements and satellite retrievals.
- Develop satellite concepts for measurements of snow water equivalent and solid precipitation and initiate a comprehensive validation program for in situ and satellite observations of these elements.
- Promote research and development of operational methods to determine sea ice thickness; in particular, by enhancing the Antarctic ice thickness-monitoring project. Develop appropriate best practices via establishment of ‘observer’ protocols and standard suites of instrumentation for in situ sampling and coordinate amongst respective communities (e.g. ASPeCt standard for sea-ice observation; CEOP standards). Ensure that moorings in oceans with ice cover contain Upward Looking Sonars to measure ice draft.
- Continue to develop and improve methods for estimating the spectral properties of snow and ice from optical satellite sensors.
- Propose and forge relationships for developing a virtual multi-frequency, multi-polarisation SAR constellation for meeting cryospheric requirements for: routine and frequent mapping, InSAR for topographic change and ice dynamics; and snow mapping.
- Prepare for the deployment of Cryosat 2 and plan for a laser altimeter successor to ICESat.

- Foster development of Arctic and Southern Ocean–Antarctic observing systems, including their ocean and terrestrial and atmospheric components such as Arctic-HYCOS (Hydrological Cycle Observing System).
- Coordinate near-surface, high-resolution remote sensing activities from aircraft, UAV and AUVs with satellite and in situ experiments during IPY.
- Develop observer networks for river ice, lake ice, and snow, via schools and native communities.
- Create a global 2-dimensional glacier inventory as a reference for assessing glacier change.
- Establish an IPY data management structure (or Data Information System) and standardize metadata principles (e.g. unique meta-tagging of all IPY legacy data for archive retrieval).
- Identify and initiate data rescue and reprocessing of historical benchmark datasets.

Mid Term (2010 – 2015):

Adopting these recommendations will solidify our observational understanding of how the cryosphere and climate are changing and form the basis for testing and evaluating predictive models of future climate change along with its consequences for sea level rise and local weather.

- Develop integrated, operational analysis products based on cryospheric data assimilation, models, satellite, and in situ data, and develop an operational cryospheric forecasting capability.
- Implement a dual and high frequency radar mission for Snow-Water Equivalent (SWE) and an extension to the Global Precipitation Mission (GPM) for solid precipitation.
- Develop an integrated data processing capability for cryospheric products from a SAR virtual constellation.
- Launch a high latitude radar altimeter successor to CryoSat.
- Implement recommendations of the International Conference on Arctic Research Planning (ICARP) Working Group on Terrestrial Cryospheric and Hydrologic Processes and Systems. Augment selected supersites, and extend essential geographic networks to obtain appropriate measurement density and distribution, for representative data. Employ station autonomy and near real-time telemetry to facilitate data assimilation and data exploitation for satellite calibration and validation.
- Adopt GCOS climate monitoring principles (GCMP) for all operational satellites and in situ sites.
- Train local community observers and recruit schools for observations of freshwater ice and snow.
- Implement standard data formats for distributed web/Earth data visualization services.
- Recover and reprocess long time series archived data relevant to the development and construction of cryospheric fundamental climate data records (FCDRs).
- Assure that there is adequate temporal overlap to inter-calibrate satellite sensors for consistent time series.
- Collate, digitize and analyze the long-term ice record contained in historic regional ice charts produced by various Northern Hemisphere countries in order to document historic variability and trends in the sea ice state and the climate over the past 1000 years.
- Undertake extensive reprocessing of all cryospheric variables based on an IPY legacy dataset and better calibrated and validated retrieval algorithms. Initiate an Antarctic reanalysis project.

- Implement an Antarctic Radarsat Geophysical Processing System.
- Ensure that high spectral resolution optical sensors are planned for future satellites.

Long Term (beyond 2015):

Adopting these recommendations will ensure a required stream of data into models that accurately forecast how the cryosphere will respond to changing climate and how changes in the cryosphere will drive local, regional and global changes in climate.

- Develop seamless integration and distribution of cryospheric data products, including data fusion products (e.g., mass balance of sea ice, land ice, snow cover)
- Establish operational, international SAR satellite constellation for all-weather cryospheric remote sensing, retaining essential modes for large-scale mapping, InSAR, and sea-ice charting.
- Ensure continuity in multi-frequency, high-resolution (<12km) passive microwave radiometry – including C-band channel for all-weather surface temperature observations.
- Operationalise satellite SWE and time-variable gravity measurements.
- Implement the P-band microwave concept for ice-sheet sounding, taiga biomass estimation, and potential permafrost applications.
- Evaluate in situ cryospheric reference network (CryoNet) and supplement it with new sites, and retire others, as needed. Ensure that CryoNet is an acknowledged and supported component of the WMO Integrated Global Observing System.
- Develop a large network of autonomous robots, equipped to measure surface energy and mass flux.
- Assimilate cryospheric products in next-generation Earth-system Global Circulation Models (GCMs), operational medium range and seasonal-interannual forecasting models and climate models.
- Develop interannual forecasting capability for ice sheet dynamics, mass-balance changes, and sea level rise rate estimates.

GENERAL RECOMMENDATIONS ON OTHER ENVIRONMENTAL OBSERVATIONS

- With regard to the surface-based network, initiation of an inventory should be proposed by IGOS for all observing stations and platforms belonging to IGOS Partners, research networks, academies of sciences, and engineering communities, with a view of augmenting their programs with additional multidisciplinary observations. Reporting procedures of these observations should also be considered, noting the capabilities of the modern observational and data relay systems, such as the WMO Integrated Global Observing System and WMO Information System. Data transmission, acquisition, archival, preparation, acceptance and monitoring of adherence to reporting standards need to be reviewed. This activity will be ambitious and difficult, but it needs to be started. Assemblage of a data set of multidisciplinary surface-based and airborne observations during the IPY period could provide the necessary understanding of capabilities of such a system, at least for the polar regions.
- For the space-based system, the most general recommendation of CryOS is to proceed, as quickly as possible, with inter-agency coordination of research and operational missions, so that as complete as possible a data series from multiple sensors is available for users. The Global Inter-agency IPY Polar Snapshot Year (GIIPSY) project is an important step in this direction during the IPY period.
- CryOS recommends the systematic development of standardized distributed environmental data processing, together with the development of commonly accepted standards for data visualization and quality control and assessment.

RECOMMENDATIONS FROM THE REPORT CHAPTERS

Recommendations: Development of Snow Observations

R3.1 A coordinated plan for surface-based snow-observation networks must be developed, first at the national, then at the international level. The plan should address the needs for improved consistency in observation methods and reporting standards and for improved exchange of data. It should address current and emerging needs for measurement of other snow properties besides snow depth and SWE. A consistent approach to compiling and using considerably improved metadata for snow observations is needed.

R3.2 The capability of satellite observations must be improved. The development/validation of satellite remote sensing techniques, including the validation of existing products, support of new systems (e.g., European Global Precipitation Mission (E-GPM)/CGPM and CloudSat for solid precipitation), and support of algorithm development is required. High-frequency active and passive microwave observations, which are uniquely well-suited to observing SWE and snow depth, have low spatial and spectral resolution. Improved instruments with higher spatial and spectral resolution are required. High-frequency (Ku, X-band) SAR should be considered a priority for global SWE observation.

R3.3 Priority should be given to research and development of algorithms and new sensors to measure SWE, under a wide range of vegetation conditions. Furthermore, it may be possible to design improved algorithms to more effectively use existing data sources. Further research is necessary to realize the retrieval of SWE from SAR data, with their higher spatial resolution; SAR is the only instrument capable of mapping wet snow cover at the fine spatial resolution required in mountainous terrain (where the hydrology is dominated by the melting snowpack).

R3.4 Techniques must be developed to merge *in situ* measurements and satellite retrievals. Targeted field projects should be conducted to deal directly with the measurement of snow in multiple environments. These should seek to advance coordinated remote sensing of snow albedo and surface temperature (i.e. optical measurements) together with SWE and snow depth (i.e. microwave measurements). Study areas for intensive field campaigns should be established with long-term plans to maintain them as “Supersites” to improve knowledge of snow processes and to provide reference targets for multi-sensor remote sensing and modelling applications.

R3.5 Integrated multi-sensor data fusion and global analysis systems that blend snow observations from all sources must be improved. The ideal global snow observing system will use observations from all relevant sources in coherent, consistent high-resolution analyses of (at a minimum): the extent of snow cover, snow depth, SWE, snow wetness, and albedo. No current system provides global coverage, and a more complete system would include snow albedo and temperature, microphysical properties, and chemical constituents. Improved algorithms for the objective, optimal combination of snow observations from widely disparate sources must be developed. These must address both mass and energy considerations of snow models.

Recommendations: Development of Sea Ice Observations

R4.1 The continuity of the passive microwave and visible/infrared time series needs to be assured with an effective overlap period (at least one year) between sensors for quality inter-sensor calibration. Polarimetric passive microwave instruments (i.e., WindSat/Coriolis, Surface Moisture/Ocean Salinity (SMOS)) should be investigated for possible utility for sea ice studies.

R4.2 The passive microwave concentration data records should be reanalyzed/reprocessed and validated with other available data. This should include improved inter-sensor calibration (using longer overlaps), rigorous evaluation of current algorithms, and development of data fusion methods to obtain optimal combined products. A CDR-quality passive microwave concentration product, with well-quantified error estimates accounting for spatial/temporal variability, is feasible and should be produced.

R4.3 Rigorous validation and enhancements to other passive microwave products need to be pursued, particularly snow depth estimates and ice age/type. Strategies need to be developed to account for varying spatial scales and temporal sampling when combining in situ and airborne small-scale measurements for validation of the satellite products. There should be collaboration with land snow researchers to develop improved snow estimates over sea ice.

R4.4 Proper coverage of ice covered regions by SAR sensors for operational support needs to be continued in the Arctic. For the Antarctic, detailed coverage is lacking and needs to be improved. Enhanced spatial/temporal coverage, either from wider swath instruments or increased number of instruments, is needed in order to provide more frequent repeat coverage to track small-scale, short-term variation in the ice cover.

R4.5 New methodologies should be developed to take advantage of the capabilities of dual-polarized SAR sensors that will soon be available.

R4.6 Continuity of satellite altimeter missions and enhancement of techniques is critical for monitoring basin-wide thickness and surface topography estimates. Coordination between radar and laser altimeter missions to obtain near-coincident data will help resolve uncertainties in thickness retrievals.

R4.7 Continuing surface observations are essential for satellite validation and calibration, development of model parameterizations, and process studies. Enhanced technologies should be pursued for continuous automated observations. In particular, mass balance buoys and moored ULS provide useful autonomous information and such programs should be expanded if possible. There should be better coordination with oceanographic observation programs to leverage ocean buoy deployments (e.g., develop combined ocean Argo buoys for ice measurements as well).

R4.8 Targeted field camps should be organized to gather a variety of coincident data to understand interactions between parameters. International coordination is crucial to obtain the maximum benefit. Permission should be granted to access waters in national economic zones for maximum scientific value from research during the upcoming IPY and beyond.

R4.9 New technologies such as UAVs, AUVs, broadband radars, and airborne lidars, which have great potential, should continue to be pursued. Increasing payload capabilities and/or decreasing sensor weight will allow more sensor types (e.g., passive and active microwave on UAVs) to be deployed.

R4.10 Historical records should be sought and compiled into consistent data records to extend the newer, more complete records back in time to provide a better understanding of long-term trends and variability. Many existing ULS data and field measurements of snow and ice thickness still have not been distributed to the community at large (e.g., through data centers).

R4.11 Sea ice scientists should coordinate with those studying ice cores, chemistry, and biology to better integrate physical data with ecosystem studies (e.g., krill, benthic communities).

R4.12 Development of emissivity and backscatter models will aid the assimilation of remote sensing data in models, and may improve retrievals of surface properties.

R4.13 Satellite-based snow depth products should be extended to perennial sea ice. Dual frequency SAR sensors may offer new and independent estimates to complement passive microwave techniques.

R4.14 The continued provision of timely satellite data is critical to allow national ice services to provide comprehensive and detailed ice mapping of the marine cryosphere. Gaps and future operational requirements include:

- High-resolution coverage in the form of SAR follow-on missions, multiple satellites for revisit and operational redundancy and multi-polarization data for sea-ice classification and (small) iceberg detection.
- Sea-ice thickness observations at operational spatial and temporal scales.
- Routine data fusion/integration products, e.g., microwave plus optical/thermal (AVHRR/MODIS/MERIS-type sensors), and radar scatterometer plus a passive-microwave radiometer. Methods will need to address resolution, coverage and temporal differences between data types.
- Quantitative retrievals for model assimilation, requiring validation of algorithms and determination of error characteristics.

R4.15 International cooperation between ice agencies is increasing and should be encouraged. It should include data access and sharing, and agreement on standards in nomenclature, analysis practices and data exchange. Such cooperation should also extend to the research community and national funding agencies.

R4.16 Satellite data from the Southern Ocean commonly fill in large gaps in Antarctic observations, and their acquisition by, and archiving at, the Arctic and Antarctic Research Center (Scripps) should be continued. An important new satellite-based initiative is the European PolarView programme; it is strongly recommended that this continues to operate in both polar regions.

R4.17 It is critical that the requirements of the ice services are recognized and met in the long-term strategies of cryospheric observation missions. The socio-economic benefits of ice information are enormous. Meeting ice service requirements in future missions will help ensure continuing benefits, and the realization of even more.

Recommendations: Development of Freshwater Ice Observations

R5.1 A major data rescue effort for Russia (and other countries) must be undertaken and submitted to the World Data Centre for Glaciology at the National Snow and Ice Data Center (NSIDC), to accompany existing historical records archived there. Several regional archives (part of the network) are needed.

R5.2 A set of target regions and lakes/rivers (some of which were part of an existing historical network) must be identified for future long-term ice monitoring.

R5.3 The status of ice observations at largest reservoirs should be reviewed and provisions of data exchange considered.

R5.4 Existing lake ice or river ice sites need to be reactivated and new observation sites added. The establishment of networks of volunteers and schools must be encouraged. These networks can provide a framework for educating young students (future decision makers) and teachers, as well as the general public, as to the importance of freshwater ice monitoring. Such observational networks have recently been established in the Canada (IceWatch: http://www.naturewatch.ca/english/icewatch/ and Alaska (Lake Ice and Snow Observatory Network, or ALISON: http://www.gi.alaska.edu/alison/).

R5.5 A set of lake and river experimental sites must be established for remote sensing algorithm development and testing (ground-based, airborne, and satellite). Initial sites include the Great

Slave Lake/Mackenzie River area, Hudson Bay Lowland/Churchill River area, and more southern (temperate climate) locations.

R5.6 Conventional (surface-based) observations of freeze-up and break-up need to be compared with satellite-derived time series, starting in the 1970s-1980s with AVHRR data. This would ensure some continuity in the transition between the surface-based and satellite observations (i.e. post 1980s when many of the lake/river ice sites were lost).

R5.7 Mapping ice on lakes and rivers requires a finer spatial resolution than for most sea ice mapping applications, because of the small size of some lakes and narrow river channels. On larger lakes and rivers, like the Great Lakes and St. Lawrence River, polar orbiting visible infrared sensors provide useful information on the ice cover. The MODIS 500-m snow product needs to be validated for lake ice. The development of a composite lake-ice product from the combination of MODIS Aqua and Terra data (i.e. increasing the number of MODIS swaths) should be examined along with the possible improvements that can be made with the integration of passive and active microwave data.

R5.8 SAR is the optimal sensor class because it has a higher spatial resolution and is able to image through cloud and in darkness. The latter characteristic is important for episodic events such as river and lake ice break-up. It has been shown that SAR can be used to map ice cover and areas of open water on rivers and lakes, and to identify areas of floating and grounded ice. The development of operational methods based primarily on the use of high-resolution SAR imagery is needed.

R5.9 The potential of passive and active microwave data to map ice cover (concentration and extent), open water, ice thickness, and snow depth on ice on large lakes needs to be examined.

R5.10 Integrated multi-sensor data fusion and numerical model output must take place to improve estimates of ice parameters and for ice forecasting.

R5.11 The development of lake ice products for data assimilation into numerical weather prediction (and regional climate) models is needed.

Recommendations: Development of Ice Sheet Observations

R6.1 Implement a C-band synthetic aperture radar optimized for SAR interferometry and capable of measuring the velocity field of the whole of the Greenland and Antarctic Ice Sheets. Data from this system would also provide new estimates on grounding lines, ice edge and shear margin positions.

R6.2 Continue surface elevation measurements from polar orbiting altimeters. Continuous observations with new altimeter instruments including Cryosat-2, ICESat, and ICESat-2 are necessary to extend the time series. Increased spatial resolution of surface topography should be obtained using TANdem-X interferomerically derived topography.

R6.3 Continue passive microwave observations of ice sheet surface melt through the re-inclusion of a passive microwave radiometer on NPOESS. As new or replacement sensors are deployed, it is essential that observations overlap so that the derived surface melt records can be reconciled for changes in calibration and viewing geometries. Passive microwave data in combination with wide-bandwidth nadir sounding radars may also be useful in refining estimates of surface accumulation rate.

R6.4 Increase the density of ice thickness measurements, particularly in East Antarctica where data are sparse. Ice thickness measuring radars should be evolved into systems that provide spatial information on the glacier bed, in particular, to identify where the bed is wet or where pooled subglacial water exists. Fixed wing aircraft, UAV and satellite implementations of advanced ice sounding synthetic aperture radars should be explored.

R6.5 Continue the acquisition of high (10 m) and moderate (250 m) resolution optical imagery for detecting rapid changes in ice shelves, ice streams and outlet glaciers and for measuring surface velocity as a complement to InSAR. Continue acquiring low-resolution (1 km) thermal infra-red data for measuring surface temperature.

R6.6 Time series GPS based observations of surface displacement should be made on several outlet glaciers and ice streams (for example, Jacobshavn Glacier, Kangerdlussuaq Glacier, Peterman Glacier, Byrd Glacier, Thwaites Glacier and Whillans Ice Stream). In combination with passive seismic event monitoring systems, this network will help identify the physical processes behind unexpected observations of rapid (hours to days) changes in local ice sheet motion.

R6.7 Continue the time series of spaceborne gravity observations for monitoring changes in ice sheet mass and the contribution of ice sheet mass loss to sea level rise. Spaceborne observations should be complemented by surface based gravity networks.

R6.8 Collect deep ice cores for paleoclimate studies. Acquire the oldest climate and greenhouse gas record from an Antarctic ice core (~1.5 M years). Investigate the last interglacial and beyond with a northwest Greenland deep ice core drilling project. Establish a 40,000-year network of ice cores to provide a bipolar record of climate forcing and response. Boreholes through ice sheets should be continued into bedrock so as to measure geothermal heat flux in places where the glacier is frozen to the bed. New ice core drilling technologies must be investigated.

R6.9 In situ observations of snow accumulation on ice sheets should be expanded. These include firn and ice cores, snow pits, ultrasonic sounders, stakes (single, lines, farms), and shallow ground-penetrating radar.

R6.10 Develop instrumentation to observe the basal melting of ice shelves. This can be achieved through further development of autonomous underwater vehicles to provide spatial sampling. Likewise, development of vertical profilers would allow for sustained temporal sampling, albeit at a limited number of sites. Such data can be used as a foundation for building a parameterization of ice-shelf basal melting and for direct validation of basal melting inferred from other observational techniques, such as satellite sensing.

Recommendations: Development of Glacier and Ice Cap Observations

R7.1 For climate research, priority needs include the completion of the global glacier inventory and the improvement of models that link meteorology to glacier mass balance and dynamic response.

R7.2 Downscaling techniques need to be developed for feeding such models with GCM data. Remote sensing data are needed to initialize and validate these models. Water management tools for glacier runoff will also benefit from these developments.

R7.3 In order to achieve these objectives, on the space infrastructure side long-term continuation of Landsat/SPOT type missions, providing data at favorable costs, are needed to obtain global inventories of glaciers and their changes in time intervals of 5 to 10 years.

R7.4 A dedicated mission for precise mapping of glacier topography is a high priority for determining the evolution of changes in glacier mass directly or from distributed mass balance models. Single pass or short-repeat InSAR will provide coverage of all glaciers worldwide. Such an InSAR mission would also provide ice motion data. For the mass balance and hydrological modeling and for downscaling of circulation models a satellite mission providing spatially distributed information on accumulation should be implemented, such as the candidate

CoreH2O Earth Explorer mission concept based on dual frequency (Ku- and X-band) SAR that is considered in ESA's Living Planet Programme.

R7.5 In parallel with advancing the space infrastructure it is essential to maintain a solid ground-based glacier observation network. Drivers for this are continuation and improvement of long time series of key climate parameters such as mass balance (seasonal data) and glacier length, which includes resuming long-term observation series on several glaciers, as well as the use of these observations as anchor stations for calibration and validation of process models and satellite-derived glacier products.

R7.6 The coordination of global glacier monitoring activities by WGMS and generation of a standardized database of glacier measurements is of high priority. Support of already established monitoring networks like GTN-G needs to be strengthened by establishing an adequate share of international and national funding to guarantee the continuation of the operational services, to maintain the international network, and to face the challenges of the 21st century.

R7.7 A global 2D glacier inventory (polygon outlines, cf. GLIMS initiative and GlobGlacier project) is needed as a reference for glacier change assessment within the framework of GTN-G.

Recommendations: Development of Surface Temperature and Albedo Observations

R8.1 The continued production of unified, consistent time series maps of surface temperature is recommended to add to the time series of surface skin temperature and broadband albedo from NOAA AVHRR that extend back to the early 1980s.

R8.2 The surface network of radiation measurements must be expanded to validate satellite-derived surface albedo and temperature measurements.. Surface albedo datasets should capture the progression of large-scale melt-freeze at sufficient resolution for surface energy budget evaluations and model validation. Future airborne deployments of albedo and reflectance instruments, as well as surface-based measurements, are essential to evaluate the accuracy of satellite albedo estimates.

R8.3 The MODIS daily snow albedo product should be extended to include sea ice.

R8.4 The fusion of infrared and passive microwave data would help to improve accuracy and spatial as well as temporal coverage. The microwave data are most valuable when done over areas where the emissivity of the surface is well known. In those areas, spatially detailed measurements from passive microwave data could be used with infrared data to obtain surface temperature maps that have high temporal resolution and spatially consistent values.

R8.5 Multi-angular satellite measurements e.g., from MISR and PARASOL, are required to better characterize the bidirectional reflectance functions (BRDF) of snow and ice.

R8.6 Vicarious calibration efforts of AVHRR visible channels from all NOAA satellites need to be continued.

R8.7 Methods for estimating the spectral albedo of snow and ice from satellite should continue to be developed. Future satellites should carry spectrometers.

Recommendations: Development of Frozen Ground Observations

R9.1 Existing GTN-P borehole and active layer networks must be expanded and the "International Network of Permafrost Observatories (INPO)" must be created. During the IPY period new sites are to be added to the networks; some of them should help to fill gaps in coverage. In addition to refinements in sampling protocols, existing sites require upgrades to include automated data loggers, remote data acquisition and instrumentation for collection of ancillary climate data including snow observations.

R9.2 Further development of the GTN-P requires partnerships to co-locate permafrost monitoring sites with those monitoring other cryospheric components (e.g., snow) and to expand existing networks at reduced cost. Partnerships with industry can help to establish monitoring sites in key resource development areas.

R9.3 Data rescue and sustained management activities must continue. Resources are needed for funding for permafrost data management. The IPY provides an ideal opportunity to recover past permafrost-related and worldwide soil temperature data and to encourage long-term commitments to shared data practices and distributed products. Included is the production and archiving of frozen ground data, information and maps for the production of the third CD Rom Circumpolar Active Layer and Permafrost System (CAPS Version 3.0) by the National Snow and Ice Data Center during the immediate post-IPY period 2009–2010.

R9.4 An international network should be created to monitor seasonally frozen ground in non-permafrost regions. Soil temperature and frost depth measurements should be recommended as standard parameters to all WMO and national cold regions meteorological stations. This new network should develop partnerships to co-locate seasonally frozen ground sites with those monitoring other components such as snow and soil moisture and to standardize protocols.

R9.5 As part of the new network remote sensing algorithms to detect soil freeze/thaw cycles (microwave passive and active sensors) should be developed and validated.

R9.6 New upscaling techniques for research sites and permafrost networks should be developed. A novel area of research is the development, validation and implementation of techniques to extend point source process and permafrost monitoring to a broader spatial domain, to support permafrost distribution modelling and mapping techniques implemented in a GIS framework, and to complement active layer and thermal observing networks with monitoring of active geological processes (e.g. such as slope processes, thermokarst development on land and under lakes, coastal dynamics, and surface terrain stability). High resolution DEMs are required.

R9.7 The application of multi-temporal, basin-scale gravity data for the detection of mass loss from ground ice melting in lowland permafrost regions should be evaluated.

Recommendations: Development of Solid Precipitation Observations

R10.1 Solid precipitation observations should be addressed through effective cooperation between GCOS's Atmospheric Observations Panel for Climate (AOPC), the CliC GEWEX projects, and the International Precipitation Working Group (IPWG) of the Coordination Group for Meteorological Satellites (CGMS). Solid precipitation should become a focus for the second phase of the Coordinated Enhanced Observing Period (CEOP).

R10.2 Recommendations for gauge networks and observations include:

- continue conventional point precipitation measurements in existing networks,
- sustain and enhance the gauge network in the cold regions,
- develop guidelines on the minimum station density required for climate research studies on solid precipitation in cold climate regions,
- ensure regular monitoring of the snowfall real-time data quality control and transmission,
- undertake bias analysis and corrections of historical precipitation gauge data at regional to global scale, including the Antarctic,

- examine the impact of automation on precipitation measurement and related QA/QC challenges, including compatibility between national data, and manual vs. auto gauge observations,
- develop digitized metadata for regional and national networks,
- identify and establish intercomparison sites for standardized testing of new technology, such as polarization radar, CASA radar networks, hot plate, pressure, or blowing snow sensors,
- encourage national research agencies to establish programs to provide support for the development of new instruments to measure solid precipitation at high latitudes,
- expand the use of wind shields and direct measurement of winds at emerging auto gauge sites/networks, and
- augment existing AWS networks to include near real-time snow depth measurements in cold regions.

R10.3 Satellite precipitation data and products have greatly advanced our ability to monitor and observe liquid precipitation (rainfall) globally. Similar ability should be developed to measure snowfall from space. The Global Precipitation Mission (GPM) and its European adjunct, EGPM, are critical in this context, as they will cover large regions with a significant portion of snowfall in yearly precipitation.

R10.4 The launch of the GPM should not be delayed further. The EGPM concept was designed to detect and measure snowfall and light precipitation using innovative radiometric techniques combined with a high-sensitivity radar. Future satellite missions adopting the EGPM concept should be strongly encouraged.

R10.5 Improve the blending (combining) of data from different sources (in situ, model, satellite) and develop further intensive field efforts to address scaling issues. Encourage further use of combined active and passive satellite data for snowfall detection/retrieval. Lower the detectability threshold of active space-borne instruments to better than than 5 dBz to detect light rainfall and snowfall. Deploy rain radars with lower detectability threshold. Develop new passive microwave instruments and new channel combinations– particularly at high frequency.

R10.6 Implement the sounding channel technique proposed by the European Global Precipitation Mission (EGPM). Explore use of the new Meteosat Second Generation channels for estimating precipitation. Use aircraft sensors together with extended channel selection studies as a testbed for future satellite instruments. Dedicate high latitude aircraft campaigns for snowfall remote sensing.

R10.7 Expand the network of ground radars to the northern/cold regions to obtain more useful radar observations of snowfall. Deploy the CASA radar concept with high sensitivity for the detection of snow, low level measurements and in complex terrain.

R10.8 Share data and create regional and global radar data sets. Carry out international radar data quality intercomparisons to remove inter-radar biases of precipitation estimates. Make common or open source algorithms available for generating precipitation estimates.

R10.9 Develop and further refine inexpensive ground-based remote sensing instruments for snowfall, including vertically pointing micro radars, such as (Precipitation Occurrence Sensing System) POSS or Micro-Rain-Radar (MRR). Develop dedicated andintegrated ground validation programs, for example, within the frameworks of IPWG and NASA's GPM, and Cloudsat (e.g., C3V project), WMO/WWRP (e.g. Helsinki Winter Nowcasting Testbed) or within NHMS' (e.g., Vancouver 2010 Winter Nowcasting in Coastal and Complex Terrain project). Capitalise on emerging technologies and validation opportunities, such as advanced radars or the use of hydrological models, regional or basin water budget analyses, and SWE forecasts.

R10.10 Develop an inventory of all possible technologies for snowfall/parameter retrievals, including other regional assets, such as measurements from power companies, volunteer networks, and web-based data sets. Make data freely available to the international research community. Formalize and coordinate international partnerships for validation of remote sensing precipitation data and products. Coordinate international ground validation programs for snowfall (e.g., GPM, GEWEX, CliC, IPWG) to advance the current state of snowfall retrievals and applications.

Recommendations: Data Assimilation and Reanalysis

R11.1 Promote detailed validation of reanalysis projects for cold climates and cryosphere-related elements.

R11.2 Promote the use of reanalysis as a monitoring tool.

R11.3 Evaluate the maturity of new data products that can be assimilated by models or used for model verification.

R11.4 Promote the further development of data assimilation schemes and objective analyses for cryospheric variables, together with a thorough treatment of error covariances.

R11.5 Establish appropriate dynamical downscaling techniques of reanalysis data to facilitate their use in cryospheric impact models that operate in high-mountain terrain at about 10 to 100 m spatial resolution.

R11.6 Consider opportunities for an Antarctic reanalysis.

R11.7 Facilitate the development of a climate system reanalysis with inclusion of cryospheric components.

R11.8 Improve the utilization of satellite data in automated analyses and incorporate fractional ice cover and ice dynamics in global circulation models.

R11.9 Investigate indirect methods of combining multiple remote-sensing products and physically-based models to infer ice thickness.

R11.10 Improve algorithms for estimating global sea ice concentrations from passive microwave sensors by using data assimilation techniques, and compare results with those from sensors with a higher spatial resolution.

Observing System Type	Near Term IPY: 2007-2008	Mid Term Post-IPY: 2009-2015	Long Term
Space Infrastructure	Ensure coordinated interagency planning of the IPY Polar Snapshot (plan for SAR/InSAR; high-resolution Vis/IR; and optimization of coverage in respect to ICESat laser cycles) and continuity in higher-level polar data products for an IPY legacy dataset. Forge inter-agency relationships for the development of a virtual multi-frequency, multi-polarisation SAR constellation for meeting requirements for: routine and frequent cryospheric mapping; InSAR for topographic change and ice dynamics; and snow mapping. Continue to develop and improve methods for estimating the spectral properties of snow and ice from satellites, Obtain relevant data for digital terrain models of ice sheets, ice caps and glaciers (InSAR laser, and stereo images). Plan the continuity of Landsat class optical mapping capability for world glacier monitoring. Develop and establish satellite concepts for measurements of SWE and solid precipitation and assess retrieval uncertainties. Develop a laser altimeter successor to ICESat.	Implement a virtual SAR constellation for polar applications – based on uniform, standard, routine data acquisition. Develop integrated data processing capabilities for cryospheric products from SAR virtual constellation, and investigate GRID-based processing. Develop integrated, operational analysis products based on cryospheric data assimilation, models, satellite, and in situ data, and develop operational cryospheric forecasting capability. Implement a mission concept for routine DEMs of glacierised surfaces. Implement a mission to guarantee continuity in satellite sensors with Landsat capability for glacier monitoring. Implement a dual-, high-frequency radar mission for SWE and extension to GPM for solid precipitation. Launch a high latitude radar altimeter successor to CryoSat. Assure adequate temporal overlap of satellite sensors for inter-calibration and consistent time series.	Establish an operational, international SAR satellite constellation for all-weather cryospheric remote sensing, retaining essential modes for large-scale mapping and charting, InSAR terrain mapping, and sea-ice dynamics. Implement cooperative, global, operational World Glacier Inventory monitoring service. Ensure continuity in multi-frequency, high-resolution (<12 km) passive microwave radiometry – including C-band channel for all-weather SST. Operationalise satellite SWE and time-variable gravity measurements. Implement P-band concept for ice-sheet sounding, taiga biomass, and potential permafrost applications. Ensure that high spectral resolution optical sensors are planned for future satellites.
Near Surface: AUV/UAVs	Coordinate near-surface, high-resolution remote sensing activities from aircraft, UAV and AUVs with satellite and in situ experiments during IPY.	Develop 'smart', autonomous, in situ sensors for ice and polar ocean sampling with satellite data relay mechanisms.	Established a balanced plan comprising satellite and new (AUV/UAV) autonomous observing system elements.
In Situ Infrastructure	Supplement sparse, sporadic, and declining basic in situ observation networks with precipitation, SWE, snow depth, lake and river ice, permafrost	Sustain/Convert essential short-term/temporary post-IPY network into long-term Cryo-Net sites.	Implement an integrated in situ network (CryoNet) – across range of different cryo environments.

	borehole temperatures, ice-sheet/glacier core properties, met/ocean/ice mass balance tracked buoys, glacier mass balance. Plan selection of at least 15 reference CryoNet “Supersites” with comprehensive suites of relevant measurements (e.g., by augmentation of existing CEOP and/or GTN sites). Ensure that in situ moorings in oceans with ice cover contain Upward Looking Sonar ice draft measurement capability. Review and develop as needed appropriate best practices via the establishment of ‘observer’ protocols and standard suites of instrumentation for in situ sampling and coordinate amongst respective communities (e.g., ASPeCt and CEOP standards). Create a global 2D glacier inventory (polygon outlines) as a reference for glacier change assessment within the framework of GTN-G. Strengthen the support of already established monitoring networks like GTN-G or GTN-P. Develop observer networks in Native communities and involve schools.	Augment selected supersites, and extend essential geographic networks to obtain appropriate measurement density and siting, for representative data. Implement recommendations of the International Conference on Arctic Research Planning Working Group on Terrestrial Cryospheric and Hydrologic Processes and Systems. Guarantee continuity in essential historical time-series (e.g. reference glacier sites). Employ, in so far as possible, station autonomy and NRT telemetry to facilitate data assimilation and data exploitation for satellite cal/val. Adopt GCOS climate monitoring principles (GCMP) for all operational satellites and in situ sites. Capacity building measures: regional training of local community observers and recruitment of schools, particularly for river-, lake-ice, and snow networks.	Evaluate an in situ cryospheric reference network (CryoNet) and supplement with new sites, and retire others, as needed. Ensure that CryoNet is an acknowledged and supported component of the WMO Integrated Global Observing System. A large network of autonomous robots, equipped to measure surface energy and mass flux, should be developed.
Data and Data Management	Establish IPY Data Management Structure (or Data Information System) and standardize metadata principles (e.g. unique meta-tagging of all IPY legacy data for archive retrieval). Coordinate the unification and quality control of historical datasets (e.g. GLIMS & WGMS). Identify and initiate data rescue and reprocessing of historical benchmark datasets (e.g. glacier terminus locations and previously classified imagery). Develop tools for integrating diverse and geographically distributed remote sensing and in	Implement an Antarctic Geophysical Processing System for routine SAR sea-ice drift dynamics data products. Develop integrated, operational analysis products based on data assimilation, and develop operational cryospheric forecasting capability. Recover and reprocess long-time-series archived data for cryospheric fundamental climate data records (FCDRs). Undertake reprocessing of all cryospheric variables based on IPY legacy dataset and better calibrated and validated	Ensure long-term validation, quality control, reprocessing, and media updates of essential cryospheric data sets. Develop seamless integration and distribution of cryospheric data products, including data fusion products (e.g. mass balance of sea ice, land ice, terrestrial snow cover). Assimilate cryospheric products in next-generation Earth-system GCMs, operational weather forecast models, and climate models covering short-range to

	situ data. Establish public/educational interface/visualisation of IPY data using Google or Virtual Earth forums.	retrieval algorithms. Initiate an Antarctic reanalysis project. Initiate co-location, digitization and analysis of the long-term ice record contained in historic regional ice charts produced by various countries needed to document variability and trends over the past 1000 years. Facilitate the development of processing of distributed data based on GRID technology. Implement standard data formats for distributed web and data visualization services.	seasonal forecasts.
Integrative Actions	Develop long-term plan and begin to augment CEOP supersites with essential CryoNet capabilities. Encourage efficient data collection and NRT (GTN) transmission or transfer to IPY data system. Run process studies during IPY to determine error covariance characteristics for data assimilation. Develop a plan for repatriation and reprocessing of essential cryospheric datasets for reanalysis projects. Promote data integration efforts including development of techniques to merge in situ and satellite measurements. Promote a unified data policy for satellite and in situ data access across international and national agencies, and data providers. Promote development of operational methods for sea ice thickness determination, particularly in Antarctica by enhancing the Antarctic ice thickness monitoring project. Educate the public on where and how to access CryOS and IPY data. Identify a Community of Practice.	Establish network of stations for all cryospheric applications (CryoNet) and satellite calibration and validation and data assimilation. Establish near real-time data transfer capability for all CryoNet data. Develop process-oriented science to facilitate assimilation of all cryospheric data into NWP and climate models. Reprocessing to be planned and financed as part of fundamental activities for satellite Agencies and IPY Data repositories. Federate independent providers of cryospheric data products and services, on national and international level (e.g. EuroClim, PolarView)	Reprocessing of climate records must be planned and financed as part of fundamental activities for satellite agencies and cryosphere data repositories. Develop seasonal-interannual forecasting capability for ice-sheet and glacier, dynamics, mass-balance changes, melt runoff, and sea-level rise rate estimates. Establish governance of sustained integrated Cryo Observing System in partnership with GEO, with appropriate mechanisms for long-term sustained financing. Develop a plan for funding for sustained in conjunction with GEO

ANNEX 7

GCOS Climate Monitoring Principles

(*http://www.wmo.int/pages/prog/gcos/index.php?name=ClimateMonitoringPrinciples*)

The ten basic principles (in paraphrased form) were adopted by the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) through decision 5/CP.5 at COP-5 in November 1999. This complete set of principles was adopted by the Congress of the World Meteorological Organization (WMO) through Resolution 9 (Cg-XIV) in May 2003; agreed by the Committee on Earth Observation Satellites (CEOS) at its 17th Plenary in November 2003; and adopted by COP through decision 11/CP.9 at COP-9 in December 2003.

Effective monitoring systems for climate should adhere to the following principles:

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.
2. A suitable period of overlap for new and old observing systems is required.
3. The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e., metadata) should be documented and treated with the same care as the data themselves.
4. The quality and homogeneity of data should be regularly assessed as a part of routine operations.
5. Consideration of the needs for environmental and climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.
6. Operation of historically-uninterrupted stations and observing systems should be maintained.
7. High priority for additional observations should be focused on data-poor regions, poorly observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution.
8. Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.
9. The conversion of research observing systems to long-term operations in a carefully-planned manner should be promoted.
10. Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

Furthermore, operators of satellite systems for monitoring climate need to:

(a) Take steps to make radiance calibration, calibration-monitoring and satellite-to-satellite cross-calibration of the full operational constellation a part of the operational satellite system;

(b) Take steps to sample the Earth system in such a way that climate-relevant (diurnal, seasonal, and long-term inter-annual) changes can be resolved. Thus satellite systems for climate monitoring should adhere to the following specific principles:

11. Constant sampling within the diurnal cycle (minimizing the effects of orbital decay and orbit drift) should be maintained.
12. A suitable period of overlap for new and old satellite systems should be ensured for a period adequate to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations.

13. Continuity of satellite measurements (i.e. elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured.
14. Rigorous pre-launch instrument characterization and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured.
15. On-board calibration adequate for climate system observations should be ensured and associated instrument characteristics monitored.
16. Operational production of priority climate products should be sustained and peer-reviewed new products should be introduced as appropriate.
17. Data systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained.
18. Use of functioning baseline instruments that meet the calibration and stability requirements stated above should be maintained for as long as possible, even when these exist on decommissioned satellites.
19. Complementary in situ baseline observations for satellite measurements should be maintained through appropriate activities and cooperation.
20. Random errors and time-dependent biases in satellite observations and derived products should be identified.

ANNEX 8

IDEAS ON MONITORING STATIONS IN CRYONET

A8.1 Finnish Meteorological Institute (14 Nov. 2011)

The focus here is on seasonally-snow covered, terrestrial (non-mountainous) cryosphere (boreal forest and sub-arctic zones). Regarding the monitoring of snow cover, the network should cover different snow regimes of the world. They are listed in Table 1 following the article: Sturm, M., Holmgren, J., and Liston, G. (1995), A seasonal snow classification system for local to global applications, *Journal of Climate*, 8:1261-1283.

***Table 1**: Snow classes to be included (and excluded) in target areas of the Phase 1 of the mission with a 3-day repeat cycle, classes and their description according to Sturm et al. (1995).*

Snow cover class	*Typical characteristics*	*Indicative range of max. SWE before melt (mm)*
Tundra	A thin, cold and wind blown snow cover; high density	40 - 280
Taiga	Thin/moderate depth cold snow cover with low density, depth hoar typical	80 – 300
Alpine	A deep snowpack with intermediate to cold temperatures, some wind crust and some melt-refreeze effects	200 – 750
Maritime	A warm deep snow cover, melt features very common	250 – 1700
Ephimeral	A thin, very warm snow cover	0 – 150
Prairie	A thin (except in drifts) moderately cold snow cover. Wind effects.	0 – 180
Mountain (special class)	Highly variable snow cover	-

A8.1.1 Parameters to be monitored at supersites

Continuous automatic data (distributed observations covering, for example, different ecosystems/soil/land cover types)

- Soil moisture profiles (distributed)
- Soil temperature/soil frost profiles (distributed)
- Snow depth and/or SWE (distributed)
- Snow temperature profiles (distributed)
- Automatic synoptic weather station observations (including temperature 2 m, temperature ground, dew point temperature, air pressure, air relative humidity, wind speed, wind direction, precipitation, cloud height, amount of clouds, visibility, snow depth, prevailing weather code)

- Radiation observations (incoming and reflected)
- Distrometer observations on precipitation
- Atmospheric soundings (troposphere and stratosphere)
- CO_2 and/or methane fluxes between the atmosphere and soil-vegetation system (preferably for different ecosystems)
- Water table depth on wetlands

Regular manual observations

- SWE and snow depth on snow pits (forest and bog sites)
- Snowpack layering and snow grain size on snow pits (visible snow grain size observations/photography and/or SSA measurements)
- Soil frost depth
- Snow surveys (snow courses with a preferable length of some kilometres)

Optionally

- Specific reference measurements for Earth Observation (EO) instruments (e.g. reference systems of cryosphere monitoring satellite instruments)
- Aerosol optical depth
- Energy fluxes (sensible, latent and soil heat), evaporation/transpiration and soil respiration.

A8.1.2 Parameters to be monitored at regular sites

Continuous automatic data

- Soil moisture profiles
- Soil temperature/soil frost profiles
- Snow depth and SWE
- Snow temperature profiles
- Automatic synoptic weather station observations
- Radiation observations (incoming and reflected)

Regular manual observations

- SWE and snow depth on snow pits (forest and bog sites)
- Snowpack layering and snow grain size on snow pits (visible snow grain size observations)
- Snow surveys (snow courses with a preferable length of some kilometers).

A8.2 China (High Asian Cryosphere)

The State Key Laboratory for Cryospheric Sciences has summarized their ECV measurements for the cryosphere and also identified gaps. Examples are below.

An Example of Observed ECVs and methods Used: Glacier

Component	ECVs	Methods（manual/auto）	accuracy	Standard method recommended
Glacier	Mass balance	• stake/snow pit (manual) • water balance (manual/auto) • Geodetic survey (altimetry, in-situ survey, stereography, DEM) (manual/Aut)	• 5 mm ~ 20 mm • 10 mm ~ 100 mm • -	Stake/snow pit
	Surface ice velocity	• In-situ survey (theodolite, all-station, RTK-GPS（manual） • InSAR（auto） • Sub-pixel methods（auto）	• 1 mm ~ 1 m • - • variable	In-situ survey
	Area	• in-situ geodetic（manual） • stereography（manual） • remote sensing（auto）	• 1 mm ~ 1 m • Instrument depends • variable	in-situ geodetic
	Thickness	• ice-penetrating radar（manual） • DEM (SAR、in-situ geodetic、stereography, remote sensing） （manual/auto）	• ~ 5m	Ice-penetrating radar
	Ice temperature	20m quartz temperature sensor（manual/auto）	0.1□	20m quartz temperature sensor(auto)
	Meltwater runoff	Hydrological section survey (manual/auto）	Instrument depends	Hydrological section survey (manual/aotu)
	Surface energy balance	AWS（auto）	Instrument depends	AWS

An Example of Gaps in ECV Measurements: Freshwater Ice

Applications	Essential Cryospheric Variables (ECV) *
River ice	**Length of frozen river**, **thickness**, **frozen date**, **break-up date**, snow cover on ice, concentration, **types**, roughness, ice volume, **width**, flow velocity
Lake ice	**Frozen date**, **break-up date**, **thickness,** snow cover on ice, concentration, temperature, salinity, surface energy balance

Bold: operated ECVs

ANNEX 9

Proposed Pilot and Demonstration Activities on Permafrost Under the GCW Framework

National level, Russian Federation, coordinator: Oleg Anisimov (oleg@oa7661.spb.edu); Implementation team: Vasily Kokorev (vasilykokorev@gmail.com), Julia Strelchenko (julia.amberia@gmail.com), all at the State Hydrological institute, St. Petersburg

A pilot project targeted at aggregation, analysis and dissemination of available permafrost data for Russia was launched recently at the State Hydrological institute. The project core team consists of Professor Oleg Anisimov and two young scientists, Vasily Kokorev and Julia Strelchenko. They established and maintain the dedicated bi-lingual (Russian and English) web portal (www.permafrost.su), which may be used among others by a wide range of Russian speaking users interested in permafrost data and processes in the northern lands. This project has developed on a voluntary basis without any funding and is currently driven forward mainly by the enthusiasm of the participants.

As it stands now, the project contributes to GCW activities, with one of the important and valuable functions being to bridge the gap between the Western (English speaking) and Russian (Russian speaking) users in terms of the availability of up-to-date data, metadata, and general information about permafrost and associated processes. The portal gives access to the raw permafrost and related soil and climate data, and maps, including model-based permafrost projections. The portal contains the bibliographic section, where many of the permafrost papers (in Russian or English) are available and may be downloaded free of charge. This is particularly important for Russian users, because even scientists working in the Federal research institutes and in the Russian Academy of Science often do not have free access to full text bibliographical databases in their institutes, and finding the papers they are interested in is often problematic and a time consuming task.

The portal also contains the “bank of permafrost models”, where users can get information about the available models as well as get in touch with their developers.

It would be beneficial to link the further development of this portal with the GCW pilot activities. Recognition of these activities as part of GCW goals will allow us to secure the further work on this dedicated portal and facilitate fund raising to support these activities.

ANNEX 10

ECV Dataset Inventory

There is currently no uniform, robust, centralized set of information that describes datasets available for climate research. Instead, users must query data centers, international programs, and research scientists to find the data that best suits their application. The type of descriptive information for each dataset varies widely, so it is difficult to quickly compare multiple products for the same geophysical variable. An ECV dataset inventory would provide a listing and uniform description of datasets that contain quantitative information on the various GCOS ECVs. Ideally, the datasets will have reached a basic level of maturity, be based on peer-reviewed methods, cover or have the potential to cover a sufficiently long period of time for climate studies, have uncertainty estimates, and be available to the scientific community. The following inventory structure and elements was formulated at a 2011 workshop organized by the WCRP Observations and Assimilation Panel.

The inventory description for each ECV dataset will contain:

1. Date of this inventory entry
2. Dataset name
3. Lead investigator
4. Geophysical parameter and related ECV
5. Intended uses and users (existing or potential)
6. History and outlook; sustainability
7. Availability (web/ftp, restrictions, is it registered with DOI system)
8. Maturity (Bates & Barkstrom maturity index)
9. Description of how the effort adheres to the 12 GCOS guidelines
10. Strengths and weaknesses or limitations
11. Uncertainty estimates, possibly as a function of time
12. Long-term homogeneity and stability
13. Have there been self and independent assessments? Identify other datasets used in the assessment
14. Have the algorithm theory, FCDR characteristics, self assessment and independent assessments been published? If so, give reference(s).
15. Dataset details:
    - Product version number
    - Time period covered
    - Spatial coverage (global, Arctic, etc.)
    - Spatial and temporal sampling intervals
    - Based on what fundamental climate data records (FCDR)
    - Ancillary inputs used to derive product
    - Other datasets used in the development of this product:
    - Output data product contents
    - Output product format(s)

While these descriptors capture what the workshop participants agree is the most useful information about a dataset, the list may evolve over the short term. Many of the descriptive elements above are self-explanatory, though a few warrant further explanation:

History and outlook; sustainability: Some datasets are new; others have a more complex history. For example, the NASA Pathfinder program gave rise to many products that have evolved over the last two decades with funding from other sources and, in some cases, with other goals. The outlook and sustainability of a data product is also of interest. Will the product be reprocessed and extended in time?

Maturity (Bates & Barkstrom maturity index): Give the maturity index for each element (Software Readiness, Metadata, Documentation, Product Validation, Public Access, and Societal Impacts) as well as an arithmetic average.

Description of how the effort adheres to the 12 GCOS guidelines: At a minimum, list which of the 12 guidelines the dataset meets or, conversely, which it doesn't meet. Additional clarification may be appropriate. A few of the GCOS guidelines also appear in the inventory list of descriptors. This is intentional, meant to emphasize the importance of characteristics such as homogeneity, uncertainty estimates, and maturity.

Strengths and weaknesses or limitations: Describe under what conditions the product excels, and when and where it fails. For example, sea ice concentration products based on passive microwave data have much larger uncertainties under melt conditions. Making the strengths and weaknesses clear helps potential users quickly determine if the product meets their needs.

Uncertainty estimates, possibly as a function of time: Provide a quantitative estimate of uncertainty. If the uncertainty varies as a function of time, region, or other conditions, a brief explanation would be useful. The assessment of uncertainty can be very complex, in which case a link to other documentation would be helpful.

Long-term homogeneity and stability: Changes in instruments, satellite or in situ, are the most common cause of instability in climate data records. Intercalibration methods can alleviate, though not necessarily eliminate, such instability. Briefly describe your approach to this problem, if applicable.

Have there been self and independent assessments? An organized, multi-product, multi-investigator, independent assessment of climate datasets is the best way to evaluate uncertainties, strengths, and weaknesses. The GEWEX cloud climatology assessment workshops are a good example of an independent assessment. More commonly, a dataset creator has performed a "self assessment", a comparison to other datasets that is generally more limited in scope than an independent assessment. Briefly describe any assessments that have been performed. Identify other datasets used in the assessment and provide links to additional information and publications.

ANNEX 11

Examples of Cryospheric Data Products and Possible Metadata

Data products: Glaciers

Data set	Source	rs/in-situ	Type	free?	Coverage	Temporal	comment
Glacier outlines	GLIMS	RS + maps	vector (shape file)	yes	global (not complete)	1960s - maps 1984 (sat)	part of GTN-G web portal avail.
Glacier fluctuation data (mass, length)	WGMS	in-situ (most)	point (glacier-ID) with value	yes	global (selected sites)	16th. cent. (ΔL) 1947 (mb)	order via email
World Glacier Inventory (WGI)	NSIDC / WGMS	maps, aerial, satellite	point (location w. attrib.)	yes	global (not complete)	1955-1985	ftp link
GGHydro Glacier layer	Trent Univ. (G. Cogley)	WGI, maps	grid (ASCII)	yes	global (complete)	1950s-1990s	ftp link

5/20

Data products: Ice sheets

Data set	Source	rs/in-situ	Type	free?	Coverage	Temporal	Comm.

6/20

Data products: Sea ice

Data set	Source	rs/in-situ	Type	free?	Coverage	Temporal	Comm.
NOAA/NSIDC CDR	NSIDC/NOAA	RS, SMMR-SSM/I	gridded, NetCDF	yes	global	1978-now	
EUMETSAT OSI-SAF	EUMETSAT	RS, SMMR-SSM/I	gridded, swath, NetCDF	yes	global	1978-now	
AARI 10-days period historical ice charts	AARI	in-situ, aircraft, rs (VIS, radar)	gridded, SIGRID (15)	yes	Eurasian Arctic	1933-1992	

7/20

Data products: Lake and River Ice

Data set	Source	rs/in-situ	Type	free?	Coverage	Temporal	Comm.
Grate Lakes weekly ice charts	NAIS (CIS and NIC)	rs, coastal stations	vector, WMO SIGRID3	free	Great Lakes	2006 - ongoing	NWP, research

8/20

Data products: Frozen ground

Data set	Source	rs/in-situ	Type	free?	Coverage	Temporal	Comm.
Thermal State of Permafrost	GTN-P/IPA	in-situ	point	yes (send email)	global		
Circumpolar Active Layer Monitoring	GTN-P/IPA	in-situ	point	yes (send email)	global		

9/20

Data products: Snow

Data set	Source	rs/in-situ	Type	free?	Coverage	Temporal	Comm.
NOAA CDR weekly snow cover	Rutgers U.	rs (optical)	0/1 grid (190.5 km)	yes (send email)	N Hemisph.	1967 - now	used by IPCC
GlobSnow	FMI	rs (weather station obs)	25 km EASEgrid	yes	N Hemisph.	1979 - now	NWP, research
NOAA/IMS	NIC	rs	4 km	yes	Global	2004 - now	NWP, research

10/20

Data products: Solid Precipitation

Data set	Source	rs/in-situ	Type	free?	Coverage	Temporal	Comm.
GPCC Monitoring Product	DWD	in-situ	grid / lat/lon 1.0 / 2.5 deg	yes	global	1986-present	**all** precip.
GPCC Full Data Re-Analysis	DWD	in-situ	grid / lat/lon 0.5/1.0 / 2.5 deg	yes	global	1901-2010	**all** precip.

11/20