WORLD METEOROLOGICAL ORGANIZATION

GLOBAL CRYOSPHERE WATCH

CRYONET IMPLEMENTATION MEETING
FIRST SESSION

VIENNA, AUSTRIA
20 – 22 NOVEMBER 2012

Final report

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

WORLD METEOROLOGICAL ORGANIZATION

May 2013
GCW Report-2

EXECUTIVE SUMMARY

1. The First Implementation Meeting of the Global Cryosphere Watch (GCW) CryoNet was held at Zentralanstalt für Meteorologie und Geodynamik (ZAMG, the Austrian Weather Service) in "Vortragssaal" (Julius Hann Haus), Vienna, Austria from November 20-22, 2012. The meeting was organized by the CryoNet Team of the GCW Observing Systems Working Group, led by Wolfgang Schoener. All documents and presentations prepared for, or given at, the meeting are available online at http://www.wmo.int/pages/prog/www/OSY/Meetings/GCW-CN1/DocPlan.html.

2. A background session set the context for the development and implementation of the GCW CryoNet with a brief history and summary of the evolution of GCW, development of the GCW Implementation Plan and a summary of the discussion and outcomes of CryoNet from the First GCW Implementation Meeting. GCW cuts across all WMO Programmes and has links to all Technical Commissions, with the WMO Integrated Global Observing System (WIGOS) and the WMO Information System (WIS) being especially relevant. It was accepted that GCW/CryoNet utilize international standards and best practices set by WMO and partner organizations.

3. To initiate a comprehensive cryosphere observing network, the workshop initiated the process to define the types of surface sites in cold climate regions, on land or sea, operating a sustained, standardized programme for observing and monitoring as many cryospheric variables as possible. Participants provided input in advance of the meeting to share their thoughts on the purpose and benefits, structure and scope of the network. Key messages from the responses included:

- Establishment of a tiered CryoNet network was ranked at the highest priority
- Implementation of a tiered network was most realistic
- High need for standards and guidelines in cryospheric observations
- Existing cryo-networks are highly interested in cooperation
- Fill gaps in existing networks
- Data policy and data provision
- Serve science and practitioners

Development of formal procedures for establishing the GCW network, evaluation of potential sites, discussion of the measurement standards and determination of data availability and exchange were initiated at this workshop.

4. CryoNet initially aims to build on existing and planned cryosphere observing programmes at observatories and in other operational and research observing networks. Participants provided information on 90 potential CryoNet sites in advance of the meeting, describing the sites and associated measuring programme. Each site's input is provided in this report. Most of these sites were established for atmospheric monitoring, but the current cryospheric monitoring is very variable between sites and cryospheric components. Development of a tiered network was favoured by most participants to be able to address different time and space scales, varying data quality and the extensiveness of the environmental observing programme at the site.

5. Some of the common issues which arose in participants' discussions included:

- The critical importance of sustainability of stations in the network; links to global and national priorities are needed;
- Water resources and associated policy are a driver for cryospheric information in many countries;
- The high cost of communication, particularly satellite transmission, from remote regions can limit real-time access to data;

- The challenge to get data accepted from remote non-standard stations into the WMO/WIS;
- Importance of open data exchange and the availability of detailed metadata; there are still challenges related to data sharing within and among countries;
- The challenge of establishing Antarctic reference sites;
- Some nearby observatories with complementary observing programmes, and possibly operated by different agencies, might be considered as a regional "supersite", such as the alpine stations of Sonnblick, Weissfluoch and Zugspitze/Schneefernerhaus, or the Russian stations of Tiksi and Station Samoylov.
- lessons from GAW could serve as an example for GCW in how CryoNet could evolve from building on existing sites/networks to filling the gaps

6. The design of CryoNet to provide reference sites for validation of satellite and model outputs was recognized as extremely important. Participants from the modelling, remote sensing and water resources user communities provided background information on their need for sustained cryospheric observations at reference or supersites and identified how specific measurements could benefit those communities. ECMWF outlined potential benefits of the CryoNet initiative to NWP modelling. Satellites will provide observations for GCW while the user community will benefit from CryoNet through calibration and validation activities for satellite products on a global scale. It was emphasized that water resources was one of the most important policy and decision making drivers for GCW and for CryoNet.

7. Valuable views of international organizations/data centres were provided by the International Association of Cryospheric Sciences (IACS), the World Glacier Monitoring Service (WGMS), the International Permafrost Association (IPA) and the Global Terrestrial Network-Permafrost, and the International Arctic Systems for Observing the Atmosphere (and Surface) (IASOA(S)). Some points for consideration in the design and implementation of CryoNet included:

- develop a network that equally serves scientists and practitioners (operational services);
- fill known gaps of already existing networks in close collaboration with the latter;
- best practices, standards, and guidelines should be homogenized and harmonized as much as possible; emphasize the quality and the representativeness of the data from a site;
- foster the exchange and availability of data across the various communities involved, but recognize that archiving and accessing the data are very difficult problems;
- integrate existing observation programmes of individual cryospheric components.
- foster a network of high elevation automatic weather stations, close to long-term cryospheric monitoring sites.
- recognize that It is very hard to coordinate between facilities that operate with different organization mandates and funding structures
- consider the experience of IASOA on how a network of networks can facilitate data sharing
- Development of synthesis science objectives as rallying points for national funding agencies, etc.; both cross-site objectives and interdisciplinary single-site objectives are important.

8. Perspectives on CryoNet in Antarctica and Greenland were provided. Given that Antarctica is a vast continent with 98% of it covered in snow and ice, one suggestion was that it may be best to consider this as a single cryospheric site with some supersites inside of it located at some of the research stations. CryoNet needs to develop an effective way to use and contribute to existing networks/stations. Like Antarctica, Greenland provides its own challenges for observing networks. Practical ways for GCW and CryoNet to contribute and improve on the current situation were provided, based on Greenlandic experience. It was emphasized that it is important to address the needs of policy makers and he suggested that GCW/CryoNet should define a limited set of prompt, reliable,

clear, and representative, easily communicated and understood products in support of defining regional to global scale state of the cryosphere, its variability and trends.

9. Participants agreed that a critical component in the development of CryoNet is the effort to establish best practices, guidelines and standards for cryospheric measurements based on all available, or to be developed, manuals, guides or other documents from organizations and bodies involved in cryospheric measurement. WMO Standards and Best Practices provide some of the procedures needed in CryoNet development. IUGG/IACS/IAHS provide standardised schemes for the terminology for glacier mass balance measurements and for classification of snow on the ground. For sea ice, the documents of the WMO Joint Commission on Marine Meteorology (JCOMM) will provide the core information for defining GCW standards, guidelines and terminology. Participants urged WMO to incorporate all existing documents on standards and guidelines to the greatest extent possible in the development of any GCW Manual.

10. The structuring of CryoNet is a key issue. The chair of the CryoNet task team outlined initial thinking on a tiered structure for CryoNet that then served as a basis for further breakout discussion. Structures of some other network observing initiatives were also considered. For example, the ENVIronmental Research and Monitoring SONNBLICK Programme for 2011-2015, was given as an example of integrated monitoring with a strong cryospheric component, in other words an example of a "GCW Supersite". Within GCOS, priority is currently given to the establishment of key baseline networks making *in-situ* observations, selected comprehensive networks many of which use satellite technology, a selected number of reference networks, and the long-term operation of a number of research networks**.** Standards and guidelines for taking observations, the communications protocols required to exchange the data, the data management and archiving procedures, and the regular evaluation of performance are required. The Coordinated Enhanced Observing Period (CEOP), now the Coordinated Energy and Water–cycle Observations Project, offered important aspects for consideration during the development of CryoNet:

(1) Agree on a written data policy at an early stage; all participants must know and understand it.
(2) Get cooperation of advanced IT technical people, and develop a system, which can be used (applied) by observation people easily for quality management and meta data registration.
(3) Identify a data researcher, independent from field scientists and model scientists, or find an organization which has this ability early in the design of the project.

11. Data policy is one of the most challenging issues in observing and in establishing an authoritative information network of data and products, including archiving, data sharing and exchange. Participants, as part of their questionnaire response, indicated that this was one of the top priorities for CryoNet. Within WMO, cryospheric data, such as snow depth, snowfall and solid precipitation, are governed by the Manual on Global Observations and associated regional annexes and by these resolutions. It is expected that through GCW and WIGOS that cryospheric observation and exchange will be reviewed as per current needs of Members and the community. The data policies of other projects/programmes were also outlined for participants, including FUTUREVOLC, and the Declaration of Intent between the Nordic Centres of Excellence (NCoE) within the sub-programme 'Interaction between Climate Change and the Cryosphere (ICCC)' regarding an Open Data Policy which was based on the existing "International Polar Year Data Policy". The GEOSS Data Sharing Principles and Action Plan aim at addressing the growing trend towards full & open sharing of Earth observation data. All of the above provide guidance on data policy and/or data sharing, which in the end must be developed to serve GCW, CryoNet, WMO and partner needs and requirements.

12. Parallel breakout sessions addressed the structure of CryoNet and focussed on the development and implementation of CryoNet. Three groups addressed the same questions, prepared in advance by the organizing committee, with outcomes to include:

- *: A draft structure for CryoNet site "levels", e.g., supersites, reference sites, observation sites, or tier 1, tier 2, etc.*
- *A draft list outline of requirements for a site to be included in CryoNet*
- *Identification of documents of existing standards, guidelines, and best practices; recommendations on next steps for GCW/CryoNet and partners/contributors to proceed.*

13. A breakout synthesis is provided in the report. Varying perspectives were shared and the results of the discussion are to be used by the CryoNet task team in developing the CryoNet implementation plan. A common response was that no matter the final structure, high priority should be on continuous temporal sampling with a policy of being as inclusive as possible to incorporate existing observations; all GCW sites should be sustainable and accessible. All groups put forward suggestions for some form of tiered structure. Likewise each group has extensive discussion on principles for including a site in the network. These views are summarized in the report and in Annexes. Likewise standards, guidelines and best practices were discussed, all acknowledging their fundamental importance in CryoNet. Noting that many documents for standards and best practices exist (e.g. sea ice, snow, glaciers, permafrost…), standards for all cryosphere measurements are not necessarily complete, consistent, or up to date. All participants were asked to forward applicable documents on standards, guidelines and best practices to the CryoNet Team for the team to consolidate for CryoNet.

14. The CryoNet Task Team was expanded and given the task to prepare a draft classification system and its attributes for subsequent discussion by all participants. It will use the ideas and guidance discussed in the breakout groups. This system can then be tested by categorizing the sites submitted by participants for this meeting.

15. The participants had an open discussion on sources of funding of CryoNet, both for operations and common support, noting that this is very important if there is to be a sustained network. Potential sources are through organizations such as WMO, Member countries, national programmes, and international funding agencies. WMO, EU and regional organizations were identified as a potential source of support and it was agreed that efforts by everyone at the national level are extremely important. It is important for CryoNet to link to national policies and the science needed to support good policy and decision making. A letter to countries' Permanent Representative for WMO to reaffirm the GCW focal point and to seek support for GCW and CryoNet will be very valuable.

16. It was agreed that the first step for the task team was to draft the classification system and then try to assign sites submitted by participants to test its applicability. The need for a support person to help keep this moving forward was identified by the participants. They also suggested the following tasks:

- Development of a demonstration project to show how CryoNet could operate (WGMS offered an example).
- a demonstration to ingest data into NWP centres and into the GTS (ECMWF provided subsequent feedback on next steps).
- development of a data and exchange policy (Iceland offered to lead, using what is currently available)
- collation of appropriate best practices, guidelines, and standards
- identification and pursuit of funding opportunities. As CryoNet sites would be operated by national entities, it would be important to start the dialogue with national ministries to seek commitments to operating such sites.

Further input was received after the meeting addressing some of these topics and is included in this report.

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1. ORGANIZATION OF THE SESSION

1.1 The First Implementation Meeting of the Global Cryosphere Watch (GCW) CryoNet was held at Zentralanstalt für Meteorologie und Geodynamik (ZAMG, the Austrian Weather Service) in "Vortragssaal" (Julius Hann Haus), Vienna, Austria from November 20-22, 2012. The meeting was organized by the CryoNet Team of the GCW Observing Systems Working Group, led by Wolfgang Schoener.

1.2 Dr. Wolfgang Schöner welcomed the participants on behalf of ZAMG. ZAMG has had a long standing relationship with WMO, noting that the first weather observatory was established in 1873. The Sonnblick Observatory (Austrian Alps, 3100m.a.s.l) has a time series dating back to 1886 and is considered as a potential alpine reference site for CryoNet. Dr. Barry Goodison, Scientific Officer in the Observing and Information Systems Department, welcomed participants on behalf of the World Meteorological Organization (WMO). He emphasized that this meeting was a major step in the definition, development and implementation of CryoNet within GCW. He noted that over 80 sites or networks were suggested by the participants as possible candidates for CryoNet, indicating a very strong interest in CryoNet by participants.

1.3 Dr. Arni Snorrason, co-chair of the EC-PORS Observations Task Team, served as General Chairperson for the meeting. He noted that meteorologists became organized over 100 yrs ago and that hydrologists have also organized their programmes. He felt that now is the time for the cryosphere community to organize its activities in a similar manner which would allow it to contribute effectively to new multi-disciplinary initiatives, such as the Global Framework for Climate Services (GFCS).

1.4 The programme for the workshop was adopted with minor amendments. The final programme is attached as **ANNEX 1**.

1.5 Participants **(ANNEX 2)** briefly introduced themselves and identified their interests and background relevant to the themes of the session (see also **ANNEX 3**).

1.6 All documents and presentations prepared for, or given at, the meeting are available online at http://www.wmo.int/pages/prog/www/OSY/Meetings/GCW-CN1/DocPlan.html.

2. CRYONET BACKGROUND

This session set the context for the development and implementation of the GCW CryoNet. All participants were asked to review the Final Report of the First GCW Implementation Meeting (GCW-Report-1) and the GCW Implementation Plan (GCW IP) as these provided the framework for discussions at this meeting. All of the presentations and written documents of GCW-IM-1 are hyperlinked in its Documentation Plan http://www.wmo.int/pages/prog/www/OSY/Meetings/GCW-IM1/DocPlan.html.

2.1 GCW Implementation Plan

2.1.1 Jeff Key provided a brief history and summary of the evolution of GCW and the development of the GCW Implementation Plan which guides its development (presentation 2.1) accessible on the GCW-CN-1 zip file. The Plan includes activities and timelines which will be updated regularly. The need to develop metrics of success is recognized as an important element in developing GCW and CryoNet. GCW is being developed to build on what exists currently by engaging other communities and is not taking on the mandate of others. The General Chairman noted that cryosphere is now seen as a major source of information for assessing climate variability and change and hence there is a need for standardization to have confidence in the observations and their use. It must be remembered that the GCW is global and not just polar or alpine.

2.1.2 The GCW website was introduced. This site is now available for public access at http://globalcryospherewatch.org.

2.1.3 The link with GEO and its new Cold Region initiative was raised by a participant as there is some confusion in the community. This relationship continues to be discussed to ensure efforts are complementary and not duplicative.

2.2 Summary of CryoNet Discussion at GCW-IM-1

2.2.1 Wolfgang Schöner, lead of the CryoNet team, presented a summary of the discussion on, and outcomes of, CryoNet from the First Implementation Meeting (GCW-IM-1). This summary is available as INF.15 with the presentation (2.2 Summary CryoNet) accessible on the GCW-CN-1 zip file. This CryoNet meeting (GCW-CN-1) would further the discussion and identify activities with timelines, and task teams to develop and implement CryoNet. Schöner noted that we should rely not only on WMO to establish CryoNet. CryoNet should draw on the strengths that WMO offers such as intercomparison studies, guidelines, standards, networking, promotion, etc. while engaging partners and others in the promotion and development of CryoNet. This offers an opportunity to expand networks and avoiding conflict with others. It was noted that WMO would not directly fund a CryoNet station, as this is normally a national responsibility, but it does work with funding agencies in an effort to secure resources.

2.3 CryoNet in the Context of WMO Programmes

2.3.1 Two major observing system activities of WMO are the WMO Integrated Global Observing System (WIGOS) and the WMO Information System (WIS). GCW exists within the WIGOS structure, and the GCW portal is WIS compliant. Through WIGOS and WIS, GCW will also provide a fundamental contribution to the Global Earth Observation System of Systems (GEOSS). GCW cuts across all WMO Programmes and has links to all Technical Commissions. A major new initiative of WMO is the Global Framework for Climate Services (GFCS) to which GCW would contribute.

2.3.2 INF. 6 and presentation 2.3 on Benefits of WIS (accessible on the GCW-CN-1 zip file) provided an overview of the WMO Information System (WIS). WIS aims to increase data visibility, broaden data access and simplify data use. WIS is intended to build on the success of the Global Telecommunication System (GTS), adding new Discovery Access and Retrieval (DAR) function and communications technologies based on the international standards to those of the GTS. This document was written by representatives of Members of the WMO RA-VI (Europe) in collaboration with the WMO Secretariat and is available at
http://www.wmo.int/pages/prog/www/WIS/wiswiki/tiki-index.php?page=wis-in-a-nutshell
This document explains WIS for the "management level" and will useful for the CryoNet community and their discussion on data, metadata and accessibility. The link at the end of the document takes one to a Russian translation of this document.

2.3.3 Joachim Dibbern presented a summary of the WMO Integrated Global Observing System (WIGOS) (presentation 2.3 WIGOS, accessible on the GCW-CN-1 zip file). WIGOS (INF.7) is an integrated, comprehensive, and coordinated system primarily comprising the surface-based and space-based observing components of the Global Observing System (GOS), Global Atmosphere Watch (GAW), World Hydrological Cycle Observing System (WHYCOS), and GCW, plus all WMO contributions to Global Climate Observing System (GCOS), Global Ocean Observing System (GOOS) and Global Terrestrial Observing System (GTOS), to satisfy requirements of WMO and WMO co sponsored Programmes. WIGOS provides a new framework for WMO global observing systems and the contributions of WMO to co-sponsored observing systems. WIGOS does not replace the existing observing systems, but is rather an over-arching framework for the evolution of these systems that will continue to be owned and operated by a diverse array of organizations and programmes, both research and operational. Therefore, the interaction between research and operational observing communities is important for the continued evolution of observing systems and practices, in line with new science and technology outcomes, and for operational availability and migration to operations, where appropriate, of some research-based observing systems. Two key components which are very relevant to CryoNet are integrated quality management and standardization, system interoperability and data compatibility. Taking into account the ongoing rapid progress in technology that will continue to provide a basis for further improvements in the capability, reliability, quality and cost-effectiveness of observations, *WIGOS, and hence GCW/CryoNet must utilize international standards and best practices set by WMO and partner organizations.*

3. INITIATION OF A COMPREHENSIVE CRYOSPHERE OBSERVING NETWORK

3.1 CryoNet background and synthesis of participant questionnaire responses

3.1.1 One of the main initial priorities of the GCW is the initiation of CryoNet, the surface-based observational network. Engagement of participants in advance of the meeting was essential in order to share background information before the meeting. The first implementation workshop for CryoNet aims to initiate the process to define the types of surface sites, e.g., supersites, reference sites, and/or tiered sites in cold climate regions, on land or sea, operating a sustained, standardized programme for observing and monitoring as many cryospheric variables as possible. This would also involve initiation of the development of formal procedures for establishing the GCW network, evaluation of potential supersites, discussion of the measurement standards and determination of data availability and exchange.

3.1.2 CryoNet, through long-term, sustainable observing and monitoring, will contribute to:

- Quantification of changes in the cryosphere over a range of time and space scales
- Quantification and understanding of the effects of climate change on cryosphere and vice-versa covering changes and underlying processes as well as feedbacks
- Assessment of changes in the cryosphere and impacts of, and interactions with, other earth spheres, in particular the hydrosphere, the biosphere and the lithosphere
- Verification of satellite data with in-situ measurements to enable modelling approaches for interpretation of satellite data and to extend the point information from CryoNet stations into the space domain
- Standardized cryosphere observations for NWP and hydrologic model development and verification
- Training in cryospheric measurements
- Harmonization of cryospheric information for the public

3.1.3 As identified at the first GCW Implementation Meeting, a GCW *CryoNet Team* will help guide the development of the network. This meeting initiates the tasks identified at that meeting, including:

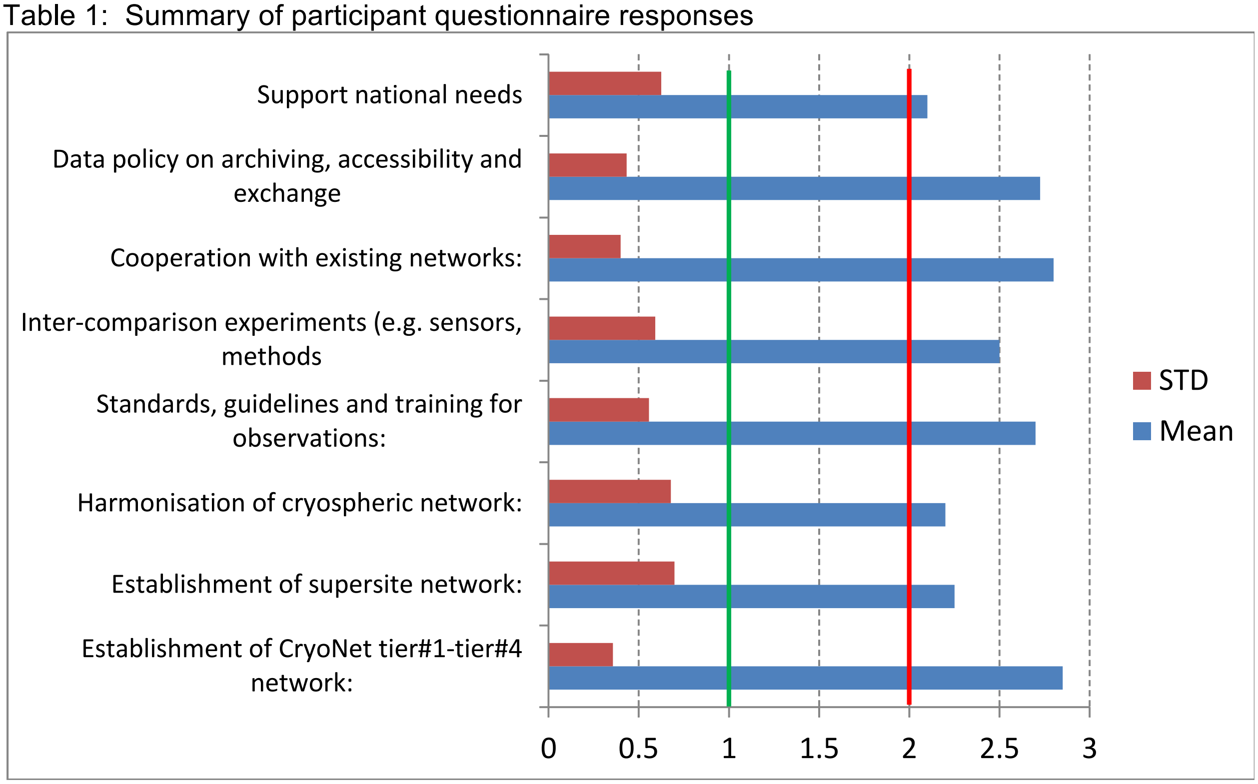
- definition of the types of surface sites, e.g., supersites, reference sites, and/or tiered sites in cold climate regions, on land or sea, operating a sustained, standardized programme for observing and monitoring as many cryospheric variables as possible;
- initiation of the process to develop site and observing standards, guidelines and protocols;
- determination of data availability and exchange;
- evaluation/identification of potential supersites; and,
- initiation of the development of formal procedures for establishing the GCW network.

3.1.4 To stimulate initial thinking about the GCW-CryoNet prior to the meeting and to share participants' thoughts on the purpose and benefits, structure and scope of the network, participants were asked to answer the following questions:

1. How could GCW-CryoNet help meet your national, regional or global interests?
2. What could you or your organization contribute to the implementation of GCW-CryoNet?
3. What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
4. What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
5. Please prioritize CryoNet activities according your personal view (select High/Medium/Low):
Establishment of CryoNet tier#1-tier#4 network
Establishment of supersite network:
Harmonisation of cryospheric network:
Standards, guidelines and training for observations:
Inter-comparison experiments (e.g. sensors, methods):
Cooperation with existing networks:
Data policy on archiving, accessibility and exchange
Support national needs:
6. Please share any other thoughts for participant to consider at the meeting.

Participants' responses are given in Annex 3, as submitted, and summarized in Table 1. Participants were from different organizations, agencies and institutions from several countries that operate stations or networks which could contribute to CryoNet, particularly as reference or supersites.

Table 1: Summary of participant questionnaire responses



5 Key messages from the questionnaire responses included:

- Establishment of a tiered CryoNet network was ranked at the highest priority

- Implementation of a tiered network was most realistic
- High need for standards and guidelines in cryospheric observations
- Existing cryo-networks are highly interested in cooperation
- Fill gaps in existing networks
- Data policy and data provision
- Serve science and practitioners

These issues re-emphasized the initial recommendations derived from discussions at the First GCW Implementation meeting.

3.2 Potential CryoNet Sites/Networks

3.2.1 CryoNet aims initially to build on existing and planned cryosphere observing programmes at observatories and in other operational and research observing networks. Some sites had been suggested at the First GCW Implementation meeting and details may be found in the GCW-Report-1). Participants in this CryoNet meeting represented a broader community involved in such observatories and networks and many operated "supersites" already. In order to expedite discussion participants were asked to provide relevant information on these potential CryoNet sites in advance of the meeting, describing the sites and associated measuring programme. The questionnaire is given in Annex 4. Ninety sites were submitted and the link to each site's input is available in Annex 4.

3.2.2 Table 2 is a graphical summary of the observations taken at selected sites. Most of these sites were established for atmospheric monitoring, and the current cryospheric monitoring is very variable between sites and cryospheric components. Many of these sites are also associated with other specialized programs, such as the Global Atmosphere Watch (GAW), GTN-P (GTOS network for permafrost) or the World Glacier Monitoring Service (WGMS) which coordinates the GTN-G (glaciers). Discussion identified issues for further discussion including the need for many more cryospheric measurements, how to design a tiered network for CryoNet, and the engagement of other stations not yet included (e.g. Abisko, SIOS in Norway).

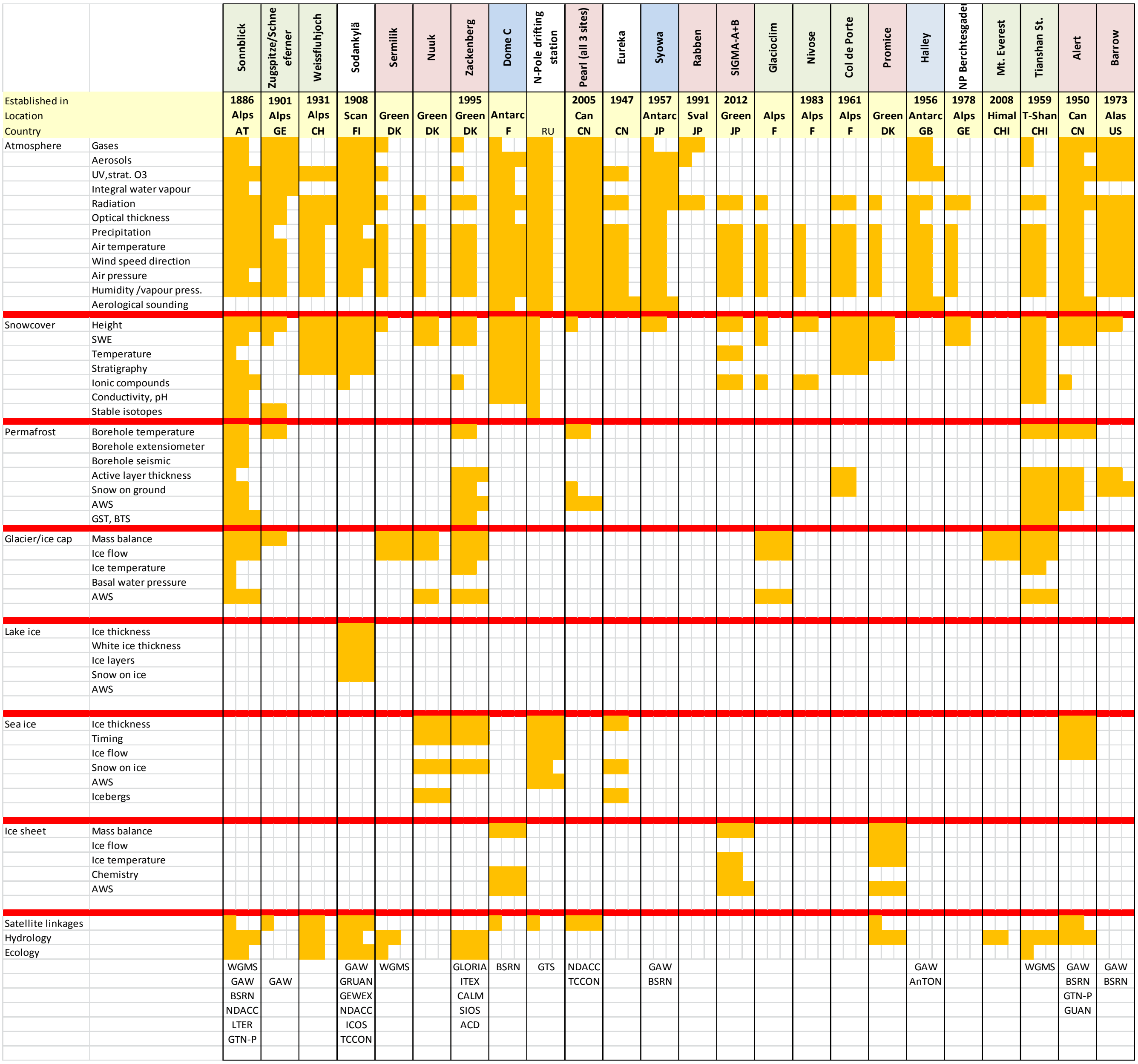
3.2.3 Development of a tiered network was favoured by most participants to be able to address different time and space scales, varying data quality and the extensiveness of the environmental observing programme at the site. Drawing on the responses to the participant questionnaire and the site questionnaire, participants would try to define what CryoNet and its tiered network could look like.

3.2.4 Participants were invited to present their site or network to complement their site questionnaire. These presentations are included in the zip file available for download through the document plan and are identified with the number 3.2…These provided an important perspective on the range of sites/networks which exist and provided essential background which could be used in subsequent breakouts.

Presentations available include:

- Argentina and CryoNet – *Juan Manuel Horler*
- ENVIronmental Research Programme SONnblick - *Wolfgang Schöner, Bernd Niedermoser, Anne Kasper, SONNBLICKBEIRAT (Austria)*
- The British Antarctic Survey's new Halley VI station - *Steve Colwell*
- Canada: SPICE and C-SPICE – *Dave Wartman*
- Cryosphere Observation Sites /Networks in Canada: Research Perspective – *Anne Walker*
- Consideration of Sites for CryoNet in Canada– *Dave Wartman*
- Cryosphere Monitoring in China - *DING Yong-jian and XIAO Cunde*
- FMI Infrastructure for CryoNet at Sodankylä-Pallas, Finland - *Kari Luojus, Rigel Kivi, Petteri Ahonen, Pauli Heikkinen, Esko Kyrö and Jouni Pulliainen*

Table 2: Graphical Summary of Observations at selected Observing Sites



- Four proposed GCW CRYONET sites/network of sites – *Eric Brun and Christophe Genthon (France)*
    - I - Dome C site (high Antarctic plateau)
    - II - GLACIOCLIM, a network of sites for glacier mass balance monitoring (Alps, Andes, Antarctica)
    - III - Col De Porte site (Alps)
    - IV - Nivose network (Alps)

- Modellierung der Schneedecke an der Zugspitze mit Hilfe des hydrologischen Modells ALPINE3D - *Matthias Bernhardt, Karsten Schulz, Michael Lehning, Stefan Härrer & Karl F. Wetzel (Germany)*
- Greenland Ecosystem Monitoring - *Stine Højlund Pedersen (Denmark& Greenland)*
- Programme for Monitoring of the Greenland Ice Sheet (PROMICE) - *Michele Citterio (Denmark)*
- A supersite for cryospheric studies in Iceland? - *Thorsteinn Thorsteinsson, Tómas Jóhannesson & Árni Snorrason*
- CryoNET and Japanese contribution – *Tetsuo Ohata and Teruo Aoki*
- North pole drifting stations - *Vasily Smolyanitsky (Russia)*
- Region Davos: A multi-purpose site – *Charles Fierz (Switzerland)*

Some of the common issues which arose in these presentations included:

- The critical importance of sustainability of stations in the network; links to global and national priorities are needed
- Water resources and associated policy is a driver for cryospheric information in many countries
- The high cost of communication, particularly satellite transmission, from remote regions can limit real-time access to data
- The challenge to get data accepted from remote non-standard stations into the WMO/WIS; changing height of a station above "ground" (e.g. above the surface of an ice sheet) has limited the acceptance of data from some stations
- Importance of open data exchange and the availability of detailed metadata; there are still challenges related to data sharing within and among countries
- The availability of historical data, some of which may have to be rescued, but analyses could show the importance of maintaining the site or even re-opening closed stations The challenge of establishing Antarctic reference sites; however, several countries suggested stations which could be considered for inclusion
- Some nearby observatories with complementary observing programmes, and possibly operated by different agencies, might be considered as a regional "supersite", such as the alpine stations of Sonnblick, Weissfluoch and Zugspitze/Schneefernerhaus, or the Russian stations of Tiksi and Station Samoylov.
- Building on existing sites/networks was recognized as the best way to proceed initially, but then how would CryoNet proceed to fill gaps; lessons from GAW could serve GCW well in this regard

4. CRYONET: OBJECTIVES AND BENEFITS

4.1 Background

4.1.1 It is recognized that the design of CryoNet to provide reference sites for validation of satellite and model outputs is extremely important. Participants from the modelling and remote sensing communities and water resources user community provided background information on their need for sustained cryospheric observations at reference/supersites and identified how specific measurements could benefit those communities. Wolfgang Schöner provided some initial ideas for the development of CryoNet, particularly a structure, which would allow it to meet the aims of the project identified in 3.1.2 above. This is summarized in **ANNEX 5**, and is to be seen as a starting point from which subsequent deliberations will lead to a framework for CryoNet that would provide tangible benefits to various communities.

4.2 Benefits to modelling, remote sensing, research and policy

4.2.1 *Modelling:* Gianpaolo Balsamo provided a concise summary on the benefits of the GCW-CryoNet initiative to NWP Modelling using the questionnaire outlined in 3.1.4. The input from the ECMWF perspective is given in **ANNEX 6**. He articulates not only benefits to ECMWF of CryoNet, but also indicates how they would be able to contribute to GCW and CryoNet. Based on past experience, they offered the following suggestions:

- A step-wise development starting from a prototype network that encompasses the possibility of a growth is an advisable strategy that had shown some success in other context (e.g. the International Soil Moisture Network, http://www.ipf.tuwien.ac.at/insitu/ as an example of a surface research-based network).
- The benefit of open-access data are not often immediate to data provider and require a cultural change (costly observations and free-access are difficult to reconcile until a given network gains recognition that feedbacks into the research/operational grants to maintain it).
- Finally the GCW initiative has the potential to play a crucial role in providing access to a centralized reprocessing and archive facility for existing cryosphere dataset and may consider to archive also co-located model products output as there are already successful initiative in different contexts (e.g. the Year of Tropical Convection, YOTC, http://www.ucar.edu/yotc/data.html or as planned for the Year of Polar Prediction, YOPP discussed within the World Weather Research Program, WWRP). Co-located model and observational data at field site locations permit a larger involvement of the scientific community with mutual benefits for both the observation network and the modelling sides.

Additional information on the potential benefits of the CryoNet initiative to NWP modelling is provided in INF.27, particularly on in-situ observations in NWP and the value of ground-based network & single key sites for (i) clouds/precipitation, (ii) land surface parameterizations, (iii) snow initial conditions, (iv) global past reanalysis.

4.2.2 *Earth observation satellites and CryoNet:* Einar-Arne Herland and Vigdis Lonar Barth provided a very comprehensive summary of the Earth observation satellites in the context of the Svalbard Arctic Earth Observing System (SIOS) (Doc. 4.2.2); and presentation accessible on the GCW-CN-1 zip file. GCW has an observational component that comprises both satellite and ground-based observations, with CryoNet representing the latter. Satellites will, in addition to providing observations for GCW, also benefit from CryoNet through calibration and validation activities for satellite products. These benefits are discussed in the document, and although GCW, and accordingly CryoNet, are global undertakings, the SIOS (Svalbard Integrated Arctic Earth Observing System) project is used as an example. This document is essentially a reduced version of a deliverable “Report on prioritized satellite calibration, validation and algorithm needs for implementation of SIOS research” in the SIOS Preparatory Project which was written by an international team led by the National Research Council of Italy. There is very valuable reference material on satellite sensors being used for all cryospheric components and discussion of calibration of sensors and validation of products involving the cryosphere, and the benefits of using Svalbard. It was noted that the CryoNet measurements are very important for calibration and validation of satellite products on a global scale, and as calibration and validation of satellite products are recognised goals of SIOS, CryoNet should consider the inclusion of SIOS measurements in its network.

4.2.3 *Global Cryosphere Watch: Relevance for Water Resources* - Arni Snorrason presented a very thoughtful summary of the importance of the cryosphere in both Iceland and the Third Pole region (particularly the Himalayas) from the perspective of water resources (Doc. 4.2.3). It was noted that most glaciers in Iceland were projected to essentially disappear in the next 100–200 years. For partly covered glacier watersheds the magnitude of spring floods is predicted to decrease and they will appear earlier in the year. Seasonal discharge becomes more evenly distributed with higher winter discharge. Seasonality changes due to a changing climate relate to snow cover storage and glacier

changes. Such changes are extremely important in assessing future water resources. GCW recognizes that one of the most important policy and decision making drivers is water resources.
Two very useful documents were also provided which further emphasize the importance of the link between cryosphere and water resources. INF. 25 is the final report from the Nordic-Baltic research project: Climate and Energy Systems on Climate Changes in the 21st century and their impacts on renewable energy resources. INF. 26 is a UNEP report on Measuring Glacier Change in the Himalayas. Both reports provided additional information supporting the presentation.

5. HARMONIZATION OF CRYOSPHERIC OBSERVATIONS

One of the aims of CryoNet is to be able to provide sustained, standardized observations of as many cryospheric components as possible from sites operating in a network with established procedures and protocols. This harmonized network would provide compatible and comparable information to meet the needs of a range of uses as noted in the GCW IP. There was a need to look at similar networks and other organizations to learn from their experience. The WMO Global Atmosphere Watch (GAW) is one such network and many of the participants suggested sites which are already GAW stations. What are the procedures for becoming a GAW station and what are the responsibilities of operators in such a network? Partner organizations were asked to present their perspectives and experiences with such harmonized observing initiatives and the associated challenges and benefits of establishing standardized observing procedures, availability and exchange of data and analysis and dissemination of cryospheric information. Unique issues as found with stations on Antarctica, on Greenland and on floating ice were considered.

5.1 Experiences from participation in the Global Atmosphere Watch (GAW)

5.1.1 GCW needs to learn from the experiences of other networks. GAW is in fact a very good analogue for CryoNet. Wolfgang Schöner gave a summary presentation on GAW and its networks (accessible on the GCW-CN-1 zip file) and the structure of its focal areas, network, quality assurance, working groups, expert teams and mode of operation. GAW is a tiered network, currently with 28 global, 410 regional and 81 contributing stations. **ANNEX 7** provides background on the GAW in-situ observing system network, including:

- Essential Characteristics of a GAW Regional or Contributing Station
- Essential Characteristics of a GAW Global Station
- Procedure for acceptance of new stations/networks in GAW
- Procedure for designation of GAW Central Facilities

This provides context for what is necessary to have a sustainable, relevant, coordinated observing system that will meet user needs. Quality assurance is very important. It was recognized that there are many similar characteristics which GCW should incorporate in CryoNet. It was also noted that many of the global stations are in regions with cryosphere so there may be an opportunity to build cryosphere observations at existing GAW sites.

5.2 Views of International Organizations/Data Centres

5.2.1 Charles Fierz, International Association of Cryospheric Sciences (IACS) provided some **very useful thoughts on what IACS and his own experience deems essential to CryoNet** (INF.14 and summary presentation 5.2.1 accessible on the GCW-CN-1 zip file)), including:

- develop a network that equally serves scientists and practitioners (operational services);
- fill known gaps of already existing networks in close collaboration with the latter. Best practices, standards, and guidelines should be homogenized and harmonized as much as possible.

- not only consider the number of parameters available at a specific site (quantity) but also emphasize the quality and the representativeness of the data. Data series extending in the past should be considered as an added value.
- foster the exchange and availability of data across the various communities involved.
- recognize that scientific networks or services like WGMS usually provide processed or/and verified data but only some time after their collection.

5.2.2 Michael Zemp, Director of the World Glacier Monitoring Service, provided further thoughts on GCW-CryoNet from a glacier perspective (see INF.10 and summary presentation 5.2.2 accessible on the GCW-CN-1 zip file). He suggested that the **largest potential of CryoNet** could be in:

- the integration of existing observation programmes of individual cryospheric components.
- fostering a network of high elevation automatic weather stations, close to long-term cryospheric monitoring sites.
- developing a label (e.g., GCW Supersite) for a network of existing monitoring sites (e.g., research stations) that are running long-term cryospheric observations. Such a label should only be assigned to monitoring sites that fulfil a well-defined set of criteria, e.g.:
    - monitoring of at least two cryospheric components
    - for more than 30 years
    - together with meteorological measurements
    - making these data freely available through the corresponding international data centres
    - …
- bringing funding (or at least visibility) to these monitoring sites.

He brought to the attention of the meeting sites with long-term mass balance programmes (37 sites with more than 30 years of on-going measurements). He noted that potential sites close to permafrost, glacier, and snow monitoring might be Tarfala Research Station in Sweden, Sonnblick Observatory in Austria, Gornergrat in Switzerland, Tien Shan Research Station in China. He also emphasized the importance of reliable cryospheric data centres.

5.2.3 Inga May, Secretariat of the *International Permafrost Association (IPA)* provided an overview of IPA and the Global Terrestrial Network-Permafrost (INF. 23). GTN-P is the primary international programme for permafrost monitoring, is managed by the IPA under GCOS and GTOS and consists of TSP (ground temperature) and CALM (active layer thickness) measurements. The participants were updated on their new programme structure and the national and international organization for measurement and data submission, and data management, the latter through the PAGE21 project. IPA is the key partner for permafrost in GCW. **CryoNet sites will include permafrost measurements** (as appropriate), although it is recognized that such measurements may or may not exist at all sites. A possible supersite at Samoylov and Tiksi was suggested, the former being a joint effort of the Alfred Wegener Institute (AWI) and the Russian Academy of Science (RAS) (see presentation 5.2.3 accessible on the GCW-CN-1 zip file). This was seen as a very intriguing suggestion. Oleg Anisimov raised the **issue of sub-sea permafrost** and the need to consider this component. It is currently a research initiative, rather than operational monitoring, and hence how could the data be input to a permafrost data base. This was recognized as an important consideration.

5.2.4 Taneil Uttal (NCAR, USA) provided a summary on some lessons learned from the experiences of the *International Arctic Systems for Observing the Atmosphere (and Surface) (IASOA(S))* network. INF. 12 summarizes **experiences and issues which GCW should consider in its implementation of CryoNet.** Although GCW is a different entity then IASOA, it is likely that GCW would benefit greatly from having clearly identified outcomes and metrics in advance. These can be developed with full foreknowledge that these outcomes and metrics will evolve over time. Some of the things that IASOA has discovered include:

- It is easier to build and deploy new facilities and instruments and collect data sets than it is to use the resulting data sets to do meaningful network science.

- It is very hard to coordinate between facilities that operate with different organization mandates and funding structures
- Archiving and accessing the data are very difficult problems
- Keeping an active, engaging, informative and useful web site is also very difficult
- Engaging APECS is very important
- For the Arctic Cryosphere potential difficulties in communicating between Russia and the Western Hemisphere need to be identified and addressed

These are discussed more fully in INF.12 and all were relevant to GCW and CryoNet development.

Sandy Starkweather provided IASOA's perspective on how a network of networks can facilitate data sharing. This is an important issue for GCW and CryoNet. INF.22 provides concrete examples of their experience on IASOA's evolving data sharing goals, tying the effort to current inquiry-driven activities and data sharing findings. She also offered the following potential GCW-CryoNet contributions to **IASOA data sharing goals**:

a. Recommending core, vital measurements at IASOA observatories (i.e. creating a target to which to aim)
b. Facilitating inventories of current measurements at IASOA observatories; identifying gaps.
c. Recommending best practices for measurements, data representations, file formats, error correction schemes, data vocabularies, metadata standards, etc.
d. Developing synthesis science objectives as rallying points for national funding agencies, etc. Both cross-site objectives and interdisciplinary single-site objectives are important.
e. Providing synergies and reach back in relevant Arctic Council working groups so that all IASOA measurements are put to best use in working group activities. It has been recognized that observational data is not always well-integrated into IASOA-WG reports.

Sharing of the experiences of other networks like IASOA is very valuable and their suggestions for working with the network provides useful guidance on implementing value-added data for both programs.

5.2.5 Steve Colwell provided some thoughts on *Antarctica* (INF.11 and presentation 5.2.5 accessible on the GCW-CN-1 zip file). Given that Antarctica is a vast continent at 14 million km^2 with 98% covered in snow and ice, **he suggested that it may be best to consider this as a single cryospheric site with some supersites inside of it located at some of the research stations.** There already exist some networks within Antarctica (meteorological data from the manned stations and automatic weather stations, ice core and ice information, radar and seismic data for ice sheet mapping, etc) are available and much of it available through various websites (INF.11 provides links). The issue then is for CryoNet to develop an effective way to use and contribute to existing networks/stations.

5.2.6 Michele Citterio provided a perspective from ground and remote sensing monitoring of *Greenland* (INF.23 and presentation 5.2.6 accessible on the GCW-CN-1 zip file). Like Antarctica, Greenland provides its own challenges for observing networks. The document presents very valuable perspectives on ground and remote sensing monitoring of Greenland which are offered for consideration in the discussions on CryoNet. Topics included: current status of monitoring networks; coordination among monitoring programmes; the indirect contribution by (and to) research projects; on the requirements and priorities for CryoNet sites in the context of GCW; specific contributions by GCW and CryoNet. **ANNEX 8** reproduces the list given in INF.23 of **practical ways for GCW and CryoNet to contribute and improve on the current situation.** He also noted that it is important to address the needs of policy makers and he suggested that GCW/CryoNet should define a limited set of prompt, reliable, clear, representative and easily communicated and understood products in support of defining regional to global scale state of the cryosphere, its variability and trends. The CryoNet Team acknowledged that these suggestions will be extremely useful and need to be considered in the development of CryoNet.

6. GUIDELINES AND STANDARDS FOR CRYONET

6.1 WMO Procedures on Guidelines and Standards

6.1.1 A critical component in the development of CryoNet is the effort to establish best practices, guidelines and standards for cryospheric measurements based on all available, or to be developed, manuals, guides or other documents from organizations and bodies involved in cryospheric measurement. This can include consideration of data homogeneity, interoperability, and compatibility of observations from all constituent observing and monitoring systems and derived cryospheric products. WMO regulatory material (guides, manuals, technical regulations), much of which is now online, is fundamental to WMO providing standardized, authoritative data and information. Manuals provide the standard practices, while guides provide recommended practices (e.g. Manual on the Global Observing System and the Guide to Meteorological Instruments and Methods of Observation), A presentation on WMO Standards and Best Practices provided an update on the WMO's procedures as they could apply to those needed in CryoNet development. (see presentation 6.1 accessible on the GCW-CN-1 zip file). There was also discussion on this topic at the First GCW Implementation Meeting and the relevant conclusions are summarized in **ANNEX 9** for reference.

6.1.2 It was noted that CIMO conducts formal instrument intercomparisons to determine and intercompare performance characteristics of instruments under field or laboratory conditions and to link readings of different instruments, addressing data compatibility and homogeneity. Reference sites could be well suited also as intercomparison sites. The current intercomparison of relevance and importance for GCW and CryoNet is the Solid Precipitation Intercomparison Experiment (SPICE). Presentation 3.2 Canada_CryoNet_SPICE (accessible on the GCW-CN-1 zip file) provides further information on the intercomparison. Sodankyla (Finland) is a SPICE intercomparison site and a potential CryoNet site.

6.2 Other Existing Standards and Guidelines for Cryospheric Measurements

6.2.1 *Glaciers and Snow:* Charles Fierz provided a concise summary on contributions from IUGG/IACS and IAHS. The council of the International Union of Geodesy and Geophysics IUGG, at its XXV General Assembly, 26 June – 7 July 2011 in Melbourne, Australia, adopted a resolution on "Standardised schemes for the terminology for glacier mass balance measurements and for classification of snow on the ground", thereby urging snow and ice scientists, practitioners, and scientists from related disciplines to adopt these new schemes as standards (http://www.iugg.org/resolutions/).

IACS Working Groups gathering well known experts in these two fields worked out these schemes that updated existing ones: the "Glossary of Glacier Mass Balance and Related Terms" (2011) and the "The International Classification for Seasonal Snow on the Ground (ICSSG)" (2009), the third edition after 1954 and 1990. These documents have been translated into Russian, Chinese and Italian. Snow microstructure is now also being done and IASC has a new WG on intercomparison of instruments.

Both documents follow the spirit of the following citation:
"A classification, whether made for scientific use or for popular [practical] application should be scientifically correct and based only on well-established facts and not on theories. It should be able to survive any new results of research. New facts, however, may complete and refine the classification if necessary. A close agreement should be obtained in the terminology of the different languages." (de Quervain, M.R. 1957. Avalanche Classification. IAHS Publication No. 46, 387-392).

Moreover, the ICSSG states since its inception in 1954 that its purpose is:
"To set up a classification as the basic framework which may be expanded or contracted to suit the needs of any particular group ranging from scientists to skiers. It has also to be arranged so that many

of the observations may be made either with the aid of simple instruments or, alternatively, by visual methods. Since the two methods are basically parallel, measurements and visual observations may be combined in various ways to obtain the degree of precision required in any particular class of work."

Sticking to such Standards and Guidelines benefits all workers, scientists and practitioners, alike. Participants agreed that **these are fundamental contributions to GCW and CryoNet, are primary documents in their fields** and urged WMO to incorporate this information in the development of any GCW Manual.

6.2.2 *Sea Ice:* Vasily Smolyanitsky, chair of the Joint Commission on Marine Meteorology (JCOMM) Expert Team on Sea Ice (ETSI) presented "WMO standards and guidelines for sea ice: ice charting and observations" (INF. 28). Within the WMO, JCOMM ETSI is responsible for operational sea ice standards including WMO Sea Ice Nomenclature. There has been top-level standardization of terminology and "WMO Sea Ice Nomenclature" (WMO No.259, revision Mar 2010) includes terminology (terms and definitions), an illustrated glossary and the international system of sea ice symbols. It includes 193 terms and definitions in 13 sections supporting sea ice observations at a point", "ice analysis (ice charting)" and sea ice climatology [in part on operations]. The presentation includes information on the Ice Logistics portal for the Arctic and Antarctic and provision of information on the WIS.

The documents of JCOMM will provide the core information for defining GCW standards, guidelines and terminology for sea ice. GCW will use existing documents on standards and guidelines to the greatest extent possible.

7. STRUCTURING OF CRYONET

The structuring of CryoNet is a key issue. The GCW-IM-1 report recommended that GCW initiate the task on supersites and reference sites for integrated, multidisciplinary environmental monitoring. The meeting noted the need to identify measurements to be made, measuring capabilities, minimum requirements, minimum accuracies allowed, redundancy, traceability, reliability, calibration, continuity, and sustainability. Finland noted that there could be different requirements and measurements at supersites and reference sites; hence, should CryoNet be a tiered network? Wolfgang Schoener, lead of the CryoNet task team, presented the initial thinking on a tiered structure for CryoNet that would also serve as a basis for further breakout discussion (see **ANNEX 5** and presentation 7.1 on potential CryoNet structure accessible through the GCW-CN-1 zip file). Structures of some other network observing initiatives were presented to provide additional ideas for further discussion in the subsequent breakout sessions.

7.1 Potential Structures for CryoNet

7.1.1 *GCOS Networks*: The GCOS 2nd Adequacy Report noted that the GCOS implementation strategy envisages five complementary types of network that will provide observations. These are:

• *Comprehensive global observing networks* including regional and national *in situ networks as* well as satellites, which provide observations at the detailed space and time scales required to fully describe the nature, variability and change of a specific climate variable;

• *Baseline global observing networks*, which involve a limited number of observations at selected locations that are globally distributed and provide long-term high-quality data records of key global climate variables, as well as calibration for the comprehensive networks;

• *Reference networks,* which provide highly-detailed and accurate observations at a few locations for calibration purposes;

• *Research networks*, which can provide estimates of the local variability of key variables to evaluate models and/or provide comprehensive data sets to understand climate processes; and,

• *Ecosystem networks*, where a number of different variables are measured at several locations within a specific ecosystem and are used to characterize that ecosystem.

Although an ultimate goal, **it is presently unrealistic to attempt to establish and operate networks at all five levels for all climate variables.** Priority is currently given within GCOS to the establishment of key baseline networks making *in-situ* observations, selected comprehensive networks many of which use satellite technology, a selected number of reference networks, and the long-term operation of a number of research networks**.** As the terrestrial ecosystem networks develop, more use will be made of them for climate monitoring.

GCOS Baseline components specifically include:

- the *operators* who collect the observations;
- the *centres* that monitor the international exchange of the observations, conduct quality assurance and produce information on the performance of the network;
- the *analysis centres* that integrate the observations into products for the various user communities; the international data centres that are responsible for the archiving of the observations and maintaining a permanent but accessible repository of the data for subsequent analysis;
- the *telecommunications systems* that act as the glue to keep the system together.

Also, standards and guidelines for taking observations, the communications protocols required to exchange the data, the data management and archiving procedures, and the regular evaluation of performance are required. The concept and experience in establishing the GCOS networks could be useful in CryoNet discussions.

7.1.2 *Coordinated Enhanced Observing Period (CEOP):* CEOP was established in 2002 from WCRP-GEWEX discussions and was to apply to various existing continental scale observation projects. In 2008 it became known as Coordinated Energy and Water–cycle Observations Project, but funding for archiving reference site data ended in 2010, although other parts of CEOP have continued. Tetsuo Ohata summarized the strategic implementation in of CEOP (see CEPO_Ohata accessible through GCW-CN-1 zip file). Toshio Koike, one of the initiators of CEOP, provided CryoNet with the following comments based on his experiences:

- Agree to data policy at an early stage, and write it down, and let all participants know and understand about it.
- Get cooperation of advanced IT technical people, and develop a system, which can be used (applied) by observation people easily for quality management and meta data registration.
- Identify data researcher, independent from field scientists and model scientists, or find an organization which has this ability. This needs to be done at the stage of designing of the project.

These are important aspects which need to be considered during the development of CryoNet.

7.1.3 *GCW Supersites: Sonnblick* - Wolfgang Schöner outlined ENVISON, the ENVIronmental Research and Monitoring SONNBLICK Programme for 2011-2015, as an example of integrated monitoring with a strong cryospheric component (INF.18). The ENVISON monitoring is structured into three sub-programmes: ATMON (the monitoring of the atmosphere), CRYMON (the monitoring of the cryosphere) and BIMON (the monitoring of the Biosphere). Each monitoring sub-programme will be guided by an internationally accepted expert. The general aim of CRYMON is to monitor the status and the changes of the Cryosphere in the spatiotemporal domain at high elevation sites of the Alps as well as its linkages to the atmosphere and the biosphere. This includes the measurements of glaciers, perennial snow and permafrost. In order to capture all these aspects of the monitoring spatially distributed observations at glaciers, test fields of permafrost distribution and the snow cover are established. The spatial variability of atmospheric conditions in the region demands for meteorological observations not only at the summit of Sonnblick but also at various sites covering local variability. CRYMON contributes to various international monitoring programmes as e.g. WGMS (World Glacier Monitoring Service), Permanet and to the newly established WMO GCW (Global Cryosphere Watch). INF.18 provides an excellent summary of ENVISON that could serve as an example for GCW CryoNet development.

8. DATA POLICY AND EXCHANGE

One of the most challenging issues in observing and in establishing an authoritative information network of data and products is the data policy, including archiving, data sharing and exchange. **Participants, as part of their questionnaire response, indicated that this was one of the top priorities for CryoNet and GCW** (see Table 1). This is an important topic within GCW, both from an operational and research perspective. Guidance/direction and cooperation from participants in CryoNet will be incredibly valuable in moving this issue forward. There are many data policies for reference, and depend on the context in which data were collected and the purpose for their accessibility and exchange.

INF.17 provides the WMO policy and practice for the exchange of meteorological and related data and products including guidelines on relationships in commercial meteorological activities (Resolution 40) approved at Cg-XII (1995) and the WMO policy and practice for the exchange of hydrological data and products (Resolution 25) approved at Cg-XIII (1999).These resolutions provide the current basis for data exchange by WMO Members. **Cryospheric data, such as snow depth, snowfall and solid precipitation, are governed by the Manual on Global Observations and associated regional annexes and by these resolutions. It is expected that through GCW and WIGOS that cryospheric observation and exchange will be reviewed as per current needs of Members and the community.**

INF.20 provides the data policy of the project FUTUREVOLC. This policy provides a very useful perspective which will be relevant in structuring the objectives, data categories, development of cryosphere products, data management and exchange in CryoNet and for GCW, including partners.
INF.21 is the Declaration of Intent between the Nordic Centres of Excellence (NCoE) within the sub-programme 'Interaction between Climate Change and the Cryosphere (ICCC)' regarding an Open Data Policy. It is based on the existing "International Polar Year Data Policy" and covers data definition, data availability and exchange, metadata, data preservation and data acknowledgement. Again, these will be valuable reference for CryoNet. In the geophysical community it was possible to do consistent assessments because they had a consistent set of QC'd data from one source.

GEOSS has no data policy. INF. 24 provides a summary of the GEOSS Data Sharing Principles and Action Plan aimed at addressing the growing trend towards the full & open sharing of Earth observation data. Their data sharing principles are that:

- there will be full and open exchange of data, metadata and products shared within GEOSS, recognizing relevant international instruments and national policies and legislation;
- all shared data, metadata and products will be made available with minimum time delay and at minimum cost;
- all shared data, metadata and products being free of charge or no more than cost of reproduction will be encouraged for research and education.

However, GEO welcomes all data contributions into the GEOSS. When registering data in GEOSS, the contributor should present any restrictions arising from relevant international instruments and national policies and legislation, and the duration of each restriction, that is applicable to the exchange of the data, metadata, and products submitted. The **International Council for Science World Data System** (ICSU WDS), recognizing the benefits and importance of contributing to the growing international efforts of data sharing, **has adopted the same principles from GEO/GEOSS data sharing principles.**

All of the above referenced documents provide guidance on data policy and/or data sharing, which in the end must be developed to serve GCW, CryoNet, WMO and partner needs and requirements.

9. BREAK-OUT SESSIONS ON CRYONET STRUCTURE AND ASSOCIATED OBSERVING PROGRAMME

9.1 **Parallel breakout sessions** addressed the structure of CryoNet. The breakout discussions focussed on the development and implementation of CryoNet, with participants drawing on the presentations, documents and discussions at the meeting. Participants were assigned to one of three breakout groups in a manner that scientific expertise was balanced among the groups. The three groups addressed the same questions, prepared in advance by the organizing committee, as follows:

A. CryoNet Objectives and Structure
(*Outcome of discussion: A draft structure for CryoNet site "levels", e.g., supersites, reference sites, observation sites, or tier 1, tier 2, etc.*)
1) Confirm/refine CryoNet objectives
2) What observations, data and information are required in making CryoNet a value-added monitoring programme?
3) What cryospheric monitoring programs already have a structured (tiered) network of reference sites, observational sites etc and how do they fit into CryoNet
4) How many site levels or types should CryoNet comprised? What defines these levels or tiers?
5) Is there a need for “lead centres” in CryoNet?

B. Requirements for site inclusion in CryoNet
(*Outcome: A draft list outline of requirements for a site to be included in CryoNet.*)
1) What should be required of sites to be included in CryoNet?
2) Which of the GAW (or other networks) site requirements are applicable to GCW?
3) What other requirements should be added?
4) What can be learned from other networks’ experiences?

C. Standards, guidelines, and best practices
(*Outcomes of discussion: Identification of documents of existing standards, guidelines, and best practices; recommendations on next steps for GCW/CryoNet and partners/contributors to proceed.)*
1) What cryosphere observing programs already have well-defined measurement standards, guidelines, and best practices?
2) Are there snow and ice measurements that are made in a consistent manner across programs, nations, and regions?
3) Which measurements are in need of improved or enhanced standards and guidelines?
4) What is the role of training in GCW CryoNet?

10. PLENARY DISCUSSION AND DEVELOPMENT AND IMPLEMENTATION OF CRYONET

The break-out groups reported back to plenary where there was plenary discussion of the outcomes, including initial rationalization of different suggestions. The summaries provided by the three breakout groups are given in **ANNEX 10.**

10.1 Breakout Synthesis:

10.1.1 CryoNet Structure

Group 1(CZ, GB): This group suggested three tiered categories

1. **Many-Sphere sites**
2. **Cal/Val sites**
3. **Reference-long-term sites**

They emphasized that all GCW sites should be sustainable and accessible. They also stressed that a Many-Sphere site or Cal/Val site should be a location that enables Earth Observations CAL/VAL activities and/or Earth Systems process-oriented verification of models.

Group 2 (TU, AW): The team felt that the objectives are reasonably well defined in the implementation document and did not seem to require extensive discussion by the group. A more refined statement might be that "CryoNet will integrate the observations of existing ground based observing networks to achieve added value."

"To tier or not to tier" garnered considerable discussion. A multi-level network structure may not be critical, whereas the highest priority should be on continuous temporal sampling with a policy of being as inclusive as possible to incorporate existing observations. It is likely that "super sites" will naturally evolve depending on what component of the cryosphere is being observed. What would be a supersite for sea ice would be totally different from a supersite for permafrost. They noted that blended products would be important, a blended product being produced from as many components as possible e.g. an "onset of melt product" which includes sea ice, snow, ice sheet and glaciers.

Their consideration to be a supersite included:

- Wide range of observations and instrumentation
- Should be terrestrial location and secure. Russian drifting station is not a supersite (Oleg)
- GCW IP definition

Group 3 (MZ, MC):

1. **Observation/baseline (detailed info)**
2. **Reference (long time)**
3. **Integrated (several cryo elements, cal/val capability)**

Observation/Baseline sites: a cryosphere or cryosphere-related observation(s); standardized; self consistency in data quality; open access.

Reference sites: long term; all characteristics of observation/baseline sites plus being long relative to a threshold TBD (but continuity is not a requirement) and have local met data source available.

Integrated sites have several cryosphere elements and cal/val capability. All requirements for observation sites, plus have a local meteorological data source, plus x out of n from: suit the needs of process understanding and model calibration; covers at least two or three cryosphere components;

transnational accessible; online data available and real-time for some; interdisciplinary beyond cryosphere elements.*10.1.2 Site Inclusion in CryoNet*

Group 1 (CZ, GB): The GAW requirements already provide very useful guidelines that could be adapted to the cryosphere elements. It is recommended that:

- *Reference* sites are identified as having at least 10-year of availability for at least 1 key GCW parameter.
- *Multi-sphere* sites should have at least 1-key parameter each in 2 different "spheres" among the Cryosphere, Biosphere, Atmosphere and Hydrosphere.
- *Cal/Val* sites should have a clear link with EO/Models and established link with the Agencies.
- *Temporary* sites (short or partial observability) can become "reference" or "multi-sphere" sites upon reaching the defined criteria.
- Frequency of observations and observation latency should follow common practice (daily for snow-depth, annual for glaciers).

Group 2 (TU, AW): The GAW (a network of networks) model to define CryoNet cannot be followed because of the highly variable and spatially distributed nature of different components of the cryosphere (glaciers, ice shelves, ice sheets, snow, permafrost, sea-ice, river/lake ice).
The basic requirement to be a CryoNet site would include:

- Well defined measurements
- Quality assurance stamp with error bars
- Data provided in a standard format (with meta data?)
- Open access

Group 3 (MZ, MC): The criteria for inclusion were discussed (see Annex 10) and follow the criteria identified for the three tiers presented in 10.1.1, above.

10.1.3 *Standards, guidelines, best practices*

Many documents for standards and best practices exist (e.g. sea ice, snow, glaciers, permafrost…), though standards for all cryosphere measurements are not necessarily complete, consistent, or up to date.

Group 1 suggested that the revision of "best practice" could be mandated to relevant organizations rather than to individual specialists. It was also recognized that training programs are important in order to reach best practice (such as the Global Atmosphere Watch Training & Education Centre (GAWTEC), UNESCO FRIEND).

Group 2 suggested that although many CryoNet candidate networks are following WMO data observation protocols and standards this should not be a requirement for inclusion. However, a blended cryosphere data product that would be useful for satellite Cal/Val and model initialization/validation would be developed to WMO data standards with defined quality standards, standard formats and open access. In addition, CryoNet should provide guidance by (1) identifying gaps (2) data synthesis activities (3) facilitating transfer of research observations to operations (4) data rescue (5) comparison campaigns and (6) integration of the resulting cryosphere super-data set into the WMO products such as synthesis reports. The spreadsheet analysis that has been started was deemed very useful and should be continued with accommodations for distributed regional networks (for instance radiation networks on Greenland) as well as stations. The need for organization of cross-network training programs was identified.

The most practical solution is for all participants to forward applicable documents on standards, guidelines and best practices to the CryoNet Team Leads for the team to consolidate for CryoNet.

11. CRYONET WORKING GROUPS

A CryoNet Task Team was established to prepare a draft classification system and its attributes for subsequent discussion by all participants. It will use the ideas and guidance discussed in the breakout groups. This system can then be tested by categorizing the sites submitted by participants for this meeting. The team members are: Wolfgang Schöner (lead), Matthias Bernhardt, Michele Citterio, Charles Fierz, Christophe Genthon, Juan-Manuel Horler, Tetsuo Ohata, Vasily Smolyanitsky, Þorsteinn Þorsteinsson, and Xiao Cunde. Jeff Key and Barry Goodison serve as ex-officio participants. Sub-groups can be established to address particular issues as required.

12. FUNDING REQUIREMENTS FOR CRYONET

Funding of CryoNet, both for operations and common support is very important if there is to be a sustained network. Potential sources include through organizations such as WMO, Member countries, national programmes, and international funding agencies.

Arni Snorrason initiated the discussion on funding with a talk on research infrastructure and associated funding opportunities. The EU is organizing an effort for integrating national research infrastructure, in which there may be an opportunity also for non-EU participation. The European Strategic Forum for Research Infrastructure – ESFRI – could apply globally and this should be looked at to see how it might be adapted to CryoNet, especially in filling gaps in the observing system and accessing data.

The opportunities of support in WMO through its VCP and resource mobilization and Junior Professional Officer programs were noted. It is useful to have "projects ready" to respond to appropriate calls. France noted that it is often relying on short term funding. Japan has some opportunities to fund international initiatives with past topics including water resources and coastal themes. Canada and the US have looked for opportunities for enhanced observation programs which included SWIPA and GCW. Canada is now focussing on the Arctic. The Arctic Council, with its long-term office in Tromso, may have opportunities. Efforts by everyone at the national level are extremely important. It was noted that it is important to link to national policies and the science needed to support good policy and decision making. Jeff Key, for example, will be briefing the US State Dept on GCW. A letter to countries' Permanent Representative for WMO to reaffirm the GCW focal point and to seek support for GCW and CryoNet will be very valuable.

13. NEXT STEPS FOR IMPLEMENTATION OF CRYONET

13.1 It was agreed that the first step was to draft the classification system and then try to assign sites submitted by participants to test its applicability. The need for a support person to help keeping this move forward was identified by the participants.

Additional tasks were suggested:

- Development of a demonstration project to show how CryoNet could operate (WGMS offered an example).
- a demonstration to ingest data into NWP centres and into the GTS (ECMWF provided feedback on next steps).
- development of a data and exchange policy (Iceland offered to lead, using what is currently available)
- collation of appropriate best practices, guidelines, and standards

- identification and pursuit of funding opportunities. As CryoNet sites would be operated by national entities, it would be important to start the dialogue with national ministries to seek commitments to operating such sites.

Further input was received after the meeting addressing some of these topics. This input follows.

13.2 CryoNet Demonstration Project ‘Glacier Mass Balance Observations’ (WGMS, Michael Zemp): Glacier mass balance observations available through the World Glacier Monitoring Service (http://www.wgms.ch) might be a useful demonstration project for GCW-CryoNet. WGMS provided a KMZ-File (for Google Earth) which showed a global overview on glaciers with annual mass balance observations carried out according to the glaciological method. The file included meta-data on the location of the glaciers as well as on the temporal coverage of available observation series. In addition, the links were included for viewing minimal data series (i.e., observation years, balances, information on investigators and sponsoring agencies) as well as for ordering the full set of mass balance parameters (e.g., winter and summer balance, balance for elevation bins, equilibrium line altitudes and accumulation area ratio). This kind of meta-data layer is updated by the WGMS after each of its annual calls-for-data and might serve to feed the GCW/CryoNet meta-data portal. Based on the information in this file, reference glaciers with data series longer than 30 years might be highlighted as ‘GCW Reference Sites’. Contact information: Michael Zemp, wgms@geo.uzh.ch"

Zemp also reiterated the great potential for GCW-CryoNet in bringing together the cryosphere observations (e.g., glacier mass balance measurements above) with automatic weather stations (AWS) run around these sites. In the glacier community, PROMICE (http://promice.dk), GLACIODYN (http://www.mn.uio.no/geo/english/research/projects/glaciodyn/) and IASC (http://ny.arcticportal.org/) run many AWS on glaciers. He noted that the WGMS does not compile this data.

13.3 Gianpaolo Balsamo (ECMWF) noted that there are definitely large margins of improvement that can be expected from increased data uptake in NWP models. Following some of the later discussions during the meeting he forwarded the link to ERA-CLIM (ECMWF current reanalysis project) for which information is available at http://www.era-clim.eu. Dick Dee (Head of Reanalysis Section) was identified as one who could provide all relevant information (also on data policy choices); he has been kept him informed of the GCW advances.

As CryoNet advances and when discussions reach data formatting, it was noted that ECMWF has had some initiatives (at research level) to format the FLUXNET/BERMS/CEOP data in a common NetCDF format (of which the metadata was quite flexible and based on CF naming/units convention. The key for ECMWF was to accommodate both observations and co-located model output under the same format. An ERA-report describes this file format (in the appendix) and its use is available at
http://www.ecmwf.int/publications/library/do/references/show?id=90073.

This format might be something that an IT specialist would probably design differently to better comply with database requirements, but from a data-user point of view it was really useful to scale their model benchmarking activities (and "score" at once model output vs several observational field-sites).

13.4 ICSU/WDS discussion paper on open access on data and information is a key element of the World Data Monitoring System. The paper is reproduced in **Annex 11.**

13.5 Standards, Guidelines, Best Practices: A list of guidelines related to the monitoring of glacier distribution and changes can be found at:
http://www.gtn-g.org/literature.html
http://www.wgms.ch/guidelines.html

13.6 Funding Opportunities: In the EU the COST program was identified as a possible source of funds which could provide funds for coordination and cooperation of S&T activities in Europe. Proposals were submitted snow and permafrost activities.

13.7 Additional suggestions were also provided on the development of CryoNet and GCW. Stine Højlund Pedersen offered some valuable thoughts on dissemination of CryoNet information and data, including:

1. Map on CryoNet web site:
   For a future website for CryoNet it was suggested to make the front page present a map which shows the location (marked with e.g. point) of the stations currently a part of CryoNet. In the map it should be indicated where the cryosphere is present i.e. the area where monitoring of the cryosphere is actually possible. This will give a good impression of the global distribution of cryosphere observations. Additionally, in the marking of the each station in the map it could be distinguished whether the station/site represents a Cal/Val site, Reference/Observation site or an Integrated/Multisphere site (or according to the decided structure) by colors or markers. When a visitor of the website points with the mouse to the point of a station in the map, a pop-up window could appear with a short site description and a photo, as we saw it in the presentation by Steve Colwell on Antarctica data bases/portals.

2. Indication of success:
   An indication of the success of CryoNet could be the number of downloads of data set from a CryoNet station or the number of published peer-review papers which includes CryoNet data sets. For the latter, we could encourage people to report their publications on CryoNet data when they register as new user of the data portal.

3. CryoNet Library/Catalog of cryosphere related publications:
   A scheme/form for reporting ones publication should then be available on the website for this purpose and be archived to create a library of cryosphere related publications.

13.8 Sandy Starkweather provided some additional thoughts on the CryoNet structure. She noted the consensus that emerged around a purpose-based structure for the CryoNet site designations, which she felt was a very valuable outcome. There was also broad-agreement that the nature of the cryosphere is distributed rather than well-mixed and therefore direct comparisons between GCW and progressive (regional->global) GAW structures and approaches could break down in application. However, as Jeff Key pointed out several times, the GAW model has been very successful in motivating funding agencies to aim for progressive targets like "Global" stations. Sandy offered her thoughts on development of some type of progressive target as follows - let CryoNet itself use a purpose-based structure (e.g. cal-val, integrated) to describe the types of observations being made. Then at the GCW level, apply the following progressive rating system:

GCW "contribution" - A data series that meets the criteria for a CryoNet site, follows relevant protocols and submits data of known quality, as well as metadata to an archive.

GCW "end-to-end contribution" - A data series that meets the above criteria AND contributes directly to either cal-val, model process development, operational data products or some type of seasonal or longer published index. This must be a well-established relationship that results in some tangible and on-going outcome.

This then shifts the focus from how "super" the site is to how the resulting data are being applied towards the types of issues that motivate the formation of GCW in the first place. It motivates data contributors to develop partnerships and applications for their information and to develop stronger deliverables from the network. You could then even apply this standard backwards into CryoNet, with some designation related to how many "contributions" and "end-to-end" contributions they are making towards GCW (e.g. 3 = bronze, 5 = silver, 10 = gold, honourable mention, whatever). So you would still be conveying the relative importance of certain sites as magnates for GCW activity.

This is the type of standard that is trying to be set for IASOA. As we discussed at the meeting, IASOA has identified 3 pilot projects in order to demonstrate the value of focusing on stakeholders and products as a way to enhance observational efforts. IASOA volunteered to develop some thoughts around Arctic Flux Net for GCW, and Sandy offered to focus on this moving forward.

ANNEX 1

PROGRAMME

VENUE: **Zentralanstalt für Meteorologie und Geodynamik (ZAMG), Julius Hann Haus, Vienna, Austria**

TUESDAY NOVEMBER 20 (0930-1745)

09:30-10:00

1. ORGANIZATION OF THE WORKSHOP (GENERAL CHAIRMAN: A. SNORRASON)

1.1 Welcome and opening *(ZAMG and WMO)*
1.2 Adoption of the agenda and workplan
1.3 Working arrangements
1.4 Participant introductions

10:00-10:40

2. CRYONET BACKGROUND (Session Chair: A. Snorrason)

2.1 GCW Implementation Plan *(Key)*
2.2 Summary of CryoNet Discussion at GCW-IM-1 *(Schöner)*

10:40-11:10 HEALTH BREAK

11:10-12:00

2.3 CryoNet in the context of WMO Programmes *(Dibbern)*

3. ROUNDTABLE: INITIATION OF COMPREHENSIVE CRYOSPHERE OBSERVING NETWORK (Session Chair: J. Key)

3.1 CryoNet objectives and synthesis of participant questionnaire responses *(Schöner)*

LUNCH 12:00-13:00

13:00-15:00

3.2 Presentations from representatives of potential CryoNet sites/networks

15:00-15:30 HEALTH BREAK

15:30-17:45

4. CRYONET: OBJECTIVES AND BENEFITS (Session Chairs: J. Key, W. Schoener)

4.1 Background statement *(Schöner, Key)*
4.2 Benefits to modeling, remote sensing, research, policy
4.2.1 Modelling *(Balsamo)*
4.2.2 Satellite *(Herland)*
4.2.3 Water Resources *(Snorrason)*
4.3 Discussion to refine CryoNet objectives and benefits *(Key, Schöner)*

5. HARMONIZATION OF CRYOSPHERIC OBSERVATIONS (Session Chair: B. Goodison)

5.1 Experiences from participation in the Global Atmosphere Watch (GAW) *(ZAMG) (with comments from participants who have GAW experience*

SUMMARY OF THE DAY (GENERAL CHAIRMAN: A. SNORRASON)

END OF DAY (1745)

WEDNESDAY NOVEMBER 21 (0900-1745)

08:45-10:30

5. HARMONIZATION OF CRYOSPHERIC OBSERVATIONS (CONT'D)

(Session Chair: B. Goodison)

5.2 Views of International Organizations/Data Centres
IACS Perspective *(C. Fierz)*
Glacier Perspective *(M. Zemp)*
Permafrost Perspective *(I. May)*
IASOA perspectives and data sharing *(T. Uttal/S. Starkweather)*
Antarctic Experience *(S. Colwell)*
Greenland Experience *(M. Citterio)*

10:30-10:50 HEALTH BREAK

10:50-12:00

6. STANDARDS AND GUIDELINES FOR CRYONET (Session Chair: A. Snorrason)

6.1 WMO Procedures on Guidelines and Standards *(J.Dibbern)*

6.2 Other Existing Standards and Guidelines for Cryospheric Measurements
Glaciers and Snow *(C. Fierz)*
Permafrost *(I. May)*
Sea Ice *(V. Smolyanitsky)*

12:00-12:45 LUNCH

12:45-14:15

7. STRUCTURING OF CRYONET (Session Chair: J. Pulliainen)

7.1 Potential Structures for CryoNet

- Global Climate Observing System (GCOS) Network Design *(B. Goodison)*
- Coordinated Energy and water cycle Observations Project (CEOP) *(T. Ohata)*
- GCW Supersites: Sonnblick *(W. Schöner)*

8. DATA POLICY AND EXCHANGE

8.1 Discussion on Data Policy and Exchange (A. Snorrason)

14:15-17:15 (WITH HEALTH BREAK)

9. BREAK-OUT SESSIONS ON CRYONET STRUCTURE AND ASSOCIATED OBSERVING PROGRAMME

SUMMARY OF THE DAY (GENERAL CHAIRMAN: A. SNORRASON)

END OF DAY (1745)

1900 -.... GROUP DINNER (own expense, place to be determined)

THURSDAY NOVEMBER 22 (0845-1700)

08:45-17:00 (including health breaks and lunch) – time is being kept flexible to accommodate outcomes and actions of break-out sessions.

10. DEVELOPMENT AND IMPLEMENTATION OF CRYONET (SUGGESTED TOPICS)

10.1 Report of break-out groups

The following are expected to be addressed in small focus groups which will consolidate recommendations and prepare necessary text and actions:

10.2 CryoNet objectives
10.3 Site definitions and associated observing programme
10.4 Identification of potential CryoNet site
10.5 Governance of CryoNet and need for lead centres responsible for cryospheric components
10.6 Requirements for inclusion in CryoNet
10.7 CryoNet Data Policy
10.8 Potential Pilot Projects ("Showcase activities")

11. CRYONET WORKING GROUPS

11.1 Define
11.2 Duties/terms of reference

12. FUNDING OPPORTUNITIES AND SUSTAINABILITY

12.1 WMO
12.2 National programs
12.3 Funding agencies and mechanisms

13. NEXT STEPS FOR IMPLEMENTATION OF CRYONET

Finalization of tasks, activities, identification of experts, timelines

ADJOURN MEETING (1700)

ANNEX 2

LIST OF PARTICIPANTS, CRYONET 1ST SESSION

NAME	INSTITUTION	E-MAIL
Oleg ANISIMOV	**State Hydrological Institute**, St. Petersburg, Russian Federation	oleg@oa7661.spb.edu
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Arni SNORRASON	**Icelandic Meteorological Office,** Reykjavík, Iceland (*PR of Iceland with WMO, Member of EC-PORS and GCW Task Team)*	arni.snorrason@vedur.is
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	(Secretariat)	barrygo@rogers.com

Note: GCW focal points, as nominated by the Permanent Representative (PR) of their country, are underlined

ANNEX 3

PARTICIPANT RESPONSES TO CRYONET QUESTIONS

(Alphabetical by Country)

To start the GCW CryoNet discussion prior to the meeting and to share participant's thoughts on the purpose, benefits, structure and scope of the network, participants were asked to answer the following questions.

1. How could GCW-CryoNet help meet your national, regional or global interests?
2. What could you or your organization contribute to the implementation of GCW-CryoNet?
3. What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
4. What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
5. Please prioritize CryoNet activities according your personal view (select HIGH/MEDIUM/LOW):

- ***Establishment of CryoNet tier#1-tier#4 network***
- ***Establishment of supersite network:***
- ***Harmonisation of cryospheric network:***
- ***Standards, guidelines and training for observations:***
- ***Inter-comparison experiments (e.g. sensors, methods):***
- ***Cooperation with existing networks:***
- ***Data policy on archiving, accessibility and exchange***
- ***Support national needs:***

6. Please share any other thoughts for participant to consider at the meeting.

The responses of participants are given below as submitted. They were also asked to respond to a site questionnaire and those responses are given in Annex 4.

Argentina - *Response from Juan Manuel Horler, Servicio Meteorológico Nacional, Caba, Argentina*

How could GCW-CryoNet help meet your national, regional or global interests?
Serve for studying the cryosphere variables as permafrost and snow surface at high latitudes, in the long run will be used for monitoring climate variability and climate change. The data could also be used to improve the parameterization of the models in the cryosphere processes, and the development and validation of satellite products.

What could you or your organization contribute to the implementation of GCW-CryoNet?
Installing and maintaining more monitoring stations of the Global Atmosphere in cold climates. Install Instrumental to measure the amount of snow or snow depth. Improve data collection system in cold areas to enter information in the GTS. Install an automatic station in the six Antartic Bases.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
Will strengthen observation networks. At the same time strengthen the networks operational and research, modeling, etc.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
The lack of observational data of the cryosphere occurs mainly in the spacial scale, and then the time. To address these problems should generate a consolidated database and available to all countries providing data.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

- ***M*** *- Establishment of CryoNet tier#1-tier#4 network*
- ***H*** *- Establishment of supersite network*

H *- Harmonisation of cryospheric network*
H - *Standards, guidelines and training for observations*
M *- Inter-comparison experiments (e.g. sensors, methods)*
M *- Cooperation with existing networks*
M - *Data policy on archiving, accessibility and exchange*
M *- Support national needs*

Canada: Canadian Atmospheric Monitoring Program - *submitted by Dave Wartman, Atmospheric Monitoring Program, Meteorological Service of Canada, Environment Canada, as part of Canadian input on Canadian sites*

How could GCW-CryoNet help meet your national, regional or global interests?
Solid precipitation is a priority measurement area in operational atmospheric monitoring in Canada. Cryonet may serve as an opportunity to enhance the existing solid precipitation data as well as a tool to integrate and coordinate different kinds of data and information that can be used for decision making.

What could you or your organization contribute to the implementation of GCW-CryoNet?
Canada owns and operates a number of Arctic sites as part of a national network. Several of these locations are manned and may be suitable as reference sites or at the least as stable, on-going and long term sources of high quality data.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
There are many different cryospheric measurements being taken in the Canadian Arctic and at lower latitudes in Canada, some of it project-based and some of it program-based. The CryoNet initiative may offer a framework to bring together this data in a coordinated manner and make it accessible to operational, research and decision-maker stakeholder groups.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
CryoNet may offer an opportunity to establish new, synergistic working relationships for mutual benefit and also formalize existing ad hoc arrangements for common purpose. Further, the implementation of a data policy that allows for open access, common data formats and interoperability and in general enables data sharing will be beneficial.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):
H *- Establishment of CryoNet tier#1-tier#4 network*
H *- Establishment of supersite network*
M *- Harmonisation of cryospheric network*
M *- Standards, guidelines and training for observations*
M *- Inter-comparison experiments (e.g. sensors, methods)*
H *- Cooperation with existing networks*
H *- Data policy on archiving, accessibility and exchange*
H *- Support national needs*

Canada: Milne Ice Shelf and Mt Logan/Upper Kaskawulsh - *submitted by Dr. Luke Copland, station manager/operator of these sites, Department of Geography, University of Ottawa, as part of Canadian input on Canadian sites*

How could GCW-CryoNet help meet your national, regional or global interests?
Help to standardize techniques for field measurements, and provide a central location to archive data

What could you or your organization contribute to the implementation of GCW-CryoNet?
Data!

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
A way for researchers and the public to go to a central portal to see which cryospheric data is being collected, and where, and to hopefully have the ability to download that data

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
I'm not sure if there is a particular issue with gaps in observations (although more are obviously always good), but rather the issue is the lack of a central repository where data and metadata is archived. For example, many different organizations often run weather stations in close proximity to each other (e.g., in the Rockies), but it's currently often difficult for researchers to find out which other stations are running, and for them to access that data.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

- ***M*** *- Establishment of CryoNet tier#1-tier#4 network*
- ***M*** *- Establishment of supersite network*
- ***M*** *- Harmonisation of cryospheric network*
- ***H*** *- Standards, guidelines and training for observations*
- ***L*** *- Inter-comparison experiments (e.g. sensors, methods)*
- ***M*** *- Cooperation with existing networks*
- ***M*** *- Data policy on archiving, accessibility and exchange*
- ***L*** *- Support national needs*

Please share any other thoughts for participant to consider at the meeting.
We need to make sure that CryoNet doesn't just duplicate the work being done by many of the other scientific networks and organizations that are already working in the cryosphere (e.g., World Glacier Monitoring Service, Global Land Ice Measurements from Space, Polar Data Catalogue, National Snow and Ice Data Center). Creating another network without proper coordination with the existing networks would just create more work for everyone!

Canada: Alert, CANDAC - *submitted by James Drummond, PI Canadian Network for Detection of Atmospheric Change (CANDAC), Dalhousie University, as part of Canadian input on Canadian Atmospheric Monitoring Program*

How could GCW-CryoNet help meet your national, regional or global interests?
Our national interests consist of providing Canada with the scientific capacity to study the High Arctic atmosphere and therefore to document how it is changing. GCW-CRYONET can help by increasing the visibility of our site and programs, and by providing a global context in which to evaluate our work. Global interests are that quite simply, the atmosphere does not stop at any border and therefore coordination of measurements and scientific collaborations are extremely important.

What could you or your organization contribute to the implementation of GCW-CryoNet?
The data collected at PEARL to date are stored in the CANDAC database. Metadata are available in the Polar Data Catalog and we have an ongoing effort to make as much of the data as possible publicly available. Access to relevant data could be accelerated adding to whatever new data records are produced in the future under the CryoNet. Access to PEARL at Eureka on Ellesmere Island for scientists outside of CANDAC is already encouraged both remotely and in person, and we would certainly welcome CryoNet members to collaborate with CANDAC members. Note that access to the weather station at Eureka is controlled by Environment Canada.

Subject to funding and other limitations, CANDAC could also expand, intensify and generally accelerate atmospheric and related measurements relevant to CryoNet at PEARL and associated sites

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
Benefits include a forum within which to exchange ideas and information, within which to initiate collaborations and within which to coordinate wide area measurement programs. All of these can then be used to inform policy discussions. On the measurement/monitoring side, it would help to add momentum to existing efforts and to guide the decisions around the placement of new instrumentation and facilities.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
First of all, there continues to be a lack of measurement sites in the High Arctic. So an increase in the number of sites is very important. There is an even more serious lack of night measurements and therefore as many sites as possible should be operable year-round. Archiving measurements and analytical products and doing so in a manner that makes them easily available yet maintains traceability back to the original scientist(s) is a continuing concern.
It is critical that the effort going into these measurement programs be acknowledged in a concrete fashion as it is far too easy for the basic measurements to be neglected if only the derived products are considered. A unifying, global voice speaking with the authority of all scientists involved might well prove to be significant in that regard.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

M - *Establishment of CryoNet tier#1-tier#4 network*
M - *Establishment of supersite network*
M - *Harmonisation of cryospheric network*
M - *Standards, guidelines and training for observations*
H - *Inter-comparison experiments (e.g. sensors, methods)*
H - *Cooperation with existing networks*
H - *Data policy on archiving, accessibility and exchange*
M - *Support national needs*

Please share any other thoughts for participant to consider at the meeting.
The CANDAC science team welcomes the further development of Arctic science and Arctic observatories. However, the PEARL funding situation is such that it may no longer be operational after 31 March 2013.

Canada: Permafrost Network - *submitted by Dr. Sharon Smith, Permafrost Research, Geological Survey of Canada, Natural Resources Canada, as part of Canadian input on Canadian sites*

How could GCW-CryoNet help meet your national, regional or global interests?
It is a bit unclear what the advantages may be compared to other network initiatives. It may provide a better opportunity to support an integrated view of the cryosphere and support integrated assessments etc.

What could you or your organization contribute to the implementation of GCW-CryoNet?
We have a national permafrost monitoring network that could contribute to GCW-CryoNet. Our contribution however would continue to depend on available resources and alignment with organizational mandate.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
Benefits might include ensuring operation of monitoring programs to provide baseline data that are essential for assessment of environmental effects, support site/project specific environmental monitoring programs (such as that associated with resource development projects), environmental management programs and support land management decisions, decisions regarding resource development etc.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
Spatial gaps partly related to accessibility, lack of resources etc.

Co-location of monitoring of various cryospheric components might help – pool resources etc.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

- ***H*** *- Establishment of CryoNet tier#1-tier#4 network*
- ***H*** *- Establishment of supersite network*
- ***M*** *- Harmonisation of cryospheric network*
- ***M*** *- Standards, guidelines and training for observations*
- ***M*** *- Inter-comparison experiments (e.g. sensors, methods)*
- ***M*** *- Cooperation with existing networks*
- ***L*** *- Data policy on archiving, accessibility and exchange:(dealt with through other programs?)*
- ***H*** *- Support national needs*

China: Nam Co - *Response from Nam Co observing station*

How could GCW-CryoNet help meet your national, regional or global interests?
Cryosphere is one of major parts in China and the network will help us to improve our observation capacity.

What could you or your organization contribute to the implementation of GCW-CryoNet?
The Nam Co basin has environment diversity including lake, river glacier, permafrost, alpine meadow and wetland with an altitude range of 4700~7210m. The “glacier-permafrost-hydrology-atmosphere-vegetation” multisphere interaction is one key region for global change research. The Nam Co station could be a super station in the region.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
Firstly, CryoNet could help us improve our field observation.
Secondly, CryoNet could help us share the observation data to each other in worldwide.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
Every observation site or station has his own situation; they could decide what kind of observation they could do or not. But what we really need are the standards for observation and then the data could be used in the worldwide for the researchers.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

- ***M*** *- Establishment of CryoNet tier#1-tier#4 network*
- ***M*** *- Establishment of supersite network*
- ***H*** *- Harmonisation of cryospheric network*
- ***H*** *- Standards, guidelines and training for observations*
- ***M*** *- Inter-comparison experiments (e.g. sensors, methods)*
- ***H*** *- Cooperation with existing networks*
- ***M*** *- Data policy on archiving, accessibility and exchange*
- ***L*** *- Support national needs: Low*

China: Koxkar,Tianshan - *Response from Koxkar,Tianshan mountain glaciological station, China)*

How could GCW-CryoNet help meet your national, regional or global interests?
Sites in GCW-CryoNet gather glaciological and climatological data in cold polar areas and high mountain environments where observational conditions are extreme and national and local meteorological stations are rare. For glacio-hydrological modellers, data collections in these areas are difficult, especially for those data with high spatial and temporal resolution. Presently, model results are usually derived using data with rough resolution and are reluctant to describe the real physical processes. Establishment of the GCW-CryoNet will help to strengthen surface observations in these blank areas and provide key observational data for regional glaciological and hydro-glaciological modelling and other purposes.

What could you or your organization contribute to the implementation of GCW-CryoNet?
We have set up a glaciological station in Tian-Shan Mountain (Central Asia). Meteorological and glaciological data were collected regularly since 2003, including surface meteorological variables (air temperature, wind speed, radiation, etc.), glacier mass balance, ice motion velocity. We could join GCW-CryoNet and would like to share the observational data in a broadly agreed framework.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
As a hydro-glaciological modeller, I think GCW-CryoNet could provide an unique cryospheric dataset and thus greatly improve the works in environment monitoring and modelling.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
The main gaps, I think, may be the independence of the individual sites. Without an effective data exchange policy, cryospheric sites cannot benefit from each other and thus lead to regional data shortage. One of the main tasks of CryoNet may be to make the data exchanging policy with broad agreement.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

H *- Establishment of CryoNet tier#1-tier#4 network*
L *- Establishment of supersite network*
M *- Harmonisation of cryospheric network*
H *- Standards, guidelines and training for observations*
M *- Inter-comparison experiments (e.g. sensors, methods)*
H *- Cooperation with existing networks*
H *- Data policy on archiving, accessibility and exchange*
L *- Support national need*

China: Rongbuk Glacier - *Response from observation station of Rongbuk glacier in the north slope of Mt. Everest, China*

How could GCW-CryoNet help meet your national, regional or global interests?
As for the observation station of Rongbuk glacier in the north slope of Mt.Everest, we could achieve such objectives under the help of GCW-CryoNet:

- To efficiently set up the frameworks of observation followed GCW-CryoNET and establish the international criterion of observation;
- Offer the platform of data and information sharing;
- Especially collaborated with other country or groups to work on globally issues of environment change, dealing with nature disaster or management of regional water resource et al;
- Based on GCW-CryoNet, we could have more progress in water cycle questions such as initial conditions for numerical water forecasts, the role of high Himalaya glacier originated water in earth system and feedback effects on global climate change.

What could you or your organization contribute to the implementation of GCW-CryoNet?
Offered long term in-situ observation data of north Himalayas supported by local government and local residents;
Our observation station could be part of the observation net with typical location feature, so could be very important part of international GCW-CryoNet.
China has pay more and more attention to global and regional environmental change and subsequent impact, so the implementation of GCW-CryoNet could be supported strongly by governor and general republic

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?

- First, we could have regular observation criterion and reliable data results;

- Set up a forceful observation system which works efficiently for long term service;
- Offer scientific data for local residents or government to deal with regional climate change, water resource management and engineering construction;
- To know more clearly of some complex scientific issues about global change such as global change and regional response in water cycle, geo-disaster, societal issues of high altitude regions such as agricultural development, water management and sustainable development.
- Especially for satellite observation application in high altitude areas, it could give useful help in ground data calibration, model parameterization et al.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
Sparsity of observed data in cold and high altitude region has restrict the reliability of remote sensing or model outputs, so lots of unknowns still exists about cryospheric processes and Mt. Everest observation station would extend the observation parameters with particular focuses under the framework of CryoNet;
Data management and distribution are essential issues and should pay enough attention on data precision, operation training and data sharing.
Help to give strong support in observation funding especially sustainable funding support from governments and international coordination.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

H *- Establishment of CryoNet tier#1-tier#4 network*
H *- Establishment of supersite network*
M *- Harmonisation of cryospheric network*
H - *Standards, guidelines and training for observations*
H *- Inter-comparison experiments (e.g. sensors, methods)*
H *- Cooperation with existing networks*
H *- Data policy on archiving, accessibility and exchange*
M *- Support national needs*

China: Tanggula - *Response from* Tanggula Cryosphere Station (TCS)

How could GCW-CryoNet help meet your national, regional or global interests?
It will help us understanding of the influencing factors of the different regions of the cryosphere changes by GCW-CryoNet.

What could you or your organization contribute to the implementation of GCW-CryoNet?
The glaciers on Tibetan Plateau play an important role in the catchment hydrology and climatology of this region. However, our knowledge with respect to water circulation in this remote area is scarce. The Tanggula Cryosphere Station (TCS) setted by our organization is expected to make further contributions to research on the change of the cryospheric and climatic environment in the area.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
As a research site operator, the CryoNet can provide a lot of reference information on field observations for me.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
Because there is no channel of communication, the requirements of observational data of the relevant regional Often cannot meet. And CryoNet can solve this problem.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

H *- Establishment of CryoNet tier#1-tier#4 network*
M *- Establishment of supersite network*
L *- Harmonisation of cryospheric network*
H *- Standards, guidelines and training for observations*

H - Inter-comparison experiments (e.g. sensors, methods)
H - Cooperation with existing networks
H - Data policy on archiving, accessibility and exchange
M - Support national needs

China: Tianshan - *Response from Tianshan mountain glaciological station*

How could GCW-CryoNet help meet your national, regional or global interests?
Can meet particular strategic needs e.g. water security, Natural Disasters.
Improved understanding and process and climate model validation.

What could you or your organization contribute to the implementation of GCW-CryoNet?
Tianshan Glaciological Station (TGS) will provide observation data in time.
TGS also can offer the relevant observation training.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
The data and information of GCW will benefit for the 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.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
The GCW-CryoNet need for formulating a standard method for the observation
The GCW-CryoNet should publish the annual data report

Please prioritize CryoNet activities according your personal view (indicate HIGH/MEDIUM/LOW):
H - Establishment of CryoNet tier#1-tier#4 network
H - Establishment of supersite network
M - Harmonisation of cryospheric network
H - Standards, guidelines and training for observations
M - Inter-comparison experiments (e.g. sensors, methods)
H - Cooperation with existing networks
H - Data policy on archiving, accessibility and exchange
M - Support national needs

Please share any other thoughts for participant to consider at the meeting.
Financial support for the young scientists to attend the GCW meeting

France - *Response prepared by Eric Brun, Meteo-France/CNRM, and Christophe Genthon, LGGE CNRS*

How could GCW-CryoNet help meet your national, regional or global interests?
An easy access to controlled-quality long-term observations of different components of the cryosphere is of uttermost importance for research on cryosphere/climate interactions. By providing comprehensive datasets from reference sites and supersites, Cryonet will considerably help to meet this requirement. At a national scale, observations are already relatively accessible through the cooperation of the different institutes in charge of their collection. However, Cryonet initiative should facilitate the commitment of different organizations to share their observations.
The highest benefit is expected at the regional and global scale, especially for snow depth observations which are not yet accessible. It is typically the case of mountain areas (e.g. the Alps) where dense enough observation networks are generally not operated within the synoptic WMO network, limiting the access to the data.

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

The expected contribution from French organisations concerns mainly the maintaining of the proposed reference sites on the base of the best effort. These sites are Col de Porte, Glacioclim, Dôme C and Nivôse which are described in the individual site questionnaires.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
There are numerous potential benefits of Cryonet, not only for scientists.

From the French side, we expect benefits for our research community, especially for the modelling of different components of the cryosphere and of their interactions with the atmosphere which should profit from an easier access to key observations. A supersite like Sodankyla should emphasize its world-class characteristics as the ground-based reference site for seasonal snow remote-sensing, which should help in the development of snow data assimilation techniques as well.

We hope that making an easier access to Dôme C observations will promote research on ice-sheet remote-sensing and encourage satellite providers to use such facilities for the development, the evaluation and the calibration of new sensors.

By making an easier access to the data collected in the Alps and at Dôme C, we expect an effective feedback from a wide scientific community, which should help in the development/improvement of new models or new techniques for exploiting them.

We expect that the Cryonet data in general will become the world reference for the long-term monitoring of some key components of the cryosphere, especially for those components (e.g. snow cover) which are not yet taken in charge by a partner organisation.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
There are so many gaps in cryospheric observations that it is really difficult to give a comprehensive response. Data policy is clearly an issue which is common to many components of the cryosphere. It seems that it is mainly depending on the organisations or countries the data are coming from. By promoting an easy access to cryospheric data and to the relevant meta data through a Cryonet data portal, WMO initiative may have a real impact and considerably help in solving this issue.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

***H** - Establishment of CryoNet tier#1-tier#4 network*
***H** - Establishment of supersite network*
***L** - Harmonisation of cryospheric network*
***L** - Standards, guidelines and training for observations*
***M** - Inter-comparison experiments (e.g. sensors, methods)*
***M** - Cooperation with existing networks*
***H** - Data policy on archiving, accessibility and exchange*
***M** - Support national needs*

Germany - Matthias Bernhardt, *Ludwig-Maximilians-Universitat (LMU), Department of Geography, Group for Hydrology and Remote Sensing, Munich, Germany*

How could GCW-CryoNet help meet your national, regional or global interests?
The availability of measurements in cold environments is rare and most of the available models (hydrological models in my case) are developed on the basis of comparable small datasets. Better data availability would surely lead to a significant improvement of the existent model schemes and therewith to a better understanding of cold regions. This again would reduce the uncertainties within our predictions which would be very helpful for stakeholders like energy suppliers and water agencies.

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

- Rooms at the station for teaching and schoolings (it is also a GAWTEC station and we have had some GAWTEC meetings there)
- Long term measurements
- Evaluation of measurement schemes
- All year accessibility

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
I see following chances in the Alpine:

- Generating a standardized database of existing measurements
- Establishing comparable measurement schemes
- Ensure the maintenance of existing station networks
- Introduction of quality measures with respect to the existing measurement equipment.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
I see following deficits in the Alpine:

- Short time series
- Many data gaps
- No coordinated measurement programs
- High costs for the installation and hosting of stations
- Only a few test sites with a long term perspective are existent
- Nearly no gauged and well equipped basins in the Himalayans
- A low network density all over the world

But there are network activities which try to address this lack and CryoNet could support / include them.

Please prioritize CryoNet activities according your personal view (indicate HIGH/MEDIUM/LOW):

H *- Establishment of CryoNet tier#1-tier#4 network*
H *- Establishment of supersite network*
H *- Harmonisation of cryospheric network*
H *- Standards, guidelines and training for observations*
H *- Inter-comparison experiments (e.g. sensors, methods)*
H *- Cooperation with existing networks*
H *- Data policy on archiving, accessibility and exchange*
M *- Support national needs*

Greenland: PROMICE monitoring network along the margin of the Greenland Ice Sheet - *several colleagues who will not be at the meeting contributed to the responses below. Response coordinated by Michele Citterio, Geological Survey of Denmark and Greenland (GEUS)*

How could GCW-CryoNet help meet your national, regional or global interests?
Experience shows that in-situ observation networks have generally deteriorated over the last decades, while at the same time satellite remote sensing and modelling capability have grown significantly. Through CryoNet, the WMO is stressing the importance of in-situ monitoring of the cryosphere as ground truth for remotely sensed data, and as calibration and validation references for climate models.
The two major monitoring programmes of the Greenland Ice Sheet (the current ca. 16 GC-Net US stations and the ca. 25 PROMICE Danish stations) both have a policy of open data availability through the respective websites. It is important for the continued sustainability of existing networks that CryoNet promotes initiatives to increase the use of available in-situ data. A significant obstacle in bringing more in-situ observations into climate models is the scale gap between point-observations at sites on the ground and the grid cell size of even the highest resolution RCM models currently available. Similar issues exist for satellite products availably at daily or sub-daily repeat coverage interval. Along the margin of the Greenland Ice Sheet, where most of surface ablation takes place, these problems are compounded by the strong lateral gradients of surface elevation and of most climate parameters. However, downscaling techniques exist and have been applied successfully, so CryoNet could facilitate and promote larger validation exercises of climate models

and remote sensing products. Round robin exercises involving competing models and techniques would be most valuable in this context, and the opportunity exists at various sites in Greenland.

This would help PROMICE meet the goal of firmly anchoring climate model results to the observational record and produce a reliable surface mass balance estimate of the Greenland Ice Sheet

Finally, CryoNet may help identifying gaps and prioritizing resources for in-situ monitoring in regions where observations are scarce.

What could you or your organization contribute to the implementation of GCW-CryoNet?
PROMICE and GEUS can contribute free public access to year round weather, snow, and surface mass balance monitoring data from the margin of the Greenland Ice Sheet and from three glaciers and ice caps, both as near real-time observation and full temporal resolution datasets. Full metadata for sensor recalibration, instrument inventory and deployment history, and field logs are archived.

PROMICE can contribute expertise in modelling surface energy fluxes from weather station time series, in ground truthing airborne or satellite remote sensing products, and in calibration and validation of climate models.

PROMICE and GEUS can contribute technical know-how in all phases of system specification, hardware and software design, field deployment, continued operation, data flow management, quality assurance and public data dissemination for networks of remote autonomous weather and surface mass balance stations. All the components of the system, including satellite telemetry and power supply, are suitable for year round glacier operation at any latitude and are reliable solutions with a proven track record.

PROMICE and GEUS can contribute expertise in defining standards and guidelines for in-situ observations, and can support with training of personnel in all phases of setting up and operating a land ice-surface monitoring network in Arctic climates.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
By providing a common WMO framework and defining a set of recommended operational guidelines, CryoNet can facilitate the continued sustainability of the ground observational capability required to enable the calibration and ground truthing of remote sensing and modelling products. This would be of great benefits to all interested parties. It is important that such guidelines take into account existing success stories, both within the cryosphere community and in other WMO programmes like GAW. It is important to find a sustainable compromise between standardization and flexibility in the face of specific environmental, logistic and operational challenges. A system like the GAW QA and a multi-tiered structure may provide a good model.

Benefits for **operational network operators** – Defining a common ground of standards and guidelines harmonizing existing cryospheric networks will enable a wider user base for the available monitoring products, creating value both for the users and for the data providers. A side benefit is reduced specific training required for operators moving between sites and programmes.

Benefits for **research network operators** – Typically, research funding agencies are not particularly keen on large investments and long implementation times for ground monitoring sites. CryoNet could enable research projects to efficiently instrument the required filed site or network of sites by providing a thoroughly documented reference design for systems like for instance automatic glacier weather stations with satellite telemetry. Such reference designs should be based on proven, possibly modular solutions using readily available parts as much as possible. Further advantages would be a reduction in the risk of failed field experiments, easier budgeting and planning for the PIs and easier application assessment for the funding bodies.

Benefits for the **scientific and modelling community** – Physically based models are essential to the scientific understanding of any geophysical system, and implementing physical models often involves significant reformatting and pre-processing of data from a multitude of sources. CryoNet could reduce the effort currently required for interfacing to diverse providers and raw data specifications and formats. This may happen for instance by defining a comprehensive set of raw and derived standard data products, fully documented, which could be produced uniformly on an operational basis and archived at central facilities modelled after the GAW World Data Centres concept. One example may be time series of surface energy fluxes modelled from weather station observations, This could be started by a round-robin exercise to select the best performing models against actual observed melt.

Benefits for the **decision/policy making community** – Decision and policy makers need access to prompt, reliable and clear information. Raw monitoring data may sometime come promptly from the field, but it is neither reliable nor generally easy to interpret for non-specialists. CryoNet could help bridging this gap by promoting the development of quality assurance protocols for data validation, and by defining a limited set of clear, representative, easily communicated and understood parameters.

Benefits for **satellite data providers**: calibration and validation of higher processing level satellite data products would benefit from maintaining or increasing available ground observations. Similarly to ground network operators, providers of raw and lower processing level satellite data would benefit from stronger interaction between the remote sensing, the in-situ monitoring and the modellers communities

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
A significant challenge already mentioned above is to bridge the scale gap between point measurements on the ground and remote sensing or climate model outputs.

A somewhat similar issue to spatial upscaling is the mismatch between remote sensing products and in situ observations. In time, the remote sensing product may have either higher or lower time resolution depending on the specifics of the algorithms used to produce comparable ground and space estimates of geophysical variables
Precipitation, snow density and snow redistribution by wind are three difficult parameters to monitor at remote automatic stations. CryoNet may help by promoting continued intercomparison exercises of existing techniques, instruments and models, and by promoting the definition and adoption of standard procedures to make measurements at different sites more comparable.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

H *- Establishment of CryoNet tier#1-tier#4 network*
M *- Establishment of supersite network*
M *- Harmonisation of cryospheric network*
H *- Standards, guidelines and training for observations*
L-H *- Inter-comparison experiments (e.g. sensors, methods). Low for field instruments and methods; High for derived products like model and remote sensing product validation*
M *- Cooperation with existing networks*
M *- Data policy on archiving, accessibility and exchange*
L-H *- Support national needs. It is impossible to distinguish between national and international needs, as national needs politically are defining international needs and the availability of funding).*

6. Please share any other thoughts for participant to consider at the meeting:
Some low level technicalities are nevertheless essential for basic quality assurance:

- a properly specified, documented and enforced sensor recalibration plan is essential
- systematic inventory and tracking of the deployment history of each sensor are essential
- systematic recording of metadata before and after any intervention on field instruments using predefined checklists and forms are essential
- somewhere, sometime, even the best executed field operation will fail on one of the above: have a plan for not wasting slightly sub-standard observations – they just happen.

Greenland: Arctic Station, Disko Island (West Greenland) - *submitted by Birger Ulf Hansen, responsible for terrestrial snow and ice-related data, Faculty of Science, University of Copenhagen*

How could GCW-CryoNet help meet your national, regional or global interests?
Distribution of our monitoring data for climate change studies – a national contribution to the Arctic Council AMAP program for climate change.
Review and circumpolar studies on ecosystem dynamics where snow and ice are major factors.

What could you or your organization contribute to the implementation of GCW-CryoNet?
CENPERM (Centre for Permafrost dynamics in Greenland) at Department of Geography and Geology, Copenhagen University can deliver snow, ice and climate observation data from this Low-Arctic site, where a broad scale of ecosystem variables are being monitored.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
CryoNet can be a central network for setting standards for snow and ice monitoring as well as being a main distribution network for monitoring data from individual sites. This will greatly help up-scaling (e.g. of ecosystem processes) and modelling (e.g. snow distribution) through models like SnowModel, satellite products etc.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
Winter precipitation is currently not well described and represented in reanalysis data as e.g. North American Regional Reanalysis data. A structured sampling and use of data through a monitoring network might greatly improve this.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):
H - *Establishment of CryoNet tier#1-tier#4 network*
M - *Establishment of supersite network*
H - *Harmonisation of cryospheric network*
H - *Standards, guidelines and training for observations*
H - *Inter-comparison experiments (e.g. sensors, methods)*
H - *Cooperation with existing networks*
M - *Data policy on archiving, accessibility and exchange*
M - *Support national needs*

Please share any other thoughts for participant to consider at the meeting:
We believe it is important to outline and set high standards for snow and ice monitoring data. However, in order to get as much data included in the network the tier-network should be established with clearly defined demands for every tier. This is similar to other programs like ICOS, CALM a.o. Tiers should be defined so all related and “useable” data are possible to include in the network.
High emphasis should be directed towards covering the different climatic (boreal, Low-Arctic, High-Arctic) as well as regional (circumpolar) regions.

Greenland: Nuuk (West Greenland) - *with contributions from the programme managers of the Nuuk terrestrial and climate components within GEM Greenland Ecosystem Monitoring*

How could GCW-CryoNet help meet your national, regional or global interests?
Distribution of our monitoring data for climate change studies – a national contribution to the Arctic Council AMAP program for climate change
Review and circumpolar studies on ecosystem dynamics where snow and ice are major factors

What could you or your organization contribute to the implementation of GCW-CryoNet?
The Greenland Ecosystem Monitoring program can deliver snow, ice and climate observation data from a High-Arctic (Zackenberg) and a Low-Arctic (Nuuk) site on Greenland where a broad scale of ecosystem variables are being monitored.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
CryoNet can be a central network for setting standards for snow and ice monitoring as well as being a main distribution network for monitoring data from individual sites. This will greatly help up-scaling (e.g. of ecosystem processes) and modelling (e.g. snow distribution) through models like SnowModel, satellite products etc.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
Winter precipitation is currently not well described and represented in reanalysis data as e.g. North American Regional Reanalysis data. A structured sampling and use of data through a monitoring network might greatly improve this.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

H *- Establishment of CryoNet tier#1-tier#4 network*
M *- Establishment of supersite network*
H *- Harmonisation of cryospheric network*
H *- Standards, guidelines and training for observations*
H *- Inter-comparison experiments (e.g. sensors, methods)*
H *- Cooperation with existing networks*
M *- Data policy on archiving, accessibility and exchange*
M *- Support national needs*

Please share any other thoughts for participant to consider at the meeting:
We believe it is important to outline and set high standards for snow and ice monitoring data. However, in order to get as much data included in the network the tier-network should be established with clearly defined demands for every tier. This is similar to other programs like ICOS, CALM a.o. Tiers should be defined so all related and "useable" data are possible to include in the network.
High emphasis should be directed towards covering the different climatic (boreal, low-Arctic, High-Arctic) as well as regional (circumpolar) regions.

Greenland: Sermilik Station (East Greenland) - *Response coordinated by Michele Citterio, Geological Survey of Denmark and Greenland (GEUS)*

How could GCW-CryoNet help meet your national, regional or global interests?
It is always of interest to us to be part of global, international networks, to be able to do intercomparisons and method standardizations within such networks, and in general to be able to broaden our knowledge of the Arctic environment. Furthermore, the network might aide in educational possibilities on Greenlandic and arctic environments.

What could you or your organization contribute to the implementation of GCW-CryoNet?
We are responsible for a monitoring programme of a particular site in Southeast Greenland with a long record of monitoring of the glacier evolution, climatic variables and sediment transport characteristics. We are able to aide in providing access to the site, local knowledge of the area and other logistical needs in that perspective. We already collaborate with other international networks such as INTERACT, SCANNET and SEDIBUD.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
Intercomparability, standardisation of methods and increasing data availability.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
Measurements of other data than climate variables such as precipitation, wind characteristics and solar radiation. There is e.g. a lack of a more broad snow monitoring activity to study snow cover, density, water/ice content and in this way be able to understand melt-runoff routings and the timing of thawbreak and

freeze-up. Furthermore, a better understanding of the sediment transport processes through glacial erosion and the linkage to the ocean is needed.

These issues might be addresses by establishing a network of intercomparable snow monitoring stations and self-logging hydrometric stations in glacial meltwater outlet rivers, and/or by implementation of remote sensing techniques.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

M *- Establishment of CryoNet tier#1-tier#4 network*
M *- Establishment of supersite network*
H *- Harmonisation of cryospheric network*
H *- Standards, guidelines and training for observations*
H *- Inter-comparison experiments (e.g. sensors, methods)*
H *- Cooperation with existing networks*
H *- Data policy on archiving, accessibility and exchange*
M *- Support national needs*

Greenland: Zackenberg (Northeast Greenland) - *with contributions from the programme managers of the Zackenberg glaciological, terrestrial and climate components within GEM Greenland Ecosystem Monitoring*

How could GCW-CryoNet help meet your national, regional or global interests?
Distribution of our monitoring data for climate change studies – a national contribution to the Arctic Council AMAP program for climate change
Review and circumpolar studies on ecosystem dynamics where snow and ice are major factors

What could you or your organization contribute to the implementation of GCW-CryoNet?
The Greenland Ecosystem Monitoring program can deliver snow, ice and climate observation data from a High-Arctic (Zackenberg) and a Low-Arctic (Nuuk) site on Greenland where a broad scale of ecosystem variables are being monitored.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
CryoNet can facilitate the continued sustainability of the ground observational capability required to enable the calibration and ground truthing of remote sensing and modelling products. CryoNet may help promote in situ monitoring in regions where observations are scarce, improve the monitoring of ‘difficult’ parameters such as precipitation, and promote process studies relying on a coordinated infrastructure of existing supersites.

CryoNet can be a central network for setting standards for snow and ice monitoring as well as being a main distribution network for monitoring data from individual sites. This will greatly help up-scaling (e.g. of ecosystem processes) and modelling (e.g. snow distribution) through integration of modelling, ground monitoring and remote sensing.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
Winter precipitation is currently not well described and represented in reanalysis data as e.g. North American Regional Reanalysis data. A structured sampling and use of data through a monitoring network might greatly improve this.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

H *- Establishment of CryoNet tier#1-tier#4 network*
M *- Establishment of supersite network*
H *- Harmonisation of cryospheric network*
H *- Standards, guidelines and training for observations*
H *- Inter-comparison experiments (e.g. sensors, methods)*
H *- Cooperation with existing networks*

M - Data policy on archiving, accessibility and exchange
M - Support national needs

Please share any other thoughts for participant to consider at the meeting:
We believe it is important to outline and set high standards for snow and ice monitoring data. However, in order to get as much data included in the network the tier-network should be established with clearly defined demands for every tier. This is similar to other programs like ICOS, CALM a.o. Tiers should be defined so all related and "useable" data are possible to include in the network.
High emphasis should be directed towards covering the different climatic (boreal, low-Arctic, High-Arctic) as well as regional (circumpolar) regions.

Greenland: Summit Station - *Response prepared by Bob Hawley, Summit (Greenland) Science Coordination Office, USA as a national contribution within IASOA*

How could GCW-CryoNet help meet your national, regional or global interests?
Anytime we link data with other international partners, we all benefit.

What could you or your organization contribute to the implementation of GCW-CryoNet?
A wide variety of observations in a year-round, staffed station in a unique (polar ice sheet) environment in the Northern hemisphere.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
To have a unified and spatially distributed array of environmental monitoring data will be invaluable to not only the research community, but also (with sufficient digestion) the decision makers/policymakers.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
The existence of a unified portal for cryospheric observations in a trans-national sense- this looks like exactly what CryoNet is aiming to be.

Iceland - *Response from Iceland, co-ordinated by Thorsteinn Thorsteinsson, Icelandic Met. Office*

How could GCW-CryoNet help meet your national, regional or global interests?
National interests: Ice caps and glaciers cover 10% of the area of Iceland. Cryospheric components strongly affect the country´s natural environment and glacial meltwater is harnessed to produce 70% of the electricity supply. In changing climates, changes in glacier extent and meltwater runoff affect energy production and general infrastructure. Moreover, several natural hazards are associated with snow cover (avalanches) and glaciers (flash floods, subglacial eruptions). Careful monitoring of ongoing changes within a larger, international framework is thus important for society in general, including tourism.

Regional interests: Iceland´s temperate ice caps are located in the maritime and climate-sensitive North-Atlantic region. Displaying high annual rates of accumulation and ablation, they have proven to be sensitive cryospheric indicators of climate variability. Research and monitoring within the framework of GCW-Cryonet would help consolidate collaboration between glaciologists in the Nordic countries, focussing on the effect of climate change on all glaciated regions bordering on the North Atlantic Ocean: Greenland, Iceland, Svalbard and Scandinavia.

Global interests: Few large glaciated areas in the world are better monitored in terms of their contribution to ongoing sea-level rise than Iceland. Issues remain concerning biases in existing mass balance records from glaciers, remote sensing of snow cover extent and snow water equivalent, and the development of glacial and snowmelt runoff in projected warmer climates. Improvement of this situation can be expected through international collaboration within CryoNet and related programs.

What could you or your organization contribute to the implementation of GCW-CryoNet?
The Icelandic Meteorological Office (IMO) has governmental mandate to monitor key aspects of the natural environment in Iceland, including the cryosphere. The institute currently runs research and monitoring programs related to glacier mass balance, glacioclimatology and glaciohydrology. IMO has expressed interest in taking the lead in developing an Icelandic component in GCW-CryoNet, in close cooperation with the University of Iceland and other institutes.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?

Perhaps this is too early to tell, since the CryoNet concept is still under development. One obvious benefit would be improved standardization of mass balance measurement methods. Satellite determination of snow water equivalent (SWE) over large regions that cannot be covered with station data is another important issue – validation from ground-based data collected at stations operated within CryoNet would also be of key importance.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
Databases on glacier outlines and glacier volumes worldwide need to be improved. Regular mass-balance studies on selected benchmark glaciers in the Third Pole Region (Himalayas, Tibet) should be carried out under the auspices of an international organization. Regular observations of water systems are needed in selected glaciers and ice caps, in order to increase understanding of englacial and subglacial water movement, its effect on glacier flow, its relation to atmospheric warming and to subglacial geothermal/volcanic areas.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

H *- Establishment of CryoNet tier#1-tier#4 network*
H *- Establishment of supersite network*
M *- Harmonisation of cryospheric network*
H *- Standards, guidelines and training for observations*
H *- Inter-comparison experiments (e.g. sensors, methods)*
M *- Cooperation with existing networks*
H *- Data policy on archiving, accessibility and exchange*
M *- Support national needs*

Please share any other thoughts for participant to consider at the meeting.
Two possibilities for defining a **cryospheric supersite** in Iceland are currently being evaluated:

1. To define Iceland (which has 10% glacial cover and abundant glacial meltwater runoff and where substantial part of the precipitation falls as snow) as a supersite and configure several of the existing cryosphere-related monitoring systems in the country to serve GCW needs.

2. To define a particular glacier/ice cap region in Iceland as a supersite. In this case, a region where groundbreaking research can be conducted should be selected. Studies of subglacial water flow beneath the western part of the Vatnajökull ice cap have been suggested as possible GCW-related focus.

Subglacier water flow is now recognised as one of the most important physical processes that affect the flow of ice sheets and glaciers. Iceland offers a natural laboratory for studying glacier hydrology with its extensive network of hydrometric stations in glacial rivers and easily accessible glaciers for various field studies. Data collected on jökulhlaup floods from Grímsvötn and nearby locations on Vatnajökull were crucial for the development of modern theories of subglacial water flow in tunnels at the base of glaciers and ice sheets. New efforts within the framework of GCW-CryoNet could build on this legacy, by supporting new measurement programs and theoretical studies related to the melting, storage and flow of subglacial meltwater beneath Vatnajökull. Such studies would tie in with ongoing monitoring of subglacial volcanism, research on the effect of atmospheric warming on ice-cap mass balance and with studies of the biology of subglacial water bodies beneath Vatnajökull, one of few ice masses on Earth besides Antarctica that host subglacial lakes.

The Institute of Earth Sciences (IES), University of Iceland, conducts research on the mass balance, hydrology and dynamics of glaciers in Iceland. IES researchers also study subglacial volcanism and monitor volcanic hazards in collaboration with IMO and the Civil Protection Department (CPD).

The Icelandic Glaciological Society owns a well-equipped hut at Grímsvötn that can house up to 20 scientists and technicians, and advanced logistics – including heavy transport by snow-tractors – can be operated in the region.
The Icelandic Meteorological Office (IMO) operates more than 200 weather stations and 170 hydrometric stations throughout the country. Snow thickness measurements are regularly performed at manned stations and more detailed monitoring of snow cover is carried out in regions where avalanche hazards are present. The Iceland-wide networks of IMO can monitor hazards related to subglacial volcanism, including the real-time seismological stations, GPS stations and radar systems. Relevant parts of this network could be configured to serve the needs of the CryoNet station network.

Japan - *Response from Teruo Aoki, Japan Meteorological Agency*

How could GCW-CryoNet help meet your national, regional or global interests?
Since the observational data in cryosphere such as polar regions and high altitude regions are in general scarce, those data organized by GCW-CryoNet could be helpful for the initial data to be used for weather forecast by Japan Meteorological Agency (JMA), especially for long-term prediction. The important regions for Japan are Siberia, Arctic Ocean and Tibetan Plateau.
Abrupt snow and ice melting in the Arctic is also of concern for Japanese people because of potential sea level rise in the near future, economical influence and the relevant climate change induced by the cryospheric change. GCW-CryoNet data and knowledge could help to improve climate model as well as advance of our scientific understandings of cryosphere.

What could you or your organization contribute to the implementation of GCW-CryoNet?
It is possible to implement some stations in Antarctica, Ny-Alesund, and Greenland. The stations in Antarctica and Ny-Alesund are operated by National Institute of Polar Research (NIPR), and those in Greenland by Meteorological Research Institute (MRI) of JMA. Syowa Station in Antarctica is operated by JMA. Many weather stations and observatories in Japan are potentially candidates for CryoNet, but discussion is needed in JMA.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
To know accurate present states of cryosphere is most important. In-situ and satellite monitoring data are important benefits of CryoNet for operational and research network operators. Projections of future cryosphere and the influence to the other areas contain large uncertainties. The benefits of CryoNet are for scientists concerning process studies and modeling studies as well as decision/policy making community.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
The present observations in cryosphere have not always same purpose. So, thematic, spatial, temporal, availability, exchange, and data policy are in general different. How do we coordinate those different observations? To define standards and guidelines for those conditions depending on tier#1-tier#4 is necessary.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):
- ***H*** *- Establishment of CryoNet tier#1-tier#4 network*
- ***M*** *- Establishment of supersite network*
- ***M*** *- Harmonisation of cryospheric network*
- ***H*** *- Standards, guidelines and training for observations*
- ***H*** *- Inter-comparison experiments (e.g. sensors, methods)*

__H__ - Cooperation with existing networks
__H__ - Data policy on archiving, accessibility and exchange
__M__ - Support national needs

Japan - *Response from Tetsuo Ohata, Japan Agency for Marine-Earth Science and Technology*

How could GCW-CryoNet help meet your national, regional or global interests?
If CryoNET have function of recommending observation network to various countries on global cryosphere, systematic planning or implementation of observation sites would be easier in the country, and may happen that the observation presently made on voluntary or research basis may be, some, to semi-operational conditions.

What could you or your organization contribute to the implementation of GCW-CryoNet?
Our organization, JAMSTEC and several other Japanese Institute has observation network in circum-Arctic terrestrial and ice sheet region and Antarctica, and JAMSTEC and NIPR make periodic observation of Arctic and Antarctic Sea.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
CryoNET will be basis for the data archive to be used for analytical research activity and verification of various models.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
(1) Many works are done under, research basis, that means made from scientific interest and dis-continuity. As for the basis of regional/global analysis, GCM or earth system model spatially homogenous network would be recommended.
(2) Basic physical/chemical condition is not understood well, such as glacier thickness, ice amount and carbon stock in permafrost region.
(3) Many cryosphere information detecting changes are based on satellite measurement, but under changing earth, continuous measurement of ice temperature profile network especially on ice sheet and also so in permafrost, which does not exist, need to be established.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):
__H__ - Establishment of CryoNet tier#1-tier#4 network
__H__ - Establishment of supersite network
__M__ - Harmonisation of cryospheric network
__M__ - Standards, guidelines and training for observations
__M__ - Inter-comparison experiments (e.g. sensors, methods)
__H__ - Cooperation with existing networks
__M__ - Data policy on archiving, accessibility and exchange
__M__ - Support national needs

Please share any other thoughts for participant to consider at the meeting.
(1) Presently, many important observation of cryosphere is made on research (small group with small short-term money) basis. Some, which is highly important, needs to be shifted to semi-operational basis in order to maintain them as continuous data-sets. GCW should recommend countries to do so as much as they can. In doing this, global CryoNet network need to rank or show priority among the observation being done, and also to the ones to be recommended.
(2) How are we going to treat the past taken cryosphere data? As a example, snow cover data (whole set of physical parameter of snow cover by pit-work, made every week in winter from the 1950s to 2000 in Sapporo), not done now because it's too laborious.

Russian Federation: AARI (ocean) - *submitted by Vasily Smolyanitsky, Arctic and Antarctic Research Institute (AARI) of Roshydromet, St. Petersburg, Russian Federation*

How could GCW-CryoNet help meet your national, regional or global interests?
Improve information coverage up to pan-Arctic and pan-Antarctic and its diversity including marine safety.

What could you or your organization contribute to the implementation of GCW-CryoNet?
AARI contribution may include a) year-round measurements at a point at "North Pole drifting station" b) regional and close to pan-Arctic Ocean sea ice analysis c) presentation of information in the Eurasian Arctic as geo-services.
What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
All stated

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
There are still gaps between the level of information available and assimilated in studies.
Lower periodicity of analysis in the Southern Ocean in comparison to the Arctic in comparison to resources available.
Data policy should be improved for high resolution satellite imagery.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):
- ***H*** *- Establishment of CryoNet tier#1-tier#4 network*
- ***H*** *- Establishment of supersite network*
- ***M*** *- Harmonisation of cryospheric network*
- ***H*** *- Standards, guidelines and training for observations*
- ***M*** *- Inter-comparison experiments (e.g. sensors, methods)*
- ***H*** *- Cooperation with existing networks*
- ***H*** *- Data policy on archiving, accessibility and exchange*
- ***M*** *- Support national needs*

Switzerland: WSL Institute for Snow and Avalanche Research (SLF), Davos - *Dr. Charles Fierz, WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland*

How could GCW-CryoNet help meet your national, regional or global interests?
WSL Institute for Snow and Avalanche Research SLF, Davos (http://www.slf.ch): maintain a high-level observation programme at the current study site of our institute for national and regional assessment studies. The site was recognized to be very valuable for monitoring and acquiring time series of both snow depth HS and snow water equivalent SWE.

What could you or your organization contribute to the implementation of GCW-CryoNet?
Actual study site as well as possible new observation sites; institution with broad interests in monitoring, now- and forecasting, climate related topics.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
Sustained observing programme of some ECV; exchange of data and experience with other organisations.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
Exchange of data among organizations; data policy

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):
- ***H*** *- Establishment of CryoNet tier#1-tier#4 network*
- ***L*** *- Establishment of supersite network*
- ***M*** *- Harmonisation of cryospheric network*
- ***M*** *- Standards, guidelines and training for observations*

M - Inter-comparison experiments (e.g. sensors, methods)
H - Cooperation with existing networks
H - Data policy on archiving, accessibility and exchange
H - Support national needs

Please share any other thoughts for participant to consider at the meeting.
Considering data quality as much as the number of measurable parameters at one site. The state-of-the-art should allow sorting out what variables need continuous monitoring and what others could be observed depending on requirements of, for example, calibration campaign.

United Kingdom - *Steve Colwell, British Antarctic Survey, Cambridge, UK*

How could GCW-CryoNet help meet your national, regional or global interests?
I see that it would help enhance the science that can be done at BAS both in the Antarctic and the Arctic.

What could you or your organization contribute to the implementation of GCW-CryoNet?
We can make available the data that we collect in Antarctica and also I have contacts at many of the other national operators in Antarctic and can get data from them as well.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
Being able to access the data via a single portal would have tremendous advantages in assisting in research and also to support WMO's Global Integrated Polar Prediction System (GIPPS) and the Global Framework for Climate Services (GFCS).

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these*?*
Sea ice observation in the Antarctic.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low)*:*
H - Establishment of CryoNet tier#1-tier#4 network
H - Establishment of supersite network
L - Harmonisation of cryospheric network
H - Standards, guidelines and training for observations
M - Inter-comparison experiments (e.g. sensors, methods)
H - Cooperation with existing networks
H - Data policy on archiving, accessibility and exchange
L - Support national needs

United States: Barrow, Alaska *(Response prepared by Brian Vasel, NOAA, Barrow USA as a national contribution within IASOA)*

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

What could you or your organization contribute to the implementation of GCW-CryoNet?
Provide a long-term, staffed research site at Barrow, AK.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?

Please prioritize CryoNet activities according your personal view (indicate HIGH/MEDIUM/LOW):

H - *Establishment of CryoNet tier#1-tier#4 network*
M - *Establishment of supersite network*
L - *Harmonisation of cryospheric network*
M - *Standards, guidelines and training for observations*
M - *Inter-comparison experiments (e.g. sensors, methods)*
H - *Cooperation with existing networks*
H - *Data policy on archiving, accessibility and exchange*
H - *Support national needs*

International Arctic Systems for Observing the Atmosphere (IASOA) - *All questions are addressed from the standpoint of the coordinating efforts of IASOA and how GCW advances the mission of IASOA. Response coordinated by Sandy Starkweather, IASOA Project.*

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

IASOA is an international consortium, representing independent observatories for collective objectives. These responses do not aim at the individual benefits to those observatories (submitting separately), but at the collective synergies between IASOA as a whole and Cryo-Net.

IASOA currently leverages the concept of a "network of networks" in several ways:

a. Identifying regional observing gaps
b. Facilitating data sharing
c. Contributing to cross-site synthesis science

GCW-CryoNet would help us meet all of these goals by:

a. Recommending core, vital measurements at IASOA observatories (i.e. creating a target to aim for).
b. Facilitating intercomparable inventories of current measurements; identifying gaps through structured reporting tools.
c. Recommending best practices for measurements, data representations, error correction, data vocabularies, metadata standards, etc.
d. Developing synthesis science objectives as rallying points for national funding agencies, etc. Both cross-site objectives and interdisciplinary single-site objectives are important.
e. Providing synergies and reach back in relevant Arctic Council working groups so that all IASOA and CryoNet measurements are put to best use in working group activities. It has been recognized that observational data is not always well-integrated into WG reports (e.g. SLCF's)

NOTE: in the U.S. context, WMO activities and international coordination are not necessarily well-supported by discovery funding agencies like the U.S. National Science Foundation (NSF). Developing support within NSF for WMO organized objectives would be useful for developing funding for U.S. support.

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

a. One of our current key activities is the development of standardized, interoperable meta-data for all IASOA observatories. We are already using the GCW controlled vocabulary for organizing cryospheric measurements at the facilities. We are implementing the WMO-GAW core ISO metadata standard. Through this, we are promoting common, WMO-based organizational principles for data sharing.
b. Through our steering committee and WG activities, we are identifying high priority science themes which we hope become a mechanism for synchronizing international funding towards cross-site research objectives. Through coordination with GCW-CryoNet, we build a bigger community of common interest and input.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?

The benefits are entirely contingent upon the intentional engagement of these communities. CryoNet should view itself as an end-to-end provider. All of the above (operations, modelling, decision/policy, scientists, etc.)

should be engaged in defining the requirements of the network. GCW CryoNet could serve as the "one stop shopping" catalogue for information and data sharing.
The design of CryoNet should be informed from the outset by decision-relevant indices and contributions to operational monitoring requirements. There should be an intentional stakeholder research component to the development of the network and these indices. This could serve as an example to other observational networks to assure that relevance outside the science community is built in at the ground level. The iconic nature of sea ice minimums and Keeling curves should serve as the model for telling compelling stories about environmental change.

With common reporting and data management practices, stakeholder informed data formatting (e.g. consultations with the modelling community about what they will be able to put to immediate use in models with minimal efforts), GCW-CryoNet will make immediate contributions to relevant communities.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
An International Central Arctic Drift Observatory. CryoNet could make the coordination and creation of such an entity an organizational objective.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

M *- Establishment of CryoNet tier#1-tier#4 network*
H *- Establishment of supersite network*
H *- Harmonisation of cryospheric network*
M *- Standards, guidelines and training for observations*
M *- Inter-comparison experiments (e.g. sensors, methods)*
H *- Cooperation with existing networks*
H *- Data policy on archiving, accessibility and exchange*
M *- Support national needs*

European Centre for Medium-Range Weather Forecasting – *Dr. Gianpaolo Balsamo, ECMWF*

- See Annex 6 (Doc. 4.2.1)

International Association of Cryospheric Sciences (IACS) - *Dr. Charles Fierz, President- Elect, on behalf of IACS*

How could GCW-CryoNet help meet your national, regional or global interests?
International Association of Cryospheric Sciences IACS (http://www.cryosphericsciences.org)**:** the two objectives of IACS listed below perfectly fit the two goals listed below:
- 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
- to facilitate the standardisation of measurement or collection of data on cryospheric systems and of the analysis, archiving and publication of such data.

What could you or your organization contribute to the implementation of GCW-CryoNet?
Provide a link to the cryospheric scientific community. Help set up standards etc. independently of national considerations.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?
Shared access to high quality present and past data series for both the scientific and operational community.

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?
Common practices and common data policies. Application of standards. Sustained observational network and valorization of data monitoring.

Please prioritize CryoNet activities according your personal view (indicate High/Medium/Low):

- ***H*** *- Establishment of CryoNet tier#1-tier#4 network*
- ***L*** *- Establishment of supersite network*
- ***H*** *- Harmonisation of cryospheric network*
- ***H*** *- Standards, guidelines and training for observations*
- ***H*** *- Inter-comparison experiments (e.g. sensors, methods)*
- ***M*** *- Cooperation with existing networks*
- ***M/H*** *- Data policy on archiving, accessibility and exchange*
- ***L*** *- Support national needs*

Please share any other thoughts for participant to consider at the meeting.
Put an emphasis on the exchange of long term "scientific" and "operational" data series

ANNEX 4

GCW-CRYONET SITE QUESTIONNAIRE AND RESPONSES

One of the top priorities of the GCW is the initiation of CryoNet, the surface-based observational network. Engagement of participants in advance of the meeting was essential so that background information could be shared before the meeting itself. This first implementation workshop for CryoNet was to define the types of surface sites, such as supersites, reference sites, and/or tiered sites in cold climate regions, on land or sea, operating a sustained, standardized programme for observing and monitoring as many cryospheric variables as possible. GCW would also initiate the development of formal procedures for establishing the GCW network, evaluate potential supersites, discuss measurement standards, and explore data availability and exchange. CryoNet aims to build on existing sites first.

To start the GCW-CryoNet discussion prior to the meeting and to share participants' thoughts on the purpose and benefits, structure and scope of the network, participants were asked to describe sites that they operate by completing a site questionnaire or providing the information in some other form.

Additional Information:

Participants are referred to the outcomes of the First GCW implementation meeting and the current Implementation Plan (INF. 2 and 5 in the documentation plan, http://www.wmo.int/pages/prog/www/OSY/Meetings/GCW-CN1/DocPlan.html) for discussion to date on CryoNet. Annex 8 of the Final Report of the first GCW meeting provided some examples of what countries suggested that a supersite and a reference site might include.

Discussion at the meeting focussed on refining the CryoNet network strategy and the levels of observation. Incorporation into CryoNet, i.e., becoming a GCW site, is not a matter of self-definition of the proposer, but rather a well-defined appointment from GCW according to certain criteria. CryoNet, through its observational network of sites, should collectively contribute to the global status of the cryosphere through regular GCW-reports and/or annual statements on the national, regional or global state of the cryosphere. "Supersites", for example, would have a common frame of observational aims, yet the special focus of each one should be according to the regional environment. Thus, the program of a mountain supersite could, and one would expect would be different from that of a polar supersite.

Initial concepts for supersite, reference sites, observing sites, or other types of cryosphere observing sites were the focus of the breakout sessions at the meeting. CryoNet aims initially to build on existing and planned cryosphere observing programmes at observatories and in other operational and research observing networks. The responses to the questionnaire provided an initial inventory of the types of sites and networks which might be a basis for developing CryoNet sites.

GCW-CRYONET SITE QUESTIONNAIRE:

The questionnaire is listed below. Participants/contributors were asked to complete the tables below, to the extent reasonable, if they operated one or more sites. If they already had a site description in another format, they could submit that instead.

Site specific metadata:	
Name of site:	
Latitude/Longitude/Altitude:	
Landscape type (e.g. arctic coastal, tundra, alpine…):	
Onsite technical staff:	
All-year round observations y/n:	Year established:
Link to website if available:	
Station manager (Email):	
Organisation in charge of station:	
Other information	

Monitoring of the atmosphere:	
Solid precipitation:	Snowfall:
Trace gases:	
Aerosols	
UV, stratospheric ozone	
Radiation (longwave, shortwave)	
Others:	

Snow cover
Physical parameters:
Chemical parameters:
Others:

Glaciers and ice caps

Mass balance (measured parameters):
Ice flow (measured parameters):
Basal water pressure (measured parameters):
Others:

Sea ice
Mass balance (measured parameters):
Meteorology: radiation, air temperature, humidity, wind speed and direction, air pressure (measured parameters):
Snow on ice (measured parameters):
Ice chemistry (measured parameters):
Others:

Permafrost
Borehole measurements (measured parameters):
Meteorology: radiation, air temperature, humidity, wind speed and direction, air pressure (measured parameters):
Snow on ground (measured parameters):
Active layer thickness (measured parameters):
GST:
Others:

Ice sheet
Mass balance (measured parameters):
Meteorology: radiation, air temperature, humidity, wind speed and direction, air pressure (measured parameters):
Snow on ice (measured parameters):
Ice chemistry (measured parameters):
Others:

Other measurements (hydrological, ecological, oceanographic, etc)
Hydrology (measured parameters): Ecology (measured parameters) Oceanography (measured parameters): Other thematic linkages:

Linkages to satellite data (describe validation programs, applications of satellite data, etc.)

Participation in international monitoring programmes such as GAW, GTN-G, GTN-P, ….
Networks and start of contribution:

RESPONSES TO GCW-CRYONET SITE QUESTIONNAIRE

The individual responses of participants and contributors to the site questionnaire may be accessed by clicking on the link in the table below. Sites are listed by country. The complete set of responses may be downloaded as a zip file using an on-line link through the CryoNet documentation plan (http://www.wmo.int/pages/prog/www/OSY/Meetings/GCW-CN1/DocPlan.html).

NO.	COUNTRY / SITE NAME
ANTARCTIC	
1.	Halley (UK)
2.	Dome C (France/Italy)
3.	Syowa (Japan)
AUSTRIA	
4.	Sonnblick Observatory
CANADA	
5.	Upper Kaskawulsh
6.	Milne Ice Shelf
7.	National Permafrost Network
8.	Mount Pearl (St John's)
9.	Iqualuit
10.	Eureka
11.	CARE
12.	Caribou Creek
13.	Bratt's Lake
14.	PEARL, Eureka
15.	GAW Observatory and Alert Weather Station
CHINA	
16.	Tianshan
17.	Mt. Everest
18.	Tanggula
19.	Qilianshan
20.	Nam Co
21.	Koxkar Glacier
22.	Yulong Snow Mountain
23.	China 01
24.	China 02
25.	China 03
26.	China 04
27.	China 05

NO.	COUNTRY / SITE NAME
28.	China 06
29.	China QT01
30.	China QT02
31.	China QT03
32.	China QT04
33.	China QT05
34.	China QT06
35.	China QT07
36.	China QT08
37.	China QT09
38.	China QTB01
39.	China QTB02
40.	China QTB03
41.	China QTB04
42.	China QTB05
43.	China QTB06
44.	China QTB07
45.	China QTB09
46.	China QTB11
47.	China QTB15
48.	China QTB16
49.	China QTB18
50.	China TGLMS
51.	China WDLMS
52.	China XDTGT
53.	China XDTMS
DENMARK & GREENLAND	
54.	Coastal stations
55.	Promice network
56.	Sermilik
57.	Nuuk
58.	Zackenberg
59.	Disko Island
60.	Summit (by USA)
61.	Sigma-A (by Japan)
62.	Sigma-B (by Japan)

NO.	COUNTRY / SITE NAME
FINLAND	
63.	Sodankylä-Pallas
FRANCE	
64.	Nivose
65.	Col de Porte
66.	GLACIOCLIM (Global sites)
GERMANY	
67.	Nationalpark Berchtesgaden
68.	Zugspitze-Schneefernerhaus
ICELAND	
69.	All sites
JAPAN	
70.	Uonuma Basin, Snow (J-S-4)
71.	Oshirakawa (J-S-3)
72.	Ishikawa (J-S-1)
73.	SW-Net Snow (J-S-5)
74.	Nakayama Pass (J-S-2)
MONGOLIA	
75.	Potanin Glacier, Altai Mountains (by Japan)
76.	Nalaikh (by Japan)
77.	Permafrost Obs. Network (by Japan)
NORWAY	
78.	Svalbard Integrated Arctic Earth Observing System (SIOS), sites
79.	Rabben Station in Ny-Alesund (by Japan)
RUSSIAN FEDERATION	
80.	Tiksi Hydrometeorological Observatory
81.	North Pole drifting station
82.	Elegeli, Ust-maya (by Japan)
83.	Tiksi (by Japan)
84.	Chokurdakh (by Japan)
85.	Permafrost Obs. Network, Siberia (by Japan)
86.	Spasskayapad, Yakutsk (by Japan)
SWITZERLAND	
87.	Weissfluhjoch/Davos
USA	
88.	Barrow

NO.	COUNTRY / SITE NAME
89.	Poker Flat, Alaska (by Japan)
90.	Permafrost Obs. Network, Alaska (by Japan)

ANNEX 5

GCW-CryoNET: Some Initial Thoughts

W. Schöner, CryoNet Lead

W. Schöner provided some initial thoughts on CryoNet that would be an initial point for the breakout discussions. This was to provide a starting point from which the CryoNet framework could be built. It incorporates ideas presented at GCW-IM-1 and the examples of sites provided by countries, such as Finland and China (Annex 8, GCW-IM-1).

Three levels are envisaged: Supersite - reference site – observation sites are suggested (the classification is indicative and the labels of each class needs to be adjusted considering existing classifications of various cryospheric monitoring networks (WGMS, IACS, GTN-P, ….). It is important not to downgrade the quality rating of existing networks. Initial aims, standards for measurements, data availability, and monitoring components are suggested. THESE ARE FOR DISCUSSION ONLY.

1) Tier 1 CryoNET sites (tentative name SUPER-SITE)

SUPER-SITE: = CryoNET station which monitors the physical and chemical properties of all components (GCW focal areas) of the local cryosphere in its full complexity and at the highest quality standards as well as the interaction of local/regional atmosphere. It has established linkages to satellite observations and to other disciplines such as hydrology, oceanography, ecology, etc.). In many cases the stations are supported by more than one research agency, have a strong scientific supporting programme and provide facilities for intensive campaigns. Super-sites are stations/observatories with on-site personal for maintaining the monitoring and scientific experiments. Super-site is a "high-level seal" of WMO-GCW for cryospheric observations similar as GAW global station.

Aims:
a)Monitoring of changes of the physical and chemical properties of the cryosphere with respect to changes of the atmosphere (climate) and including interactions between different components of the cryosphere
b) Linkage of ground truth with satellite observations (ground truth, calibration, merge both information …) in order to monitor the global cryosphere at high spatial and temporal scale
c) Estimation of the impact of changes of cryosphere on hydrology, water management, ecology, …
d) Extensive datasets for cryospheric modelling approaches (validation, calibration)
e) Training of personal for cryospheric observations
f) Extensive information to the public

Standards for measurements:
Atmosphere: WMO, GAW, BSRN
Snow: IACS, WMO
Glaciers: IACS, WGMS/NSIDC, GTN-G
Permafrost: GTN-P
Lake/river ice: ????
Sea ice: ????

Data availability: real-time or near real-time
Monitoring components:
Atmosphere: *SW-, LW-radiation, air pressure, air temperature, humidity, wind speed, wind direction,*

precipitation, aerosols, trace gases, …
Snow: *depth, SWE, snow temperature, snow density, stratigraphy, snow chemistry, share of solid precipitation*
Glacier/Icecap: *winter-, annual mass balance, glacial discharge, surface velocity, ice thickness, stream flow water chemistry, stream flow water temperature, sediment*
Permafrost: *borehole temperature, active layer thickness, water chemistry, discharge*
Lake/river ice: *ice thickness,*
Sea ice:???

2) <u>Tier 2 CryoNET sites (tentative name REFERENCE-SITE)</u>

<u>REFERENCE-SITE</u>: (=Cryonet station monitoring at least 1 component of the cryosphere at the level of reference site of relevant network organisation, e.g. WGMS for glaciers, GTN-P for permafrost etc.)

Aims:
a) Monitoring of changes of the physical and chemical properties of the cryosphere
b) Extensive datasets for cryospheric modelling approaches
c) Training of personal for cryospheric observations
d) Information to the public

Standards for measurements:
According to the cryospheric parameter the relevant network determines the standard (e.g. IACS for glaciers and snow, GTN-P for permafrost etc.)

Data availability:
Dependent on cryospheric component, determined by relevant network-organisation

Monitoring components:
Dependent on cryospheric component, determined by relevant network-organisation

3) <u>Tier 3 CryoNET sites (tentative name OBSERVATION-SITE)</u>

<u>OBSERVATION-SITE</u>: (=Cryonet station monitoring at least 1 component of the cryosphere at the level of accepted GCW standards)

Aims:
a) Monitoring of changes of the physical and chemical properties of the cryosphere
b) Datasets for cryospheric modelling approaches
d) Information to the public

Standards for measurements:
According to the cryospheric parameter the relevant network determines the standard (e.g. IACS for glaciers and snow, GTN-P for permafrost etc.)

Data availability:
Dependent on cryospheric component, determined by relevant network-organisation

Monitoring components:
Dependent on cryospheric component, determined by relevant network-organisation

ANNEX 6

BENEFITS OF GCW-CRYONET INITIATIVE TO NWP MODELLING

(Submitted by Gianpaolo Balsamo in response to the GCW-CryoNet questionnaire; this specific topic is discussed under agenda item 4.2)

Background Questions

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

Global modelling includes necessarily areas not routinely monitored by existing conventional observation networks or where coverage is very sparse and heterogeneous and for which satellite remote sensing faces particular difficulties in the surface/cloud aliasing.
Those areas play an important role in NWP models as they contribute to the mean-state of the so-called “model-climate”. A poor representation of surface temperature evolutions in the Arctic, Antarctic and large mountain chains, such as Himalayas and Rocky Mountains, can trigger large-scale flow errors in weather and climate prediction.

The availability of quality-controlled ground-based stations in remote cold areas is of paramount importance to detect modelling shortcomings and improve predictions at all timescales from weather to climate, and particularly for what concerns the land-atmosphere coupling strength, a poorly diagnosed quantity in several models and that is object of recent research.

Among the important surface variables are the snow depth and the snow density, for which the ECMWF snow model revision in 2010 represent an example (based on the SNOWMIP-2 coordinated field-site experiment and DOME-C observational data).
Knowledge of cloud properties (liquid/ice and optical properties) is also essential for near-surface temperature and precipitation prediction.

Fostering new field campaign and coordinating high latitude observing stations to enhance the observation capabilities (e.g. towards the so-called super-site configuration) would be beneficial. More comprehensive vertical soundings (by balloon-radiosondes and drop-sondes), would also represent an essential step forward. Effort of gathering several observation types at a single site will permit process-based research studies that are important to enhance physical understanding and design model parameterizations. This is preferred to sites dedicated to a single or few selected parameters.

Observations that can be exchanged in Near-Real-Time (with latency of few hours after acquisition) from a global coordinated network matches the requirement for the highest level of interest in NWP applications especially when these observations can enter into the data assimilation cycle for the present-time analysis, which is then used to initialize the operational weather forecasts.

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

The availability of routinely modelled surface-state and near-surface weather parameters can provide temporally and spatially coherent and valuable information (within the margins of modelling errors) at the location of field-site facilities.

Model short-term prediction has proven to be a valuable information for observation quality screening in several situations where partial observability does not consent to assess fully and locally the quality of the observational data (e.g. especially in presence of extremes or unusual situations). The availability of consistent reanalysis of past weather enables to build for instance statistical information on the occurrence/likeliness of extremes.

ECMWF can therefore provide monitoring capabilities for the GCW-CryoNet network that would be of support for quality control and screening of observations.

The ECMWF ERA-Interim reanalysis (as described in Dee et al. 2011, ***http://onlinelibrary.wiley.com/doi/10.1002/qj.828/abstract***) for example provides already a global past reanalysis covering 1979-near present with 3-hour temporal frequency and with a spatial resolution of about 80 km. ERA-Interim is made publicly and freely available at full resolution (***http://data-portal.ecmwf.int/data/d/interim_full_daily***).

Information on other research data available at ECMWF is provided at ***http://data-portal.ecmwf.int/***. Research at ECMWF includes areas such as probabilistic and long-range forecasting, marine aspects and atmospheric composition as linked to NWP core activities. All these research activities heavily rely on the availability of research and operational observational datasets.

What do you see as the benefits of CryoNet: (e.g. for operational and research network operators, scientific and decision/policy making community, environmental monitoring and modelling, scientists, satellite data providers, etc.)?

Good quality field-site data enable the detection of modelling shortcomings and can support model development. A thematic separation between research-observation network (such as FLUXNET for surface fluxes, ***http://fluxnet.ornl.gov/***) that requires scientific supervision and more operational-oriented automatic or semi-automatic networks (such as the SYNOP/METAR meteorological stations) is important to streamline the applications in which the CryoNet is likely to be used.

While both research-base and operational-oriented observing networks can support model diagnostics and developments, the availability of large networks with Near-Real-Time observing capabilities enables to consider the data also for operational monitoring and data assimilation activities. Examples of operational monitoring for the GCOS Upper Air Network (GUAN) are available online at:
http://www.ecmwf.int/products/forecasts/d/charts/monitoring/guan/guan_stations/
Examples of operational data assimilation of ground-based network are represented by the SYNOP/METAR networks, as available online at:
http://www.ecmwf.int/products/forecasts/d/charts/monitoring/coverage/dcover/

In an operational assimilation configuration it is possible even to quantify the impact of a given network to the daily operational weather forecast quality, via the diagnostics of the forecast-sensitivity to observations (as described in Cardinali 2009, ***http://www.ecmwf.int/publications/library/do/references/show?id=89400***).

What do you see as existing gaps in cryospheric observations (e.g. thematic, spatial, temporal, availability, exchange, data policy, etc.) and how might CryoNet address these?

Ideally a minimum density of observations per unit surface area should be achieved in all Earth cryosphere components (1 station per X square-kilometres). This minimum observing density criteria (once established) could be a useful metric to identify the regional gaps, and such analysis should extend to land, ocean and ice-sheets. An increasing number of network-design studies exploiting more sophisticated modelling and data assimilation techniques (e.g. Observing System Simulated Experiments) are appearing in literature with the scope of supporting the optimal design of observational coverage of new networks/satellite.

Temporal stability of measurements (with the exception of field campaigns) is a suitable requirement with a minimum period of 2 years and with a minimum temporal frequency of a day (hourly for quantity related to diurnal cycle). Both surface-state observing networks (mast-installed, ground. and below-ground sensors) and vertical sounders (lidar, rass/sodar, vertical scanning radar) would be valuable to resolve the fine structure of surface atmosphere vertical profiles (e.g. temperature/humidity).

The data publicly available in large part of the cryosphere are not correspondent to the existing networks and efforts in fostering open-access policy will be of help.
In areas where data policy issues are more sensitive, requesting retrospective data (further away from Near-Real-Time) may be a starting point to prevent neglecting completely important geographical areas.

Please prioritize CryoNet activities according your personal view:

The proposed order is more consequential (and subjective), rather than by priority. All listed items are thought to be relevant for CryoNet but some are consequentially based on others that thus have higher priority:

Establishment of supersite network:
Best practice can be better defined relying on experience at super-sites.

Establishment of CryoNet tier#1-tier#4 network:
The establishment of the CryoNet observing network should have high priority.

Cooperation with existing networks:
As general principle of GCW initiative, existing networks should be included.

Support national needs:
This is achievable by engaging national institutions responsible for cryospheric components monitoring.

Inter-comparison experiments (e.g. sensors, methods):
Link with the scientific community should be envisaged as soon as possible (e.g. via workshops) as it can provide valuable feedback already in the design phase.

Harmonisation of cryospheric network:
Agreed best practice can be used to harmonise observation reporting (common formats helps the development of standards at software level) and sensors specifications for reliability of long term trends. The harmonisation needs probably point 1 to point 5 having already on-going efforts.

Standards, guidelines and training for observations:
Definition of standards and guidelines will require the previous items to have fulfilled. An early trial in the definition of standards would be useful as “draft guidelines”. A survey on the existing standards for well-established ground-based observing network is recommended.

Data policy on archiving, accessibility and exchange:
Agreement on the adoption of an open-access philosophy should be pursued.

Please share any other thoughts for participant to consider at the meeting.

A step-wise development starting from a prototype network that encompasses the possibility of a growth is an advisable strategy that had shown some success in other context (e.g. the International

Soil Moisture Network, ***http://www.ipf.tuwien.ac.at/insitu/*** as an example of a surface research-based network).
The benefit of open-access data are not often immediate to data provider and require a cultural change (costly observations and free-access are difficult to reconcile until a given network gains recognition that feedbacks into the research/operational grants to maintain it).
Finally the GCW initiative has the potential to play a crucial role in providing access to a centralized reprocessing and archive facility for existing cryosphere dataset and may consider to archive also co-located model products output as there are already successful initiative in different contexts (e.g. the Year of Tropical Convection, YOTC, ***http://www.ucar.edu/yotc/data.html*** or as planned for the Year of Polar Prediction, YOPP discussed within the World Weather Research Program, WWRP).
Co-located model and observational data at field site locations permit a larger involvement of the scientific community with mutual benefits for both the observation network and the modelling sides.

ANNEX 7

EXPERIENCES FROM PARTICIPATION IN THE GLOBAL ATMOSPHERE WATCH (GAW)

OBSERVING SYSTEMS IN GAW AND PROCEDURES FOR ACCEPTANCE

Extract from: WMO Global Atmosphere Watch (GAW) Strategic Plan: 2008 – 2015

3. OBSERVING SYSTEMS

Satellite, aircraft and surface-based observations play complimentary roles, and all are essential in addressing the challenges defined in Chapter 1 that require integrated global atmospheric chemistry observations. The GAW programme will address the challenge of implementing the WMO Integrated Global Observing System by initially developing pilot projects focussing on ozone/UV and aerosols.

3.1 Surface-based Observations

Current Status

Clearly, a globally integrated system of observations must include highly accurate measurements at and near the ground in all regions of the globe. This cannot be provided by space-based measurements alone. In 1992, the EC (XLIV) adopted Resolution 3-Technical Regulations of the WMO (Chapter B.2, Global Atmosphere Watch, GAW) under which all stations in the existing WMO Global Ozone Observing System (GO_3OS) and the Background Air Pollution Monitoring Network (BAPMoN) were declared GAW stations [*WMO*, 1992]. Surface-based *in situ* and remote sensing observations are the backbone of the GAW network, which consists of Global, Regional and Contributing stations as defined in Box 9 and Box 10.

Members wishing to contribute new stations to the network are requested to contact the GAW Secretariat. Global or Regional GAW stations are operated by WMO members. A Contributing station is one that is operated by a WMO partner network or organization that contributes data of known quality to one of the GAW World Data Centres and that is linked to the GAW Primary Standard for a particular variable. Contributing station networks include the Network for Detection of Atmospheric and Climate Change (NDACC), BSRN and EMEP. Some of the stations within these networks are also classified as Global or Regional GAW stations.

Box 9. Essential Characteristics of a GAW *Regional* or *Contributing* Station

1. The station location is chosen such that, for the variables measured, it is regionally representative and is normally free of the influence of significant local pollution sources.
2. There are adequate power, air conditioning, communication and building facilities to sustain long term observations with greater than 90% data capture (i.e. <10% missing data).
3. The technical support provided is trained in the operation of the equipment.
4. There is a commitment by the responsible agency to long term observations of at least one of the GAW variables in the GAW focal areas (cf. Section 7).
5. The GAW observation made is of known quality and linked to the GAW Primary Standard.
6. The data and associated metadata are submitted to one of the GAW World Data Centres no later than one year after the observation is made. Changes of metadata including instrumentation, traceability, observation procedures, are reported to the responsible WDC in a timely manner.
7. If required, data are submitted to a designated data distribution system in near-real-time.
8. Standard meteorological *in situ* observations, necessary for the accurate determination and interpretation of the GAW variables, are made with known accuracy and precision.
9. The station characteristics and observational programme are updated in the GAW Station Information System (GAWSIS) on a regular basis.

10. A station logbook (i.e. record of observations made and activities that may affect observations) is maintained and is used in the data validation process.

Box 10. Essential Characteristics of a GAW *Global* Station
In addition to the characteristics of Regional or Contributing stations, a GAW Global station should fulfil the following additional requirements *(Global Stations in developing countries that fill major gaps in the global network are allowed exceptions as they strive toward these criteria)*, namely:

11. Measure variables in at least three of the six GAW focal areas (see item 4 above).
12. Have a strong scientific supporting programme with appropriate data analysis and interpretation within the country and, if possible, the support of more than one agency.
13. Make measurements of other atmospheric variables important to weather and climate including upper air radio sondes at the site or in the region.
14. Provide a facility at which intensive campaign research can augment the long term routine GAW observations and where testing and development of new GAW methods can be undertaken.

The present network of GAW Global stations as of April 2007 consists of 24 stations. These key observatories provide comprehensive atmospheric observations of all sorts and many serve as centres for process oriented research that benefit from a core set of observations at the station and long time series of composition measurements. These long time series can be used to assess how representative a campaign was of the climatological atmospheric chemical situation. It should be emphasized that not only Global stations but also Regional and Contributing stations are needed for an adequate global network of any of the GAW variables. In some cases, such as greenhouse gases and total column ozone, global observations are mostly made by the research departments of NMHSs. However, in most cases the global network consists of a large number of stations in networks operated independently by other research or environmental institutions. WMO Members must cooperate with these networks if they are to have access to – and realize the power of – the full set of global observations. In this respect, the role of the GAW programme in expediting cooperation and sometimes taking the lead internationally is central.

Goals

- Secure precise and traceable measurements to meet the GAW long-term objective.
- Increase the number and quality of GAW stations to provide better global coverage focusing particularly on areas where there are significant regional issues.
- Maintain and improve the network of observing stations for near-real-time monitoring of the atmosphere, producing comprehensive, reliable, and timely measurements that cover all regions of the world.
- Improve collaboration and communication between all station types and networks.
- Improve and extend observations on the total column and vertical profiles of appropriate atmospheric variables.
- Support the development of formats for near-real-time (NRT) data transmission of chemical variables to GTS/WIS for appropriate variables.

ADDENDUM FOR THE PERIOD 2012 – 2015

ANNEX 2: PROCEDURE FOR ACCEPTANCE OF NEW STATIONS/NETWORKS IN GAW

The backbone of GAW observations is the surface-based in situ and remote sensing network of stations and sampling sites. These are classified as Global, Regional, or Contributing stations. All stations and networks supporting GAW are expected to contribute data of known quality to one of the GAW World Data Centres and to document traceability of observations for a particular variable to the GAW Primary Standard. The requirements for each category are specified in the GAW Strategic Plan [*WMO*, 2007c].

Global or Regional GAW stations are operated by WMO members. A Contributing station is one that is operated by a WMO partner network or organization that contributes data of known quality to one of the GAW World Data Centres and that is linked to the GAW Primary Standard for a particular variable [*WMO*, 2007c]. A contributing network is one that has signed a letter of agreement (LoA) with WMO. Any such agreement should contain a list and the characteristics of the stations that will be included in the GAW network as Contributing stations. Some of the stations within these networks are also classified as Global or Regional GAW stations.

Examples of GAW contributing networks are TCCON, NDACC, BSRN or EMEP. Contributing stations can apply individually for designation as Regional or Global station. The procedure for acceptance of individual stations or networks is as follows:

Box 1 - Procedure for acceptance of new stations / networks in GAW

1. Prior to the application of an individual station to be accepted as a Contributing, or Regional or Global station, or a network as a Contributing network, the essential characteristics as given in Boxes 9 and 10 of the GAW Strategic Plan: 2008-2015 [*WMO*, 2007c] should be consulted to make sure the station / network qualifies.

2. An application letter should be sent by email and by regular mail to the Chief of the Atmospheric Environment Research Division at the WMO Secretariat. To upgrade the status of already registered stations, a similar letter is required. A template for an application letter is available from the GAW web site[22]. Concurrent with the application letter to the WMO Secretariat, the station should be registered in the GAW Station Information System GAWSIS)[23].

3. A contributing network is one that has signed a letter of agreement (LoA) with WMO. Any such agreement should contain a list and the characteristics of the stations that will be included in the GAW network as Contributing stations. The applications for Regional station status are evaluated by the relevant SAG(s), depending on the measurement programme. JSC OPAG EPAC is responsible for evaluating applications for Global station status. As soon as a letter of acceptance is sent by the WMO Secretariat, the station is recognized as such in the GAW Programme and will be displayed in GAWSIS.

4. If measurements at a station were started more than a year prior to the application and satisfy the requirements of the GAW Programme, submission of the data and metadata to the responsible World Data Centre[24] is expected as part of the application. Data and metadata submission is required in due time after acceptance of a station in the GAW Programme as specified in Box 9 of the GAW Strategic Plan: 2008-2015 [*WMO*, 2007c].

To reflect the activities of a station registered in GAWSIS as adequately as possible, station managers are required to check and update the information in GAWSIS concerning measurement programme and station status at least annually (or more often, e.g. always after changes of the measurement programme). The status of stations registered in GAWSIS will be classified as follows:

- ‘Active’: Station is submitting data to the World Data Centres in due time for at least one variable registered in GAWSIS.
- ‘Inactive’: Station has not submitted data for any variable registered in GAWSIS for the past 27 months.
- ‘Intermittent operation’: Stations operating long-term but on a campaign or opportunity basis can request this operating status.
- Effective January 2012, information on stations registered in GAWSIS that have no measurement programme listed in GAWSIS and no record of any data submission to one of the recognized data centres will be archived but no longer be displayed in GAWSIS, after consultation with the GAW Country Contact.

22 *http://www.wmo.int/pages/prog/arep/gaw/documents/Application_template_Aug10.doc*
23 *http://gaw.empa.ch/gawsis/codes.asp*
24 *see www.wmo.int/gaw/wdc or http://gaw.empa.ch/gawsis/ for more information*

ANNEX 3: PROCEDURE FOR DESIGNATION OF GAW CENTRAL FACILITIES

Five types of Central Facilities dedicated to six groups of measurement variables form the basis of quality assurance and data archiving for the GAW global monitoring networks. These Central Facilities include:

- Central Calibration Laboratories, CCLs (Terms of Reference are given in Box 5 of the GAW Strategic Plan [*WMO*, 2007c])
- Quality Assurance/Science Activity Centres, QA/SACs (Box 6, ibid.)
- World Calibration Centres, WCCs (Box 7, ibid.)
- Regional Calibration Centres, RCCs (Box 7, ibid.)
- World Data Centres, WDCs (Box 8, ibid.)

Table 1 in Chapter 1.3.1 lists the facilities and organizations responsible for each measurement variable as of January 2011. There are still a number of variables that do not have a complete set of Central Facilities assigned to them in the GAW Programme, and GAW welcomes applications from interested organizations. Institutions offering to establish a Central Facility for the GAW Programme are requested to submit an application to the GAW Secretariat, addressing in particular the following requirements:

Box 2 - Requirements of GAW Central Facilities

- A confirmed capacity to run a Central Facility in accordance with the respective Terms of Reference;
- Long term experience in performing the activities assigned to the particular type of Central Facility;
- Availability of high level laboratory and equipment, and trained personnel dedicated to performing the required work and to running the facility;
- Annual reporting to the Secretariat using a template provided. The reporting depends on the kind of Central Facility as specifically described in the Terms of Reference and the respective agreement;
- If relevant to the task, a willingness to participate in BIPM key comparisons;
- Other relevant information (e.g., connection with GAW stations, support of exchange/ twinning programmes in GAW etc.);

The organization operating the Central Facility shall bear all costs arising in the course of the implementation and its operation, and shall strive to perform to the best of their knowledge, taking into account the current state of the art.

Applications submitted to the GAW Secretariat are evaluated by the respective expert group (e.g. SAG) that will make a recommendation for decision by JSC OPAG EPAC. Designations of Central Facilities in general have no time limitation. Central Calibration Laboratories, and World and Regional Calibration Centres designated within the GAW Programme are not necessarily operated by National Metrological Institutes and may thus not be eligible automatically for key comparisons organized by BIPM. If an institution operating a Central Facility (e.g., a CCL or a WCC) is not yet eligible for key comparisons as organized by BIPM, a nomination should be sought. One of the mechanisms is the establishment of a side agreement with BIPM through the already existing agreement between BIPM and WMO. An agreement is signed with institutions responsible for each individual Central Facility, which specifies the mutual rights and obligations of the Parties.

ANNEX 8

GCW-CRYONET: A PERSPECTIVE FROM GROUND AND REMOTE SENSING MONITORING OF GREENLAND *(extract from INF. 23)*

(Michele Citterio, Geological Survey of Denmark and Greenland (GEUS))

On the requirements and priorities for CryoNet sites in the context of GCW:

CGW and CryoNet must be careful to define a structure flexible enough to reflect the diverse elements of the cryosphere being monitored, the operational conditions in each region and the length of existing time series. A tiered structure allows setting different requirements for supersites, reference sites and so on. Even so, there are unique cases such as Greenland and Antarctica which may require special consideration. For instance, currently available resources allow very remote sites on the ice sheet to be visited only once per year or less, meaning single sensor failures can occasionally introduce extended data gaps. In Greenland there is also a lack of longer uninterrupted time series of ground measurements of specific cryosphere relevance. However, there are several relatively recent sites with comprehensive monitoring programmes. On the other hand, the very size and relatively smooth topography of the ice sheet simplify downscaling and intercomparison with gridded products from models and remote sensing.

From a pure monitoring perspective, long, continuous time series of consistent observations may be all CryoNet could concern itself with. If climate normals and change trends were the only tasks of CryoNet, we would focus only on sites with long time series. But, CryoNet is the ground monitoring component of the ambitious and comprehensive GCW. Besides simply collecting cryosphere observations, CryoNet is also expected to enable process studies, calibration and validation of models and remote sensing products, and finally implementation of operational services and products. In this context, the selection of observed variables, their spatial gradients and the representativeness of point measurements for larger areas become very important. For instance, let's consider what would be more useful for remote sensing product validation and future operational products between: 1) a century-long time series from a station on the summit of a mountain peak surrounded by glaciers, rock outcrops and steep complex topography; 2) a site established a few years ago as a transect of two automatic stations monitoring all components of the surface energy balance along an elevation gradient which is laterally representative of hundreds of kilometres of homogeneous ice sheet margin? As a minimum, GCW CryoNet supersites and reference sites should monitor enough observables for the surface energy balance to be calculated, and the representativeness of measurements over wider surroundings should be given similar weight than having a long time series. Sites with significant lateral gradients in surface elevation and land cover type may consider adding measuring points to capture such gradients, ideally over an area comparable to relevant remote sensing products (1 km?)

Specific contributions by GCW and CryoNet

Given the situation outlined above, here is a list practical ways for GCW and CryoNet to contribute and improve on the current situation. I believe most of these suggestions are generally relevant also beyond the Greenland case.

- GCW and CryoNet can further contribute to the sustainability of monitoring programmes by increasing the visibility, usability and relevance of ground and remote sensing observations and modelling results both for policy makers and for the general public:
  - ➢ Define a limited set of reliable, clear, representative, easily communicated and understood products capturing the state of the cryosphere, its variability and trends, both over time and space.
  - ➢ Define authoritative sources for these products.

- GCW and CryoNet can help preserve and support the current ground monitoring capabilities:
  - Establish a tiered operational network of ground sites satisfying standard requirements in terms of minimum monitored parameters, measurement rates, recalibration protocols.
  - Support the availability of real-time and archived monitoring data in a uniform data format. To avoid duplication of efforts, no new data repository is really needed, just a good data format specification, a recommendation to use established facilities as for instance the NSIDC, and an up to date directory of data repositories.

- GCW and CryoNet can assist in identifying and filling gaps in the current monitoring capabilities:
  - Define criteria for adequate in-situ coverage of a region. For high gradient environments like high relief mountain areas or the margin of the ice sheet, require transect made of at least two stations at different elevations rather than a single station.
  - Define criteria for adequate in-situ coverage of a site. Take into account the difficulties and scale issues involved in comparing ground point measurements with gridded datasets from RCM models and remote sensing observations. Again, transects or arrays of ground measurement points may be necessary for certain sites to be usable for remote sensing and modelling product validation.

- CryoNet can define standard quality requirements and instructions for monitoring sites and automatic stations:
  - Specify requirements, best practices and guidelines for the measurement and quality assurance of field observations specific for cryosphere, including traceability and strict requirements for complete metadata.
  - Carefully assess the negative impact of any change or additional requirement on existing programmes, in terms of costs, data continuity, and homogeneity

- GCW and CryoNet can increase the operational and research use of data from existing monitoring sites
  - Encourage adoption of low latency satellite telemetry for remote ground sites. When carefully planned, it can be done with modest costs and power requirements.
  - Affirm that no operational products should be released unless it includes relevant and publicly available ground observations, or as a minimum the deviations from measurements should be displayed with the product.

- GCW and CryoNet can significantly increase the use of already available high quality ground observations for the assessment of modelling and remote sensing products:
  - sponsor or facilitate round robin exercises involving competing climate models or remote sensing products and assessing their performance against actual ground measurements

- GCW and CryoNet can promote the development of operational analysis products from real-time as well as archived monitoring data
  - In a first stage, aim at products separated but mutually consistent from ground sites and remote sensing (e.g. albedo from satellite but calibrated with the ground observations)
  - In a second stage, aim at products integrating ground observations, remote sensing and climate models (e.g., surface mass balance of the Greenland Ice Sheet)

- GCCW and CryoNet can assist the operators of future monitoring networks and research projects by removing the costs, delays and uncertainties connected with designing, producing and setting up ad hoc technical solutions for applications where good previous experience exist:
    - provide a set of recommended and well documented reference designs for modular and flexible automatic stations suitable for various environments, based as much as possible on components readily available commercially.
    - The reference designs should be modelled after proven success stories from existing monitoring programmes, and provide the option of obtaining ready to use systems if so desired

- GCW and CryoNet can increase the public availability of otherwise closed (and after some time often lost) field observations
    - Encourage research funding bodies, especially public ones, to mandate the public availability of field data produced within research projects, with a time-limited embargo to allow for research and publication time. This could be acceptable if applying PI's could expect the funding body to cover reasonable costs for data documentation, validation, formatting to the CryoNet-defined standard, and delivery to an open repository.
    - Create a specific 'label' ('CryoNet Snapshot' perhaps?) for deliberately short-term, but systematic, documented and quality controlled ground time series: compared to more 'mundane' environments, in many Arctic regions we can't be too choosy. With all due cautions, a single full year of near surface weather observations from a glacier in a region otherwise devoid of data is significant. Quality requirements should not be relaxed though.
    - Promote the retrieval, documentation and digitization of unique legacy datasets: for Greenland alone, we have already discovered and digitized within PROMICE more than 1350 ablation stake measurements from Greenland, some of them more than a century old.

- GCW and CryoNet may increase the availability of key proprietary datasets locked behind licensing walls, such as the SPOT imagery and SPIRIT DEM products which were temporarily made available for free during the IPY, or Radarsat-2 SAR data.
    - Lobby for access to be granted at affordable cost or on co-funding basis between the provider and the user, where the user is allowed to pay in-kind, e.g. by processing SAR data to ice surface velocity. Underused processing and analysis capacity may exist which is not fully exploited due to prohibitive data costs, especially for vast Arctic regions. It would be a win-win solution, as no income is lost for the provider and their data gain a wider visibility.

- GCW and CryoNet can facilitate augmentation of existing permanent monitoring sites, and conversion of selected temporary research sites into permanent monitoring sites:
    - Define a set of recommended measurements of relevant cryosphere parameters, with clear rationales and priorities for their addition to existing sites
    - Encourage and facilitate early collaboration between research projects and monitoring projects which may be operating in the same country or region

- GCW and CryoNet can promote wider participation of the affiliated sites to relevant international research projects, especially those concerned with to remote sensing and climate modelling. Open issues future research may be: downscaling and upscaling to and from the in situ measurements scale, improving the monitoring of solid precipitation and the snowpack, standardize the reporting of measurement error sources, improving and validating remote sensing albedo and surface temperature products.

- By defining standards for CryoNet sites, ideally all sites in a given region of interest should be relevant and easy to include in research projects regardless of the data providers operating the stations.
- Lobby for appropriate funding bodies to devote resources fo this
- Provide early information on available funding calls

- GCW and CryoNet may promote a framework for periodic assessments of state of the cryosphere, at the regional (e.g. Greenland) and hemisphere or global scale.

- GCW and CryoNet may assist raise seminal funding for ‘exotic’ under-researched components of the cryosphere, such as e.g. perennial cave ice, which may hold unexplored potential.

ANNEX 9

BEST PRACTICES, GUIDELINES AND STANDARDS FOR CRYOSPHERE MEASUREMENTS AND OBSERVATIONS *(extract from GCW-Report-1)*

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**)

ANNEX 10

SUMMARIES OF BREAKOUT GROUPS' DISCUSSIONS ON CRYONET STRUCTURE AND ASSOCIATED OBSERVING PROGRAMME

Following are the summaries prepared by each group based on their discussions while addressing the prepared questions. Their approach may have differed but all thoughts are needed in the development and implementation of CryoNet.

BREAKOUT GROUP 1: Chair: C. Fierz; Rapporteur: G. Balsamo
Participants: V. L. Barth, M. Bernhardt, J. Dibbern, J. Key, K. Luojus, S. Pedersen, W. Schöner, V. Smolyanitsky, Th. Thorsteinsson.

CryoNet Objectives and Structure:

- Purpose-oriented classification. Three categories are identified in:
    - **Many-sphere sites**
    - **CAL/VAL sites**
    - **Reference-long-term sites**
- All GCW sites should be sustained and accessible
- Many-Sphere site or Cal/Val site should be a location that enables Earth Observations CAL/VAL activities and/or Earth Systems process-oriented verification of models.

Standards, Guidelines and Best Practices

- We have starting base for many components: Sea-Ice, snow, glacier mass balance, permafrost, …
- The revision of "best practice" could be mandated to relevant organizations (rather than to individual specialists?).
- Training programs are recognized to be important to reach best practice (such as the Global Atmospheric Watch Training and Education Center (GAWTEC provides scientific guidance and instructions for GAW station personnel from worldwide global and regional stations), or UNESCO IHP Flow Regimes from International Experimental and Network Data (FRIEND) which aims to develop better understanding of hydrological variability and similarity across time and space, through the mutual exchange of data, knowledge and techniques at the regional level).

Requirements for Site Inclusion in CryoNet

The GAW requirements provide already very useful guidelines that could be adapted to the cryosphere elements. It is recommended that:

- Reference sites are identified as having at least 10-year of availability for at least 1 key GCW parameter.
- Multi-sphere sites should have at least 1-key parameter each in 2 different "spheres" among the Cryosphere, Biosphere, Atmosphere, Hydrosphere.
- The CAL/VAL sites should have a clear link with EO/Models and established link with the Agencies.
- Temporary sites (short or partial observability) can become "reference" or "multi-sphere" sites upon reaching the defined criteria.
- Frequency of observations and observation latency should follow common practice (daily for snow-depth, annual for glaciers).

BREAKOUT GROUP 2: Chair: T. Uttal; Rapporteur: A. Walker
Participants: O. Anisimov, C. Genthon, E-A Herland, T. Aoki, A. Snorrason, J. Pulliainen, Xiao C.

CryoNET Objectives:

- These are reasonably well defined in the implementation document and did not seem to require extensive discussion by breakout group 2. Somewhat more refined statement was crafted as follows:

  "CryoNet will integrate the observations of existing ground-based cryosphere observing networks to achieve added value".

- Specific focused objectives should still be flexible as the program develops.

CryoNet Standards and Practices:

- Although many CryoNet candidate networks meet data collection WMO protocols and standards of observation and data collection, this should not be a requirement for inclusion. However, a blended cryosphere data product that that will be useful for satellite CALVAL and model initialization/validation will be developed to WMO data standards with defined quality standards, standard formats and open access.

- In addition, CryoNet will provide guidance by (1) identifying gaps (2) data synthesis activities (3) facilitating transfer of research observations to operations (4) data rescue (5) comparison campaigns and (6) integration of the resulting cryosphere super-data set into the WMO products such as synthesis reports.

- The spreadsheet analysis that has been started is useful and should be continued with accommodations for distributed regional networks (for instance radiation networks on Greenland) as well as stations.

- Organization of cross-network training programs was discussed.

Requirements for site inclusion in CryoNet:

- The GAW (a network of networks) model to define CryoNet cannot be followed because of the highly variable and spatially distributed nature of different components of the cryosphere (glaciers, ice shelves, ice sheets, snow, permafrost, sea-ice, river/lake ice). Lots of discussion on "to tier or not to tier". Highest priority on continuous temporal sampling with a policy of being as inclusive as possible to incorporate existing observations. It is likely that "super sites" will naturally evolve depending on what component of the cryosphere is being observed.

BREAKOUT GROUP 3: Chair: M. Zemp; Rapporteur: M. Citterio
Participants: S. Colwell, Ding, Y., J M Horler, J. Key, T. Ohata, V. Smolyanitsky, S. Starkweather, D. Wartman

Needed for Implementation of CryoNet:

- The coordination and setting up work can't happen on a voluntary base: need operational secretariat office (we gladly answer coordinated questions though!)
- Clarify roles and split of responsibilities between GCW and CryoNet
- Browse/discover and include existing data not represented here, giving an ID number, better involving non-European regions
- Reality check: site requirements vs. results of the inventory
- Contact potential national and international data providers
- Also include significant but discontinued series
- Implement a structured way to directly involve stakeholders (national policymakers, operational forecasting agency, NGOs, …)

- Evaluate existing sites in terms of **long** (in time), **broad** (spatially representative) and **deep** (multidisciplinary in the ecological sense, process oriented)
- Focal point of contact for cryosphere in each country
- Define an application structure for becoming a site, advertised through cryolist
- Plan for visibility within AGU, EGU, …
-

CryoNet Objectives:

- Provide an Interface to available information
- Single-stop web portal within the GCW portal:
    - for data repositories
    - for addressing users needs (metadata, coordination, …
    - for disseminating products
- End to end design from data-in to general public and policymakers usability
- Should we have 'data mentors'?
- Minimum quality standards for all sites

Structure and Site Types of CryoNet:

- What adds value to the existing data and sites?
- Long (in time), broad (spatially) and deep (multidisciplinary, process oriented)
- Different quality requirements?

- Supersite?: is long, deep, open access, accessible,
- Observation/baseline (detailed info), Reference (long time), Integrated sites (several cryosphere elements, cal/val capability) ?
- Broad = broad coverage in time and or space?
- 'Observation' is not sexy → 'baseline'?
- Growth path?
- 'Flagship'?

Requirements for Site Inclusion:

Observation/baseline (detailed info), = a cryosphere or cryosphere-related (AWS, chemistry) observation

- Standardized: comparable data, data steward, usability level + discovery level including provider and citation metadata, minimum quality requirement TBD, quality attributes descriptively as part of metadata? Metadata is also photographs where available, …
- Versioned
- Data quality: self consistency (changes must have sufficient overlap)
- Open access

Reference (long term),

- all what is for observation sites, plus:
    - Long relative to threshold TBD specific to each cryospheric component
    - Continuity is not a requirement
    - have a local met data source available

Integrated sites (several cryosphere elements, cal/val capability),

- all what is for observation sites, plus x out of n:
    - have a local met data source available
    - suits the needs of process understanding and model calibration
    - covers at least two or three cryospheric components (reference status not required)
    - transnational accessible infrastructure with logistic support for min 2 persons
    - online data available and real-time for selected components
    - interdisciplinary beyond cryosphere elements

Standards, Guidelines, Best Practices:

- Already discussed last year
- Most practical solution is for all participant to forward applicable document

ANNEX 11

WDS AND OPEN ACCESS

Discussion paper submitted by ICSU World Data System Prepared by the International Programme Office (03/10.2012)

1. Historical background

The World Data System (WDS) builds on the 50+ year legacy of former World Data Centres (WDCs) and Federation of Astronomical and Geophysical data Analysis Services (FAGS), established by the International Council for Science (ICSU) to keep and organize data generated by the International Geophysical Year (IGY) in 1957–1958. While they readily served and preserved the IGY data legacy for more than half a century, the WDCs and FAGS were facing tremendous challenges. The International Polar Year (IPY 2007–2008)—another data-intensive international research effort launched by ICSU and the World Meteorological Organization—revealed that they were not equipped to anticipate and respond to the sheer multidisciplinary scope of IPY-sponsored research. In 2009, the ICSU General Assembly discontinued both bodies and established WDS as a new ICSU Interdisciplinary Body to incorporate re-applying WDCs and FAGS, as well as state-of-the-art data centres and services.

WDCs and FAGS were created as part of ICSU's longstanding commitment to promote access to scientific data and information, which is enshrined in its Principle of Universality of Science. One of the guiding principles of the WDCs was indeed to '*provide data to scientists in any country free of charge, on an exchange basis or at a cost not to exceed the cost of copying and sending the requested data'.* Therefore, the concept and spirit of open access to data were already put into practice by these organizations. In 1996, an ICSU resolution was adopted by its General Assembly that recommends '*…as a general policy the fundamental principle of full and open exchange of data and information for scientific and educational purposes'.* In actuality, several ICSU bodies embraced this recommendation, most notably IPY, which adopted a full, free, and open access Data Policy (http://ipy.arcticportal.org/images/uploads/final_ipy_data_policy-1.pdf) for all of the data generated through its sponsored projects.

2. WDS Data Policy

ICSU WDS is an evolution from WDCs and FAGS and its mission is tightly linked to the full and open access to scientific data and information. Its objectives are to '*Enable **universal and equitable** access to quality-assured scientific data, data services, products, and information, and to ensure long-term data stewardship*' and '*Foster compliance to agreed-upon data standards and conventions, and to provide mechanisms to facilitate and improve access to data and data product'.*

To promote an Open Access Policy to data, the WDS Data Policy (http://www.icsu-wds.org/organization/data-policy) derives from the GEOSS Data Sharing Principles (http://www.earthobservations.org/geoss_dsp.shtml) developed under the auspices of the Group on Earth Observations and under the guidance of ICSU CODATA. The WDS Scientific Committee (WDS-SC) decided that it was unnecessary to not only reinvent a new data policy but also go into further details, since the default position must be full and open access and any exception should be dealt with on a case-by-case basis as such. It is obvious that WDS will directly benefit from a wider adoption of the principle of 'Full and Open Access' to scientific data as this would allow an expansion of its membership and ultimately better serve the scientific community and multidisciplinary research. WDS is also contributing to its adoption through the recruitment of relevant data and service providers.

3. Open access challenges

3.1. For WDS

The largest challenge for WDS has been the implementation of a WDS Data Policy as decided by the WDS-SC whilst respecting ICSU's recent terminology. On the WDS website and within our documentation (Constitution, Data Policy, etc.), we use both the term '**universal and equitable access'**—as employed by ICSU—for scientific information (published journals) and '**full and open access**' for data. ICSU's phrasing, used for scientific information as opposed to data, was adopted to avoid any confusion with open access journal publishing. However, the distinction between scientific information and data is relatively fuzzy, especially in the context of emerging concepts such as data publication, making this distinction cumbersome. Moreover, the publication landscape has dramatically changed, with an influx of open access publishers, and a widespread advocacy of open access practices. As a result, ICSU's definition must be reconsidered. Although there has been movement towards full and open access, ICSU's meaning of open access is still not in line with that generally accepted. WDS would appreciate clarification on this.

3.2. For WDS Members

Although WDS Members share the principle of providing open access to their holdings, in general, there is huge variability in attitudes towards data sharing across research disciplines, and only 25% of research data collections are thought to be openly available. This discipline-dependency is a microcosm of national implementations of sharing principles, which even at this level are highly inconsistent, no matter internationally.

In part, this inconsistency is considered to be due to unrestricted data sharing being contradictory to the highest bodies in the scientific community, as well as the majority of academic journals and funding agencies, that value scientific novelty over long-term data stewardship. The success of open access depends on the ability to address this discrepancy.

a. Incentivising scientists—Data citation?

WDS Members identify the biggest challenge to open access as convincing scientists to share their data. Scientists often feel that there is a cost and no immediate benefit or reward for data sharing (others are perceived to receive most of the benefits). In particular, scientists focused on the production of datasets do not receive adequate professional recognition for their efforts. Consequently, there is increasing support from the scientific community for peer-reviewed data publication and data citation when using published data. Several WDS members state that they will only provide data if they are recognized as the data source, while others insist on 'rewarding' others through citation.

It is unclear, however, how effective an incentive data citation is and whether citation is a reward in itself. Traditionally, the culture of science has been to predominantly judge a researcher's merit—and hence their evaluation and funding—on the number and quality of their peer-reviewed publications. This culture encourages restriction of data access such that researchers maximize their number of publications, and provides little enticement to compile and document data beyond the needs of the original research. Hence, academia at large needs to endorse fair and formal credit and attribution for data producers, which must in turn be recognized by evaluation and funding bodies (in a manner similar to the h-index). By doing this, not only is a clear incentive established for data providers to share data but also efforts to acquire new high-quality data by providers are promoted and reinforced. Attempts at data citation are not considered to have been particularly successful thus far, with citation of datasets often missing or incorrect. Internationally correct citation of both literature and datasets is vital for the reproducibility of science. Areas of responsibility for ICSU to rectify this include development of standards for citing data, such as where in a journal article data be should cited; and assignment, management, and versioning of unique (digital or analogue) data identifiers to create stable links for cited data. Data identifiers are recognized by WDS members as being particularly pertinent, and scientists must be encouraged to cite datasets by referring to those data identifiers when they publish their results. Existing DOIs can be used as data identifiers or a set of new identifiers can be applied to existing data alone.

b. Technical difficulties—the need for infrastructure

The above implies that an infrastructure exists to curate, disseminate, and publish research data. Data curation requires dedicated data centres; but, a lack of professional data management training and resources, as well as inadequate support for data archives, is evident within research programmes. Moreover, so that it can generally be reused by others, data must be properly described. Making data available thus involves significant effort and cost; even more so for real-time and provisional datasets, which require further processing to use in precise scientific analyses. The cost of long-term data preservation is hence one of the impediments to continued access, and the most appropriate business model appears to be linked to the awarding of a predictable percentage of grants.

It is obviously not possible to keep everything indefinitely, however, and some scientific grounding for the practice of 'what to keep and what to throw away' is necessary. Furthermore, it is often difficult for open archive managers to know what practices are allowed and what are not. An increasing need hence exists for informatics specialists, and basic data management training should be included in the core scientific curriculum such that researchers of all types take a ‘data class’ as part of obtaining an advanced degree.

Most current journals are patently not intended for data publication, and the issue of journals especially designed for publication of scientific data should be encouraged by ICSU.

c. The role of funding agencies

Many institutions and projects with relatively short-lived funding are not in a position to provide the required infrastructure for open access. It is clear that funding agencies have a strong part to play in encouraging open access. The strongest incentive for data sharing is thought to be when data deposition into an identified, financially supported open archive is a requirement for on-going research funding. Although, whether such a hard requirement leads to lower quality data being deposited is open to debate. Agencies that fund data collection must therefore assume responsibility for data management and develop the necessary infrastructure to support their preservation and use. To achieve this, a basic requirement of project proposals—which do not normally identify individual datasets to be delivered—should be the inclusion of data management plans. Moreover, if data is to be available for free (or at minimal cost), all funding agencies must agree to policies that cover author publication charges in their grant awards.

d. The extent of open access—Embargos and exclusions

Some exceptions and qualifications to the extent of providing unlimited open access are considered valid. Current restrictions to open access again often stem from pressures on researchers to publish, which has fostered a practice of embargoing data until formal publication. While an ICSU general policy of full and open exchange of data and information for scientific and educational purposes is lauded, WDS Members feel that this right has to be balanced by reasonable measures to allow researchers to exploit the academic value of their work without undue competition, typically in the period leading up to publication of a paper or thesis.

One WDS Member grants a one-year retention period to allow investigators time to properly analyse, document, and publish their data before submitting them in standardized format. Another Member permits an embargo period that exists for the life of a project (in most cases, less than 4 years) because papers are typically not written until towards the end of a project. However, with different research domains moving at different speeds and having different lengths of relevance, the correct period for embargoing data is a contentious issue. What works for one field may be completely inappropriate for others, and a uniform embargo period (e.g., 12 months) would be too long in well-funded and fast-moving disciplines and too short to be practical in fields such as mathematics, in which articles have citation lifetimes of years.

Natural restrictions may also apply when data centres are not the primary source of the data. In this case, the data exchange policy of the originator should be applied and the contract with that provider regulates the accessibility of each dataset. Unfortunately, this can lead to conflicts since data upon which research results are based cannot be made open because of the originator's wishes. Open access to data can therefore depend on the willingness and efforts of individual members. In fact, WDS Members with open access data policies state that this can sometimes cause concern for potential international collaborators.

e. Lack of trust? A 'common' answer

A significant barrier to data sharing seems to be a general lack of trust between data providers and users. Providers do not trust others with their datasets, fearing that users will apply data incorrectly, misuse it for ethical or legal breaches, or gain financially from it. In contrast, users do not trust the accuracy or believability of data or results that they find in journal articles. Such prejudices must be removed and data producers, curators, and users need to establish closer working relationships based on mutual trust. To aid in this process, more research is needed to create effective incentives that cultivate trust and motivate data sharing. An evolving legal and social science research agenda is also required to balance society's need for open data and protection of people, heritage, endangered species, and cultures from misuse.

Although in reality there appears to have not been great take-up of the concepts behind the Polar Information Commons, the most popular solution to problems of trust is the creation of an open 'commons' that allows researchers to place data in the public domain with limited retention of intellectual property rights through permissive licenses. Historically, there has been an absence of data-sharing norms and traditions within research communities. To develop such a commons, expected norms (not legal requirements) on the behaviour of data users and providers as regards ethical, collaborative data sharing must be defined and asserted. Publishing of standard global licenses (similar to Creative Commons licenses) is beneficial since when, for example, data is classified because of conservation concerns, everyone will be served by a globally accepted and understood license.

f. (Inter)National Policy

Implementation of an efficient scientific data commons may be difficult in practice because of the proliferation of open access copyright licenses used by governments. Such licences should be standardized to streamline permissions and facilitate efficient sharing and reuse. However, standardization requires support at the international level, and work is needed to harmonize governmental policies across national jurisdictions in accordance with common principles of openness and ethical use.

Although data policies should include clear identification of roles, responsibilities, and resources, the details of data policy will necessarily vary with discipline and research culture. Therefore, policy development must be a dynamic and interactive feedback process that involves all stakeholders and with active leadership by the sponsors of data collection. Again, the most adaptable policy approach is one based on community-accepted norms of ethics and behaviour rather than rigorous enforcement of licenses and contracts.

Unfortunately, tensions often exist between the drive towards free and open access, and current or future national legislation, especially those dealing with intellectual property rights and protection of information. The intent of these Acts is typically not of concern; nevertheless, they can be abused to restrict access and thereby harming knowledge creation and socio-economic development.

Tensions are particularly harsh between the public and private use of publicly-funded research. Ideally, all data, information, and research outputs generated by state-funded means should be included in national policies of open access. However, developing countries often regard research data as sensitive, based on (possible) future commercial value or on conservation implications (natural resources). In the case of developed countries, for areas of publically funded research in which they have a competitive advantage, it can be considered to be against national interest to publish everything since industry is supported by the margin created through intellectual property. Specifically, there is a ‘public’ obligation to create wealth for the domestic economy. One solution to this problem would be to mitigate those that derive a significant proportion of their income from the sale of publicly funded data.

4. Final comments

The diversity of approaches to open access reflects the complexities of its implementation. The public domain status of factual data is an especially complex subject in terms of legality. For this reason, it is highly desirable for ICSU to take a leading role in both open access of scientific data and its publication. It is also very important for the entire scientific community that ICSU show a strong commitment to this issue. To achieve this, it needs to encourage broader research focused on producing valuable scientific data rather than prestigious publications. ICSU WDS must be consolidated and promoted as the system of choice to achieve open access to ICSU-sponsored research data. The chances that a data management plan is successful are increase by including data centres and data service providers in the initial phases of research planning. In concert, CODATA and WDS can help maximize the chances of open access to the ICSU research data legacy by providing an appropriate mix of lawyers, data experts, and practitioners.

In the future, we hope that ICSU research programmes and their funders will have increased interest in, and active involvement with, ICSU data bodies (CODATA, WDS, INASP) and other partner organizations (ICSTI, GEO, etc.). Future Earth, the current ICSU flagship programme, is the first of its kind to be designed by both scientists and their funders, and unfortunately, it is still not addressing the important issues of data management and data legacy.