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STEERING GROUP
5TH SESSION
OSLO, NORWAY, 10-12 January, 2018

World Meteorological Organization
Weather · Climate · Water

GCW Global Cryosphere Watch

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GROUP PHOTO, 10 JANUARY 2018

EXECUTIVE SUMMARY

The 5th session of the Steering Group of the Global Cryosphere Watch (GSG-5) was hosted by Norwegian Meteorological Institute (Met Norway), in Oslo, Norway, from 10th to 12 January.

The meeting Chair, Dr. Árni Snorrason, noted that the session will provide a roadmap on the future of GCW to further build partnerships with relevant science and research communities. It will, also, provide guidance on how to further enhance the GCW leadership, as a collaboration mechanism in an emerging domain for WMO. It was noted that the planned governance reform of WMO, including of the Executive Council, could impact the EC PHORS panel and the governance of GCW, and GCW needs to be positioned within the value chain of WMO.

The meeting reviewed the progress made by each of its Working Groups, Observations, Integrated Products, and Information and Services. Over 150 stations are proposed for inclusion in the GCW Surface Observing Network, and these will be submitted for approval by EC-70. It was agreed that additional work will be conducted on the regulatory material (Manual WMO 1160 and Technical Regulations No. 49), to ensure clarity of GCW related information. The meeting reviewed and provided guidance on the development of the GCW Best Practices Guide for cryosphere variables.

The meeting examined the progress on the exchange of snow depth data, and the plans regarding the exchange of Snow Water Equivalent. It also examined the potential for engagement with JCOMM relevant teams and tasks, regarding sea ice observations, data exchange and products. Further planning and coordination is required, including with the relevant WCRP and SCAR WGs.

The meeting reviewed the progress made on the development and distribution of assessment and cryosphere products, and the use of the GCW website as an interface for dissemination. It was agreed that the website is a very valuable tool, and that it needs to be more visible and sustainable. Additionally, the meeting examined the linkages between the GCW Integrated Products WG and the Polar Regional Climate Centres, including plans for better coordination for the Arctic and Third Pole RCCs. It also examined the cooperation with the Polar Space Task Group (PSTG) and the WMO Hydrological Programme.

The progress made in the development of the Data Portal was examined in details, agreeing on a roadmap for developing cryosphere variable metadata, application to enable the interoperability between each GCW station and the Data Portal. The meeting noted the contribution of the Institute for Snow and Avalanche Research SLF, working with Meteorological Institute of Norway, in achieving these goals.

The meeting invited the presentation of updates from key partners. Presentations were made on behalf of the Third Pole Environment, INTAROS project, UNESCO International Hydrological programme, Norwegian Research Council, SAON, UN Arctic Observing Network (AON). As part of its engagements, it was agreed that GCW will play a key role in the organization of the WMO High Mountain Summit, the development of the proposal for a UN International Year of Snow and Ice, and in the organization in 2020 of a conference on Cryosphere and Climate Change.

The participants discussed the next steps in the implementation of GCW, agreeing to continue with a pre-operational phase, during the next financial period, subject to Cg-18 approval. Following Cg-18, GCW will convene a strategic meeting to plan its transition within the WMO Programmes.

It was agreed that the next meeting could be organized in conjunction with the EC PHORS-9 session, in Alaska. In preparation, a reduced GCW Steering Group meeting will be required during the latter part of 2018, to develop the GCW Pre-operational Plan, for submission to Congress.

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MEETING REPORT

1. Opening OF THE MEETING

1.1. Welcome address, introduction of participants

The 5th session of the Steering Group of the Global Cryosphere Watch (GSG-5) was hosted by the Norwegian Meteorological Institute (Met Norway), in Oslo, Norway, from 10th to 12 January. Dr Árni Snorrason, the Chair of the GCW Steering Group (GSG) and the Permanent Representative (PR) of Iceland, opened the session on 10 January 2018, at 09:00. He thanked the host, Dr Roår Skålin, the Director General of Met Norway and the PR of Norway, for hosting the meeting, and for the significant contribution made by MetNo to the Global Cryosphere Watch (GCW). In particular, the development of the GCW Data Portal was highlighted. He also thanked the participants for contributing to this meeting and to the implementation of GCW.

Dr Skålin welcomed the participants on behalf of Met Norway, noting that monitoring and understanding the changes in the cryosphere are important research and operational activities for Norway.

Dr Wenjian Zhang, the Assistant Secretary General of the World Meteorological Organization (WMO), welcomed the participants on behalf of the WMO Secretary General, Professor Petteri Taalas. W Zhang thanked the PR of Norway for the kind invitation and hospitality.

The meeting agenda was adopted without changes, and is available in Annex 1.
Á Snorrason, who chaired the meeting, invited the participants to introduce themselves. The complete list is available in Annex 2. All actions resulting from this meeting are summarized in Annex 5, in addition to being detailed in this report.

1.2. Overview of meeting goals

Á Snorrason appreciated the work done by the GCW experts, noting the significant progress made in the implementation of GCW, including the increased visibility of GCW. He recalled that representatives of GCW Working Groups (WG) met on 8 and 9 January. He thanked the experts for their productive discussions, and invited the WG Chairpersons to report on the outcome of those discussions.

Á Snorrason and W Zhang outlined the goals of the meeting, and noted the need to provide a roadmap on the future of GCW, in particular to further partnerships with relevant science and research communities. The session was expected to result in guidance on enhancing the GCW leadership, as a collaboration mechanism regarding cryosphere observations and services. It was noted that the planned governance reform of WMO, could impact the future of the EC PHORS panel and the governance of GCW. Both urged GCW experts to focus on strengthening the GCW role, effectively positioning GCW within the value chain of WMO.

1.3. Overview of Norwegian Meteorological Institute

R Skålin provided an overview of Met Norway. He noted that the mandate of Met Norway is to safeguard life and property. The changes in the arctic are evident, e.g.,

Svalbard has experienced 85 consecutive months with temperatures above normal. Norway is actively engaged in advancing the understanding of changes in the arctic, and taking action on it, including playing a global role. He spoke of the MET value chain and three foundational principles: R&D&I (research, development and innovation) which contribute to learning and improvements via feedback. These principles create a shorter path for the operational use of information, with national and international collaboration, as well as an open data policy with a modular system for data access and visualization. R Skålin reiterated the Met Norway support to WMO and GCW.

1.4. Norwegian Meteorological Institute: Arctic research priorities

Dr Lars Anders Breivik, Director of Research and Development of Met Norway, provided an overview of their Arctic research priorities.

He highlighted several items of interest to GCW. The snow activities include in situ and satellite measurements and snow modelling for ESM (Earth System Model) and NWP. Monitoring Climate Change in the Cryosphere (CryoClim), has a distributed data system, similar to GCW Data Portal, which is used to advance the infrastructure for cryosphere data management (http://www.cryoclim.net/cryoclim/index.php/HOME), and for the Ocean and Sea Ice Satellite Application Facility (OSI SAF).

Met Norway is committed to make its results and data available for science and operational applications. He reiterated the support to the development of the GCW Data Portal.

1.5. GCW in the context of WIGOS

Dr Sue Barrell, the WIGOS representative on GSG, provided an overview of the WIGOS priorities, relevant to GCW. Specifically:

- WIGOS Metadata Standard: GCW is invited to review the list of 'observed variables' and recommend additional cryosphere variables and their attributes, as needed. **See actions in section 2.1 and 3.**
- On WIGOS Data Quality Monitoring System (WDQMS): GCW was asked to follow up on the actions from the June 2017 Integration Workshop, and ensure that the GCW needs are represented in the mandates of the Global/Regional monitoring centres **[CryoNet, Data Portal, GSG-6]**
- On WIGOS 2040 Vision: GCW is invited to provide input on the vision for 2040, regarding cryosphere observing systems. The vision is expected to be a tool to influence future space missions and the evolution of in-situ observing systems, and it will be submitted, for information, to EC-70. **[Secretariat to coordinate input from experts, March 2018]**

S Barrell encouraged GCW to pursue, through its partners, the integration of GCW in national WIGOS plans, to strengthen their relationships with NMHSs, and to contribute to the development of the WIGOS Data Partnerships. She also urged GSG to align GCW's future plans with the WMO Strategy for the next financial period. As GCW is moving into its pre-operational phase, GCW must enable Members to "own" their cryosphere observations and services. **[Will be reflected in the Pre-Operational Plan, GSG-6]**

The participants raised the concerns about difficulties regarding the allocation of WIGOS IDs for GCW stations, which are not part of observing programs of NMHSs. Without a WIGOS ID, a station cannot be included in the WMO OSCAR database, nor exchange

data. S Barrell was asked to represent this concern at ICG-WIGOS and throughout the operationalization of WIGOS. B Goodison will attend the ICG-WIGOS meeting in January 2018, and he will request a resolution for this issue. S Colwell noted that Antarctic stations also fall outside NMHS programs, and asked that clarity is provided on where the obligation lies for the issuance of the WIGOS ID and for populating OSCAR, for these stations. **[S Barrell, B Goodison, 2018]**

S Barrell recalled that WIGOS is about to become operational, which means that all Members must be ready to embrace the four observing components of WIGOS, including the observing component of GCW. The issuance of WIGOS IDs is a critical first step in this process.

On the WMO Information System (WIS), S Barrell noted that WIS is integral to WIGOS, but it extends beyond it. WIS is about finding, accessing, and exchanging information, and it includes original, repackaged, and redistributed data. S Barrell noted that, currently, WIS, still, mostly represents the World Weather Watch, and more needs to be done for the other WMO Programmes. Also it is still difficult to find data, add new data on WIS. In its current form, WIS and GTS primarily support the expert meteorological community.

For GCW, there are challenges related to the real time data exchange and the WIS metadata. For additional information and support, GCW should facilitate the engagement of its partners with their country's principal Global Information System Centre (GISC), http://www.wmo.int/pages/prog/www/WIS/centres/index_en.php). Information on the structure and operations of WIS is available on the Manual on WIS (WMO-No. 1060), and the Guide to WIS (WMO-No. 1061).

S Barrell provided an overview of WIS 2.0, which is envisioned to be the long term solution, with the goal that all WIS data will be managed, documented, discoverable, accessible, and easy to use. A planned API will improve the available selection and granularity of requested data sets, as well as provide better services for visualizing or processing the data . It was noted that WIS 2.0 will recognize NetCDF data formats. The group requested that more information must be provided on how WIS 2.0 will handle NetCDF, as this format is most widely used by the research community. **[Secretariat, May 2018]**

The group agreed that the goal of establishing the GCW Data Portal as a Data Collection or Processing Centre (DCPC) during the next financial period, is an important milestone for the pre-operational phase.

2. GCW Working Groups progress and plans

2.1. Observations WG

2.1.1 CryoNet and GCW Observing Network

Dr Wolfgang Schöner, the Lead of the Observation Working Group (WG) and the Chair of the CryoNet Team, outlined the outcomes of the WG meeting held on 8 January.

GSG agreed with the recommendations made by the Observations WG, as follows:

2.1.1.1 Updates to the WMO Technical Regulations, WMO-No 49, and the Manual on WIGOS WMO-No. 1160

GCW will provide updates to the WMO Technical Regulations (WMO-No 49) and the Manual on WIGOS (WMO-No. 1160) to improve the clarity of the GCW terminology, thus, addressing feedback received from users. GSG approved the following changes:

- The term "*Site*" will be replaced with "*Cluster*", i.e. CryoNet cluster;
- The approval of "CryoNet Clusters" will be done by GSG, at the recommendation of the Observations WG Lead. Once approved, the proponent will be asked to reflect the information in the OSCAR database.
- The criteria for CryoNet stations and contributing stations were clarified, and are summarised in Annex 3.
- A definition for the GCW surface observing network will be provided to include CryoNet stations, contributing stations, and stations of affiliated networks;
- The inactive CryoNet stations would become contributing stations;

[Secretariat to coordinate the updates with WIGOS, March 2018].

2.1.1.2 Input to the WIGOS Metadata Standard

- Finalise the list of CryoNet cryosphere variables by consulting more broadly with the cryosphere communities (in particular for lake and river ice) – **[GCW experts to connect with their peers, Secretariat to coordinate, GSG-6]**
- Provide input to the WIGOS Metadata Standard in the form of variable definitions and names, also requested by S Barrell (see 1.5):
    - For variables already included in the WIGOS Metadata Standard, confirm or update, as needed.
    - Add new cryosphere variables, focusing on recommended variables by cryosphere component. Variable names and streamlined definitions to be included.
    - Priority will be given to snow, sea ice, glaciers, and permafrost components.

  GCW needs to establish a process of defining and validating the names and definitions of reported variables for inclusion in the Metadata Standard. This process could follow the CF convention, as detailed in Section 3 of this report. This is a cross-cutting action for CryoNet, Portal, and Terminology Teams.

  It was recommended to handle one variable at a time, with the responsibility being assigned to a designated individual.

  [Obs WG, Terminology, and Data Portal Team to coordinate input to WIGOS MD TT, snow variables for March 2018, the rest to follow;
  Secretariat to provide a road map for updating the WIGOS Metadata Standard, June 2018.]
- Link the recommended CryoNet observing requirements to existing WMO Application Areas (AA), already documented in the respective Statements of Guidance; and consult with the GCW station owners to assess the opportunity for recommending additional AAs. This work is part of the Rolling Review of Requirements process. **[WG Chairs, GSG-6]**

For additional information of the specifics of this actions, see Section 3.4

2.1.1.3 Assessment of candidate stations for the GCW surface observing network

W Schöner summarized the outcome of the assessment of candidate stations, since GSG4. The GCW Steering Group agreed that:

- All submissions made before 26 February 2018 will be assessed and submitted for the approval by GSG by 5 March 2018[1]. Approval will be given by e-mail.
- Observations WG will review all outstanding submissions, including those received prior to 2017.
- The final list of recommended CryoNet and contributing stations will be submitted for consideration by EC PHORS-8 which will take place on 21-24 March, 2018 . EC PHORS will recommend the final list for approval by EC-70. To avoid distribution of partial lists, the final list of recommended stations will be published in the EC PHORS-8 report and, as approved, in the EC-70 session report.[2] **[Secretariat to coordinate with W Schöner, March 2018].**
- The Vesleskarvet station (South Africa) has an observing programme which currently does not include any observations of the cryosphere, however, it will be maintained as candidate and the proponent will be informed. **[Secretariat, August 2018].**
- Secretariat will inform all proponents of the outcome of EC-70 regarding station approval **[Secretariat, August 2018]**
- Guidance will be developed and provided to contributing stations on how they could become CryoNet stations.**[Observations WG Co-Leads, 2018]**
- Guidance will be developed for assessing and including mobile platforms in the GCW observing network. Consider whether the mobile platforms could be accepted as affiliated networks, e.g. the International Arctic Buoy Programme (IABP) and International Programme for Antarctic Buos (IPAB) **[Observations WG Co-Leads, GSG-6]**
- Secretariat to verify how to record affiliated networks in OSCAR. Currently, OSCAR has provisions for GCW Stations and this includes a "child" station type called "CryoNet". **[Secretariat, March 2018]**

As proposed by W Schöner, GSG agreed to amend the GCW station evaluation process as follows **[WGs Leads, 2019+]** :

- First phase: approval will be determined based on the information provided by the proponent, relative to the minimum requirements for a GCW station.
- Second phase: with two steps:
  - One year after the 1st approval, GCW will confirm the availability of metadata to the GCW Data Portal (once all systems are established).
  - Two years after the 1st approval, GCW will confirm that the data are accessible via the GCW Data Portal.

[1] Following the complete evaluation of current candidate stations, GSG approved the submission for consideration by EC-PHORS-8; a number of the 105 stations are recommended for approval as CryoNet, and 48 stations as Contributing Stations.

[2] GCW will request EC PHORS to recommend to EC-70, the approval of the GCW Surface Observing Network, as a component of WIGOS, and comprising of all stations deemed as meeting the CryoNet and Contributing stations criteria, including those already approved by EC-68 and EC-69. Once the GCW Surface Observing Network is established, Members will have the opportunity to, more effectively, support it.

2.1.2 Best Practices : Engagement with CIMO

Dr Charles Fierz, the Co-Chair of the Best Practices Team, provided an overview of the outcome of the meeting held on 8 January 2018.
He noted that:

- Significant progress has been made on the development of the Best Practices guidelines for snow, sea ice, and glaciers.
- The development of guidelines for permafrost, in collaboration with Alfred Wegener Institute (AWI), is under consideration. Anna Irrgang (AWI), one of the meeting's attendees, will be the point of contact. **[C Fierz, A Irrgang, GSG-6].**
- A significant body of knowledge was developed by Aldís Elfarsdóttir, an intern of the Icelandic Meteorological Office, Nov 2017 to Feb 2018.
- The section on snow observing practices is the most advanced. This has been developed in collaboration with the WMO Commission on Instruments and Methods of Observation (CIMO). The first draft will be shared with the CIMO Editorial Board in March, and will be formally sent for review to all WMO Members, with the goal of approval by Members at the 17th CIMO session in October, 2018. **[C Fierz, Secretariat, March 2018]**
- Contributions from lake and river ice experts are necessary for developing the relevant chapters of Best Practices Guide. All experts are asked to provide recommendations to Secretariat **[GSG, June 2018]**

C Fierz informed GSG that GCW and CIMO agreed to publish the GCW Best Practices in a new standalone volume on the "Measurement of Cryosphere Variables", as part of the existing CIMO Guide (WMO. No-8). This volume will include individual chapters on best practices for each cryosphere component. C Fierz took the lead in developing a Chapter One for this volume, which will outline general requirements for cryosphere observations, and will include the list of observed variables. This chapter will follow the model of the existing Chapter 1, Part I, Measurement of Meteorological Variables. The content would evolve in time. **[C Fierz, March 2018]**
The participants agreed that the CIMO Guide is easily accessible by the scientific community, and is a success of WMO/CIMO. The inclusion of GCW Best Practices in this Guide allows GCW to benefit from an already proven process for managing guidance documentation, and to reach out to a larger community. As a component of WIGOS, the GCW observing component needs to utilize to its benefit the existing WMO mechanisms.

GSG was informed that CIMO has agreed to change the name of the Guide WMO-No 8, to "Guide to Instruments and Methods of Observation", in recognition of its relevance to all observations within the WIGOS framework. The name change will be formalized at the 17th CIMO session, in October 2018. It was noted that GCW is setting an example for the other communities in reflecting the spirit of WIGOS.
GSG welcomed the collaboration with the CIMO. The CIMO Management Group will review the collaboration with GCW, at its meeting in March 2018**.**

B Goodison recommended that historical practices with pictorial descriptions be reflected in the guidelines, as these will support the understanding of historical data.

The group agreed on the following additional actions:

- To develop a GCW structured electronic library to include the currently available references on the GCW website, and any other sources referenced in the

guidelines for best practices. This would support the assessment of the data (including historical data), methodologies, and metadata.
- To consider additional historical or emerging measurement techniques for being included in the set of references available via GCW.
- To prepare a roadmap for the development of the Guide to Cryosphere Variables by component.

It was agreed to establish small task teams for developing the Best Practices Guides, by area of expertise, in order to address the actions above. T Thorsteinsson made the following recommendations:
- Engage additional experts on the development and review of the guide.
- Include definitions of variables that are consistent with definitions recommended by the Terminology Team and also with the WIGOS Metadata.
- Include modern methods of measurement.

T Thorsteinsson noted that some GCW stations are not reporting the minimum variables recommended for CryoNet. The group agreed that, for the time being, the list will not be expanded.
The group asked Secretariat to find out whether the OSCAR database could be used for the repository of historical metadata.[**Secretariat, June 2018]**

2.1.2.1 Best Practices - Glaciers

Dr Thorsteinn Thorsteinsson presented the early draft of the Glacier Best Practices Guide, developed in collaboration with Aldís Elfarsdóttir. He noted that the measurement of snow on glaciers will be included in the Snow chapter, and that glacier specific topics to be included in the Glacier chapter. The structure will be based on the structure recommended by the CIMO Guide, adapted to reflect the specifics of measuring glacier variables.
He noted that, the guide for glaciers will have to:
- Reconcile the point and spatial observations for glacier thickness and volume.
- Give specific considerations to methods of measurement and definitions for glacier area and surface mass balance (e.g. point vs areal measurement) as well as the relationship to elevation.
- Include references to glacial lakes.

The group agreed to limit the level of details included in the first version, and that the background material is made available separately on the GCW electronic library.

Mark Drinkwater strongly recommended that the development of best practices guides, e.g. for glaciers, recognize the complementarity of in situ and satellite observations. While each chapter will focus on the in situ methods of measurement, it is important to note of value of complementary remote sensing and satellite methods **(on going consideration).**

2.1.2.2 Best Practices - Sea Ice

The development of a Sea Ice Best Practices Guide was discussed in a session preceding the GSG-5 meeting. The discussions were led by Dr Petra Heil and Dr Penelope Wagner. Dr Hajo Eicken participated remotely, representing the Climate and Cryosphere Project of the World Climate Research Programme. He provided an overview of the activities of the Arctic Sea Ice Working Group. Its goals are to develop, standardize, and implement measurement protocols for Arctic sea ice, and to integrate surface-based observations

with remote sensing and modelling efforts. He noted that there was interest in cooperating with GCW in the context of the work on ship-based observations and of the MOSAiC project (Multidisciplinary drifting Observatory for the Study of Arctic Climate).

The group agreed that the GCW Sea Ice Best Practices will be published as a chapter in the new Volume of the Guide to Instruments and Methods of Observations. (CIMO Guide). **[P Heil, P Wagner, V Smolyanitsky, GSG-6].**
The group discussed the in-situ sea ice variables recommended at GCW stations, and noted that they need further review and consultation. It was agreed that these variables need to be relevant to modelling and the satellite community, i.e. reflecting the perspective of data users; e.g. sea ice topography.

H Eicken invited GCW to collaborate with MOSAiC, as the sea ice properties and surface based measurement group have been developing protocols for ice-core measurements, including standardized data sheets ad data entry/archival formats. Further refinement of these is planned for 2019. This could also help with refining the list of other observed sea ice variables. The team will continue its consultations before the list of sea ice in-situ observed variables is finalised for CryoNet stations in 2018, to ensure broad acceptance and representation. **[P Heil, P Wagner, V Smolyanitsky, GSG-6]**

H Eicken noted that CliC initiated work on ship based observations to complement the operational ice charting products and to reflect the needs of modellers (e.g. melt ponds). Vasily Smolyanitsky recommended that the development of the Sea Ice Best Practices Guide include a review of the information available in the JCOMM Electronic Chart System Ice Objects Catalogue with the addition of what is missing, while trying to avoid duplication of efforts. **[P Heil, P Wagner, V Smolyanitsky, GSG-6]**

H Eicken invited GCW to consider the cooperation with the Arctic Sea Ice Working Group and MOSAiC on coastal observatories and autonomous observations. He proposed that specific joint initiatives are discussed following this meeting, e.g. organizing a workshop or a field-based effort. It was agreed to explore specific opportunities during 2018, e.g. use MOSAiC for testing the Lagrangian measurements of sea ice. **[P Heil, P Wagner, V Smolyanitsky, GSG-6]**

It was agreed that, in 2018, the Team will decide how to include measurement ship based, drift buoy-based, and relevant coastal observations, in the Sea Ice Best Practices. **[P Heil, P Wagner, V Smolyanitsky, GSG-6]**

The team agreed to explore the possibility of connecting in the context of the International Ice Charting WG meeting in Helsinki in September, 2018. **[P Heil, P Wagner, V Smolyanitsky, GSG-6]**

2.2. Integrated Products WG: Snow Watch

Dr Kari Luojus and Dr Vasily Smolyanitsky, the Co-Leads of the Integrated Products WG, provided an overview of the progress made since GSG-4, and the proposed activities for the upcoming period.

The Integrated Products WG includes the Snow Watch Team and the Sea Ice Products Team, which is in its early stages of development. They recommended (re)establishing similar teams on Glaciers, Ice Caps, Ice Sheets, Frozen Ground/Permafrost and Lake and River Ice products. They acknowledged that, currently, the focus is primarily on the development of best practices, which require coordination with space based observations, and the transition to focusing on products would be rather natural.

As most experts active in the Integrated Products WG are, mainly, from US and Canada, they recommended including experts from other regions, and inviting experts on lake and river ice. They proposed to expand the Sea Ice team as the Sea Ice Floating Ice Team. **[K Luojus; V Smolyanitsky, GSG-6]**

2.2.1 Snow Watch status update

K Luojus and Patricia de Rosnay provided updates on the results of the Snow Watch Team. K Luojus noted the active engagement of all Snow Watch Team members, and thanked them for their commitment.

Overall, in 2018, the Team will focus on:

- initiating the work of the Solid Precipitation Products Task Team, as agreed at GSG-4, by inviting new members with appropriate expertise and finalising the ToRs **[Snow Watch co-Chairs, GSG-6],**
- developing additional products for publication on the GCW website (assessments, authoritative information),
- working closer with other GCW teams such as CryoNet,
- ensuring visibility and interactions at national levels, and
- an increased focus on the observations and products for the Southern Hemisphere.

2.2.1.1 Reporting Snow Depth and Snow Water Equivalent

P Rosnay provided an update on the implementation of Resolution 15 (EC-69) requiring Members to exchange internationally, snow depth data and the “zero’ snow depth. She noted that more data is already available on GTS. ECMWF conducted Observing System Experiments (OSE), demonstrating that the increased availability of snow depth data from all sources has a positive impact on the short and medium range forecast.

The group expressed appreciation for the ongoing collaboration with ECMWF, thanking P Rosnay and her colleagues for their work, and reiterated the commitment for this engagement.

P Rosnay noted:

- Over 200 additional stations from China are distributing snow depth data on GTS, in BUFR format. The group agreed that GCW/WMO needs to send a letter of appreciation to China, as well as to other Members, for the contribution with additional datasets. **[Secretariat, June 2018 (China)]**
- US SNOTEL data is available on GTS since August 2017, in SHEF format (Standard Hydrometeo Exchange Format), not in BUFR. ECMWF, through P Rosnay, is providing support to NOAA for converting from SHEF to BUFR format. **[P Rosnay, GSG-6]**
- Additional data are available in BUFR and SYNOP (TAC+BUFR) formats, and there is good coverage over Europe, with some gaps over Bulgaria and Ukraine, for

example. Secretariat will work with P Rosnay and Regional Association VI to address these gaps**.[Secretariat, Sept 2018].**

- P Rosnay asked that GCW actively promotes the implementation of Resolution 15 (EC-69), especially in areas with major gaps, e.g. South America, North America, Central and Western parts of Asia, e.g. the Tibetan Plateau, where the data is available, but not exchanged in BUFR format. It was agreed that the Snow Watch Team identifies gaps in reporting snow depth. Secretariat will prepare letters from WMO SG to the respective PRs, asking for the available data to be exchanged, highlighting the value of the additional data sets, including for contribution to the global statement on climate. Focus on the Southern Hemisphere. **[Secretariat, K Luojus, R Brown, P Rosnay, GSG-6].**
- The group noted that in the OSCAR database, only stations from Germany indicate the reporting of snow depth, in spite of stations in many other countries reporting and exchanging snow depth, regularly. These stations should be associated with GCW. The group requested that the matter is investigated and addressed **[Secretariat, P Rosnay, GSG-6].**

A BUFR template for reporting Snow Water Equivalent (SWE) will be submitted in 2018 to the WMO IPET-CM (INTER-PROGRAMME EXPERT TEAM ON CODES MAINTENANCE). This will open the possibility to use SWE observations for NWP applications. The team will develop a roadmap for archiving and exchanging the in-situ SWE data. **[P Rosnay, R Brown, GSG-6].** P Rosnay noted that there are still gaps in satellite observations for SWE, and this may be addressed through future work including in cooperation with the Polar Space task Group (PSTG).

P Rosnay recommended that GCW, through the Snow Watch and Best Practices Teams, continue the collaboration with COST Action HarmoSnow on general observations practices and data exchange, and with GODEX (Global Observation Data Exchange), to ensure the acceptance and use of the new SWE BUFR template. **[P Rosnay, C Fierz, GSG-6]**

2.2.1.2 SnowPEx

K Luojus provided an overview of the SnowPEx project, funded by ESA, which ran from 06/2014 to 12/2016, as a joint initiative of PSTG and the Snow Watch Team. The final workshop (ISSPI-3) will be held in Europe in 2018 or in 2019, to wrap up final results and prepare outlines for several scientific papers.

SnowPEx has demonstrated the significant value when the scientific community endorses large scale experiments, with multiple stakeholders. K Luojus recommended that GCW endorse other future similar efforts, focusing on innovation in observations, space observations, in particular, as a mechanism to pursue clear scientific goals. The group agreed with the recommendation.

K Luojus informed the group about the upcoming consultation on future snow missions, organized jointly by GCW and PSTG-SAR WG in January, 2018, and the potential for other projects similar to SnowPEx. K Luojus will inform GSG on the outcome of this workshop. **[K Luojus, GSG-6]**

2.2.1.3 Other snow products

K Luojus and V Smolyanitsky informed GSG about the increased engagements of GCW with the Arctic Polar Regional Climate Centre (ArcRCC) network. They noted the request that GCW develops products contributing to ArcRCC functions, at the regional and sub-regional level, such as daily snapshots, trackers, anomaly plots, multi-dataset trackers, as well as the combined sea ice concentration and SWE. They recommended the use of the results from SnowPEx for guidance on the derivation of products using the multi-dataset approach. **[K Luojus, R Brown, V Smolyanitsky, GSG-6].**

The group agreed to explore how to provide similar products to all RCC, reflecting the state of the cryosphere at lower latitudes. **[K Luojus, R Brown, V Smolyanitsky, GSG-6].**

The group acknowledged that the Canadian Historical Snow Survey data set, covering the period 2004-2016, contains data from ten different agencies, and should be published through GCW portal or website, once the permission to distribute these data, freely, is granted. **[Snow Watch Co-Chairs, J Key, GSG-6]**

K Luojus recommended that a Snow Watch Team meeting, together with the Solid Precipitation Products Task Team is be organized in the next year. **See sub-section 2.2.1.4. [GSG-6, Snow Watch Co-Chairs and Secretariat]**

2.2.1.4 SPICE Project

Dr Mareile Wolff (Met Norway) provided an overview of the Solid Precipitation Intercomparison Project (SPICE) organized by WMO/CIMO, and which began in 2013. The project assessed the currently available technologies for measuring solid precipitation and snow on ground, in-situ. CIMO will publish the final report in 2018. Over the last few years project results have been published as scientific papers in peer reviewed journals (e.g. SPICE Special Issue https://www.hydrol-earth-syst-sci.net/special_issue400_78.html)

The project is relevant in the context of the newly established Task Team on Solid Precipitation Products, which is expected to carry out assessment on the practical application of SPICE results, and make recommendations on the utilization of solid precipitation data from automatic weather stations. The recommendations of SPICE will be used to inform the ToRs for the Solid Precipitation Team.

2.2.2 Proposal for establishing a World Snow Monitoring Service (WSMS)

C Fierz invited GSG to explore the feasibility of establishing within the framework of GCW, a snow focused initiative, providing broad support on the quality and long term sustainability of snow data, e.g. named the World Snow Monitoring Service (WSMS) or similar. WSMS would be backed up by WMO/GCW and would have the International Association for Cryosphere Sciences (IACS) as its scientific advisor. WSMS would be modeled, to a certain degree, after the World Glacier Monitoring Service (WGMS). Its role would not be to replace the existing centres, rather, it would complement them by providing services currently not available in a coordinated and consistent manner. In particular, it would target regions where there are no sufficient resources to sustain these services. Its functions would include:

- Rescue and host data for organizations without means to do so, and which, otherwise, would be lost. In this effort, GCW would collaborate with other Programmes of WMO (e.g. CCl).
- Cure, recover, and homogenise snow data series at regional and sub-regional level.
- Being a centre of excellence for snow science, snow data, and snow data products.

The group appreciated the proposal and recommended to further refined the objectives and engagements, and position the proposal in the context of the GCW regional engagements, and the links to RCCs. The group requested that the item be presented at EC PHORS-8, for further guidance, and to plan how to engage other bodies. The Secretariat will work with the Climate and Water Department of WMO on further developing this proposal**. [C Fierz; Secretariat, EC PHORS-8, GSG-6]**

2.3. GCW engagement with JCOMM

V Smolyanitsky, the co-chair of the Integrated Products WG, and the Chair of the Expert Team on Sea Ice (ETSI) of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) presented the outcomes of 5th Session of JCOMM (JCOMM-5), which took place 25-29 October 2017, in Genève, Switzerland, with relevance to GCW:

Decision 5, on the Participation in the work of WMO Projects, Programmes and co-sponsored Programmes, decided to support the implementation of the Arctic-RCC Network.
Decision 6, on the Collaboration with the Global Cryosphere Watch: JCOMM-5 decided to continue its close collaboration with GCW, focusing on sea ice activities and on the Arctic and Antarctic buoy programs. It invited GCW to organize joint work planning with the relevant Expert Teams of JCOMM, specifically:

1) *ETSI to collaborate with GCW for developing standards and best practices for observations and data exchange for sea ice, satellite products validation, and the derivation of relevant products, on the role of sea ice in the global climate system;*
2) *The Data Buoy Cooperation Panel (DBCP), the International Arctic Buoy Programme (IABP) and the WCRP-SCAR International Programme for Antarctic Buoys (IPAB), were invited to collaborate closely with GCW for developing standards and best practices for sea ice observations and data exchange;*

With Decision 12 on the Contribution of JCOMM to the Global Framework for Climate Services (GFCS), JCOMM-5 agreed to support the inclusion of sea-ice products in the Arctic Polar Regional Climate Centre Network operations.
In Recommendation 12—Revised Manual on Marine Meteorological Services (WMO-No. 558) and Recommendation 13 — Revised Guide to Marine Meteorological Services System (WMO-No. 471), JCOMM-5 recommended the approval of these documents by EC-70. These are closely and technically linked to the WMO Sea Ice technical publications, including sea-ice and iceberg terminology, sea-ice information charts, and are relevant to the sea ice focus of GCW.

The revised ToRs of the Expert Team on Sea Ice are available in Annex 7. The updated terms are noted in red.
He urged GCW to facilitate the collaboration between JCOMM and research communities on developing new products, on addressing emerging needs due to the rapidly changing

sea ice conditions. He acknowledged the difficulties in bringing operational and research communities together, however this is a critical function for ensuring the consistency in the technical documents and methods made, broadly, available.

Operational sea ice data are disseminated through several portals. Of these, the JCOMM "Ice Logistics Portal" (http://www.bsis-ice.de/IcePortal/) remains the main source; it provides mostly weekly circumpolar and regional sea ice products from the sea ice Services worldwide for the Arctic, sub-Arctic and the Southern Ocean.

Daily and sub-daily optical and microwave imagery and daily Marginal Ice Zone analyses are available through the PolarView portal (http://www.polarview.org), which is a user-customized interface. Alternately, the Southern Ocean ice and icebergs portal (http://ice.aari.aq) provides access to 7-14 days of sea ice and iceberg information through the contribution of the Arctic and Antarctic Research Institute (AARI) National Ice Centre (NIC), in which the Norwegian Meteorological Institute (NMI) provides point and shape analysis for the Southern Ocean.

V Smolyanitsky recommended that the GCW website continues to link to most of the integrated sea ice products and provides access to the latest material, as an interface to the numerous sources of information.

V Smolyanitsky, also, noted that the 2017 edition of the WMO-No.574 “Sea Ice Information Services in the World” provides the latest information for operational sea ice integrated products. This publication continues to provide information on best practices in sea-ice services available world-wide to mariners and other users, complementing the WMO publications, No.9, Volume D – Information for Shipping and No.558 – Manual on Marine Meteorological Services (WMO-No. 558). Additionally, WMO-No.574 reflects new information on types of sea ice and on icebergs, areas that have seen substantial progress in 2014-2017, including sea-ice forecasts based on numerical models, and Southern Ocean sea ice and icebergs analysis. These manuals support the YOPP Core Phase.

The group agreed with the recommendations made by V Smolyanitsky that GCW work jointly with JCOMM ETSI, IICWG, ArcRCC, and research groups on developing uncertainty estimates for sea ice, which is of great value for modellers, as well as outlooks and seasonal forecasts (for the ArcRCC network). Additionally, increasing the availability of products in NetCDF format would make information more accessible to the scientific user community. The recommendations made will help refining the terms of reference for the Sea Ice Products Team.

It was agreed to define a joint work plan with JCOMM ETSI, to reflect the JCOMM-5 decisions and the recommendations of this meeting. [**V Smolyanitsky, P Heil, P Wagner, GSG-6]**

2.4. Information and Services WG

Dr Jeff Key, the Co-Chair of the Information and Services WG, provided an overview of progress made on developing the GCW Website, and the Glossary of cryosphere terms.

He noted that, overall:

- On terminology: Significant progress has been made in compiling a large database of cryosphere terms. In parallel, the CryoNet recommended variables have been identified. Together, these will enable the development of a GCW Glossary, and will support the development of cryosphere metadata, facilitating the interoperability between the GCW Data Portal and the GCW stations.
- *Cryosphere Now* products: The number of GCW products has increased. The goal is to link the products posted on the website with the Data Portal. Data Portal visualization tools may be used for graphics on the website.

2.4.1 GCW Glossary

Dr Jeff Key informed the group that GCW has compiled cryospheric terms from a variety of well-known sources, including WMO, UNESCO, National Snow and Ice Data Center (NSIDC), Antarctic Sea Ice Processes and Climate (ASPeCt), ECCC, NOAA, USGS, IPCC, IPA, BoM, and others. In 2017, 1282 additional terms were added from six new sources, through a contract with a young scientist, Clement Hutin. There are, currently, 4141 entries from 26 sources, and over 2200 of these, are unique. Cryospheric terms have been added into the crowdsourced meta-dictionary YAMZ.

The glossary is being evaluated under contract, by Ruth Duerr, from Ronin Institute. The terms are being assess from a semantics point of view. R Duerr will identify inconsistencies and will make recommendations on how to address overlaps and discrepancies, and where feasible, recommending the consolidation of some terms. When completed, the assessment reports could be made public. The group expressed its support for this initiative.

A meeting of the Terminology team took place during GSG5. The meeting assessed the interim reports from R Duerr. They agreed to:

1. Eliminate “non-cryospheric terms” from the proposed official “GCW Glossary” terms, (e.g. purely atmospheric or magnetospheric terms such as aurora, auroral arc, aurora australis, aurora borealis, auroral bands, auroral corona, auroral curtains, auroral oval, auroral rays, auroral zone). The team will agree on list of terms to be eliminated, based on the recommendations from Ruth Duerr. The final reports will be uploaded on Google drive, and will be available to the team.[**Secretariat, G Casassa, GSG-6]**
2. Examine the final recommendations from R Duerr, and decide on how to use them. The follow up discussions will take place by teleconference(s) throughout 2018, for follow up.[**Secretariat, G Casassa, GSG-6]**
3. The team invited China to nominate an expert for the Terminology Team **[L Ma, March 2018]**

2.4.2 GCW Website

The GCW Website contains dynamic information (news, state of the cryosphere plots, highlights, calendar), as well as background, higher-level information, GCW documents, and outreach material. It links to the METNO GCW Data Portal. J Key noted the increase in traffic on the website (see Figure 1)

J Key noted several recent changes:

- A new Cryosphere Trends web page has been added, with updated assessments. There are 11 trackers, currently displayed (Figure 2).
- Cryosphere in the News items are, now, archived.
- CryoNet recommended variables lists have been added.
- New products are displayed: sea ice trackers from JAXA and NOAA/CIMSS, regional sea ice products for Alaska.
- Meeting pages are created, as meetings are organized.
- Added an Educational Resource page (needs more content).

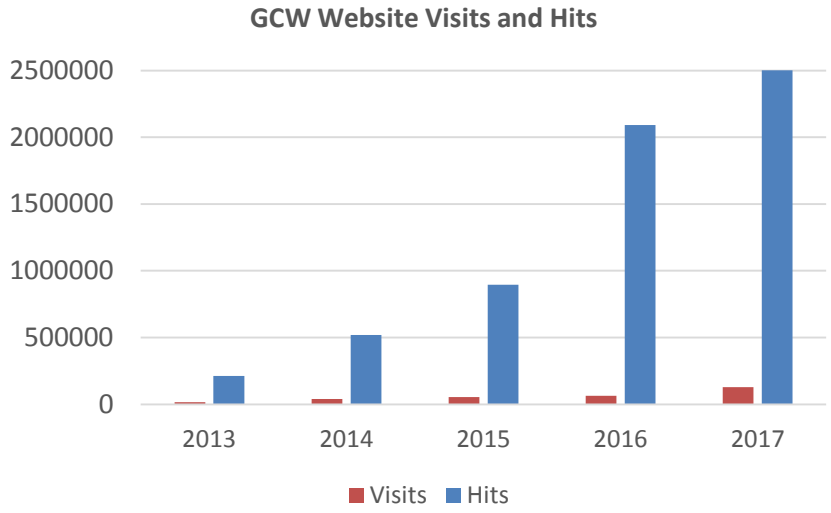

Figure 1: GCW Website Visits

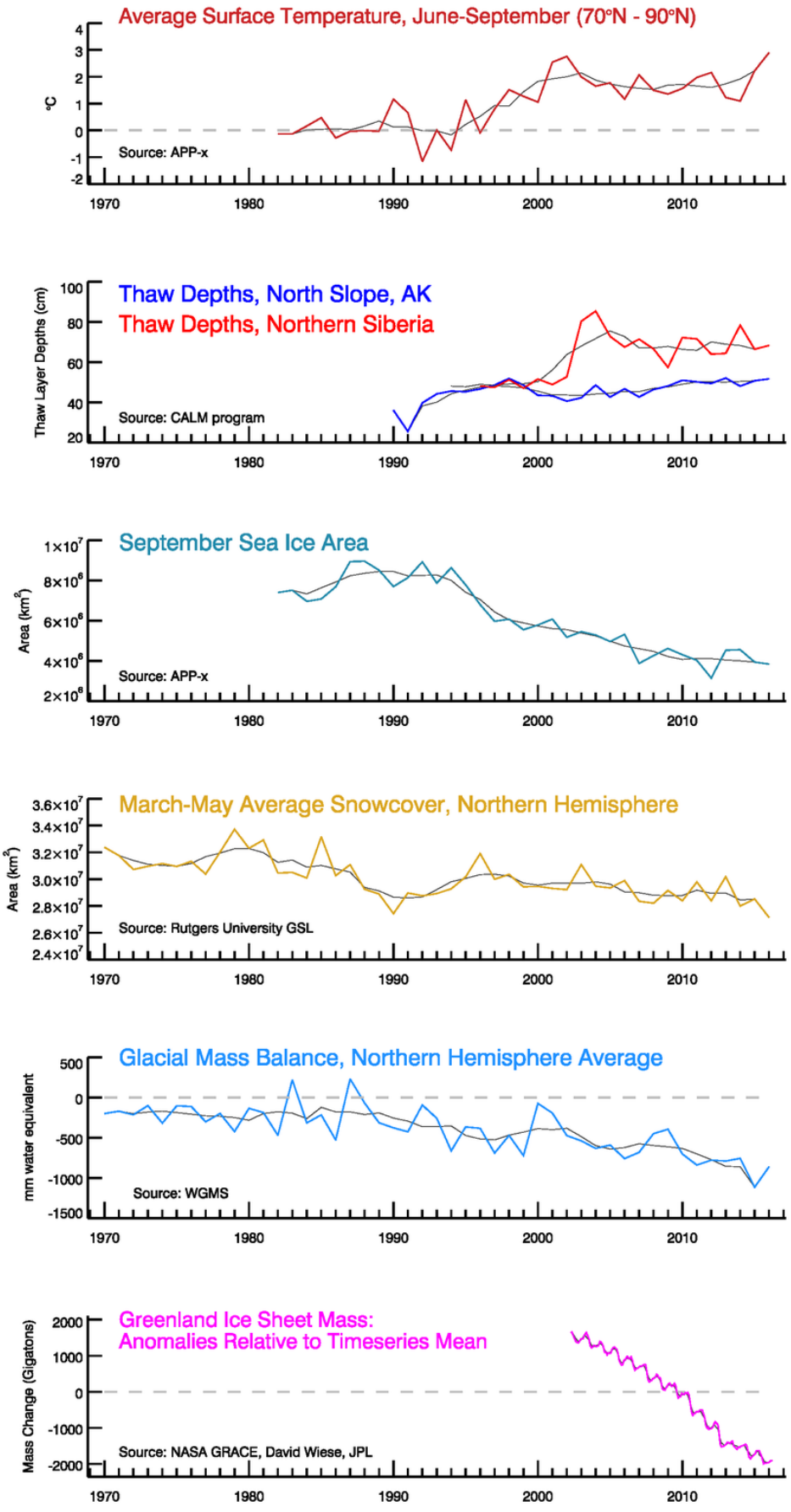

Figure 2: Norther Hemisphere Cryosphere Assessments

J Key noted that the assessment and products displayed in the *Cryosphere Now* section of the GCW website, are, either, created for/by GCW, or offered to GCW for posting on the GCW website, or are used with permission. See Annex 4 for the list of currently available products.

Some products in the *Cryosphere Now* section are graphics that are publicly available on the web, and are of interest for the community. The published "Trackers" are used to examine the current state of some variable in the context of recent climatology. Products that are not trackers only show the current state of a variable with no reference to the past. In some cases, approved data have been replotted by NOAA/Cooperative Institute for Meteorological Satellite Studies (CIMSS).

The group agreed that one of the most visible products is the cryosphere world map by component. J Key proposed that GCW funds a student to update the 2005 map. The group was invited to recommend to Secretariat options for completing this work. **[GSG, Secretariat, GSG-6]**

The group agreed with the following plan forward **[J Key, GSG-6]:**

- Find a backup/future website location, and run it as a parallel system. The option of using the Met Norway capabilities developed for the Data Portal was discussed.
- Resubmit a Wikipedia entry;
- Develop a GCW mobile application;
- Prepare a regular GCW newsletter;
- Prepare and publish a quality assurance CryoNet web page (perhaps linking it with the Data Portal and WDQMS, see Section 1.5).

Á Snorrason and W Zhang thanked J Key for his dedication, and sustained and valuable contribution to GCW. The GCW website has been a significant asset, providing GCW with increased visibility. They also acknowledged J Key's initiative regarding the preparation of annual assessments.

The group agreed that more needs to be done to promote the GCW website with the NMHSs. It also noted that NOAA's Arctic Report card is a valuable communication tool, and that the GCW website should be linked to it.

3. GCW Data Portal, Data Exchange and Interoperability (Data as a service)

Dr. Øystein Godøy, the Chair of the GCW Data Portal Team provided an overview of the GCW Data Portal, including data exchange and interoperability aspects. He noted the goal of developing the Data Portal to provide data as a service.

Highlights:

- The GCW Data Portal, similar to the Global Atmosphere Watch (GAW) interacts with an inhomogeneous community of NMHSs, Universities and independent research institutions. This diversity poses numerous challenges for metadata and data interoperability.
- The Data Portal is not a repository of data. If resources are available, it could develop capabilities to store data.

- When fully operational, the Data Portal will provide access to data sets with the goal of becoming a Data Collection or Processing Centre (DCPC).
- The preferred data format for the GCW data portal is NetCDF, which is the format most widely used by scientists. BUFR exchange could also be made available, only upon request from the community.
- The GCW Data Portal is an open data space, and does not predefine the data types, however it operates on the principle of a consistent use of common data models.
- Currently the Data Portal supports the WIS metadata.

Ø Godøy informed that a new solution for the Data Portal will be available in 2018. It will offer transformative data services, via a web interface, as long as a common data model is used (a model similar to that used by IPCC). This will allow data visualization in the form of time series plots, which will allow users to compare products and extract tailored products to meet specific needs.

Additionally:

- There are requirements for WIS/WIGOS interaction, including:
    - participation in discussions on WIGOS Metadata Standards (WMDS) as part of the WIGOS Metadata Task Team (WMD TT),
    - testing the transformation of CryoNet information to WDMS XML, following discussions on information exchange, and
    - the need to review vocabularies (Parameter/variable descriptions are needed in the discovery metadata, not only for WIGOS purposes);
- Progress is underway on the development of:
    - interoperability guidelines and an operations manual,
    - automatic filtering of harvested records (“cryosphere” or “GCW” datasets),
    - manually supervised ingestion of harvested metadata, where metadata are exposed through OAI-PMH;
- Utilisation / traceability using DOIs: Implementation is planned for 2018;
- Reimplementation of the portal solution as a service oriented architecture. A new test server has been set up (where tests are ongoing) and will be available at a later date.

Sue Barrell highlighted the fact that GCW, as well as GAW, are examples of the collaboration which WMO aspires to achieve in the context of WIGOS. The goal of WIS is to bring in other communities, and the efforts made by GCW to facilitate the data access from CryoNet stations show how to meet the others half way and create a sustainable system.

3.1. Interoperability with CryoNet stations and Data Centres

Since 2015, with dedicated effort from WSL/SLF Davos, significant progress has been made to support the interoperability between data systems (e.g. station-Data Portal), at data level. SLF has kindly agreed to continue its support for the development of the interoperability package, in collaboration with the GCW Data Portal. When completed this will be made available to all GCW stations, allowing them to become interoperable with the Data Portal, regarding their data model.

A pilot was initiated in September 2017, as a three way effort between SLF, GCW Data Portal, and a WMO consultant, Dr Joel Fiddes. As part of this project, SLF has further developed its applications, permitting access to data files of arbitrary format and converting them to a standard based data model with ability to query the portal, e.g. NetCDF (Figure 3).

Discussions are underway for deploying the applications for further testing at Sodankylä (Finland), Kluane Lake (Canada), and for INTERACT stations. For Sonnblick, W Schöner will provide contact to Ø Godøy **[Ø Godøy, K Luojus, Shawn Marshall, J Fiddes, W Schöner, 2018].**
A demonstration of this application will be made at Polar 2018 (June 2018). **[Ø Godøy, June, 2018]**

As part of this pilot project, GCW conducted a survey of data capabilities of CryoNet and contributing stations. This revealed that, although there is recognition of the value of standardizing data and metadata, the GCW stations use a variety of formats and vocabularies, and have limited capabilities to make changes to their data management systems in view of interoperability. Most have expressed interest in adopting the GCW recommended applications, and become interoperable with the Data Portal.

GSG thanked C Fierz and SLF, as well as to Ø Godøy and Met Norway, for the significant contribution to GCW for achieving the interoperability with the GCW stations. The group also acknowledged the significant contribution made by Dr J Fiddes in advancing the development of the interoperability package.

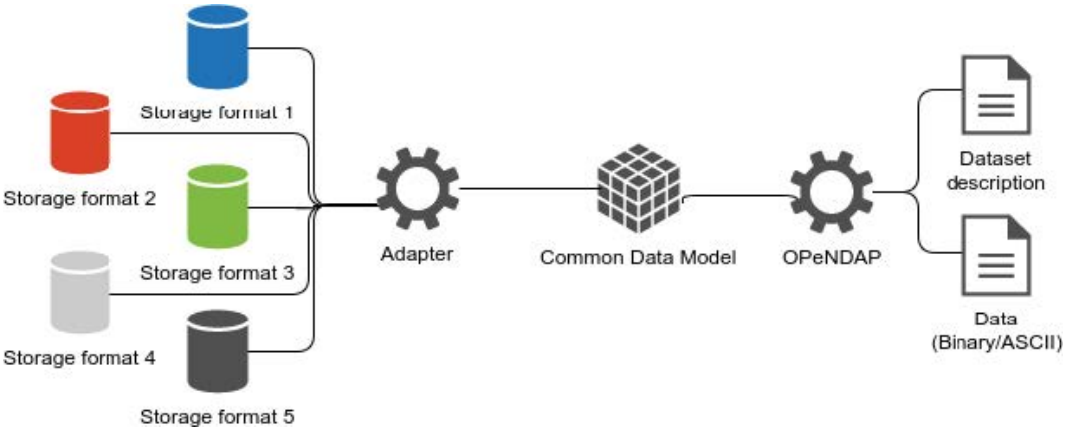

Figure 3: GCW Data access model

The group agreed that there is a need to define the "operational readiness" checklist of a GCW station and include it in the pre-operational plan **[W Schöner, Ø Godøy, GSG-6]**

3.2. Data Portal and OSCAR

Ø Godøy noted that the Data Portal does not fully support the WIGOS metadata. A lighter version of WIGOS metadata is currently tested by Met Norway for the Svalbard Integrated Observing System (SIOS).

Ø Godøy informed the group that:

- *The GCW observing network, CryoNet, is a collaboration between NMHSs and scientific institutions. NMHSs will integrate with OSCAR directly, as this is part of*

their regular approach. This is different for scientific institutions; they either integrate directly with OSCAR or through the GCW Data Portal.

- *Ideally stations should connect directly to OSCAR, but that requires that stations are allowed to do so and they have resources to do it. The process of enabling stations to link to OSCAR can vary between nations.*
- *Some stations operated by scientific communities have indicated a wish for the GCW Data Portal to operate as the interface to WMO systems and requirements in order to simplify the process for these stations.*
- *If the GCW Data Portal is to facilitate this process, that also raises the issue of who is eligible to update information in OSCAR.*
- *On a general note, there is a wish from the community that the process of interfacing WMO systems like WIS and WIGOS, the last represented by OSCAR, should reuse interfaces to keep development and maintenance costs down.*

It was agreed that GCW must find ways to harvest the station metadata from questionnaires, and feed the information to OSCAR. The GCW Data Portal could do this if resources are available, and if it is on the 2018 work plan. **[Ø Godøy, J Key, GSG-6]** Currently, Ø Godøy is exploring the development of a special API for interaction with OSCAR. This will be of real benefit for small stations which may not have the resources for entering their station information in OSCAR. **[Ø Godøy, 2018]**

It was reiterated that the interoperability of CryoNet and contributing stations depends on the allocation of unique WIGOS ID. See item 1.5 for actions.

3.3. GCW Data Portal linkages with other Data Portals (YOPP, ArcRCC, SIOS)

Ø Godøy informed the group that the GCW Data Portal development is linked to several other initiatives, which increase the impact of its services; specifically:

- the Year of Polar Prediction (YOPP) Portal,
- the Arctic PRCC Portal Nordic Node,
- SAON-Arctic Data Committee (ADC),
- INTERACT and APPLICATE (EU H2020 projects),
- Svalbard Integrated Observing System (SIOS) / Nansen Legacy,
    - its functionality is developed through SIOS KC (RCN), for which the WIGOS metadata describing the observing infrastructure is relevant,
- the Norwegian Scientific Data Network (RCN),
- the Norwegian Marine Data Centre (RCN), and
- the Norwegian Satellite Earth Observation Database for Marine and Polar research (RCN)

3.4. Metadata and data standards;

Ø Godøy reminded the group that the development of the Data Portal continues to face challenges at the metadata level in terms of semantics and terminology, and at the data level in terms of formats, semantics, terminology, and the use of a common data model. If data are not harmonized in a common form, they are not going to be used by the community.

He requested that GCW develop a governance procedure for terminology. One option for GCW is to use the Climate Forecast (CF) convention (http://cfconventions.org/), which has a process for proposing new terms, allowing for broad review: once a term is proposed, if there is no objection, and the guidelines are followed, the terms are accepted.
In regards to mapping the terminology through consensus, the GCW Data Portal has teamed up with the SAON/IASC Arctic Data Committee (ADC), the Standard Committee on Antarctic Data Management (SCADM) and the Interagency Arctic Research Policy Committee of US (IARPC).

He recalled the discussions recorded in Sections 1.5 and 2.1, which emphasized the priority for including the GCW observed variables in the WIGOS Metadata Standard, without which the interoperability is not feasible.
While linked to the work on reviewing the terms on the GCW Glossary of Cryosphere terms, the input to WIGOS Metadata Standard is not the same. For interoperability at data level, GCW needs to develop practical, simplified descriptions of datasets.

It was agreed that the GCW keywords need to cover both measured and derived variables; for use in OSCAR, the WIGOS Standard is limited to measured variables. For GCW data access, keywords for measured and derived variables are needed to describe the data which is expected to be accessed from providers, and expected by users.

GCW immediate actions:
Define a process for input to WIGOS Metadata standard. Regular meetings to make progress on input of variables to WIGOS MD (need to provide variables in a machine readable form). A core people to engage in it in collaboration with the Observations WG.
Actions resulted from this request are captured in Section 2.1, of this report.

The group noted that increased standardization could be further achieved by recommending the use of standard output formats by equipment manufacturers, including for data loggers. GSG has asked the Secretariat to work with CIMO and Hydro-meteorological Equipment Industry Association (HMEI) to develop and recommend standards for data output, using NetCDF**. [Secretariat, GSG-6].**

The interoperability with WGMS and the stations reporting through WGMS is desirable and efforts are being made in this sense. Those stations reporting through WGMS, and which are designated as CryoNet, would need to provide additional data to the GCW Data Portal (e.g. meteorological data). They would also need to provide information to the Data Portal and not through WGMS or Pangea or other data centres (GTN-P, etc). **[Ø Godøy, C Fierz, Secretariat, GSG-6]**

4. GCW Regional Activities

4.1. GCW regional activities;

J Key and G Casassa provided a summary of the GCW Regional activities.

In July 2017, GCW held a workshop in Arusha, Tanzania, on the cryosphere in tropical regions. The workshop was attended by experts from South America (Bolivia, Colombia, Ecuador, Peru), Africa (Tanzania, Kenya, DR of Congo, Morocco), and Asia (Indonesia). Following this workshop, Mount Kilimanjaro Ice Field was submitted jointly by the University of Massachusetts and the Tanzanian Meteorological Agency as the first CryoNet station in Africa.
One topic raised at the workshop was related to the nature of the relationship between the NMHS and the international research organization establishing and running the observing stations (e.g. Mount Kilimanjaro Ice Field). Most cryosphere observations in tropical regions are organized by research organizations from outside the country where operational. Issues regarding permits restrict the access to sites for observations. GCW was asked to facilitate the linkages between the NMHS and the sponsoring organization, to ensure that the operation of such stations is sustainable in time (e.g. acting as a liaison between the proponent organization and relevant government departments), and that the NMHS gains access to the data. **[Secretariat, Obs WG Chair, GSG-6]**
These relationships need to be mutually beneficial, to be sustainable.

It was noted that all workshops generated lots of enthusiasm, and were useful to establish contacts with the local communities and work towards understanding specific issues. C Fierz encouraged GSG to focus on the sustainability of regional initiatives by addressing practical aspects, such as developing skills locally and by showing people how to do it. He mentioned that the proposed Snow Monitoring Service is intended as a mechanism by which specific projects can be run, regionally. These projects can include practical topics like data observations, data access and skills. Practical goals would also increase the chance of funding.

The group agreed that GCW needs to work at regional level through the WMO Regional Associations (RA), which have a better understanding of the local landscape.

The group agreed on the following activities, in cooperation with UNESCO, where possible:

- Advance the concept of the World Snow Monitoring Service, and plan a demonstration project in one country, e.g. in collaboration with RA VI (submission made for RA VI-17), in conjunction with a workshop in Caucasus region.**[C Fierz, Á Snorrason, Secretariat, Feb 2018, GSG-6]**
- Further promote the snow depth data exchange at country level and identify barriers to this. Chile and Argentina are interested in reporting snow. See 2.2.1.1 for actions.
- Planning additional training activities, e.g. in Argentina.

The group noted that the engagement in each region needs to account for strengths and weaknesses specific to that region. For example, in South America, there is a strong Group on Glacier Mass Balance sponsored by UNESCO IHP, which is already providing data to CryoNet. They are, however, weak in terms of snow and permafrost research: there would be a good opportunity for GCW to be involved together with IHP (Snow) & IPA (Permafrost), e.g. permafrost in Argentina and the Patagonia ice sheets.

The group was informed that Decision 21 of the RA II-16 session (Feb 2017), on the Development of the Asia High Mountain Global Cryosphere Watch Observing Network,

approved the project proposed by the PR of Pakistan "Cryosphere monitoring to understand the trend of glacial hydrology of high Asia Mountains". This project is linked to GCW through the WMO framework for achieving the desired goals. The expected key deliverables are Snow/glacier melt contribution, which will be incorporated in hydrological models to improve the flood forecasting system, and assessment of the seasonal water availability. It was agreed that this project will be included in the GCW Regional Plans, as part of the updated GCW Pre-Operational Implementation Plan. **[Secretariat, GSG-6].**

4.2. WMO High Mountain activities

W Zhang informed the group that WMO is strengthening its focus on activities in high mountain regions, for the next financial period. He recalled that Decision 48 (EC-69) refined the definition of high mountain regions within the scope of WMO as: "…high mountain regions shall be defined as *"mountain areas where seasonal or perennial cryosphere is present and poses potential and serious risks to society related to water scarcity and disaster resilience"*.

The activities to be undertaken within this strategy, include:

- the development of weather, water and climate services and information to support decisions and policies on adaptation strategies in mountain areas;
- stimulating innovation and transferring research results to operations;
- provide a framework for broad engagement at regional level;

On the roadmap to Cg-18, an important milestone is the organization of the WMO Global High Mountain Summit under the leadership of EC PHORS. The details of this event will be discussed at EC PHORS-8.

The proposal for the Summit was presented by the President of WMO at the Third Pole Science Summit (TPSS) in Kunming, China, in July 2017, and by the WMO Secretary General at the Mountain Partnership Initiative conference, in Rome, Italy, in December 2017. A WMO Water conference will also take place in May 2018, in Geneva.

GSG recommended that, as the issues facing the high mountain regions are very diverse and dispersed, GCW will be a key player in defining and implementing the WMO plans. GCW will also play important role in other relevant WMO Programmes, such as: the Commission for Hydrology, the Disaster Risk Reduction Programme, and the Regional Association.

GSG agreed to recommend to EC PHORS that GCW should play an active role in the development of the High Mountain Strategy and the organization of the High Mountain Summit, given its demonstrated engagements at regional level. **[Secretariat, EC PHORS-8]**

5. GCW: building strategic partnerships

5.1 INTAROS

Y Gao and Michele Citterio provided overviews of INTAROS (Integrated Arctic Observing System) activities, (https://www.nersc.no/project/intaros), noting that the project has

49 partners in 20 countries. INTAROS aims at developing an integrated Arctic Observation System (iAOS) by extending, improving, and unifying existing and evolving systems in Arctic regions, covering atmosphere, ocean, and terrestrial themes. The results of INTAROS are relevant to GCW. They noted that Copernicus is a major driver for satellite–based observing and modeling. Additionally, INTAROS will facilitate enhancements to in-situ observational networks on Coastal Greenland (offshore, onshore, and on the Greenland ice sheet), Eastern Canadian Arctic, Northern Finland (Sodankylä-Pallas), and Central Arctic (snow and sea-ice mass balance buoys).

Regarding cryospheric data, INTAROS has several demonstrative applications:

- Coordinate with the parallel H2020-BG-10-2016 projects, APPLICATE and BLUE-ACTION, to assess the impact of assimilating the iAOS cryospheric data in weather and climate predictions;
- iAOS in situ and satellite snow and sea ice data will be used to produce near-real-time ice thickness and concentration charts for Operational Sea Ice Services;
- iAOS in situ snow observations from Svalbard will be used to improve extreme precipitation forecasts in Svalbard;
- iAOS in situ and satellite observation of ice mass balance in Greenland and Svalbard will be applied to model sea level rise and iceberg production.

M Citterio highlighted some INTAROS activities, relevant to GCW:

- Documenting procedures and instruments, for standardization and calibration/validation of observations, towards interoperability of Arctic data.
- Improving the integration of space-based and in-situ Arctic observations into process models and forecast systems;
- Contributing to the long-term improvement of Arctic observation systems and related services.
- Integrating existing pan-Arctic monitoring networks by building additional capacity, and adding new parameters to existing programmes.
- Improving the cost-effectiveness of data collection in support of Arctic-related economic and societal activities.
- Supporting international assessments of global challenges such as climate change, scarcity of natural resources and global scale hazards.
- Contributing to the GEO Cold Region Initiative and to the Transatlantic Ocean Research Alliance (TORA).
- Contributing to the WMO Programme Year of Polar Prediction (YOPP).

M Citterio noted that, in the context of INTAROS, the Geological Survey of Denmark and Greenland (GEUS), is developing an open design for self-sustained AWS for remote locations. Once completed, the design will be made broadly available. It was recommended that GCW promote the design for applications in remote locations. Some examples are**:**

- Installing, at PROMICE locations in 2018, SnowFox devices (WP3) for snow water equivalent measurement with accompanying data quality evaluation.
- Developing and field testing in 2018, a prototype for high accuracy Global Navigation Satellite System (GNSS) AWS positioning. It will include a power solution for remote locations, through the polar night.
- Improving the AWS radiation measurement which includes:
    - accounting for changes in azimuth,
    - removing alignment error between the radiometer and tilt sensors, and

- providing in-situ validation for satellite albedo products.

M Citterio will share the results of testing these new technologies with the Best Practices Team. The potential for broad dissemination, via GCW, will be considered at that time. **[M Citterio, Best Practices Team, GSG-6]**

GSG requested that GCW Best Practices and Data Portal build closer ties with INTAROS regarding standards for observations, data discoverability and data access. It is requested that there be a report on this at GSG-6. **[M Citterio, Ø Godøy GSG-6].**

Á Snorrason noted that GCW needs to be the liaison between WMO and the emerging Arctic observing initiatives. FMI put weather, climate, and oceans on the Arctic Council agenda, and the NMHSs of Arctic countries would like to continue with these themes.

W Zhang recommended that GCW take a lead role in establishing an umbrella forum, to facilitate the interactions at high level, and coordinate arctic observations. As a WMO initiative, GCW is about long term sustained observations, and could provide mechanisms to bridge between different projects. WMO should create such a forum through its status as an observer at the Arctic Council. This will be explored further, in the definition of the GCW Pre-operational phase **[Á Snorrason, Secretariat, GSG-6].**

5.2 Third Pole Environment Programme (TPE)

Prof Ailikun, the Executive Director of the Third Pole Environment Programme (TPE), of the Institute of Tibetan Plateau Research (ITP), of the Chinese Academy of Sciences (CAS), presented an overview of TPE activities and goals. The 2018 TPE action plan is focused on establishing a working group for running intercomparisons between Earth System models in the Third Pole region.

A strategic priority for 2018-2022, is the ”Pan-TPE environment and green development”. Some of its goals are relevant to GCW, e.g.:

- integrated assessment of regional environment change,
- natural disaster and risk assessment,
- climate change impact on ecosystem and biodiversity,
- westerly-monsoon interaction and
- water resource change.

The scarcity of observations over the Third Pole was noted; there are only 73 stations with quality controlled data. She mentioned the network of 17 stations of the China High-Cold Region Observation and also the Research Network for Land Surface Processes and Environment(HORN-CN), which has two stations (Tianshan and Qilianshan). These two stations are already designated as CryoNet stations, and the Nam Co station is a contributing station.

It was agreed that the TPE Data Centre (http://en.tpedatabase.cn) and the GCW Data Portal will explore the feasibility of interoperability. Ø Godøy requested that a contact person be nominated as the interface between TPE and GCW Data Portal to work with,

for developing a work plan to move forward. A machine interface is needed to access the data automatically. **[Ø Godøy, Ailikun, June 2018]**

Prof Ailikun noted that the sensitive runoff data is difficult to share, but the basic glacier and snow data can be shared with GCW. The database is completely open, however an interface will be needed to convert between native formats and GCW recommended formats. At the request of GSG, Prof Ailikun has agreed to assess how CAS could support the development of an interface to translate the TPE data formats into a format suitable for access through the GCW Data Portal. **[Ailikun, GSG-6]**

Prof Ailikun offered to provide TPE results for posting on the GCW website. **[Ailikun, J Key, GSG-6]**

W Zhang thanked Prof Yao and Prof Ailikun for engaging WMO at very high level, and agreed to work with Prof Yao on the collaboration between WMO and CAS.

5.3 UNESCO IHP

Dr Anil Mishra, from the International Hydrological Programme (IHP), Division of Water Sciences, UNESCO, gave a presentation on the "Assessment of Snow, Glacier and Water Resources: IHP Perspective". This presentation highlighted the IHP activities and the opportunities for collaboration between GCW and IHP.

He noted that UNESCO-IHP has collaborated with GCW since its early stages, and this is mutually important in addressing the increased cryosphere –hydrology related challenges.

He provided an overview of the eighth phase of IHP (IHP-VIII), aligned with the new eight-year Medium-term Strategy of UNESCO (2014-2021).
A Mishra noted that UNESCO is effective in creating the knowledge platform, highlighting the recently established Central Asian Regional Glaciological Centre under the auspices of UNESCO in Almaty, Kazakhstan, and the outcome of the recent project 'The Impact of Glacier Retreat in the Andes: International Multidisciplinary Network for Adaptation Strategies' . Also, IHP is effective in providing the scientific knowledgebase for policy advice on managing and coping with challenges to water resources, translating it into policy briefs, for decision makers and for the general public.

UNESCO has issued several scientific and technical publications on education, capacity building and adaptation strategies, addressing the impact of the retreat of glaciers. Which include: The project accomplishment- The Impact of Glacier Retreat in the Andes: International Multidisciplinary Network for Adaptation Strategies', Mountain Ecosystem Services and Climate Change, Glacier Mass balance Manual in Spanish, The International Classification for Seasonal Snow on the Ground, Glossary of Glacier Mass Balance and related terms, Third Pole Environment Policy Brief, Assessment of Snow, Glacier and Water Resources in Asia (https://en.unesco.org/themes/238259/publications/all)

UNESCO is actively engaged with the international scientific community. Most recently, it organized in October 2017, Knowledge Forum on Water Security and Climate Change. UNESCO also co-convening a session on 'The Human-Climate Water Nexus, Climate

Change, and Water Security during the 8th GEWEX open science conference, in May 2018, with the theme “Extremes and water of the edge”;.

Several recent milestones for IHP are the launches of the Glacier App, with WGMS, the Rainmapper App, and the iRain at COP22.

Maintaining the momentum of these activities, UNESCO would like to partner with GCW for engaging the national organizations, as this is where WMO is quite effective.

The group agreed that GCW and IHP need to have an active engagement, that GCW could benefit from IHP’s experience in developing policy briefs and translating scientific results into policy input and educational material. **[GCW Project Office, A Mishra, GSG-6]**
Additionally, A Mishra suggested that that WMO and UNESCO should discuss, co-operate and collaborate on promoting cryosphere and hydrology at the higher-level policy discussions including at UN and international platforms, and explore possibility of facilitating a discussion on UN International Year of Snow and Ice. See Section 6.8 for details and actions.

5.4 Norwegian Research Council

Thomas Hansteen, from the Department for Cooperation and Development Research and Jon Børre Ørbæk, from the Department for Climate and Polar Research, of the Research Council of Norway (RCN), provided an overview of RCN. This outline provided information on RCN’s international collaboration and funding strategies, as well as projects of relevance with India and China. It was noted that polar research (Arctic and Antarctic) is of high priority for RCN.

It was noted that RCN is an indirect contributor to GCW, as a funding agency of SIOS, and also as providing resources to enable the development of the GCW Data Portal. Several INTAROS projects also have funding from RCN.

The GSG expressed interest in using the RCN funding mechanisms to further the goals of WMO GCW. The GSG encouraged RCN to consider including, in their funding policies, requirements for funded projects to feed into operational services.

The RCN representatives encouraged GCW to ensure an active dialogue with other organizations and initiatives with similar goals. GCW was also urged to participate in joint proposals targeting research infrastructure such as vessels, observing systems, and databases. Meteorological institutes could be part of the proposal.

As a competitive based institute, RCN invites operational and research organizations to provide proposals. They mentioned that the Arctic Council Science Ministerial Meeting identified a need for a joint call platform for Arctic research.

They provided overviews of projects funded in collaboration with China and India which could be of interest to GCW. Specifically, there is a call with India, for new partners,

which could include Third Pole research. When these collaborative calls are issued, there is a possibility to include the GCW-specific goals, supporting other scientific disciplines.

When RCN awards projects, there is no specific requirement for data to be provided, but all proposals are required to show a data management plan, and all data must be accessible.

Á Snorrason thanked Thomas Hansteen and Jon Børre Ørbæk for their participation, and for the information provided. He invited GCW experts to consider how to link with current and future projects funded by RCN, and contribute to the implementation of GCW objectives.

5.5 SAON; Arctic Data Forum

Jan Rene Larsen, the Secretary of the Sustained Arctic Observing Network (SAON) office provided an overview of their activities.

He informed the group that the goals of SAON are to:

- create a roadmap to well-integrated Arctic Observing System;
- promote free and ethically open access to all Arctic observational data;
- ensure sustainability of Arctic Observing.

SAON has two committees: the Committee on Observations (CON) and the Arctic Data Committee (ADC). There is a close and active engagement between the GCW Data Portal and ADC (arcticdc.org).

Current activities of ADC include: the International Ecosystem of Organizations and Data Resources, and the ADC-IARPC-SCADM Vocabularies and Semantics Working Group. The project on Federated search, is seeking to reinvigorate an earlier project on metadata elements, based on already published information. The GCW Data Portal team is already engaged in this work.

The Polar Data Planning Summit will take place on 22-24 May, 2018, Boulder, Colorado. Its goal is to coordinate the efforts to facilitate the systematic access to arctic data. The focus will be to generate detailed plans on how to mobilize activities to develop a particular case study for international data sharing. This summit will complement past workshops and fora (e.g. IPY, Polar Data Forums etc.) that have been effective in defining important community challenges and technical issues of data sharing. Ø Godøy, will have an active role in defining test cases, and will lead the discussions. Preliminary co-organizers include: the Arctic Data Committee, GCW, the EU Arctic Cluster, Polar View, GEOCRI and the Arctic Spatial Data Infrastructure.

The next meeting of the Arctic Data Committee, in the fall of 2018, could be hosted by WMO, in Geneva. Discussions will follow, facilitated by the GCW Project Office. **[Secretariat, Oct 2018]**

5.6 UN AON

Sandy Starkweather, the Executive Director of the US Arctic Observing Network (US AON), of the NOAA Climate Program Office, provided an overview the Consultative Phase of U.S. AON. She noted the growing foundation of support for systematic arctic observing, in the USA, since 2006.

AON is a mechanism for working within the US communities, through SAON, to advance the value framework process, in "ready-to-go" areas, building on the International Arctic Observations Assessment Framework, developed by SAON and Science and Technology Policy Institute (STPI) in 2017. The AON Framework calls for partnership with international bodies (e.g. SAON, GCW, GCOS) to develop an Arctic observing roadmap of essential variables, which maximizes societal benefits of observations, by connecting Arctic Observations thru Key Products and Services to Societal Benefits.

US AON has been tasked to participate in the Framework for Ocean Observing (GOOS) Essential Ocean Variables. An additional assignment is to work towards an operational, multi-sensor Sea Ice Thickness (SIT) Product, which is a fit-for purpose, multi-sensor product(s).

In 2018, US AON is tasked to focus on issues related to:

- wildfire detection,
- ecosystem response to sea ice decline,
- arctic ship tracks,
- snow cover products.

S Starkweather noted the critical role of coordination among different initiatives, on the data side (cyberinfrastructure). It is important to identify specific application areas, and their specific requirements in a technologically neutral manner.

S Starkweather invited GCW to collaborate with US AON, and the invitation was accepted by GSG. The GCW Project Office will follow up with S Starkweather for exploring opportunities for collaboration. **[Secretariat, GSG-6]**

5.7 Satellite-based Climate-Consistent Data Records of the Sea Ice ECV;

Thomas Lavergne, provided an overview of the activities to develop, maintain, and promote the sea ice CDRs (including ice concentration, type, edge, drift) results of Met Norway.

5.8 NOAA/NWS Alaska: High Quality Multi Parameter Arctic Stations

Carven Scott, the Director of NOAA/NWS Alaska Region presented an overview of how his organization is addressing the accelerated changes in the Arctic. There are emerging needs for operational programs in the Arctic These are driven by:

- increased marine traffic linked to the reduction in sea ice,
- increased explorations for minerals, gas, and oil extraction,
- security issues,
- infrastructure needs,
- increased frequency of disaster-level storms,
- vulnerability of Arctic communities.

Regarding snow depth observations in Alaska, C Scott noted the sparsity of observations at higher elevations, in spite of the need for avalanche forecasting services and hydroelectric power management in southeast Alaska.

The need for sustaining observations, in the very remote areas of Alaska, is being addressed with innovative observing technologies for snow, permafrost, ground temperature, wave buoy observations and river gauges.

The participants appreciated the practicality of solutions presented. M Citterio recommended that GCW promote the use of IRIDIUM telemetry for remote locations, as most cryosphere observations are in areas with extremely difficult access to traditional data transmission infrastructure, likely through SATCOM. **[Secretariat, GSG-6]**

C Scott recommended that, in preparing the revised Implementation Plan, GCW answers the "so what" question of "why would someone use GCW capabilities?" He urged GSG to clarify the meaning of terms such as operational and functional, for example. These clarifications are required, since GCW has a broad spectrum of "contributors" spanning the full range of Technology Readiness Level (TRL)[3], who have different expectations. **[Secretariat to coordinate, GSG-6]**

In the USA, NWS serves as the country's PR to WMO. As the cryosphere is a cross-cutting programme, it's important that the support for GCW in the USA comes from NWS. At the same time, NWS is an operationally focused organization, as are all NMHSs. The allocation of resources are based on objectives. Future support to GCW, through NWS, needs to be linked to clear requirements. **[Chair, Secretariat, GSG-6, to follow up on practical approaches]**

C Scott invited the Chair or the Vice-Chair of the GCW Steering Group to make a presentation on the objectives of GCW for the interagency group of the State of Alaska. This would provide more leverage to develop a working relationship between GCW and the various parties in Alaska.**[C Scott, Á Snorrason, 2018]**

C Scott committed to provide a point of contact to the Snow Watch Team (K Luojus) to help with accessing the snow measurement data on the GTS. This access would include existing and new stations, under multiple agencies, where possible). **[C Scott, GSG-6]**

6 GCW Products Strategy and Engagements with WMO Programmes

6.1 Current GCW products

J Key provided the list of products currently available on the GCW Website, and available in Annex 4.

The group agreed that GCW needs to do more to provide value added products, as an end to end activity, which is an important goal of the pre-operational phase. In response to the needs for specific cryosphere products, e.g. PRCCs and RCCs (see next sections), it was agreed to:

[3] https://www.nasa.gov/pdf/458490main_TRL_Definitions.pdf

- Invite the GCW experts to prepare additional assessments and align them with the publication of the WMO annual statements on climate, as a concrete contribution of GCW to the WMO Programmes **[J Key, Integrated products WG Co-Leads, GSG-6].**
- Develop near real-time graphics for snow, glaciers and permafrost in the Southern Hemisphere**[J Key, Team Leads, GSG-6].**
- Prepare additional educational resources, picture, videos are desirable, and make them available, publically.**[J Key, GSG-6]**
- Invite feedback on the use and content of assessments **[J Key, GSG-6]**

The group invited A Irrgang to discuss with GTN-P and IPA how to engage with GCW in generating assessments of permafrost, in collaboration with GCW. This could be published periodically via the WMO annual assessments. **[A Irrgang, J Key, GSG-6]**

6.2 GCW linkages with the Arctic Polar Regional Climate Centres (A-PRCC)

Eivind Støylen (MET Norway) provided an overview of the Arctic Regional Climate Centre Network (ArcRCC). He noted the engagement between ArcRCC and GCW, with the first planning meeting held in Montreal, Canada, in Sept 2017. The following points were highlighted:

- Availability of GCW Surface Network data, for product validation;
- GCW products such as snow trackers, snow watch and snow assessments;
- Promote improved exchange of cryospheric data and information, via the Data Portal, including metadata;
- Availability of GCW technical expertise on cryosphere, which is an important resource for PRCC;
- GCW experts to review, assess, and recommend PRCC cryosphere products;
- There is mutual interest in research and development;
- Co-development of new products on the cryosphere;
- Networking of providers and users of cryospheric information;

The Portal for ArcRCC is under development by MET Norway, and is linked to the GCW Data Portal. A node leader meeting is planned for February 2018, and the PARCOF and a Network meeting will take place in Ottawa, on May 15-17, 2018. The evaluation of the implementation is planned by the end of 2018, and the designation as ArcRCC is planned by 2020.

The group agreed with the areas of collaboration proposed, and appreciated the opportunity to position GCW in the WMO value chain, thus demonstrating its value to Members. **See action under 6.1**.

V Smolyanitsky, the lead of the Eur-Asia node of ArcRCC, noted the engagement of all Arctic Council countries, as WMO has an observer status with the Arctic Council. He showed examples of content for the pan-Arctic Bulletin, including:

- meteorological conditions in the Northern Polar Region (Large-scale atmospheric processes, Meteorological parameters),
- ice conditions and processes in the Arctic Ocean,
- hydrological and hydro-chemical conditions in the Arctic Ocean (thermohaline conditions, sea level, wind waves).

The bulletins will include content from all three nodes, and will be published monthly. V Smolyanitsky encouraged the participants to identify which other parameters need to be included. The input from the GCW CryoNet needs to be defined, e.g., as agreed previously, including CryoNet station time series (using Data Portal as interface). **[WG Leads, Ø Godøy , V Smolyanitsky, GSG-6]**

He noted that the sea ice section will contain:

- ice conditions (based on blended ice charting material),
- ice drift,
- ice extent,
- ice area anomaly graphs,
- other sea ice parameters.

The section on sea ice will also contain contributions from Ice Services, ETSI/JCOMM and IICWG. It is recommended that GCW has an active role, as well.

The group agreed to nominate GCW points of contact for each node of the Arctic PRCC and identify which products will be provided by GCW. Ms Leslie Malone (Canada) was nominated as an interim point of contact between GCW and ArcRCC. **[GSG, Secretariat, June 2018]**

6.3 GCW and the Third Pole/Asia High Mountain RCC

Dr Lijuan Ma, from the National Climate Centre of the China Meteorological Administration (CMA), and an expert of the GCW Integrated Products WG, provided an overview of the CMA concept paper for developing a PRCC for the Asia High Mountain Region (Third Pole) (TP-PRCC), and the linkages with GCW.

The proposal highlighted functions and recommended products which would be developed within the framework of GCW. Among those are the operational data services which are designed to promote:

- integrated observing networks,
- cryospheric and climate data collection
- cryospheric and climate data quality assessment and quality control,
- cryospheric and climate data archival and distribution,
- operational monitoring activities (specific products contributing to sub-seasonal to seasonal prediction).

Some of the services supported would include:

- warnings (snow avalanche, glacier surges, GLOFs, snowstorms, gale/gusts),
- forecasting (precipitation-snowfall, snowstorms, cold waves, sandstorms),
- prediction (air temperature, precipitation, first frost date, etc).

L Ma indicated that CMA could take a lead role in advancing the concept and developing an implementation plan, in collaboration with GCW, and under the guidance of WMO.

The proposal was received with interest and it was agreed that the Secretariat will consult with the appropriate groups in WMO, for follow up and action. **[Secretariat, L Ma, Jan 2018]**

6.4 GCW and Polar Space Task Group

Mark Drinkwater, the Chair of the Polar Space Task Group (PSTG) provided an update on the cryospheric space observing activities of the agencies member of PSTG.

He noted that there has been considerable progress gained towards achieving the strategic objectives identified in PSTG Strategic Plan (2015-18). These include the relevance of satellite observations to GCW Integrated Products WG, and the recommendation that further product intercomparisons (sat + in situ) are to build upon experience from SnowPEx. He also highlighted the PSTG commitments, in support of YOPP and MOSAIC.

The 7th session of PSTG took place in December in Innsbruck, Austria, focusing on:

- progress against objectives in PSTG Strategic Plan (2015-2018);
- GCW;
- YOPP & MOSAIC
- SOOS needs; and
- Continuity in PMW imaging of sea ice.

GCW was represented by P Wagner (in person), and P Heil and J Key (remotely). The meeting report is available at http://www.wmo.int/pages/prog/sat/documents/PSTG-7_Final-Report.pdf

At this meeting, Jeff Key presented an overview of Global Cryosphere Watch (GCW) activities. Penelope Wagner presented jointly with Petra Heil, on the progress made in developing best practices for sea ice. The meeting explored the potential of PSTG and GCW coordinating the establishment of sea ice "supersites" in predefined areas.
The next PSTG-8 planned in October 2018 in WMO, Geneva.

M Drinkwater informed GSG about the planned workshop on Snow Radar Science, 30-31 January, 2018, in Geneva, cohosted by PSTG-SAR WG and GCW. The meeting will focus on:

- mission-relevant recommendations from the stakeholder community,
- reviewing gaps regarding "all-weather" observing system capabilities and key snow products (SWE/SE),
- address priority science, technical, operational challenges of new space-borne radar snow missions. **K Luojus, Jan 2018 – action under 2.2**

The presentation made by M Drinkwater covered information on the monitoring of glaciers and ice caps in high mountain regions, on snow, ice sheets, permafrost, atmosphere and sea ice. GSG expressed support for the engagement with PSTG, and invited the experts to follow up on the specific actions from the PSTG meeting. **[P Wagner, P Heil, J Key, GSG-6]**

Y Gao noted that there are numerous sources for daily sea ice products, thereby, international experts have difficulties identifying which dataset is most reliable. He encouraged GCW to promote the organization of intercomparisons/assessments, and to provide a relative assessment of available products**.[Integrated Products Co-Chairs, M Drinkwater, GSG-6]**

6.5 GCW linkages with WMO hydrological observations and applications

Dominique Berod, the Chief of the Basic Systems in Hydrology Division, Climate and Water Department at WMO, provided an overview of the hydrologic activities within the WMO framework, and outlined the potential for collaboration with GCW. He noted that the Hydrological Observing Network is one of the four components of WIGOS, together with the observing component of GCW. He also noted that of specific interest to GCW, is the Arctic HYCOS project of CHy (http://arctic-hycos.net/Arctic-HYCOS/Home.html).

He recalled Resolution 1 (CHy-15) requesting that the Advisory Working Group "explores with the Global Cryosphere Watch Project Office possible joint activities and to propose a plan for collaboration that would allow the translation into practice of Resolutions 40 (Cg-17) and 43 (Cg-17) regarding high-latitude and high-altitude services, with a focus on observations and availability of data".

D Berod provided a short overview of the Global Hydrological Data Centres. One of the major challenges facing the hydrological communities, is related to lack of sharing of data, especially for transboundary waters, which diminished the effectiveness of hydrological transboundary models.

Additionally, the hydrological community is facing the same challenges as the cryosphere community, regarding the need for agreement on ontology, standard vocabularies, metadata, and data format standards. He noted the opportunity for GCW and CHy to share their experience in addressing these issues. A follow up will be organized to explore options. **[Secretariat, GSG-6]**

D Berod noted that information on cryosphere is critical to hydrological products. He provided the example of the project proposal on Enhancing Adaptive Capacity of Andean Communities through Climate Services for Chile, Colombia and Peru (ENACACS), under development for submission to the Adaptation Fund, which includes a component on cryosphere.

The Commission for Hydrology has had a long standing collaboration with UNESCO on water, and there are relevant cryosphere linkages. The engagement of GCW with UNESCO IHP could be included in the existing framework of collaboration. **[Secretariat to explore options, GSG-6]**

D Berod informed the group about the upcoming WMO Global Conference Prosperity through Hydrological Services, organized by WMO, on May 5-7, 2018, in Geneva. Á Snorrason is invited as one of the keynote speakers.

Á Snorrason noted that the linkages between cryosphere and hydrology need to be stronger. Specifically, in the Earth system model, the impact of the cryosphere is critical, e.g.:

- snow hydrology at all latitudes,
- glacier melting,
- impact of permafrost melting on the water resources in the arctic,
- projection of climate change scenarios.

Á Snorrason noted that since water is considered to be a resource, it has a market value, which is why there are difficulties in sharing data. Similarly, the agreement for sharing the water data in the context of Arctic HYCOS, took about 10 years to negotiate.

6.6 GCW and the WMO Antarctic Activities

Steve Colwell and Petra Heil presented a summary of the WMO and the Scientific Committee for Antarctic Research (SCAR) Antarctic activities.

The presentation provided an overview of the Antarctic sea-ice observations, from:

- the Arctic Fast-Ice Network [AFIN]
- ASPeCt underway data,
- ASPeCt transect data,
- International Programme for Antarctic Buoys (IPAB);

IPAB is a program of WCRP SCAR where data is currently stored at AWI, although other options are being considered. A summary of the SCAR projects including iceREADER, SnowAnt, and Polar View were also provided.

S Colwell briefly shared an overview of the BAS Javlins. He noted that the data are available to be distributed.

Issues for consideration by GSG:

- Most meteorological and cryospheric data collected in Antarctica are not collected by national meteorological agencies, but rather by research groups or national Antarctica operators. These data are not compliant with WMO regulations.

- More Antarctica stations and AWS need to be put forward as GCW stations. This process can be pushed through the ATT and SCAR expert groups on operational meteorology in the Antarctic as well as the annual Workshop on Antarctic Meteorology and Climate (WAMC). **[S Colwell, GSG-6]**

- S Colwell invited GSG to consider whether all of Antarctica should be considered as a single CryoNet cluster. Could the same be applied to Greenland? M Citterio recommended that practicality of management of groups of stations should drive the decision. This issue requires further consideration by the Observations WG, for reaching consensus. **[Observations WG, S Colwell, GSG-6]**

S Colwell noted the proposal for an Antarctic RCC should be similar to the Arctic RCC, and, hopefully, will include sea ice forecasting. The GSG was invited to consider whether GCW has a role to play, and whether there is a need to coordinate with other research organizations (SCAR, CliC). GSG invited S Colwell to work with the Services Task Team of EC PHORS regarding options, road map, obligations and requirements. He was asked to report back to GSG-6 on the opportunities for GCW.

S Colwell noted that the Antarctic Task Team of EC PHORS has been very effective in coalescing the issues in this region, and expresses the support that, in the new governance structure, this team will find continued support.

6.7 Climate Change and the Cryosphere Conference (C3-2020).

Árni Snorrason noted that with WMO becoming an observer at the Arctic Council, the first Arctic Meteorological Workshop took place in Sept 2017, in Helsinki. It focused on how to improve meteorological observations and services in the Arctic. He will report on the outcome at the Arctic Council meeting in March, 2018, in Levi, Finland. Iceland will hold the chairmanship of the Arctic Council, between 2019 and 2021.

Árni Snorrason informed the group about Iceland planning a conference on Climate Change and Cryosphere (in all regions), in Sept 2020. GCW will have a central role to play in this event. The conference is organized in the context of the 100th anniversary of the Icelandic Meteorological Office. He invited GCW and WMO to work with Iceland in developing the conference concept and participate in the organization of the conference. this conference will be linked to the WMO High Mountain agenda and the proposal for the International year of Snow and Ice (presented in this report). **[Á Snorrason, Secretariat, March 2018]**

6.8 Proposal for a UN International Year of Snow and Ice

Based on the discussions, WMO and UNESCO-IHP agreed to follow up, cooperate and collaborate on promoting cryosphere and hydrology at the higher-level policy discussions including at UN and international platforms, and explore possibility of facilitating a discussion on UN International Year of Snow and Ice. Its scope and the associated process need to be refined by the two organizations, including its benefits and the links with several UN Sustainable Development Goals (SDG). Some of these include: water, climate resilience, reducing uncertainty, the link to the Paris Agreement, and the Sendai framework. The proposal needs to be in a language the governments want to hear, and it needs a champion. The group received the proposal, with interest. Within the context of the Arctic Council, Á Snorrason will approach Iceland ministries, to assess the feasibility of this proposal.

To be successful, this will require an engagement with the UN office, and could be coordinated through the WMO office in New York. A plan is required to scope the goals and roadmap, with the target year being 2020. As IPCC is preparing a report on Cryosphere, its publication might be linked to the activities of the year of snow and ice.

The group agreed to pursue this idea, and the it will be presented at EC PHORS-8 **[Secretariat, March 2018]**

7 Mainstreaming of GCW as a WMO cross-cutting activity

7.1 GCW Pre-Operational Phase

W Zhang informed the participants about the planned WMO governance reform. He noted that, once operational, GCW will have to merge into the new WMO Programme structure, taking into account its cross cutting nature. At the same time, as an end-to-end activity, GCW needs to provide specific value propositions on observations, research, and services. He strongly recommended that the implementation of GCW continues with a preoperational phase over the next financial period, to ensure the readiness of GCW.

The group agreed that the cryosphere scientific community appreciates the value of GCW, as it is supported by the regulatory framework of WMO, a mechanism for ensuring standardization and consistency[4]. The group agreed that GCW has come a long way, and that the observation component of GCW is well defined, has increased visibility, and global representation. However, more work needs to be done on products and services.

The engagements with PRCCs is an important milestone. When fully operational, GCW will be the WMO mechanism providing high level coordination of cryosphere related activities.

GSG agreed on the following steps forward:

- Prepare for Cg-18 (2019), an updated GCW Pre-Operational Implementation Plan, and provide a high level report on results to date, to EC-70. **[Secretariat to coordinate, 2018]** A meeting will be organized in this sense in Oct-Nov, 2018.
- Following Cg-18, GSG will convene a strategic planning meeting to develop its strategy for the future, and to proposed a functional structure to support the strategy, aligned with the structure of WMO Programmes. **[Secretariat to coordinate, June 2019]**
- Submit to EC 70, through EC PHORS, a recommendation for a Cg-18 resolution on the pre-operational phase of GCW, identifying the key focus areas for the next 4 years. **[Secretariat, April 2018]**
- Communicate the outcome of EC-70 and Cg-18 to all GCW contributors and partners. **[Secretariat, July 2018]**

W Zhang encouraged GSG to ensure that the cryosphere goals are accurately represented in the WMO Strategic Plan. The plan sets out long-term goals for the 2030 horizon, and the strategic objectives are focused on addressing the most pressing developments and needs during the 2020-2023 planning cycle of the Organization.

GSG proposed three overarching priorities for the next financial period:

- Broad access to quality cryospheric data, with a focus on real time data exchange;
- Positioning GCW in the value chain: linking cryosphere products and services to high priority applications (water security and disaster risk reduction).
- Building a framework for national partnerships focusing on cryosphere, as a pilot for partnership for WIGOS.

To reach these goals, GCW will pursue:

- Improving the global coverage of the GCW Surface Observing Network to include at least 80% of countries where cryosphere is present, and ensure access to their data;

[4] WMO Technical Regulatory framework includes (1) *Technical Regulations (TRs, Vol 1-4)* which are prescriptive, Basic Standards and Recommended Practices (SARPS), which are definitive, requirement-driven, approved by Congress, and, are relatively conservative, and where “shall” and “should” have specific meaning, include; (2) *Manuals (Annex 1-8),* which are more details SARPs (procedures and specifications), more technology driven, relatively dynamic, and approval is delegated to EC., and (3) *Guides*, which are descriptive non-regulations, where “shall” and should” have ordinary meaning, and include procedures and practices, implementation guides, explanations, examples, good practice, flexible update.

- Establishing the GCW Data Portal as a Data Collection and Production Centre, and provide data quality monitoring, within the WIGOS Data Quality Monitoring System;
- Advancing the availability of real time cryosphere information, in support of operational services.
- Finalize and publish the GCW relevant regulatory and guidance materials;
- Develop regular statements on the state of the cryosphere, aligned with the respective Polar Regional Climate Outlook Forums (PARCOFs) and the PRCCs;
- Develop and conduct at least one pilot program per region, on a framework for national partnerships with a focus on the cryosphere, linked to national WIGOS plans, e.g. using the cryosphere as the link between hydrology and meteorology;

WMO Strategic Plan, at a glance:

WMO will focus resources in accordance with three overarching priorities:
(1) Enhancing preparedness and reducing losses of life and property from hydro meteorological extremes;
(2) Supporting climate-smart decision-making to build resilience and adaptation to climate risk;
(3) Enhancing socioeconomic value of weather, climate, hydrological and related environmental services.

The long term goals and strategic objectives, include:

- Better serve societal needs: delivering authoritative, accessible, user-oriented and fit-for-purpose information and services.
- Enhance Earth system observations and prediction: strengthening the technical foundation for the future.
- Advance targeted research: leveraging leadership in science to improve understanding of the Earth system for enhanced services.
- Close the capacity gap on weather, climate, hydrological and related environmental services: Enhancing service delivery capacity of developing countries to ensure availability of essential information and services needed by governments, economic sectors and citizens
- Strategic realignment of WMO structure and programmes for effective policy- and decision-making and implementation.

The participants agreed that the Implementation Plan for GCW needs to be updated to reflect the decisions of this meeting. The updated plan will provide specifics on:

- Identifying how GCW will work with WMO Commissions and Programmes.
- Positioning GCW in the value chain, as the liaison between the operational and scientific communities, while engaging key users.
- Supporting the building of national partnerships, promoting national implementation plans.
- Including an increased focus on high mountain cryosphere services (e.g. snow hydrology, water resources, avalanche forecasting, natural disaster risks assessment and preparedness).
- Playing an active role in training, capacity building and coordinating closely with UNESCO IHP, etc.
- Disseminating GCW best practices guides though workshops.
- Engaging with Regional Associations, on region specific projects on cryosphere;
- Developing a communication plan.

S Barrell urged GSG members to actively promote GCW goals, as Members are the ones implementing the building blocks made available during the GCW implementation period. She noted that the sustainability of GCW rests with the ability to get to the hearts and mind of Members, and obtain their sustained commitment to keep it running.

7.2 GCW structure and long term strategy.

The current GCW structure, and membership is provided in Annex 5 of this report. The GSG noted was informed that several new experts, have joined GCW since GSG-4. These are:

- Rainer Prinz, Austria, Observations WG
- Petra Heil, Australia, Integrated Products WG and Observations WG
- Leslie Malone, Canada, Integrated Products WG, liaison with PRCC
- Tom Kralidis, Canada, Information and Services WG
- Lijuan Ma, China, Integrated Products WG
- Feiteng Wang, China, Observations WG
- Zhao Ping, China, Member of the GCW Steering Group
- Penelope May Wagner, Norway, Integrated Products WG

The meeting agreed with the nomination of two experts for the Solid Precipitation Task Team. They are:

- Vincent Fortin, Canada
- Mareile Wolff, Norway

The meeting considered the proposal of re-activating the Glacier Team of the Integrated Products WG. The WG co-leads were invited to propose the team membership and activities, in collaboration with the glacier exerts in GCW. As GCW progresses, the Steering Group needs to evolve the GCW structure, to include hydrology, climate and modelling. This requires a true end to end, cross cutting activity approach.

Dr Tetsuo Ohata (Japan) informed GSG that he will be stepping down following this meeting. Á Snorrason thanked T Ohata for his valuable contribution to the development of GCW, and for his efforts in promoting the goals of GCW within the Japanese cryosphere community. T Ohata was invited to recommend a replacement from Japan, finding a good balance between the scientific and the operational communities, as the engagement of the cryosphere experts from Japan is important for WMO. He will work with the GCW Project Office on the nomination **[T Ohata, Secretariat, July 2018].**

8 REPORT TO EC-PHORS

The group agreed to submit the following items, for consideration by EC PHORS-8 **[Secretariat, March 2018]:**

a. Proposal for establishing the GCW Surface Observing Network, to include CryoNet Stations, contributing stations, and CryoNet sites, based on the agreements reached at this meeting;
b. Proposal for the preoperational phase of GCW, as discussed during this meeting;
c. Inform EC PHORS -8 about the changes in the membership of GCW, since GSG-4.
d. Proposed that GCW plays an active role in the definition of the WMO High Mountain agenda, including on the organization of the High Mountain Summit. This proposal is

taking into account the demonstrated leadership in building partnerships with the cryosphere scientific communities, at a regional level. Some of GCW achievements in this sense are the Asia CryoNet and South America CryoNet regional groups; the engagement in tropical regions; the large number of GCW stations in high mountain regions, at all latitudes; the planned collaboration with RA VI, on high mountain activities; the existing collaboration with scientific communities active in high mountain areas, e.g. IACS, Chinese Academy of Sciences, UNESCO, etc.

e. Promote the concept for a World Snow Monitoring Service.

f. Provide an update on the GCW Sustainability, and the continued need for support with human and financial resources.

   Established through a Cg-17 resolution, the GCW Project Office has been funded from the WMO regular budget. The implementation of GCW has been possible with funding from the WMO regular budget, and a significant contribution from the Global Framework for Climate Services, the “Canada project” (a total of CHF 325,000, available from 2014 to March 31, 2018).

   Additional financial support for the implementation of GCW has been provided by Australia, Norway, Canada, USA, Sweden. In-kind contributions have been the backbone of the GCW implementation; E.g. Data Portal (Met Norway), Data Interoperability package (SLF, Switzerland), GCW Website (Univ Wisconsin, USA).

9 OTHER BUSINESS

W Zhang noted the progress made by GCW, and the increased focus on promoting its end to end, cross cutting mission. He drew attention on the increased work load to support the pre operational phase of GCW. He indicated that an effective programme development will require increased resources for the GCW project office, and invited the community to continue its support to the implementation of GCW. He invited the participants to consider contributions to the GCW Trust Fund, secondments to WMO, and junior project officers, including volunteer contributions. A formal letter will be sent to Members, in this sense, before GSG-6, identifying the priority activities underway. **[mid-2018, Secretariat]**

10 NEXT MEETING

The next GSG meeting, GSG-6, will take place in Feb-March 2019, and will focus on preparing the GCW draft resolutions to Cg-18. The Implementation Plan will also be updated, to include the pre-operational phase of GCW, as defined during the discussions at this meeting, and which is based on additional guidance from EC PHORS-8.

Prior to GSG-6, a small team will be invited to contribute to the preparation of the draft of the revised Implementation Plan. A working meeting will be organized to address this in the last quarter of 2018. **[Q4, 2018, Secretariat]**

The location will be finalized at a later date. C Scott invited GSG to consider the opportunity of organizing the GSG-6 and EC PHORS-9, back to back, in Alaska. The invitation was accepted by GSG, and the details will be established following EC PHORS-8. **[Secretariat, March 2018]**

Annex 1: Meeting Agenda

1. ORGANIZATION OF THE MEETING

2. GCW WORKING GROUP REPORTS (WG AND TEAM LEADS)
(High level summary of accomplishments, gaps and challenges towards an operational GCW; work plans, recommendations for EC-PHORS)

3. Mainstreaming of GCW as a WMO cross-cutting activity:
GCW in the context of WIGOS and WIS Vision.

4. Data Exchange and Interoperability

5. GCW High Mountain activities

6. GCW Product Strategy and Strategic Engagements

7. REPORT TO EC-PHORS
7.1 Draft Resolutions to EC-70/Cg-18.

8. ANY OTHER BUSINESS
8.1. Next GSG meeting.

9. CLOSURE OF GSG MEETING

Annex 2: List of Participants

No.	Name	Institution/Affiliation	e-mail
1	Árni Snorrason Chair, GCW Steering Group	Director General, Icelandic Meteorological Office, Permanent Representative of Iceland Reykjavik, Iceland	arni.snorrason@vedur.is
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5	Sue Barrell Co-chair, ICG-WIGOS	Chief Scientist and Group Executive, Science and Innovation Bureau of Meteorology, Melbourne, Australia	s.barrell@bom.gov.au
6	Michele Citterio Co-Chair Observations WG	GEUS - Geological Survey of Denmark and Greenland, Copenhagen, Denmark	mcit@geus.dk
7	Charles Fierz Co-Lead Best Practices Team	WSL Institute for Snow and Avalanche Research SLF, International Association of Cryospheric Sciences (IACS), Davos, Switzerland	fierz@slf.ch
8	Gino Casassa Lead, Terminology Team	Geostudios, University de Magellanes, Chile	gino.casassa@gmail.com
9	Øystein Godøy Co-Chair Information and Services WG; Lead, Data Portal Team	Norwegian Meteorological Institute, Oslo, Norway	o.godoy@met.no
10	Petra Heil GCW Expert	Australian Antarctic Division and Antarctic Climate and Ecosystems , University of Tasmania, Hobart, Australia	petra.heil@utas.edu.au
11	Jeff Key Co-Chair Information and Services WG; Lead, Website and Outreach Team	National Oceanic and Atmospheric Administration (NOAA) Madison WI, USA	jkey@ssec.wisc.edu
12	Kari Luojus Co-Chair, Integrated products WG; Co-lead, Snow Watch Team	Finnish Meteorological Institute (FMI), Helsinki, Finland	kari.luojus@fmi.fi

13	Samantha Pullen GCW Expert	UK Met Exeter, United Kingdom	samantha.pullen@metoffice.gov.uk
14	Vasily Smolyanitsky Co-Chair, Integrated products WG;	Arctic and Antarctic Research Institute, St. Petersburg, Russian Federation	vms@aari.aq
15	Þorsteinn Þorsteinsson Co-Lead, Best Practices Team	Icelandic Meteorological Office, Reykjavík, Iceland	thor@vedur.is
16	Patricia de Rosnay GCW Expert	European Centre for Medium-Range Weather Forecasts (ECMWF)	patricia.rosnay@ecmwf.int
17	Wolfgang Schöner Co-Chair Observations WG; Lead CryoNet Team	University of Graz, Dept. of Geography, Graz, Austria	wolfgang.schoener@uni-graz.at
18	Penelope Mae Wagner GCW Expert	Sea Ice Researcher Norwegian Ice Service Tromsø , Norway	penelopew@met.no
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		Sciences, Beijing, China	
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Annex 3: Station criteria for the GCW observing network

Requirement	GCW Cryonet	GCW Contributing	GCW Affiliated
Measure at least one variable of one component of the cryosphere (variable from CryoNet variable list)	■	■	■
Measure ancillary variables as described by CryoNet variable list	■		
Representativity of measurement is described	■	■	
Station has to be active	■		
Commitment of long term observatons (4+ years)	■		
Metadata available and up to date and available at GCW portal	■	■	
Compliance with Agreed Regulatory Practice	■	■	
Data and Ancillary Data Freely Available whenever possible in real-time	■	■	■
Personnel must be trained in the operation and maintenance of the station	■	■	

Annex 4: List of Products available on the GCW Website

Product	Source	Offered or Approved
Trackers:		
JAXA-NiPR Ice Extent Tracker	NiPR	Offered
JAXA-NiPR Ice Trend Tracker	NiPR	Offered
APP-x Ice Thickness Tracker	NOAA/CIMSS	GCW
APP-x Temperature Tracker	NOAA/CIMSS	GCW
APP-x Surface Albedo Tracker	NOAA/CIMSS	GCW
GCW/FMI SWE Tracker	FMI	GCW
EC/GCW NH Snow Extent Tracker	ECCC (EC)	GCW
EC/GCW NH SWE Tracker	ECCC (EC)	GCW
Glacier Mass Balance (annual tracker)	WGMS	GCW
Alaska Permafrost (annual tracker)	Univ. Alaska-Fairbanks	Permission
Northern Hemisphere Thaw Depth	Univ. Zurich, Metno (?)	Offered
Assessments:		
All annual time series plots in Assessments	Various sources, processed by NOAA/CIMSS	GCW
All assessments (snow, sea ice, etc.)	Written by NOAA/CIMSS	GCW
PRODUCT	SOURCE	OFFERED OR APPROVED
DAILY OR MONTHLY PLOTS (NOT TRACKERS):		
NOAA MULTISENSOR SNOW AND ICE	NOAA	APPROVED
JAXA AMSR2 SNOW AND ICE	JAXA	OFFERED
SSM/I ICE CONCENTRATION	NOAA/CIMSS	OFFERED
VIIRS ICE CONCENTRATION	NOAA/CIMSS	OFFERED
VIIRS ICE SURFACE TEMPERATURE	NOAA/CIMSS	OFFERED
CRYOSAT ICE THICKNESS	ESA	OFFERED
SMOS ICE THICKNESS	ESA, UNIV. HAMBURG	OFFERED
JAXA-NIPR ICE THICKNESS	NIPR	OFFERED
JAXA-NIPR ICE DRIFT	NIPR	OFFERED
ASIP ALASKA ICE CONCENTRATION (3 REGIONAL PRODUCTS)	NOAA ALASKA SEA ICE PROGRAM	OFFERED
ARGENTINA SH ICE CONCENTRATION FORECAST	ARGENTINE NAVAL HYDROGRAPHIC SERVICE	OFFERED
AARI/NIC/NMI ICE (3)	AARI	OFFERED
EC GLOBAL SNOW COVER	ECCC	PERMISSION
RUTGERS DAILY SNOW DEPARTURE	RUTGERS UNIV.	PERMISSION
IMS SNOW COVER	NATIONAL ICE CENTER	PERMISSION
CIMSS AMSR2 SWE	NOAA/CIMSS	OFFERED
JAPAN SNOW DEPTH	NIPR	OFFERED
DAILY ATMOSPHERE PRODUCTS	NOAA/CIMSS	OFFERED

Annex 5: GCW work plan and roadmap to operationalization.

No	Section #	Action	Responsible	Due
1	1.5	On WIGOS Data Quality Monitoring System (WDQMS): GCW to follow up from the June 2017 Integration Workshop actions and ensure that the GCW needs are represented in the mandates of the Global/Regional monitoring centres	CryoNet, Data Portal, Secretariat	GSG-6
2	1.5	GCW is invited to provide input on the WIGOS vision for 2040, regarding cryosphere observing systems	Secretariat with input from experts,	March 2018
3	1.5	S Barrell to represent the concern regarding the allocation of WIGOS IDs for GCW stations throughout the operationalization of WIGOS. B Goodison to request a resolution, at the ICG-WIGOS meeting in January 2018. This is applicable for the Antarctic Observing Network stations, as well.	S Barrell, B Goodison, S Colwell	2018
4	1.5	The group requested Secretariat to provide more information on how WIS 2.0 will handle NetCDF.	Secretariat,	May 2018
5	1.5	Review the WIGOS data partnership, and recommend content to reflect the specifics of GCW data exchange requirements. The GCW Data Protocol to be reflected in the WIGOS data partnership.	WG Leads	GSG-6
6	2.1.1.1	Providing updates to the WMO Technical Regulations, WMO-No 49, and the Manual on WIGOS WMO-No. 1160, to improve the clarity of the GCW terminology	Secretariat Observations WG	March 2018
7	2.1.1.2	Establish a small task team to work on providing input to the WIGOS Metadata Standard, on cryosphere variables and promote the use the WIGOS Key words Organize regular meetings to advance the input of variables to WIGOS MD. With priority, focus on snow, sea ice, glaciers, permafrost. (details, also included in Section 3.4 of the report)	C Fierz, W Schöner, Ø Godøy	March 2018
8	2.1.1.2	Finalise the list of CryoNet cryosphere variables, by consulting more broadly with the cryosphere communities (in particular for lake and river ice) – [W Schöner to work with the GCW experts to connect with their peers]	W Schöner , Secretariat to coordinate	GSG-6
9	2.1.1.2	Secretariat to provide a road map for updating the WIGOS Metadata Standard.	Secretariat	June 2018
10	2.1.1.2	Link the recommended CryoNet observing requirements to existing WMO Application Areas (AA), already documented in the respective Statements of Guidance; consult with the GCW station owners to assess the opportunity for recommending additional AAs	WG Chairs	GSG-6
11	2.1.1.3	All station submissions will be assessment by end Feb 2018, for recommendation to EC-70, through EC PHORS-8. All will constitute the newly established GCW Surface Observing Network	Secretariat	March 2018
12	2.1.1.3	Establish guidelines on the inclusion of mobile platforms in the GCW observing network. Consider whether the mobile platforms could be accepted as affiliated networks, e.g. the International Arctic Buoy Programme (IABP) and International Programme for Antarctic Buoys (IPAB)	W Schöner	2018
13	2.1.1.3	Secretariat to ensure that affiliated networks can be recorded in OSCAR. Currently OSCAR has provisions for GCW Stations and, its child, “CryoNet”	Secretariat	March 2018
14	2.1.2	The first draft of Chapters 1 and 2 of the new volume on the “Measurement of Cryosphere Variables” for the CIMO Guide, WMO No. 8 will be provided to the CIMO Editorial board in March, which will formally send it for review to all WMO Members, with the goal of approval by members at the 17th CIMO session, in Oct 2018.	C Fierz	March 2018

15	2.1.2	Explore engagement with AWI for the development of Best Practices for permafrost	C Fierz, A Irrgang	GSG-6
16	2.1.2	Contact lake and river ice experts for developing the relevant chapters of Best Practices Guide. GCW experts are asked to provide recommendations to Secretariat.	C Fierz, T Thorsteinsson	June 2018
17	2.1.2	Develop a GCW electronic library to store reference documents consulted in the development of Best Practices	Best Practices Team Co-Chairs.	GSG-6
18	2.1.2	Secretariat to check whether the OSCAR database could be used for the repository of historical metadata	Secretariat	June 2018
19	2.1.2.2	The Sea Ice Task Team to continue its consultations before finalise the list of sea ice in-situ observed variables for CryoNet stations, in 2018, to ensure broad acceptance and representation.	P Heil, P Wagner, V Smolyanitsky	GSG-6
20	2.1.2.2	Explore specific opportunities for collaboration with MOSAiC and the Arctic Sea Ice Working Group of CliC	P Heil, P Wagner, V Smolyanitsky,	GSG-6
21	2.1.2.2	At the meeting of IICWG in Helsinki, in Sept 2018, a joint meeting IICWG-JCOMM-GCW Integrated products, might be considered, as a cross cutting engagement with experts from different domains (operational, research, commercial).	P Heil, P Wagner, V Smolyanitsky,	Sept 2018
22	2.2	The Integrated Products WG to invite additional experts from other regions (outside North America and Europe), and experts on lake and river ice.	K Luojus; V Smolyanitsky	GSG-6
23	2.2.1	Initiate the work of the Solid Precipitation Products Task Team, as agreed at GSG-4, and invite new members with appropriate expertize. Finalise ToRs.	Snow Watch co-Chairs	GSG-6
24	2.2.1.1	send a letter of appreciation to China, as well as others, for the contribution with additional snow datasets	Secretariat	June 2018 (China); on-going
25	2.2.1.1	P Rosnay to report back on the conversion of US SNOTEL data from SHEF format to BUFR.	P Rosnay	GSG-6
26	2.2.1.1	Secretariat to work with P Rosnay and Regional Association VI, to address gaps in snow depth reporting	Secretariat to work with P Rosnay	Sept 2018
27	2.2.1.1	Snow Watch Team experts to identify gaps in reporting snow depth. Secretariat will prepare letters from WMO SG to the respective PRs, asking for the available data to be exchanged.	Secretariat, K Luojus, r Brown, P Rosnay	GSG-6
28	2.2.1.1	Assess if feasible to associate with GCW those stations reporting and exchanging snow depth.	Secretariat to work with P Rosnay	GSG-6
29	2.2.1.1	Finalise the BUFR template for reporting Snow Water Equivalent (SWE) . The Snow Watch Team to develop a roadmap for archiving and exchanging the in-situ SWE data.	P Rosnay, R Brown	GSG-6
30	2.2.1.1	GCW, through the Snow Watch and Best Practices Teams continue the collaboration with COST Action HarmoSnow, on general observations practices and data exchange, and with GODEX (Global Observation Data Exchange), to ensure the acceptance and use of the new SWE BUFR template	P Rosnay, C Ferz	GSG-6
31	2.2.1.2	K Luojus to inform GSG-6 on the outcomes of the consultation on future snow missions, organized jointly by GCW and PSTG-SAR WG, in January, 2018, and the potential for other projects, similar to SnowPEx.	K Luojus	GSG-6
32	2.2.1.3	Prepare plan for new snow products using the multi-dataset approach using the results from SnowPEx for guidance , for use by ArcRCC and all RCCs	K Luojus, R Brown, V Smolyanitsky	GSG-6
33	2.2.1.3	Canadian Historical Snow Survey data set, covering the period 2004-2016, contains data from ten different agencies, and should be published through GCW portal or website, once the permission to distribute freely, is granted.	Snow Watch Co-Chairs, J Key	GSG-6
34	2.2.1.3	Organize a Snow Watch Team meeting, together with the Solid	Snow Watch	GSG-6

		precipitation Products Task Team should be organized in 2018 or 2019.	Co-Chairs, Secretariat	
35	2.2.2	Prepare submissions to EC PHORS on the proposal for a World Snow Monitoring Service. Explore partnerships and a feasibility analysis.	Secretariat, C Fierz	EC PHORS-8; GSG-6
36	2.3	Define a joint work plan with JCOMM ETSI, to reflect the decisions of JCOMM-5.	V Smolyanitsky, P Heil, P Wagner	GSG-6
37	2.4.1	Examine the final recommendations from R Duerr, and decide on how to proceed regarding the GCW Glossary Follow up reviews will be organized by teleconference throughout 2018	G Casassa, Secretariat	2018
38	2.4.2	It was proposed to fund a student to update the 2005 cryosphere map. The group was invited to recommend to Secretariat options for completing this work.	GSG, Secretariat,	GSG-6
39	2.4.2	Investigate the feasibility of developing a parallel platform for the GCW Website, as backup. J Key will organize the information on the current server to consolidate from the different servers. Explore options and secure long term commitment for support.	Ø Godøy, J Key,	GSG-6
40	2.4.2	Resubmit a GCW Wikipedia entry; Develop a GCW mobile application; Prepare a regular GCW newsletter;	J Key	GSG-6
41	3.1	Work with Sodankylä (Finland), Kluane Lake (Canada), also, with INTERACT stations for testing the application for converting data formats, developed in collaboration with SLF	Ø Godøy, K Luojus, J Fiddes	2018
42	3.1	Data Portal Interoperability Sonnblick, W Schöner will provide contact to Ø Godøy	W Schöner, Ø Godøy,	June 2018
43	3.1	A demonstration of the SLF-based application will be made at Polar 2018	Ø Godøy	June 2018
44	3.1	Continue the development of interoperability between the GCW Data Portal and the GCW stations and clusters, in collaboration with SLF.	Ø Godøy, J Fiddes,	GSG-6
45	3.1	The interoperability manual and guidelines will be further developed, once the interoperability is establish.	Ø Godøy, J Fiddes,	GSG-6
46	3.1	Define the "operational readiness" check list of the GCW station and include in the pre-operational plan	W Schöner, Ø Godøy,	GSG-6
47	3.2	GCW to assess how feasible is to harvest the station metadata from questionnaires, and feed the information to OSCAR	Ø Godøy, J Key,	GSG-6
48	3.2	development of a special API for interaction with OSCAR.	Ø Godøy	GSG-6
49	3.4	Secretariat to work with CIMO and Hydro-meteorological Equipment Industry Association (HMEI) to develop and recommend standards for data output, using NetCDF.	Secretariat	GSG-6
50	3.4	Explore establishing interoperability with WGMS	Ø Godøy, C Fierz, Secretariat	GSG-6
51	4.1	GCW to facilitate the linkages between the NMHS and the sponsoring organization, to ensure that the operation of such stations is sustainable in time, and that the NMHS gains access to the data (priority given to Mount Kilimanjaro Ice Field)	Secretariat, Obs WG Chair	**GSG-6**
52	4.1	Advance the regional engagements of GCW with a focus on collaboration with RA VI in the Caucasus region in 2018 or 2019; as well as Scandinavian , and the Alps. Will be discussed at RA VI-17 session, in Feb 2018.	C Fierz, Á Snorrason, Secretariat,	Feb 2018, GSG-6
53	4.1	Follow up on Decision 21 (RA II-16), on the proposal from Pakistan regarding the project Cryosphere monitoring to understand the trend of glacial hydrology of high Asia Mountains	GSG, Secretariat	GSG-6
54	4.2	Recommend to EC PHORS that GCW could assume an active	Secretariat	EC PHORS-8

		role in the development of the High Mountain Strategy, and the organization of the High Mountain Summit.		
55	5.1	M Citterio to share with the Best Practices Team the results of field tests within the context of INTAROS, for assessing the next steps (see report details)	M Citterio, Best Practices Team	GSG-6
56	5.1	GCW Best Practices and Data Portal build closer ties with INTAROS regarding standards for observations and data discoverability and access, and report back at GSG-6.	M Citterio, Ø Godøy	GSG-6
57	5.1	GCW Data Portal and HWOS will explore potential synergies. Will coordinate through Secretariat	Ø Godøy ,Dominique B	GSG-6
58	5.2	Ø Godøy requested that a contact person is nominated as the interface between TPE and GCW Data Portal to work with, for developing a work plan to move forward.	Ø Godøy, Ailikun	June 2018
59	5.2	CAS could support the development of an interface to translate the TPE formats for data into a format suitable for access through the GCW Data Portal.	Ailikun	GSG-6
60	5.2	Prof Ailikun offered to provide TPE results for posting on the GCW website.	Ailikun, J Key,	GSG-6
61	5.3	GCW and UNESCO IHP to continue the active engagement, in coordination with the CHy engagements	Secretariat, A Mishra, D Berod	GSG-6
62	5.5	GCW to work with the Arctic Data Committee, on organizing the ADC meeting, in the fall of 2018, hosted by WMO, in Geneva.	Secretariat	Oct 2018
63	5.6	S Starkweather invited GCW to collaborate with US AON. The GCW Project Office will follow up with S Starkweather for exploring opportunities for collaboration.	Secretariat	GSG-6
64	5.8	M Citterio recommended that GCW promotes the use of IRIDIUM telemetry for remote locations, as most cryosphere observations are in areas with extremely difficult access to traditional data transmission infrastructure, likely through SATCOM.	Secretariat	GSG-6
65	5.8	C Scott urged GSG to clarify the meaning of terms used, e.g. operational, functional, as GCW has a broad spectrum of “contributors” spanning the full range of capabilities and expectations.	Secretariat to coordinate	GSG-6
66	5.8	GCW to explore with C Scott how to ensure future support to GCW, through NWS, linked to clear requirements. to follow up on practical approaches.	Chair, Secretariat,	GSG-6
67	5.8	C Scott invited the Chair or the Vice-Chair of the GCW Steering Group to make a presentation on the objectives of GCW for the interagency group of the State of Alaska. This would provide more leverage to develop a working relationship between GCW and the various parties in Alaska	C Scott, A Snorrason	2018
68	5.8	C Scott to provide a point of contact to the Snow Watch Team (K Luojus) to help with accessing the snow measurement data onto GTS (existing and new stations, multiple agencies, where possible).	C Scott	GSG-6
69	6.1	Engagement with PRCCs: maintain an active engagement with the PRCC initiatives in the Arctic, Third Pole, and Antarctic, also, promote cryosphere products for the existing RCC. Integrated Products WG. (see action 32)	L Ma, Z Ping, V Smolyanitsky, K Luojus,	GSG-6
70	6.1	GCW experts to prepare additional assessments and align them with the publication of the WMO annual statements on climate, as a concrete contribution of GCW to the WMO Programmes (relevant to 6.2)	J Key, Integrated products WG Co-Leads	GSG-6
71	6.1	Develop near real-time graphics for snow, glaciers and permafrost in the Southern Hemisphere	J Key, Integrated products WG Co-Leads	GSG-6
72	6.1	Available educational resources, pictures, videos should be made available via the website	J Key, GCW Experts	GSG-6

73	6.1	Invite feedback on the use and content of assessments published on the GCW Website	J Key	GSG-6
74	6.2	Define and develop the input from the GCW CryoNet to the pan-Arctic bulletins, e.g., as agreed previously, CryoNet stations time series (using Data Portal as interface). See actions 32 and 68.	WG Leads, Ø Godøy , V Smolyanitsky	GSG-6
75	6.2	Nominate GCW points of contact for each node of the Arctic PRCC and identify which products will be provided by GCW. Ms Leslie Malone (Canada) was nominated as an interim point of contact between GCW and ArcRCC.	GSG, Secretariat,	June 2018
76	6.3	Secretariat will consult with the appropriate groups in WMO, for follow up and action regarding Third Pole RCC proposal.	Secretariat, L Ma	Jan 2018
77	6.4	GSG expressed support for the engagement with PSTG, and invited the experts to follow up on the specific actions from the PSTG meeting.	P Wagner, P Heil, J Key	GSG-6
78	6.4	GCW to work with PSTG in promoting the organization of intercomparisons/assessments, and to provide a relative assessment of available sea ice products	Integrated Products Co-Chairs, M Drinkwater	GSG-6
79	6.5	GCW Data Portal and HWOS will explore potential synergies. Will coordinate through Secretariat	Ø Godøy ,Dominique B	GSG-6
80	6.6	Encourage additional Antarctica stations and AWS to apply as GCW stations	S Colwell,	GSG-6
81	6.6	GSG to consider whether all of Antarctica be considered as a single CryoNet cluster. The same for Greenland.	Observations WG, S Colwell	GSG-6
82	6.7	Contribute to the draft concept note for the proposed Climate Change and the Cryosphere Conference, Iceland, 2020 , for submission to EC PHORS-8	A Snorrason, Secretariat	March 2018
83	6.8	Contribute to the proposal for a UN International Year of Snow and Ice	Secretariat, A Snorrason, A Mishra	March 2018
84	7.1	Prepare for Cg-18 (2019), an updated GCW Pre-Operational Implementation Plan, and provide a high level report on results to date, to EC-70. Organize meeting in this sense in Oct-Nov, 2018.	Secretariat to coordinate	2018
85	7.1	Following Cg-18, GSG will convene a strategic planning meeting to develop its strategy for the future, and to proposed a functional structure to support the strategy, aligned with the structure of WMO Programmes.	Secretariat to coordinate	2019
86	7.1	Submit to EC 70, through EC PHORS, a recommendation for a Cg-18 resolution on the pre-operational phase of GCW, identifying the key focus areas for the next 4 years.	Secretariat	April 2018
87	7.1	Communicate the outcome of EC-70 and Cg-18 to all GCW contributors and partners, in particular approval of stations	Secretariat	August 2018
88	7.2	Secretariat to work with Dr Ohata to nominate an expert from Japan, as a member of the GCW Steering group	Secretariat	July 2018
89	8.0	Secretariat to prepare submission to EC PHORS-8, as outlined in section 8 of this report.	Secretariat	March 2018
90	9.0	Secretariat to prepare letters to Members requesting support to GCW, through contributions to the Trust Fund and contributions from experts.	Secretariat	July 2018

Annex 6: GCW Membership

Name	Organization, Country		GSG[5]	OBS WG[6]	INT PROD WG[7]	Inf Serv GW[8]
Angelo Corona	National Weather Service. 2601 North Rambo Rd, Spokane, Washington 99224, United States	angel.corona@noaa.gov				
Arni Snorrason	Permanent Representative of Iceland with WMO. Director-General. Icelandic Meteorological Office (IMO), Bustadavegur 9, IS-150 Reykjavik, Iceland.	arni.snorrason@vedur.is	Chair			
Barry Goodison	Canada	barrygo@rogers.com	Vice-chair			
Carven Scott	Director, Alaska Region, National Weather Service NOAA. 222 West 7th Avenue, 23, Suite 517, Anchorage, Alaska 99513, United States of America.	Carven.Scott@noaa.gov	x			
Charles Fierz	Research scientist WSL Institute for Snow and Avalanche Research SLF WSL Institute for Snow and Avalanche Research SLF, Flüelastrasse 11, CH-7260 Davos Dorf, Switzerland.	fierz@slf.ch	x	x		x
Chris Derksen	Research Scientist Climate Research Division Environment and Climate Change Canada 4905 Dufferin St Toronto, Canada, M3H 5T4	Chris.derksen@canada.ca			x	
Christophe Genthon	Universite Grenoble Alpes, Grenoble, France	christophe.genthon@univ-grenoble-alpes.fr		x		
Craig Smith	Climate Research Division, Saskatoon Environment Climate Change Canada	craig.smith2@canada.ca		X		
Dave Robinson	Professor NJ State Climatologist Rutgers University 54 Joyce Kilmer Avenue, Piscataway, NJ 08854-8045	david.robinson@rutgers.edu			x	
Eric Holloway	NOAA-National Weather Service, Alaska Pacific River Forecast Center, USA	eric.holloway@noaa.gov		x		

[5] GCW Steering Group
[6] Observations WG
[7] Integrated Products WG
[8] Information and Services WG

Feiteng Wang	Cold and Arid Regions Environmental and Engineering Research Institute (CAREERI), Chinese Academy of Science (CAS) Lanzou, China	wangfeiteng@lzb.ac.cn		X		
Gianpaolo Balsamo	ECMWF, Shinfield Park, Reading, RG2 9AX, England.	gianpaolo.balsamo@ecmwf.int	x			
Gino Casassa	Director, Glaciological Department at Instituto de la Patagonia, Universidad de Magallanes, Av. Bulnes 01855, Punta Arenas, Chile	gino.casassa@gmail.com	x	x		x
Giovanni Macelloni	Consigli O NAZIONALE DELLE RICERCHE - Firenze, Italy	g.macelloni@ifac.cnr.it		x		
Hironori Yabuki	National Institute for Polar Research, Japan	yabuki.hironori@nipr.ac.jp		x		X
Hugues Lantuit	Alfred Wegener Institute Telegrafenberg A43 14473 Potsdam Germany	Hugues.Lantuit@awi.de	x			
Jeff Key	Branch Chief, Advanced Satellite Products Branch NOAA Satellite and Information Service Madison, Wisconsin USA, University of Wisconsin-Madison, 1225 West Dayton Street; Madison; WI 53562; USA,	jeff.key@noaa.gov; jkey@ssec.wisc.edu	x	x		Co-chair
Julie Friddell	Director, Canadian Cryospheric Information Network/Polar Data Catalogue Department of Geography & Environmental Management University of Waterloo 200 University Avenue West Waterloo, Ontario, Canada N2L 3G1	julie.friddell@uwaterloo.ca				x
Kari Luojus	Finnish Meteorological Institute (FMI), Erik Palménin aukio 1, FI-00560 Helsinki, Finland.	kari.luojus@fmi.fi	x	x	Co-Chair	x
Lawrence Hislop	Director, Climate and Cryosphere Programme, WCRP	lawrence@climate-cryosphere.org	x			
Leslie Malone GCW Liaison with the Arctic-PRCC	Canada	lesliemalone@rogers.com			X	
Lijuan Ma	National Climate Center China Meteorological Administration 46 Zhongguancun Nandajie	malj@cma.gov.cn			X	

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Mark Drinkwater	Head, Mission Science Division (EOP-SM). European Space Agency (ESA), ESTEC, Keplerlaan 1, NL-2201 AZ Noordwijk, The Netherlands.	mark.drinkwater@esa.int	x			
Michele Citterio	GEUS - Geological Survey of Denmark and Greenland, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark	mcit@geus.dk	x	Co-chair		x
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Patricia de Rosnay	Coupled Assimilation Team Leader European Centre for Medium-Range Weather Forecasts	patricia.rosnay@ecmwf.int			x	
Penelope May Wagner	Sea Ice Researcher Norwegian Ice Service Tromsø , Norway	penelopew@met.no		X	X	
Peter Pulsifer	National Snow and Ice Data Centre, Boulder, CO, USA	pulsifer@nsidc.org				x
Petra Heil	Australia Antarctic Division, Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC), Hobart	petra.heil@utas.edu.au		x	x	
Rainer Prinz	University of Graz Department of Geography and Regional Science, Graz, Austria	rainer.prinz@uni-graz.at		X		
Rick Thoman	Climate Science and Services Manager. Environmental and Scientific Services Division, National Weather Service , NOAA, Alaska Region, Fairbanks, Alaska.	richard.thoman@noaa.gov				x
Ross Brown	Environment and Climate Change Canada, Canada	Brown.Ross@ouranos.ca	x		x	
Samantha Pullen	NWP SAF Manager Satellite Applications Met Office FitzRoy Road Exeter EX1 3PB United Kingdom	samantha.pullen@metoffice.gov.uk			x	
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Starkweather	Executive Director | US Arctic Observing Network (US AON) Boulder,CO, USA	a.gov				
Sean Helfrich	NOAA/NESDIS/OSDPD— NOAA Science Center, 5200 Auth Road, Camp Springs Maryland, MD 20746, USA.	sean.helfrich@noaa.gov			x	
Steve Colwell	British Antarctic Survey (BAS), High Cross, Madingley Road, Cambridge, CB3 OET, United Kingdom.	src@bas.ac.uk	x			
Sue Barrell **WIGOS** rep	Bureau of Meteorology. G.P.O. Box 1289, Melbourne 3001, VIC, Australia.	s.barrell@bom.gov.au	x			
Tetsuo Ohata	National Institute for Polar Research, Tokyo, Japan		x			x
Þorsteinn Þorsteinsson	Icelandic Meteorological Office (IMO), Bústadavegi 9, IS-150 Reykjavik, Iceland,	thor@vedur.is	x	x		x
Tom Kralidis	Monitoring and Data Services Directorate Environment and Climate Change Canada	tom.kralidis@canada.ca				X
Tómas Jóhannesson	Icelandic Meteorological Office, Iceland	tj@vedur.is				x
Vasily Smolyanitsky	Arctic and Antarctic Research Institute (AARI), Bering str., 38, St.Petersburg, Russian Federation	vms@aari.aq	x	x	Co-Chair	x
Vincent Fortin	Research scientist, Meteorological Research Division Environment and Climate Change Canada,	vincent.fortin@canada.ca		X		
Wolfgang Schöner	Professor Department of Geography and Regional Sciences University of Graz, Graz, Austria	wolfgang.schoener@uni-graz.at	x	Chair	x	x
Zhao Ping	Vice-President, Chinese Academy of Meteorological Sciences CMA Beijing, China	zhaop@cma.gov.cn	X			
Julia Boike	Alfred Werner Institute, Germany			x		
Anett Bartsch,	Austria			x		
Bard Saadatnejad	Norwegian Meteorological Institute, Norway					x

Annex 7. JCOMM-5, ToR Expert Team on Sea Ice (ETSI)

Updated Terms of Reference

(a) Coordinate and advise Members/Member States on products and services required by user communities in sea ice areas, to support navigation, coastal and off-shore activities, monitoring of the sea ice cover;

(b) Provide advice to the WWMIWS Committee and ETMEER on all aspects of impacts of sea ice relevant to maritime safety, marine pollution response and search and rescue services;

(c) Maintain linkages with ETOOFS and ETDRR on the relevant sea ice modelling and forecasting techniques;

(d) Maintain linkages with projects and programmes related to the role of sea ice in the global climate system, including through the WCRP and the Global Cryosphere Watch;

(e) Develop technical advice and guidance material, software exchange, specialized training and other appropriate capacity building activities with regard to sea ice observations, analysis and services, and provide assistance to Members/Member States as required;

(f) Keep under review and provide guidance as appropriate on the operations of the Global Digital Sea Ice Data Bank (GDSIDB), in collaboration with ETMC;

(g) Maintain and develop formats, nomenclatures and procedures for sea ice data and information exchange as well as relevant terminology, coding and mapping standards;

(h) Develop, in accordance with existing standards (e.g. from IHO), graphical/numerical product specification for floating ice (sea ice, glacier ice, lake and river ice) parameters in Electronic Navigation Chart Systems (ENCs);

(i) Maintain linkages with relevant international organizations and programmes, in particular BSIM, CLIC, EIS, IICWG, NAIS, ASPeCt, GCOS and IHO.

As a general principle, these terms of reference will be implemented through specific, defined, time-limited projects.

Membership

…Up to eight core Members …representative of a range of activities related to sea ice and the ice-covered regions within JCOMM, and to maintain an appropriate geographical and gender representation….Representatives of regional and international sea ice bodies in particular the…. International Ice Charting Working Group …will also be invited… Additional experts may be invited as appropriate, representative of the range of activities related to sea ice…

Annex 8: List of acronyms

AA	Application Area
ADC	Arctic Data Committee (SAON)
AntON	Antarctic Observing Network
APECS	Association of Polar Early Career Scientists
ArcRCC	Arctic Regional Climate Centre (see PRCC)
ASPECT	Antarctic Sea ice Processes and Climate
ATCM	Antarctic Treaty Consultative Meeting
AWI	Alfred Wegener Institute
BAS	British Antarctic Survey
BUFR	Binary Universal Form for the Representation of Meteorological Data
CAS	Chinese Academy of Sceinces
CBS	Commission for Basic Systems (WMO)
CF	Climate and Forecast Convention
Cg	Congress
CHy	Commission for Hydrology (WMO)
CIMO	Commission for Instruments and Methods of Observation (WMO)
CIMSS	NOAA/Cooperative Institute for Meteorological Satellite Studies
CliC	Climate and Cryosphere project
CMA	China Meteorological Administration
CON	Committee on Observing Networks (SAON)
CryoNet	GCW core observing network
DBCP	Data Buoy Cooperation Panel
DCPC	Data Collection or Processing Centre
DOI	Digital Object Identifier
ECCC	Environment and Climate Change Canada
EC	Executive Council
EC-69	Sixty-Ninth Session of the Executive Council
EC-PHORS	WMO Executive Council Panel of Experts on Polar and High Mountain Observations, Research and Services (formerly EC-PORS)
ECMWF	European Centre for Medium-Range Weather Forecast
ECV	Essential Climate Variables
EPB	European Polar Board
ESA	European Space Agency
ETSI	Expert Team on Sea Ice (JCOMM)
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FMI	Finnish Meteorological Institute
GAW	Global Atmosphere Watch
GCOS	Global Climate Observing System (WMO-IOC-UNEP-ICSU)
GCW	Global Cryosphere Watch
GEO	Group on Earth Observations
GEOCRI	GEO Cold Regions Initiative
GEUS	Geological Survey of Denmark and Greenland
GEWEX	Global Energy and Water Cycle Exchanges Project
GFCS	Global Framework for Climate Services
GOS	Global Observing System
GODEX	Global Observation Data Exchange
GNSS	Global Navigation Satellite System
GSG	GCW Steering Group
GTN-P	Global Terrestrial Network - Permafrost
GTS	Global Telecommunications System
HICAP	Himalayan Climate Change Adaptation Programme
HIMAP	Hindu Kush Himalayan Monitoring and Assessment Programme
HKH	Hindu Kush Himalayan region
HYCOS	Hydrological Cycle Observing System
IARPC	Interagency Arctic Research Policy Committee of US

IACS	International Association of Cryospheric Sciences
IASC	International Arctic Science Committee
ICG-WIGOS	Inter-Commission Coordination Group on WIGOS
ICIMOD	International Centre for Integrated Mountain Development
ICSU	International Council for Science
IGOS	Integrated Global Observing System-Cryosphere Theme
IHP	International Hydrological Program (of UNESCO)
IICWG	International Ice Charting Working Group
INARCH	International Network for Alpine Research Catchment Hydrology
INTAROS	International Arctic Observation System
INTERACT	International Network for Terrestrial Research and Monitoring in the Arctic
IOC	Intergovernmental Oceanographic Commission (UNESCO)
IOS	Integrated Observing Systems
IPA	International Permafrost Association
IPAB	International Programme of Antarctic Buoys
IABP	International Arctic Buoy Programme
IPCC	Intergovernmental Panel on Climate Change
IPET OSDE	Inter Programme Expert Team on Observing System Design and Evolution
ISSC	International Social Science Council
ITPR	Institute of Tibetan Plateau Research
JAXA	Japan Aerospace Exploration Agency
JCOMM	Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology
MetNo	Norwegian Meteorological Institute
MRI	Mountain Research Initiative
NASA	National Aeronautics and Space Administration
NetDCF	Set of software libraries and self-describing, machine independent data formats
NMHS(s)	National Meteorological and Hydrological Service(s)
NOAA	National Oceanographic and Atmospheric Administration
NWP	Numerical Weather Prediction
OpeNDAP	Framework that simplifies all aspects of scientific data networking
OSCAR	Observing System Capability Analysis and Review tool
OSE	Observing System Experiments
OSI SAF	Ocean and Sea Ice Satellite Application Facility
PARCOFs	Polar Regional Outlook Forums
PR	Permanent Representative (of Country with WMO)
PRCC(s)	Polar Regional Climate Centre(s)
PROMICE	Programme for Monitoring of the Greenland Ice Sheet
PSTG	Polar Space Task Group
PSTG-SAR	PSTG Sinthetic Aperture Radar Working Group (WG)
RA	Regional Association
RAS	Russian Academy of Science
RRR	Rolling Review of Requirements
SAON	Sustained Arctic Observing Network
SAR	Synthetic Aperture Radar
SCADM	Standing Committee on Antarctic Data Management
SCAGI	Standing Committee on Antarctic Geographic Information
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee on Ocean Research
SHEF format	Standard Hydrometeo Exchange Format
SnowPEX	Snow Product Intercomparison Exercise
SOOS	Southern Ocean Observing System
SPICE	Solid Precipitation Intercomparison Experiment
SWIPA	Snow, Water, Ice, Permafrost in the Arctic
ToR	Terms of Reference
TORA	Transatlantic Ocean Research Alliance

TT-WMD	Task Team on WIGOS Metadata
TPE	Thirs Pole Environment
TPSS	Third Pole Science Summit
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
US AON	US Arctic Observing Network
WCRP	World Climate Research Programme (WMO-IOC-ICSU)
WGMS	World Glacier Monitoring Service
WIGOS	WMO Integrated Global Observing System
WIGOS MD TT	WIGOS Metadata Task Team
WMDS	WIGOS Metadata Standard
WDQMS	WIGOS Data Quality Management System
WIS	WMO Information System
WMO	World Meteorological Organization
WWRP	World Weather Research Programme (WMO)
WWW	World Weather Watch
YOPP	Year of Polar Prediction