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GLOBAL CRYOSPHERE WATCH

STEERING GROUP

SESSION #6 (REDUCED)

26-28 November 2018
Davos, Switzerland

Technical Report # 22/2018

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GCW Global Cryosphere Watch

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Group Photo, Davos, 28 November 2018

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Executive Summary

The sixth reduced session of the Steering Group of the Global Cryosphere Watch (GSG-6R) was hosted by the WSL Institute for Snow and Avalanche Research SLF, in Davos, Switzerland, from 26 to 28 November 2018.

Dr Árni Snorrason, the Chair of the GCW Steering Group (GSG) and the Permanent Representative (PR) of Iceland, chaired the meeting.

Á Snorrason outlined the goals of the meeting, noting its importance, in preparation for reporting to the 18th World Meteorological Congress, and as a demonstration in practice of the WMO Integrated Global Observing System (WIGOS). He acknowledged the need for a feasible plan on the pre-operational phase of GCW, and ensuring appropriate linkages and resources to achieve its operational phase, by 2024.
Dr Lars Peter Riishojgaard, the Project Manager of WIGOS provided an overview of WIGOS, and spoke about the pre-operational phase of WIGOS, 2016-2019, which is representative for the pre-operational phase of GCW. The group agreed on specific actions, within the framework of WIGOS, to ensure that the observing component of GCW is well defined and functional within an operational WIGOS.

Barry Goodison, the Vice-Chair of GSG, presented an overview of the implementation of GCW and its major milestones.

The group discussed the priority activities for the pre-operational period, regarding observations and relevant regulatory and guidance material, the development of the Data Portal, the data interoperability capabilities, the development of integrated products, and the engagement with users. A special focus was given to Snow Watch and Sea Ice activities.
Dr Charles Fierz led a session on the proposal for establishing a World Snow Centre within the framework of GCW, and in cooperation with other scientific organizations.
The future of GCW in the context of the WMO governance reform was discussed, including options for future governance.

The participants agreed to prepare a revised pre-operational plan for submission to the 9th session of EC PHORS, and for approval by EC. It is expected that Cg-18 will discuss and approve the pre-operational phase of GCW.
Dr Wenjian Zhang, the Assistant Secretary General (ASG) of WMO, encouraged GCW experts to provide input to the strategic documents developed in preparation of Congress.

The meeting closed on 28 November 2018.

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MEETING REPORT

1. Organization of the meeting

1.1 Welcome address, agenda and introduction of participants

The sixth session of the Steering Group of the Global Cryosphere Watch (GSG-6R) was hosted by the WSL Institute for Snow and Avalanche Research SLF, in Davos, Switzerland, from 26 to 28 November 2018. The meeting was attended by a core group of GSG members, directly engaged in the development of GCW.

Dr Árni Snorrason, the Chair of the GCW Steering Group (GSG) and the Permanent Representative (PR) of Iceland, who chaired the meeting, opened the session on 26 November 2018, at 09:00 am. He thanked SLF and in particular Dr Charles Fierz, one of the most active experts in GCW, for hosting the meeting. He thanked all participants and experts for their commitment and ongoing efforts in support of GCW.

Dr Charles Fierz welcomed the participants on behalf of SLF. He introduced SLF activities, including the observing activities at the Weissfluhjoch station. Dr Jürg Schweizer, the Head of the SLF (https://www.slf.ch/en/employees/schweizj.html), welcomed the participants, noting the engagement of SLF, especially Dr Charles Fierz, on topics of international interest related to cryosphere.

The meeting agenda was adopted without changes, and is available in Annex 1.
Á Snorrason invited the participants to introduce themselves. The list of participants is available in Annex 2. All actions resulting from this meeting are summarized in Annex 3, in addition to being detailed in this report. The acronyms used in this report are detailed in Annex 11.

1.2 Meeting goals

Á Snorrason outlined the goals of the meeting, noting its importance in preparation for reporting to the 18th World Meteorological Congress (Cg-18), and as a demonstration of integration within the framework of the WMO Integrated Global Observing System (WIGOS). He invited the participants to develop a feasible plan on the pre-operational phase of GCW, seeking to establish appropriate linkages and resources, to achieve the GCW operational phase, by 2024.

GCW Project Manager (GCW PM) recalled Recommendation 17 (EC-70), on the Pre-operational phase of the Global Cryosphere Watch, which r*ecommended to Congress the draft Resolution on the Pre-Operational Phase of the Global Cryosphere Watch as provided in the Annex to Recommendation 17.*
The draft Resolution for Congress 18 (Cg-18) states that "*THE WORLD METEOROLOGICAL CONGRESS, Decides that the development of GCW will continue during its pre-operational phase in the eighteenth financial period, with the aim proving to Members the benefits of a fully operational, end-to-end GCW, as a cross cutting activity, from 2024 onward;*
Decides further that the GCW priorities during the pre-operational phase will be:

- *Supporting Members in developing national frameworks for cryosphere end-to-end monitoring and service partnership;*

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- *Developing and publishing value added cryosphere products, relevant to water resource and ecosystems management, to safety (e.g. transportation), to understanding natural hazards and risks, to energy production, etc.;*
- *Establishing the GCW Data Portal as a Data Collection or Production Centre (DCPC) in the WMO Information System (WIS), thus improving the access to, and the management of quality of current and past cryosphere data, information, and products;*
- *Developing and publishing GCW regulatory and guidance material, including for supporting capacity development;*

2. Lessons Learned from WIGOS pre-operational phase

2.1 Overview

Dr Lars Peter Riishojgaard, the Project Manager of WIGOS provided an overview of WIGOS, in particular the pre-operational phase of WIGOS, 2016-2019. He noted the integrated nature of WIGOS, across national borders, across disciplines, across organizational boundaries, across technological boundaries, with space- and surface-based observing system as one, and across different levels of performance. He also noted that needs of weather and climate are different, but that networks need to be operated as an integrated system. This discussion was relevant to this meeting, as the observing component of GCW is a component of WIGOS.

He emphasized the need to be clear with Members on the attributes of the operational system proposed (what's in it for them). The WIGOS Pre-Operational Phase (2016-2019) was developed to increase the emphasis on regional and national activities, and included five main priority areas:

- WIGOS Regulatory Material, supplemented with necessary guidance material
- WIGOS Information Resource, including the Observing Systems Capabilities analysis and Review tool (OSCAR), especially OSCAR/Surface
- WIGOS Data Quality Monitoring System (WDQMS)
- Regional Structure; Regional WIGOS Centres
- National WIGOS Implementation, coordination and governance mechanisms.

LP Riishojgaard noted that achieving the goals of WIGOS has involved a significant investment of resources, expertise, travel, workshops, Secretariat support, without which the operational status cannot be achieved. He encouraged GCW to state clearly the resources needed to become operational, including people and financial aspects.

LP Riishojgaard stressed out the importance of gaining wide acceptance by Members, and through their PRs. Tools like OSCAR, as the new WMO station catalogue, have contributed to facilitating the support from Members. Its value rests with the ability to support the monitoring of performance, and availability of observations, which is part of the WIGOS Data Quality Monitoring System (WDQMS).

2.2 GBON

LP Riishojgaard noted that the Global Basic Observing Network (GBON) requirements, are developed as a set of mandatory requirements for observations, which must be met by all

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Members. The group asked about the inclusion of snow observations within the set of requirements for GBON.
Action: Secretariat to follow closely the development of GBON requirements, and promote the inclusion of snow observations, required by NWP. Deadline: ICG-WIGOS meeting, Jan 2019

2.3 OSCAR database registration

The group discussed the need for a clear procedure for registration of GCW sites in OSCAR/surface, as more than half of GCW stations are operated by non-NMHSs organization. LP Riishojgaard mentioned that each Member has a National OSCAR Focal Point, who could delegate the authority for registration, to others, at national level. In practice, this has not been tested yet, though. He noted that OSCAR archives the historical metadata of stations registered.

The group agreed to proceed with the registration of GCW stations in OSCAR with a WIGOS-light approach, by including a minimum set of station metadata into OSCAR surface. The Data Portal could interface between stations and OSCAR database, if needed.

Action: GCW Secretariat to work with the WIGOS Project Office to develop a feasible approach for registering the GCW stations in OSCAR. Deadline: ICG-WIGOS meeting, Jan 2019
Action: GCW to provide examples of engagements of National OSCAR FP, to support improvements in the current process. Deadline: ICG-WIGOS meeting, Jan 2019
Action: Ø Godøy to assess the feasibility of the GCW Data Portal acting as an interface between GCW stations and OSCAR. Deadline: ICG-WIGOS meeting, Jan 2019

2.4 WIGOS Identification Numbers (WIN) and other topics

On WIGOS Identification Numbers (WIN), LP Riishojgaard recalled that the PRs of Members have the authority to issue them. EC-70 decided that the Secretary General could also issue WINs, in case of stations unable to obtain one from the respective PR. The group recalled that the PRs are expected to endorse a GCW station operating in their country.

Action: Secretariat to work with WIGOS PO regarding the development of the observing component of GCW, e.g. the development of cryosphere related WIGOS metadata, OSCAR registration, WIGOS IDs, Regulatory Material, regional workshops. Deadline: ICG-WIGOS meeting, Jan 2019 and on-going

Action: WIGOS PM was asked to involve GCW Project Office in the preparation of Regional Workshops, and include GCW related and relevant aspects. Deadline: on-going.

The group agreed that GCW has a lot in common with the Global Atmosphere Watch (GAW) and these similarities need to be explored, especially regarding WIGOS, WIS, and OSCAR. LP Riishojgaard acknowledged that there needs to be closer co-operation between WIGOS and GCW Secretariat.

3. GCW Data Portal and interoperability with CryoNet

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3.1 Expectations

Dr Øystein Godøy provided an overview of the status of the development of the GCW Data Portal, at the Norwegian Meteorological Institute (MetNo). He focused on topics, which are critical for the development of the Data Portal during the pre-operational phase, as defined in Recommendation 17 (EC-70). Specifically:

1. Achieving interoperability at data level, with CryoNet stations:
    a. Agree on a practical approach regarding on data access, specifically, the imperative need to finalise the GCW Data Level Interoperability application, under development by SLF.
    b. Assess feasibility of hosting data, where and if needed, including a business model: individual data centres vs Data Portal.
    c. Governance of new data streams, from third parties, expected to be distributed on GTS.
    d. WIGOS metadata and registration of GCW stations in OSCAR.
2. Terminology: GCW developed terminology and semantics need to be aligned with those from similar projects of the international scientific community, to achieve acceptance and be used.
3. Funding: how to sustain services, as funding regimes are changing in many countries, a sustainable business model is needed.
4. The need for transparency of processes.

3.2 Overview of progress of the GCW Data Portal

Ø Godøy recalled that the GCW Data Portal is developed as a distributed system, metadata driven, capable of providing access to data sets, in real time and archive access. Currently it does not host data, but it may need to, to be effective; this, however, would come at a cost.

GCW Data Portal connects GCW with WMO Information System (WIS) and WIGOS. It reaches out to a heterogeneous community of cryosphere data providers, with varying degrees of structured data management and interoperability for metadata and data, and which are interested in the mutual benefits of standardisation, provided by GCW.

Ø Godøy highlighted the challenges on achieving interoperability between the Data Portal and GCW stations, e.g. metadata aspects (semantics and terminology) and data (formats/encoding, semantics/terminology, and common data models). Significant progress has been made, already, on discovery metadata protocols and structures, and data protocols.

Ø Godøy emphasized the important contribution made by WSL/SLF, on developing software for discovery and data interoperability, based on their existing package MeteoIO, and, in particular, the work of Dr. Joel Fiddes.. This was discussed at GSG5, in Jan 2018, https://gcw-test.met.no/node/10. More work needs to be done for completion. When finalised, it will facilitate the access to data from a wide range of input streams.

A new Data Portal system will be deployed developed and operated by MetNo, in early 2019, https://gcw-test.met.no/. It has a new front end and a modular structure, based on web services, and is ready to support the integration of data. It supports parent child relation in managing datasets, a hierarchy to create relations among datasets. To date, it harvests only IPY legacy systems and one CryoNet cluster, Weissfluhjoch. The new portal supports transformation

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and visualization services (e.g. time series plots), with access to datasets, upon request. Transformations allow users to do comparisons of products and to extract tailored products for their specific needs. The old GCW Data Portal is still available at http://gcw.met.no. Specific information is available in the presentation made at the meeting.

Ø Godøy informed the group that a WIGOS metadata light approach is being implemented for the Svalbard Integrated Observing System project (SIOS). In this context, the system needs to support multiple Station Identification Numbers, as requested by users and operators. This system is relevant to GCW, and can be used to support CryoNet stations.

3.3 GCW Data Portal – future development

3.3.1 Data Interoperability package

The group acknowledged that many GCW stations do not have resources and capabilities to achieve interoperability on their own, and that the full implementation of GCW goals requires that GCW focuses with the highest priority to make available the Data Interoperability software package (G-DIoS), as an essential tool to access their data.

Action: Ø Godøy, C Fierz, and the GCW PO to organize a side event during CG-18 (potentially in conjunction with other activities) to demo the access to data from GCW stations, via Data Portal and SLF interoperability package. Deadline: Cg-18 (note this is conditioned by the completion of the data interoperability application).

Action: Ø Godøy, C Fierz, and the GCW PO to develop a feasible roadmap for addressing interoperability with GCW stations, and the development of G-DIoS is an essential step towards this. Deadline: Cg-18.

3.3.2 Access to the WGMS data:

Currently, following a dedicated effort between GCW and WGMS in 2018, the GCW Data Portal could point to the WGMS data; data is handled at discovery level, only.

3.3.3 Interoperability with Sodankylä cluster

The access to the Sodankylä data is still an outstanding issue.

Action: Ø Godøy and Kari Luojus to collaborate on achieving interoperability between Sodankylä and the Data Portal, for Cg-18. Deadline: Cg-18
NOTE: the software package under development at SLF must be finalized, before interoperability with any new GCW stations is attempted.

3.3.4 Interoperability with the GTN-P data centre.

Ø Godøy summarized the challenges regarding the interoperability with the GTN-P data centre, as this is not funded to develop interoperability with GCW Data Portal, and may not see the value in establishing it. Their governance process is still evolving, and it's difficult to engage. In the near future Norway permafrost data, including from new stations on Svalbard, will be added to the Portal.

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Action: GSG to connect with GTN-P and IPA leadership. C Fierz to communicate with GTN-P and PERMOS. Deadline: 2019

Michele Citterio recommended that GCW review the communication with station proponents regarding the access to data, to ensure that the proponents understand and accept the current approach to interoperability.
Action: GCW PO to follow up on M Citterio's recommendations. Deadline: 2019

3.3.5 Sustainability of Data Portal Development

Ø Godøy reiterated that the development of the Data Portal has been funded through the Norwegian Meteorological Institute, exclusively, and, to a large degree, through research projects initiated at the Institute, funded as part of other national and regional initiatives (soft money), e.g. SIOS., and a sustainable model is needed.
The Chair thanked MetNo and Ø Godøy, in particular, recognizing the significant contribution to GCW, the sustained leadership, and the vision for developing the Data Portal.
The group agreed on the need to find a working solution to provide a repository, i.e. storage, (not long-term archiving the data) for stations unable to provide accessibility to their data. C Fierz offered to test the principle by using the SLF server, by holding all Swiss data on it.
M Citterio recommended that GCW develop an approach for versioning the data. A DOI for data would solve the questions, but not entirely**.**

Action: The GCW PO was asked to coordinate with Ø Godøy, C Fierz, M Citterio, to develop proposals for the sustainability of the Data Portal development and operation, archival/storage of data, and traceability, as part of the pre-operational phase. Deadline for plan: 2019

4. GCW Snow strategy

4.1 Proposal for establishing a World Snow Centre

4.1.1 Overview of the proposal

Dr C Fierz provided an overview of the proposal for a World Snow Centre (WSC), within the framework of GCW, with scientific support from other entities (e.g. IACS). He noted that WSC is envisioned as a component of GCW- Integrated Products WG, closely linked with the Snow Watch team. It is envisioned as a world class research and consultation framework, connecting science with practitioners, providing guidance on how to assess, process, cure, and homogenize in-situ and remotely sensed snow, snow pack and snow-cover data services.
A summary of proposed functions of WSC, as presented, is available in Annex 4 to this report.

The proposal aims at addressing current gaps and issues related to snow ECV, the connection between airborne and in situ data, and data management. The WSC will build on existing infrastructure, and will not replace existing centres; it will not be a monitoring service, or another pointer to existing data. WSC should increase the visibility of GCW, by promoting standardization, quality checks, pointing to sources of data.

The participants welcomed the proposal, in particular as a mechanism to support developing countries.
It was agreed that GCW needs to be an active contributor to the development of the WMO Statement on State of Climate, and that WSC will have a role to play in this.

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4.1.2 Summary of discussions on the role of WSC

4.1.2.1 Discussion on scope and engagements:

C Fierz noted that WSC would focus on snow observations, data, and standardization, as measured over land, glaciers, sea ice. He recalled the goal of GCW for achieving consistency regarding observations and data, including from projects organized independently, as are those from scientific communities. WSC will aim at providing analysis of snow products, overlapping between operational and scientific agencies, to support specific services, underrepresented currently, e.g. snow avalanche services.

The intent is to invite two organizations with a strong focus on hydrology and meteorology, to initiate the centre, jointly. C Fierz informed that he discussed this proposal with representatives of IACS, ICSIH (IAHS), IASC, and SCAR, and they are interested. An overview was presented at a 2018 meeting of the HarmoSnow Action.
B Goodison emphasized that operational hydrological agencies and hydropower agencies could be partners in developing WSC.

Dr Gino Casassa expressed interest in the proposal, as in South America, there are numerous data gaps and significant differences in methodologies regarding snow observations and data. In his view, WSC could be a mechanism to address these gaps, for snow and for other cryosphere components.

W Schöner raised the issue of machine-made snow, and whether this is within the scope of WSC.

4.1.2.2 Discussion on standards

- B Goodison agreed that using common standards and guidelines provides a sustainable observational and data framework. The WSC could provide advice through its experts on region specific observing technologies and practices.
- Dr Yves-Alain Roulet noted the need for standardizing and disseminating consistent observing methods, at global level, and the need to engage systematically, different players, climate-hydrology-NWP. Standardization and consistency of methods of observations and associated data reporting and quality are goals shared by GCW and the Commission for Instruments and Methods of Observation (CIMO). He welcomed the collaboration of GCW and CIMO regarding the development of the new volume of the Measurement of Cryosphere variables, included in WMO-No. 8 (2018) Guide to Instruments and Methods of Observations (through CIMO).
  He noted that MeteoSwiss has been collaborating with WSL related to data quality and that MeteoSwiss would support developing countries regarding capacity building.
- Dr Philippe Gyarmati noted that downstream countries are interested on snow data from mountainous regions, as water resulting from snow and glacier melt has multiple impacts, e.g. economic, risks, on low land areas.

4.1.2.3 Discussion on sustainability

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- The participants agreed that the success of GCW depends on the ability to build institutional ownership and interest, on engaging internationally recognized experts, and on the engagement with developing countries, which should be pursued in collaboration with the Regional Associations of WMO, e.g. RA VI (Europe and Western Asia).
- B Goodison noted that the Snow Watch team has been successful in making available snow trackers (SWE and Snow Cover Extent for the Northern Hemisphere). He noted the need for more regional products, as expressed during the first PARCOF meeting (May 2018). In his view, WSC would complement the work of the Snow Watch team, e.g. verification of model output or satellite products with observations. WSC could be a mechanism for encouraging developing countries to exchange data, internationally.
- The group agreed that consistency of products, as requested by users (temporal and spatial scales) is critical, e.g. the discussions at the recent PARCOF sessions (2018).
- M Citterio suggested that it should be easy to communicate with WSC and offer relevant products and services, to gain support, e.g. supporting a country with fewer resources. WMO may sponsor some technological survey and provide toolkits and procedures, which would facilitate the standardization of observations, as part of capacity building efforts.

The participants welcomed the session "C11 – TOWARDS THE DEVELOPMENT OF A WORLD SNOW CENTRE OF EXCELLENCE?" planned during the 27th IUGG General Assembly (Montreal, 8-18 July 2019), (http://iugg2019montreal.com/c.html). C Fierz is the convener of the session, and the co-conveners are Ross Brown (Canada) and Masahiro Hori (Japan).

4.1.3 Next Steps

The group agreed that the proposal for WSC has merit.
Á Snorrason requested the group to assess and articulate with clarity the additional value proposition of WSC, focusing on those aspects that are not already included in the scope of GCW, and how this builds on the contributions of the Data Portal, the Best Practices guidelines, and the results of the Snow Watch team.
He also requested that the plan forward for GCW, as a whole, take into account all priorities, e.g. sea ice, which is important for NWP community.

Actions:

- Articulate the arguments for pursuing WSC within the framework of GCW, and identify key users who would benefit from the WSC services.
- Engage UNESCO in advancing the proposal.
- Assess options for an authoritative Steering group, the terms of reference of which should be well aligned with those of the Snow Watch Team.
- Identify the linkages between WSC and the Snow Watch team.
- Assess the practical steps for establishing a WSC, during the GCW pre-operational phase.

C Fierz, with support from Secretariat will coordinate these next steps, as requested by the group. A report will be provided at the next Steering group meeting.

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4.2 Snow Watch activities

Dr Patricia de Rosnay provided an overview of the progress made by the Snow Watch Team, and its goals for the pre-operational phase.

4.2.1 Snow Watch Membership and Terms of Reference

P de Rosnay informed about the changes in membership since GSG5. Specifically,

- Dr Mareile Wolff (Norway) is as a new member representing the solid precipitation community.
- Dr Lijuan Ma (China) is a seconded expert with the WMO Secretariat, the GCW Project Office, from Oct 2018 to Oct 2019.
- Dr Vincent Fortin (Canada) is no longer active in GCW, following his departure from Environment and Climate Change Canada.

Decision: The GSG members agreed with and welcomed Dr Patricia de Rosnay as the new co-chair of the Snow Watch Team, replacing Ross Brown; the other co-chair is Kari Luojus (Finland).

Because of these changes, it has been agreed that:

- **Action** R Brown and Secretariat to follow up on the potential for an additional representative from Canada**.**
- **Action** L Ma to follow up on the potential for engaging an additional representative from China.

P de Rosnay presented the revised Terms of Reference of the Snow Watch team, which include a focus on solid precipitation products. These are available in Annex 5.

Decision: The group approved the updated ToRs for the Snow Watch Team. It was agreed that the activities of the Team, related to solid precipitation products will be planned in collaboration with the Commission for Instruments and Methods of Observations (CIMO).

4.2.2 International exchange of snow observations

P de Rosnay provided an overview on the progress on the international exchange of snow depth data. Improvements from Ukraine, Bulgaria, South America and China were highlighted. www.ecmwf.int/en/about/media-centre/news/2018/extra-weather-station-data-improve-ecmwfs-forecasts .

She noted the ongoing activities regarding the transmission of snow data via GTS, from US SNOTEL (Snow telemetry network), the National Weather Service Cooperative Observer Program (COOP), and the Soil Climate Analysis Network (SCAN). NOAA is working on the BUFR conversion of the snow data from these US national networks, needed for making them available on GTS. The topic was to be discussed at the GODEX (Global Observation Data Exchange) meeting in India (Nov 2018).

Action: P de Rosnay and Secretariat to follow up on the distribution of SNOTEL data on GTS. Deadline: 2019

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P de Rosnay noted that on GTS the snow data are available from TAC SYNOP, BUFR SYNOP, and National data. The stations providing National data are not registered in OSCAR, in general.

4.2.3 New SWE BUFR Table

P de Rosnay informed the group about the completion of the BUFR template for Snow Water Equivalent (SWE). SWE data are a model prognostic variable, is relevant for data assimilation, and has long-term benefits for NWP and hydrology. The new SWE BUFR (see Annex 6) was approved in May 2018: http://www.wmo.int/pages/prog/www/ISS/Meetings/IPET-CM_Offenbach2018/IPET-CM_DocPlan.html, and has been available to WMO Members, as of November 2018. The template includes SWE and snow depth, and could be used for both variables. The impact of SWE data availability will be assessed, once data are available.
B Goodison reiterated the value of SWE data to the hydrological community and they should be invited and informed about the new BUFR table.

Action: Secretariat to write to Members about the international exchange of snow data, and the availability of the new template. Deadline: March 2019

4.2.4 Exchange of data on GTS

The exchange of SWE and other data on GTS, was discussed. The group acknowledged the issue of propriety of SWE data, the associated financial value on the energy market, and the diversity of data providers. As a result, the SWE data will likely be only partially shared, in real time.
To exchange SWE (and other) data on GTS, when the data belong to other than the National Meteorological and Hydrological Service (NMHS), GCW need to address the question on who could upload the data on GTS; could this be done via the GCW Data Portal?
It was recognized that Member countries report data, and not the NMHS, alone, although in practice GTS is linked to NMHSs.
Action: Secretariat to follow up on this aspect. Deadline 2019

As many CryoNet stations output data in NetCDF, and many of these data should be exchanged in (near) real-time, GCW needs to evaluate the feasibility of converting other formats into BUFR, for (near) real-time exchange.
Action: Ø Godøy to send an example of a NetCDF file to P de Rosnay for conversion to BUFR. Should contain snow depth, SWE...

4.2.5 Other topics relevant to Snow Watch Activities:

The presentation made by P de Rosnay included results of Observing System Experiments on the value of snow data to T2m forecasts. Ross Brown, who attended remotely, updated the participants on the Canadian Historical Snow Survey dataset to 2016, Snow Watch Team contributions to snow cover assessments, Evaluation of SWE and solid precipitation products and datasets over southern Québec, Annual maximum SWE (SWEM) evaluation results.

R Brown provided updates on the next steps on publishing the results from SnowPEx. Its major outcomes are protocols and methods for inter-comparison and validation by community, and are available on the SnowPEx website https://earth.esa.int/web/sppa/activities/qa4eo/snowpex. A summary paper is planned for publication in 2019. K Luojus is the main point of contact.

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P de Rosnay and R Brown provided a brief summary of the outcomes of the joint Polar Space Task Group (PSTG) – GCW meeting on planning future satellite snow. The report is available at http://www.wmo.int/pages/prog/sat/documents/FinalReport-SnowRadarScienceMeeting_January2018.pdf. See Annex 7.

4.2.6 Snow Watch objectives for the GCW Pre-operational Phase

P de Rosnay outlines several goals of the Snow Watch team for the pre-operational phase of GCW. The list was only briefly discussed during the meeting.

- Promote improved/new observations of snow and data sharing in real time, internationally (e.g. SWE, snow depth on the ground, on GTS), linked to the Data Portal, with a focus on regions with sparse observations.
- Provide regular, global and regional assessments of changes of the cryosphere, tracking anomalies and extremes (mainly snow, glacier, permafrost, sea ice);
- Advocate to address the long-term global decline in ground station networks, e.g. by highlighting role and impacts of snow monitoring, and assimilation, demonstration of the value of the snow observing systems.
- Explore innovative ways to address the lack of long-term observations in specific areas (high elevation) e.g. by highlighting role and impacts of snow/glacier/sea ice and permafrost monitoring, and assimilation, contributing to the demonstration of the value of the snow observing systems.
- Status of snow data products: Advance the development of new satellite mission concepts through coordinated engagement of technical, scientific, programmatic, and applications- focused elements.
- Identify priority science drivers: Improve communication and linkages between snow mission development activities to strengthen proposal development for both mission concepts and supporting scientific activities.
- Mission Requirements Maturity and Technical Readiness: Endorse a wide-swath, moderate spatial resolution Ku-band radar concept as one approach to address snow, ice, and ocean winds applications. Continue to develop the potential viability of other options, including InSAR-based (single and repeat pass) approaches.
- Support Experimental Campaigns and Modelling Requirements: Continue coordinated campaign planning and data sharing between ESA, CSA/ECCC, NASA, and other agencies.
- Data assimilation: Coordinate progress between operational centres on coupling physical snow models with forward radar models; identify priority research areas (i.e. OSSEs, required model development) to advance the capacity to assimilate radar measurements over snow covered areas.
- Potential Secondary Parameters for Snow Radar Missions: Emphasize variables in addition to terrestrial snow in mission proposal documents; increase engagement of sea ice and ocean winds scientific and user communities.
- Inter-Agency Programmatic and Collaboration: Use existing programs and coordination frameworks (distributed globally) to ensure coherent and cohesive advancement of scientific and technological challenges related to the monitoring of snow cover - building on existing technology development and scientific advancement programs.

4.2.7 Snow Watch activities – other topics

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The Chair commended the impressive progress made by the Snow Watch team, and welcomed the recommendations made by P de Rosnay regarding the team's future work.

V Smolyanitsky inquired about how to address the snow on sea ice, which is not included explicitly within the ToRs of Snow Watch team. Different ice buoys have been launched, providing info of snow cover on sea ice. This topic was further discussed under the agenda item on Sea Ice activities.
Action: Secretariat to follow up with the co-leads of Snow Watch and V Smolyanitsky and P Heil, on this topic.

B Goodison raised the issue of availability of snow data and related assessments in the Southern Hemisphere. Currently, these assessments rely on ECMWF.
Action: Secretariat to work with P de Rosnay and G Casassa to assess how to access additional sources of snow data from the Southern Hemisphere, either via GTS or via the Data Portal.

J Key suggested that GCW needs to encourage experts to include error assessments on their products C Fierz suggested it could be a task of WSC.

5. Overview and Implementation Status of GCW:

5.1 Overview

B Goodison provided an overview of GCW accomplishments since being initiated, at the 16th World Meteorological Congress (2011). Details are available in the presentation made at the meeting. He focused on the progress made since the 17th World Meteorological Congress (Cg-17th), Resolution 43, which decided the implementation of GCW, as a cross cutting activity, across WMO Programmes. He highlighted the engagement and contribution of internationally renowned experts, the diversity of engagements through meetings, workshops, formally establishing the GCW surface observing network (Resolution 28, EC-70), and the significant effort and the notable contributions of a large and diverse group of stakeholder organizations.

He noted the publication in 2018, of the Best Practices Guide for the Measurement of Cryosphere Variables (Chapter 1, General and Chapter 2, on Snow Observations), as a standalone volume of the Guide to Instruments and Methods of Observation, WMO-No. 8 (2018), http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/Prelim_2018_ed/Preliminary-2018-edition.html, and the publication of GCW network requirements in the WMO Technical Regulations, WMO-No. 49, and Manual of WIGOS, WMO-No. 1160, http://www.wmo.int/pages/prog/www/wigos/WRM.html. B Goodison recognized the leadership of C Fierz and T Thorsteinsson in advancing the development of Best Practices.

B Goodison highlighted several other key accomplishments:

- the availability of Cryosphere assessments and products on the GCW website and highlighted the efforts of Dr Jeff Key in developing and maintaining these assessments and the website;
- the results of the Snow Watch team, including the international exchange of data and the SnoPEx intercomparison;
- the engagement of GCW with the Polar Regional Climate Centres;
- the progress made on consolidating the cryosphere terminology;
- The development of the Data Portal and the leadership of Ø Godøy.

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B Goodison highlighted the essential contribution of the Norwegian Meteorological Institute, regarding the development of the GCW Data Portal, a flagship for GCW.

Action: Secretariat to send a thank you letter to the PR of Norway, and inviting Norway to continue this essential contribution.

B Goodison requested that the development of the observing component of GCW continue over the pre-operational period, and he encouraged the Observations WG to develop a plan for assessing the compliance to observing criteria and the application of best practices guides, as a measure of progress of the development of the observing component of GCW.

5.2 Development of the Best Practices Guide

5.2.1 Glaciers:

Thorsteinn Thorsteinsson informed the group that the chapter of Best Practices for Glaciers is under development, and noted the engagement with the snow team guidelines for the measurement of snow on glaciers.
The group agreed that a balance is needed regarding the level of details on describing practices and relevance. It was recommended to involve other experts in the review and the further development of this chapter.
Action: T Thorsteinsson to engage Matthias Huss from the Swiss Glacier Monitoring Service (GLAMOS), proposed by C Fierz.

5.2.2 Permafrost:

B Goodison reiterated the need to engage the international permafrost community, e.g. GTN-P, IPA, to collate the existing guidance material for permafrost best practices, and to include the high latitude and the alpine permafrost.
W Schöner suggested nominating two people to o-lead the permafrost best practices, representing the two communities of expertise.
C Fierz informed that an alpine permafrost best practices guide would be published by Swiss experts, in 2019, which could be used to expand the engagement with other organizations, with relevant expertise.

Action: The group agreed to continue focusing on snow, glacier, sea ice, and as feasible, on permafrost, and pursue gradual progress.
The goal is to propose new chapters on Glaciers and Sea Ice, in 2020.

5.3 GCW role in supporting the GCOS Implementation Plan

B Goodison noted that the GCOS Implementation Needs (GCOS-200, 2016), https://gcos.wmo.int/en/gcos-implementation-plan, which articulates actions required to sustain the global climate observing system, has identified GCW as having a role in meeting some of the identified needs. A summary of cryosphere references in the GCOS Implementation Plan is available in Annex 8.
He noted that GCW has to include regular review of its contribution to GCOS in its implementation planning.

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5.4 Recommended priorities for the GCW pre-operational Phase

B Goodison recommended that the implementation of GCW continue during the next financial period of WMO, with a pre-operational phase, focusing on the following priorities:

- Continuing to improve the global coverage of the GCW Surface Observing Network, and develop and publish GCW regulatory material within the framework of WIGOS, complemented with necessary guidance material to assist Members with the implementation of the technical regulations, including for supporting capacity development;
- Establishing the GCW Data Portal as a Data Collection or Production Centre (DCPC) in the WMO Information System (WIS), and interoperability with GCW stations, thus improving the access to, and the management of quality of current and past cryosphere data, information, and products;
- Developing and publishing value-added cryosphere products, addressing specific needs at regional and sub-regional level, e.g. relevant to water resource and ecosystems management, to safety (e.g. transportation), to understanding natural hazards and risks, to energy production, etc.
- Fostering collaboration between operational and scientific communities regarding cryosphere goals;
- Supporting Members on developing national frameworks for cryosphere end-to-end monitoring and service partnership.

The participants agreed with the proposal made and committed to refine these priorities as part of the pre-operational phase proposal, for submission to EC PHORS9 (March 2019), and then to Cg-18 and EC-71.
Specific actions for the pre-operational phase are included in this report.

6. Value added cryosphere products and links with users

The participants took note of the cryosphere products and assessments available on the GCW webpage. They acknowledged the need for promoting more actively the GCW assessments, for use by various services, e.g. PRCC.
The group agreed that GCW is a mechanism for international collaboration, which facilitates the development of value added products, by providing a framework for engagement of scientists and practitioners from different countries.

6.1 Arctic Regional Climate Centre Network and GCW

Dr Vasily Smolyanitsky provided an overview of the opportunities for GCW, for developing value added cryosphere products, and links with users.
He highlighted the progress made in 2018 on the development of the Arctic RCC (https://arctic-rcc.org/), the outcomes of the two PARCOFs, and the content of the two consensus statements, issued (https://arctic-rcc.org/parcof). The next PARCOF will take place in Jan 2019 (virtual) and on 8-10 May 2019, face to face, in Rovaniemi, Finland.

V Smolyanitsky noted that Arctic RCC has been making progress in working with users, including indigenous users; he provided a sample of stated needs. He summarized the feedback provided during PARCOF regarding available products, e.g. on the timing of summaries, the

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agreement of a common geographical coverage, consistency of products, and higher resolution. He noted that some products were proposed by GCW.

V Smolyanitsky recommended the following activities for the pre-operational phase of GCW:

- Provide access to timely observations for marine environment beyond ice charts: snow on ice and ice thickness from drifting buoys (YOPP), sea ice phenomena at coastal stations, and sea ice parameters from space for the Arc/AntRCC.
- Provide access to timely observations or trackers for terrestrial environment beyond weather: snow, permafrost, glaciers and river and lake ice
- Map GCW products with RCCs predefined seasonal periods
- Map GCW products with RCCs predefined presentations (coverage, colour, scale)
- Map GCW products with RCCs reference periods
- Develop products uncertainties
- Interaction/integration of resources with JCOMM,/YOPP/INTAROS

The group expressed the aim that products generated with contribution from GCW experts, to include explicit recognition for GCW. It was agreed that, in practice, institutions are mandated to output certain products at national level, and they need deliver according to their mandates. It would not be possible to publish products under the GCW logo before being published by the home organization.

M Citterio urged the participants to pursue value added through GCW, by facilitating what no one/single organization could provide; for example, no institute has the mandate to intercompare the remote sensing products with the in-situ data. He recommended that after assessments/graphs are published at national level, the data are sent to an entity, e.g. GCW Portal, and GCW facilitates generating ensemble of products, the uncertainty assessment of products, and provide an overview of products available.
The participants discussed the need to facilitate institutional arrangements, and build ownership with national institutions, as a guarantee of sustainability.

Á Snorrason clarified that for RCCs, Members develop and distribute climate information.

6.2 MetNo Cryosphere Website

Ø Godøy presented the https://cryo.met.no/ website, under development at MetNo, which will include the representation of station information and data from stations measuring cryosphere parameters. This is an example for potential evolution of the GCW website.

6.3 Third Pole Regional Climate Centre Initiative

Lijuan Ma provided a brief of the proposal for establishing a Third Pole RCC Network (TPRCC-N). She proposed the engagement of GCW in TPRCC-N, as a former co-chair of TPRCC-N task team. In this proposal, GCW Data Portal would play a key role, by facilitating the access to data and the monitoring of operational availability. Secondly, she highlighted that the contribution of the GCW authoritative observing standards, best practices, terminology, and definitions would be critical for Members and users. Finally, GCW expertise would be required to guide datasets assessment, model improvement, etc.

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At the time of the GSG meeting, the TPRCC Implementation Plan meeting was being planned for 13-14 December 2018, in Beijing. L Ma was scheduled to represent GCW Project Office, and Feiteng Wang (CAS) to represent GCW Observations WG. The meeting was to include discussions on the role of GCW in supporting the implementation of TPRCC. This footnote includes the request from the TPRCC Project Task Team, for support from GCW, as documented in the meeting report. This information is included to support developing the deliverable plan for the next period.[1]

7. GCW activities regarding sea ice, lake and river ice

7.1 Interaction with JCOMM

V Smolyanitsky provided an overview of JCOMM-5 decisions, recommendations, and resolutions relevant to Polar Regions and GCW.
He proposed the following activities for the pre-operational phase, with respect to sea ice observations and services:

- Collaborate on sea ice best practices (WMO-574) and ice analyst competence manual (ETSI, IICWG)
- Collaborate on missing trackers for marine & terrestrial environment (RCCs)
- Collaborate on mapping GCW products with RCCs predefined seasonal periods, presentations (coverage, colour, scale) and reference periods (ETSI, RCCs)
- Collaborate on products uncertainties (ETSI, IICWG)
- Investigate possibility on collaboration on summaries (RCCs)
- Interact on integration of resources (and metadata?) with ArcRCC portal s (main and regional at nodes) and JCOMM Ice logistics portal (ETSI, IICWG)

7.2 Interaction among Operational and Research Sea Ice Communities

Dr Petra Heil provided an overview of proposed sea ice priorities for the pre-operational phase, with contributions from Penelope Wagner (MetNo).

7.2.1 Sea Ice Observed variables and Best Practices

P Heil noted that the Best Practices for observing required variables for sea ice were largely completed, although still in skeleton version. Review is ongoing, and, as for glaciers, there is an open question on the level of detail required across the range of observational approaches and

[1] Outcome of the TPRCC-Network meeting, relevant to GCW:

- *GCW PO communicates with the GCW steering group on requirement of data sharing from CryoNet stations and the existing cryospheric products*
- *WMO Secretariat facilitate focal points of consortia members connect with GCW on expansion/contribution of CryoNet station/cluster/contributing stations*
- *Members of TPRCC-Network get in touch with GCW and the potential ministers that would be invited, to propose draft address/presentation related to TPRCC-Network; make flyers (Kumar will provide templates from the Arctic RCC-Network) to disseminate TPRCC-Network during the High Mountain Summit (end of Oct. 2019)*
- *GCW experts may be invited to provide guidance on relevant product development.*

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the recommendation of methods. The operational community agreed on the parameters listed in the initial draft, which was presented at the IICWG general assembly 2017 and 2018. All snow on sea ice observations were referred to the snow section.

P Heil noted that progress has been made, based on existing procedures and are focused on required variables for CryoNet stations. The structure is relatively similar to that used for snow. Best Practices for snow observations on sea ice are included in the Snow Best Practices chapter. The Sea Ice group has reached out for consultations, but little feedback has been received.

7.2.2 Nomenclature and variable naming

Recognizing the diversity of sea ice protocols (WMO, ASPeCt, ASSIST, and AFIN), P Heil proposed that GCW undertakes to develop a translation table between different communities, and agree on observed versus derived variable names and definitions. It is expected that a CryoNet station would provide observed and derived variables. A draft exists, and further consultations are needed, to finalise it.
Action: Secretariat to follow up with P Heil on this proposal, and agree on a feasible schedule for completion.

7.2.3 Data access

P Heil proposed that a trial case is organized for accessing sea ice data via the GCW Portal. She noted that GCW and SCAR are well positioned to encourage unified access and format of data, for the Antarctic.
Regarding historical data, P Heil proposed that data recovery projects are identified, and funding is sought.
Action: Secretariat to follow up with P Heil on this proposal, and set a feasible schedule for completion.

7.2.4 Sea Ice CryoNet stations

P Heil noted the poor coverage over the Arctic/Antarctic regions, the issue of sustainability of observations in these regions, (e.g. sea ice buoys, snow buoys), the diversity of observing procedures, and that the historical data are seldom available.

P Heil stressed out the need to allow Lagrangian data/stations (buoys, ships) as CryoNet stations, e.g. IceBox (ASPeCt, Ant) & ASSIST (Arc) observations, recognizing the limitations of these observations versus the value added from their data availability. These provide useful data for remote sensing and model validation, ongoing EU projects (i.e. CIRFA, and soon ExtremeEarth), and potential H2020 Arctic observing network calls. This will enhance the visibility of GCW. Currently the IceWatch (ASSIST) ship observations software is being transitioned to be hosted at the Norwegian Meteorological Institute on the https://cryo.met.no/ site. This is expected to increase its visibility and be adopted by several users already taking routine ship based sea ice observations in the Arctic. IceWatch and ASPeCt are working together to standardize additional parameters that apply to both regions. The use of ships as observation stations will provide routine measurements based on the ships trajectory that can vary in a given area.

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Therefore, GCW could exercise leadership by developing a mechanism and procedure for ship operators, instructing them on how to contribute to GCW Lagrangian stations.

Action: Secretariat to follow up with P Heil on the proposal regarding Lagrangian stations, related to the topic of mobile platforms discussed at GSG4 and GSG5.

7.2.5 Engagements with the Sea Ice scientific community

P Heil noted the existing engagements of GCW experts with current initiatives and activities. Among those are the Antarctic Sea Ice Processes and Climate (ASPeCt), the Antarctic Fast-Ice Network of SCAR, the International Antarctic Buoy Programme (IPAB), the AON Sea Ice Collaboration Team (estab 2013), the International Arctic Buoy Programme (IABP), Sea Ice Prediction Network (SPIN), ASSIST, Ice Bridge, International Ice Charting Working Group (IICWG), the operational observations communities (through ETSI), and the modelling and the satellite observation communities.

7.2.6 Sea Ice product Intercomparison

P Heil proposed that GCW engages interested parties towards developing a feasibility plan for a sea ice product intercomparison in collaboration with PSTG, focusing on satellite footprints versus sea ice length scales. She recommended that CryoNet stations are recruited and data made available to cover multiple footprints, to derive statistical information through spatial extent.
She advocated for co-locating sustained satellite coverage with GCW CryoNet stations, to include stationary sites, Lagrangian sites, and other Arctic stations.
Action: Secretariat will follow up with P Heil, P Wagner, P de Rosnay to invite other experts for developing jointly an early concept for a potential intercomparison.[2].

7.2.7 Plan for 2020-2023:

- 2019: Finalize V0.86 of Sea Ice BP
- 2019: Admit Lagrangian observational platforms as CryoNet stations.
- 2019: Proto-type streaming of sea ice data from two or more CryoNet stations to the GCW Data Portal.
- 2020: Promote Sea ice BP to wider community
- 2020: Implementation plan: sea ice product intercomparison
- 2020: CryoNet SI data routinely available on GCW Data Portal.
- 202x: Liaise with AntRCC
- 2021: Initiate sea ice product intercomparison
- 2022: Review Sea ice BP

Action: The group agreed that the proposals made are relevant in support of maritime research and services, and asked V Smolyanitsky and P Heil to ensure that these are reflected in the pre-operational plan.

[2] *Following the GSG6R meeting, P de Rosnay discussed with ESA the potential for assessing the feasibility of an intercomparison. An ad-hoc group was formed to prepare an initial draft to support further discussions. P Heil, P de Rosnay, P Wagner, Steve Howell (Canada), J Key, and Steffen Tietsche (ECMWF) are part of the group. S Tietsche is the point of contact with ESA.*

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8. Other priority activities

8.1 International Snow and Ice Year, 2021

Á Snorrason introduced the concept of a potential International Snow and Ice for 2021. The proposal was endorsed in 2018 by UNESCO and WMO. The group agreed that strong promotion is needed, to ensure broad international support.

8.2 2020 Cryosphere Conference

Þ Þorsteinsson outlined the proposal to host the Cryosphere 2020 Conference in Iceland on 21-24 September 2020. The conference will be jointly organised by IMO, WMO, IACS, and IAHS and by the International Glaciological Society (IGS). IGS plans to publish a thematic volume of *Annals of Glaciology*, with papers presented at the conference, which will also be open to policy makers and stakeholders. Recommendations prepared by delegates will be presented at the Arctic Circle Symposium in October 2020. Ideas to promote existing training programs in glacier mass balance studies, in Iceland and elsewhere, at the 2020 Cryosphere conference, were discussed.

9. Progress on Terminology and Vocabulary

9.1 Vocabulary

G Casassa recalled the reports prepared by Ruth Duerr on the assessment of cryosphere terms available on the Glossary of the GCW website. He noted that a small percentage of terms were identified with definition discrepancies. GCW PO informed about the request from the scientific community to publish these reports, as a GCW contribution to reaching broader consensus on terminology, and this was agreed by participants.

Action: Secretariat to work with R Duerr, to publish the reports.

The group explored how to ensure broad acceptance of terminology and minimize the duplication of efforts, through a transparent process. The group agreed on the need to engage the broad scientific community, and in particular, the CryoNet station managers. Among the options discussed are liaising with relevant projects in DataOne.com, NSF data centre. In practice, the terminology work should be coordinated with IASC, SCAR, others, e.g. ENVO and SWEET ontologies manage subcategories. WMO could invite these communities.

Ø Godøy urged GSG to facilitate the consultation on terminology and vocabulary with broader scientific and operational community, to assure broader acceptance.
G Casassa suggested that the terminology published by IPCC WG I is a good starting point.

9.2 GCW WIGOS Metadata Input

Secretariat clarified that for registration of GCW stations in OSCAR, observed variables need to be available in the OSCAR database. For this, the observed variables need to be included in the

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WIGOS Metadata Standard (WMO No. 1192). There are very few cryosphere variables in the Metadata Standard, right now, and GCW has the opportunity to provide this essential contribution, with names of variables and a short definition for each of them.
A submission on CryoNet Recommended Snow Variables was made in 2018 (see Annex 9). The Snow variables proposed (*snow depth, water equivalent of snow cover, presence of snow, depth of snowfall, water equivalent of snowfall, snow cover extent, snow surface state*) have been accepted for inclusion in the WIGOS Metadata Standard, with one exception, snow layer properties. The WIGOS Metadata Task Team (WMD-TT) members felt that it encompasses several observed variables and those should be identified. GCW was asked to provide additional clarification if resubmitting this variable.

W Schöner, M Citterio, G Casassa, and T Thorsteinsson finalised a first list of glacier variables (recommended variables) for inclusion in WIGOS Metadata Standard, during the GSG6R meeting, and was submitted as to the 7th session of the WMD-TT. It includes the following variables: *surface mass balance (point), surface mass balance (glacier wide), glacier area, surface accumulation (point), surface ablation (point)*. See Annex 10.

Action: GCW PO to coordinate with GCW experts, the development of contributions to the WIGOS Metadata Standard, for all cryosphere variables recommended and desired for the GCW observing network. Deadline: completion by 2021.

Action: W Zhang urged GSG to seek support from WIGOS office on the high priority issues. The partnerships within the GCW framework are a success story for WIGOS, also. Deadline: ongoing

10. GCW High Mountain Activities

10.1 South America cryosphere activities

Dr Gino Casassa is now with the Glacier and Snow Unit of the General Water Directorate (DGA), under the Ministry of Public Works of Chile.
He presented a summary of cryosphere activities in South America and of the observing program of the Glacier and Snow Unit of DGA, tasked among others, with maintaining the inventory of glaciers in Chile (77% of glaciers in South America, and a strategic water resource). He provided details on the importance of glaciers in Chile and results from the assessment of their change over time.

G Casassa recommended that the glacier and snow observing stations of DGA share data via the Data Portal.

G Casassa highlighted that the most pressing challenges in South America are on basic permafrost monitoring, snow monitoring , e.g. at ski centres, and the inventory of glacier lakes, assessing the role of decreased albedo in the acceleration of the glacier retreat.

He informed the group about the recent UNESCO publication on The Andean Glacier and Water Atlas, The Impact of Glacier Retreat on Water resources and of the Advanced Course on CONiCET “Glaciología de los Andes del sur”, 6-12 August 2018, IANIGLA, Mendoza, Argentina.

G Casassa proposed that for 2019, GCW supports the organization of a CryoNet Latin America meeting to include a course on methodologies for the measurement of cryosphere variables with

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a focus on snow, permafrost, mountain river runoff, and mountain meteorology. He noted that the engagements with the cryosphere scientific community in South America, including the capacity development activities have focused mostly on glaciers. There is a need to strengthen the focus on the other cryosphere components, in terms of observations, data access, best practices, capacity building and this is the role which should be assumed by GCW. The participants agreed with this proposal.

Action: The Secretariat will work with G Casassa, to develop a feasible approach to GCW's role in South America, as part of the pre-operational phase. Deadline: 2019

Secretariat noted that RA VI-17, in February 2018, decided that a workshop will be organized by GCW, RA-VI, and CHy, to engage countries in the Caucasus region.
Action: GCW to follow through on the decision of RA VI.

10.2 WMO High Mountain Summit

GCW PO provided an update on the organization of the WMO High Mountain Summit, rescheduled for 29-31 October 2019, in Geneva. A meeting will take place in Geneva on 26-27 February, to prepare a White Paper, which will identify the needs and opportunities for WMO' s engagement addressing the challenges in High Mountain areas, downstream and in lowlands, as a result of accelerated changes in the cryosphere.

11. GCW pre-operational phase

11.1 GCW in the context of the WMO strategic plan for 2020-2023

Dr Wenjian Zhang, the WMO Assistant Secretary General, introduced the 2020-2023 WMO strategic plan and the WMO long-term goals to 2030. He outlined the overarching priorities for

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the WMO strategic plan, which related to reducing losses of life and property, building resilience and adaptation to climate risk, and enhancing socio-economic value.

He noted that improving the skill of the 10-day forecast is still a challenge. The focus of the next strategic plan is centred on enhancing Earth system prediction capabilities, which require earth system observations. GCW data and products are required by multiple application areas and research. It has been agreed that the future focus needs to be on ocean, atmosphere greenhouse gases, land, cryosphere and water cycle observations. Additionally the validation within the framework of the Global Multi Alert System (GMAS) requires observations.

It was recommended to engage WMO Programmes and NWP to identify their needs for cryosphere observations and their consistency, and for the quality of the outputs of the respective applications.
P de Rosnay noted the availability of a paper published by the European Environmental Agency, in 2018, which stresses out the needs for consistency of observations from multiple sources, and could serve as reference for documenting the contribution of GCW.

Action: A small team to provide input to the WMO Strategic Plan, to emphasize the focus on cryosphere. This input to be reflected in the WMO Strategic Operating Plan, which will be presented at Cg-18. Members: Á Snorrason, B Goodison, G Casassa. Deadline Jan 20, 2019.

Action: GCW PO to coordinate review and input to the WIGOS Vision 2040, specific to cryosphere. Deadline Feb, 2019

Action: GCW PO to ensure that cryosphere is referenced in the plans for GMAS and GFCS. Deadline: March 2019

Action: GCW PO to coordinate the input from GSG for inclusion in the Cg-18 report, on GCW accomplishments and plans.

11.2 GCW pre-operational phase: strategic planning

W Zhang noted with appreciation the progress made by GCW in linking the operational and scientific communities, and is an example for the other WMO Programmes.
W Zhang provided an overview of the WMO governance reform, with the goal of facilitating a seamless integrated approach, based on the earth system model. Information is available on the WMO website https://public.wmo.int/en/governance-reform.
He noted that the proposal is to reduce the existing eight Commissions to two, together with a Research Board. The two commissions will be coordinated by the Executive Council through a Technical Coordination Committee. These will work on a 2-year cycle of sessions of constituent bodies, instead of the current 4-year cycle.

W Zhang urged that GCW strengthen its connections with hydrology, oceans, and climate.
As Á Snorrason is the Lead of the EC Task Force on Hydrology, ensure that the cryosphere and the goals of GCW are well represented at the extraordinary session of the Commission for Hydrology, 13-14 February 2019, in Geneva.

Á Snorrason thanked W Zhang for the guidance on positioning GCW in the new structure, and emphasized the need for GCW to cooperate actively with the newly established Joint WMO-IOC Committee for Oceanography and Meteorology (JCOM).

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B Goodison highlighted that GCW has been a contributor to the implementation of GFCS, and that this role should continue, as well as the collaboration of GCW with WCRP and GCOS. He requested ASG's support to ensure the alignment of GCW in the new structure.

Action: GSG to define criteria to be used for demonstrating that GCW is operational, by Cg-20 (2023), with achievable milestones (4-year roadmap), showing a direct impact at Member level. In this sense, GCW should examine lessons that could be learned from IPCC, GAW, and Davos Economic Forum.

Action: GSG will develop a costing plan for achieving the operational phase, to demonstrate the need for resources to achieve the set goals, to go to EC PHORS9. Deadline: Feb 2019

It was agreed that, the work forward should cover:

- Technical aspects related to the availability of observations and data;
- Publication of value added products and information, on a regular basis, as a WMO publication, similar to those published under the leadership of GAW, and reflect global and regional perspectives.

The group agreed that over the next four years, there is a need for sustained and concerted effort to make GCW outcomes visible to the international community.
Action: Develop a 4-year communication and partnership plan, in conjunction with the Pre-operational Phase Implementation Plan

Actions: establish small teams to develop short high-level documents reflecting the importance of cryosphere for hydrology, for oceans, for climate, for NWP, respectively, for discussion at EC PHORS. These should include, among others, the needs for improved observations, improved access to existing observations, access and use of satellite data, importance of cryosphere information for mitigating disaster risk and building resilience. Deadline 20 Jan 2019.
Secretariat to coordinate these activities.

Team for drafting:

- hydrology : Á Snorrason (lead), B Goodison, G Casassa;
- oceans: V Smolyanitsky (lead) , P Heil, J Key, S Colwell, Á Snorrason.
- climate with a focus on the Polar regional Climate Centres. V Smolyanitsky (lead), S Colwell, P Heil, P Zhao, T Thorsteinsson.
- emphasize the importance of cryosphere to transportation and the impact on NWP. P de Rosnay, C Fierz.

Action: draft plan for achieving the interoperability at data level, including the additional development required and the long-term commitment to be solicited from Members to the necessary support the data centre(s). It needs to be linked directly to the Strategic Plan and 2020-23 objectives Team members: Ø Godøy (lead), C Fierz, J Fiddes, M Bavay. (See Section 3 of this report)

Actions:
(1) prepare a strategy for certification of CryoNet stations, as a component of WIGOS, to on requirements for sustained observations, and interoperability at data level and
(2) terminology and semantics to achieve interoperability at data level.

Team: W Schöner (lead), M Citterio, C Fierz, T Thorsteinsson, Ø Godøy, S Colwell, G Casassa.

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Dr Ping Zhao recommended that GCW focus on two target audiences: science and decision makers, recognizing that the scientific information is most valuable when used to facilitate the development of new policy. He gave the example of Members in the Third Pole region; as they have no observations, techniques, reanalysis, it's necessary for them to improve their capacity within the framework of GCW.

12. GCW Governance during the pre-operational phase

The group agreed that the Steering Group needs a strong link with the Executive Council, and thus a stronger representation at the PR level, is needed.

The group agreed that in the new governance:

- the Chair of the Steering Group of GCW to become a member of the Executive Council – Technical Coordination Committee (EC-TCC),
- GCW to be represented on the two newly established commissions, and on the Research Board.

The group assessed the potential reporting structure of GCW to the Executive Council and Congress, and whether EC PHORS will remain the reporting mechanisms.
Recognizing that the details on the implementation of the new governance regarding EC panels will be decided at EC-71 (June 2019), the group agreed to consider two options:

- (1) report to EC during the pre-operational phase, in which case the chair of GCW should be nominated by EC.
- (2) report to TCC, and be led by a mechanism similar to ICG-WIGOS, with representatives from the new commissions and the Research board.

Action: These considerations need to be discussed at the upcoming meetings on WMO governance reform. The GSG Chair will endeavour to attend the following meetings:

- ICG-WIGOS from Jan. 24-26, 2019
- Jan. 28, the WMO Bureau meeting
- PTC-PRA; Jan. 29-31, 2019
- CBR-TF: Feb. 1st, 2019
- March 11-12: CBR-TF (final preparation of the input to EC-SOP) and
- March 13-15: EC-SOP (final check for the submissions to Congress for the Strategic Plan and Governance Reform.

The group agreed that the future governance should include an Advisory Committee, with strategic focus, whose members to include leaders from the scientific communities and PRs, and a scientific and operational Steering Committee.
An improved governance structure should enable the engagement of active contributors (expertise and investors), and link with other influential entities concerned with changes in cryosphere, and their impact, as is the Third Pole Environment.

Additional discussions on membership and structure below the Steering Group will follow the meeting.

13. Plan GCW work to Congress

All proposals for Congress will be ready by end February 2019, for submission to EC-PHORS9.

EC-PHORS will make recommendations for submission to Cg-18 and EC-71.

14. Closure of Meeting

The meeting ended on 28 November 2018, at 15:30

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Annex 1 PROVISIONAL AGENDA

VENUE: WSL Institute for Snow and Avalanche Research SLF

2.0 Organization of the meeting

3.0 GCW Implementation status at the end of the 17th financial period (overview)

4.0 **GCW Pre-operational plan strategic objectives:**

4.1 Develop and publish value added cryosphere products and developing links with stakeholders;

4.2 Operationalize the GCW Data Portal to be interoperable with CryoNet and other data centres; and a Data Collection or Production Centre (DCPC).

4.3 Develop and publish GCW regulatory and guidance material, including supporting capacity development;

4.4 Provide support to Members in developing national frameworks for cryosphere end-to-end monitoring and service partnership;

5.0 GCW high mountain activities

6.0 GCW Governance during the pre-operational phase

7.0 **Closure of the meeting**

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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 with WMO Reykjavik, Iceland	arni.snorrason@vedur.is
2	Barry Goodison Vice-Chair, GCW Steering Group	Retired (Environment and Climate Change Canada and WMO) Kanata, Canada	barrygo@rogers.com
3	Michele Citterio Co-Chair Observations WG	GEUS - Geological Survey of Denmark and Greenland, Copenhagen, Denmark	mcit@geus.dk
4	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
5	Gino Casassa Lead, Terminology Team	Geostudios, University de Magellanes, Chile	gino.casassa@gmail.com
6	Øystein Godøy Co-Chair Information and Services WG; Lead, Data Portal Team	Norwegian Meteorological Institute, Oslo, Norway	o.godoy@met.no
7	Petra Heil GCW Expert	Australian Antarctic Division and Antarctic Climate and Ecosystems University of Tasmania Australia	petra.heil@utas.edu.au
8	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
9	Vasily Smolyanitsky Co-Chair, Integrated products WG	Arctic and Antarctic Research Institute, St. Petersburg, Russian Federation	vms@aari.aq
10	Þorsteinn Þorsteinsson Co-Lead, Best Practices Team	Icelandic Meteorological Office, Reykjavík, Iceland	thor@vedur.is
11	Patricia de Rosnay Co-Lead, Snow Watch Team	European Centre for Medium-Range Weather Forecasts (ECMWF)	patricia.rosnay@ecmwf.int

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12	Wolfgang Schöner Co-Chair Observations WG; Lead CryoNet Team	University of Graz, Dept. of Geography, Graz, Austria	wolfgang.schoener@uni-graz.at
13	Zhao Ping GSG Member	Vice President, Chinese Academy of Meteorological Sciences Beijing, China	zhaop@cma.gov.cn
14	Steve Colwell GSG Member	British Antarctic Survey, Cambridge, United Kingdom	src@bas.ac.uk
	Yves-Alain Roulet	MeteoSwiss	Yves-Alain.Roulet@meteoswiss.ch
	Christoph Marty	WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland	marty@slf.ch
	Joel Fiddes	WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland	joelfiddes@gmail.com
	Philippe Gyarmati	Fed. Department of the Environment, Transport, Energy and Communications DETEC Federal Office for the Environment (FOEN) Hydrology Division	philippe.gyarmati@bafu.admin.ch
	Ross Brown (remote)	Environment and Climate Change Canada, Montreal, Canada	Ross.brown@canada.ca
15	Dr Jürg Schweizer	WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland	
16	Wenjian Zhang	Assistant Secretary General WMO Secretariat Geneva, Switzerland	wzhang@wmo.int
17	Lars-Peter Riishojgaard	WIGOS Project Manager WMO Secretariat Geneva, Switzerland	lriishojgaard@wmo.int
18	Rodica Nitu	GCW Project Manager WMO Secretariat, Geneva, Switzerland	rnitu@wmo.int
19	Lijuan Ma	Seconded Expert, GCW Project Office WMO Secretariat Geneva, Switzerland	lma@wmo.int

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Annex 3 List of Actions

Annex 3: List of actions from the GCW Steering Group Meeting, 26-28 November 2018

Action GSG6R	Deadline	Responsible	Comments
2.2 GBON Follow closely the development of GBON requirements, and promote the inclusion of snow observations, required by NWP.	Jan 2019, ICG-WIGOS	GCW PO, WIGOS PO	
2.3 OSCAR database registration			
GCW PO to work with the WIGOS PO, to assess the tools available for registering the GCW stations in OSCAR. Deadline: ICG-WIGOS meeting	Jan 2019	GCW PO	
GCW to provide examples of engagements of National OSCAR FP, to support improvements in the current process. Deadline: ICG-WIGOS meeting,	Jan 2019	GCW PO	
2.4 WIGOS Identification Numbers (WIN) and other topics			
GCW PO to work with WIGOS PO regarding the development of the observing component of GCW, Jan 2019 and on-going	Jan 2019 and on-going	GCW PO, WIGOS PO	
WIGOS PM to involve GCW Project Office in the preparation of Regional Workshops, to provide mechanisms to promote GCW within WIGOS.	On-going	WIGOS PO	
3.3.1 Data Interoperability package			
Organize a side event during CG-18 (in conjunction with other activities) to demo the access to data from GCW stations, via Data Portal and SLF interoperability package.	Cg-18	Ø Godøy, C Fierz, and the GCW PO	Note: coordinate with Arctic HYCOS
Develop a feasible roadmap for addressing interoperability with the GCW stations, which must include the development of the GCW Data Interoperability Software (GDIoS), include the additional development and the long-term commitment required from Members to support data centre(s). GCW PO to support team	Cg-18	Ø Godøy (lead), C Fierz, J Fiddes, M Bavay	
3.3.2 Interoperability with Sodankylä cluster			
interoperability between Sodankylä and the Data Portal, for Cg-18.	Cg-18	Ø Godøy; Kari Luojus	

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3.3.4 Interoperability with the GTN-P data centre.			
connect with GTN-P and IPA leadership. C Fierz to communicate with GTN-P and PERMOS.	2019	C Fierz, Ø Godøy	
review the communication with station proponents and ensure that they understand and accept the current approach to interoperability.	2019	GCW PO, M Citterio	
3.3.5 Sustainability of Data Portal Development			
Develop proposals for the sustainability of the Data Portal development and operation, archival/storage of data, and traceability.	2019	Ø Godøy, C Fierz, M Citterio	
4.1 Proposal for establishing a World Snow Centre			
Á Snorrason requested that the group articulate with clarity the additional value proposition of WSC, focusing on those aspects that are not already included in the scope of GCW, and how this builds on the contributions of the Data Portal, the Best Practices guidelines, and the results of the Snow Watch team.		C Fierz, with support from GCW PO	
4.2.1 Snow Watch Membership and Terms of Reference			
Follow up on the potential for an additional representative from Canada**.**	2019	R Brown, GCW PO	
L Ma to follow up on the potential for an additional representative from China.	2019	L Ma	
Decision: The group approved the updated ToRs for the Snow Watch Team. The activities of the Team related to solid precipitation products, will be planned in collaboration with CIMO. New ToRs to be published.		Co-chairs, CIMO	
4.2.2 International exchange of snow observations			
follow up on the distribution of SNOTEL data on GTS.	2019	P de Rosnay GCW PO	
4.2.3 New SWE BUFR Table			
communicate with Members, reminding them about Resolution 15 (EC-69), on the international exchange of snow data, and about the availability of the new template.	March 2019	GCW PO	
4.2.4 Exchange of data on GTS			
Member country reports data, not only the NMHSs, although in practice GTS is linked to NMHSs. GCW to assess how to facilitate the exchange of non-NMHSs data.	2019	GCW PO	
send an example NetCDF file to P de Rosnay for conversion to BUFR. Should contain snow	Feb 2019	Ø Godøy	

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depth, SWE, ...			
4.2.6 Snow Watch objectives for the GCW Pre-operational Phase			
Include the list of Snow Watch proposed objectives in the pre-operational phase plan.	2019	P de Rosnay K Luojus GCW PO	
Snow on sea ice is not included explicitly within the ToRs of Snow Watch team. **Action:** assess where this is best suited.	2019+	P de Rosnay K Luojus V Smolyanitsky GCW PO	
availability of snow data and related assessments for the Southern Hemisphere: assess how to access additional sources of snow data either via GTS or via the Data Portal.	2019	P de Rosnay and G Casassa	
5.0 Overview and Implementation Status of GCW:			
Send a thank you letter to the PR of Norway, and expressing the request for continuation of this essential contribution.	March 2019		
5.1 Development of the Best Practices Guide			
5.1.1 Glaciers: engage Matthias Huss from the Swiss Glacier Monitoring Service (GLAMOS), proposed by C Fierz.	2019	T Thorsteinsson	
5.1.2 Permafrost: Action: endeavour to establish linkages with the Permafrost community	2019+	C Fierz	
Continue focusing on snow, glacier, sea ice, and as feasible, on permafrost, and pursue gradual progress. The goal is to propose new chapters on Glaciers and Sea Ice, in 2020.	2019+	T Thorsteinsson P Heil, C Fierz	
5.2 GCW role in supporting the GCOS Implementation Plan			
Address GCOS goals on cryosphere in the Pre-operational Plan	March 2019	B Goodison	
5.3Recommended priorities for the GCW pre-operational Phase			
Draft doc on the pre-operational phase for submission to EC PHORS9 (March 2019), and then submitted to Cg-18 and EC-71, in June 2019.	March 2019	GCW PO to coordinate all input	
6.1 Arctic/Antarctic Regional Climate Centre Networks and GCW			
The group agreed to continue its engagement with the Arctic and Antarctic RCC:		V Smolyanitsky	

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Interaction/integration of resources with JCOMM,/YOPP/INTAROS		P Heil S Colwell	
6.2 MetNo Cryosphere Website			
Ø Godøy presented the cry.met.no website. Action: monitor progress on the cry.met.no site and assess linkages with the GCW website	2019	GCW PO to coordinate	
6.3 Third Pole Regional Climate Centre Initiative			
A footnote is included in this report, outlining the outcome of this meeting on TPRCC (Beijing, Dec 0218); Integrated Products co-Leads to follow up on these recommendations. Link with Data Portal (support from GCW PO)		Integrated Products co-leads F Wang	
7.1 Interaction with JCOMM			
V Smolyanitsky proposed the following activities for the pre-operational phase: ● Collaborate on sea-ice best practices (WMO-574) and ice analyst competence manual (ETSI, IICWG) ● Collaborate on trackers for marine & terrestrial environment (RCCs) ● Collaborate on mapping GCW products with RCCs predefined seasonal periods, presentations (coverage, colour, scale) and reference periods (ETSI, RCCs) ● Collaborate on products uncertainties (ETSI, IICWG) ● Investigate possibility on collaboration on summaries (RCCs) ● Interact on integration of resources (and metadata?) with ArcRCC portal s (main and regional at nodes) and JCOMM Ice logistics portal (ETSI, IICWG)	2019+	V Smolyanitsky (integrated Products co-leads)	
7.2.2 Nomenclature and variable naming Sea Ice			
Recognizing the diversity of sea-ice protocols (WMO, ASPeCt, ASSIST, AFIN), develop a translation table between different communities, and agree on observed versus derived variable names and definitions **Action:** GCW PO to follow up with P Heil on this proposal, and on a feasible schedule for completion.	2019+	P Heil	
7.2.4 Sea-Ice CryoNet station: status			
2019: Admit Lagrangian observational platforms to CryoNet. P Heil, Obs WG to review the proposal regarding Lagrangian stations, related to the topic of mobile platforms discussed at GSG4 and GSG5.	2019+	W Schöner P Heil	

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7.2.2 Sea Ice Best Practices:			
2019: Finalize V0.86 of Sea-Ice BP consider organizing meeting in the context of IICWG meeting (Sept 2019) 2020: Promote Sea-Ice BP to wider community	2019+	P Heil V Smolyanitsky	
7.2.6 Sea-Ice product Intercomparison			
Develop an initial proposal for a potential intercomparison (2021+). 2020: Implementation plan: sea-ice product intercomparison	2019+	P Heil, P Wagner P de Rosnay	
7.2.7 Sea Ice Plan for 2020-2023: The proposals made regarding sea ice activities in support of maritime research and services, to be reflected in the pre-operational plan. ● 2019: Proto-type streaming of sea-ice data from two or more CryoNet stations to the GCW Data Portal. ● 2020: CryoNet SI data routinely available on GCW Data Portal.	2019+	P Heil, P Wagner V Smolyanitsky	
8.1 International Snow and Ice Year, 2021			
Á Snorrason introduced the concept of the International Snow and Ice Year, 2021. GCW to be engaged in the development of the proposal	2019+	Á Snorrason	
8.2 2020 Cryosphere Conference			
Þ Þorsteinsson briefed the initiation of 2020 Cryosphere Conference in Iceland, which is fixed at 21-25 September 2020. GCW to be engaged in the development of the proposal	2019+	Þ Þorsteinsson	
9.1 Vocabulary			
GCW PO to work with R Duerr, to publish the reports.	March 2019	**GCW PO**	
9.2 GCW WIGOS Metadata Input			
GCW experts to expand the list of variables included in the WIGOS Metadata Standard. Deadline: ongoing, with estimated completion by end 2020.	2019+	**GCW PO**	
GSG to get support from WIGOS office on the high priority issues.	ongoing	**GCW PO**	

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10.1 Regional activities of GCW			
Develop a feasible approach, as part of the pre-operational phase for a workshop in South America (see RA III-17 report, also)	2019	G Casassa, GCW PO	
GCW to follow through on the decision of RA VI. workshop will be organized by GCW, RA-VI, and CHy, to engage countries in the Caucasus region.	2019	C Fierz GCW PO	
10.2 WMO High Mountain Summit			
GCW to play a key role in the organization of the Summit. C Fierz represents GCW in the Program Committee.	2019	C Fierz	
11.1 GCW in the context of the WMO strategic plan for 2020-2023			
small team will be formed to provide input to the WMO Strategic Plan, to emphasize the focus on cryosphere. This input to be reflected in the WMO Strategic Operating Plan, which will be presented at Cg-18. Members: Á Snorrason, B Goodison, G Casassa.	Jan 2019	GCW PO to coordinate	
coordinate review and input to the WIGOS Vision 2040, specific to cryosphere.	Feb, 2019	GCW PO to coordinate	
ensure that cryosphere is referenced in the plans for GMAS and GFCS.	March 2019	GCW PO to coordinate	
coordinate the input from GSG for inclusion in the Cg-18 report, on GCW accomplishments and plans.	March 2019	GCW PO to coordinate	
11.2 GCW pre-operational phase: strategic planning			
GSG to include in the pre-operational plan clear criteria for demonstrating that GCW is operational, by Cg-20 (2023), with achievable milestones for the period 2020-2023, (4 year roadmap) with input from Co-Chair and WG leads.	March 2019	GCW PO to coordinate	
GSG will develop a costing plan for achieving the operational phase, to demonstrate the need for resources to achieve the set goals, to go to EC PHORS9. Deadline:	Feb 2019	GCW PO to coordinate	
Develop a 4-year communication and partnership plan, in conjunction with the Pre-operational Phase Implementation Plan	2019+	GCW PO to coordinate	
Develop short high-level documents reflecting the importance of cryosphere, to include the needs for improved observations, improved access to existing observations, access and use of satellite data, importance of cryosphere information for mitigating disaster risk and building resilience.	Jan 2019	GCW PO to coordinate	

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• Hydrology: Á Snorrason (lead), B Goodison, G Casassa; - oceans: V Smolyanitsky (lead) , P Heil, J Key, S Colwell, Á Snorrason. - climate with a focus on the Polar regional Climate Centres. V Smolyanitsky (lead), S Colwell, P Heil, P Zhao, T Thorsteinsson. - importance to transportation and the impact on NWP. P de Rosnay, C Fierz.			
(1) prepare a strategy for certification of CryoNet stations, as a component of WIGOS, to on requirements for sustained observations, and interoperability at data level and (2) terminology and semantics to achieve interoperability at data level. Team: W Schöner (lead), M Citterio, C Fierz, T Thorsteinsson, Ø Godøy, S Colwell, G Casassa.	2019	GCW PO to coordinate	
12. GCW Governance during the pre-operational phase			
The GSG Chair will endeavour to attend the WMO high level meetings Jan-March, 2019 Draft proposal for governance of GCW	Jan 2019	GSG Chair GCW PO	
Follow up with additional discussions on membership and structure.	Dec 2018	GCW PO	Under way
13. Plan GCW work to Congress			
All proposals for Congress: ready by end February 2019, for submission to EC-PHORS9. EC-PHORS will make recommendations for submission to Cg-18 and EC-71.	February 2019	J Key, Á Snorrason, GCW PO	

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Annex 4: World Snow Centre proposal

Summary of presentation made by C Fierz at the meeting

As reported by the 17th Session of the GCOS/WCRP Terrestrial Observation Panel for Climate (TOPC-17), **gaps and issues existing in Snow Cover ECV include data management, accessibility, and usability.** "A comprehensive and strategic data management approach through a centralized in situ snow data center is one strong approach to addressing the[se] issues."

Considering gaps and issues on Snow Cover ECV and field campaigns of COST Action HarmoSnow Project, the role of WSC can be as *one of identifying key gaps (where the engagement with GCW would take place), providing published results/datasets to the community, and mobilizing resources*

WSC **WILL**:

- be a world class research and consultation institute, **connecting scientists with practitioners**
- provide guidance on how to assess, process, cure, and homogenise **in-situ** and **remotely sensed** snow, snowpack and snow-cover data series
- be part of the GCW Integrated Products Working Group, backed by the Snow Watch Team
- receive scientific advice from international organisations like IACS and ICSIH(IAHS)
- identify key long term data series for **snow** and **snow cover** (e.g. snow depth, SWE, solid precipitation, etc.)
- identify key data sets of **snow properties** around the globe like profiles of density, specific surface area, chemistry, etc. ("snowpack data")
- engage water agencies for which snow is essential for their operations
- use the GCW Data Portal to identify, access, transfer, visualize snow metadata and data
- be a facilitator to find a host for data series that would get lost otherwise
- build GCW's Snow Dataset Inventory, used for the development and validation of snow models
- provide guidance on how to collect, process, cure, homogenise, and use these data
- provide agreed-on standards, guidelines, protocols and quality check (QC) procedures
- rely on existing infrastructure.
- be based in various institutions in different regions/countries.
- take advantage of modern communication tools for management.

WSC **will** collaborate with:

- International Association of Cryospheric Sciences (IACS)
- International Commission for Snow and Ice Hydrology (ICSIH/IAHS)
- Global Climate Observing System (GCOS) and Terrestrial Observation Panel for Climate (TOPC)
- Global Precipitation Climatology Centre (GPCC) operated by DWD under auspices of WMO
- Copernicus in situ component (insitu.copernicus.eu)
- National Snow and Ice Data Centre (NSIDC)
- Canadian Cryospheric Information Network (CCIN)
- National Hydro- and Meteorological Services (NMHS)
- Russia Research Institute of Hydrometeorological Information World Data Centre (RIHMI-WDC)
- Chinese Academy of Sciences (CAS)

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Annex 5: Updated Terms of Reference of the Snow Watch Team
Integrated Products WG - Snow Watch Team, as updated in 2018

Roles:

- Assess the maturity, accuracy and homogeneity of snow on the ground and solid precipitation observing systems, data, products and information
- Identify priority issues and actions for improved observing of solid precipitation and snow on the ground at global, regional and national scales
- Provide advice to WMO on issues related to real-time in situ reporting practices for solid precipitation and snow on the ground as well as for remotely sensed and other sources of real-time information
- Liaise with the cryosphere community, and WMO bodies, to maintain up-to-date knowledge of solid precipitation and snow cover monitoring technologies, programs, datasets and products
- Provide information and advice accessible from the GCW Website on solid precipitation and snow on the ground-related products and issues e.g. anomalous snow cover conditions, extreme events, annual assessments
- Contribute to establishing “Guidelines and Best Practices” for solid precipitation and snow on the ground observing practices
- Contribute to defining/refining solid precipitation and snow on the ground related terminology
- Contribute to the WMO Rolling Review of Requirements database on matters related to snow and solid precipitation
- Provide progress updates to the Integrated Products WG and/or GCW Secretariat upon request
- Provide support to GCW Steering Group, Working Groups and Teams as required

Membership:

- Team members are recognized experts in solid precipitation and/or snow on the ground.
- Ensure global participation. To the extent possible, the Team should include at least one expert from each WMO Region.
- The Team will have two co-leads. The period for co-leadership is not limited, but should be rotated around the Team and reviewed on an annual basis.
- Members of the Team will be identified based on their capacity to respond to Team priorities; Team membership should include experts with experience relevant to the present Terms of Reference.
- Membership will be reviewed annually by the Team co-leads, in consultation with Team members, and submitted to the Integrated Products WG for endorsement and subsequent approval by the GCW Steering Group

Accountability:

- The co-leads report to the chairs of the Integrated Products WG

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Working Methods:

- Regular telecom/webex meetings will be held at least twice yearly with a face-to-face meeting approximately once every two years
- The chair of meetings will be rotated between the co-leads and the meeting co-chair is responsible for the reports of the meetings
- A draft agenda, proposed by the co-leads, will be circulated at least one month prior to the proposed meeting date with a request for discussion items
- Experts may be invited to participate in meetings to address certain topics
- Tasks defined by the Team will be on-going between meetings, as defined by the Team's workplan

Review:

- The Terms of Reference are to be reviewed annually.

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Annex 6 Snow Water Equivalent BUFR

Based on the existing 3-07-101 (snow observation) by adding the WIGOS Station Identifier and the required elements to report the Snow Water Equivalent

New BUFR sequence 3 07 103 & corresponding BUFR table B entries and code

TABLE REFERENCE F X Y	TABLE REFERENCES	ELEMENT NAME
3 07 103		(Snow observation, snow density, snow water equivalent)
	3 01 150	WIGOS identifier
	3 07 101	Snow observation
	0 13 117	Snow density
	0 03 028	Method of snow water equivalent measurement
	0 13 163	Snow water equivalent

Code table 0 03 028 – Method of Snow Water Equivalent Measurement

Code figure	
0	MULTI POINT MANUAL SNOW SURVEY
1	SINGLE POINT MANUAL SNOW WATER EQUIVALENT MEASUREMENT
2	SNOW PILLOW OR SNOW SCALE
3	PASSIVE GAMMA
4	GNSS/GPS METHODS
5	COSMIC RAY ATTENUATION
6	TIME DOMAIN REFLECTOMETRY
7-62	Reserved
63	Missing

WORLD METEOROLOGICAL ORGANIZATION
COMMISSION FOR BASIC SYSTEMS

SECOND MEETING OF
INTER-PROGRAMME EXPERT TEAM ON
CODES MAINTENANCE

OFFENBACH, GERMANY, 28 MAY - 1 JUNE 2018

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MANUAL ON CODES: TABLE-DRIVEN CODE FORMS
FM 94 BUFR/FM 95 CREX

New BUFR sequence for Snow Water Equivalent (SWE)

Submitted by Marijana Crepulja, Enrico Fucile and Patricia de Rosnay, all from (ECMWF)

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Annex 7: Recommendations from the PSTG-SAR WG-GCW Snow Radar Science Meeting
(January 2018)

http://www.wmo.int/pages/prog/sat/documents/FinalReport-SnowRadarScienceMeeting_January2018.pdf

Status of snow data products: Advance the development of new satellite mission concepts through coordinated engagement of technical, scientific, programmatic, and applications-focused elements.

Identifying priority science drivers: Improve communication and linkages between snow mission development activities to strengthen proposal development for both mission concepts and supporting scientific activities.

Mission Requirements Maturity and Technical Readiness: Endorsement of a wide-swath, moderate spatial resolution Ku-band radar concept as one approach to address snow, ice, and ocean winds applications. Continue to develop the potential viability of other options, including InSAR-based (single and repeat pass) approaches.

Supporting Experimental Campaigns and Modelling Requirements: Continue coordinated campaign planning and data sharing between ESA, CSA/ECCC, NASA, and other agencies.

Data assimilation: Coordinate progress between operational centers on coupling physical snow models with forward radar models; identify priority research areas (i.e. OSSEs, required model development) to advance the capacity to assimilate radar measurements over snow covered areas.

Potential Secondary Parameters for Snow Radar Missions: Emphasize variables in addition to terrestrial snow in mission proposal documents; increase engagement of sea ice and ocean winds scientific and user communities.

Inter-Agency Programmatics and Collaboration: Use existing programs and coordination frameworks (distributed globally) to ensure coherent and cohesive advancement of scientific and technological challenges related to the monitoring of snow cover - building on existing technology development and scientific advancement programs.

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Annex 8: GCOS Cryosphere ECV Product Requirements

Cryosphere ECV Product Requirements							
ECV	**Products**	**Frequency**	**Resolution**	**Required measurement uncertainty**	**Stability (per decade unless otherwise specified)**	**Standards/ References**	**Entity (see Part II section 2.2)94F95**
				Satellite In Situ			
Snow	Area covered by snow	Daily	1km (100m in complex terrain)	5% (maximum error of omission and commission in snow area); location accuracy better than 1/3 IFOV with target IFOV 100 m in areas of complex terrain, 1 km elsewhere	4% (maximum error of omission and commission in snow area); location accuracy better than 1/3 IFOV with target IFOV 100 m in areas of complex terrain, 1 km elsewhere	WMO (2008c) IGOS (2007), IACS/UNESCO, 2009	WIGOS, GCW
	snow depth	Daily	1km (100m in complex terrain)	10mm	10mm	WMO (2008c) IGOS (2007), IACS/UNESCO, 2009	WIGOS, GCW
	snow water equivalent	Daily	1km	10mm	10mm		WIGOS, GCW
Glaciers	Glacier area	Annual (at end of ablation season)	Horizontal 15-30m	5%		IGOS (2009) Paul et al. (2009) Zemp et al. (2013)	WGClimate GCW
	Glacier elevation change	Decadal	Horizontal 30m-100mx Vertical 1m	2m/decade	1m/decade	IGOS (2009) Paul et al. (2009)	WGClimate GCW

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						Zemp et al. (2013)	
	Glacier mass change	seasonal to annual (the latter at end of ablation period)	Vertical: 0.01m or 10kg/m2 (at point location)	better than 200kg/m2/year (glacier-wide)		IGOS (2009) Paul et al. (2009) Zemp et al. (2013)	WGClimate GCW
Ice Sheets	Surface Elevation Change	30 days	Horizontal 100m	0.1m/year	0.1m/year		WGClimate GCW
	Ice velocity	30 days	Horizontal 100m	0.1m/year	0.1m/year		WGClimate GCW
	Ice mass change	30 days	Horizontal 50km	10km3/year	10km3/year		WGClimate GCW
	Grounding line location and thickness	yearly	Horizontal 100 m Vertical 10 m	1 m	10 m		WGClimate GCW
Permafrost	Thermal State of Permafrost	Daily to weekly	Sufficient sites to characterise each bio-climate zone	0.1K			GCW
	Active Layer Thickness	Daily to weekly	Sufficient sites to characterise each bio-climate zone	2cm			GCW
Sea Ice	Sea Ice Concentration	Weekly	10 km to 15 km	5% ice area fraction	5%	See spec sheets at www.ioc-goos-oopc/obs/ecv.php	WGClimate

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	Sea Ice Extent/Edge	Weekly	1 km to 5 km	5 km	unspecified	See spec sheets at www.ioc-goos-oopc/obs/ecv.php	WGClimate
	Sea Ice Thickness	Monthly	25km	0.1 m	unspecified	See spec sheets at www.ioc-goos-oopc/obs/ecv.php	WGClimate
	Sea Ice Drift	Weekly	5 km	1 km/day	unspecified	See spec sheets at www.ioc-goos-oopc/obs/ecv.php	WGClimate
Precipitation	Estimates of liquid and solid precipitation	Monthly (resolving diurnal cycles and with statistics of 3 hr values)	25km/NA	0.5 mm/h	0.02mm/decade	CMSAF requirements related to the HOAPS release 4.0 (CM-12611)	WGClimate WIGOS
Lakes	Lake ice thickness	Monthly	100m	1-2 cm			WGClimate HYDROLARE
	Lake Ice Cover	Daily	300 m	10 %	1 % /decade		WGClimate HYDROLARE
Soil Moisture	Freeze/thaw	Daily	1-25 km	90 %	tbd		ISMN

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Annex 9: Snow Variables submitted for WIGOS Metadata Standard

Cryosphere Variables proposed by GCW for inclusion in the WIGOS Metadata Standard, WMO-No. 1192, as of 30 November 2018.

(Submitted by Secretariat, on 27.03.2018)

	Current WIGOS Metadata Standard variable name	Variable Name recommended by GCW	Current WIGOS definition	GCW Proposed definition	*Current WIGOS key word*	Key word proposed by GCW	*GCW Recommended Actions*
	Snow depth	Snow depth	Vertical distance from the snow surface to the underlying surface (ground, glacier ice or sea	Vertical distance from the snow surface to a stated reference level.	*snowDepth*	snowDepth	*Update definition*
	Snow water equivalent	Water equivalent of snow cover	Vertical depth of the water that would be obtained by melting a snow layer. Linked to snow depth through the density of	The vertical depth of water that would be obtained if the snow cover melted completely, which equates to the snow-cover mass per unit area.	*snowWaterEquivalent*	snowWaterEquivalent	*Update definition and name*

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			the snow layer				
		Presence of snow		A binary observation of the presence of snow cover at the measurement location.		snowPresence	*New entry*
		Snow layer properties: *this variable was not accepted by the WIGOS MD TT. They have requested that more details on the exact property observed is provided. Currently, GCW has withdrawn this proposal.*		The physical, mechanical, and chemical properties of a snow layer.		snowLayerProperties	*New entry*
	Depth of fresh snowfall	Depth of snowfall	No definition	The vertical depth of freshly fallen snow that has accumulated during a specific period.	*depthFreshSnowfall*	snowfallDepth	*Update variable name and key word, and add definition*
		Water equivalent of snowfall		The vertical depth of water that would be obtained if the freshly fallen snow melted completely, which equates to the new		waterEquivalentSnowfall	*New entry*

				snow mass per unit area.			
	Snow cover (fraction of area)	Snow cover extent	Fraction of a given area which is covered by snow	The area of snow-covered ground, ice, or firn based on the fractional threshold used to define presence of snow.	*snowCover*	snowCoverExtent	*Update variable name, definition, and key word*
	Snow status (wet/dry)	Snow surface state		Binary product (dry or wet) expressing the presence of liquid water at the surface of the snow cover	*snowStatus*	snowSurfaceState	*Update variable name, definition, and key word*

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Annex 10: Glacier variables for WIGOS Metadata Standard

Cryosphere Variables proposed by GCW for inclusion in the WIGOS Metadata Standard, WMO-No. 1192, as of 30 November 2018.

Glacier Variables (Submitted for inclusion in the WIGOS Metadata Standard on 30.11.2018)

Number	**Current WIGOS Metadata Standard variable name**	**Variable name recommended by GCW**	**Current WIGOS definition**	*GCW proposed definition*	**Current WIGOS key word**	**Key words proposed by GCW (it may change to meet general requirements)**	**GCW recommended actions**
1	none	Surface mass balance (point)	-	*Surface mass balance is the result of all processes adding and removing mass from the glacier at a point on its surface, expressed over a stated period of time*	-	glacierSurfaceMassBalancePoint	New Entry
2	none	Surface mass balance (glacier wide)	-	*Surface mass balance (glacier wide) is the result of all processes adding and removing mass from the glacier at its surface, expressed over a stated period of time and integrated over the entire glacier area*	-	glacierSurfaceMassBalanceWide	New Entry
3	Glacier cover	Glacier area	Fraction of a land area covered by permane	Area enclosed by the projection of the glacier outline onto the surface of an ellipsoid approximating the surface of the Earth or onto a planar horizontal	glacierCover	glacierArea	Update variable name, definition, and keyword

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			nt ice.	approximation to that ellipsoid. The glacier area excludes nunataks but includes debris-covered parts of the glacier. The glacier outline separates the glacier from unglacierized terrain and from contiguous glaciers			
4	none	Surface accumulation (point)	-	The mass added to the glacier at a point on its surface expressed over a stated period of time.	-	glacierSurfaceAccumulationPoint	New Entry
5	none	Surface ablation (point)	-	The mass removed from the glacier at a point on its surface expressed over a stated period of time.	-	glacierSurfaceAblationPoint	New Entry

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ANNEX 11: 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 (World Meteorological 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

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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
IAHS	International Association of Hydrological Sciences
IASC	International Arctic Science Committee
ICG-WIGOS	Inter-Commission Coordination Group on WIGOS
ICIMOD	International Centre for Integrated Mountain Development
ICSIH	International Commission on **Snow and Ice Hydrology**
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
ISC	International 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	Pan-Arctic Regional Climate 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 Synthetic 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

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SCAGI	Standing Committee on Antarctic Geographic Information
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee on Ocean Research
SHEF format	Standard Hydro-meteo 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	Third 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-ISC)
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