

Annex to paragraph 11.9.17 of the general summary

GLOBAL CRYOSPHERE WATCH (GCW)

GCW IMPLEMENTATION STRATEGY

1.0 BACKGROUND:

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

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

2.0 GCW Meets User Needs

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

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

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

- Changes in large scale dynamics such as the Arctic Oscillation (AO) Index have major and currently not well predicted impacts on climate in North America, Europe and Asia.

3.0 Mission and Objectives

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

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

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

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

4.0 GCW and the WMO Strategic Plan

The cryosphere, by its nature, is intrinsically interdisciplinary. GCW, in the context of the WMO Strategic Plan 2012-2015, is a crosscutting activity contributing to all five priority areas and to

achieving the expected results of all Strategic Thrusts. It cuts across all the WMO technical departments (Observing and Information Systems, Research, Climate and Water, Weather and Disaster Risk Reduction Services), joint sponsored activities (e.g. WCRP, GCOS) and WMO TCs. GCW will

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

5.0 GCW Implementation

5.1 Phases

GCW Definition Phase (2007 - 2011)

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

GCW Implementation phase (2012-2019)

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

GCW Operational Phase (2020 onward)

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

5.2 Tasks

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

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

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

Implementation of CryOS recommendations

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

Pilot and Demonstration Projects

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

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

Reference Sites

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

will facilitate the establishment of high-latitude supersites with co-located measurements of key variables, especially permafrost and snow cover, thus enhancing GCOS/GTOS Networks for Permafrost (GTN-P), Glaciers (-G) and Hydrology (-H) and including the measurements of solid precipitation. GAW stations and WCRP/Coordinated Energy and Water Cycle Observations Project (CEOP) reference sites in cold climates are potential candidates.

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

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

Inventory of Satellite Data Products

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

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

GCW Web Portal

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

The portal and associated data and information will be capable of including all elements of the cryosphere at national, regional and global scales. It will provide access to data and information on past, present and future cryospheric conditions, and be able to draw on operational and research-based observation and monitoring and modelling. GCW will ensure access to real time, near-real

time and historical cryospheric data and products through WIS. GCW will respect partnership, ownership and data-sharing policies of partners. It will allow new types of information to be widely distributed, such as real-time cryospheric “hot news” (e.g. extremes, physical or socio-economic impacts, new research results).

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

Capacity Building

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

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

Communications and Outreach

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

6.0 Collaborations, Partnerships, Sponsorship

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

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

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

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

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

7.0 GCW Management and Governance

7.1 *Conceptual Framework for GCW*

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

7.2 *Deliverables and Milestones*

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

7.3 *Resources*

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

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

7.4 Governance within WMO

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

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

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

Figure 1: GCW Milestones and Deliverables

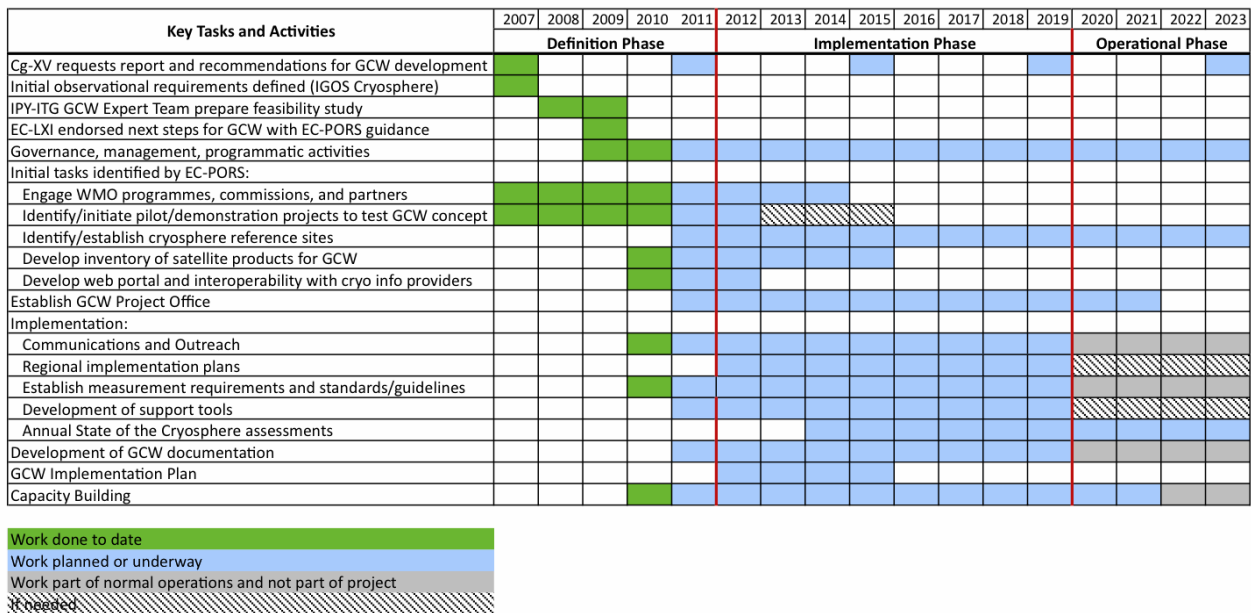
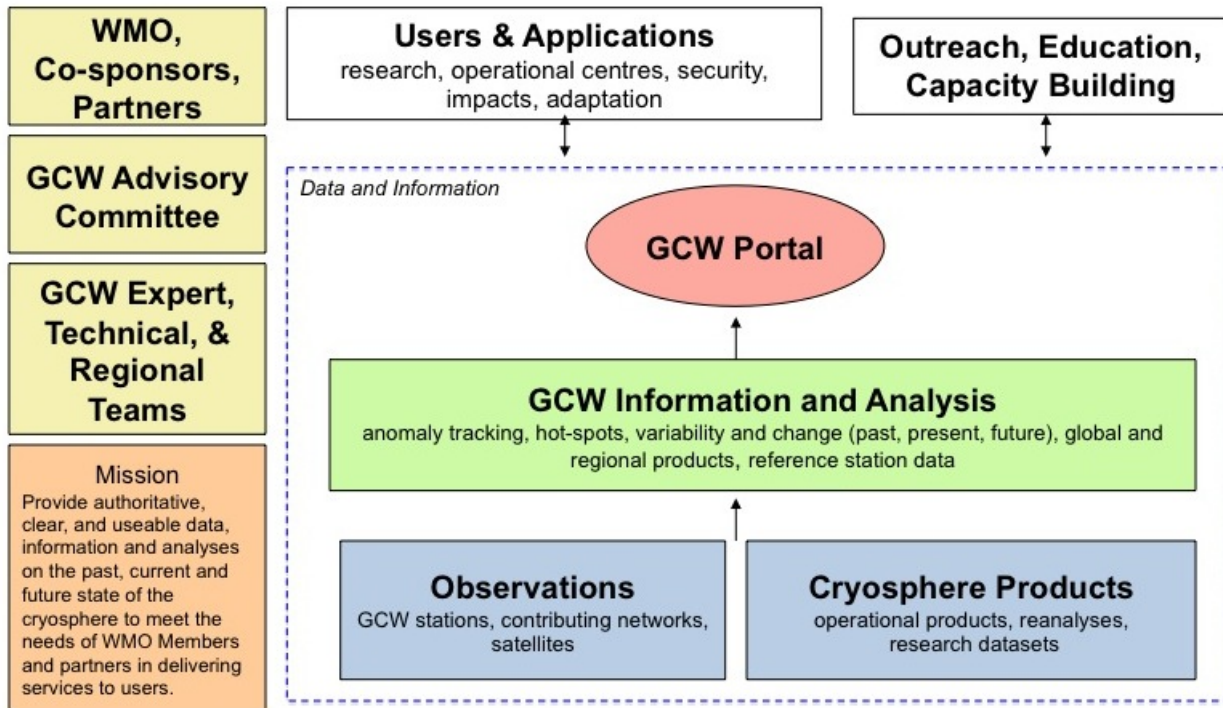


Figure 2: Conceptual Framework for GCW Operation



Res. 11.9/6 (Cg-XVI)

GLOBAL CRYOSPHERE WATCH

THE CONGRESS,

Noting:

- (1) Resolution 11.9/5 (Cg-XVI) – International PolarDecade Initiative,
- (2) That Fifteenth Congress welcomed the proposal to create a Global Cryosphere Watch (GCW) as an important part of the International Polar Year legacy,
- (3) That EC-LXII agreed that it would be highly desirable for coordinated international efforts to secure and develop an IPY legacy process,
- (4) The GCW Implementation Strategy developed under the auspices of the Executive Council,

Considering:

- (1) The cryosphere is global, existing in various forms spanning all latitudes and occurring in approximately one hundred countries in addition to the Antarctic continent,
- (2) The cryosphere is an integrative element within the climate system and provides one of the most useful indicators of climate change, yet it is arguably the most under-sampled domain in the climate system,
- (3) The role of the cryosphere-related feedbacks in the amplification of anthropogenic climate change in Polar Regions, including the “Third Pole” and the significant impact of a changing cryosphere on weather, climate and water globally,
- (4) The cryosphere, its changes, and its impacts, not only have received increased scientific scrutiny in recent years, but also now receive continual attention by decision makers and coverage by the media, creating an unparalleled demand for authoritative information on past, present and future state of the world’s snow and ice resources,
- (5) GCW is significant component of WIGOS and WIS, particularly in promoting interoperable and reference observations, and near-real time data and information exchange,
- (6) GCW can only succeed by working with WMO Members and with other organizations which have cryospheric interests,

Acknowledging in particular the contributions of Members’ national operational and research programmes to monitor and provide data on the cryosphere,

Decides to embark on a development of the Global Cryosphere Watch (GCW), as an IPY Legacy with a view of an operational GCW;

Urges Members and **Invites** international partner organizations and programmes to:

- (1) Collaborate actively in, and give all possible support to, the development and implementation of this initiative;
- (2) Support the Global Cryosphere Watch by providing both human and financial resources to implement GCW;

Requests the Executive Council to:

- (1) Establish a mechanism to steer and monitor the activity and to achieve the broadest possible collaboration and cooperation;
- (2) Ensure the active participation and representation of the principal bodies concerned and also the participation, as appropriate, of technical experts and representatives of agencies undertaking observing and research initiatives relevant to the cryosphere;
- (3) Submit a comprehensive report including an updated implementation plan of GCW to the Seventeenth WMO Congress;

Requests the regional associations and technical commissions to include this activity in their work programmes in order to fully accommodate the cross-programme nature of this cross-cutting initiative;

Requests the Secretary General:

- (1) To strengthen coordination and collaborate closely with relevant international partner organizations and programmes in pursuing this endeavour;
 - (2) To put in place an appropriate mechanism in the Secretariat to ensure optimal management of, and support to, the initiative.
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