Global Cryosphere Watch (GCW)

Barry Goodison¹ and Jeff Key²
¹Vice-Chair, GCW Steering Group (WMO, retired)
²GCW Senior Scientist (US NOAA/NESDIS)
On behalf of GCW Steering Group

Scoping Workshop on Climate Services for Polar Regions:
Establishing Polar regional Climate Centres Towards
Implementing an Arctic PRCC-Network

Geneva, Switzerland, Nov 17-19, 2015
Changes in the cryosphere can have significant impacts on....

The Global Earth System:
- Sea level rise
- Climate
- Ocean circulation
- Atmospheric circulation

Regional and local impacts:
- Natural resources and hazards
- Ecosystems
- Food production and fisheries
- Infrastructure
- Transportation
- Recreation
- GHG emissions

Cg-16 (2011) WMO needs to have a focus on global cryosphere issues to be able to provide authoritative information to meet Members' responsibilities on regional and global weather, climate, water and related environmental matters and seasonally frozen ground (*GCOS ECV)

Cg-17 (2015) decided:
- to mainstream and implement GCW in WMO Programmes as a cross-cutting activity;
- that implementation activities will be undertaken during the next financial period as one of the major efforts of the Organization with the goal that GCW should become operational;

Cryosphere: solid precipitation*, snow cover*, sea ice*, lake and river ice, glaciers*, ice caps*, ice sheets*, ice shelves, permafrost* and seasonally frozen ground (*GCOS ECV)
**GCW Mission:** GCW will provide authoritative, understandable, and useable data, information, and analyses on the past, current and future state of the cryosphere to meet the needs of WMO Members and partners in delivering services to users, the media, public, decision and policy makers.
GCW Building on Past Accomplishments:
UNESCO - Climate Change and Arctic Sustainable Development: scientific, social, cultural and educational challenges – Monaco, 2009

Identified knowledge gaps and made more than 67 recommendations: Education, communication and outreach (6+); Cultural heritage (7); Well-being and health (4); Economic development and resource management (11); Arctic Governance (14); Establishing, sustaining and strengthening research and monitoring systems (15+); Information access and data sharing (4+); Policy and decision Support (6)

- Given the limited number of observation networks in the Arctic, sustaining, strengthening and further developing long-term comprehensive multidisciplinary integrated pan-arctic observing systems is recommended
- Recommended the cryosphere aspects of this pan-arctic system be linked to GCOS (GOOS, GTOS) in the Arctic, and GCW.
- Promote implementation of research and monitoring activities into operational services, including establishment of a viable operational mechanism, such as the Polar Climate Outlook Forum (PCOF) to facilitate effective interactions between climate professionals and users/stakeholders (as an IPY legacy).
- WMO and UNESCO, as designated conveners by the UN for enhanced UN collaboration on climate knowledge: science, assessment, monitoring and early warning, invited to promote UN collaboration for establishing, sustaining and strengthening research and monitoring systems in the Arctic.
GCW Building on Past Accomplishments: SWIPA recommendations are important considerations for GCW observing systems in the Arctic

- There are numerous snow and ice measurement sites across the Arctic, but operations at existing sites are, in general, not well coordinated.
- A need to improve coordination of resources provided by national and international agencies responsible for cryospheric observations, and to facilitate transition of research-based products into sustained monitoring systems.
- Need to standardize the types and methods of measurements at surface stations.
- Satellite observing system is robust, with a few potential gaps in long-term.
- Traditional knowledge can provide important value-added content to data products and information and serves to make data more useful and relevant to northern users.
- Community based observing programs provide a mechanism for two-way knowledge transfer.
- Existing cryospheric data are underutilized; use of cryospheric data in weather and climate models needs to be extended.
GCW Building on Past Accomplishments: 
User Needs are Critical: CryoLand User Group

**CRYOLAND USER GROUP:**
60 Organisations from 15 European countries + 3 EU organisations:
- Product & Service Requirements and Specs
- Product & Service Testing and Evaluation

- Hydropower companies
- Energy traders
- Hydrological services
- Meteorological services
- Climate monitoring institutions
- Avalanche warning centres
- Road, Railway and River Authorities
- Geotechnical & Construction companies
- Ecologists
- Reindeer herders
- Environmental agencies
GCW - Relevance to PRCC

GCW will ensure a comprehensive, coordinated and sustainable system of observations and information to allow for a more complete understanding of the cryosphere (past, present and future) and to contribute to the improved observations, research and services that are essential to fully assess, predict, and adapt to the variability and change now witnessed in the Arctic.

Cryosphere is a defining characteristic of polar and high mountain regions.

GCW addresses GCOS ECVs (more than T&P)

GCW and PRCC both have operational mandates
GCW Activities Relevant to PRCC (what is GCW doing, or what’s happening that wouldn’t otherwise happen)

- developing a **network of surface observations**, with "CryoNet“ at the core, which builds on existing networks;
- establishing **measurement guidelines** and best practices;
- refining **observational requirements** for the WMO RRR;
- engaging in and supporting **intercomparisons of instruments and products**, e.g., the **GCW Snow Watch** project;
- **enhanced** near real-time snow depth observation on the GTS/WIS and **reporting** of zero snow depth (with modelling centres and CBS);
- contributing to WMO’s space-based capabilities database (with PSTG);
- **evaluation/intercomparison** of satellite snow products initiated with ESA (SnowPEX);
GCW Activities Relevant to PRCC...2

- producing *unique hemispheric products*, e.g., “snow anomaly trackers” for SCE and SWE in collaboration with partners;
- engaging in *historical data rescue* (e.g., snow depth);
- building a *glossary of cryospheric terms*;
- developing international training, outreach materials; co-sponsoring workshops
- providing *up-to-date information on the state of the cryosphere*;
- providing *access to data and metadata* through a portal;
THE NEED FOR COMMON GCW CRYOSPHERE TERMINOLOGY (in all WMO languages)….an issue for PRCC and PCOF?

- **Snowfall:** (1) Snow falling. (2) Depth of fresh snow deposited on the ground during a specific period. (WMO)

- **Snow cover:** Covering of the ground, either completely or partially, by snow. (METEOTERM)

- **Snow cover:** Areal extent of snow-covered ground, usually expressed as percent of total area in a given region.

- **Snow cover:** In general, the accumulation of snow on the ground surface, and in particular, the areal extent of snow-covered ground (NSIDC, 2008); term to be preferably used in conjunction with the climatologic relevance of snow on the ground. See also snowpack. (UNESCO Seasonal Snow on the Ground)

- **Snow cover:** (1) in general, the accumulation of snow on the ground surface (2) the areal extent of snow-covered ground, usually expressed as percent of total area in a given region. (NSIDC)

- **Snow coverage:** ratio of the snow covered area to the total area of a basin. (WMO/UNESCO, Int. Glossary Hydrology)

- **Inuktitut** - *qanik* snow falling; *aputi* snow on the ground; *pukak* crystalline snow on the ground
an immediate GCW priority is to establish the core network of GCW surface measurement stations/sites – CryoNet, one part of the whole GCW observing system.

• GCW/CryoNet is a component observing system of the WMO Integrated Global Observing System (WIGOS).

- CryoNet stations/sites must meet a minimum set of requirements
- CryoNet covers all components of the cryosphere (glaciers, ice shelves, ice sheets, solid precipitation, snow, permafrost, sea ice, river/lake ice) through an extensive approach of in-situ observations.
- CryoNet is initially comprised of existing stations/sites, rather than creating new sites; some SEARCH and AON sites are already part of CryoNet.
- GCW Contributing Stations provide useful measurements of the cryosphere, but whose data records may be shorter or with large gaps, or do not provide the quality and consistency of data required of CryoNet stations; may be in remote, hard to access regions where cryospheric observations are scarce.
CryoNet Sites/Stations approved for pre-operational testing phase

<table>
<thead>
<tr>
<th>Site</th>
<th>Operating Country</th>
<th>Location</th>
<th>Site Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGMA-A</td>
<td>Japan</td>
<td>Greenland</td>
<td>Basic</td>
</tr>
<tr>
<td>PROMICE Greenland Ice Sheet Monitoring Network</td>
<td>Denmark</td>
<td>Greenland</td>
<td>Basic</td>
</tr>
<tr>
<td>Sonnblick</td>
<td>Austria</td>
<td>Austria</td>
<td>Integrated</td>
</tr>
<tr>
<td>Gilianshan Station of Glaciology and Ecologic Environment</td>
<td>China</td>
<td>China</td>
<td>Basic</td>
</tr>
<tr>
<td>Sodankyla-Pallas</td>
<td>Finland</td>
<td>Finland</td>
<td>Integrated</td>
</tr>
<tr>
<td>Gilian</td>
<td>China</td>
<td>China</td>
<td>Integrated</td>
</tr>
<tr>
<td>Tanggula Cryosphere and Environment Observation Station</td>
<td>China</td>
<td>China</td>
<td>Basic</td>
</tr>
<tr>
<td>Eureka</td>
<td>Canada</td>
<td></td>
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<tr>
<td>Hofsjökull</td>
<td>Iceland</td>
<td></td>
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<tr>
<td>Antisana 15 alfa</td>
<td>Ecuador</td>
<td></td>
<td></td>
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<tr>
<td>Zongo Glacier</td>
<td>France</td>
<td></td>
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<tr>
<td>Morenas Coloradas Rockglacier</td>
<td>Argentina</td>
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<tr>
<td>Quolccaya Ice Cap</td>
<td>USA</td>
<td></td>
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<tr>
<td>Weissfluhjoch - Davos</td>
<td>Switzerland</td>
<td></td>
<td></td>
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<tr>
<td>Glaciār Norte</td>
<td>Mexico</td>
<td></td>
<td></td>
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<tr>
<td>Saint-Sorlin Glacier</td>
<td>France</td>
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</tbody>
</table>

36 sites/stations were approved by Cg-17 for the pre-operational phase
CryoNet will support RCC functions

CryoNet will achieve its own comprehensive potential and contribute to RCC mandatory and recommended functions through

- **Linkages** with cryospheric observational networks beyond the WMO family, *long-term, sustainable* observing and monitoring, *harmonized measurements and products*
- Providing cryospheric-data for *improved process understanding and modelling*
- Providing *calibration and validation* data for satellite and modelling products
- Linking cryospheric ground truth observations to cryospheric *models*
- **Training** for cryospheric observations
- **Standardized guidelines** for cryospheric observations
Measurement standards and practices

SEARCH and AON are discussing measurement methods. Collaboration with GCW is essential.

GCW is part of the WMO Integrated Observing System (WIGOS) and contributes to technical regulations of WMO through WIGOS.

“IUGG urges snow and ice scientists, practitioners, and scientists from related disciplines to adopt these new schemes as standards.”
Measurement Standards and Best Practices

GCW is drawing on existing measurement methods where possible and where a scientific consensus has been or can be reached.

Step 1: Inventory of existing guidelines:

<table>
<thead>
<tr>
<th>Cryosphere Element</th>
<th>Existing Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permafrost</td>
<td>Smith and Brown (2009), GTN-P (2012)</td>
</tr>
</tbody>
</table>

Step 2: GCW works through these documents, engages the community, and reaches a consensus on best practices for each variable.
15 countries hosting a total of 20 field sites; Australia, Chile, Canada, Finland, France, Italy (Nepal), Japan, Korea, Norway, New Zealand, Russia, Poland, Switzerland, Spain, USA.

Investigating the in-situ measurement and reporting of precipitation amount:
- over various time periods (minutes, hours, days, seasons),
- as a function of precipitation phase (liquid, solid, mixed);
- Snow on the ground (snow depth) - Will include linkages between snow on the ground and snowfall.
One instrument (weighing gauge): three sites, three climate regimes

**Site 1**

**Continental climate**

- Catch ratios of 30 minute accumulation (ratio of sensor under test/reference) for events as a function of mean wind speed (season 2014/2015), with:
  - reference accumulation > 0.25 mm
  - mean temperature < -2 °C.
- The mean temperature for each event is indicated by colour (colour bar).
- **Catch ratio <1, wind speeds<8 m/s (inside the magenta line rectangulars)**

**Site 2**

**Blowing snow event**

**Site 3**

**Alpine climate**
GCW: Authoritative Products

- Routine evaluation of products
- Product intercomparisons
- Self-assessments of maturity, etc.
- Products meet user needs
- Sustainable product development and production
- Transfer from research to operations

Sea Ice Area and Extent obtained by passive microwave sea ice algorithms
These 3 trackers are currently on-line.

Daily graphs distributed via GCW-website
Uncertainty in Mass of Seasonal Snow

Observation of SWE by means of Passive MW (GlobSnow, NASA Std/Prototype, AMSR-E, CMA, etc.)
Product Intercomparisons

Desired Outcomes of SnowPEX
(GCW perspective)

1. Compile list of products and reference datasets.
3. Establish validation/intercomparison protocol.
4. Evaluate product maturity.
5. Quantify differences (and overall spread) in products for pre-selected cases and interpret the differences.
6. Standardize geophysical parameters relevant to users, including definitions, units, and quality flags.
7. Make the intercomparison case study data available (reproducibility leads to “authoritative”).
8. Convey results to end users, including the modeling community.

Colors: Done, In progress, Not started or just started
Snow Dataset Inventory – February 2015

Current draft Includes 60 dataset entries:
- 18 Satellite-derived snow products and datasets
- 20 Analyses, reanalyses and reanalysis-driven snow products and datasets
- 22 In-situ snow products and datasets

<table>
<thead>
<tr>
<th>Product(s)</th>
<th>Type</th>
<th>Organization</th>
<th>Description</th>
<th>Period</th>
<th>Areal Coverage</th>
<th>Resolution</th>
<th>Variables</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>GlobSnow SWE</td>
<td>Satellite</td>
<td>ESA, Finnish Meteorological Institute (FMI)</td>
<td>Combination of climate station snow depth observations and forward microwave emission model simulations with SMMR and SSM/I satellite passive microwave data</td>
<td>1979-</td>
<td>Non-alpine Northern Hemisphere</td>
<td>25 km</td>
<td>SWE</td>
<td>Daily; week monthly</td>
</tr>
<tr>
<td>GlobSnow Snow Extent</td>
<td>Satellite</td>
<td>ESA, Finnish Meteorological Institute (FMI)</td>
<td>Estimation of fractional snow covered area from SCAmod algorithm</td>
<td>1995-</td>
<td>Northern Hemisphere</td>
<td>0.01 deg</td>
<td>Fractional Snow Cover</td>
<td>Daily; week monthly</td>
</tr>
<tr>
<td>NASA Standard AMSR-E</td>
<td>Satellite</td>
<td>NASA</td>
<td>19 and 37 GHz Tb difference; enhancements for vegetation and grain size evolution; distinction between shallow and deep snow</td>
<td>2002-2011</td>
<td>Northern Hemisphere</td>
<td>25 km</td>
<td>SWE</td>
<td>Daily; pentamonthly</td>
</tr>
<tr>
<td>NASA Prototype AMSR-E</td>
<td>Satellite</td>
<td>NASA</td>
<td>Combination of numerical techniques, snow emission modeling and climatology</td>
<td>2002-2011</td>
<td>Northern Hemisphere</td>
<td>25 km</td>
<td>SWE</td>
<td>Daily; monthly</td>
</tr>
<tr>
<td>NOAA AMSR2 Snow Products</td>
<td>Satellite</td>
<td>NOAA</td>
<td>Variation of NASA AMSR-E methodology</td>
<td>2014-</td>
<td>Global</td>
<td>25 km</td>
<td>Snow Cover, Depth, SWE</td>
<td>Daily</td>
</tr>
</tbody>
</table>
Product Intercomparisons for Cryospheric Variables

For example:
A robust, international, ice thickness intercomparison project along the lines of GCW’s Snow Watch or the GEWEX CREW series of workshops would be beneficial.
Requirements and Capability for observations (in progress)

- GCW Requirements are **being** formulated and documented on the GCW website;

- They will **draw** from various sets of existing user requirements and will be vetted by the scientific community;

- Those requirements will become part of the WMO **Rolling Review of Requirements** (RRR);

- Will be accessible through the Observing Systems Capability Analysis and Review Tool (OSCAR), the official source for WMO requirements, which has a cryosphere theme;

- Need for a new **application area** “GCW”.

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**Observational Requirements**

GCW observational requirements are being formulated. They will draw from various sets of existing user requirements and will be vetted by the scientific community. They will become part of the WMO Rolling Review of Requirements (RRR) and will be accessible through the Observing Systems Capability Analysis and Review Tool (OSCAR), which has a cryosphere theme. OSCAR is the official source for WMO requirements. The IGOS Cryosphere Theme Report (see Documents) contains the most comprehensive set of observational capabilities and requirements for the cryosphere. It is the starting point for GCW. The IGOS and OSCAR cryosphere requirements are given below. Click the Filter Options button to filter the results. Each entity in the table gives the current measurement capability in green, the threshold requirement (minimum necessary) in blue, and the objective requirement (target) in orange, if available.
The GCW Data Portal will exchange cryosphere data, metadata, information and analyses among a distributed network of providers and users in support of informed decision-making. The **GCW Data Portal is part of WIS**, a Data Collection and Production Centre (under development), and is interoperable with data centres.

**Data quality, sharing and access are fundamental principles**
- improve access to, and utilization of observations and products from WMO and other observing systems and national and international data centres, built using the principles developed for IPY2007-2008.
- facilitates the interaction between users and providers of the products
- YOPP data management builds on GCW data management (both principles and solution)
The website differs from the METNO GCW Data Portal in that it contains more dynamic information (news, state of the cryosphere plots, highlights, calendar), as well as background, higher-level information, GCW documents, and outreach material. It links to the METNO data portal.

http://globalcryospherewatch.org
Moving Forward...
Moving Forward…

The following are some suggestions for discussion which are important for GCW and for Arctic PRCC-network designation:

- Defining the highly recommended functions in addition to mandatory functions for an Arctic PRCC
- Determining elements to be produced (T&P is not enough); identifying cryospheric elements to be included; role for satellite or merged/blended products
- Defining the spatial domain of an Arctic PRCC – hemispheric? pan-Arctic (how far south?), RA II, IV, VI could subdivide? Evaluation/validation in data sparse regions.
- Defining suitable temporal scale especially for climate monitoring (minimum update frequency is monthly – strive for weekly, daily as well?)
- Data policy; access to data; timely exchange of data observed to meet user needs (forecasting, monitoring, data services); interoperability among data centres; role of GCW data portal/DCPC
- Determining user needs beyond NMSs (NMHSs?), e.g. those of Indigenous Peoples
- Engaging organizations outside WMO in developing Arctic-PRCC
- Identifying key gaps that would hinder development of operational LRF products, climate monitoring and data services of an Arctic PRCC (incl. review of outcomes of relevant workshops, conferences, meetings)
What can the GCW do for the PRCC?
What can the PRCC do for the GCW?
GCW Upcoming Meetings and Workshops

- GCW CryoNet Team Meeting Fifth Session; Boulder, USA, 7-8 December 2015
- GCW Steering Group meeting Third Session; Boulder, USA, 9-11 December 2015
- 2nd GCW CryoNet Asia Workshop; Salekhard, Russian Federation, 2-5 February 2016
- GCW Snow Watch Team Meeting Second Session; Columbus, Ohio, USA, 13-14 June 2015
GCW........Authoritative information for the past, present and future state of the cryosphere

GCW Website: http://globalcryospherewatch.org/
GCW Portal: http://gcw.met.no/