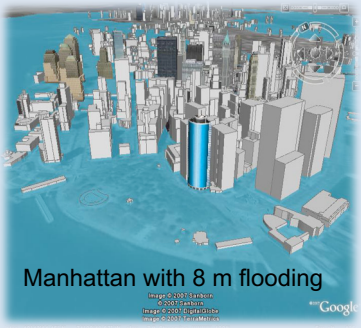
World Meteorological Organization
Global Cryosphere Watch

Impacts of a Changing Cryosphere

Changes in the cryosphere can have significant impacts on water supply, food production, hydropower production, transportation, infrastructure, hunting, fisheries, recreation, ecology and the risk of floods and droughts.



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.

Natural hazards such as icebergs, avalanches and glacier outburst floods create risks for transportation, tourism and economic development.

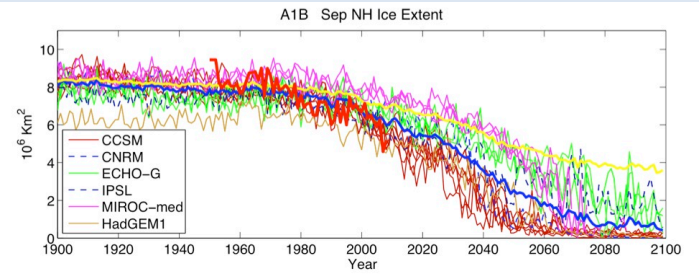
Retreating sea ice results in a loss of habitat for mammals such as polar bears and seals.

Permafrost thawing impacts infrastructure and is potentially a major source of methane, a greenhouse gas.

Changes in the cryosphere have major impacts on society: agriculture, transportation, security, hydropower, fisheries, recreation, floods and droughts.

Disappearing glaciers and sea ice affect ecosystems by changing habitat.

Cryospheric data and information are required for improved numerical weather and climate prediction, a necessary step in assessing future impacts.



GCW is providing the information needed to better assess impacts of a changing cryosphere on society. For more information visit globalcryospherewatch.org.

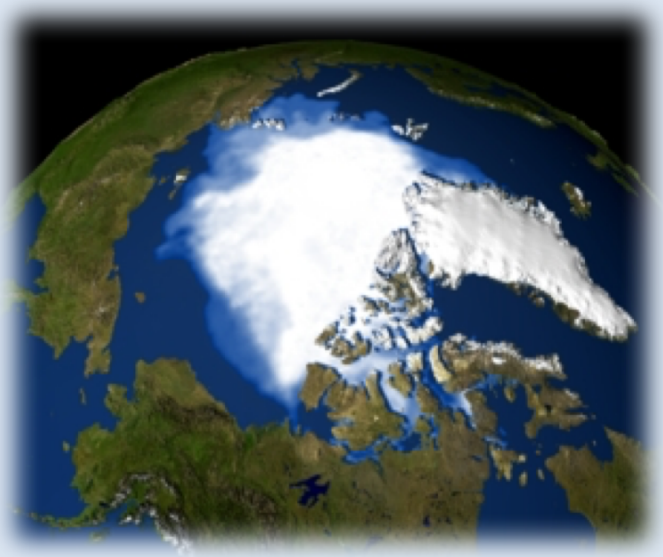
Figure Credits. p.1 (top left-anticlockwise): Leszek Pawlowicz, http://freegeographytools.com; Canadian Ice Service; IGOS Cryosphere Theme Report, 2007; Roger Braithwaite; Chris Hopkinson (CCIN); Terry Prowse (Environment Canada); Claude Duguay (CCIN); Helga P. Finnsdottir (Iceland); United Nations Environment Programme; Henry Huntington (Alaska); p.2 (top left-anticlockwise): Canadian Cryosphere Information Network/CRYSYS; CRYSYS; Spyros Beltaos (Environment Canada); Uzhydromet; Gita Laidler (CRYSYS); Jeff Key (NOAA); Monique Bernier (CRYSYS); Terry Prowse; bottom graph: James Overland (NOAA).

World Meteorological Organization
Global Cryosphere Watch

Observing the Cryosphere

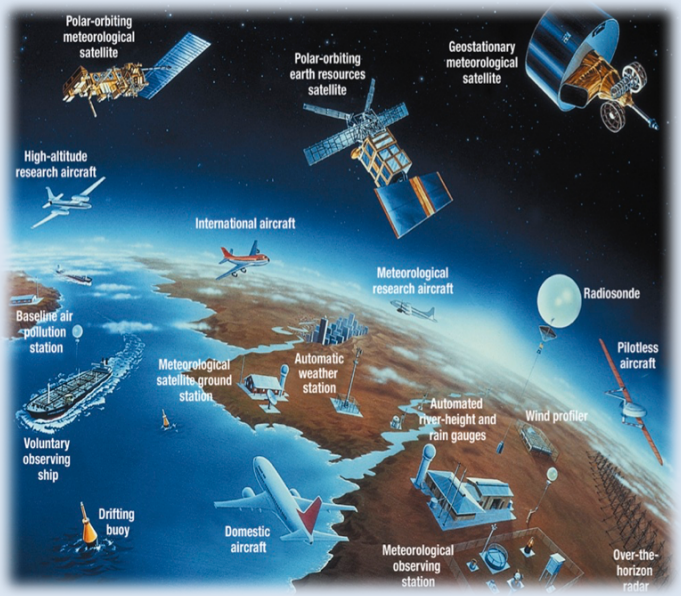
A comprehensive cryosphere observing system must be a combination of ground-based instrumentation, satellite remote sensing, aircraft measurements, modeling, and data management.

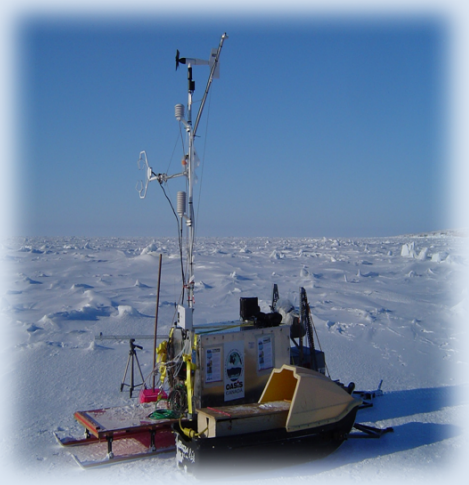
Conditions in areas where the cryosphere exists are harsh, and in situ observations there are difficult and expensive. Satellite monitoring overcomes some of the logistical obstacles, but satellites are costly and do not yet fully address the range of geophysical variables needed to understand the cryosphere.



Surface and airborne observations provide data that cannot be measured from space, more detailed information in critical areas, and observations with which to validate satellite retrievals.

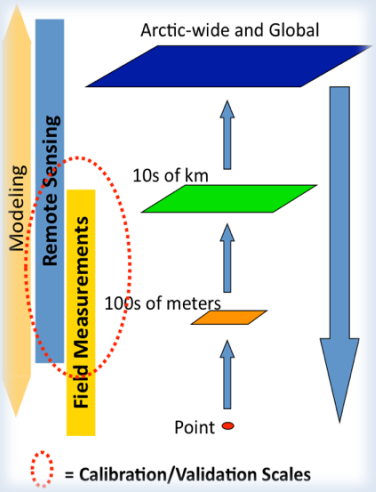
The complex system of satellites is essential for delivering sustained, consistent observations of the global cryosphere and are a key to extending local in situ measurements. No one all-encompassing sensor exists; rather, the combination and synthesis of data from different yet complementary sensors is essential, and underlines the critical importance of maintaining key synergetic elements of the system.





Similarly, surface-based measurements take many forms. Some are operational with semi-permanent infrastructure; others may be mobile and cover a short time span.

Together, in situ, satellite, and aircraft measurements cover all scales of observation, providing the data needed for small-scale process studies and global climate prediction.



As robust as the cryosphere observing system is, many surface observation networks have been reduced and some decommissioned. Monitoring efforts are in need of sustained funding. Space-based capabilities for some snow/ice properties are very limited. *There needs to be a concerted effort to improve and expand systematic, comprehensive, ground-based monitoring, and to support the development of remote sensing methods.*

For more information visit globalcryospherewatch.org.

Figure Credits. p.1 left side: SHEBA; Chinese Meteorological Administration; John Cassano (U Colorado); NOAA/NOHRSC; NASA; p.2 left side: Jan Bottenheim (Environment Canada); Waleed Abdalati, NASA; WMO/WIGOS.

World Meteorological Organization
Global Cryosphere Watch

GCW Overview

The Global Cryosphere Watch includes all components of the cryosphere, globally, regionally, nationally

The Global Cryosphere Watch (GCW) is establishing a sustained, global, robust, end-to-end cryosphere observing and monitoring system. GCW will provide data, information and products that will help to reduce the loss of life and property from disasters, improve management of energy and water resources, contribute to a better understanding of environmental factors affecting health, understand, assess, predict, mitigate and adapt to climate change, improve weather forecasts and hazard warnings, aid in management of ecosystems, and support sustainable agriculture.

The Cryosphere

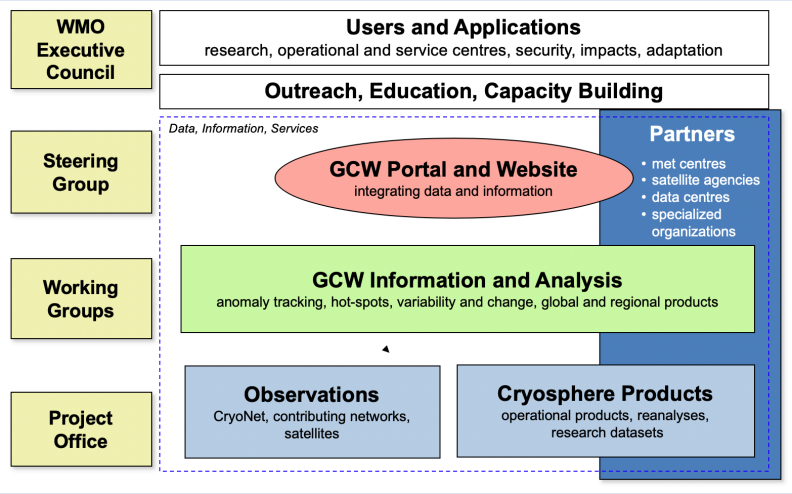
The cryosphere is a component of the Earth System that includes solid precipitation, snow cover, sea ice, lake and river ice, glaciers, ice caps, ice sheets, permafrost, and seasonally frozen ground. The cryosphere is global, existing not just in the Arctic, Antarctic and mountain regions, but at all latitudes and in approximately one hundred countries.

GCW encompasses:

- ***Requirements***: Meet evolving observing requirements;
- ***Integration***: Provide a framework to assess the state of the cryosphere and interactions in the Earth System;
- ***Standardization***: Enhance the quality of observational data by improving measurement practices;
- ***Access***: Improve exchange of, access to, and utilization of observations and products;
- ***Coordination***: Foster research, development, and planning activities for future observing systems and global observing network optimization.

GCW, working with WMO Members and partners, will provide authoritative, clear, and useable data, information, and analyses on the past, current and future state of the cryosphere to meet the needs of Members and partners in delivering services to users, the media, public, decision and policy makers. *Partnering is essential.*

GCW is a cross-cutting activity. It is an essential component of the WMO Integrated Global Observing System (WIGOS) and will coordinate cryospheric activities with the Global Climate Observing System (GCOS), 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 is also providing a fundamental contribution to the Global Earth Observation System of Systems (GEOSS). GCW partners include government agencies, institutions and international bodies. Over 40 WMO Members have nominated GCW focal points.

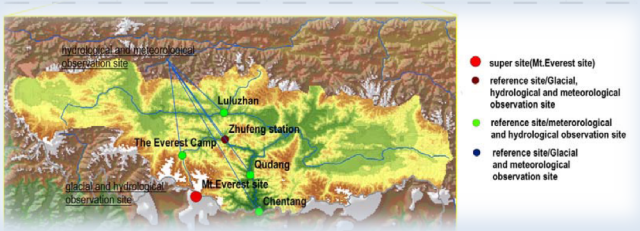


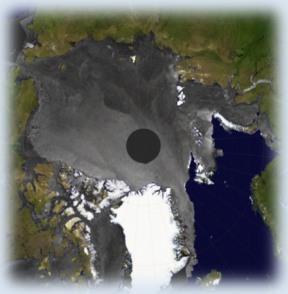
Conceptual Framework

Cryospheric data, information, and products are provided by NMHSs and partner organizations. GCW includes an interface with the user community. Capacity building and training are included throughout the framework. Expert teams are responsible for developing, implementing and managing tasks. A GCW Steering Group provides high-level guidance on GCW activities, tasks, and structure.

Current GCW activities include:

- developing a **core standardized network of surface observations** called "CryoNet", building on existing networks;
- developing **measurement guidelines**;
- refining **observational requirements**;
- **product intercomparisons**;
- creating **unique products ("trackers")**;
- engaging in **historical data rescue**;
- building a **snow and ice glossary**;
- providing **up-to-date information on the state of the cryosphere**;
- providing **access to data** through a portal.





GCW includes observation, monitoring, assessment, product development, prediction, and research. It provides the framework for reliable, comprehensive, sustained observing of the cryosphere through a coordinated and integrated approach on national to global scales, and delivers quality-assured global and regional products and services. For more information visit globalcryospherewatch.org.

Credits: p1 (top-bottom) Jeff Key (NOAA); Canadian Ice Service; Don Cline (NOAA); p2 Xiao Cunde (CMA); NSIDC; SnowStar2007

World Meteorological Organization
Global Cryosphere Watch

GCW CryoNet

CryoNet is an immediate priority in GCW development

The core Global Cryosphere Watch (GCW) surface-based observational network, called *CryoNet*, is comprised of stations with varying capabilities. It builds on existing cryosphere observing programmes and promotes the addition of standardized cryospheric observations to existing facilities in order to create more robust environmental observatories.

General objective of CryoNet

CryoNet is a comprehensive network of cryospheric *in-situ* observations. Its aims are:

- extensive monitoring of the cryosphere through **GCW (standardized) practices** for cryospheric observations;
- providing **cryospheric data** for improved process understanding and modelling;
- providing **calibration and validation** data for satellite data;
- linking **cryospheric ground truth** observations to cryospheric models;
- **training** in measurement methods.

"IUGG urges snow and ice scientists, practitioners, and scientists from related disciplines to adopt these new schemes as standards."

CryoNet covers all components of the cryosphere - glaciers, ice shelves, ice sheets, snow, permafrost, sea ice, river/lake ice - through an extensive approach of standardized in situ observations.

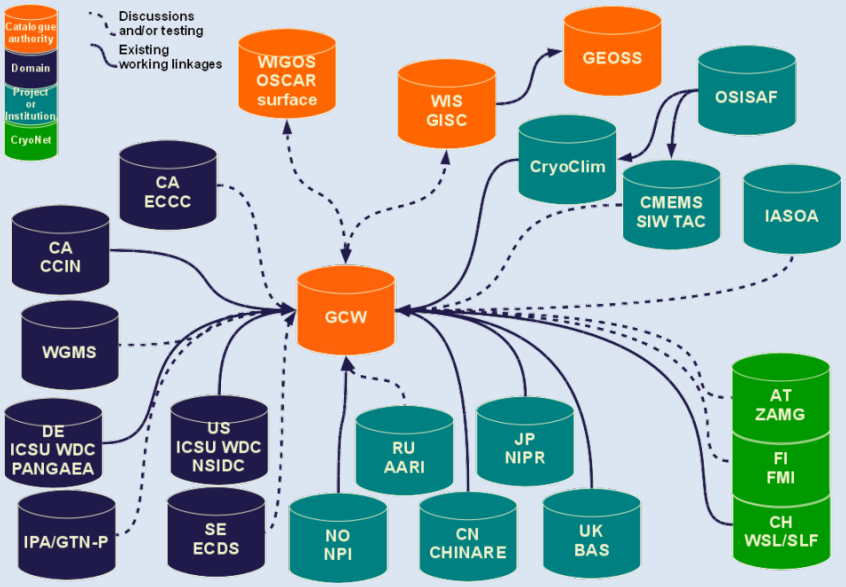
The GCW surface observation network is comprised of *core* component, **CryoNet**, and *contributing stations* that are not part of CryoNet. The basic component of the GCW network is the Station. A station measures one or more components of the cryosphere and one or more variables of each component, for example the depth and density of snow. CryoNet stations must meet a minimum set of requirements, which includes providing ancillary meteorological measurements. A CryoNet Cluster generally encompasses an area greater than a conventional observing station and is comprised of two or more active GCW stations with varying capabilities that are operated as a coordinated unit. At least one station in a cluster has to be a CryoNet station. A cluster may encompass several micro-climatological regions or extend over larger altitudinal gradients.

Why be a part of CryoNet? GCW will drive performance and provide motivation for high quality observations. Being a CryoNet station means being part of an international, operational, global observing system and thus providing observations of known quality for research and operations. Being part of a global network brings better visibility and a recognition of the importance of your observations. GCW promotes the exchange of data, so CryoNet sites may see broader use of their data and products. For more information visit globalcryospherewatch.org.

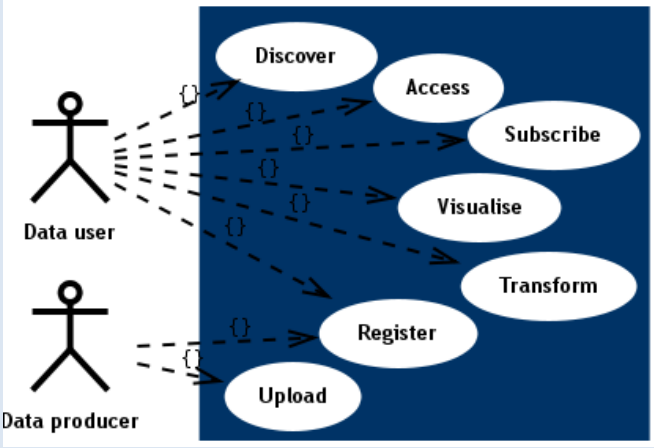
World Meteorological Organization
Global Cryosphere Watch

GCW Portal

The Global Cryosphere Watch (GCW) aims to establish a sustained, global, robust, end-to-end cryosphere observing and monitoring system. A major goal of GCW is improved exchange of, access to, and utilization of observations and products from WMO and other observing systems. Establishing interoperability between data management systems supporting cryospheric data directly addresses GCW objectives.



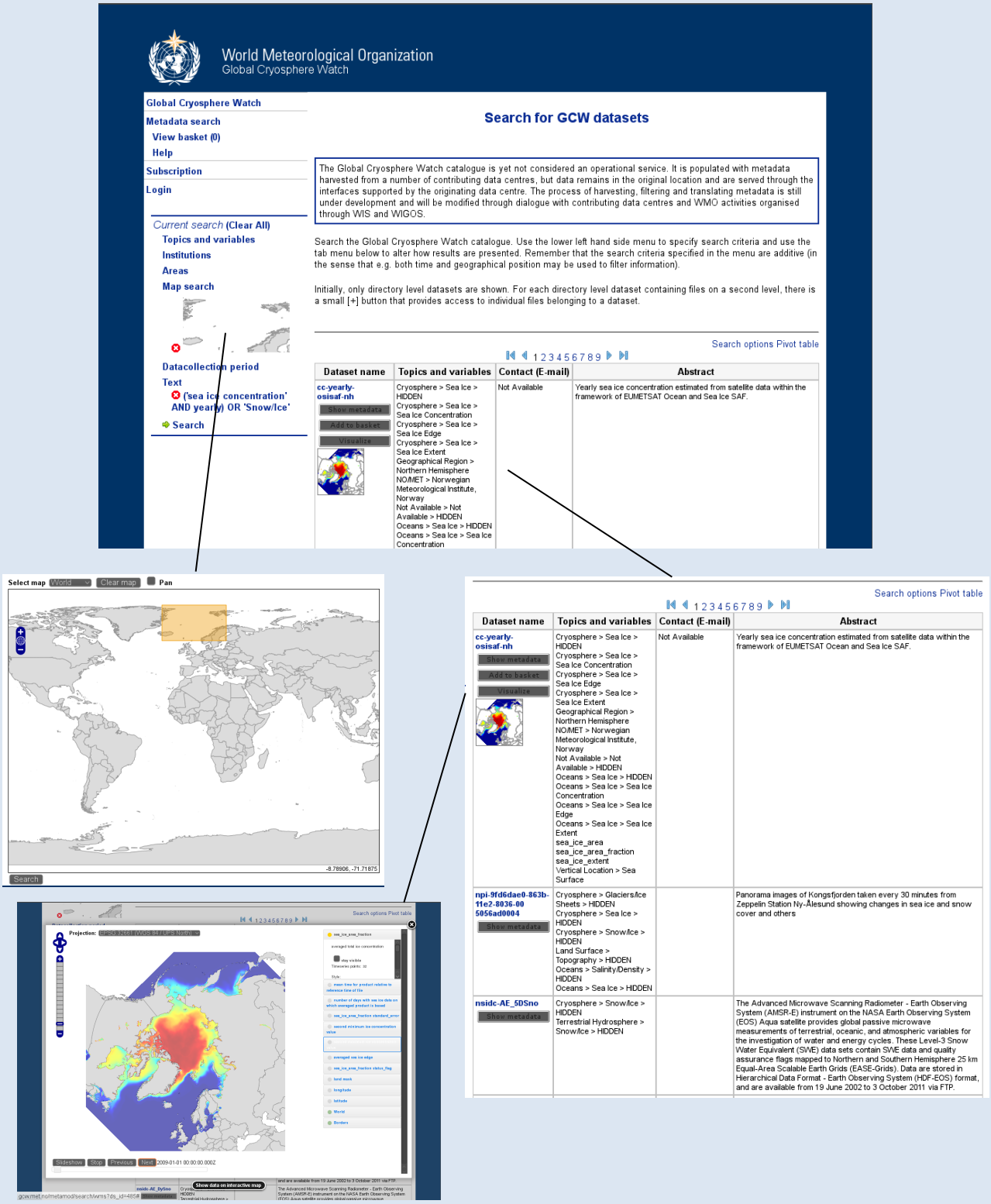
Rather than trying to establish "the one and only portal", a solution linking existing catalogues and portals is more sustainable. Data resides in its original location while metadata are exchanged. Interoperability between data centres is essential.



Functional Requirements: Users of cryospheric data, products and information should be able to easily find what they need. The portal requires both human and machine interfaces. While discovery and access to data is the primary function of any portal, users request more advanced functionality, like visualisation, transformation, reformatting, and reprojection of datasets as part of the data mining activity.

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 the WMO Information System (WIS), will allow for rapid exchange of data, metadata, information, and analyses.

The GCW Portal, which is currently pre-operational, is available at http://gcw.met.no. The Portal focuses on data discovery and access. It demonstrates the concept of linking catalogues as it includes datasets hosted by the National Snow and Ice Data Center, a data centre belonging to ICSU WDS, and the Arctic Data Center at the Norwegian Meteorological Institute which is part of WIS. Being part of WIS, the GCW Portal provides access to a massive range of data providers and users. GCW will respect partnership, ownership and data-sharing policies of partners.



Credits: Information courtesy of Norwegian Meteorological Institute.

World Meteorological Organization
Global Cryosphere Watch

GCW Website

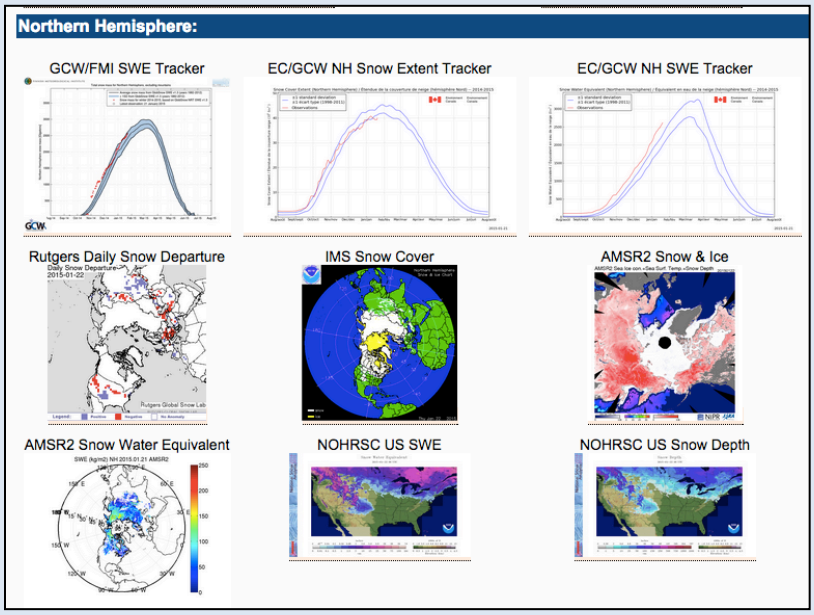
The Global Cryosphere Watch (GCW) is dedicated to providing access to data and information on the cryosphere. While the GCW Portal provides access to data, the GCW website provides information on the current state of the cryosphere, news about the cryosphere, and GCW activities.

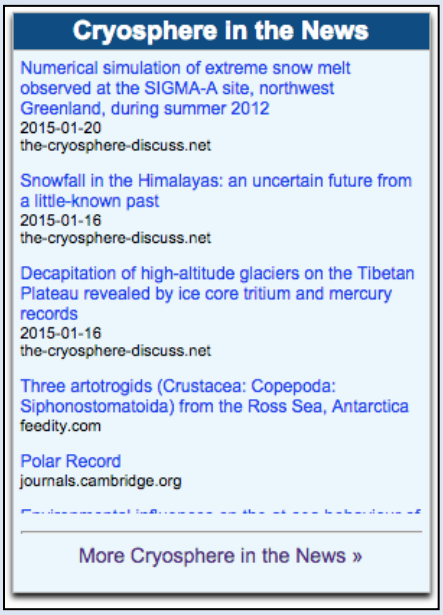
The GCW information website is globalcryospherewatch.org.

GCW Website. The purpose of the website is to provide a centralized point of access for background and operational information, observational user requirements, the state of the cryosphere, news and "hot topics", meeting information, GCW documents, outreach material, a description of the contributing observing networks and their capabilities, information on standards and best practices, and data policies. It links to the METNO data portal. The website is an information resource; the portal is a metadata and data resource.

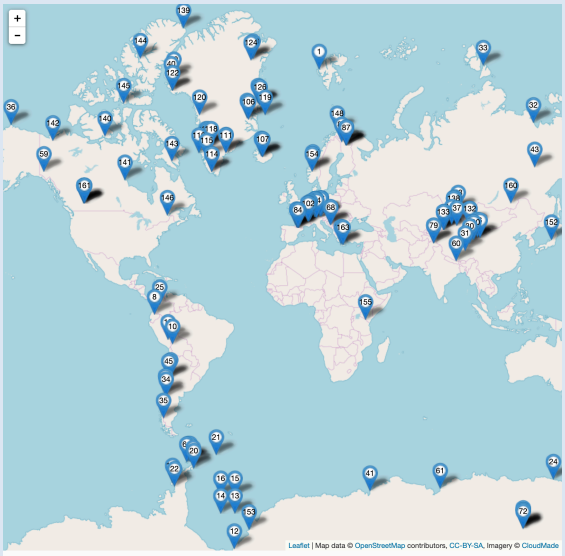
The GCW website provides information on the cryosphere for WMO Members, their partners, scientists, and the public. Near real-time information on the state of the cryosphere, news, and GCW activities is easily accessible.

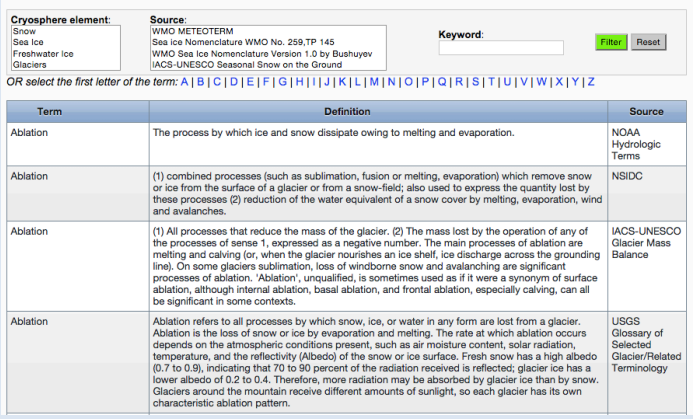
Cryosphere Now: The current state of the cryosphere is illustrated through a variety of near real-time graphics - generally daily but annual in some cases - for snow, sea ice, permafrost, glaciers, ice sheets, and the atmosphere. Near real-time scientific and media news is also available. Assessments of each cryosphere component are done at least annually.





GCW Surface Network: The GCW website provides all necessary information on the GCW surface network, including its core network "CryoNet". Site information, maps, requirements, and a site application are available.





Cryosphere element: Snow, Sea Ice, Freshwater Ice, Glaciers

Source: WMO METEOTERM; Sea ice Nomenclature WMO No. 259,TP 145; WMO Sea Ice Nomenclature Version 1.0 by Bushuyev; IACS-UNESCO Seasonal Snow on the Ground

Keyword: Filter Reset

OR select the first letter of the term: A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z

Term	Definition	Source
Ablation	The process by which ice and snow dissipate owing to melting and evaporation.	NOAA Hydrologic Terms
Ablation	(1) combined processes (such as sublimation, fusion or melting, evaporation) which remove snow or ice from the surface of a glacier or from a snow-field; also used to express the quantity lost by these processes (2) reduction of the water equivalent of a snow cover by melting, evaporation, wind and avalanches.	NSIDC
Ablation	(1) All processes that reduce the mass of the glacier. (2) The mass lost by the operation of any of the processes of sense 1, expressed as a negative number. The main processes of ablation are melting and calving (or, when the glacier nourishes an ice shelf, ice discharge across the grounding line). On some glaciers sublimation, loss of windborne snow and avalanching are significant processes of ablation. 'Ablation', unqualified, is sometimes used as if it were a synonym of surface ablation, although internal ablation, basal ablation, and frontal ablation, especially calving, can all be significant in some contexts.	IACS-UNESCO Glacier Mass Balance
Ablation	Ablation refers to all processes by which snow, ice, or water in any form are lost from a glacier. Ablation is the loss of snow or ice by evaporation and melting. The rate at which ablation occurs depends on the atmospheric conditions present, such as air moisture content, solar radiation, temperature, and the reflectivity (Albedo) of the snow or ice surface. Fresh snow has a high albedo (0.7 to 0.9), indicating that 70 to 90 percent of the radiation received is reflected; glacier ice has a lower albedo of 0.2 to 0.4. Therefore, more radiation may be absorbed by glacier ice than by snow. Glaciers around the mountain receive different amounts of sunlight, so each glacier has its own characteristic ablation pattern.	USGS Glossary of Selected Glacier/Related Terminology

Other tools: The website contains a number of other databases, including a multi-source glossary, observational requirements, satellite sensors for the cryosphere, and extreme events.

World Meteorological Organization
Global Cryosphere Watch

Snow Watch

The main goals of Snow Watch are to assess the maturity and accuracy of snow products, improve the reporting of and access to in situ snow measurements, promote the exchange of snow data and information for snow cover monitoring, and identify critical snow-related issues that need to be addressed in GCW.



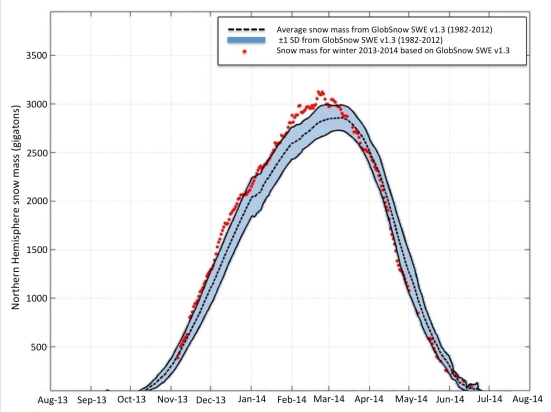
Snow Watch Activities

Current Snow Watch activities include:

- a satellite snow product validation and intercomparison project (ESA SnowPEX),
- a product inventory and self-assessment of products by principal investigators,
- a global snow data rescue project,
- "Snow Trackers" for snow cover extent and snow water equivalent (SWE),
- efforts to standardize snow-related nomenclature, and
- Improving reporting practices and real-time data for in situ snow measurements on the GTS network, enabling wider access to these observations.

Snow Watch: Development of Integrated Products

Snow Watch is making major advances in snow cover observation, monitoring and exchange of data and products from in-situ and satellite sources as part of GCW's goal to provide authoritative cryospheric information. Team members are drawn from across the global snow community.



FMI Northern Hemisphere SWE tracking product developed for WMO GCW

Credits for the photographs: Dave Halpin and Peter Toose (Environment Canada)

Examples of Snow Watch activities

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

Snow Watch snow dataset inventory

globalcryospherewatch.org/reference/snow_inventory.php

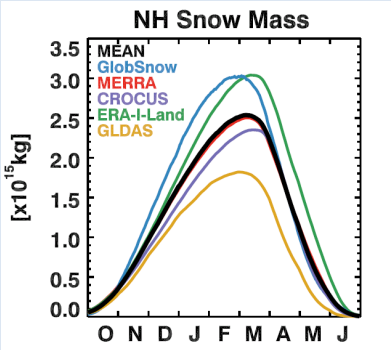
A searchable summary of currently available in situ, satellite-derived and reanalysis-driven snow datasets including information on documented caveats/issues. It is a living document with ongoing updates and additions.

ESA SNOWPEX
Satellite Snow Product Intercomparison and Evaluation Experiment

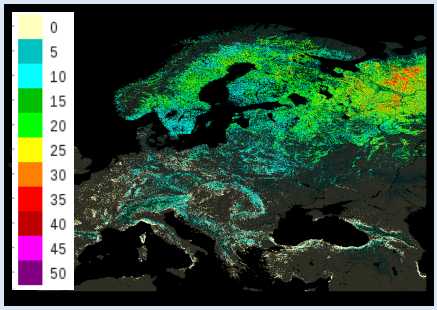
- The goal of SnowPEX is to assess the quality of current satellite-based snow extent and snow water equivalent products, and to develop guidelines for improvement.
- SnowPEX will obtain a quantitative understanding of the uncertainty in remotely sensed products through a coordinated and consistent evaluation exercise using ground reference measurements, high resolution optical imagery, and reanalysis and land surface model products.
- The GCW Snow Watch Team is supported in part by the SnowPEX program.

Participating snow extent and snow water equivalent products, and details on reference datasets are available at: http://snowpex.enveo.at

Project deliverables and supporting documentation are available at: http://calvalportal.ceos.org/263



The climatologies of Northern Hemisphere snow water mass (SWM; 1981-2010) vary by up to 50%



Disagreement between fractional snow covered area products reaches 40% particularly in forested areas

World Meteorological Organization
Global Cryosphere Watch

Snow Reporting

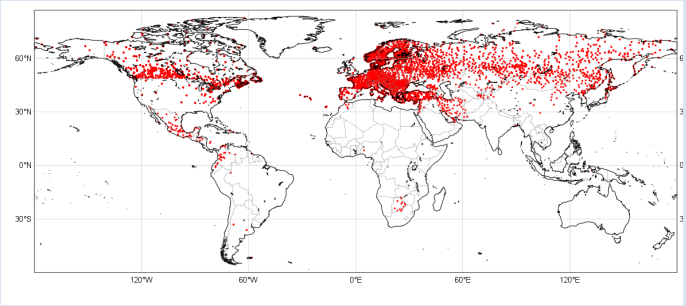
A Global Cryosphere Watch (GCW) *Snow Watch* Activity

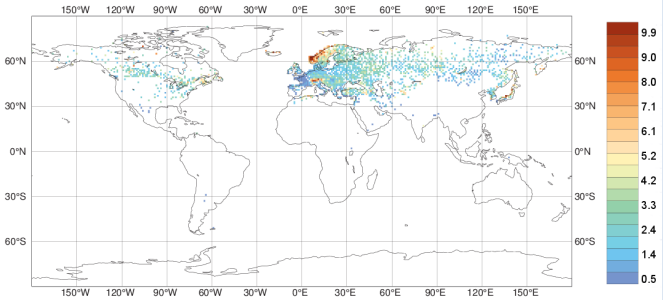
The GCW Snow Watch Team is striving to improve the reporting practices for in situ snow observations, to promote exchange of real-time observations between member states, and to improve the availability of in situ snow depth reports on the Global Telecommunication System (GTS). Ground-based observations of snow are very important for monitoring, model verification, validation of satellite-derived data, and assimilation into weather forecasting models. However, there are large amounts of potentially valuable data that are not reported or not available outside the country of origin. Snow Watch is actively promoting improvements to international snow data exchange on GTS with the aim of increasing the value of existing in situ snow networks.

In situ Snow Observations for Numerical Weather Prediction

- In situ snow depth and other snow observations constitute a very important and very reliable source of information for snow data assimilation.
- They are provided by the surface synoptic observations (SYNOP) station network and are made available in near real time on the GTS for numerical weather prediction (NWP).
- In addition to SYNOP observations, national meteorological services have access to their national snow depth measurement networks. However, these additional snow depth observations are currently not available on the GTS for the international NWP community.

Snow Depth data availability on WMO GTS, on 7 January 2017 (source ECMWF). Large gaps exist in USA, China and Southern Hemisphere. Recent improvements have been made in China, as all new reports are BUFR SYNOP.



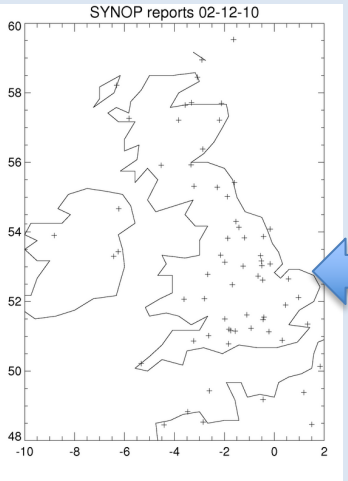


Above: Standard deviation of ECMWF background departure (cm of snow depth) December 2014 to February 2015. Large areas are blank, illustrating regions with observation gaps.

One of the key objectives of Snow Watch is to make the data from SYNOP and climate networks more widely available over the GTS.

Reporting Zero Snow Depth

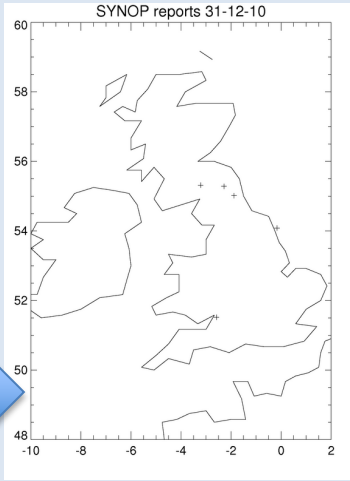
- Snow depth is generally only reported when snow is present, with “missing data” recorded for snow depth in snow-free conditions rather than “0 cm”.
- Data users cannot know whether this missing data indicates “no snow” or a missing report for another reason, e.g. technical issues at station. This “missing data” must therefore be discarded, though the majority of it could potentially contain valid positive reports of zero snow.
- For NWP applications, observations of no snow are very important for constraining model snow extent.



This example shows the large difference in the number of valid in situ snow depth reports in the UK between:

A day with extensive snow cover (02-12-10)

A day with little snow cover (31-12-10)

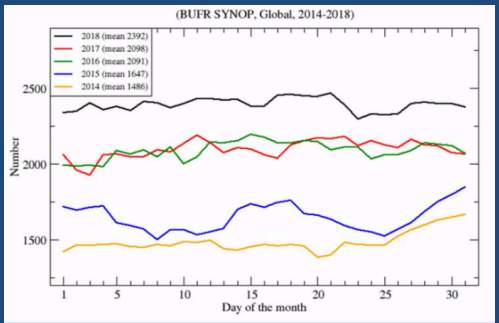


Snow Watch is addressing these issues by:

- Identifying non-SYNOP snow station networks that could contribute data.
- Engaging nations to encourage, and identify barriers to, more open data exchange.
- Promoting changes to WMO data exchange and reporting practice regulations.
- Encouraging nations to adopt improved reporting practices as soon as is practical.

Recent Improvements in Snow Reporting

As a result of Snow Watch efforts, the number of SYNOP stations reporting snow depth has increased dramatically over the last five years.



SYNOP Stations reporting snow depth in WIS, in December

For more information contact Samantha Pullen (Met Office) or Patricia de Rosnay (ECMWF).