WMO CBS activities relevant to observations in the Arctic

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Executive Summary

The WMO Rolling Review of Requirements (RRR) process has documented the user requirements for observations for all applications within WMO programmes and has developed Statements of Guidance (SoGs) on the extent to which these requirements are or will be met by present, planned and proposed observing systems. This paper describes the RRR process and explains the role of the user requirements and the SoGs in the development of the WMO "Vision for the Global Observing System (GOS) in 2025" and the Implementation Plan for the Evolution of the Global Observing Systems (EGOS-IP).

The paper discusses to what extent the requirements for observations in polar regions, and also the observing capabilities in these regions, are already captured by the RRR process and by the "Vision" and the EGOS-IP. Although it has been the intention to address polar observations in all these documents, it is likely that they contain some deficiencies. The Arctic observing community is encouraged to engage with the RRR process and to assist us in improving these processes and documents. This will help to drive appropriate developments within the WMO community to improve observing systems in polar regions and the application of the observations they provide.

1. The WMO/CBS Rolling Review of Requirements (RRR) process

1.1 Overview

It is a challenging exercise to develop a consensus view on the design and implementation of composite observing systems, in particular where the need and implementation occur on global or regional scales. The WMO Commission for Basic Systems (CBS) has encouraged the development of a process to accomplish this, as objectively as possible. The process is known as the Rolling Review of Requirements (RRR). It applies to each of the application areas covered by WMO programmes. Those currently identified are:

- Global numerical weather prediction (GNWP)
- High-resolution numerical weather prediction (HRNWP)
- Nowcasting and very short range forecasting (NVSRF)
- Seasonal and inter-annual forecasting (SIAF)
- Aeronautical meteorology
- Atmospheric chemistry
- Ocean applications
- Agricultural meteorology
- Hydrology
- Climate monitoring (as undertaken through the Global Climate Observing System, GCOS)
- Climate applications
- Space weather

Most of these applications cover, at least in part, polar regions. Special requirements and particular observing issues in polar regions are covered within the RRR process, as addressed in sections 4-6.

The RRR process jointly reviews users' evolving requirements for observations, and also the capabilities of existing and planned observing systems to meet them. As a result, through so-called "Statements of Guidance", experts in each application area address the extent to which the capabilities meet the requirements, and they produce **gap analyses** with recommendations on how these gaps could be addressed.

For each application area, the process consists of four stages:

(i) a review of "technology-free"[1] user requirements for observations, within an area of application covered by WMO programmes and co-sponsored programmes;

(ii) a review of the observing capabilities of existing and planned observing systems, both surface- and space-based;

(iii) a Critical Review of the extent to which the capabilities (ii) meet the requirements (i); and

(iv) a Statement of Guidance based on (iii).

The aims of the Statement of Guidance are:

- to inform WMO Members on the extent to which their requirements are met by present systems, will be met by planned systems, or would be met by proposed systems. The Statement of Guidance is essentially a gap analysis with recommendations on how to address the gaps. It also provides the means whereby Members, through the WMO's Technical Commissions, can check that their requirements have been correctly interpreted.
- to provide resource materials useful to WMO Members for dialogue with observing system agencies regarding whether existing systems should be continued or modified or discontinued, whether new systems should be planned and implemented, and whether research and development is needed to meet unfulfilled aspects of the user requirements.

The RRR process feeds information into two key documents:

- the "Vision for the Global Observing System" for the coming decade(s) – see section 2,
- the Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP) – see section 3.

These two documents are periodically revised and submitted to the WMO's Commission for Basic Systems (CBS) and Executive Council for approval. Indeed, the whole RRR process is a rolling activity through which all documents are periodically reviewed and updated, as observational requirements change and observing technology progresses. Figure 1 indicates the anticipated interactions with observing system agencies and user groups.

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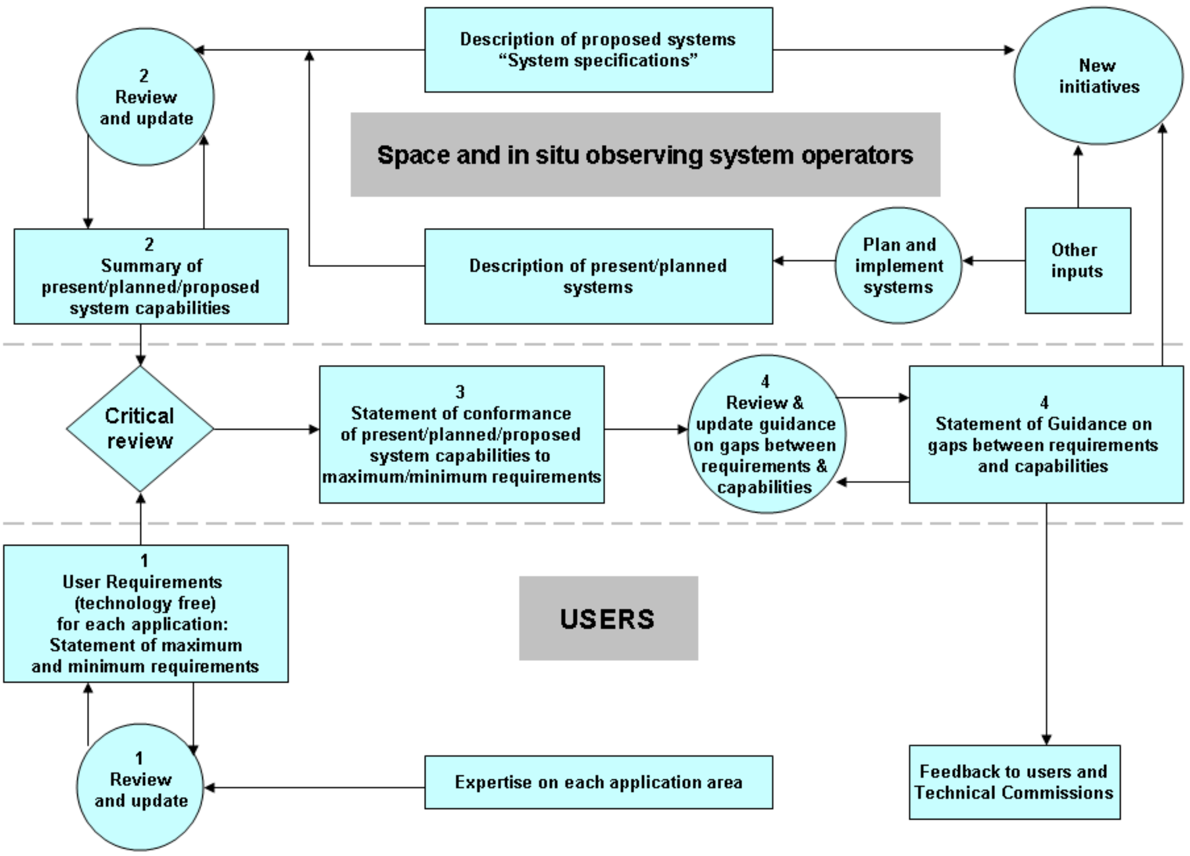
1 Technology-free means that the requirements do not take into account the available technology for making the observations, whether it is surface-based or space-based; they are independent of observing system capabilities as far as is possible.



Note: 1, 2, 3, 4 are the stages of the RRR process

Figure 1. Anticipated interactions within the Rolling Review of Requirements

1.2 Database of user requirements and observing system capabilities

To facilitate the RRR process, the Observing and Information Systems Department of the WMO Secretariat collects the requirements for observations to meet the needs of all WMO Programmes and co-sponsored Programmes, and also catalogues the current and planned provision of observations. The resulting database is called the Database on User Requirements and Observing System Capabilities and is accessible via the WMO website through the Observing Systems Capability Analysis and Review Tool (OSCAR)[2].

1.2.1 User requirements

The user requirements are not system-dependent; they are intended to be technology-free. No consideration is given to what type of instruments, observing platforms or data processing systems are necessary (or even possible) to meet them. The database is structured by application area (see section 1.1). The requirements for observations are stated quantitatively in terms of five criteria: horizontal and vertical resolution, frequency (observation cycle), timeliness (delay in availability), and uncertainty (i.e. acceptable r.m.s. error and any limitations on bias). For each application, there is usually no abrupt transition in the utility of an observation as its quality changes; improved observations (in terms of resolution, frequency, accuracy, etc.) are usually more useful while degraded observations, although less useful, are usually not useless. Moreover, the range of utility varies from one application to another. Therefore, for each of these criteria, the requirement includes three values determined by experts: the "goal", the "threshold", and the "breakthrough".

2 http://www.wmo.int/oscar

- The “goal” or “maximum requirement” is the value above which further improvement of the observation would not cause any significant improvement in performance for the application in question. The goals are likely to evolve as applications progress and develop a capacity to make use of better observations.

- The “threshold” or “minimum requirement” is the value that has to be met to ensure that data are useful. Threshold requirements for any given observing system cannot be stated in an absolute sense; assumptions have to be made concerning which other observing systems are likely to be available (and this represents a departure from the strict idea of “technology-free”).

- Within the range between threshold and goal requirements, the observations become progressively more useful. The “breakthrough” is an intermediate level between “threshold” and “goal” which, if achieved, would result in a significant improvement for the targeted application.

1.2.2 Observing system capabilities

For the capabilities of space-based observing systems, each of the contributing space agencies has provided a summary of the potential performances of their instruments, expressed in the same terms as the user requirements, together with sufficiently detailed descriptions of the instruments and missions to support evaluation of the performances. Assessment of service continuity is based on the programmatic information supplied. Particular care has been taken to establish a common language, in the form of agreed definitions for the geophysical variables for which observations are required / provided and agreed terminology to characterise requirements and performances. The space-based capabilities are accessible through the satellite component of OSCAR[2] (i.e. OSCAR/Space).

The performance of elements of surface-based observing systems are to be characterised in a similar manner, and made accessible via the surface component of OSCAR[2] (i.e. OSCAR/Surface), taking into account their uneven distribution on a global basis. While the development of OSCAR/Space is well advanced and now operational, OSCAR/Surface is yet to be specified and implemented.

1.3 Critical Review and Statements of Guidance

The comparison of requirements to capabilities utilizes the information contained in the database of OSCAR[2]. As the database changes to reflect more effectively the user requirements as well as existing and planned observing capabilities, the RRR must be performed periodically.

With the aid of the information in the database and additional expert knowledge, the critical review phase of the RRR process compares user requirements with the observing system capabilities in terms of the extent to which the capabilities of present, planned and proposed systems meet the stated requirements. In some cases, it is possible to make use of the results of impact studies such as Observing System Experiments (OSEs), Observing System Simulation Experiments (OSSEs) and other assessment tools.

The role of a Statement of Guidance (SoG) is to provide an interpretation of the output of the critical review as a gap analysis, to draw conclusions, and to identify priorities for action. The process of preparing such a statement is necessarily more subjective than that of the critical review. Moreover, whilst a review attempts to provide a comprehensive summary, a SoG is more selective, drawing out key issues. It is at this stage that judgements are required concerning, for example, the relative importance of observations of different variables.

The following terminology has been adopted in the SoGs. “Marginal” indicates minimum user requirements are being met, “Acceptable” indicates greater than minimum but less than maximum requirements (in the useful range) are being met, and “Good” means close to maximum requirements are being met.

Since the preliminary SoGs were published in 1998, several updates and additions have been completed in order to extend the process to new application areas, to take into account the evolving nature of requirements, and to include the capabilities of surface-based sensors. The latest SoGs can be found on the WMO website[3].

2. Vision for the Global Observing System in 2025

The “Vision for the GOS” provides high-level goals to guide the evolution of observing systems in the coming decades. These goals are intended to be challenging but achievable. The Vision foresees that future observing systems will build upon existing sub-systems, both surface- and space-based, and capitalize on existing, new and emerging observing technologies not presently incorporated or fully exploited. Incremental additions to observing systems will be reflected in better data, products and services from the National Meteorological and Hydrological Services (NMHSs).

The Vision for the GOS is proposed by the CBS following wide consultation with experts in the user and observational communities, taking into account the SoGs and foreseen technological developments, both in terms of future application areas’ requirements and observational technology evolution, both surface- and space-based.

The latest version of the Vision – the "Vision for the GOS in 2025“ - is available from the WMO website[4].

3. Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP)

Responding to the Vision and to the needs of the WMO Integrated Global Observing System (WIGOS), the EGOS-IP is a key document providing Members with clear and focused guidelines and recommended actions, in order to stimulate cost-effective evolution of the observing systems and to address in an integrated way the requirements of WMO programmes and co-sponsored programmes.

The EGOS-IP is produced by the CBS following wide expert review through the RRR process, considering the SoGs for all WMO Applications Areas, and taking account of cost-effectiveness and WMO priorities.

The latest version of EGOS-IP was endorsed by CBS in 2012 and is available from the WMO website[5].

4. Some challenges of observing in polar regions

Some applications of observations, e.g. global NWP and climate monitoring, are global in nature; for many geophysical variables, the requirements for observations from polar regions are not significantly different from those for other parts of the world. However, the problems faced in obtaining them are often special and challenging. Surface-based observations in the polar regions are usually expensive, as in other sparsely populated areas, and the harsh environments pose unique challenges for observing technologies. Space-based observations also face special difficulties of interpretation, e.g. snow and ice cause problems for the detection of cloud, and the variable surface emissivities of ice and snow complicate the retrieval of atmospheric variables.

In addition, geophysical variables of marginal interest in other parts of the world become dominant in polar regions: all aspects of the cryosphere, and the fluxes of heat, water and momentum between the cryosphere and the ocean and land.

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3 http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html#SOG
4 http://www.wmo.int/pages/prog/www/OSY/gos-vision.html
5 http://www.wmo.int/pages/prog/www/OSY/gos-vision.html#egos-ip

Satellite observations from geostationary platforms become of decreasing value at high latitude. Greater emphasis is placed here on observations from polar orbiters. There is also a growing interest in new satellites in highly elliptical orbits, which offer improved frequency of coverage in polar regions.

Argo floats providing profiles of ocean water temperature and salinity have specific problems when under sea ice; they cannot pop up to the surface in order to transmit their observations in real-time via satellite. The use of ice tethered platforms can address this gap to some extent.

5. EGOS-IP and polar observations

The EGOS-IP contains 115 "Actions". Some of these are generic and apply just as much in polar regions as elsewhere. However, some are specific to or particularly important in polar regions, as described below.

The introduction to the 2012 version of EGOS-IP (section 1.3) recognises that the new EGOS-IP responds to important inputs from several sources. Among these are the plans of the Global Cryosphere Watch (GCW).

The section addressing the expansion of observing networks (EGOS-IP section 3.4) recognises that some observations of the land-based cryosphere are part of operational networks; others are part of research programmes and are not acquired in a consistent manner. There is a large and acknowledged gap internationally in the ability to measure reliably solid precipitation (snowfall, snow depth, ice and rain water equivalent). Solutions should leverage new technologies and techniques for making in situ and remotely-sensed observations, and research is needed to integrate the two types of observations. For example, while snow depth is regularly measured at many land stations, lake ice cover and glacier mass balance are not. Improvements in snowfall observing practices and consistent and regular reporting are needed along with other variables. Some critical snow and ice properties, such as snowfall, snow water equivalent (SWE) and permafrost properties, are difficult to measure from space as well as in situ, though new technologies and satellite sensors are promising. The GCW will evaluate the surface- and space-based cryosphere observing systems and will provide recommendations for reducing the gap between current capabilities and user needs.

Section 5.3.2.3 of EGOS-IP explicitly covers Global Cryosphere Watch stations. It recalls that the recently established Global Cryosphere Watch (GCW) programme will set up a comprehensive cryosphere observing network called "CryoNet": a network of reference sites or "super-sites" in cold climate regions, operating a sustained, standardized programme for observing and monitoring as many cryospheric variables as possible at each site. Initially, it will build on existing cryosphere observing programmes or add standardized cryospheric observations to existing facilities as part of super-site environmental observatories. As encouraged by GCOS, GCW will facilitate the establishment of high-latitude super-sites 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). GAW stations in cold climates are logical candidates. CryoNet reference sites will provide long-term data sets for monitoring climate variability and change, improved model parameterization of cryospheric processes, and support for development and validation of satellite products and forecast, climate, hydrologic and cryospheric models. The CryoNet Team of the GCW Observing Systems Working Group will develop formal procedures for establishing the GCW network, evaluate potential supersites, and determine data availability. This section of the EGOS-IP includes two Actions:
Action G35: Implement as soon as possible a comprehensive cryosphere observing network of reference sites "CryoNet".
Action G36: Provide, as far as possible, a real-time or near-real-time exchange of the cryospheric data from CryoNet. Follow the GCW, WIGOS and WIS practices for implementing this dissemination, and the standard quality assessment practices and archiving.

Section 5.3.6.5 covers ice buoys. Ice buoys observe some of the following variables: surface pressure, temperature, wind, ice thickness, and upper ocean temperature and salinity. Sea ice motion

is derived from the buoys' movements. Some buoys measure only air temperature, surface pressure, and position (therefore motion). More robust measurements are made by ice mass balance (IMB) buoys, which can measure snow depth, ice thickness, the ice temperature profile, ice motion and some meteorological variables. In 2012, about 50 buoys were in service in the Arctic Ocean at any time, though fewer than ten measure ice and snow thickness. As with buoys deployed in the open ocean, surface pressure is a very important variable for NWP, and this is especially true for the northern polar cap which is otherwise a gap in the data coverage. Ice thickness, snow depth and temperature are also key variables to monitor in the context of climate change, and also for many marine applications. This section of EGOS-IP includes an Action:
Action G55: Increase ice buoy data coverage on the northern polar cap through a regular deployment of new drifters.

Section 5.3.7.2 covers ice tethered platforms. The ice-tethered platforms move at the speed of the ocean ice cover (slowly) while observing the temperature, the salinity and the current underneath. Because of the lack of other techniques for monitoring the deep polar oceans that are frozen at the surface, the ice-tethered platforms have an important role with respect to the global data coverage of oceanic data. In the context of research projects dedicated to the Arctic Ocean, pCO_2 (ocean acidity) and CH_4 sensors have been also used on ice-tethered platforms. [6]

Section 6.3.2.3 covers high-resolution multi-spectral visible/infra-red imagers on polar-orbiting satellites. Data from these instruments have many uses, including the generation of AMVs (cloud-tracked winds or water-vapour-tracked winds) at high latitudes. MODIS[7] winds have been used in operational NWP for several years, and a very significant positive impact has been demonstrated, probably due to the lack of other types of upper-air wind observations over the polar caps.
This section includes two EGOS-IP Actions:
Action S18: Use the imagers of all operational polar orbiting platforms to produce AMVs from the tracking of clouds or water vapour features.
Action S19: Implement a water vapour channel (e.g. 6.7 µm) on the imager of all core meteorological polar-orbiting satellites to facilitate the derivation of polar winds from water vapour motion.

Section 6.3.2.4 covers microwave imagers on polar orbiting satellites. These are used to monitor many atmospheric, land and ocean variables including surface temperature, sea-ice and snow water equivalent. Microwave sensors have been particularly important for monitoring the sea ice limits around the polar caps.

Section 6.3.3.3 covers the satellite altimeter constellation. Several altimeters are able to provide measurements on ice topography (over sea and land) and on the lake levels (applications to glacier monitoring and hydrology). Unfortunately, there is a gap in laser altimetry between NASA's first and second ICESat satellites. While the radar altimeter on Cryosat-2 is also for sea and land ice measurements, the ideal altimeter constellation would have both laser and radar altimeters. The combination would provide greater accuracy in sea ice thickness estimates, and might provide information on the depth of snow on the ice.

Section 6.3.3.10 covers Synthetic Aperture Radar (SAR). These instruments provide information on many geophysical variables including sea ice caps, ice sheets and icebergs.

Section 6.3.4.5 addresses visible / infra-red imagers on satellites in high inclination and highly elliptical orbit (HEO). The HEO has never been used in meteorology and oceanography. Its main advantage is that the satellite can stay close to the vertical of one particular region of the Earth (at high altitude) for several hours, and only a reduced time on the opposite side of the Earth. When the orbit inclination on the equator is high, it almost offers the observation continuity similar to that of a geostationary satellite but in a polar region. With visible / infra-red sensors onboard, a HEO satellite would offer an almost continuous observation of the large number of meteorological and oceanic variables normally observed by this type of sensors: clouds (and AMVs) at high latitudes, surface temperature, sea-ice, ash plumes, vegetation, fires and snow cover. This section of EGOS-IP

6 http://www.whoi.edu/science/PO/arcticgroup/projects/ipworkshop_report.html
7 MODIS: MODerate-resolution Imaging Spectrometer (onboard AQUA and TERRA satellites).

includes an Action:
Action S35: Plan and design a demonstration mission with visible / infra-red instruments onboard a HEO satellite with a highly elliptical orbit and a high inclination over the equator, in order to target a polar area. The aim is to obtain the same environmental observations with a quality similar to those obtained from GEO satellites.

6. Deficiencies in current WMO/CBS efforts – how the polar community might contribute

The databases of user requirements and of observing system capabilities are living documents, which are regularly updated. Similarly, the SoGs are periodically reviewed and updated. Also, progress against Actions in the EGOS-IP is regularly reviewed and, when necessary, Actions are revised or added.

These activities are managed within CBS in collaboration with other Technical Commissions, and efforts are made to involve appropriate contacts (applications experts and observing technology experts) to ensure that the information is accurate and relevant. Nevertheless, the information will only be as good as the inputs received and the extent to which the key documents of the RRR process have been reviewed by external experts and stakeholders.

CBS encourages feedback from WMO Members, Regions, other Technical Commissions and other stakeholders. The RRR process is intended to be comprehensive, covering all application areas of WMO programmes and co-sponsored programmes. Therefore it should cover applications, whether global, regional or national. It is important that any deficiencies in this respect are reported back to CBS so that they can be considered and corrected. Members and Regions are also encouraged to adopt the concepts of the RRR process when considering observing system developments specific to their own country or region.

During the development of the SoGs, the Vision and the EGOS-IP, it has been our intention to address the requirements and capabilities in polar regions. However, for most applications areas, polar regions have not been the focus of attention, and it is likely that deficiencies exist in statements and plans for this reason.

We therefore encourage experts in polar observations and in their application: to help us improve the contents of the databases of user requirements and of observing system capabilities, to review the SoGs for applications that span polar regions and to draw attention to any deficiencies, and to comment on the “Vision” and the EGOS-IP with regard to any important gaps concerning statements on observing systems in polar regions.

Engagement in these activities will be an effective way of reaching out to the WMO/CBS community, and thus to gaining the attention of key agencies involved in the implementation of global observing systems, including those that are crucial for monitoring in polar regions. It is our intention to continue to involve experts in polar observing in our efforts to monitor progress against the EGOS-IP and to review evolving requirements and capabilities.