ECMWF Feature article

from Newsletter Number 153 – Autumn 2017

METEOROLOGY

How to evolve global observing systems

www.ecmwf.int/en/about/news-centre/media-resources
doi:10.21957/9fxea2

This article appeared in the Meteorology section of ECMWF Newsletter No. 153 – Autumn 2017, pp. 37-40.

How to evolve global observing systems

Erik Andersson

The evolution of global observing systems is driven by user requirements as coordinated by the World Meteorological Organization (WMO). The WMO Integrated Global Observing System (WIGOS) is the combination of satellite-based and surface-based observations that contribute information for WMO programmes. The observations come from satellite programmes managed by space agencies and from a number of observing networks managed by government agencies or commercial operators (Figure 1).

ECMWF works closely with the WMO to make sure the best possible observations are available to the Centre. They are used for data assimilation in ECMWF's Integrated Forecasting System (IFS), which comprises atmosphere, ocean, land, river, sea-ice and atmospheric composition models, as well as for forecast verification. ECMWF is represented in the WMO Expert Teams that gather observation requirements and update them in line with the evolving needs for more complete real-time monitoring of the Earth system and higher accuracy.

As part of a rolling requirements review, Statements of Guidance are produced in several application areas. These feed into a vision document which gives high-level guidance on how observing systems should develop. A 'Vision for WIGOS in 2040' is currently under review. One of the developments acknowledged in the draft Vision is the increasing variety of organisations that are running observing systems of interest to WMO application areas. The aim, strongly supported by ECMWF, is to integrate these observations into one overall system where possible.

Figure 1 The WMO Integrated Global Observing System (WIGOS) combines the observing capabilities of surface- and space-based platforms and stations to serve a variety of weather and climate needs. (*Graphic: WMO*)

ECMWF's involvement

The IFS is observation hungry: observations are needed to initialise the various components of the Earth system model at increasing resolution, with the best possible accuracy and in a timely manner. ECMWF's Strategy 2016–2025 calls for improved Earth system modelling and data assimilation to enable better weather forecasts. This will require more observations of the atmosphere, the deep ocean, the ocean and land surfaces, rivers and lakes, atmospheric composition and sea ice. The associated observation requirements evolve in time as the models' realism improves. Continued progress towards improved weather forecasts thus depends on sustained investment in the capabilities to observe the Earth system.

doi:10.21957/9fxea2

ECMWF plays an active role in the WMO rolling requirements review process. In addition to its representation in WMO Expert Teams on observations, ECMWF's Deputy Director of Forecasts (the Author) was until recently the Point of Contact in the global numerical weather prediction (NWP) application area and the Rapporteur to the WMO on the scientific evaluation of the impact of observations on NWP. He now chairs the WMO Inter-Programme Expert Team on the Observing System Design and Evolution (IPET-OSDE). ECMWF's participation is an important avenue to emphasise the importance of the WIGOS observing networks that weather forecasting relies on.

Rolling review

To make sure that all WMO programmes are served by relevant data, observation requirements are gathered in a systematic way. This is done in a similar manner for 12 application areas that each make direct use of observations. Examples of application areas are Global NWP, Regional NWP, Nowcasting and Very Short Range Forecasting, Sub-Seasonal to Longer Prediction, Climate Monitoring, and Hydrology. The full list of application areas is given in Table 1. A WMO application area comprises activities for which it is possible to compile a consistent set of observational user requirements agreed by community experts working operationally in this area.

An expert in each application area serves as the Point of Contact: the conduit between the stakeholder community for that application area to the rolling requirements review (RRR) and the requirements database (OSCAR). The stakeholder community includes national meteorological and hydrological services (NMHSs), WMO Regional Associations, and WMO Technical Commissions and their expert teams.

Application area	Point of Contact for latest SoG	Date of latest SoG
Global NWP	Erik Andersson (ECMWF)	June 2016
High Resolution NWP	Thibaut Montmerle (France)	June 2016
Nowcasting and Very Short Range Forecasting	Paolo Ambrosetti (Switzerland)	June 2015
Sub-seasonal to longer predictions	Yuhei Takaya (Japan)	June 2016
Aeronautical Meteorology	Jitze van der Meulen (Netherlands)	June 2016
Forecasting Atmospheric Composition	Oksana Tarasova (WMO)	-
Ocean Applications	Guimei Liu (China)	June 2016
Agricultural Meteorology	Robert Stefanski (WMO)	June 2011
Hydrology	Silvano Pecora (Italy)	July 2014
Climate Monitoring	GCOS Secretariat	2010
Climate Science	WCRP	-
Space Weather	Terry Onsager (USA)	May 2012

Table 1 For each application area, the Statement of Guidance (SoG) provides an assessment of the adequacy of observations to fulfil requirements and suggests areas of progress towards improved use of space-based and surface-based observing systems.

The RRR process serves to review the evolving requirements for observations and the capabilities of existing and planned observing systems. Through so-called 'Statements of Guidance' (SoG), the expert Point of Contact in each application area addresses the extent to which the capabilities meet the requirements, and they produce gap analyses with recommendations on how these gaps could be addressed. The SoGs are available online at: *www.wmo.int/pages/prog/www/OSY/GOS-RRR.html*.

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

(i) a review of technology-free 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).

This process is repeated in an approximately 18-month cycle. The aim of the SoGs is to inform WMO Members of the extent to which their requirements are met by present systems, will be met by planned systems, or would be met by proposed systems. An SoG is essentially a gap analysis with recommendations on how to address the gaps. The SoGs also serve as a useful resource for dialogue with observing system agencies on whether existing systems should be continued, modified or discontinued; whether new systems should be planned and implemented; and whether research and development is needed to meet unfulfilled user requirements.

For example, the most recent update of the SoG for Global NWP highlights the need for more wind observations, particularly in the tropics and the Arctic. It notes that, over most of the Earth, observations of 3D wind fields are "marginal or poor", while coverage of surface wind is "marginal or absent" over some areas in the tropics and the Arctic. The Statement concludes that wind profiles at all levels outside the main populated areas are a top priority among variables that are not adequately measured by current or planned systems. A full summary of the SoG for global NWP is given in Box A.

Summary of Statement of Guidance for global NWP **A**

Global NWP centres:

- make use of the complementary strengths of in situ and satellite-based observations;
- have shown strong positive impact from advanced microwave sounding instruments (such as AMSU-A);
- have shown strong positive impact also from high spectral resolution sounders with improved vertical resolution (AIRS, IASI and CrIS);
- have shown strong positive impact from radio occultation data in the upper troposphere and lower stratosphere in particular;
- use 4D data assimilation systems to benefit from more frequent measurements (e.g. from geostationary satellites, aircraft and automated surface stations) and from measurements of cloud, precipitation, ozone, etc.;
- benefit from the improved timeliness of key satellite data resulting from systems such as DBNet;
- would benefit from further increased coverage of aircraft data, particularly from ascent/descent profiles in the tropics;
- are beginning to see the benefits from global dissemination of high-resolution BUFR radiosonde measurements with detailed time-space information;
- would benefit from more timely availability and wider distribution of some observations, in particular several types of in situ measurement and radar that are made but not currently disseminated globally, such as soil wetness, snow depth, precipitation from rain gauges and radar and ground-based GPS;
- would benefit from more ice thickness data and surface salinity.

The critical atmospheric variables that are not adequately measured by current or planned systems are (in order of priority):

- wind profiles at all levels outside the main populated areas;
- temperature and humidity profiles of adequate vertical resolution in cloudy areas, particularly over the poles and sparsely populated land areas;
- satellite based rainfall estimates;
- snow equivalent water content.

 doi:10.21957/9fxea2

Based on knowledge of the current and planned observing systems, the gaps identified by the SoGs, and an assessment of which future observing systems are likely to be feasible and affordable, the 'Vision for WIGOS in 2040' (currently under review) provides guidance on the component observing systems to which the WMO community should aspire. A plan to achieve this Vision will subsequently be developed. Currently WMO Members are working towards the 'Implementation Plan for the Evolution of Global Observing Systems', which is based on the vision document for 2020. The implementation plan is available at: *www.wmo.int/pages/prog/www/OSY/Publications/EGOS-IP-2025/EGOS-IP-2025-en.pdf*.

Defining user requirements

The user requirements are not system dependent and are intended to be technology-free. No consideration is given to what type of measurement characteristics, observing platforms or data processing systems are necessary (or even possible) to meet them. An online database has been constructed that can be viewed in the context of a given application via a convenient user interface (OSCAR, see Figure 2 and Box B). 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 (acceptable 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.

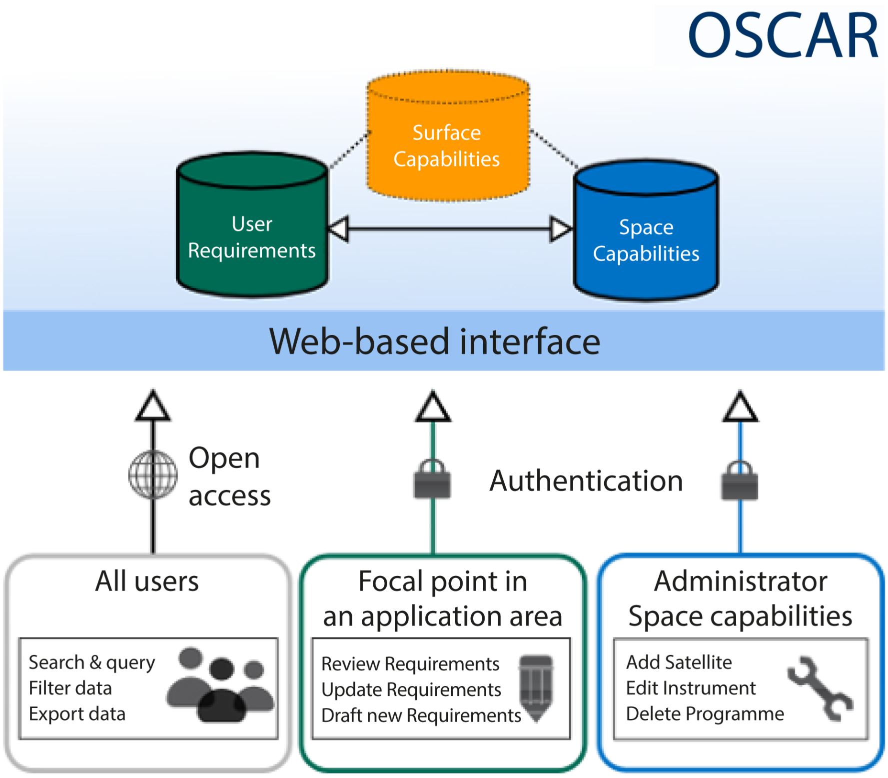

Figure 2 Schematic overview of OSCAR, the WMO Observing Systems Capability Analysis and Review Tool. OSCAR can be accessed online at: *www.wmo-sat.info/oscar*. (*Diagram: WMO*)

What is OSCAR?

B

OSCAR is a resource developed by the WMO in support of Earth observation applications, studies and global coordination.

OSCAR/Requirements contains quantitative user-defined requirements for observations of physical variables in WMO application areas (i.e. related to weather, water and climate). OSCAR/Space provides detailed information on all Earth observation satellites and their instruments and measurement capabilities, while OSCAR/Surface contains information about in-situ observing stations.

Through its three databases OSCAR targets all users interested in the status and the planning of global observing systems as well as data users looking for instrument specifications and the observing capabilities of each platform or station.

User requirements are recorded in tables which can be sorted and filtered, e.g. by variable, application or spatial domain. Variables are defined in a technology-free manner, i.e. without being constrained by space- or surface-based measuring capabilities. They do not necessarily overlap with the direct output of a specific instrument. Requirements for these variables are expressed in terms of the following criteria: uncertainty, horizontal and vertical resolution, observing cycle and timeliness.

For each WMO application area, requirements are directly maintained online by the designated Point of Contact and are regularly reviewed by groups of experts. This process is overseen by the Inter-Programme Expert Team on the Observing System Design and Evolution (IPET-OSDE).

Therefore, for each of these criteria, the requirement includes three values determined by experts: the ‘goal’, the ‘threshold’, and the ‘breakthrough’ value.

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. This is deemed to be the case if the cost of improving the observations beyond the goal would not be matched by a corresponding benefit. 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. Below this minimum, the benefit derived does not compensate for the additional cost involved in using the observation. 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.

Within the range between the threshold and the goal, 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.

Vision for 2040

The ‘Vision for WIGOS 2040’ 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 attempts to address the needs of all application areas with WMO programmes and co-sponsored programmes to which WIGOS responds. The Vision considers that future observing systems will build upon existing sub-systems, both surface- and space-based, while making use of existing, new and emerging observing technologies not presently incorporated or fully exploited. The Vision incorporates observations acquired by commercial operators (surface- and space-based) and acknowledges their importance as well as the challenges involved in ensuring the free and open exchange of such data between NMHSs.

The Vision document has recently been drafted and is currently going through an extensive review process amongst WMO Members and Expert Teams with the aim of final approval in 2019.

The draft Vision acknowledges that NMHSs are no longer the sole providers of ground-based meteorological observations. Instead, typically a variety of organisations are now running observing systems of interest to WMO application areas. These may be different government agencies operating under the ministries of agriculture, energy, transport, tourism, environment, forestry, water resources, etc. Especially in developing countries, they may be non-profit organisations or commercial entities. It is a principle of WIGOS to integrate these observations into one overall system as far as possible.

doi:10.21957/9fxea2

On the satellite side, the Vision retains a strong focus on operational geostationary and polar-orbiting platforms. In addition it considers the possibilities of instruments in Highly Elliptic Orbits (HEO) that would permanently cover the polar regions; Low-Earth Orbit (LEO) satellites with low or high inclination for a comprehensive sampling of the global atmosphere; and lower-flying platforms, for example small satellites serving as gap fillers or for dedicated missions which are best realised that way.

Amongst surface-based platforms, the Vision includes the traditional networks as well as new opportunities from automated low-cost observations collected from mobile phones and cars for example, which have the potential to provide a wealth of information in urban areas in particular.

Conclusion

The global observing system needs to evolve constantly to meet changing user requirements in all WMO application areas. One of the challenges WIGOS faces is the growing variety of potential observation providers, including commercial entities. ECMWF plays an active role in the WMO-led process to define user requirements and develop guidance on future observing systems. In this way the Centre can help to ensure that WIGOS provides the observations that are needed for continued improvements in global numerical weather prediction.

doi:10.21957/9fxea2