REQUIREMENTS FOR OBSERVATIONAL DATA :

THE ROLLING REQUIREMENTS REVIEW

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 Requirements Review (RRR). It applies to each of the application areas covered by WMO programmes, namely :

- Global Numerical Weather Prediction (GNWP)
- High Resolution Numerical Weather Prediction (HRNWP)
- Synoptic meteorology
- Nowcasting and Very Short Range Forecasting (NVSRF)
- Seasonal and Inter-annual Forecasts (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

In addition, requirements for WMO polar activities, and the developping Global Framework for Climate Services (GFCS) are also being considered.

1 The Rolling Requirements Review (RRR) Process

The process jointly reviews users' evolving requirements for observations and the capabilities of existing and planned observing systems. As a result, through so called Statements of Guidance, experts in each application area address the extent to which such capabilities meet the requirements, and produce gap analysis with some recommendations on how those gaps could be addressed.

Initially, the process was applied to the requirements of GNWP and the capabilities of the space-based subsystem but more recently the range of requirements has been expanded and the technique has begun to be applied successfully to surface-based observing systems and other application areas.

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

(i) a review of *technology free*[1] users' 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;

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 not observing system dependant.

(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 aim of the Statement of Guidance, together with the output of the Critical Review, is:

- 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 anylysis with recommendations on how to address the gaps. It also provides the means whereby Members, through the Technical Commissions, can check that their requirements have been correctly interpreted and can update them if necessary, as part of the Rolling Requirements Review process.

- 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.

Recommendations to WMO Members are compiled within two key documents, which production requires wide community review looking at all Statements of Guidance, address cross cutting issues between application areas, as well as cost-effectiveness and priorities:

1. The Vision of the Global Observing System for the coming decade(s);
2. The Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP), which is responding to the Vision of the Global Observing System (GOS).

These two documents are eventually submitted to the CBS and the Executive Council for approval.

Clearly, the RRR process needs to be repeated periodically as requirements change and further information becomes available. Figure 1 indicates the anticipated interactions with observing system agencies and user groups.

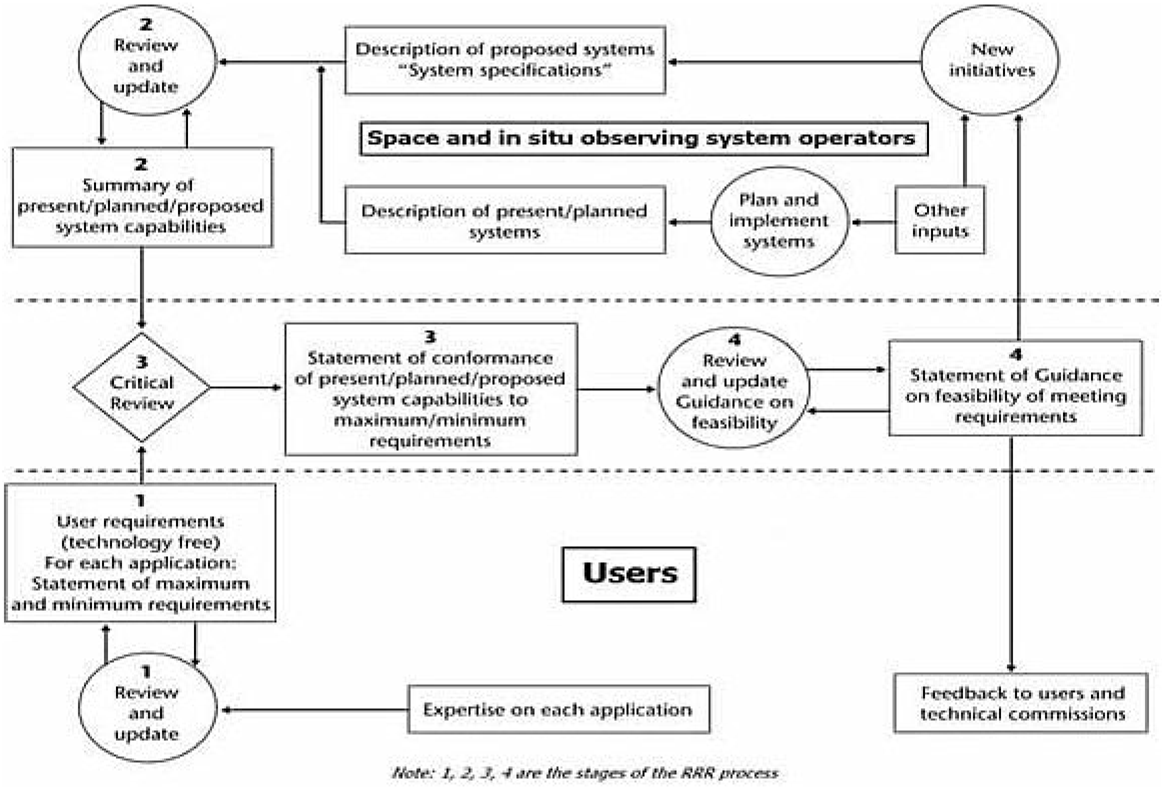

Figure 1: Anticipated interactions within the Rolling Requirements Review

2 The Database on User Requirements and Observing System Capabilities

To facilitate the RRR process the Observing and Information Systems Department of the WMO Secretariat is collecting the requirements for observations to meet the needs of all WMO Programmes, and also cataloguing the current and planned provision of observations, initially from environmental satellites and now extended to in situ observing systems. The resulting database is called the Database on User Requirements and Observing System Capabilities and is accessible via the WMO website[2]. For example, Annex I, extracted from this database, tabulates a part of the observations required currently for GNWP.

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 measurement characteristics, observing platforms, or data processing systems are necessary (or even possible) to meet them. The requirements are aimed at the *GOS Vision*[3] time frame. The database has been constructed in the context of a given application (use). The requirements for observations are stated quantitatively in terms of five criteria, which are horizontal and vertical resolution, frequency (observation cycle), timeliness (delay in availability), and accuracy (acceptable RMS 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

2 http://www.wmo.int/pages/prog/www/OSY/RRR-DB.html
3 The Vision of the GOS for the coming decade(s) is provided on the following website: http://www.wmo.int/pages/prog/www/OSY/gos-vision.html

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“.

- The “goal” is a maximum requirement. It is an ideal value above which further improvement of the observation would not cause any significant improvement in performance for the application in question. 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” is the minimum requirement 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 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. The breakthrough level may be considered as an optimum from a cost-benefit point of view, when planning or designing observing systems.

2.2 Observing system capabilities

Initially, attention has focussed on the capabilities of the GOS space-based subsystem. 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 parameters for which observations are required / provided and agreed terminology to characterise requirements and performances.

At present, the performance of elements of the GOS surface-based subsystem have also been characterised in a similar manner, taking into account their uneven distribution on a global basis in thirty-four homogeneous regions.

3 Cost-benefit considerations

User requirements are expressed in a technology-free manner, and therefore cost-free also. However, decisions on design and implementation of observing systems must take account of cost. The relationship between user requirements, as defined by the RRR process, and decisions on design and implementation of observing systems based on cost-benefit considerations is therefore important. The cost-benefit curve for a single observing system, in the context of a single application, is illustrated schematically in Figure 2 below. It is assumed that "benefit" can be estimated quantitatively and also that it can be expressed in financial terms. The cost-benefit curve has the following generic characteristics:

- A significant cost must be incurred before any significant benefit is derived. Beyond this point (B), additional cost then results in increasing benefit. However, a point (A) is reached beyond which additional cost does not bring any significant benefit;
- The "maximum" and "minimum" requirements of the CBS method map on to points A and B respectively.;
- The costbenefit curve will (normally) first cross the line of equal cost-benefit at the "break even" point. It represents the point above which we can make a (business) case for implementing the system.
- The optimal point, representing the highest ratio of benefit to cost, is also shown.

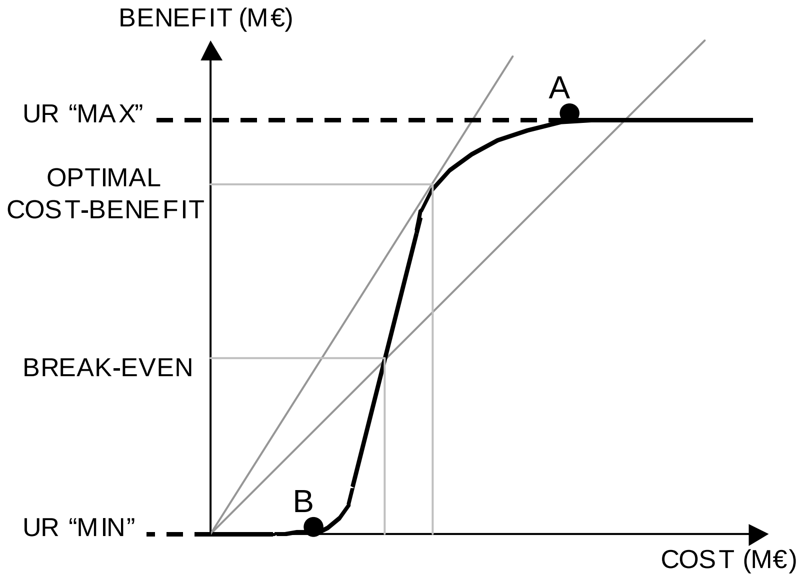

Figure 2. Generic cost-benefit curve for an observing system.

Note that the point of optimal cost-benefit represents a benefit (and cost) that is, in general, lower than the point of "maximum requirement". This is important; it is often assumed that we should be striving to meet the maximum requirement. Whereas this analysis shows that a system meeting "maximum" requirements is likely to deliver a level of benefit in a region of diminishing returns. Also a system's performance must exceed the "minimum" requirement before it is likely to be cost-effective.

3 The Critical Review

The comparison of requirements to capabilities utilizes the database. As the database changes to better reflect the user requirements as well as existing and planned observing capabilities, the RRR must be performed periodically.

The process compares user requirements with the observing system capabilities and records the results in terms of the extent to which the capabilities of present, planned and proposed systems meet the stated requirements. In some cases, impact studies are conducted using Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs). The critical review is a challenging process and considerable work has been done to evolve a process and presentation for the Critical Review to meet the following criteria:

- The presentation must be concise and attractive, and understandable to senior managers and decision makers, whilst retaining sufficient detail to represent adequately the full range of observation requirements and observing system capabilities;

- The presentation of user requirements must be accurate; although it is necessarily a summary, it must be recognizable to experts in each application as a correct interpretation of their requirements;

- The presentation of the observing system capabilities must be accurate; although it is also a summary, it must be recognizable to expert data users as a correct interpretation of the systems' characteristics and potential;

- The results must accurately reflect the extent to which current systems are useful in practice, whilst drawing attention to those areas in which they do not meet some or all user requirements; and the process must be as objective as possible.

4 Statements of Guidance

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 Statement of Guidance 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 Statement of Guidance was 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 statements of guidance can be found on the WMO website[4].

5 The vision of the GOS

The Vision of the GOS provides high-level goals to guide the evolution of the Global Observing System in the coming decades. These goals are intended to be challenging but achievable. The Vision considers that the future GOS 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 the GOS will be reflected in better data, products and services from the National Meteorological and Hydrological Services (NMHSs); this will be particularly true for developing countries and Least Developped Countries (LDCs).

4 http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html#SOG

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

The Vision of the GOS is available from the WMO website[5].

6 The Implementation Plan for the Evolution of the Global Observing Systems (EGOS-IP)

Responding to the Vision of the GOS and WIGOS needs, the Implementation Plan for the Evolution of global observing systems (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 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 Rolling Review of Requirements, looking at all Statements of Guidance for all WMO Applications Areas, taking overall cost-effectiveness into account, as well as the WMO priorities.

The EGOS-IP is available from the WMO website[6].

5 http://www.wmo.int/pages/prog/www/OSY/gos-vision.html
6 http://www.wmo.int/pages/prog/www/OSY/gos-vision.html#egos-ip

ANNEX I

EXAMPLE OF USER REQUIREMENTS FROM THE WMO DATABASE[7]

(Global Numerical Weather Prediction – as of 25 October 2011)

Variable	Layer	Uncertainty Goal	Uncertainty BT[8]	Uncertainty TH[9]	HR[10] Goal	HR[10] BT[8]	HR[10] TH[9]	VR[11] Goal	VR[11] BT[8]	VR[11] TH[9]	OC[12] Goal	OC[12] BT[8]	OC[12] TH[9]	Avail[13] Goal	Avail[13] BT[8]	Avail[13] TH[9]
Accumulated precipitation (over 24 h)	2D	0.5 mm	2 mm	5 mm	10 km	30 km	100 km	N/A	N/A	N/A	60 min	3 h	12 h	24 h	5 d	30 d
Aerosol column burden	TC	10 %	20 %	50 %	15 km	50 km	250 km	N/A	N/A	N/A	60 min	6 h	24 h	6 min	30 min	6 h
Aerosol mass mixing ratio	HS&M	10 %	20 %	50 %	15 km	50 km	250 km	km	km	km	60 min	6 h	24 h	6 min	30 min	6 h
Aerosol mass mixing ratio	HT	10 %	20 %	50 %	15 km	50 km	250 km	km	km	km	60 min	6 h	24 h	6 min	30 min	6 h
Aerosol mass mixing ratio	LS	10 %	20 %	50 %	15 km	50 km	250 km	0.2 km	2.99 km	3 km	60 min	6 h	24 h	6 min	30 min	6 h
Aerosol mass mixing ratio	LT	10 %	20 %	50 %	15 km	50 km	250 km	0.2 km	2.99 km	3 km	60 min	6 h	24 h	6 min	30 min	6 h
Air pressure (at surface)	Over land	0.5 hPa	0.99 hPa	1 hPa	15 km	100 km	500 km	N/A	N/A	N/A	60 min	6 h	12 h	6 min	30 min	6 h
Air pressure (at surface)	Over sea	0.5 hPa	0.99 hPa	1 hPa	15 km	100 km	500 km	N/A	N/A	N/A	60 min	6 h	12 h	6 min	30 min	6 h
Air specific humidity (at surface)	Surface	2 %	5 %	10 %	15 km	50 km	250 km	N/A	N/A	N/A	60 min	3 h	12 h	6 min	30 min	6 h

7 http://www.wmo.int/pages/prog/www/OSY/RRR-DB.html
8 BT: Breakthrough
9 TH: Threshold
10 HR: Horizontal Resolution
11 VR: Vertical Resolution
12 OC: Observing Cycle
13 Avail: Availability (i.e. data timeliness, delay after observation)

Variable	Layer	Uncertainty Goal	Uncertainty BT[8]	Uncertainty TH[9]	HR[10] Goal	HR[10] BT[8]	HR[10] TH[9]	VR[11] Goal	VR[11] BT[8]	VR[11] TH[9]	OC[12] Goal	OC[12] BT[8]	OC[12] TH[9]	Avail[13] Goal	Avail[13] BT[8]	Avail[13] TH[9]
Air temperature (at surface)	Surface	0.5 K	1 K	2 K	15 km	50 km	250 km	N/A	N/A	N/A	60 min	6 h	12 h	6 min	30 min	6 h
Atmospheric temperature	HS&M	0.5 K	3 K	5 K	50 km	100 km	500 km	km	km	km	60 min	6 h	24 h	6 min	30 min	6 h
Atmospheric temperature	HT	0.5 K	1 K	3 K	15 km	100 km	500 km	km	km	km	60 min	6 h	24 h	6 min	30 min	6 h
Atmospheric temperature	LS	0.5 K	1 K	3 K	15 km	100 km	500 km	km	km	km	60 min	6 h	24 h	6 min	30 min	6 h
Atmospheric temperature	LT	0.5 K	1 K	3 K	15 km	100 km	500 km	km	km	km	60 min	6 h	24 h	6 min	30 min	6 h
Cloud base height	2D	0.2 km	0.5 km	1 km	5 km	15 km	50 km	N/A	N/A	N/A	60 min	3 h	12 h	6 min	30 min	6 h
Cloud cover	2D	0.05 %	0.1 %	0.2 %	5 km	15 km	50 km	N/A	N/A	N/A	60 min	3 h	12 h	6 min	30 min	6 h
Cloud drop effective radius	Cloud-top	1 N/A	2 N/A	5 N/A	5 km	15 km	50 km	N/A	N/A	N/A	60 min	3 h	12 h	6 min	30 min	6 h
Cloud ice	HT	20 %	50 %	100 %	5 km	15 km	50 km	km	km	km	60 min	3 h	12 h	6 min	30 min	6 h
Cloud ice	LT	20 %	50 %	100 %	5 km	15 km	50 km	km	km	km	60 min	3 h	12 h	6 min	30 min	6 h
Cloud ice (total column)	TC	5 g/m^2	10 g/m^2	20 g/m^2	5 km	15 km	50 km	N/A	N/A	N/A	60 min	3 h	12 h	6 min	30 min	6 h
Cloud liquid water	HT	20 %	50 %	100 %	5 km	15 km	50 km	0.2 km	1 km	2 km	60 min	3 h	12 h	6 min	30 min	6 h
Cloud liquid water	LT	20 %	50 %	100 %	5 km	15 km	50 km	0.2 km	1 km	2 km	60 min	3 h	12 h	6 min	30 min	6 h
Cloud liquid water	TC	10 %	20 %	50 %	5 km	15 km	50 km	km	km	km	60 min	3 h	12 h	6 min	30 min	6 h
Cloud liquid water	HT	20 %	50 %	100 %	5 km	15 km	50 km	0.2 km	1 km	2 km	60 min	3 h	12 h	6 min	30 min	6 h
Cloud liquid water	LT	20 %	50 %	100 %	5 km	15 km	50 km	0.2 km	1 km	2 km	60 min	3 h	12 h	6 min	30 min	6 h
Cloud liquid water	TC	10 %	17.1 %	50 %	5 km	15 km	50 km	km	km	km	60 min	3 h	12 h	6 min	30 min	6 h
Cloud top height	2D	0.2 km	0.5 km	1 km	5 km	15 km	50 km	N/A	N/A	N/A	60 min	3 h	12 h	6 min	30 min	6 h
Cloud type	2D	0 Classes $^{-1}$	0 Classes $^{-1}$	0 Classes $^{-1}$	0.99 km	1 km	5 km	N/A	N/A	N/A	60 min	3 h	12 h	6 min	30 min	6 h
Dominant wave direction	Surf-	10 degrees	15 degrees	30 degrees	15 km	50 km	250	N/A	N/A	N/A	60 min	3 h	12 h	6 min	30 min	6 h

Variable	Layer	Uncertainty Goal	Uncertainty BT[8]	Uncertainty TH[9]	HR[10] Goal	HR[10] BT[8]	HR[10] TH[9]	VR[11] Goal	VR[11] BT[8]	VR[11] TH[9]	OC[12] Goal	OC[12] BT[8]	OC[12] TH[9]	Avail[13] Goal	Avail[13] BT[8]	Avail[13] TH[9]
	sea						km									
Dominant wave period	Surf-sea	0.25 s	0.5 s	1 s	15 km	50 km	250 km	N/A	N/A	N/A	60 min	3 h	12 h	6 min	30 min	6 h
Downward short-wave irradiance at Earth surface	Surface	1 W/m^2	10 W/m^2	20 W/m^2	10 km	30 km	100 km	N/A	N/A	N/A	60 min	3 h	12 h	24 h	5 d	30 d
Downward long-wave irradiance at Earth surface	Surface	1 W/m^2	10 W/m^2	20 W/m^2	10 km	30 km	100 km	N/A	N/A	N/A	60 min	3 h	12 h	24 h	5 d	30 d
Earth surface SW bidirectional reflectance (BRDF)	Surface	1 %	2 %	5 %	10 km	30 km	100 km	N/A	N/A	N/A	60 min	3 h	12 h	24 h	5 d	30 d
Fraction of Absorbed PAR (FAPAR)	Surf-land	0.05 %	0.1 %	0.2 %	2 km	10 km	50 km	N/A	N/A	N/A	24 h	5 d	10 d	3 h	24 h	10 d
Land surface temperature	Surf-land	0.5 K	1 K	4 K	5 km	15 km	250 km	N/A	N/A	N/A	30 min	3 h	6 h	6 min	30 min	6 h
Leaf Area Index (LAI)	Surf-land	0.05 %	0.1 %	0.2 %	2 km	10 km	50 km	N/A	N/A	N/A	24 h	5 d	10 d	3 h	24 h	10 d
Long-wave Earth surface emissivity	Surf-land	0.5 %	1 %	3 %	5 km	15 km	50 km	N/A	N/A	N/A	24 h	5 d	30 d	24 h	5 d	30 d
Normalised Difference Vegetation Index (NDVI)	Surf-land	0.05 %	0.1 %	0.2 %	2 km	10 km	50 km	N/A	N/A	N/A	24 h	5 d	10 d	3 h	24 h	10 d
O3	HS&M	5 %	10 %	20 %	15 km	100 km	250 km	km	km	km	60 min	6 h	12 h	6 min	30 min	6 h
O3	HT	5 %	10 %	20 %	15 km	100 km	250 km	1 km	2.2 km	10 km	60 min	6 h	12 h	6 min	30 min	6 h
O3	LS	5 %	10 %	20 %	15 km	100 km	250 km	1 km	2.2 km	10 km	60 min	6 h	12 h	6 min	30 min	6 h
O3	LT	5 %	10 %	20 %	15 km	100 km	250 km	1 km	2.2 km	10 km	60 min	6 h	12 h	6 min	30 min	6 h
O3 (Total column)	TC	5 DU	10 DU	20 DU	15 km	100 km	250 km	N/A	N/A	N/A	60 min	6 h	12 h	6 min	30 min	6 h
Ocean salinity	Upper oc	0.1 psu	0.2 psu	0.3 psu	5 km	100 km	250 km	1 m	2 m	10 m	24 h	30 d	60 d	3 h	24 h	5 d

Variable	Layer	Uncertainty Goal	Uncertainty BT[8]	Uncertainty TH[9]	HR[10] Goal	HR[10] BT[8]	HR[10] TH[9]	VR[11] Goal	VR[11] BT[8]	VR[11] TH[9]	OC[12] Goal	OC[12] BT[8]	OC[12] TH[9]	Avail[13] Goal	Avail[13] BT[8]	Avail[13] TH[9]
Ocean temperature	Upper oc	0.3 K	0.5 K	1 K	5 km	100 km	250 km	1 m	2 m	10 m	24 h	2 d	30 d	3 h	24 h	5 d
Precipitation intensity at surface (liquid or solid)	Surface	0.1 mm/h	0.5 mm/h	1 mm/h	5 m	15 m	50 m	N/A	N/A	N/A	60 min	3 h	12 h	6 min	30 min	6 h
Precipitation intensity at surface (solid)	Surface	0.1 mm/h	0.5 mm/h	1 mm/h	5 km	15 km	50 km	N/A	N/A	N/A	60 min	3 h	12 h	6 min	30 min	6 h
Sea surface salinity	Surf-sea	0.1 psu	0.2 psu	0.3 psu	5 km	100 km	250 km	N/A	N/A	N/A	24 h	30 d	60 d	3 d	24 d	120 d
Sea surface temperature	Surf-sea	0.3 K	0.5 K	1 K	5 km	15 km	250 km	N/A	N/A	N/A	3 h	24 h	5 d	3 h	24 h	5 d
Sea-ice cover	Surf-sea	0.05 %	0.1 %	0.2 %	5 km	15 km	100 km	N/A	N/A	N/A	3 h	24 h	5 d	3 h	24 h	5 d
Sea-ice surface temperature	Surf-sea	0.5 K	1 K	4 K	5 km	15 km	250 km	N/A	N/A	N/A	60 min	3 h	12 h	6 min	30 min	6 h
Sea-ice thickness	Surf-sea	20 cm	50 cm	100 cm	15 km	50 km	250 km	N/A	N/A	N/A	24 h	5 d	30 d	24 h	5 d	30 d
Sea-ice type	Surf-sea	0.25 Classes $^{-1}$	0.333 Classes $^{-1}$	0.5 Classes $^{-1}$	10 km	25 km	100 km	N/A	N/A	N/A	3 h	24 h	5 d	3 h	24 h	5 d
Short-wave cloud reflectance	2D	0.01 %	0.03 %	0.1 %	10 km	30 km	100 km	N/A	N/A	N/A	60 min	3 h	12 h	24 h	5 d	30 d
Significant wave height	Surf-sea	0.1 m	0.3 m	0.5 m	15 km	50 km	250 km	N/A	N/A	N/A	60 min	3 h	12 h	6 min	30 min	6 h
Snow cover	Surf-land	0.1 %	0.2 %	0.5 %	5 km	15 km	100 km	N/A	N/A	N/A	3 h	24 h	5 d	3 h	24 h	5 d
Snow water equivalent	Surf-land	2 mm	10 mm	20 mm	5 km	15 km	100 km	N/A	N/A	N/A	3 h	24 h	5 d	3 h	24 h	5 d
Soil moisture at surface	Surf-land	0.01 m^3/m^3	0.02 m^3/m^3	0.05 m^3/m^3	5 km	15 km	100 km	N/A	N/A	N/A	3 h	24 h	5 d	3 h	24 h	5 d
Specific humidity	HT	2 %	5 %	10 %	15 km	50 km	250 km	0.5 km	1 km	3 km	60 min	6 h	12 h	6 min	30 min	6 h
Specific humidity	LT	2 %	5 %	10 %	15 km	50 km	250 km	0.3 km	1 km	3 km	60 min	6 h	12 h	6 min	30 min	6 h

Variable	Layer	Uncertainty Goal	Uncertainty BT[8]	Uncertainty TH[9]	HR[10] Goal	HR[10] BT[8]	HR[10] TH[9]	VR[11] Goal	VR[11] BT[8]	VR[11] TH[9]	OC[12] Goal	OC[12] BT[8]	OC[12] TH[9]	Avail[13] Goal	Avail[13] BT[8]	Avail[13] TH[9]
Specific humidity (Total Column)	TC	1 kg/m^2	2 kg/m^2	5 kg/m^2	15 km	50 km	250 km	N/A	N/A	N/A	60 min	6 h	12 h	6 min	30 min	6 h
Upward short-wave irradiance at TOA	TOA	5 W/m^2	10 W/m^2	20 W/m^2	10 km	30 km	100 km	N/A	N/A	N/A	60 min	3 h	12 h	24 h	5 d	30 d
Upward spectral radiance at TOA	TOA	0.05 SNR^{-1}	0.1 SNR^{-1}	0.2 SNR^{-1}	10 km	30 km	100 km	N/A	N/A	N/A	5.8 min	18 min	5 d	24 h	5 d	30 d
Upward long-wave irradiance at TOA	TOA	5 W/m^2	10 W/m^2	20 W/m^2	10 km	30 km	100 km	N/A	N/A	N/A	60 min	3 h	12 h	24 h	5 d	30 d
Upward long-wave irradiance at Earth surface	Surface	1 W/m^2	10 W/m^2	20 W/m^2	10 km	30 km	100 km	N/A	N/A	N/A	60 min	3 h	12 h	24 h	5 d	30 d
Vegetation type	Surf-land	0.055 $Classes^{-1}$	0.08 $Classes^{-1}$	0.11 $Classes^{-1}$	2000 m	10000 m	50000 m	N/A	N/A	N/A	7 d	15 d	30 d	24 h	2 d	7 d
Wind (horizontal)	HS&M	1 m/s	5 m/s	10 m/s	50 km	100 km	500 km	1 km	2 km	3 km	60 min	6 h	12 h	6 min	30 min	6 h
Wind (horizontal)	HT	1 m/s	3 m/s	8 m/s	15 km	100 km	500 km	0.5 km	1 km	3 km	60 min	6 h	12 h	6 min	30 min	6 h
Wind (horizontal)	LS	1 m/s	3 m/s	5 m/s	15 km	100 km	500 km	0.5 km	1 km	3 km	60 min	6 h	12 h	6 min	30 min	6 h
Wind (horizontal)	LT	1 m/s	3 m/s	5 m/s	15 km	100 km	500 km	0.5 km	1 km	3 km	60 min	6 h	12 h	6 min	30 min	6 h
Wind (vertical)	HS&M	1 cm/s	4.99 cm/s	5 cm/s	15 km	200 km	500 km	0.5 km	2 km	3 km	60 min	6 h	12 h	6 min	30 min	6 h
Wind (vertical)	HT	1 cm/s	4.99 cm/s	5 cm/s	15 km	200 km	500 km	0.5 km	2 km	3 km	60 min	6 h	12 h	6 min	30 min	6 h
Wind (vertical)	LS	1 cm/s	4.99 cm/s	5 cm/s	15 km	200 km	500 km	0.5 km	2 km	3 km	60 min	6 h	12 h	6 min	30 min	6 h
Wind (vertical)	LT	1 cm/s	4.99 cm/s	5 cm/s	15 km	200 km	500 km	0.5 km	2 km	3 km	60 min	6 h	12 h	6 min	30 min	6 h
Wind speed over the surface (horizontal)	Over land	0.5 m/s	1.5 m/s	2 m/s	15 km	100 km	250 km	N/A	N/A	N/A	60 min	6 h	12 h	6 min	30 min	6 h
Wind speed over the surface (horizontal)	Over	0.5 m/s	1.5 m/s	2 m/s	15 km	100	250	N/A	N/A	N/A	60 min	6 h	12 h	6 min	30 min	6 h

Variable	Layer	Uncertainty Goal	Uncertainty BT[8]	Uncertainty TH[9]	HR[10] Goal	HR[10] BT[8]	HR[10] TH[9]	VR[11] Goal	VR[11] BT[8]	VR[11] TH[9]	OC[12] Goal	OC[12] BT[8]	OC[12] TH[9]	Avail[13] Goal	Avail[13] BT[8]	Avail[13] TH[9]
	sea					km	km									
[Wind vector over the surface (horizontal)]	Over land	0.5 m/s	2 m/s	3 m/s	15 km	100 km	250 km	N/A	N/A	N/A	60 min	6 h	12 h	6 min	30 min	6 h
[Wind vector over the surface (horizontal)]	Over sea	0.5 m/s	2 m/s	3 m/s	15 km	100 km	250 km	N/A	N/A	N/A	60 min	6 h	12 h	6 min	30 min	6 h

ANNEX II

ACRONYMS

CBS	Commission for Basic Systems (WMO)
EGOS-IP	Implementation Plan for the Evolution of Global Observing Systems
GCOS	Global Climate Observing System (WMO, IOC, UNEP, ICSU)
GFCS	Global Framework for Climate Services
GOS	Global Observing System (WMO)
ICSU	International Council for Science
IOC	Intergovernmental Oceanographic Commission of UNESCO
LCD	Least Developped Country
NMHS	National Meteorological and Hydrological Service
OSE	Observing System Experiment
OSSE	Observing System Simulation Experiment
RMS	Root Mean Square
RRR	Rolling Requirements Review
UN	United Nations
UNEP	UN Environment Programme
UNESCO	UN Educational, Scientific and Cultural Organization
WMO	World Meteorological Organization