THE WMO DOSSIER ON THE SPACE-BASED GLOBAL OBSERVING SYSTEM

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Abstract

The WMO Dossier on the Space-based Global Observing System (in short: "GOS Dossier") is edited by the WMO Space Programme Office since 2004 in support (but not exclusively) of the Coordination Group for Meteorological Satellites (CGMS). It is available online from the WMO web site, split in one Introduction and five Volumes connected by hyperlinks. This paper provides a short description of the contents of the five volumes, and highlights a few recent applications based on the GOS Dossier:

- a Gap analysis for the Essential Climate Variables (ECV)
- the update of the Guide of the WMO Commission for Instruments and Methods (CIMO).

INTRODUCTION

The first version of the WMO Dossier on the Space-based Global Observing System (in short: "GOS Dossier"), edited by the WMO Space Programme Office in support (but not exclusively) of the Coordination Group for Meteorological Satellites (CGMS), was first submitted to CGMS-32 in 2004. It was updated yearly up to 2008. Since 2009 it is being updated three times per year. The current version, submitted to CGMS-39, is the 3rd issue of 2011, dated 1st September 2011, available on line from the "Information Resources" page of the new WMO Space Programme web site (www.wmo.int/sat).

The scope of the GOS Dossier was progressively extended from operational meteorological programmes to other programmes of GOS interest, including R&D programmes and demonstration of future operational capabilities. The latest version of the Dossier covers:

- operational meteorological programmes
- specialised atmospheric missions
- missions to ocean and ice
- land observation missions
- missions to Solid Earth
- missions to Space Weather.

The Dossier is split into an Introduction and five volumes:

- Vol. 1: Satellite programmes description
- Vol. 2: Earth observation satellites and their instruments
- Vol. 3: Gap analysis in the space-based component of GOS
- Vol. 4: Estimated performance of products from typical satellite instruments
- Vol. 5: Compliance analysis of potential product performances with user requirements.

On the WMO web site, the six files (.doc) are collected in a single .zip file. The volumes/files are connected by hyperlinks (see *Figure 1*) and must be extracted in a single folder; and the file names should never be changed.

The Dossier contains comprehensive reference information and can be used as a tool for planning purpose from both a satellite-provider and a user perspective. In the following sections a short description of the contents of the five volumes is provided.

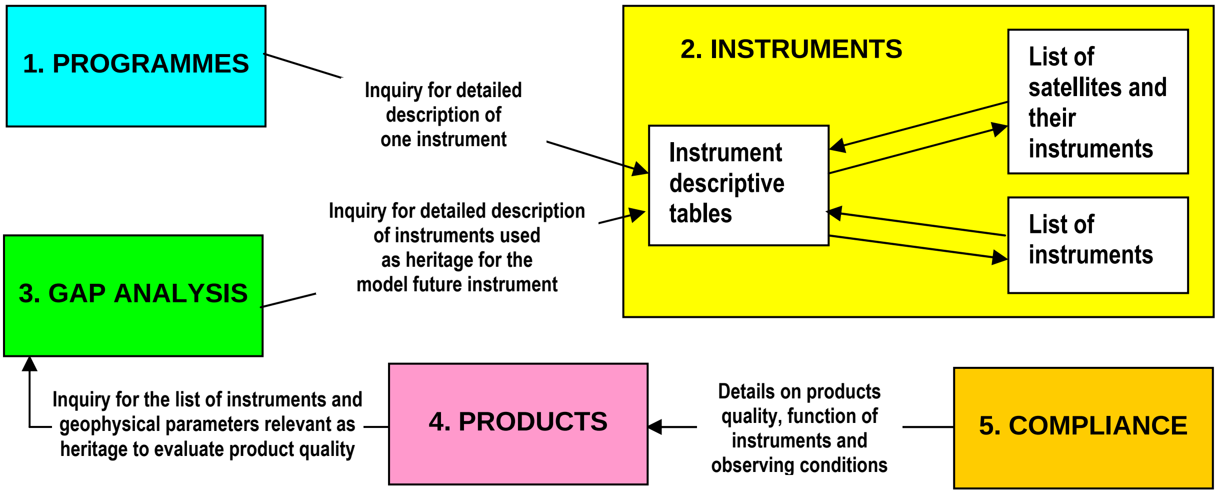

Figure 1: **Logic of the hyperlinks connecting the five Volumes of the GOS Dossier.**

CONTENTS OF VOLUME 1 (PROGRAMMES)

Volume 1, that in previous issues of the Dossier used to be structured by satellite operators, is now structured by application areas, as follows:

- Operational meteorological satellites:
  - satellite constellation in geostationary orbits (including a reference to HEO missions)
  - satellite constellation in sunsynchronous orbits.
- Specialized atmospheric missions, for:
  - precipitation
  - radio occultation
  - atmospheric radiation
  - atmospheric chemistry
  - atmospheric dynamics.
- Missions to ocean and ice, for:
  - ocean topography
  - ocean colour
  - sea surface wind
  - sea surface salinity
  - waves
  - ocean ice.
- Land observation missions:
  - main operational or near operational missions
  - disaster monitoring constellation
  - all-weather high resolution monitoring (by SAR).
- Missions to Solid Earth, for:
  - space geodesy
  - earth's interior.
- Missions to Space Weather:
  - solar activity monitoring
  - observation of the magnetosphere
  - observation of the ionosphere
  - space environment observation from operational meteorological satellites.

The Space Weather section has been recently expanded, following the approval of Space Weather by the WMO Congress, in May 2011, as an activity of the WMO Space Programme.

Table 1, *Figure 2* and *Figure 3* report, as example, fragments of a programme description (Meteosat).

Satellite	Launch	End of service	Position	Status (Sep 2011)	Instruments
Meteosat-1	23 Nov 1977	24 Nov 1979	Not relevant	Inactive	MVIRI, DCS
Meteosat-2	19 Jun 1981	2 Dec 1991	Not relevant	Inactive	MVIRI, DCS
Meteosat-3	15 Jun 1988	22 Nov 1995	Not relevant	Inactive	MVIRI, DCS
Meteosat-4	6 Mar 1989	8 Nov 1995	Not relevant	Inactive	MVIRI, DCS
Meteosat-5	2 Mar 1991	6 Feb 2007	Not relevant	Inactive	MVIRI, DCS
Meteosat-6	20 Nov 1993	15 Apr 2011	Not relevant	Inactive	MVIRI, DCS
Meteosat-7	2 Sep 1997	≥ 2013	57.5°E	Operational	MVIRI, DCS
Meteosat-8	28 Aug 2002	≥ 2016	9.5°E	Rapid scan	DCS, GERB, GEOSAR, SEVIRI
Meteosat-9	21 Dec 2005	≥ 2019	0°	Operational	DCS, GERB, GEOSAR, SEVIRI
Meteosat-10	≥ 2012	≥ 2019	~ 0°	In storage	DCS, GERB, GEOSAR, SEVIRI
Meteosat-11	≥ 2014	≥ 2021	~ 0°	In storage	DCS, GERB, GEOSAR, SEVIRI
Meteosat MTG-I1	≥ 2017	≥ 2025	~ 0°	Planned	DCS, FCI, GEOSAR, LI
Meteosat MTG-S1	≥ 2019	≥ 2027	~ 0°	Planned	DCS, GEOSAR, IRS, UVN
Meteosat MTG-I2	≥ 2022	≥ 2030	~ 0°	Planned	DCS, FCI, GEOSAR, LI
Meteosat MTG-I3	≥ 2026	≥ 2034	~ 0°	Planned	DCS, FCI, GEOSAR, LI
Meteosat MTG-S2	≥ 2027	≥ 2035	~ 0°	Planned	DCS, GEOSAR, IRS, UVN
Meteosat MTG-I4	≥ 2030	≥ 2038	~ 0°	Planned	DCS, FCI, GEOSAR, LI

Table 1: **Example of satellite programme (Meteosat) recorded in Vol. 1.**

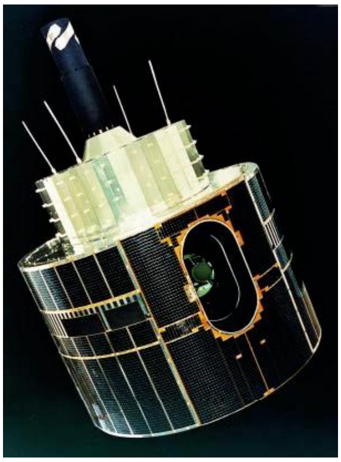

Figure 2: **Sketch view of Meteosat 4 to 7. Mass in orbit: 320 kg.**

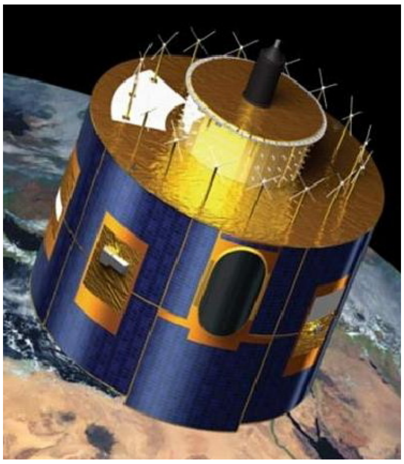

Figure 3**: Sketch view of Meteosat 8 to 11 (Meteosat Second Generation). Mass in orbit: 1070 kg.**

CONTENTS OF VOLUME 2 (INSTRUMENTS)

Volume 2 includes:

- A list of Earth Observation satellites (currently 268) selected as: currently being flown or available till recently; about to be flown; approved; or planned (only in cases where the plan is supporting a continuing series).
- The list of instruments (currently: 413) being flown on the selected satellites.
- Definition of instrument types (currently 36 + communication services) indicating their main applications and examples.
- Instrument descriptive tables (see example in *Table 2*): for each instrument of the "List of instruments" a descriptive table is provided, recording information on:
  - satellites on which the instrument is flown
  - status of development
  - mission (driving objective and other main application areas)
  - instrument type (one of the defined 36)
  - scanning technique

- coverage/cycle
- resolution
- resources (mass, power, data rate)
- channels (central wavelength, bandwidth, polarisations, radiometric accuracy).

AVHRR/3	**Advanced Very High Resolution Radiometer / 3**
Satellites	**NOAA-15, NOAA-16, NOAA-17, NOAA-18, NOAA-19, MetOp-A, MetOp-B, MetOp-C**
Status	**Operational** - Utilisation period: 1998 to ~ 2014 on NOAA; 2006 to ~ 2021 on MetOp
Mission	Multi-purpose imagery
Instrument type	Multi-purpose imaging VIS/IR radiometer - 6 channels (channels 1.6 and 3.7 alternative)
Scanning technique	Cross-track: 2048 pixel of 800 m s.s.p., swath 2900 km - Along-track: six 1.1-km lines/s
Coverage/cycle	Global coverage twice/day (IR) or once/day (VIS)
Resolution (s.s.p.)	1.1 km IFOV
Resources	Mass: 33 kg - Power: 27 W - Data rate: 621.3 kbps

Central wavelength	Spectral interval	Radiometric accuracy (NEΔT or SNR)
0.630 µm	0.58 - 0.68 µm	9 @ 0.5 % albedo
0.862 µm	0.725 - 1.00 µm	9 @ 0.5 % albedo
1.61 µm	1.58 - 1.64 µm	20 @ 0.5 % albedo
3.74 µm	3.55 - 3.93 µm	0.12 K @ 300 K
10.80 µm	10.3 - 11.3 µm	0.12 K @ 300 K
12.00 µm	11.5 - 12.5 µm	0.12 K @ 300 K

***Table 2:* Example of instrument descriptive table.**

CONTENTS OF VOLUME 3 (GAP ANALYSIS)

33 missions are considered for Gap analysis in the current GOS Dossier (GOS-2011-September). Their list is recorded in *Table 3*.

Multi-purpose VIS/IR imagery from LEO	Multi-purpose VIS/IR imagery from GEO
IR temperature/humidity sounding from LEO	IR temperature/humidity sounding from GEO
MW temperature/humidity sounding from LEO	MW temperature/humidity sounding from GEO
Multi-purpose MW imagery	Low-frequency MW imagery
Radio occultation sounding	Earth radiation budget from LEO
Earth radiation budget from GEO	Sea-surface wind by active and passive MW
Radar altimetry	Ocean colour imagery from LEO
Ocean colour imagery from GEO	Imagery with special viewing geometry
Lightning imagery from LEO	Lightning imagery from GEO
Cloud and precipitation profiling by radar	Lidar-based missions
Cross-nadir short-wave spectrometry from LEO	Cross-nadir short-wave spectrometry from GEO
Cross-nadir IR spectrometry from LEO	Cross-nadir IR spectrometryfrom GEO
Limb-sounding short-wave spectrometry	Limb-sounding IR spectrometry
Limb-sounding mm-submm wave spectrometry	High-resolution imagery for land observation
Synthetic Aperture Radar	Solid Earth
Space Weather from LEO	Space Weather from GEO
Space Weather from specific high orbits	

***Table 3:* Missions submitted to the Gap analysis.**

For each of the addressed 33 missions, the gap analysis involves a number of steps. They are listed below by referring to one example (Sea-surface wind by active and passive MW).

Step 1: Instrument model - Representative characteristics of the instrument addressing the mission are tabled, referring to likely post-2020 technology:

Representative characteristics of radar scatterometers and MW polarimeters to meet post-2020 requirements					
	Frequency	**Swath**	**Special features**	**Resolution**	**Scanning**
Scatterometer	C-band (preferred) or Ku-band	1000-1500 km	3-4 look angles	20 - 50 km	pushbroom (preferred) or conical conical
Polarimeter	At least four, 10 to 37 GHz		Up to 6 polarisations		

Step 2: Reminding of the geophysical variables for which the instrument may be useful:

Geophysical variables addressed by wind scatterometers and MW polarimeters				
Wind vector over the surface (horizontal)	Sea-ice type	Soil moisture at surface	Leaf Area Index (LAI)	Snow water equivalent

Step 3: List of instruments flown currently or till recently, or firmly planned.

Current or planned instruments relevant for the mission "Sea-surface wind by active and passive MW"				
Instrument acronym	**Instrument full name**	**Satellite**	**ECT/incl.**	**Lifespan**
AMI-SCAT	Active Microwave Instrument - Scat mode	ERS-2	10:30 d	1995-2011
ASCAT	Advanced Scatterometer	MetOp-A	09:30 d	2006-2012
ASCAT	Advanced Scatterometer	MetOp-B	09:30 d	2012-2017
ASCAT	Advanced Scatterometer	MetOp-C	09:30 d	2016-2021
MIS	Microwave Imager/Sounder	DWSS-1	05:30 d	2018-2023
MIS	Microwave Imager/Sounder	DWSS-2	05:30 d	2022-2028
SCA	Scatterometer	EPS-SG-B1	09:30 d	2021-2027
SCA	Scatterometer	EPS-SG-B2	09:30 d	2026-2032
SCA	Scatterometer	EPS-SG-B3	09:30 d	2031-2037
SCAT	Scatterometer	OceanSat-2	12:00 d	2009-2014
SCAT	Scatterometer	OceanSat-3	12:00 d	2012-2017
SCAT	Scatterometer	HY-2A	06:00 d	2011-2016
SCAT	Scatterometer	Meteor-M N3	TBD	2014-2019
SeaWinds	SeaWinds	QuikSCAT	06:00 d	1999-2009
WindRAD	Sea Wind Measurement Radar	FY-3E	10:00 d	2017-2020
WindRAD	Sea Wind Measurement Radar	FY-3G	10:00 d	2021-2024
WindSat	WindSat	Coriolis	06:00 d	2003-2011

Step 4: Qualification/ranking of instrument performances

Comparison of instrument performances	
MIS, WindSat	Passive MW, polarimetric, conical scanning
AMI-SCAT	Single-side viewing, C-band
SCAT (OceanSat, HY-2A, Meteor-M N3), SeaWinds	Two beams, conical scanning, Ku-band
ASCAT, SCA	Double-side swath, C-band
WindRAD	C- and Ku- bands

Step 5: Reference observing strategy. Compliance with the "Vision for the GOS to 2025" that was approved by the 61st WMO Executive Council is generally pursued. In the case of sea-surface wind the strategy is:

- three orbital planes (early morning: 5:30±2 h; mid-morning: 9:30±2 h; early afternoon: 13:30±2 h);
- radar scatterometers in at least two of the planes;
- redundant radar scatterometers or MW polarimeters in the three orbital planes for contingency;
- exploitation of other MW radiometers, though missing the information on direction, in order to have an average observing cycle of 3 hours.

Step 6: Plotting the currently known information in the interval 2008-2025:

Instrument	Satellite	ECT/incl.	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
MIS	DWSS-1	05:30 d											X	X	X	X	X	X		
MIS	DWSS-2	05:30 d															X	X	X	X
SeaWinds	QuikSCAT	06:00 d	X	X																
SCAT	HY-2A	06:00 d				X	X	X	X	X	X									
WindSat	Coriolis	06:00 d	X	X	X	X														
ASCAT	MetOp-A	09:30 d	X	X	X	X	X													
ASCAT	MetOp-B	09:30 d					X	X	X	X	X	X								
ASCAT	MetOp-C	09:30 d									X	X	X	X	X	X				
SCA	EPS-SG-B1	09:30 d														X	X	X	X	X
SCAT	Meteor-M N3	TBD							X	X	X	X	X	X						
WindRAD	FY-3E	10:00 d										X	X	X	X					
WindRAD	FY-3G	10:00 d														X	X	X	X	
AMI-SCAT	ERS-2	10:30 d	X	X	X	X														
SCAT	OceanSat-2	12:00 d		X	X	X	X	X	X											
SCAT	OceanSat-3	12:00 d					X	X	X	X	X	X								

Step 7: Commenting the scenario and identifying gaps or gap risks.

Gap analysis for the mission "Sea-surface wind by active and passive MW" after 2020	
05:30 ± 2 h	The DWSS MIS will provide wind information, subject to confirmation of near-real time data availability by the USA, but is not expected to be accurate for low-intensity wind. The HY-2 SCAT is not known to be planned for long-term continuity, and near-real time data availability is still to be confirmed by China.
09:30 ± 2 h	Adequate data are expected to be provided by the EPS-SG SCA, the likely follow-on of the FY-3 WindRAD and the Meteor-M N3 SCAT.
13:30 ± 2 h	Adequate data would be provided by the OceanSat SCAT if long-term continuity is confirmed.
Overall	Due to the limited swath of radar scatterometers and conical-scanning MW radiometers, the 3-hour observing cycle would require 8 regularly spaced satellites. The temporal gap could be mitigated by blending the data from radar scatterometers and MW polarimeters with other (without full polarization) passive MW radiometers providing incomplete information (missing the direction).

CONTENTS OF VOLUME 4 (PRODUCTS)

In Vol. 4 the potential capability of satellite observation is estimated. The names and definitions of the geophysical variables that can be observed by satellite remote sensing have been aligned as far as practical with the updated typology of variables adopted in the WMO Observing Requirements Database (http://www.wmo-sat.info/db/). Their current number is 112, listed in *Table 4*.

Basic atmospheric 3D and 2D variables	Upward LW irradiance at Earth's surface	**Solid Earth**
Atmospheric temperature	Long-wave Earth surface emissivity	Geoid
Specific humidity	Photosynthetically Active Radiation (PAR)	Crustal plates positioning
Wind (horizontal)	Fraction of Absorbed PAR (FAPAR)	Crustal motion (horizontal and vertical)
Wind vector over the surface (horizontal)	**Ocean and sea ice**	Gravity field
Height of the top of PBL	Ocean chlorophyll concentration	Gravity gradients
Height of the tropopause	Colour Dissolved Organic Matter (CDOM)	**Atmospheric chemistry**
Temperature of the tropopause	Ocean suspended sediments concentration	O_3
Cloud and precipitation	Ocean Diffuse Attenuation Coefficient (DAC)	BrO
Cloud top temperature	Oil spill cover	C_2H_2
Cloud top height	Sea surface temperature	C_2H_6
Cloud type	Sea surface salinity	CFC-11
Cloud cover	Ocean dynamic topography	CFC-12
Cloud base height	Coastal sea level (tide)	CH_2O
Cloud optical depth	Significant wave height	CH_4
Cloud liquid water	Dominant wave direction	ClO
Cloud drop effective radius	Dominant wave period	$ClONO_2$
Cloud ice	Wave directional energy frequency spectrum	CO
Cloud ice effective radius	Sea-ice cover	CO_2
Freezing level height in clouds	Sea-ice thickness	COS
Melting layer depth in clouds	Sea-ice type	H_2O
Precipitation (liquid or solid)	**Land surface**	HCl
Precipitation intensity at surface (liquid or solid)	Land surface temperature	HDO
Accumulated precipitation (over 24 h)	Soil moisture at surface	HNO_3
Lightning detection	Soil moisture (in the roots region)	N_2O
Aerosol and radiation	Fraction of vegetated land	N_2O_5
Aerosol Optical Depth	Vegetation type	NO
Aerosol concentration	Leaf Area Index (LAI)	NO_2
Aerosol effective radius	Normalised Difference Vegetation Index (NDVI)	OH
Aerosol type	Fire fractional cover	PAN
Volcanic ash	Fire temperature	PSC occurrence
Downward solar irradiance at TOA	Fire radiative power	SF_6
Upward spectral radiance at TOA	Snow status (wet/dry)	SO_2
Upward LW irradiance at TOA	Snow cover	**Space Weather**
Upward SW irradiance at TOA	Snow water equivalent	Total Electron Content (TEC)
Short-wave cloud reflectance	Soil type	Electron density
Downward LW irradiance at Earth's surface	Land cover	Magnetic field
Downward SW irradiance at Earth's surface	Land surface topography	Electric field
Earth's surface albedo	Glacier cover	Charged particles
Earth's surface SW bidirectional reflectance	Glacier topography	Solar activity

Table 4: **List of geophysical variables possible to be measured from space.**

In Vol. 4, for each possible sensing technique the measurement principle is highlighted, as well as the elements that control horizontal and vertical resolution, accuracy, and coverage. Possible limiting conditions are pointed out, and whether the observation is possible from LEO and/or GEO. Quantitative performance figures are estimated. See the results for "Wind (horizontal)".

Estimated potential quality of product "Wind (horizontal)" **(> 2020)**								
Layer	**Orbit**	**Technique**	**RMS (unit)**	**Δx (km)**	**Δz (km)**	**Δt (h)**	**Number of sats**	**Conditions**
Troposphere (@ ~500 hPa)	LEO	Doppler lidar (non-scanning)	1 m/s	50	0.5	180	1	Clear-air
	LEO	VIS/IR image sequences	5 m/s	15	6	4	3	Need for tracers, polar regions
	GEO	VIS/IR image sequences	3 m/s	50	6	1	6	Need for tracers
	LEO	IR imager-sounder	3 m/s	160	2	4	3	Clear-air, polar regions
	GEO	IR imager-sounder	2 m/s	160	2	1	6	Clear-air
Stratosphere (@ ~30 hPa)	LEO	Doppler lidar (non-scanning)	4 m/s	50	2	180	1	Non-scanning
	LEO	Doppler shift (limb mode)	5 m/s	300	2	72	1	Daylight

CONTENTS OF VOLUME 5 (COMPLIANCE)

Vol. 5 provides a tool to assess the compliance of satellite-derived products with user requirements. The tool is validated by using "synthetic" user requirements interpolated/extrapolated from a wide number of sources. These are compared with calculated performances of relevant observing techniques (derived from Vol. 4) for each of the 112 addressed geophysical variables. One example is given in the *Table 5*.

Wind (horizontal) - Compliance analysis																									
KEY APPLICATION	**LAYER**	**REQUIREMENTS**																**OBSERVING TECHNIQUES**		**PERFORMANCES**				**OBSERVING CONDITIONS**	
		Uncertainty (RMS)				**Δx (km)**			**Δz (km)**			**Δt (h)**			**δ (h)**			**Orbit**	**Principle of**	**Accuracy**	**Δx**	**Δz**	**Δt**	**Assumed**	**Limitations or**
		Unit	thres	break	goal	thres	break	goal	thres	break	goal	thres	break	goal	thres	break	goal	**type**	**the instrument**	**(RMS)**	**(km)**	**(km)**	**(h)**	**no. of sats**	**special features**
NWP (large-scale)	Troposphere	m/s	5	3	1	300	50	10	3	1	0.3	24	3	1	6	0.5	0.1	LEO	Doppler lidar (non-scanning)	1 m/s	50	0.5	180	1	Clear-air
		m/s	5	3	1	300	50	10	3	1	0.3	24	3	1	6	0.5	0.1	LEO	VIS/IR image sequences	5 m/s	15	6	4	3	Need for tracers, polar regions
		m/s	5	3	1	300	50	10	3	1	0.3	24	3	1	6	0.5	0.1	GEO	VIS/IR image sequences	3 m/s	50	6	1	6	Need for tracers
		m/s	5	3	1	300	50	10	3	1	0.3	24	3	1	6	0.5	0.1	LEO	IR imager-sounder	3 m/s	160	2	4	3	Clear-air, polar regions
		m/s	5	3	1	300	50	10	3	1	0.3	24	3	1	6	0.5	0.1	GEO	IR imager-sounder	2 m/s	160	2	1	6	Clear-air
	Stratosphere	m/s	10	3	1	1000	100	20	10	3	1	48	12	3	6	0.5	0.1	LEO	Doppler lidar (non-scanning)	4 m/s	50	2	180	1	Non-scanning
		m/s	10	3	1	1000	100	20	10	3	1	48	12	3	6	0.5	0.1	LEO	Doppler shift (limb mode)	5 m/s	300	2	72	1	Daylight
NWP (small-scale)	Troposphere	m/s	5	2	1	30	5	1	1	0.3	0.1	6	1	0.25	3	0.5	0.1	LEO	Doppler lidar (non-scanning)	1 m/s	50	0.5	180	1	Clear-air
		m/s	5	2	1	30	5	1	1	0.3	0.1	6	1	0.25	3	0.5	0.1	LEO	VIS/IR image sequences	5 m/s	15	6	4	3	Need for tracers, polar regions
		m/s	5	2	1	30	5	1	1	0.3	0.1	6	1	0.25	3	0.5	0.1	GEO	VIS/IR image sequences	3 m/s	50	6	1	6	Need for tracers
		m/s	5	2	1	30	5	1	1	0.3	0.1	6	1	0.25	3	0.5	0.1	LEO	IR imager-sounder	3 m/s	160	2	4	3	Clear-air, polar regions
		m/s	5	2	1	30	5	1	1	0.3	0.1	6	1	0.25	3	0.5	0.1	GEO	IR imager-sounder	2 m/s	160	2	1	6	Clear-air
Actual weather	Troposphere	m/s	5	2	1	300	30	3	3	1	0.3	6	1	0.25	1	0.25	0.1	LEO	Doppler lidar (non-scanning)	1 m/s	50	0.5	180	1	Clear-air
		m/s	5	2	1	300	30	3	3	1	0.3	6	1	0.25	1	0.25	0.1	LEO	VIS/IR image sequences	5 m/s	15	6	4	3	Need for tracers, polar regions
		m/s	5	2	1	300	30	3	3	1	0.3	6	1	0.25	1	0.25	0.1	GEO	VIS/IR image sequences	3 m/s	50	6	1	6	Need for tracers
		m/s	5	2	1	300	30	3	3	1	0.3	6	1	0.25	1	0.25	0.1	LEO	IR imager-sounder	3 m/s	160	2	4	3	Clear-air, polar regions
		m/s	5	2	1	300	30	3	3	1	0.3	6	1	0.25	1	0.25	0.1	GEO	IR imager-sounder	2 m/s	160	2	1	6	Clear-air
Climate (large-scale)	Troposphere	m/s	5	3	1	500	100	20	3	1	0.3	24	3	1	168	72	24	LEO	Doppler lidar (non-scanning)	1 m/s	50	0.5	180	1	Clear-air
		m/s	5	3	1	500	100	20	3	1	0.3	24	3	1	168	72	24	LEO	VIS/IR image sequences	5 m/s	15	6	4	3	Need for tracers, polar regions
		m/s	5	3	1	500	100	20	3	1	0.3	24	3	1	168	72	24	GEO	VIS/IR image sequences	3 m/s	50	6	1	6	Need for tracers
		m/s	5	3	1	500	100	20	3	1	0.3	24	3	1	168	72	24	LEO	IR imager-sounder	3 m/s	160	2	4	3	Clear-air, polar regions
		m/s	5	3	1	500	100	20	3	1	0.3	24	3	1	168	72	24	GEO	IR imager-sounder	2 m/s	160	2	1	6	Clear-air
	Stratosphere	m/s	5	3	1	500	100	20	3	1	0.3	24	3	1	168	72	24	LEO	Doppler lidar (non-scanning)	4 m/s	50	2	180	1	Non-scanning
		m/s	5	3	1	500	100	20	3	1	0.3	24	3	1	168	72	24	LEO	Doppler shift (limb mode)	5 m/s	300	2	72	1	Daylight
Climate (small-scale)	Troposphere	m/s	5	3	1	100	20	5	1	0.3	0.1	12	3	1	168	72	24	LEO	Doppler lidar (non-scanning)	1 m/s	50	0.5	180	1	Clear-air
		m/s	5	3	1	100	20	5	1	0.3	0.1	12	3	1	168	72	24	LEO	VIS/IR image sequences	5 m/s	15	6	4	3	Need for tracers, polar regions
		m/s	5	3	1	100	20	5	1	0.3	0.1	12	3	1	168	72	24	GEO	VIS/IR image sequences	3 m/s	50	6	1	6	Need for tracers
		m/s	5	3	1	100	20	5	1	0.3	0.1	12	3	1	168	72	24	LEO	IR imager-sounder	3 m/s	160	2	4	3	Clear-air, polar regions
		m/s	5	3	1	100	20	5	1	0.3	0.1	12	3	1	168	72	24	GEO	IR imager-sounder	2 m/s	160	2	1	6	Clear-air
Biosphere (large-scale)	Troposphere	m/s	10	5	2	500	100	20	6	3	1	168	72	24	720	168	24	LEO	Doppler lidar (non-scanning)	1 m/s	50	0.5	180	1	Clear-air
		m/s	10	5	2	500	100	20	6	3	1	168	72	24	720	168	24	LEO	VIS/IR image sequences	5 m/s	15	6	4	3	Need for tracers, polar regions
		m/s	10	5	2	500	100	20	6	3	1	168	72	24	720	168	24	GEO	VIS/IR image sequences	3 m/s	50	6	1	6	Need for tracers
		m/s	10	5	2	500	100	20	6	3	1	168	72	24	720	168	24	LEO	IR imager-sounder	3 m/s	160	2	4	3	Clear-air, polar regions
		m/s	10	5	2	500	100	20	6	3	1	168	72	24	720	168	24	GEO	IR imager-sounder	2 m/s	160	2	1	6	Clear-air

Table 5: **Example of compliance analysis. The first two columns display "key applications", with the layer of interest. The columns displaying the "synthetic" requirements follow (with uncertainty, horizontal, vertical and temporal resolution, and timeliness, each being characterized by threshold, breakthrough and goal values). In the next columns the product performances are displayed as evaluated in Vol. 4. Colours indicate the degree of compliance.**

This static document is delivered with a collection of 112 Excel files, one for each of the variables, which constitute a tool that can be used for entering actual user requirements instead of the "synthetic" requirements, and validated performances instead of "estimated" performances. The colours rating the degree of compliance will adjust automatically. The tool may be used to support the Rolling Requirements Review process (RRR) aimed at providing guidance to space agencies about desirable developments, and to users about realistic expectations.

A FEW APPLICATIONS OF THE GOS DOSSIER

The GOS Dossier can be used for a number of specific exercises, and also for educational purposes. One systematic application is the use of Vol. 3 for running the Gap analysis and reporting at each CGMS session, recommending actions aimed at filling or mitigating the gaps.

Gap analysis of the Essential Climate Variables

On request of the Expert Team on Satellite Systems (ET-SAT), the Gap analysis has been applied to the GCOS "Essential Climate Variables" (ECV). The final report was submitted to ET-SAT-6 in April 2011 (http://www.wmo.int/pages/prog/sat/meetings/documents/ET-SAT-6_Doc_06-04_ECVGapAnalysis.zip). For current and future activities (2008-2025) the gap analysis is rather detailed, extracted from Vol. 3 of the Dossier (Gap Analysis). For past periods, the information is extracted from the historical parts of Vol. 1 (Programmes). The ECV gap analysis spreads over 50 years (1975-2025). Bar charts like the one in *Figure 4* summarize the situation for each ECV.

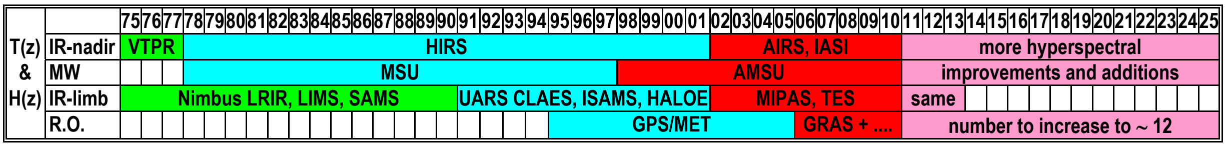

Figure 4: **Bar chart of measurement availability for a given ECV, from 1975 to 2025.**

The analysis shows that several gaps found in the general GOS Gap analysis would also impact on the ECV provision. Examples: Precipitation, depending on the GPM follow-on; and Earth radiation budget, not committed for long-term continuity in the a.m. orbit. Furthermore, two major systematic gaps have been found:

- on limb sounding missions after the termination of the current ones, which implies future gaps in the vertical resolution of trace gases, including ozone, in the middle and high stratosphere; and
- on mission requiring large payloads such as lidar (e.g. for clear-air wind) and L-band radiometers (e.g., for ocean salinity and volumetric soil moisture), uneasy to accommodate on multi-purpose operational satellites, thus implying dedicated platforms.

The document has been provided as an input for detailed discussion by expert teams.

Update of the CIMO Guide

The chapter on satellites of the Guide of the Commission of Instruments and Methods of Observation (CIMO) is over 15 years old. By utilising the information on the GOS Dossier a new version has been drafted for CIMO. The document is currently under refinement and finalisation. Contents:

1. General (Historical perspective, Specific features of space-based remote sensing).
2. Principles of Earth Observation from Space (Orbits and earth viewing from space, Principles of remote sensing, Data circulation and processing).
3. Remote sensing instruments (Instruments basic characteristics, Visible and Infrared imagers, Infrared sounders, Microwave imagers and sounders, Spectrometers for atmospheric chemistry, Special instruments, Radar, Lidar, In-situ measurements at platform level, Navigation and positioning systems).
4. Satellite constellations (Operational meteorological satellites, Specialised atmospheric missions, Missions to ocean and ice, Land observation missions, Missions to Solid Earth, Missions to Space Weather).
5. Space-based observation of geophysical variables (Basic atmospheric 3D and 2D variables, Cloud and Precipitation variables, Aerosol and Radiation, Ocean and sea ice, Land surface (including snow), Solid Earth, Atmospheric chemistry, Space Weather).
6. Calibration and validation (Instrument calibration, Validation of satellite-based products).
7. Cross-cutting issues (Data access, Use of the frequency spectrum).