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GAP ANALYSIS FOR SATELLITE MISSIONS SUPPORTING THE GOS

In response to action A38.43

WMO-WP-31 first describes the methodology used in Vol. 3 of the WMO Dossier on the Space-based Global Observing System (GOS Dossier) containing the "*Gap analysis in the space-based component of GOS*", which analyzes the plans related to 33 categories of missions from 2008 to 2025, and evaluates risk of gaps in the post-2020 timeframe for each of these missions.

Based on this general analysis, the document highlights critical areas from two perspectives: (i) for operational missions foreseen in the Vision of the GOS in 2025, and (ii) more specifically for the GCOS ECVs.

With respect to the Vision, gaps are identified for infrared and microwave sounding on the early morning orbit and hyperspectral sounding on some geostationary sectors. There is a risk of insufficient coverage by radio-occultation missions in the short-term and in the long term, lack of long-term plan for spaceborne precipitation radar after the Global Precipitation Measurement (GPM) mission, and lack of long-term commitment on Earth Radiation Budget.

With respect to the GCOS ECVs, the analysis underscores the same critical situation for Earth Radiation Budget, radio-occultation and for spaceborne precipitation radars. It also highlights an anticipated gap in the measurement of stratospheric ozone, long lived greenhouse gases and ozone precursors due to the lack of future limb sounding missions, and the need to develop plans for lidar missions for the measurement of aerosols and sea-ice, and for low-frequency MW follow-on missions for salinity and soil moisture.

Action/Recommendation proposed:

CGMS Satellite Operators are invited to note the results of the gap analysis of satellite data for the GOS, and more specifically for climate monitoring, and to consider actions to address these anticipated or potential gaps.

GAP ANALYSIS FOR SATELLITE MISSIONS SUPPORTING THE GOS

1 INTRODUCTION

A gap analysis is performed in comparing satellite mission plans to a reference. Two approaches are followed:

- either the reference is defined in terms of satellite capabilities to be made available,
- or the reference is defined in terms of observations to be delivered.

The Dossier on the space-based GOS (See CGMS-39 WMO-WP-16) includes in its Vol. 3 a "*Gap analysis in the space-based component of GOS*" which corresponds to the first approach above. It provides a detailed analysis of satellites and instruments available or planned for the period 2008 to 2025, and considerations on identified gaps or risk of gaps in the post-2020 timeframe for 33 different categories of missions for which a reference configuration is indicated.

Building on this initial analysis, the second approach was pursued to identify the resulting risks of gaps for each of the GCOS Essential Climate Variables (ECV) observable from space. The preliminary outcome of this analysis was presented to CGMS-38 (CGMS-38 WMO-WP-04), then in a revised form to the Workshop on Continuity and Architecture Requirements in January 2011, and the final outcome was presented to the sixth session of the Expert Team on Satellite Systems (ET-SAT-6) in April 2011 (http://www.wmo.int/pages/prog/sat/meetings/documents/ET-SAT-6_Doc_06-04_ECVGapAnalysis.zip) .

The present document, which builds on the latest information available in the GOS-Dossier, recalls the methodology applied in these gap analyses and focuses on the risks of gaps from two perspectives:

for all operational missions as compared to the Vision of the GOS in 2025, and

more specifically for climate, with reference to the continuous observation of ECVs.

2 GENERAL GAP ANALYSIS

2.1 Methodology

Thirty-three missions are considered in the Gap Analysis of the current version of the GOS Dossier (GOS-2011-September) as listed in Table 1.

Table 1. List of the missions considered in the Gap Analysis of the GOS Dossier, Vol. 3

01	Multi-purpose VIS/IR imagery from LEO
02	Multi-purpose VIS/IR imagery from GEO
03	IR temperature/humidity sounding from LEO
04	IR temperature/humidity sounding from GEO
05	MW temperature/humidity sounding from LEO
06	MW temperature/humidity sounding from GEO
07	Multi-purpose MW imagery
08	Low-frequency MW imagery
09	Radio occultation sounding
10	Earth radiation budget from LEO
11	Earth radiation budget from GEO

12	Sea-surface wind by active and passive MW
13	Radar altimetry
14	Ocean colour imagery from LEO
15	Ocean colour imagery from GEO
16	Imagery with special viewing geometry
17	Lightning imagery from LEO
18	Lightning imagery from GEO
19	Cloud and precipitation profiling by radar
20	Lidar-based missions (for wind, for cloud/aerosol, for trace gases, for altimetry)
21	Cross-nadir short-wave spectrometry (for chemistry) from LEO
22	Cross-nadir short-wave spectrometry (for chemistry) from GEO
23	Cross-nadir IR spectrometry (for chemistry) from LEO
24	Cross-nadir IR spectrometry (for chemistry) from GEO
25	Limb-sounding short-wave spectrometry
26	Limb-sounding IR spectrometry
27	Limb-sounding millimetre-submillimetre wave spectrometry
28	High-resolution imagery for land observation
29	Synthetic Aperture Radar
30	Solid Earth
31	Space Weather from LEO
32	Space Weather from GEO
33	Space Weather from specific high orbits.

For each of the 33 missions listed in Table 1 above, the gap analysis was performed in seven steps. This is illustrated in annex with one example.

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

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

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

Step 4: Assignment of the instruments to different instrument performance classes.

Step 5: Reference observing strategy.
Note: While the previous steps are factual, this step introduces an *a priori* definition of the required architecture. For most missions, this definition reflects the space-based elements of the "Vision for the GOS in 2025" that was approved by the sixty-first Executive Council. For other missions, which were not detailed in the Vision (e.g. contribution to at mospheric chemistry, or missions in demonstration phase, or missions to space weather and solid earth) a tentative observation strategy is indicated.

Step 6: Bar chart of relevant missions in the 2008-2025 time frame, displaying the planned availability of instruments over time, by orbital location, colour-coded by class of performance.

Step 7: Overall assessment of the plans and identification of actual or potential gaps.

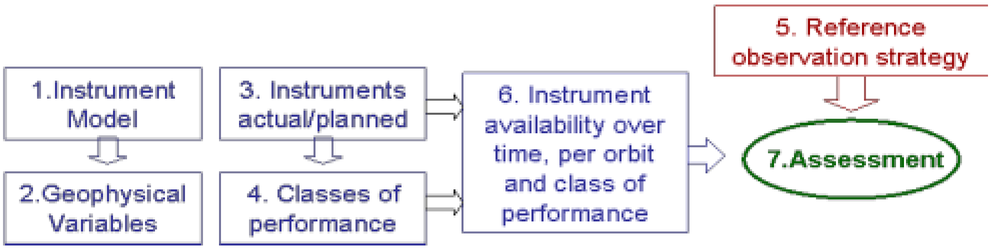

Figure 1. Schematic flow diagram of the steps followed for the Gap Analysis

2.2 Overall assessments for the considered missions

The overall assessments resulting of the gap analysis contained in Vol. 3 of the GOS Dossier, focusing on the post-2020 timeframe, are reported in Table 2 below, mission by mission.

Table 2. Overall assessments of the 33 missions as extracted from the GOS-Dossier Vol. 3

Multi-purpose VIS/IR imagery from LEO	Issues in the early morning orbit: DWSS/VIIRS data access and lack of redundancy.
Multi-purpose VIS/IR imagery from GEO	Since no satellite is positioned in the 180° 30° sector and the interval between the neighbouring satellites reaches 85 degrees, the Ocean Pacific is only covered up to the latitude of 47° for quantitative applications (such as cloud-motion winds). The requirement is for coverage up to 55° latitude.
IR temperature/humidity sounding from LEO	Full gap of IR sounding in the early morning orbit. Only MW, with non-optimal scanning (conical).
IR temperature/ humidity sounding from GEO	Three consecutive sectors, from 150°E to 30°W, i.e. half of the total coverage from GEO, will have no sounder, that implies not only missing temperature and humidity profiles (that in some way are provided by LEO satellites), but also wind profile that is derived from frequent humidity profiling from GEO. Plans for a hyperspectral sounder on follow-on of GOES-R/S or parallel free-flyer are not yet scheduled.
MW temperature/humidity sounding from LEO	Issues in the early morning orbit: DWSS/MIS lower performance in respect of sounding, no confirmation of near-real time availability, and lack of redundancy.
MW temperature/humidity sounding from GEO	No operational plan is available for the foreseeable future; only a possible pathfinder in the 120°W 30° sector.
Multi-purpose MW imagery	Few high-resolution instruments (DWSS MIS in early morning and AMSR-2 in afternoon), and lack of plans for long-term continuation of the Global Precipitation Measurement mission.
Low-frequency MW imagery	The main gap consists of the lack of long-term plans for exploiting L-band (1.4 GHz) for ocean salinity and volumetric soil moisture.
Radio occultation sounding	The achievement of the observing strategy critically depends on the implementation and long-term continuation of the COSMIC-2 plan.
Earth radiation budget from LEO	Serious problem of long-term continuation of upward radiation measurements in the afternoon orbit. Need to demonstrate that the combined use with GEO VIS/IR frequent images (missing UV and FIR) is sufficient to interpolate/extrapolate for the diurnal cycle. For downward short-wave radiation, there is no redundancy in the long-term.
Earth radiation budget from GEO	Only MWIR and TIR covered, only in sectors 0° 30° and 60°E 30°. Need to demonstrate that the GEO VIS/IR frequent images are sufficient to support the measurements from LEO to account for the diurnal cycle.

Sea-surface wind by active and passive MW	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).
Radar altimetry	Within the known limits of nadir-viewing only, the altimetry mission seems in good shape, especially if the HY-2 programme is provided with long-term continuity. The very important perspective of large-swath altimetry will be explored by SWOT (of the US Decadal Survey).
Ocean colour imagery from LEO	The late morning will be covered by more and generally better performing instruments than the early afternoon. If confirmed, the PACE OES (proposed in the US Decadal Survey) should present improved performance and might benefit of multi-spectral, multi-polarisation and multi-viewing capability of APS-NG companion instrument.
Ocean colour imagery from GEO	Coverage limited to a partial area of sector 120°E 30°. The mission is for sub-regional use.
Imagery with special viewing geometry	If confirmed, the PACE APS-NG (proposed in the US Decadal Survey) that also embarks OES for ocean colour, would extend the multi-spectral, multi-polarisation and multi-viewing capability to the early afternoon orbit.
Lightning imagery from LEO	There is a gap of lightning observation from space at high latitudes. Continuation of lightning mission in LEO should be considered in the context of possible continuation of the GPM mission.
Lightning imagery from GEO	Reduced latitude coverage in the Pacific Ocean and lack of redundancy in the 120-170°W longitude range.
Cloud and precipitation profiling by radar	Long-term continuity of cloud and precipitation radar is currently not planned.
Laser-based missions	Long-term continuity of lidar-based missions is currently not planned.
Cross-nadir short-wave spectrometry from LEO	Satisfactory time coverage and redundancy are only planned for ozone. Wide spectral range is only provided by EPS-SG UVNS, only in the morning,
Cross-nadir short-wave spectrometry from GEO	Coverage limited to partial areas of sectors 0° 30° and 120°E 30°. The mission is for sub-regional use.
Cross-nadir IR spectrometry from LEO	Without a very-high spectral resolution IR sounder, the profiles of species such as HNO_3, SF_6, N_2O_5, PAN, C_2H_6 and C_2H_2 could not be observed. Currently only the EOS-Aura TES (approaching end-of-life) is suitable. It is assumed that the FY-3 GAMI could be comparable,
Cross-nadir IR spectrometry from GEO	The mission covers one half of the longitude sectors, though only for total columns.
Limb-sounding short-wave spectrometry	There is no long-term plan for providing chemistry observation in the limb mode. Therefore, it will not be possible to observe profiles with sufficiently high vertical resolution in the stratosphere and mesosphere. In the short-wave range, important species such as ClO, BrO and ozone will be missing. This gap adds to similar gaps for IR and millimetre/sub-millimetre instruments.
Limb-sounding IR spectrometry	There is no long-term plan for providing chemistry observation in the limb mode. Therefore, it will not be possible to observe profiles with sufficiently high vertical resolution in the stratosphere and mesosphere. In the IR range, important species such as HNO_3 (but also ozone !) will be missing. This gap adds to similar gaps for SW and millimetre/sub-millimetre.
Limb-sounding millimetre-submillimetre wave spectrometry	There is no long-term plan for providing chemistry observation in the limb mode. Therefore, it will not be possible to observe profiles with sufficiently high vertical resolution in the stratosphere and mesosphere. In the millimetre-submillimetre range, important species such as HCl and OH and ozone will be missing. This gap adds to similar gaps for SW and IR. The only millimetre-submillimetre limb-sounding mission currently considered is GACM in the framework of the US Decadal Survey.

High-resolution imagery for land observation	No problem of data availability is foreseen. The issue is to ensure user friendly data access and minimum cost and delivery time.
Synthetic Aperture Radar	Main issues with SAR utilisation is the timeliness, conditioned by the need for intensive processing, and the cost, limiting the use of SAR for operational meteorology and climatology.
Solid Earth	The Solid Earth theme suffers of being on the border line between application and research. Progress is steady but slow, considering the relevance of issues such as earthquakes and tsunami.
Space Weather mission from LEO	With the exception of *in situ* charged particles monitoring, and radio occultation, very few missions to Space Weather are planned with long-term continuity, especially in the outmost important fields of magnetosphere and of solar activity.
Space Weather mission from GEO	The contribution from GEO satellites to Space Weather monitoring is substantial, also because measurements from GEO are probably more accurate (less impact from the atmosphere and the Van Allen belts). More effort is required in the area of magnetic field observation.
Space Weather from specific high orbits	Since solar-terrestrial relationship is still at the border-line between science and application, programmes are basically undertaken in a research framework with no explicit long-term commitment. However, it is expected that R&D space agencies will continue to implement and operate suitable missions with sufficient continuity.

3 CRITICAL GAPS WITH RESPECT TO THE VISION FOR THE GOS IN 2025

From the overall assessments summarized in Table 2, the following critical areas are emphasized with respect to the implementation of the Vision of the GOS in 2025.

IR sounding in the early morning - The lack of IR sounders in the early morning orbit is a serious problem for NWP. With sounders only in the mid-morning and early afternoon orbits, there are two temporal gaps of about 8 hours between 01:30 to 09:30 and 13:30 to 21:30.

Hyperspectral IR sounding from geostationary orbit - About one half of the total coverage from GEO will have no sounder, that implies not only missing temperature and humidity profiles (that in some way are provided by LEO satellites), but also wind profile that is derived from frequent humidity profiling from GEO.

Global Precipitation Measurement mission - Long-term commitment for the GPM, particularly for the precipitation radar, is missing. Among MW radiometers, only few have high spatial resolution and, anyway, without the support of one radar, data quality cannot be very high.

Radio occultation sounding - The replacement strategy of satellites flying in constellation must be solidly established. For example, as the capability of the COSMIC constellation is gradually decreasing and COSMIC-2 is still in the planning phase, any delay in the implementation of COSMIC-2 would result in a seriously reduced availability of radio-occultation soundings. Plans should also be made for the long term.

Earth radiation budget - Long-term commitment for ERB measurement in the afternoon orbit is missing. The capability to account for diurnal variations with due accuracy is questionable due to the scarce plans for ERB measurement from GEO.

4 CRITICAL GAPS WITH RESPECT TO THE ECVs

A preliminary analysis with respect to ECVs was provided to CGMS in 2010 (*Mapping of the Gap Analysis with the GCOS ECV, CGMS-38 WMO-WP-04*) . The final report on this analysis was submitted to the Expert Team on Satellite Systems in April 2011 (*ET-SAT-6/Doc. 6.4/Gap Analysis of Satellite Missions with respect to GCOS ECVs*). The outcome of this analysis is summarized below.

4.1 Methodology

Many of the ECVs involve in fact the observation of several elementary geophysical variables either by ground systems, or from space. This study focuses on the possible contribution of satellites.

The starting point was to split each ECV into a set of observations of elementary variables, and identify those that can be provided by satellites. Thereafter, the gap analysis is applied to these satellite observations. The study heavily relies on the GOS Dossier. 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 availability of historical records varies with observation. Considering the overall situation, it was decided to start the analysis with the year 1975. Therefore, the ECV gap analysis spreads over 50 years (1975-2025). Bar charts like the one in Figure 2 below summarize the situation for each ECV.

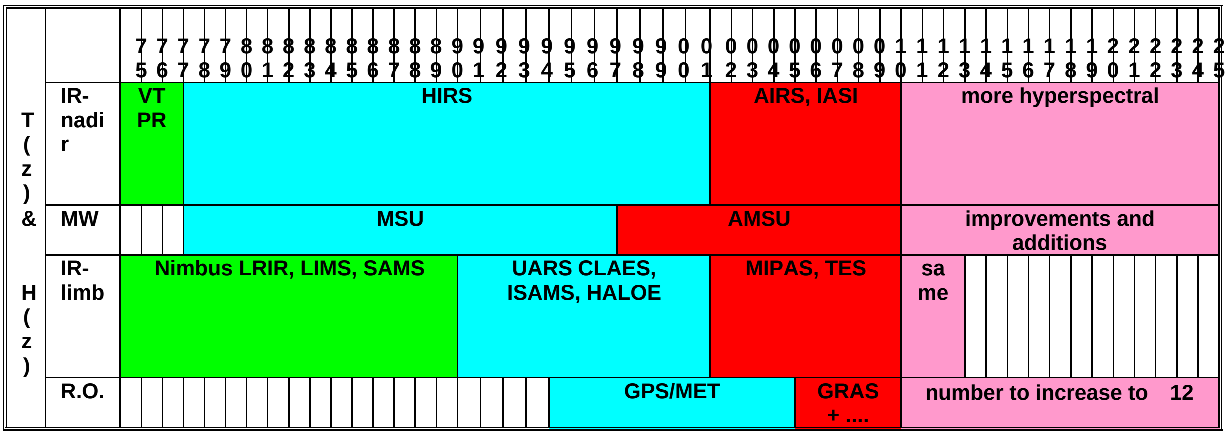

Figure 2. Bar chart of measurement availability for a givenECV, from 1975 to 2025. Each row corresponds to type of mission, each colour to a class of performance.

4.2 Main findings

Satellite observations can support 40 elementary variables (corresponding to 34 ECVs since several variables are grouped into only one ECV) to a greater or lesser extent, out of the 60 elementary variables (corresponding to 50 ECVs) currently defined. For 16 other variables there is little hope of any support, for the remaining 4 the current definition is too general, not allowing quantitative evaluation. The gap analysis performed on the 40 variables potentially benefiting from satellites is summarised in Table 3 below.

Table 3. Summarized risk assessment for the 40 variables measurable from space

Code		ECV	Summary risk assessment for satellite support to ECV
Sfc	A.03	Precipitation	Quality of retrieved precipitation depends on GPM follow-on (with radar)
Sfc	A.04	Surface radiation budget	Problematic quality and risk of long-term continuity of solar irradiance measurements
Sfc	A.06	Wind speed and direction	No risk, but limited to sea surface
Upper	A.07	Cloud properties	Risk of limited quality as regards cloud interior
Upper	A.08	Earth radiation budget	Risk of limited quality and risk for long-term continuity
Upper	A.09	Temperature	Troposphere: no risk - Stratosphere: limb sounding missions not planned

Upper	A.10	Water vapour	Troposphere: no risk - Stratosphere: limb sounding missions not planned
Upper	A.11	Wind speed and direction	Troposphere: problematic quality - Stratosphere: limb sounding missions not planned
Comp	A.12	Aerosol	Troposphere: problematic quality - Stratosphere: limb sounding missions not planned
Comp	A.13	Carbon dioxide	Troposphere: problematic quality - Stratosphere: limb sounding missions not planned
Comp	A.14	Methane	Troposphere: limited quality - Stratosphere: limb sounding missions not planned
Comp	A.16	Ozone	Troposphere: no risk - Stratosphere: limb sounding missions not planned
Comp	A.15.1	Trichlorofluoromethane	Troposphere: no risk - Stratosphere: limb sounding missions not planned
Comp	A.15.2	Dichlorodifluoromethane	Troposphere: no risk - Stratosphere: limb sounding missions not planned
Comp	A.15.3	Nitrous Oxide	Troposphere: limited quality - Stratosphere: limb sounding missions not planned
Comp	A.15.4	Sulphur hexafluoride	Troposphere: no risk - Stratosphere: limb sounding missions not planned
Comp	A.17.1	Nitrogen peroxide	Troposphere: limited quality - Stratosphere: limb sounding missions not planned
Comp	A.17.2	Sulfur dioxide	Troposphere: limited quality - Stratosphere: limb sounding missions not planned
Comp	A.17.3	Formaldehyde	Troposphere: no risk - Stratosphere: limb sounding missions not planned
Comp	A.17.4	Carbon monoxide	Troposphere: limited quality - Stratosphere: limb sounding missions not planned
Sfc	O.02	Current	No risk, but limited to the geostrophic component as from ocean topography
Sfc	O.03	Ocean colour	No risk
Sfc	O.04	Sea ice	Risk of limited quality of ice thickness observation (lidar altimeter not for long-term)
Sfc	O.05	Sea level	No risk of data availability (altimeters), but system limitations (coverage)
Sfc	O.06	Sea state	No risk of data availability (altimeters and SAR), but system limitations (coverage)
Sfc	O.07	Sea surface salinity	No mission planned for the long term
Sfc	O.08	Sea surface temperature	No risk
Sfc	O.14	Ocean tracers	Risk depends on the addressed tracer. No risk in the case of Oil spill
Sfc	T.04	Lakes	No risk for several lake parameters, risk of limited quality for lake topography
Sfc	T.05	Snow cover	No risk for several snow parameters, risk of limited quality for snow water equivalent
Sfc	T.06	Glacier and ice caps	No risk for several glacier parameters, risk of limited quality for glacier topography
Sfc	T.07	Permafrost	No risk
Sfc	T.08	Albedo	No risk
Sfc	T.09	Land cover	No risk
Sfc	T.10	Fraction of Absorbed PAR	No risk
Sfc	T.11	Leaf Area Index (LAI)	No risk
Sfc	T.12	Above-ground biomass	Risk of limited quality, depending on the specific user requirement to be fulfilled
Sfc	T.13	Fire disturbance	No risk
Sfc	T.14	Soil moisture	Risk of limited quality in the roots region (L-band MW radiometer not for long-term)

Sfc	T.15	Ice sheets	No risk for several land ice parameters, risk of limited quality for land ice topography

Table 3 shows that several gaps found in the previous analysis (section 3) would impact on the ECV provision, including A03 (Precipitation, depending on the GPM follow-on); A8 (Earth radiation budget, not committed for long-term continuity).

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 measurement of ozone, long-lived greenhouse gases and ozone precursors in the middle and high stratosphere; and
- On lidar and L-band radiometers, which are large payloads uneasy to accommodate on multi-purpose operational satellites, thus implying dedicated platforms. Given the lack of a follow-on plan to the current demonstration missions the continuity of ocean salinity observations is not secured, and soil moisture and sea ice observation will be limited.

It has to be stressed that this gap analysis only refers to the avail ability of satellite observations. However, the existence of observational data sets does not imply that the product has being or will be effectively retrieved and archived. Thus, the identified contribution is only potential.

5 PROPOSED ACTION

CGMS Satellite Operators are invited to note the results of the gap analysis of satellite data for the GOS, and more specifically for climate monitoring, and to consider actions to address these anticipated or potential gaps.

Annex: Example of gap analysis applied to one mission category

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)
Polarimeter	At least four, 10 to 37 GHz		Up to 6 polarisations		or conical conical

Step 2: Recall 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 currently or recently flown, 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

In the case of sea-surface wind the reference observation 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: Bar chart of relevant missions in 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: Comment on the overall plans and identification of actual or potential gaps.

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).