Subject	**WMO Gap Analysis**
In response to CGMS action/recommendation	WIII/A47.15
HLPP reference	1.1 and 1.2
Executive Summary	WMO gap analysis for Earth observation and space weather observation capabilities against the requirements presented in WMO Vision for WIGOS 2040 was provided. It compares space-based observation capabilities recorded in OSCAR/Space to the WMO WIGOS Vision for 2040 requirements for the period of next decade. In this working paper detailed descriptions of the missing observations capabilities related to the specific observation types in WIGOS subcomponent 1 and 2 were given. The work summarises totally 18 gaps for Earth observation types and 4 gaps for space weather observation types as main concerns non-compliant with WIGOS Vision 2040 requirements. Out of these gaps many are including periodic totally missing observation capabilities. These are for Earth observations: cloud radar, altimeter lidar, back scatter dial lidar, IR/MW limb sounder and SW occultation limb sounder. Related to space weather it concludes gaps with regards to WIGOS subcomponents 1 and 2 in magnetograph, radiospectrograph, X-ray imager and LEO magnetometer observations.
Action/Recommendation proposed	1. CGMS to consider the findings from this working paper and provide follow-on for the identified gaps of the observation capabilities, especially for those including periodical total gaps.

1 INTRODUCTION

The annual CGMS WG III Risk Assessment Workshop performs the analysis with regards to three different viewpoints:

- the CGMS Baseline, i.e. the scenario encompassing the satellite systems that the CGMS members and observers commit to implement and sustain for at least the next decade;
- the User requirements, i.e. the needs expressed by several user communities represented by several bodies and groups belonging to or coordinated with WMO, aiming at reviewing the actual status of observation processing capability and observing technology, and providing guidance for developments so as to pursue convergence (Rolling Requirements Review, RRR);
- the WIGOS Vision 2040, i.e. the projected developments of the WMO Integrated Global Observing Systems to meet long-term objectives of the RRR.

The WMO Gap Analysis is performed against the WIGOS Vision 2040. For input it uses the WMO OSCAR/Space database on 1 January 2025 noting it is continuously updated with the latest satellite status provided by the space agencies. The results are dependent on the lifetime of the satellites being accurate which is often not the case as dates can be extended subject to payload's technical functionality and funding being available.
The analysis is shown in Fig. 1 for Earth Observations and any potential gaps in the coverage are discussed in the sections below. It should be noted that the instruments included in this analysis are based on a broader set of criteria for instruments to be included than the CGMS-53 risk assessment (CGMS-53-WGIII-WP-02) recently undertaken by NOAA. For example, instruments not finally approved for funding may be included or not assured to be operational when launched but would still contribute valuable observations. Therefore, this analysis is a rather more optimistic picture than that seen in the official risk assessment report.

The WIGOS Vision 2040 and the RRR is promoted by WMO to be considered by space agencies as reference user requirements to guide future developments for the medium (RRR) and long-term (WIGOS) space-based observations. The results of the WMO gap analysis for Earth observations and space weather for the WIGOS Vision 2040 are shown in Fig. 1 and 3 respectively with each row corresponding to a specific type of measurement in a specific set of orbits (e.g. Geostationary, Polar, Drifting) listed in the WIGOS Vision 2040. The rows in pink are those measurements which are part of the CGMS baseline. The analyses only cover those observations included in the WIGOS subcomponents 1 and 2. For both the Earth observations and Space Weather observations it is assumed in this analysis that the measurements are made available to users in near real time. However, it should be noted that some measurements are from research missions where this is not the case and data access can be limited. For space weather a column was included in Fig. 3 to indicate if the data is available in near real time as there are many research missions. Figures 2 and 4 provide summaries of the status of the Earth observations and space weather observations for the next decade.

The text below summarises the main concerns arising from this analysis for each observation type and orbit including only those observations where the colours are going from green to amber/red at the end of the period. Where the trend is for the same or better coverage it is assumed that there are no concerns. This report is for information only and does not assign actions to specific space agencies as to how to mitigate these gaps.

2 EARTH OBSERVATIONS FROM GEOSTATIONARY ORBITS (WIGOS SUBCOMPONENT 1)

2.1 Infrared hyperspectral sounders

Sounding of the atmosphere at infrared (IR) wavelengths from geostationary orbit is transitioning to advanced IR sounders which sample the entire thermal IR spectrum at a resolution around 0.5cm-1 or better. Currently the FY-4 series is the only geostationary satellite with these sounders but the Meteosat Third Generation (MTG) series will also host an advanced IR sounder from 2025. Himawari-10 will cover the western Pacific from 2028 and NOAA has plans with GEO-XO to cover the continental U.S. but not until 2035. Gaps over the Atlantic and Indian Oceans are not planned to be filled in the next decade leaving gaps in the GEO ring with no firm plans to fill them.

2.2 UV/VIS/NIR sounders

Sounding of the atmosphere using reflected solar radiation at UV and visible wavelengths is limited at present with GEO-KOMPSAT-2B and recently TEMPO, covering the U.S., but the latter is not part of an operational series. For the baseline coverage after GEO-KOMPSAT-2B retires in 2031 it will no longer be met unless a follow-on satellite is planned. The new MTG series will enhance the coverage over Europe from 2025 with Sentinel-4 and the NOAA GEO-XO system over the U.S. from 2035. This leaves gaps over the mid-Atlantic, most of Asia and the Pacific well into the next decade which is a significant gap in the planned observing system for atmospheric chemistry measurements from geostationary orbit.

3 EARTH OBSERVATIONS FOR POLAR ORBITS (WIGOS SUBCOMPONENT 1)

3.1 Microwave Imagers

The number of MW imagers is set to reduce with the retirement of the SSMIS instruments on the DMSP satellites. They are replaced in the early morning orbit (~06:00 LT) with the U.S. WSF-M satellites. Both the early morning (06:00 LT) and early afternoon (13:30 LT) orbits are at risk in the next decade and plans need to be put in place to provide continuity in both these orbits and maintain the baseline after 2031. FY-3D/3H and GOSAT-GW will help to continue the coverage in this decade.

3.2 Scatterometers

Coverage of the Earth with scatterometers is assured in 3 sun synchronous orbits and drifting orbit up to 2031 but after that there are no plans for scatterometers in the drifting orbits unless the HY-2 (China) satellite series are extended to maintain the baseline. The afternoon orbit is covered by Oceansat-3A until 2030 and then the Russian Meteor-MP N1 is planned to provide continuity beyond that.

3.3 UV/VIS Nadir and Limb Sounders for atmospheric chemistry

Coverage of the Earth with UV/VIS nadir viewing sounders is assured for both late morning and early afternoon orbits up to 2041. There are various research missions for targeted species also planned. Coverage from drifting orbits is only planned out to 2028.

For limb view sounders (scanning or occultation views) the early afternoon orbit is covered by NOAA with OMPS-Limb but the morning orbit only has a commitment out to 2032 with FY-3F. The proposed NASA AOS HAWCSat mission could continue the measurements in the afternoon orbit through the next decade. Most of the requirements for stratospheric chemistry are for 6 hr or longer sampling times so a 2 polar orbiter system should be maintained.

3.4 Low frequency microwave imager

Measuring the surface at the lower microwave frequencies (<10 GHz) is important for SST, soil moisture and salinity measurements. The ESA proposal for CIMR should ensure no gaps well into the next decade. SMOS and SMAP provide coverage in the early morning orbit prior to CIMR but there is a risk of a short gap later this decade before CIMR comes on line.

3.5 Rain radar and Cloud radar

Selected FY-3 satellites (FY-3G/I) and INCUS-1/2/3 will have rain radars in a drifting orbit which should provide measurements after GPM-Core well into the next decade. The proposed AOS-PMM mission will also contribute from 2029. High temporal microwave sounders may go some way to fulfilling the requirement for frequent sampling of precipitation (see 4.6 below). When EarthCARE retires later this decade there are no planned cloud radars to continue the record. The requirement is for 3 hourly or better sampling.

3.6 Earth Radiation Budget and Total and Spectral Solar Irradiance

The Russian Electro and Meteor satellites are planned to provide observations of the Earth's radiation budget through the next decade from geostationary and polar orbits. The NOAA planned Libera measurements will continue until 2034 which provides the continuity with earlier measurements from CERES for the climate record.

Continuity of total solar irradiance measurements in polar orbits are planned from FY-3, Electro-L/M and the ESA TRUTHS mission well into the next decade. The record of spectral solar irradiance will be degraded after 2028 when TSIS-2 is retired. After that only FY-3E/J and TRUTHS will provide continuity in the early morning orbit and drifting orbit. A follow-on to TSIS would continue the current record from ACRIM and TSIS and help to provide some redundancy into the next decade.

3.7 GNSS radio occultation

The baseline requirement is for a minimum of 6000 occultations from low inclination orbits (<30°) distributed geographically and temporally in local time, 1000 occultation from other drifting orbits, and 7600 occultations from sun-synchronous orbits. When COSMIC-2 is retired in the middle of this decade the coverage at low latitudes will reduce significantly although the sun-synchronous orbit coverage will be maintained with many of the operational meteorological polar orbiters making GNSS-RO observations. There are now several commercial sources of radio occultation data which can help to mitigate any gaps in the core constellation but their long-term availability is not assured.

3.8 Day-Night visible imagery

Satellites with a day-night visible channel capability are only in the early morning (FY-3) and early afternoon (NOAA) orbits. There are no plans for day-night imagery in the late morning orbit.

4 EARTH OBSERVATIONS FOR POLAR AND DRIFTING ORBITS (WIGOS SUBCOMPONENT 2)

4.1 GNSS Reflectometry

HydroGNSS should provide coverage for the rest of this decade with the FY-3 satellites. It degrades into the next decade with only the FY-3 satellites providing it in several orbital planes. It should be noted that the current missions are in research mode to demonstrate the benefits of this type of measurement which have not been used operationally.

4.2 Doppler Wind Lidar

After the retirement of Aeolus in 2023 there is now a gap in coverage until the planned launch of Aeolus-2 in 2034. As the technology improves doppler wind lidars should be considered on a more operational basis with coverage from several orbital planes.

4.3 Lidars and interferometric radars for surface observations

There are no planned lidars for observing biomass after the ISS-GEDI and ISS_MOLI retire by 2030. For the ice observations using interferometric radars Cryosat-2 will retire soon to be followed by the Copernicus CRISTAL satellites which are due to last until 2036. The potential loss of coverage over the high polar latitudes needs to be considered if wide swath altimeters are not planned for future satellites.

4.4 Limb sounders in Shortwave, Infrared and Microwave

For the infrared and microwave limb sounders once Aura/MLS and Odin are retired in the next few years there will be no limb sounders operating leading to a loss of valuable information on stratospheric chemistry and a discontinuity in any climate data records from these measurements. At present there are no planned successors to MLS.

For the shortwave (UV/VIS) occultation limb sounders only SAGE-III, ALTIUS and the GaoFen satellites provide some measurements in this decade with no plans for coverage beyond 2030.

4.5 UV/VIS/NIR spectrometer

To monitor greenhouse gases GHGSat and then CO2M will provide continuity of measurements of parts of the UV/VIS/NIR spectrum at high spectral resolution through this decade and next. However apart from Sentinel-5 on Metop-SG, there are no firm plans for long-term monitoring out to 2040. There is a strong requirement to continue these measurements to monitor greenhouse gas concentrations and maintain the baseline after 2036.

4.6 High Temporal Microwave Sounders

Currently there is good coverage of microwave sounders (MW) in polar orbits due to the older NOAA satellites drifting into orbits with different equator crossing times and it has been demonstrated these are valuable for NWP. However, they will be retired by 2025 and so the operational MW sounders will then only be in the 3 baseline orbits. The TROPICS constellation is potentially enhancing the coverage for a short period but will retire in a few years. The proposed EUMETSAT EPS-Sterna mission will mitigate this in the next decade. Commercial satellite constellations of MW sounders may also contribute in the future such as the recently launched six Tomorrow-IO sounders.

5 SPACE WEATHER OBSERVATIONS FOR WIGOS SUBCOMPONENT 1

The results of the analysis for space weather observations against the WMO vision are shown in Fig. 3. For the WIGOS Vision the core observations (subcomponents 1 and 2) are divided into the different measurement domains of observations of the sun, measurements of the solar wind and magnetic field in interplanetary space, measurements in the magnetosphere and ionosphere and the thermosphere as shown in Fig. 3. For the solar observations the rows are ordered in wavelength being measured. The text lists the status for some of the measurements according to the WIGOS subcomponents 1 and 2 for space weather observations which are listed in annex A. A summary table was prepared to combine many observations contributing to the same requirement. It is presented in Fig. 4 focusing on the availability of observations in the period 2030-2034 from the various orbits. Those measurements which are part of the CGMS baseline are underlined in the text.

5.1 Solar wind and magnetic field observations from L1

Measurements of the in-situ interplanetary solar wind (including magnetic field) from L1 will rely on ACE, SWFO-L1, DSCOVR and IMAP to cover to the end of this decade and SWNext until 2038 after which there are no approved missions to L1.

5.2 Solar coronagraph at L1

For solar coronagraph observations at L1 we are relying on SOHO and Aditya-1 until SWFO-L1 is launched and then measurements are assured up until 2038 after which there are no plans to maintain the baseline. Firm plans need to be put in place for satellites to monitor the sun at L1 beyond then.

5.3 Energetic particles and magnetic field in Earth Orbit (GEO/LEO)

The space particle environment is measured in all 6 geostationary sectors and the three baseline sun synchronous orbits out to 2035. The particle density for satellite drag estimates can also be inferred from the gravitometry sensing platforms which have good coverage well into the next decade.

The magnetic field is measured in 5 geostationary sectors out to 2033 but after that plans are less clear with only 2 slots planned.

5.4 Solar X-ray spectrometer observations from geostationary orbit (GEO)

There are many solar X-ray spectrometers in geostationary orbit throughout the period. There are a few missing sectors beyond 2033 when future plans for GOES and FY-4 are unclear.

6 SPACE WEATHER OBSERVATIONS FOR WIGOS SUBCOMPONENT 2

6.1 Solar X-ray spectrometers (on/off Earth-Sun line)

Aditya-1 has an X-ray spectrometer to measure the sun from L1 but it will retire towards the end of the decade. SWFO-L1 will continue the coverage into the next decade. There is poor coverage from polar orbits with only FY-3E/3J providing assured measurements.
For off Earth-Sun line only Solar Orbiter, a research mission, has an X-ray spectrometer and it will retire around 2030.

6.2 Solar EUV spectrometers and imagers (on Earth-Sun line)

The GEO orbit has several EUV spectrometers in orbit for the foreseeable future on GOES, Electro-L/M and FY-4 but are subject to eclipse periods preventing continuous coverage. Future plans for EUV measurements need to be planned to ensure continuity into the next decade noting GOES-18 end of life is now 2040. Only the Electro-M series provides EUV spectrometer measurements from a LEO orbit beyond 2034.

For the L1 orbit once SOHO retires by 2026 there will only be an EUV spectrometer on IMAP at L1 out to 2028. A mission to continue EUV measurements at L1 for the next decade needs to be considered.

6.3 Solar EUV spectrometers and imagers (off the Earth-Sun line)

The Solar Orbiter platform measures Visible, EUV and X-rays out to the end of this decade and the ESA Vigil-L5 mission will continue from the L5 point from 2031.

6.4 Observations of interplanetary in-situ plasma and magnetic fields (off the Earth-Sun line)

From solar orbit solar wind measurements will be measured through to the end of this decade by the solar orbiter mission. Vigil will cover the L5 position in the next decade but with no capability to measure high energy particles. These measurements are complementary to those from the L1 orbit.

6.5 Solar coronographic and heliospheric imagers (GEO, LEO, L5)

Current firm proposals suggest that for coronographic images only the GOES-19 geostationary satellite will provide a long-term capability until 2033 from geostationary orbit with PUNCH, a research mission, in polar orbit for part of this decade. Vigil will provide coronographic imagery at L5 from 2031 off the Sun-Earth line. See section 5.2 for the L1 coronagraphs.
For solar heliospheric imagers the current observations in solar orbits will cease when Solar Orbiter retires soon. PUNCH in a polar orbit is a possible contributor but will retire in 2028. The Vigil mission has a heliospheric imager which will extend the record from solar orbit well into the next decade for the off Sun-Earth line.

6.6 Cross-magnetospheric observations (HEO/GEO)

The Russian Arctica-M mission is one source of cross-magnetosphere observations of electron and proton concentrations but no measurements are available for heavy ions and alpha particles so this latter capability will cease in the next few years when the CLUSTER satellites retire. There is good coverage from all 6 geostationary sectors up to 2035 when plans are not yet clear.

6.7 Observations of magnetic field from polar orbits (LEO, HEO)

Measurements of the geomagnetic field from sun-synchronous orbit are only from the Chinese FY-3 satellite series with just the early morning orbit covered after 2026.

Earth Observation	Orbit	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Orbits or Satellites	WIGOS Vis.	Notes
Backbone system with specified orbital configuration and measurement approaches (Subcomponent 1)															
Geostationary core constellation with a minimum of five satellites providing complete Earth coverage															
VIS/IR Imagery	GEO	6	6	6	6	6	6	6	6	6	6	6	Orbits	≥5 satellites	No anticipated gaps in imagery out to 2033
IR Sounding	GEO	3	3	3	3	3	3	3	3	3	3	4	Orbits	≥5 satellites	No hyperspectral sounder over W.Atlantic/Indian Oceans
Lightning	GEO	4	5	5	5	5	5	5	5	5	5	5	Orbits	≥5 satellites	ELECTRO-M N3 covers Pacific from 2029
UV/VIS/NIR Sounder	GEO	3	2	2	2	2	2	2	1	1	1	2	Orbits	≥5 satellites	Lose TEMPO by 2026, Gain GEO-XO in 2035
Earth Observation	Orbit	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Orbits or Satellites	WIGOS Vis.	Notes
Backbone system with specified orbital configuration and measurement approaches (Subcomponent 1)															
Sun-synchronous core constellation satellites in three orbital planes (morning, afternoon, early morning)															
IR Sounding	LEO	3	3	3	3	3	3	3	3	3	3	3	Orbits	3 SSO	Good coverage from all 3 orbits
MW Sounding	LEO	3	3	3	3	3	3	3	3	3	3	3	Orbits	3 SSO	Good coverage from all 3 orbits
VIS/IR Imagery	LEO	3	3	3	3	3	3	3	3	3	3	3	Orbits	3 SSO	Good coverage from all 3 orbits
Day/Night VIS Imagery	LEO	3	2	2	2	2	2	2	2	2	2	2	Orbits	2 SSO	FY-3E/J for early AM and NOAA for PM orbit
MW Imager	LEO	3	3	3	3	3	3	2	2	2	2	2	Orbits	3 SSO	Assumes access to WSF-M
Scatterometers	LEO	4	4	4	4	4	4	3	3	3	3	3	Orbits	3 SSO	Lose drifters (HY-n) after 2031
Earth Observation	Orbit	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Orbits or Satellites	WIGOS Vis.	Notes
Backbone system with specified orbital configuration and measurement approaches (Subcomponent 1)															
Instruments on other satellites in low-Earth orbit															
Radar Altimeters	LEO/DRIFT	3	3	3	3	3	3	3	3	3	3	3	Orbits	LEO	Note potential loss of >80N obs
Dual-view IR SST/LST	LEO	1	1	1	1	2	2	2	2	2	2	2	Orbits	LEO	Only 10:00 with Sentinel 3. LSTM (13:30) later this decade.
MW SST/LST	LEO	2	2	2	2	2	2	2	1	1	1	1	Orbits	LEO	Assumes CIMR flies in 2029
Strato/Meso Sounder	LEO	3	3	3	3	3	3	3	3	3	3	3	Orbits	LEO	Sterna assures good coverage
UV/VIS/NIR Sounder	LEO	3	3	3	3	2	2	2	2	2	2	2	Orbits	LEO	05:30 orbit not covered and drifters (OCO-3, NACHOS) cease in 2026
Greenhouse Gas measurements	LEO	19	17	16	16	16	14	9	9	10	6	5	Satellites	LEO	Only METOP-SG-A2 and Meteor after 2033
Limb sounder (UV/VIS)	LEO/DRIFT	4	3	2	2	2	2	2	2	1	1	1	Orbits	LEO	Lose drifters in 2026. AOS HAWKSat may help after 2031
Low frequency MW	LEO	1	1	0	0	1	1	1	1	1	1	1	Orbits	LEO	Potential gap between SMOS/SMAP and CIMR
Precipitation radar	DRIFT	2	3	5	5	6	2	2	2	1	1	0	Satellites	LEO	INCUS provides good coverage 2027-30. Potential gap after 2034.
Cloud radar	LEO	1	1	1	0	0	0	0	0	0	0	0	Satellites	LEO	EarthCARE only mission in place. None planned
Earth Radiation Budget	LEO	15	13	11	8	7	6	5	5	5	4	3	Satellites	LEO	CERES + Libera + 2X Meteor-M N2
Total solar irradiance	LEO/DRIFT	4	4	5	5	5	4	4	4	3	2	1	Satellites	LEO	Relies on FY-3 satellites at end of period
Spectral solar irradiance	LEO/DRIFT	3	3	3	3	2	1	2	2	2	2	2	Satellites	LEO	Degrade after lose TSIS-2 in 2028. FY-3E/J provides continuity.
Core GNSS constellation	LEO/DRIFT	4	4	4	4	4	4	4	3	4	4	4	Orbits	LEO	Loss of COSMIC-2 reduces coverage over tropics.
Ocean Colour	LEO	2	2	2	2	2	2	2	2	2	2	2	Orbits	2 SSO	No 05:30 measurements
HS imager for vegetation	LEO	2	1	1	1	1	1	2	2	2	2	2	Orbits	LEO	No drifters until TRUTHS 2031. CHIME after 2029. All in morning orbits.
High Resolution land imagery	LEO	2	2	2	2	2	2	2	2	2	2	2	Orbits	LEO	Many commercial satellites not included here. Lose drifters in 2027
SAR imagery	LEO	52	35	34	30	27	20	15	11	8	7	6	Satellites	LEO	C band only committed to 2032 but many commercial systems
Gravitometry (Drift orbits)	DRIFT	20	18	12	12	12	13	13	11	11	10	10	Satellites	LEO	Mainly for laser ranging.
Earth Observation	Orbit	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Orbits or Satellites	WIGOS Vis.	Notes
Backbone system with open orbit configuration and flexibility to optimize the implementation (Subcomponent 2)															
GNSS Reflectometry	LEO/DRIFT	4	4	4	4	4	3	3	3	1	1	1	Orbits	LEO	Relies on FY-3 satellites in next decade
Doppler wind lidar	LEO	0	0	0	0	0	0	0	0	0	1	1	Satellites	LEO	Assumes EPS-Aeolus in 2034
Backscatter lidar	LEO	1	1	1	0	0	0	0	0	0	0	0	Orbits	LEO	Only EarthCARE
DIAL lidar	LEO	1	2	2	2	2	2	2	1	1	0	0	Orbits	LEO	MERLIN+DQ
Altimeter lidar	DRIFT	3	3	2	2	1	1	0	0	0	0	0	Orbits	LEO/DRIFT	Nothing planned after ISS-MOLI/GEDI 2024-2030
Wide swath radar altimeter	DRIFT	3	3	2	2	2	2	2	2	2	2	2	Bands	DRIFT	Green=Ku/Ka/X-band Yell=Only 2 bands/Orange=1 band
Sub-mm imager	LEO	2	1	1	1	3	3	3	1	2	2	1	Orbits	LEO	Relies on ICI/Metop-SG for continuity, boosted by POLSIR 2029-31
Limb sounder IR/MW	LEO	2	0	0	0	0	0	0	0	0	0	0	Satellites	LEO	MW relies on ODIN and Aura/MLS both close to EoL
UV/VIS/NIR Imaging	LEO	4	5	5	5	5	5	4	2	2	2	2	Orbits	LEO/DRIFT	Relies on Sentinel-5/5P, CO2M, OCO-2 and GHGSat
Multi-angle/pol. radiometer	LEO	3	3	3	3	3	2	2	2	2	1	1	Orbits	LEO	3MI+PACE+DQ
High temporal MW sounders	LEO	2	2	1	0	3	3	3	3	3	3	3	Orbits	DRIFT	TROPICS, Tomorrow-IO and EPS-Sterna
SW scanning limb sounder	LEO/DRIFT	6	3	4	4	3	3	3	3	3	3	3	Satellites	LEO/DRIFT	OMPS-Limb, ACS-Limb
SW occultation limb sounder	LEO/DRIFT	6	4	3	3	1	1	0	0	0	0	0	Satellites	LEO/DRIFT	ACS, SAGE-III, OSIRIS
Continuous polar coverage	MOL	2	3	3	3	3	3	2	2	2	2	2	Satellites	MOL	Arctica, Green=2 satellites
MW Sounding	GEO	1	1	1	1	2	1	1	1	1	0	0	Orbits	GEO	Currently only FY-4M

Indicates a CGMS baseline measurement

Definition of colours for orbital coverage	
5/6 GEO or 3 LEO orbits covered	(green)
3/4 GEO or 2 LEO orbits covered	(yellow)
1/2 GEO or 1 LEO orbit covered	(orange)
No GEO or LEO coverage	(red)

Definition of colours for number of satellites

The colours indicate the number of satellites with green indicating the requirement is met and red no satellites.

Figure 1. Gap analysis for Earth observations. The numbers in the cells either indicate orbits covered or number of satellites.

01	Hyperspectral IR sounders (GEO)	10	GNSS Reflectometry (LEO/Drift)
02	UV/VIS/NIR sounders (GEO)	11	Doppler Wind Lidar (LEO/Drift)
03	Day-night visible imagers (LEO)	12	Backscatter Dial Lidar (LEO/Drift)
04	Microwave Imagers (LEO)	13	Lidar and wide swath radar for Altimetry (LEO/Drift)
05	Low frequency microwave imager (LEO)	14	Limb sounder in IR and MW (LEO/Drift)
06	UV/VIS Nadir and Limb Sounders (LEO)	15	UV/VIS/NIR spectrometer (LEO/Drift)
07	Precipitation radar and cloud radar	16	High Temporal MW Sounders (LEO/Drift)
08	Total and spectral solar irradiance (LEO)	17	Multi-angle polarised radiometer (LEO)
09	Altimeter lidar (Drift) for biomass	18	SW Occultation limb sounder

Figure 2. Summary plot of the main gaps for Earth Observations in WIGOS Vision 2040 subcomponents 1 and 2 with the colours yellow to red indicating the severity of the gap.

Solar Remote Sensing Observations	Orbit	NRT Data?	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Orbits or Satellites?	Notes
Solar X-ray spectrometer	GEO	Y (GOES)	13	13	15	13	14	12	13	14	12	7	4	Satellites	Not MTG or Himawari
Solar X-ray spectrometer	Sun-Earth Line		21	18	21	19	18	15	15	17	15	10	7	Satellites	Aditya-1, SWFO, GOES, FY4, Electro-L, PUNCH
Solar X-ray spectrometer	Off Sun-Earth Line		1	1	1	1	1	1	0	0	0	0	0	Satellites	Relies on Solar orbiter
Solar X-ray imager	Sun-Earth Line		4	3	3	2	2	1	1	1	1	1	1	Satellites	Relies on FY-3E/3J in early orbit later
Solar X-ray imager	Off Sun-Earth Line		0	0	0	0	0	0	0	0	0	0	0	Satellites	No capability
Solar EUV spectrometer	Sun-Earth Line	Y (SOHO)	24	20	24	23	23	19	20	21	17	11	7	Satellites	No data from L1 after SOHO and IMAP
Solar EUV imager	Sun-Earth Line	Y (SDO, GOES)	13	10	12	12	12	10	10	10	7	3	1	Satellites	SDO, GOES, Electro, FY-3E/J and FY-4
Solar EUV spectrometer	Off Sun-Earth Line		2	1	1	1	1	1	0	0	0	0	0	Satellites	Relies on Solar orbiter
Solar EUV imager	Off Sun-Earth Line	Y (Vigil)	2	1	1	1	1	1	1	1	1	1	1	Satellites	Solar Orbiter + Vigil
Solar UV spectrometer	Sun-Earth Line		4	2	1	1	0	0	0	0	0	0	0	Satellites	Aditya-1
Solar UV imager	Sun-Earth Line		3	1	0	0	0	0	0	0	0	0	0	Satellites	ASO-S only satellite, Zond-M may help
Solar UV imager/spectrometer	Off Sun-Earth Line		0	0	0	0	0	0	0	0	0	0	0	Satellites	No measurements from solar orbit
Solar VIS spectrometer	Sun-Earth Line	Y (SOHO)	4	1	1	1	0	0	0	0	0	0	0	Satellites	SOHO, Aditya-1
Solar VIS imager	Sun-Earth Line	Y (SOHO)	4	1	1	1	0	0	0	0	0	0	0	Satellites	SOHO, Aditya-1
Solar VIS spectrometer	Off Sun-Earth Line		2	1	1	1	1	1	0	0	0	0	0	Satellites	Solar Orbiter
Solar VIS imager	Off Sun-Earth Line	Y (Vigil)	1	0	0	0	0	0	1	1	1	1	1	Satellites	Vigil-L5
Solar radio waves	L1		1	0	0	0	0	0	0	0	0	0	0	Satellites	SOHO close to EoL
Solar radio waves	Off Sun-Earth Line		2	1	1	1	1	1	0	0	0	0	0	Satellites	Solar Orbiter
Solar coronograph imager	L1	Y (SWFO)	3	3	2	2	2	2	1	2	2	1	1	Satellites	SWFO-L1, SOHO, Aditya-1
Solar coronograph imager	Sun-Earth Line	Y (GOES)	8	5	5	5	4	4	2	3	3	1	1	Satellites	GOES-19, PUNCH, PROBA-3O
Solar coronographic imager	Off Sun-Earth Line	Y (STEREO Beacon mode): Y (Vigil)	2	1	1	1	1	1	1	1	1	1	1	Satellites	Solar Orbiter, STEREO-A and Vigil-L5
Solar heliospheric imager	Sun-Earth Line		2	1	1	1	0	0	0	0	0	0	0	Satellites	PUNCH, SOHO
Solar heliospheric imager	Off Sun-Earth Line	Y (STEREO Beacon mode): Y (Vigil)	2	1	1	1	1	1	1	1	1	1	1	Satellites	STEREO-A and Vigil-L5
Solar magnetic field imager	Sun-Earth Line	Y (SDO, SOHO)	5	2	1	1	0	0	0	0	0	0	0	Satellites	SDO, ASO-S, Solar-B, SOHO
Solar magnetic field imager	Off Sun-Earth Line	Y (Vigil)	2	1	1	1	1	1	1	1	1	1	1	Satellites	L5 Vigil, Solar Orbiter
Interplanetary solar wind and magnetic field	**Orbit**	**NRT Data?**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Orbits or Satellites?**	**Notes**
Solar wind plasma speed/density	L1	Y (SWFO, ACE, DSCOVR)	5	5	3	2	2	2	1	2	2	2	1	Satellites	SWFO-L1, IMAP, DSCOVR, ACE, Aditya-1
Solar wind plasma speed/density	L5/Solar	Y (Vigil)	2	1	1	1	1	1	1	1	1	1	1	Satellites	Solar Orbiter, Parker Solar Probe, Vigil-L5
High energy particles	L5/Solar		2	1	1	1	1	1	0	0	0	0	0	Satellites	Solar Orbiter, Parker Solar Probe
In-situ magnetic field	L1	Y (SWFO, ACE, DSCOVR)	6	5	4	3	2	2	1	2	2	2	1	Satellites	SWFO-L1, IMAP, DSCOVR
In-situ magnetic field	L5/Solar		2	1	1	1	1	1	1	1	1	1	1	Satellites	Solar Orbiter, Vigil-L5
Magnetosphere	**Orbit**	**NRT Data?**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Orbits or Satellites?**	**Notes**
Proton, electron, ion differential flux	LEO/HEO/MOL		6	5	4	4	4	4	3	3	3	3	2	Orbits	Arctica, ARESA(ERG), CLUSTER
Proton, electron, ion differential flux	GEO	Y (GOES), MTG, Himawari-10	6	6	6	6	6	6	6	6	6	6	3	Orbits	FY-4, GOES, Electro-L/M, MTG, Himawari
Geomagnetic field	LEO/HEO/MOL		2	1	1	1	1	1	1	1	1	1	1	Orbits	Only FY-3
Geomagnetic field	GEO	Y (GOES)	4	5	5	5	5	5	5	5	2	2	0	Orbits	Not MTG or Himawari
Ionosphere and Thermosphere	**Orbit**	**NRT Data?**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Orbits or Satellites?**	**Notes**
Proton, electron, ion differential flux	LEO		4	4	4	4	4	4	3	4	4	4	4	Orbits	Meteor-M, Ionosfera and FY-3
TEC/Electron density	LEO/HEO/MOL	Y (COSMIC-2), Sentinel-6	4	4	4	4	4	4	4	4	4	4	4	Orbits	GNSS RO constellation + LEO
Ionospheric plasma density	LEO/HEO		4	4	4	4	4	4	3	3	3	3	3	Orbits	Meteor-M, Ionosfera and FY-3
Density for satellite drag assessment	LEO	Y (COSMIC-2)	4	4	4	4	4	4	4	3	4	4	4	Orbits	COSMIC-2, FY-3G/I, GRACE-FO

Indicates a CGMS baseline measurement	(pink)

Definition of colours for orbits	
5/6 GEO or 3 LEO/DRIFT orbits covered	(green)
3/4 GEO or 2 LEO/DRIFT orbits covered	(yellow)
1-2 GEO or 1 LEO/DRIFT orbits covered	(orange)
No coverage from any orbit	(red)

Definition of colours for number of satellites	
2 satellites or more in earth orbit or 1 satellite for L1/Off sun-earth line	(green)
1 satellite in earth orbit	(orange)
No satellites	(red)

Figure 3. Gap analysis for space weather observations. The numbers in the cells either indicate orbits covered or number of satellites.

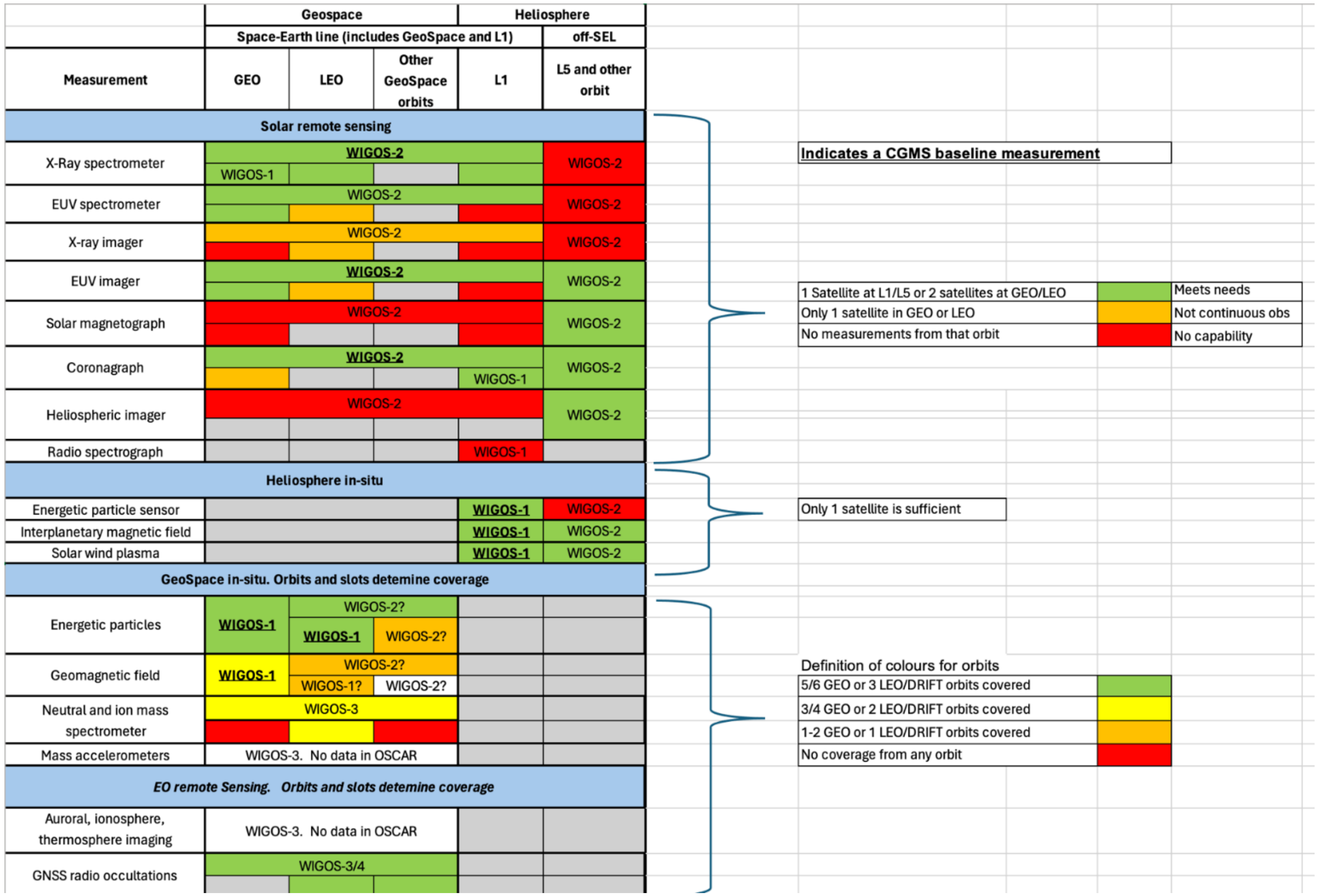

Figure 4. Summary plot of the gap analysis for space weather observations in WIGOS Vision 2040 for subcomponents 1 and 2 for the period 2030-2034.

Annex A. Space Weather observations in WIGOS Vision subcomponents 1 and 2

Solar wind at L1 - Electron sensor
Solar wind at L1 - Proton sensor
Solar wind at L1 - Alpha-particle sensor
Solar wind at L1 - Heavy ion sensor
Solar wind at L1 - Plasma density sensor
Solar wind at L1 - Plasma temperature sensor
Solar wind at L1 - Plasma velocity sensor
Solar wind at L1 - Magnetometer
Solar coronographic imager at L1
Solar radio wave receiver at L1
Electron sensor at GEO
Proton sensor at GEO
Alpha-particle sensor at GEO
Heavy ion sensor at GEO
Plasma density sensor at GEO
Plasma temperature sensor at GEO
Plasma velocity sensor at GEO
Electron sensor at LEO
Proton sensor at LEO
Alpha-particle sensor at LEO
Heavy ion sensor at LEO
Plasma density sensor at LEO
Plasma temperature sensor at LEO
Plasma velocity sensor at LEO
Magnetometer at GEO
Magnetometer at LEO
X-ray spectrometer at GEO
X-ray spectrometer at LEO

Solar X-ray spectrometer [from L1, GEO, LEO]
Solar X-ray imager [from L1, GEO, LEO]
Solar EUV spectrometer [from L1, GEO, LEO]
Solar EUV imager [from L1, GEO, LEO]
Solar UV spectrometer [from L1, GEO, LEO]
Solar UV imager [from L1, GEO, LEO]
Solar VIS spectrometer [from L1, GEO, LEO]
Solar VIS imager [from L1, GEO, LEO]
Solar X-ray spectrometer [from solar orbit, ecliptic, L5]
Solar X-ray imager [from solar orbit, ecliptic, L5]
Solar EUV spectrometer [from solar orbit, ecliptic, L5]
Solar EUV imager [from solar orbit, ecliptic, L5]
Solar UV spectrometer [from solar orbit, ecliptic, L5]
Solar UV imager [from solar orbit, ecliptic, L5]
Solar VIS spectrometer [from solar orbit, ecliptic, L5]
Solar VIS imager [from solar orbit, ecliptic, L5]
Solar magnetic field [from L1, GEO, LEO]
Solar electric field sensor [from L1, GEO, LEO]
Solar velocity field sensor [from L1, GEO, LEO]
Solar radio wave sensor [from L1, GEO, LEO]
Solar magnetic field [from solar orbit, ecliptic, L5]
Solar electric field sensor [from solar orbit, ecliptic, L5]
Solar velocity field sensor [from solar orbit, ecliptic, L5]
Solar radio wave sensor [from solar orbit, ecliptic, L5]
Electrons [at solar orbit, ecliptic, L5]
Protons [at solar orbit, ecliptic, L5]
Alpha-particles [at solar orbit, ecliptic, L5]
Heavy ions [at solar orbit, ecliptic, L5]
Solar wind density [at solar orbit, ecliptic, L5]
Solar wind temperature [at solar orbit, ecliptic, L5]
Solar wind velocity [at solar orbit, ecliptic, L5]
Interplanetary magnetic field [from solar orbit, ecliptic, L5]
Solar coronographic imager [from L1, GEO, LEO]
Heliospheric imager [from L1, GEO, LEO]
Solar coronographic imager [from solar orbit, ecliptic, L5]
Heliospheric imager [from solar orbit, ecliptic, L5]
Electrons [cross magnetosphere]
Protons [cross magnetosphere]
Alpha-particles [cross magnetosphere]
Heavy ions [cross magnetosphere]
Geomagnetic field [in LEO and cross magnetosphere]
Electric field sensor [in LEO and cross magnetosphere]
Ionospheric total electron content sensor [in LEO and cross magnetosphere]
Ionospheric electron density sensor [in LEO and cross magnetosphere]
Ionospheric plasma density sensor [in LEO and cross magnetosphere]
Radio wave receiver [in LEO and cross magnetosphere]