Item 2: Space-based observation needs for space weather and related actions for consideration by CGMS satellite operators

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In November 2012, WMO informed CGMS on the activities of the WMO ICTSW and highlighted in particular the Statement of Guidance for Space Weather Observations (SOG-SW) issued in June 2012, and the corresponding actions of the Implementation Plan for Evolution of Global Observing Systems (EGOS-IP).

The text below is extracted from CGMS-40 WMO-WP-03. It gives a brief overview of the SOG-SW and highlights the EGOS-IP actions of direct relevance to CGMS.

The EGOS-IP (including the actions) was endorsed in June 2013 by the WMO Executive Council.

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1. Summary of the Statement of Guidance for Space Weather Observations

Space weather observations are required: to forecast space weather disturbances; to detect hazardous events and drive alerts when relevant; to establish a Space Weather "climatology" for the design of both space based systems (i.e., satellites and astronaut safety procedures) and ground based systems (i.e., electric power grid protection and airline traffic management); to validate numerical models and conduct research. A comprehensive space weather observation network must include ground-based and space-borne observatories. Both the ground-based and the space-based segments shall contain a combination of remote sensing and in-situ measurements. These measurements shall address five domains: ionospheric, geomagnetic, energetic particles, solar conditions, solar wind and interplanetary environment. Table 1 below summarizes the main variables and measurement methods for each of these domains, and related issues.

Table 1: Observation domains, variables, main measurement methods and issues.
(Space-based measurements in bold)

Domain	Main variables	Measurement methods	Issues
Ionospheric	Total Electron Content Radio absorption h'P, hmF2,h'F,fof2, foEs plasma velocity scintillation	Ionosonde **Two-frequency altimeters** **GNSS, GNSS-RO** Incoherent Scatter Radar Coherent radar Radio absorption Scintillation receivers	Timeliness, coverage, data exchange

Geomagnetic	Vector magnetic field at surface and in space	Magnetometer arrays **Magnetometers in GEO** **Magnetometers in LEO**	Ground network, data availability
Energetic particles	Low- & high-energy flux of trapped, solar, and galactic particles	**Particle detectors and flux sensors in LEO, MEO, GEO, HEO and at L1**	Mission continuity Add HEO missions Data sharing Intercalibration Assimilation
Solar monitoring	Sun imagery in various spectral ranges (H-alpha, EUV, X-Ray, white light, Ca-II-K) Sun magnetic field Solar flux (EUV, X-ray, radio emissions), Corona Heliosphere	Ground-based observatories **Space-based observatories**	Sustainability of research missions, coordination, standardization
Solar wind and interplanetary	Velocity, density, temperature and magnetic field	**Observatory at Lagrange points L1 and L5**	Coordinated plans to ensure continuity at L1 and L5

Today, significant gaps in our observing capabilities limit our ability to provide a comprehensive characterization of the driving physical parameters, and limit the accuracy of predictive models. Existing ground-based and space-based assets have not all been integrated into a coordinated observing network. These include a number of Global Navigation Satellite System (GNSS) receiver sites, ground measurements of Earth's magnetic field, and satellite measurements of energetic particles and magnetic field in space. Furthermore, continuity of some essential space-based monitoring missions is not planned. The Statement of Guidance for Space Weather Observations, issued in June 2012, evaluates the gaps and identifies priority corrective actions and recommendations.

2. EGOS-IP actions

Building on the Statement of Guidance mentioned above, the following actions have been recorded in the Implementation Plan for Evolution of Global Observing Systems (EGOS-IP) that has been approved by the Commission for Basic Systems in September 2012 (http://www.wmo.int/pages/prog/www/OSY/gos-vision.html#egos-ip).

The actions below are of particular relevance to CGMS satellite operators:

Action W1
Action: To develop and implement a coordinated plan ensuring continuity of solar measurements, solar wind and interplanetary magnetic field measurements, and heliospheric imaging, including measurements at different locations such as at the L1 Lagrange point, the Sun-Earth line upstream from the L1 point, the L5 Lagrange point, as well as the required global network of ground-based antennas for data reception and processing.
Who: ICTSW , CGMS and space agencies.
Time-frame: End 2014.

Performance indicator: Availability of coordinated plans for continuity until 2030.

Action W4
Action: To improve the timeliness of space-based GNSS measurements from LEO satellites to get near-real-time information about the 3D electron density distribution of the ionosphere/plasmasphere system. (e.g. by use of a RARS concept or other network of satellite ground stations for rapid transmission).
Who: ICTSW, CGMS, relevant space agencies, and WMO Members who support ground stations.
Time-frame: Continuous.
Performance indicator: Number of occultations per day available with a timeliness to meet user requirements.

Action W5
Action: To foster sharing of ground-based GNSS data and GNSS Radio-Occultation among the meteorological and space weather communities, and to facilitate the near-real-time access to these data through WIS.
Who: ICTSW, IROWG and WMO/WIGOS project office.
Time-frame: Continuous.
Performance indicator: Agreement on data sharing.

Action W6
Action: To coordinate the use of dual-frequency radar altimeter observations by Space Weather community to improve or validate ionospheric models and for operational TEC monitoring over the oceans.
Who: ICTSW, WMO Space Programme and altimetry satellite operators.
Time-frame: Continuous.
Performance indicator: Number of satellite altimeters providing data for space weather.

Action W8
Action: Develop a plan for maintaining and improving space weather observations of the plasma and energetic particle environment along the following priorities: (1) maintain long-term continuity, and if possible improve the spatial resolution of measurements at all altitudes from LEO through GEO orbits; (2) improve the sharing of existing and planned plasma and energetic particle measurements; (3) include energetic particle sensors on HEO satellites; and (4) conduct research to incorporate the plasma and energetic particle data into numerical models to give flux estimates at all locations where our satellites are in orbit.
Who: ICTSW, CGMS and space agencies.
Time-frame: End of 2014.
Performance indicator: Availability of a plan for space weather observation of plasma and energetic particle environment.

3. Spacecraft anomaly records

An important, indirect source of information on space weather is the record of spacecraft anomalies attributed to space environment and solar events. In this respect, a template has been provided to help harmonize the information collected from the various satellite operators.