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WMO AND CGMS COORDINATION OF SPACE WEATHER EFFORTS

Submitted by Terry Onsager, co-chair of the WMO Inter-Programme Coordination Team on Space Weather (ICTSW)

ABSTRACT

The space weather interests of the WMO and CGMS are complementary and, among the international organizations engaged in space weather, uniquely focused on operational service aspects. The purpose of the WMO Inter-Programme Coordination Team on Space Weather (ICTSW) is to support space weather observations, data exchange, product and service delivery, and operational applications. CGMS provides a substantial contribution to space weather in operating space environment and solar instruments on meteorological satellites, and CGMS has an interest in mitigating the impacts of space weather on satellites.

CGMS members are encouraged to develop a strategy for involvement in space weather and are invited to coordinate with the WMO/ICTSW. It is envisioned that CGMS could contribute in numerous areas, including the utilization of satellite anomaly information, the acquisition of space weather observations, the development of a plan for long-term continuity of observations, and the solicitation of space weather product requirements.

Proposed actions and recommendations

Action: CGMS to nominate points of contact to work with WMO/ICTSW in order to define jointly a strategy to improve the collection, availability, and uses of satellite anomaly information.

Recommendation: CGMS to coordinate the acquisition and availability of space weather observations made by meteorological satellites.

Recommendation: CGMS and WMO, in coordination with other international organizations, to promote a strategy to ensure the long-term continuity of space weather observations.

Recommendation: CGMS to solicit requests/requirements for space weather products and services and feedback on the value of products currently available.

Coordination of Space Weather Efforts

1 Background

The Inter-Programme Coordination Team on Space Weather (ICTSW) was established by the WMO in May, 2010, under the auspices of the Commission for Basic Systems (CBS) and the Commission for Aeronautical Meteorology (CAeM). The purpose of the ICTSW is to support space weather observations, data exchange, product and service delivery, and operational applications. Currently ICTSW includes members from 21 countries and 7 international organizations.

ICTSW activities (http://www.wmo.int/pages/prog/sat/spaceweather-intro_en.php) to date have included the establishment of a Space Weather Product Portal, completion of a first iteration of space weather observing requirements for global services, and an assessment of the current gaps. The Statement of Guidance on Space Weather Observations, which identifies gaps in current observing capabilities, was drafted by the ICTSW in 2012. The main recommendations have been incorporated as actions in the Implementation Plan for Evolution of Global Observing Systems (EGOS-IP). The EGOS-IP was subsequently approved by the WMO Commission for Basic Systems (CBS-15, September 2012) and was endorsed by the WMO Executive Council in May 2013. The ICTSW is reviewing the observing capabilities described in the Observing System Capability Analysis and Review tool (OSCAR) and will provide recommendations for the classifications and descriptions of space weather instrumentation. The ICTSW is also coordinating with the International Civil Aviation Organization (ICAO) on its Concept of Operations for International Space Weather Information for Global Aviation and on proposed service requirements to mitigate space weather impacts on airlines. An investigation has also started on a harmonized approach to space weather alerts.

The space weather interests of CGMS are complementary to those of the WMO/ICTSW, and the coordination of efforts between CGMS and WMO can enhance the effectiveness of space weather activities and accelerate progress in improving services and resiliency. Specifically, CGMS can :

- contribute to ensuring that observing gaps are addressed and observations are coordinated,
- assist with defining user requirements for space weather products,
- provide information on space weather-related spacecraft anomalies, and
- contribute to the international coordination and sharing of observing assets that will promote the long-term continuity of high-priority observations in a cost-effective manner.

ICTSW supports having a close working relationship with CGMS on space weather matters and encourages the identification of common priorities and complementary and/or joint activities.

2 Space Weather Effects on Spacecraft

CGMS satellite operators have interest in space weather, both from the perspective of the impacts of space weather on satellite systems and through the opportunity to coordinate space weather observations being made from meteorological satellites. A permanent action item had been for CGMS members to report on spacecraft anomalies from solar events at CGMS meetings. At CGMS-39, this permanent action item was modified, and requested

members “to report to CGMS meetings on their activities and plans related to space weather including: (i) impacts of solar events, space radiation and protective measures, (ii) space weather observations, and (iii) space weather warning systems.” A template was provided to facilitate reporting on spacecraft anomalies related to space weather, and to help standardize this information collected from the various satellite operators as part of their annual reports. (See Annex).

Efforts are also underway to improve the real-time and retrospective assessment of the space-radiation environment to enable more timely and accurate information on the possible causes of anomalies (e.g., CGMS-41, NOAA-WP-21). This includes improving the availability of space environment data, supporting anomaly investigations, and partnering with the international community to improve design standards.

Sharing information about anomalies that occur is essential for advancing our capability to identify the environmental conditions responsible for satellite anomalies and for improving mitigation strategies. By improving the database of satellite anomalies along with the database of environmental conditions, improved statistics and more accurate relationships can be established that will enhance the accuracy of anomaly-resolution investigations and lead to improved spacecraft design. CGMS is encouraged to acquire anomaly information wherever possible and make this available to the space weather service providers. ICTSW is willing to work closely with CGMS to explore approaches that would facilitate the use of the anomaly data.

Action: CGMS to nominate points of contact to work with WMO/ICTSW in order to define jointly a strategy to improve the collection, availability, and uses of satellite anomaly information.

3 Satellite Observations for Space Weather

With the documentation of space weather observing requirements and gap analysis (Statement of Guidance) in place, space weather is becoming an integral part of the WMO Integrated Global Observing System (WIGOS) and its Rolling Review of Requirements (RRR). The observing requirements and the gap analysis will be updated every other year, each offset by one year. Current plans for updating the observing requirements in 2013 include the addition of thermosphere observation requirements, important for satellite drag and for coupled atmosphere-ionosphere data assimilation models, and the addition of radiation dose observations to support the assessment of radiation levels on commercial airlines during large solar storms.

The Statement of Guidance recommended that all Members be encouraged to improve the collection and open dissemination of space weather data, both satellite-based and ground-based. For example, effort should be made to maintain and improve space weather services for the plasma and energetic particle environment encountered by satellites. This should include actions to: (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; and (3) include energetic particle sensors on HEO satellites. In addition, efforts are needed to improve numerical models that can utilize the limited observations available to estimate particle flux levels at all satellite locations.

The actions below, taken from the Space Weather Statement of Guidance, are of particular relevance to CGMS members (see also CGMS-40-WMO-WP-03):

- WMO Action W1: 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.

- WMO Action W4: 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.

- WMO Action W5: 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.

- WMO Action W6: 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.

- WMO Action W8: 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.

Based on these actions and the broader Statement of Guidance, CGMS is encouraged to consider approaches to improve the availability and coordination of space weather data. This includes the coordination and sharing of observations currently being obtained by meteorological satellites, such as plasma and energetic particle data, GNSS radio-occultation data, and dual-frequency radar altimeter data, as well as consideration of obtaining non-traditional measurements, such as solar corona observations and satellite-based ionospheric soundings.

It is also recommended that CGMS contribute to establishing a strategy for high-level international coordination to ensure the long-term continuity of key observations. A cost-effective, shared approach to obtaining the minimum set of space-based measurements required for space weather services should be defined and updated regularly. At least some of the measurements, including space environment monitoring and solar observations that are supported by Earth observation satellites, should be coordinated through the Coordination Group for Meteorological Satellites (CGMS), but a broader forum will be needed to address the whole range of space weather observations in the Sun-Earth system, including other international committees such as the Committee on Space Research (COSPAR) and the United Nations Committee on Peaceful Uses of Outer Space (UN-COPUOS).

Recommendation: CGMS to coordinate the acquisition and availability of space weather observations made by meteorological satellites.

Recommendation: CGMS and WMO, in coordination with other international organizations, to promote a strategy to ensure the long-term continuity of space weather observations.

4 Space Weather Products

The Space Weather Product Portal (http://www.wmo.int/pages/prog/sat/spaceweather-productportal_en.php) is intended to enhance the availability and usage of space weather products being created by the service centers around the globe. Many of the products created today have global applicability. By making these products available, new groups around the world with an interest in serving their local customers can gain familiarity with space weather phenomena and impacts, and can use the existing products directly to begin delivering their own services. Furthermore, this Product Portal will facilitate the comparison of products and will encourage consistency of information and the adoption of best practices by the global service providers.

Efforts have been made recently to obtain user feedback and to identify improvements to the Portal that could enhance its usability. CGMS is encouraged to express their needs for space weather products and to evaluate and give recommendations on the information currently available on the Portal.

Recommendation: CGMS to solicit requests/requirements for space weather products and services and feedback on the value of products currently available.

5 Space Weather and CGMS

CGMS has a longstanding interest in space weather and provides a substantial contribution to space weather services and research through the operation of a diverse set of space environment and solar monitors on meteorological satellites. Through its actions, CGMS can contribute significantly to improving future space weather services and to the avoidance and mitigation of space weather-related impacts. Although a considerable number of instruments are now deployed on meteorological satellites, there remain significant challenges in terms of coverage, timeliness, data exchange and standardization, intercalibration, and the long-term continuity of observations.

Numerous organizations today are participating in the coordination of space weather efforts. These include the WMO, the International Space Environment Service (ISES), COSPAR, UN-COPUOS, International Living With a Star (ILWS), as well as CGMS. While COSPAR, UN-COPUOS, and ILWS have to date focused primarily on scientific research, CGMS and WMO (in close coordination with ISES) are unique in their primary engagement in operational services. Whereas research missions provide essential space weather observations for limited durations and the testing and development of improved capabilities, the operational-service organizations are responsible for the long-term continuity of observations and the utilization of the data for the timely and reliable issuance of products and services.

CGMS members are encouraged to develop a strategy for involvement in space weather and are invited to coordinate with the WMO/ICTSW. It is envisioned that CGMS could contribute in numerous areas, including the utilization of satellite anomaly information, the acquisition of space weather observations, the development of a plan for long-term continuity of observations, and the solicitation of space weather product requirements.

ANNEX: CGMS REPORT TEMPLATE FOR SPACECRAFT ANOMALIES DUE TO SOLAR EVENTS

(Based on Recommendations for Contents of Anomaly Database for Correlation with Space Weather Phenomena, P. O'Brien, J.E. Mazur, T. Guild, November 2011, AEROSPACE Report No.TOR-2011(3903)-5.)

0. Operator	1. Date and Universal Time of The anomaly	2. Fully specified location of the anomaly (spacecraft location)	3. Velocity or orbital elements at time of the anomaly	4. Eclipse state of the vehicle (full, penumbra, partial, none)	5. Vector to Sun in spacecraft coordinate	6. Velocity vector of spacecraft in spacecraft	7. Initial guess at type of anomaly (See taxonomy below)	8. Estimated confidence of that guess	9. Anomaly category (e.g., affected system or kind of disruption)	10. Vehicle identity	11. Notes (e.g. unusual operational states or recent changes to operations (recent commands, attitude scheme, etc.)

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Taxonomy of Satellite Anomalies (for column 7)

1. Electrostatic discharge (charging)
    - 1.1 Surface charging
        - 1.1.1 Plasma sheet (subauroral)
        - 1.1.2 Auroral
    - 1.2 Internal charging
        - 1.2.1 Subsurface charging (e.g., beneath blanket)
        - 1.2.2 Deep charging (e.g., inside a box)
2. Single-Event Effects
    - 2.1 Protons
        - 2.1.1 Solar proton event
        - 2.1.2 Geomagnetically trapped protons
    - 2.2 Heavy ions
        - 2.2.1 Galactic Cosmic Rays
        - 2.2.2 Solar energetic particles
        - 2.2.3 Geomagnetically trapped heavy ions
3. Total Dose
    - 3.1 Long-term dose accumulation (multiple causes combined)
    - 3.2 Short-term (days or less) dose accumulation
        - 3.2.1 Solar protons
        - 3.2.2 Geomagnetically trapped protons
        - 3.2.3 Geomagnetically trapped electrons