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WMO Coordination in Space Weather

(Submitted by Terrance Onsager, Co-chair ICTSW; and Jerome Lafeuille, Secretariat)

Summary and Purpose of Document

This document recalls the increasing national and international recognition of the importance of space weather and the need to develop a coordinated, global strategy to deliver space weather services to help mitigate the hazardous impacts of space weather. It describes the recent involvement of WMO in the coordination of space weather activities and the progress that has been made to date by the Inter-Programme Coordination Team on Space Weather (ICTSW).

The document describes the efforts proposed in the draft Four-Year Plan for WMO Coordination of Space Weather Activities, which will be submitted to EC-68 for approval, as requested by Cg-17.

ACTION PROPOSED

The second session is invited to consider the possible linkages between activities identified in the draft Four-Year Plan for WMO Coordination of Space Weather Activities and IPET-SUP activities, in particular regarding product validation, utilization and user training.

Appendices: A. Draft Four-Year Plan: Annex to Res. 38: http://library.wmo.int/pmb_ged/wmo_1157_en.pdf#480

DISCUSSION

Introduction

1. Space weather refers to the physical and phenomenological state of the natural space environment. Its dynamics can have severe impacts on critical infrastructures and on human health. Earth's space environment, ranging from the upper atmosphere to the Sun, is impacted both from solar disturbances as well as from upward propagating atmospheric disturbances. Solar eruptions release intense bursts of electromagnetic radiation that reach Earth in eight minutes and can cause radio-communication outages. These energetic eruptions also include Coronal Mass Ejections (CMEs), which are large bursts of magnetized plasma that propagate through interplanetary space and can reach Earth within one to three days. While en route to Earth, CMEs drive shock waves that accelerate the ambient particles to high energies, and these energetic particles can damage satellite electronics, create communication outages for aircraft on polar routes, and can represent a radiation risk for astronauts and passengers on aircraft. When the CMEs reach Earth's immediate magnetic environment, they can drive severe geomagnetic storms that can disrupt electric power generation, and they disturb the ionosphere, affecting radio propagation and reducing the reliability and accuracy of GNSS systems.

2. Space weather is an area of emerging importance with the recognized need for effective international cooperation. Although the provision of space weather services has been an important activity since the early 1900s, it has only been in the past decade or so that the need for expanded capabilities has occurred, driven, for example, by a dramatic increase in the use of polar airline routes, expanded uses of satellite-based navigation and timing, increased vulnerability of electric power grids, and an overall rise in society's dependence on a technological infrastructure with vulnerabilities to space weather.

3. It is now well recognized that space weather presents significant risks to a nation's economy and to the safety of its citizens. Space weather is now included in the United Kingdom National Risk Register of Civil Emergencies [see https://update.cabinetoffice.gov.uk/sites/default/files/resources/ CO_NationalRiskRegister_2012_acc.pdf]. The register outlines the major space weather risk areas, including electric power, satellites, and aviation, and it highlights the need to improve our understanding of the risks and to put in place plans for mitigating action. Similarly, space weather is included in South Korea's National Risk Profile, whereby the roles and responsibilities of agencies and ministries are being defined. In Sweden, the risk of space weather extreme events is addressed by the Civil Contingencies Agency. Within the United States, a new National Space Weather Strategy and Action Plan were recently released (October, 2015) by the National Science and Technology Council within the Executive Office of the President. The Action Plan includes national and international activities covering all aspects of the space weather enterprise, including research, observations, services, and risk mitigation.

4. Actions are being taken today by industries and governments around the globe. For example, the International Civil Aviation Organization (ICAO) is drafting requirements for space weather services to protect against communication outages, navigation errors and radiation risks. There are concerns with the growing congestion in the airspace, the growing use of unmanned vehicles, and also the inevitability of commercial space transportation, which will fill in the space between today's astronaut and today's airline passenger. The electric power industry is developing benchmark levels to ensure the stress of geomagnetic storms can be withstood. Space weather is increasingly being recognized and integrated into plans for precision navigation capabilities.

5. The long-term improvement of the needed space weather services requires coordinated, committed partners from around the world. International cooperation is necessary to create a shared satellite-based observing system for our critical observations, to maintain reliable access to regional data, to advance our service capabilities, and to ensure the global consistency of the end products that are

delivered.

Space weather observations from ground and space

6. Characterizing space weather disturbances and providing valuable services requires an integrated system of space-based observations, ground-based observations, and numerical prediction models. The physical parameters that need to be measured belong to two broad categories. One of these categories is the external drivers of Earth's immediate environment (e.g., the Sun, CMEs, and the solar wind). The other category consists of the geographically localized conditions that affect specific infrastructure components, such as the electric power grid and GNSS navigation systems (e.g., ground-based magnetic field, ionospheric scintillation, and total electron content). Maintaining a comprehensive network of the required space-based and ground-based measurements will require coordinated effort from countries around the world.

7. For over three decades, satellite meteorology and space weather monitoring have been sharing observing capabilities: for instance the NOAA POES, Roshydromet Meteor, CMA FY-1/3 satellite payloads have systematically included a space environment monitoring instrument suite measuring a range of parameters such as proton flux, electron flux; all GOES satellites have flown solar X-Ray or EUV sensors. For the past 10 years, the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) of Taiwan, China has provided global radio-occultation data of major importance for atmospheric sounding and ionosphere monitoring. However, these sensors are far from covering all the needs.

8. One major difficulty with regard to space weather observations is the long-term availability of key measurements of solar activity and solar wind in interplanetary space. Today, such measurements are available from research satellites supported by a number of space agencies; however, research missions generally do not have the long-term continuity which is essential for operational services, and often do not obtain the specific measurements needed for operational services and not in real time. A high-level coordination of satellite-based assets for space weather must be established to ensure that operational high-priority measurements are sustained in a cost-effective manner through shared capabilities, and available in real time. Another difficulty is the intercalibration across platforms to facilitate interoperability.

9. Recent international efforts are improving space-based observing capabilities. For example, Japan's Himawari-8 satellite launched in 2014 includes energetic particle measurements that are being intercalibrated with other satellite measurements. In early 2015, the United States launched the Deep Space Climate Observatory (DSCOVR) satellite. DSCOVR is the first operational mission to record in-situ solar wind measurements critical for high-reliability warnings of large geomagnetic storms. The soon to be launched second-generation COSMIC, supplemented by radio-occultation sensors aboard CMA's FY-3, and ultimately the future Sentinel-6, Meteor-M N3 and METOP-SG, will obtain a dense, global distribution of ionospheric measurements to improve space weather services in support of navigation and communication.

Space Weather Activities by the Inter-Programme Coordination Team on Space Weather

10. The Inter-Programme Coordination Team on Space Weather (ICTSW) was established 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 26 countries and 7 international organizations. It conducts its activities in accordance with the following Terms of Reference defined by CBS and CAeM:

(a) Standardization and enhancement of space weather data exchange and delivery through the

WMO Information System (WIS);

(b) Harmonized definition of end-products and services, including e.g. quality assurance guidelines and emergency warning procedures, in interaction with aviation and other major application sectors;

(c) Integration of space weather observations, through review of space- and surface-based observation requirements, harmonization of sensor specifications, monitoring plans for space weather observation;

(d) Encouraging the dialogue between the research and operational space weather communities.

11. 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). In addition, space weather observing missions are fully integrated in the draft Vision of the WIGOS space-based observing system in 2040, which is currently being developed.

12. The EGOS-IP 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 classification and evaluation of space weather instrumentation.

13. The ICTSW has also been working closely with ICAO on the development of space weather service requirements for aviation and on recommendations for how the provision of these services should be organized globally. The ICTSW provided extensive comments and suggested revisions for the Concept of Operations for International Space Weather Information in Support of International Air Navigation, as well as comments and suggested revisions for the space weather Standards and Recommended Practices (SARPs).

14. In addition, substantial progress has been made to understand the requirements of WIS and to identify the focus of a pilot project to test the utilization of WIS for the discovery, access, and potential redistribution of space weather information. This effort is being conducted together with the International Space Environment Service. The initial space weather parameters have been chosen, which consist of core space weather forecasts and alerts contained in the ISES codes.

15. Space weather products and services are available today from a growing number of centers around the world. These products include multi-day forecasts of solar and geomagnetic activity, short-term warnings of imminent hazardous conditions, and alerts based on real-time measurements of space weather phenomena. Many of these products are global in nature, specifying for example large-scale disturbances originating at the Sun, while other are local, describing disturbances such as geomagnetic or ionospheric variability over specific regions.

16. Working closely with the WMO, the International Space Environment Service (ISES) organization is an important organization that has been engaged in space weather services since 1962 (www.spaceweather.org). There are currently 16 Regional Warning Centers, four Associate Warning Centers, and one collaborative expert center. Most of the ISES centers also are represented on the ICTSW, and in July, 2015 letters were signed by WMO and ISES that establish the working relationship among these organizations.

17. As countries around the world increasingly need to make space weather information available to their industries and government activities, the ICTSW made the decision to enhance the knowledge and

availability of established products through the Space Weather Product Portal. The Space Weather Product Portal, which is now integrated in the “Product Access Guide” is intended to demonstrate the availability of space weather products delivered by the service centers around the globe, in order to enhance their usage.

18. Many of the products created today have global applicability. Furthermore, this Product Portal will facilitate the comparison of many of the products being created today and will encourage consistency of information and the adoption of best practices by the global service providers.

19. The Product Portal is an important point of integration among IPET-SUP and ICTSW. Links to educational material are available on the Portal, and training programs are being developed to support the understanding and use of some Portal products (http://www.nwstc.noaa.gov/spacewx/wmo/index.html). In addition, capacity building events are being planned with the support of the Committee on Space Research (COSPAR). An important function of the Space Weather Product Portal and the associated training and capacity building is to enable WMO Members to take advantage of the extensive space weather products that are routinely provided. This effort will substantially lower the barrier of entry for those wishing to utilize current products and to develop their own products for their local interests. National Meteorological and Hydrological Service (NMHSs) around the world could use the products available on the Portal to gain familiarity with space weather phenomena and the kind of services which can be delivered. They can then evaluate how they could expand to space weather the range of services they deliver to their own customers in distributing such products onward on an operational basis.

Four-Year Plan for the Coordination of Space Weather Activities

20. Cg-17 discussed the draft Four-Year Plan for the WMO Coordination of Space Weather Activities and adopted Res.38 (Cg-17) which includes the following request:

> *“CAeM and CBS to consider existing responsibilities, working mechanisms, expert teams, and integration within relevant WMO programmes in finalizing the draft Four-Year Plan for WMO Coordination of Space Weather Activities, and present to the Executive Council a recommendation to approve it and jointly ensure its efficient alignment and implementation, within available resources”.*

21. The Four-Year plan for space weather activities was developed in recognition of the increasing societal demand for space weather services and the need for global coordination. The plan describes the high-level goals for effort among WMO Members, actions to be accomplished, and a proposed organizational structure. The plan builds on prior accomplishments and current efforts, it promotes synergy with WMO core programs, and it fosters coordination with service, research, and policy organizations.

22. Within the Four-Year plan, activities are organized in terms of systems-level activities, service-level activities, and strategic-level activities. System-level activities include the coordination and continuity of observing assets, information exchange through the WIS, and dialogue with the meteorological and climate communities on modelling and verification. Service-level activities include the delivery of coordinated services to civil aviation in response to ICAO requirements, preparing for extreme events in a multi-hazard Disaster Risk Reduction approach, and training on the delivery and use of services. Strategic-level activities include the coordination with other organizations involved in space weather-related efforts, such as CGMS, ISES, ITU, and COPUOS.

23. Of particular relevance to IPET-SUP are activities related to the provision of operational products and the training and education activities. In this respect one goal of the plan is to foster the production of high-quality end products and services by WMO Members, building on the experience of ISES Regional Warning Centres or other recognized providers. This would be achieved in developing best practices to improve accuracy, reliability, interoperability, and overall cost-efficiency of provision of services; in

particular, improve the emergency warning procedures and global preparedness to space weather hazards in accordance with the WMO strategy on Disaster Risk Reduction. Best practices shall be defined in interaction with major users to best respond to the evolving needs of key socio-economic sectors and public safety. They should be based on scientific assessments and quality management principles (thus implying user focus).

24. With respect to training and capacity-building, the goal is to develop skills in the generation and interpretation of space weather products and services in order to allow WMO Members to utilize existing information in a meaningful way, build their own service capabilities, and facilitate user uptake of new products and services. It is planned to take advantage of the VLab. (See details below)

First priority actions	**Deliverable**	**Time frame**
Select existing training material and make it available on line through the Space Weather Product Portal	Training material on the Space Weather Product Portal	2016
Identify target audiences, including NMHS meteorologists who wish to establish space weather service delivery within their organization, and training objectives	Schedule of training programme to support NMHS interest	2017
Conduct training sessions in coordination with the VLab and partner organizations, provide tutorial tools.	Completed training programme, feedback for training improvements	2018
Other actions (Long term or lower priority)	**Deliverable**	**Time frame**
Develop new educational material, in different languages and with content structured for different regional needs	Region-specific resources for space weather service improvement	>2019

Conclusion

25. The demand for space weather services is growing as advances in technology lead to increasing vulnerability, both in terms of critical national infrastructures as well as human health. Increased reliance on satellites, increasing interconnectedness and loading of electric power systems, and emerging areas such as commercial space transportation will all contribute to the growing need for space weather information. NMHS centers have a key role in supporting the needed observing systems, allowing rapid access to data, developing products to service customer demand, and working in coordination with other centers to ensure the delivery of consistent, accurate information.

26. The effort to date by the ICTSW and partner organizations has established a foundation on which a global effort can be built. Existing WMO programmes can be leveraged, and interests and contributions can be coordinated. With the Space Weather Product Portal and associated training and capacity building activities, assistance can be given to allow broader usage of these resources, and as capabilities expand, new contributions to the global effort will be added. The actions described in the Four-Year Plan for WMO Coordination of Space Weather Activities provide a framework for enhanced interaction with IPET-SUP.