FOCUSING INTERNATIONAL COOPERATION ON IMPROVING OPERATIONAL SPACE WEATHER SERVICES

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Abstract

Space weather is entering an important and exciting era. Although our understanding of the Sun-Earth environment has improved considerably over the past decades, our vulnerability to space weather has also increased due to growth in our reliance on technologies impacted by space weather. Industry and government sectors are becoming more engaged in assessing the risks and developing mitigation strategies. International interest in providing space weather services is increasing, and organizations are working to coordinate the global effort. Research and numerical modeling capabilities are maturing; however, an emphasis is now needed on the development of targeted applications that will accelerate near-term improvements in our service capabilities. A global network of observations is in place, yet planning and coordination are required to ensure the continuous, long-term availability of the key measurements. With the understanding that space weather is a difficult, global challenge, we must now develop an international strategy to integrate our observing systems, our research efforts, and our service capabilities to address the increasing risks. This strategy must focus on applied research and core observations to support the need for improved operational services.

The Growing Need for Space Weather Services

It is now well recognized that space weather presents significant risks to a nation's economy and to the safety of its citizens. In the United States, space weather has been identified by the federal government as one of the grand challenges for disaster reduction [see http://www.sdr.gov]. Priority actions have been identified that will improve the ability to prevent and to recover from space weather-related disasters. A similar effort is occurring in the United Kingdom. Space weather is now included in the UK 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.

The increasing vulnerability to space weather was also the topic of a recent event organized by the European Commission's Joint Research Centre and co-hosted by the EC Directorate-General Enterprise and Industry [Krausmann and Bothmer, 2012]. This meeting gathered high-level representatives from national and international institutions, including industries impacted by space weather. Among the findings from the event were that space weather is a

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threat to critical infrastructures, both ground-based and space-based, and that international cooperation is necessary to address the multi-disciplinary and global issues regarding both the mitigation and the response to space weather events. An effort is underway in Europe to develop and deploy space weather services under the European Space Agency's Space Situational Awareness Program [Kumar, 2010].

Space weather awareness is also increasing throughout Asia, and efforts are taking place to improve capabilities and to coordinate actions. For example, the Korean Space Weather Center was formally opened in November, 2011, and actions to coordinate agency contributions within Korea are occurring [Ahn, 2011]. In addition, the Asia-Oceania Space Weather Alliance has been formed and now includes ten member countries.

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. Fortunately, with the growing interest in space weather, a number of organizations have brought space weather within their spheres of interest or expanded their efforts, and activities are underway that are facilitating interaction among space weather service providers. However, we do not have as yet a strategy to ensure the efficient coordination of our observing systems nor a strategy to focus product-development efforts on the highest priority service needs.

Space weather, as with many other application-oriented disciplines, had its genesis in basic research. Since well before the beginning of the space age in the 1940s and 1950s, solar-terrestrial physics has been an active area of international research. From the early work of Kristian Birkeland on "corpuscular rays emitted by the sun" as the cause of the aurora borealis and geomagnetic activity [Birkeland, 1908], and the work of Chapman and Ferraro on the formation of the magnetosphere [Chapman and Ferraro, 1931], our knowledge of the Sun-Earth system has progressed from an awareness of solar wind-magnetosphere coupling to an observational and modeling capability that gives a basis today for predicting space weather disturbances.

Substantial progress was made in our understanding of solar-terrestrial physics during the International Geophysical Year, which lasted from July 1, 1957 until the end of 1958 [Chapman, 1957]. Among the key considerations that drove this effort was the need for simultaneous measurements over as much of the planet as possible and to have nearly continuous observations of the Sun as much of the time as possible. Both of these considerations demanded strong international participation. In order to continuously monitor the Sun as Earth rotates, it was necessary then as it is now to have observatories positioned around the globe.

Just as the need to develop a basic understand of Earth's dynamic environment motivated the global research effort of the IGY, the need to provide timely and accurate predictive services to mitigate the impacts of space weather should motivate a new global effort today. This effort must go beyond the traditional basic research of the past decades and focus on application-oriented research and a system of space-based and ground-based observations to support operational services.

Although considerable research continues to be done around the world on the basic physics of solar-terrestrial interactions, substantially less effort is being devoted to applied research and to fostering innovation that will convert our basis understanding into specific applications. It is easy to understand why this is the case. First, Earth's vast space environment is still the territory of fundamental discovery. We have only recently acquired the capability through satellites to explore in detail the dynamics of space plasmas, and many important mysteries

remain. Furthermore, 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. Consequently, the approach that has been taken in our space science research programs to date, which emphasized fundamental research and discovery, was not designed for developing the next level of space weather service capabilities.

With regard to our observing systems for space weather, a basic difference between what was needed during the IGY to accomplish its research goals and what is needed today to support services is the continuous availability of core observations. During the IGY, it was recognized that the concentrated effort needed to obtain the required global observations could not be sustained by most countries for an extended time period. Consequently, the program had a limited duration. In contrast, we are now at the stage where establishing a global observing program with long-term sustainability for space weather services is exactly what is needed.

In order to move forward with the partnerships that will improve and deliver space weather services, efforts are going on at all levels around the world, from global coordination fostered by organizations in the United Nations to interagency agreements within individual countries. The major ongoing international activities today that support space weather are summarized below. These efforts represent a valuable foundation upon which we can maintain awareness of activities around the globe and can coordinate them. Although partnerships among agencies within an individual country are typically the easiest to establish and maintain, in many countries only a single organization has the mandate to deliver space weather services. It is often, therefore, the international partners whose missions are most closely aligned with the mission of any given space weather service-providing organization. For this reason, it is essential that we take advantage of the common goals and shared expertise among the international space weather service organizations.

International Organizations Engaged in Space Weather Coordination

International Space Environment Service

The International Space Environment Service (ISES) has been the primary organization engaged in the international coordination of space weather services since 1962 (www.ises-spaceweather.org). It currently is comprised of 14 Regional Warning Centers (RWCs) around the globe and four Associate Warning Centers, one in France and three in China [Figure 1]. The European Space Agency serves as a Collaborative Expert Center for data and product exchange in Europe. The NOAA Space Weather Prediction Center in the United States serves as the World Warning Agency and acts as a hub for the exchange of forecasts.

The mission of ISES is: "to encourage and facilitate near-real-time international monitoring and prediction of the space environment, to assist users reduce the impact of space weather on activities of human interest." The RWCs share data and forecasts among the Centers and provide space weather services to customers in their regions. The RWCs provide a broad range of services, including forecasts, alerts and warnings of solar, magnetospheric, and ionospheric conditions; extensive space environment data, customer-focused event analyses, and long-range predictions of the solar cycle. While each RWC concentrates on its own region, ISES provides a forum to share data, to exchange and compare forecasts, to discuss customer needs, and to identify the highest priorities for improving space weather services.

The establishment of new ISES Regional Warning Centers is encouraged. As members of ISES, the Regional Warning Centers interact with a wide network of experienced service

providers. ISES can be an effective forum for new space weather service providers to become familiar with the host of services available today and can help them integrate their capabilities into the global network. To be eligible to become a Regional Warning Center, an organization must have the endorsement of its national government, coordinate the collection of data in their area, allow free exchange of data and products with other Centers, provide timely forecasts and warnings for local users, and exchange forecasts with the other Centers.

Figure 1: International Space Environment Service – Regional Warning Centers

World Meteorological Organization

The World Meteorological Organization (WMO), an organization of the United Nations, has a membership of 189 countries and territories. Along with its mission to foster collaboration in the areas of weather, climate, and hydrology, the WMO has recently included space weather as one of its areas of involvement [Bogdan and Onsager, 2010]. At the 16th World Meteorological Congress in May, 2011, the WMO Members noted that a coordinated effort is needed to address the observing and service requirements for space weather (www.wmo.int/pages/prog/sat/documents/SAT-GEN_Cg-XVI-Annex-to-3-7-11-space-weather.pdf). Consequently, space weather coordination is now one of the four main components of the WMO Space Programme.

In May, 2010, the WMO formed the Inter-Programme Coordination Team on Space Weather (ICTSW). The goal of the ICTSW is to facilitate the international coordination of space weather observations, products, and services, working closely with ISES and other organizations. The following Terms of Reference were defined for the ICTSW jointly by the WMO Commission for Basic Systems and the Commission for Aeronautical Meteorology: 1. Standardization and enhancement of space weather data exchange and delivery through the WMO Information System (WIS); 2. 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; 3. Integration of space weather observations, through review of space-based and surface-based observations requirements, harmonization of sensor specifications, monitoring plans for space weather observation; and 4. Encouraging the dialogue between the research and operational space weather communities.

The ICTSW now has representatives from 18 countries and 7 international organizations (Figure 2). With the leadership of thWMO Space Programme, the ICTSW activities 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 in our observing systems. Space weather is now a new chapter in the WMO Implementation Plan for the Evolution of the Global Observing Systems. With this framework in place, space weather is now fully integrated into the WMO processes and plans for the evolution of the observing systems. The ICTSW is also coordinating with the International Civil Aviation Organization on its Concept of Operations for International Space Weather Information for Global Aviation.

Figure 2: WMO Inter-Programme Coordination Team

The Space Weather Product Portal 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.

The 16th World Meteorological Congress endorsed the need for a global space weather effort and requested the WMO Space Programme, in coordination with the ICTSW, to develop near-term and far-term action plans to implement a coordinated strategy. Countries with an interest in space weather services should consider nominating a member of the ICTSW.

International Civil Aviation Organization

The International Civil Aviation Organization, an organization of the United Nations, serves as a forum for cooperation in civil aviation among its 190 Member States. Within ICAO, aviation requirements for space weather are being considered within the International Airways Volcanic Watch Operations Group (IAVWOPSG). Within the IAVWOPSG, an ad-hoc group has been tasked to develop draft operational requirements for space weather. The ad-hoc group is developing a Concept of Operations for International Space Weather Information in Support of Aviation, which would be the basis for functional requirements.

The actions of ICAO and the IAVWOPSG demonstrate the recognized importance of space weather for international civil aviation. Space weather concerns include degradation of radio communication, reduction in the accuracy and availability of Global Navigation Satellite Systems (GNSS), and energetic particle impacts to humans and flight avionics. ICAO will work to formalize the service requirements for space weather, and as mentioned above, the WMO will work to define the observing requirements and to coordinate the end products and services. Together, these organizations will support the development of globally coordinated space weather services for aviation.

Coordination Group for Meteorological Satellites

The Coordination Group for Meteorological Satellites (CGMS) is an organization that exchanges information on geostationary and polar orbiting meteorological satellite systems. The group was formed in 1972 by representatives from the European Space Research Organization (now the European Space Agency, ESA), Japan, the U.S., observers from the World Meteorological Organization and the Joint Planning Staff for the Global Atmosphere Research Program. Its membership now includes numerous developers and operators of meteorological satellites, the WMO, and space agencies operating research and development satellites that contribute to WMO programs.

The CGMS has an interest in space weather, both from the perspective of the impacts of space weather on satellite systems and for the opportunity to coordinate space weather observations being made from meteorological satellites. A permanent action item has been for Members to report on spacecraft anomalies from solar events at CGMS meetings. At the most recent meeting (CGMS-39) in October, 2011, this permanent action item was modified for 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." An action was also agreed for "WMO, through ICTSW, to propose a template in advance of CGMS-40 in order to facilitate harmonized reporting on spacecraft anomalies related to space weather."

An important issue for future space weather services is deploying and maintaining the space-based system need to obtain the required real-time observations. At CGMS-39, the WMO emphasized the need for a high-level coordination of satellite-based and ground-based space weather observing assets to insure that high-priority gaps are addressed in a cost-effective manner through shared capabilities. The CGMS can be an important organization to assist with this coordination of space assets.

United Nations Committee on the Peaceful Uses of Outer Space

The United Nations Committee on the Peaceful Uses of Outer Space (UNCOPOUS) was established in 1959 to provide a focal point for international cooperation in the peaceful exploration and use of outer space. UNCOPOUS currently has 70 members. Within UNCOPOUS, there are two subcommittees, the Scientific and Technical Subcommittee and the Legal Subcommittee. Within the Scientific and Technical Subcommittee, a Working Group on the Long-Term Sustainability of Outer Space Activities was established in 2010.

In June 2011, expert teams were established in four areas under the Working Group on the Long-Term sustainability of Outer Space Activities. There four expert team areas are: 1. Sustainable space utilization supporting sustainable development on Earth; 2. Space debris, space operations and tools to support collaborative space situational awareness; 3. Space weather; and 4. Regulatory regimes and guidance for actors in the space arena.

Suggested topics of study for the space weather expert team include: 1. Collection, sharing and dissemination of data, models, and forecasts; 2. Capabilities to provide a comprehensive

and sustainable network of key data in order to observe and measure space weather phenomena adequately in real or near-real time; 3. Open sharing of established practices and guidelines to mitigate the impact of space weather phenomena on operational space systems; and 4. Coordination among States on ground-based and space-based space weather observations in order to safeguard space activities. The space weather expert team is currently conducting its study, with a final report anticipated in 2014.

In February, 2012, space weather was accepted as a standing agenda item for the Scientific and Technical Subcommittee of UNCOPOUS. Through the work of the space weather expert team and the ongoing consideration of space weather by the Scientific and Technical Subcommittee, the opportunity exists to document key issues that will improve the resilience of our space assets and to advocate for coordinated actions that will enhance our space weather capabilities.

Discussion

Space weather is now at an important juncture. The need for comprehensive, accurate space weather services is being recognized around the globe, and international organizations are engaged in assessing our capabilities and recommending actions. The pioneering work of international scientists involved in the research programs of the past half century have taken us to the point where our science is maturing and the core observational needs for space weather services are understood. As this has occurred, our dependence on a technology-based infrastructure for our economy and security has taken us to the point where space weather storms can have significant economic and security impacts.

Although a major shift has occurred in the information we need – from a fundamental understanding to actionable forecasts and alerts – our approach to conducting research has not appreciably changed. The need for improved understanding of the fundamental processes that control the solar-terrestrial system still remains. However, there is now also the imperative to go beyond the traditional research model of the past decades and put in place applied research programs that will foster the innovation needed for the near-term development of targeted applications, building on the fundamental knowledge we have.

Our observing systems similarly must evolve toward including a core capability that supports continuous, operational, space weather services. This can only be accomplished with the participation of countries around the world. Research satellites provide many of the important observations used for space weather services today, and research missions by their design are only available for a limited time period. In addition, many research observations, including space-based and ground-based measurements, are not available in real time and consequently have limited value for operational services.

There are two international organizations today engaged in coordinating space weather services and the required observations: the International Space Environment Service and the World Meteorological Organization. Although there is a substantial overlap in the participation in these two organizations, there are important differences. The primary difference in representation results from the fact that while some of the ISES Regional Warning Centers are contained within their country's meteorology organization, many are not. Consequently, many of the ISES centers do not have a strong familiarity with the WMO structure and procedures and do not have a history of participation in WMO decision making. At the same time, the involvement of the WMO in space weather provides a superb opportunity to raise awareness and to encourage the participation of countries around the world, taking advantage of the existing data infrastructure, the culture of operational service delivery, and the growing overlap in the customer groups for terrestrial and space weather services, such as the commercial airline industry and the electric power industry.

A key question going forward is how will we build on the foundation for collaboration that has been established and implement the needed improvements to our observing capabilities and to our services? With the increasing number of partners committed to moving the space weather enterprise forward, we must create a forum to reach global consensus on our priorities and to identify the actions that will yield the space weather observations and service capabilities needed today and in the future. This will involve a shared space-based and ground-based real-time observing infrastructure and it will involve applications-oriented research. With the changes occurring in our need for accurate, comprehensive space weather services, so too must our approach to meeting these needs.

References

Ahn, B.-H. (2011), South Korea's renewed focus on space weather, Space Weather, 9, S10010, doi:10.1029/2011SW000730.

Birkeland, K., (1908), The Norwegian Aurora Polaris Expedition 1902-1903, H. Aschehoung & Co.

Bogdan, T. J., and T. G. Onsager (2010), New Space Weather Activities in the World Meteorological Organization, *Space Weather*, 8, S10004, doi:10.1029/2010SW000626.

Chapman, S. (1957), The International Geophysical Year. In D. R. Bates, F.R.S. (Editor). The Earth and its Atmosphere, p.1-11. Basic Books, Inc., New York

Chapman, S., and V. C. A. Ferraro, (1931), A new theory of magnetic storms, Terrest. Magnetism and Atmospheric Elec., 36, 171-186.

Krausmann, E., and V. Bothmer (2012), Meeting report: European Commission's space-weather awareness dialogue, Space Weather, 10, S04006, doi:10.1029/2012SW000790.

Kumar, M. (2010), ESA soon to unveil space weather services, Space Weather, 8, S10005, doi:10.1029/2010SW000623.

Biography

Terry Onsager is a physicist at the National Oceanic and Atmospheric Administration's Spae Weather Prediction Center. His research interests include solar wind-magnetosphere interations, modeling signatures of magnetic reconnection in magnetospheric boundary layers, and the dynamics of Earth's electron radiation belts. Currently he is the Director of the International Space Environment Service, and a co-chair of the World Meteorological Organization Inter-Programme Coordination Team on Space weather. He is also a member of the Space Weather Expert Team for the UN Committee on the Peaceful Use of Outer Space Working Group on the Long-Term Sustainability of Outer Space.