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COMMENTARY
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Key Points:
- Space weather is a global threat that requires a coordinated global response
- Expanded international collaboration at the governmental policy level is needed for improved resilience against space weather effects
- International coordination proposed within UNISPACE+50 Thematic Priority 4: Framework for International Space Weather Services can achieve this goal

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International Collaboration Within the United Nations Committee on the Peaceful Uses of Outer Space: Framework for International Space Weather Services (2018–2030)

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Abstract Severe space weather is a global threat that requires a coordinated global response. In this Commentary, we review some previous successful actions supporting international coordination between member states in the United Nations (UN) context and make recommendations for a future approach. Member states of the UN Committee on the Peaceful Uses of Outer Space (COPUOS) recently approved new guidelines related to space weather under actions for the long-term sustainability of outer space activities. This is to be followed by UN Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE)+50, which will take place in June 2018 on the occasion of the fiftieth anniversary of the first UNISPACE I held in Vienna in 1968. Expanded international coordination has been proposed within COPUOS under the UNISPACE+50 process, where priorities for 2018–2030 are to be defined under Thematic Priority 4: Framework for International Space Weather Services. The COPUOS expert group for space weather has proposed the creation of a new International Coordination Group for Space Weather be implemented as part of this thematic priority. This coordination group would lead international coordination between member states and across international stakeholders, monitor progress against implementation of guidelines and best practices, and promote coordinated global efforts in the space weather ecosystem spanning observations, research, modeling, and validation, with the goal of improved space weather services. We argue that such improved coordination at the international policy level is essential for increasing global resiliency against the threats arising from severe space weather.

1. Introduction

Recent research has revealed a renewed understanding of both the increased likelihood of and potentially catastrophic impacts arising from severe space weather demanding an urgent, focused, and coordinated response from the international community. The increased confidence in socio-economic and risk assessments, and the fidelity of the results, has resulted directly from a science-driven approach to space weather combined with appropriate engineering approaches to mitigation. However, despite significant advances in understanding the drivers of extreme space weather and improvements in the fidelity of risk and impact assessments, we are still a long way from offering high-prediction efficiency for forecasting impending severe space weather. These shortcomings have been discussed in the Committee on Space Research (COSPAR)-International Living with a Star (ILWS) Space Weather Science Roadmap (2015–2025) document (Schrijver et al., 2015). In our view, it is essential that future space weather activities are underpinned by ongoing investment and focus on using the latest and most advanced scientific research while implementing best practices.

In terms of the magnitude of the socio-economic impacts from space weather, the study completed by the United States (U.S.) National Academies in 2008 concluded that a severe space storm could have a huge socio-economic impact, with a ~4 to 10-year recovery phase (Space Studies Board, 2008). More recent studies from Lloyds of London (2013), the Royal Academy of Engineering (2013), and others (e.g., Oughton et al., 2017) have subsequently revisited the potential magnitude. All have established that severe space weather is a high-impact threat. Oughton et al. explicitly highlighted additional flow-down impacts occurring outside the direct regions of electrical power loss, mainly due to the interconnectedness of both the present-day infrastructure and the economy. A number of additional studies have also highlighted the potential high likelihood of a storm of the magnitude of the Carrington 1859 storm (Cliver & Svalgaard, 2004), including Riley (2012) who argued that there is a 12% chance of a storm of such magnitude occurring in the next decade.

Such understanding has resulted in the prioritization of an appropriate national response to the space weather threat in some countries and in the development of appropriate national action plans and protocols for the protection of critical infrastructure in those jurisdictions. For example, in the United States, this included the release of the United States National Space Weather Strategy and Action Plan (2015) and the Unted States Presidential Executive Order (2016) dated 13 October 2016, on Coordinating Efforts to Prepare the Nation for Space Weather Events. The North American Electric Reliability Corporation, an international regulatory authority, followed with regulations aimed at protecting the integrity of the electrical grid in North America. Those efforts have been coordinated throughout the U.S. Government under the auspices of the Space Weather Operations Research and Mitigation Subcommittee (www.sworm.gov). In the United Kingdom (UK), socio-economic and other impact studies resulted in space weather being entered on to the UK Risk Register of Civil Emergencies, with the consequent development of dedicated space weather services at the UK Meteorological Office and related mitigation activities within civil protection administrations. In our view such first laudable efforts of individual countries need to be expanded into a more global and coordinated effort.

In the view of the authors of this Commentary, promotion of the importance of space weather, needed international policy coordination, and monitoring of progress toward improved international resilience against the impacts of space weather can be most effectively delivered in an expanded role for the United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS). This would ensure the appropriate involvement and representation from the 84 member states of the COPUOS at the required governmental policy level. With active involvement of entities engaged in space weather activities, including as appropriate some of the international intergovernmental and nongovernmental organizations that have observer status at COPUOS, new coordination, collaboration, and expansion of services along with space weather resilience could be implemented in an efficient and effective manner.

2. UN Space Weather Activities

Given the growing international appreciation for the severity of the space weather threat, the UN COPUOS began to focus on promoting and developing an improved and coordinated international response to space weather. In 2009, the COPUOS agreed that the Scientific and Technical Subcommittee (STSC) should include a new item in its agenda commencing in 2010 on the “Long-term sustainability of outer space activities”. As a response, the subcommittee established the working group on the long-term sustainability of outer space activities (LTS), which included Expert Group C, dealing exclusively with space weather. Expert group C developed proposals relating to space weather (COPUOS, 2014; see also COPUOS, 2016a) that were incorporated into a set of guidelines for the LTS working group. The guidelines agreed upon by consensus at the COPUOS in 2016 were as follows: (a) share operational space weather data and forecasts and (b) develop space weather models and tools and collect established practices on the mitigation of space weather effects. These guidelines aim to promote collection, archiving, sharing, intercalibration, long-term continuity and dissemination of critical data, and model outputs and forecasts relating to space weather (COPUOS, 2016a) and already provide an excellent basis for the beginnings of improved international space weather coordination between, and amongst, member states. In 2013 space weather became a permanent agenda item of the subcomittee, and a space weather expert group was established with a rapporteur reporting to the subcommittee. The expert group has enabled further progress to be made in relation to the coordination of space weather activities (see also COPUOS, 2017b). However, in the authors’ view, making real progress will require a renewed commitment to prioritize actions related to space weather mitigation within every member state, including the allocation of the necessary national resources. An effective mechanism to monitor global progress against the implementation of the guidelines is also needed.

In 2015 the COPUOS mandated a milestone event, branded “UNISPACE+50,” to be held in June 2018 to mark the fiftieth anniversary of the first UN Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE I) held in Vienna in 1968 (COPUOS, 2016b). The UNISPACE+50 Thematic Priority 4 (TP-4) —“Development of an International framework for Space Weather Services”—offers timely and important opportunities to coordinate international space weather efforts and to develop and deploy appropriate infrastructure in the 2018–2030 time frame.

With substantive support of the UN Office of Outer Space Affairs (UNOOSA), the expert group prepared a report promoting international coordination toward the goal of the mitigation of space weather effects to be considered by the STSC as part of UNISPACE+50. The UNOOSA supported a UN-US Workshop on this topic in Boston USA (United Nations/United States of America Workshop Report, 2017). The expert group also undertook a series of outreach events including (1) a dedicated April 2017 expert group workshop at the UN in Vienna, and (2) community Town Hall meetings at the April 2017 European Geosciences Union General Assembly in Vienna, Austria, at the July 2017 Chapman Conference on Dayside Magnetosphere Interactions in Chengdu, China, at the July 2017 International Astronomical Union Symposium 335 on Space Weather of the Heliosphere: Processes and Forecasts, in Exeter, UK, and at the November 2017 European Space Weather Week in Oostende, Belgium. The TP-4 report is now available as COPUOS (2017a), and some of the primary considerations relating to the recommendations in the TP-4 report are summarized below (see also COPUOS, 2018).

3. Roadmap for Improved International Resilience Against the Space Weather Threat

There are a number of areas where increased international collaboration between space weather researchers, service providers, users, and critical infrastructure protection administrations, within and between member states and their national and international agencies, can be advantageous. For example, member states need reliable information informing them of *when* they should react. This could be achieved, for example, through the development of a framework for an International Space Weather Warning Network, which could be implemented through agencies and organization within member states or in partnership with other UN agencies such as the World Meteorological Organization (WMO), the International Civil Aviation Organization (ICAO), and others. The space weather domain is developing an increasingly extensive observational infrastructure. However, renewed international coordination and future investment are needed to ensure the long-term operation of the required ground- and space-based instruments and for identifying and filling key measurement gaps. This could be complemented by cooperation between model developers for both physical understanding and dedicated forecasts and the existing service functions of member state forecast centers. Scientifically defined metrics for improved benchmarking and model and forecast intercomparisons could further the goal of delivering an actionable warning for use by civil protection administrations in responding to threat of an impending severe space storm.

Of course, once a severe space weather warning is issued, it also essential to know *what* to do. A set of best practices, operating procedures, and actions have to be identified by first assessing what risks and socio-economic impacts are present in each member state or region and then to recognize the correct and appropriate measures to be taken in order to mitigate the potential consequences (COPUOS, 2017c). Such studies need to recognize that geographic differences influence the severity of space weather effects on vulnerable infrastructure and technology systems. The COPUOS-approved space weather-related guidelines for LTS already include some additional elements relating to protection strategies. Their future implementation in member states would advance global space weather resiliency. In our view, the promotion of national policies, which could lead to the implementation of the guidelines in every member state, would be beneficial even from a global point of view.

We highlight that any future assessments of the impacts of (both extreme and more frequent less severe) space weather, and improvements to the accuracy of space weather forecasts, must all be underpinned by urgently required advances in the scientific understanding of the complex physical processes in the highly coupled system. In our view there should be a periodic, perhaps 5-year, reassessment of, and update to, a global Space Weather Science Roadmap, setting out from the 2015 COSPAR-ILWS Roadmap (Schrijver et al., 2015) as a baseline document. The COSPAR, perhaps through its Panel on Space Weather, provides an obvious vehicle for regular science progress assessment and consequent roadmap updates. The results could be reported to the COPUOS for dissemination to member states such that they can consider the appropriate steps for implementing new recommendations.

Figure 1. Targeting improved space weather services**.** This metaphoric picture shows schematically the connections between elements of the space weather ecosystem, all of which are needed to reach the ultimate target of improved space weather services. It is clear that even if most organizations and nations would immediately want to see most efforts concentrate on the service side of the problem, the way to reach this goal is more complicated than that, and international coordination is required in all regimes of the ecosystem. Very much like an inexperienced archer, the still relatively new and yet quite immature field of space weather will initially have to spend a lot of effort (arrows) on the outer portions of the target, that is, science, modeling, and observations, before the final goal of hitting the bulls-eye target of improved high fidelity space weather services can be achieved. Only through an iterative and intelligent assessment and communication of growing skills within the international community of scientists and service providers can the central target—a mature global space weather service that satisfies international user needs—eventually be reached.

Any progress in model development and prediction advancement, and the improvement of space weather services and forecasts with improved user utility, requires a renewed and maintained focus on the advancement of science research and the removal of barriers for the transition of research to operations. In our view, a more holistic approach to the relationship between research and operational space weather services that moves away from the linear research-to-operations and operations-to-research relationships is essential.

The schematic in Figure 1 illustrates this concept in relation to a target of improved space weather services. A combination of advances in science understanding, model functionality, and improved observations, with synergistic activities to validate and assess performance of models against metrics, paves the way forward. Improvements in dissemination activities will have to include intercomparison and cross calibration. A global network of emerging applications and interactive archives is necessary to reach the central goal of a coordinated and reliable international space weather warning network. Each of these activities would support bidirectional communications as advances in science understanding, and higher fidelity models transition to fully operational products.

Efforts are underway to implement the science and modeling end of this approach in the context of developing international space weather topical action teams. A potential revision of the COSPAR Panel on Space Weather mandate could include the coordination of such topical action team activities. Operational entities would remain responsible for the delivery and roll-out of new operational products, but it is hoped that topical action teams can drive an innovative approach to a faster transition of the latest research into the service domain with a few barriers and as efficiently as possible. When supported by other service providers and by other international implementation-oriented bodies such as the WMO, the International Space Environment Service, the ICAO, and others, this model could offer a route to accelerate delivery of improved international space weather services.

4. Improved Future International Collaboration in the UN Context

A pressing question is *how*, within the context of the numerous international space weather stakeholders, to provide an improved basis for international collaboration. This must leverage existing capacity and services, while (1) filling key measurement or other service gaps, (2) minimizing duplication within a global context, and (3) embracing outreach and capacity building especially in developing and aspiring space-faring nations. Any such process also needs to recognize that space weather services and space weather program implementation take place within the jurisdictions of individual member states, and their national and international organizations, as well as within multiple UN administrations, each with their own governance.

One of the primary recommendations to be considered during UNISPACE+50 is the need to further develop the international collaboration begun in the UN COPUOS expert group for space weather, including encapsulating and promoting the implementation of the LTS guidelines relating to space weather. A primary focus on future science research needs, as initially captured in the COSPAR-ILWS Roadmap (Schrijver et al., 2015), has also explicitly been recommended for endorsement. The proposals in the TP-4 report (COPUOS, 2017a) strongly recommend the introduction of a new International Coordination Group for Space Weather (ICSW) that would replace and supersede the UN COPUOS expert group for space weather in 2020. In the schedule proposed for UNISPACE+50 under TP-4, an international space weather workshop would be held in the summer of 2019 to define the terms of reference, mandate, and formal structure of such a group. The ICSW would be functional following approval from the STSC and the full COPUOS Committee in February and June 2020, respectively. The authors of this Commentary fully endorse the proposed approach defined in the TP-4 report (COPUOS, 2017a).

Specifically, the TP-4 report proposes that the ICSW should consist of representatives from state members of the COPUOS with participation from appropriate international space weather entities. Given the importance of dedicated science progress to future space weather endeavors, it is clear that the ICSW should include a strong role for COSPAR, for example, through ex-officio membership. The ICSW would guide space weather policy, promote the implementation of space weather guidelines and best practices, and serve as mechanism for high-level coordination between the numerous active international space weather stakeholder organizations. These would include the WMO, the ICAO, the International Space Environment Service, the COSPAR, the International Astronomical Union, the International Coordination Group for Global Navigation Satellite Systems, the International Space Weather Initiative, etc. Implementation reviews across multiple space weather stakeholders have begun in Europe, for example, with the establishment by the European Science Foundation of a European Space Weather Assessment and Consolidation Working Group. In our view, a similar overview of the global endeavor should be undertaken within the UN, with the new ICSW reporting and making recommendations to COPUOS via the STSC Space Weather agenda item. Building resilient societies through better coordination and the forging of global partnerships is also one of the key challenges in the 21st century and an integral part of meeting the commitments set by the three key UN global frameworks: the *Sendai Framework for Disaster Risk Reduction* 2015–2030, the *2030 Agenda for Sustainable Development*, and the *Paris Agreement on Climate Change* (www.un.org). The proposed prioritization of space weather for UNISPACE+50 is consistent with these broader UN goals.

Overall, in the authors' opinion, there is an immediate and urgent need to assess the vulnerability of the world's ground- and space-based infrastructure to space weather and to mitigate the related impacts. In particular, there is a pressing need to advance the scientific knowledge about the physical drivers and related impacts of severe space weather. The result of such an endeavor would be improved resiliency; more accurate and higher fidelity space weather services; better definition and assessments of the technological impacts arising from worst-case scenarios; increased sharing of best practices in design, mitigation, and resilience; more accurate risk and socio-economic impact assessments, and actionable mitigation plans.

In the 21st century, the infrastructure and economies of the world's nation states are increasingly and intimately connected, both regionally and globally. Therefore, even countries with a perceived low domestic space weather risk will benefit from a global approach to mitigating space weather impacts. Mitigating the effects of extreme space weather is hence an issue of global international importance. Global mitigation requires a coordinated global response. A renewed commitment to improved communication between, and coordination amongst, the numerous and constantly increasing space weather stakeholders appears to us to be essential for the mitigation of the impacts of space weather in a global context. In our view, the expanded international cooperation should be achieved through the development of improved services coordinated within the proposed ICSW, through the adoption of the TP-4 report at UNISPACE+50, and through the future implementation of the TP-4 recommendations at UN COPUOS.

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