The remarkable legacy of the International Space Weather Initiative

- Earth's position in the Solar System is anything but serene.
- It is subjected to the vagaries of space weather that can have catastrophic consequences.
- Much of what we know about this phenomenon comes from the International Space Weather Initiative (ISWI).
- The ISWI serves as a testament to remarkable international cooperation in instrument operation, data collection and analysis, and the publication of scientific results.
- The Earth is now better prepared for whatever the Sun throws at us.

From a celestial perspective, Earth's position is anything but serene. It is like an exposed rock on a storm-lashed coastline, constantly battered by the elements, primarily, ironically, by what is essential for life on our planet: the Sun. Just as it is the primary driver of Earth's weather, the Sun immediately powers the weather in the space around it. The term 'space weather' refers to the phenomena triggered by solar activity, such as solar wind – the stream of charged particles emitted by the Sun – and its effects in our thermosphere, magnetosphere, and ionosphere – a series of regions within our atmosphere hosting a relatively large number of electrically charged atoms and molecules.

This space weather may seem devoid of the familiar marks of the weather around us, such as wind, rain, and clouds, but its impact is tangible. It could also be catastrophic. Therefore, understanding it is critical. Much of what we know about it is new, stemming from international cooperation triggered by a United Nations initiative in 2009.

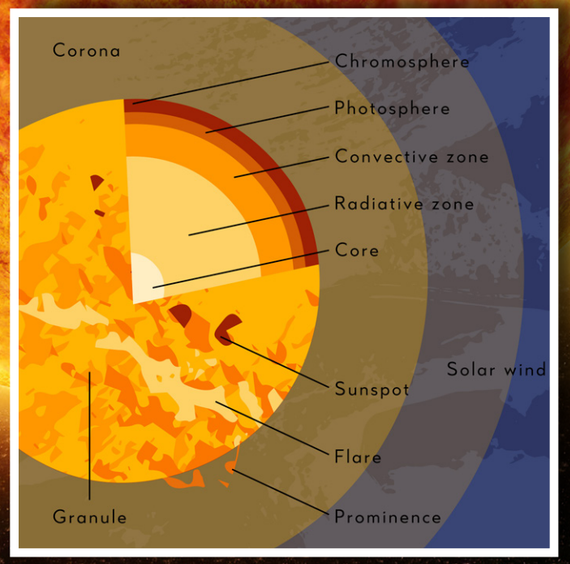
The need for a better understanding of Sun–Earth relations emerged from the International Heliophysical Year 2007 (IHY2007), an internationally coordinated effort to promote and advance research into the Sun and its effects on the solar system and beyond. In 2009, the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), in collaboration with the World Meteorological Organisation (WMO), proposed the International Space Weather Initiative (ISWI). The purpose of ISWI was to promote and coordinate space weather research and activities over a three-year work plan from 2010 to 2012. Until that point, studies in space weather had been limited to scattered pockets of research; ISWI would make it global.

Astronomical repercussions

For several reasons, a coordinated international approach to studying space weather makes sense. Firstly, space weather is inherently an international matter – it affects the whole globe. Secondly, while its impact on climate change may be minimal compared to human-created carbon emissions, space weather has astronomical repercussions on what makes us modern.

Until that point, studies in space weather had been limited to scattered pockets of research; ISWI would make it global.

The delicate web of satellites that sit above us is critical to the positioning, navigation, and timing (PNT) services we increasingly rely on. These systems have transformed numerous industries and aspects of modern life, enabling efficient transportation, business and banking, accurate mapping, reliable communication, and global synchronisation of critical systems. A simple case in point is the millions of vehicles and ships that rely on the global navigation satellite system (GNSS). The satellites and the systems on the ground connected to them are at the mercy of space weather events. Solar flares and geomagnetic storms can cause ionospheric disturbances, producing signal delays and phase shifts, signal degradation and inaccuracies in position and timing calculations. High-energy particles from space weather events



Anatomy of the Sun. Solar wind is created by the outward expansion of plasma (charged particles) from the Sun's corona, its outermost atmosphere.

Millions of vehicles and ships rely on the global navigation satellite system (GNSS) – but the satellites and systems on the ground connected to them are at the mercy of space weather events.

impact satellites' electronic components, potentially leading to temporary malfunctions or degraded performance. For ISWI, the first step to understanding and forecasting such space weather events and mitigating their effects was measuring them.

Mapping space weather

One of the critical lessons COPUOS learned through IHY2007 was how international cooperation between research organisations in developed and developing countries can accelerate global science initiatives and secure their sustainability by creating networks for sharing ideas, information, and data, and developing joint projects. To this end, for ISWI, COPUOS coordinated a series of workshops hosted by Egypt in 2010, Nigeria the following year, and Ecuador in 2012 that fostered such networks, focusing on Western Asia, Africa, and Latin America, respectively.

The purpose of these workshops went beyond knowledge exchange because although space weather is a relatively new field of research, it doesn't have the luxury of time to establish itself — it has immediate and urgent relevance. Therefore, workshops focused on challenges in researching the field, building networks, setting priorities, and discussing policy implications and decision-making regarding space weather impacts on critical infrastructure, communication systems, and satellite operations. However, before any of that was possible, they needed data, and lots of it.

The outcome was the establishment of arrays of instruments – GPS receivers, very-low-frequency receivers, magnetometers, solar spectrometers, and particle detectors – positioned around the world to record data on solar-terrestrial interaction, from coronal mass ejections to variations in the total electron content in the ionosphere.

Given the global reach of these arrays and the scope of what they measured, the ISWI instrument project generated volumes of new and valuable data, and helped develop a richer picture of space weather phenomena. Notably, these data were shared. In 2012, there were 16 such arrays worldwide. Because the ISWI Workshop in Ecuador that year encouraged longer-term cooperation, by 2021, the number of arrays had grown to 19, containing close to 1,045 individual sensors or instruments that, today, are still mapping space weather. However, ensuring sustainability in research in space weather requires more than connecting current researchers; it also relies on developing a pipeline of scientists to study space, something else close to the hearts of those at COPUOS.

ISWI may officially have lasted three years, but its legacy extends beyond 2012.

A hurricane seen from outer space.

Building the pipeline

Concurrent with the instrument projects and the workshops driving them, COPUOS organised ISWI Science Schools – educational events in space weather science and research focused primarily on developing countries. These events typically included workshops, lectures, and hands-on training by specialists in the field of space science, particularly space weather. They focused on capacity building, fostering international cooperation, encouraging interdisciplinary collaboration, and providing access to resources. Importantly, these events helped raise awareness about, and preparedness for, space weather events.

The multi-disciplinary IAU symposium on 'Space Weather of the Heliosphere: Processes and Forecasts' gave a balanced overview of the general advances in space weather.

Such preparedness is critical. A severe space weather event, such as a powerful solar or geomagnetic storm, would have widespread impacts on Earth. Given our reliance on, and the global interconnectivity of, PNT technology, such an event could trigger power grid disruptions, overwhelm satellites, ground aircraft operations, disrupt communications systems, interrupt international banking transactions, interfere with emergency operations, and affect sensitive research instrumentations.

There are ways to mitigate these potential impacts. Space agencies, governments, industries, and research organisations can actively monitor space weather conditions, develop strategies to prepare for such events, and respond accordingly. Early warnings and alerts would allow critical systems to take preventive measures, such as temporarily adjusting operations, activating backup systems, and implementing contingency plans. Early warning systems for extreme Earth-based weather events like hurricanes and tornadoes can reduce potential damage to infrastructure and save lives. Similarly, we can't stop space weather, but we can monitor it and prepare ourselves when things get rough.

ISWI may officially have lasted three years, but its legacy extends beyond 2012. It has provided a framework for collaboration among teams of scientists. It also serves as a testament to remarkable international work in instrument operation, data collection and analysis, and the publication of scientific results with an eye on real-world priorities. The Earth may still sit exposed to the Sun's shifting moods, but at least we can be better prepared for any dramatic outbursts.

ISWI fostered international cooperation and interdisciplinary collaboration.

Details

e: hans.haubold@gmail.com
t: +43 676 4252050
w: www.growkudos.com/projects/a-m-mathai-centre-for-mathematical-and-statistical-sciences-nurturing-the-love-for-mathematics

Bio

Hans J. Haubold is a professor of theoretical astrophysics at the Office for Outer Space Affairs of the United Nations, New York and Vienna. His research focuses on the internal structure of the Sun, solar neutrinos, and special functions of mathematical physics. Additionally, he is interested in the history of astronomy, physics, and mathematics.

Funding

- United Nations Secretariats in New York and Vienna
- European Space Agency (ESA)
- NASA (US)
- JAXA (Japan)
- 193 Member States of the United Nations

Collaborators

- Kiyohumi Yumoto (Japan)
- Sharafat Gadimova (UN)
- Christine Amory-Mazaudier (France)

Further reading

Amory-Mazaudier, C, Radicella, S, Doherty, P, et al, (2021) Development of research capacities in space weather: a successful international cooperation. *Journal of Space Weather and Space Climate*, 11, 28.

Gadimova, S, Haubold, H, (2013) Global navigation satellite systems and space weather: building upon the international space weather initiative. *Sun and Geosphere*, 9(1–2), 15–20.

United Nations General Assembly (2012) Report on the United Nations/ Ecuador Workshop on the International Space Weather Initiative. Quito, 8–12 October 2012.

United Nations