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Report on the United Nations/Nigeria workshop on the International Space Weather Initiative: Space Weather during a Moderate Solar Cycle

(Abuja, 6–10 October 2025)

I. Introduction

1. The need for a better understanding of Sun-Earth relations emerged from the International Heliophysical Year, an internationally coordinated effort to promote and advance research into the Sun and its effects on the solar system and beyond. The goal of the International Space Weather Initiative, launched in 2009, was to develop the insight necessary to understand the science and to reconstruct and forecast near-Earth space weather. That included developing instrument networks, enabling data-sharing and delivering capacity-building (education, training and webinars) and public outreach. Information on all the achievements resulting from international cooperation and coordination under the Initiative is made available through its newsletter and website (www.iswi-secretariat.org).

2. The United Nations/Nigeria workshop on the International Space Weather Initiative: Space Weather during a Moderate Solar Cycle was organized jointly by the Office for Outer Space Affairs and the National Space Research and Development Agency, on behalf of the Government of Nigeria. The workshop was co-organized and co-sponsored by the International Committee on Global Navigation Satellite Systems. The workshop was hosted by the National Space Research and Development Agency in Abuja from 6 to 10 October 2025.

3. The present report sets out the background, objectives and programme of the workshop and provides a summary of the observations made and the conclusions reached by participants. It has been prepared for submission to the Committee on the Peaceful Uses of Outer Space at its sixty-ninth session and for consideration by the Scientific and Technical Subcommittee at its sixty-third session, both to be held in 2026.

A. Background and objectives

4. Globally, there is growing interest in better understanding solar-terrestrial interactions, in particular patterns and trends in space weather. This is not only for scientific reasons, but also because the reliable operation of ground-based and space-based assets and infrastructure is increasingly dependent on their robustness

against the detrimental effects of space weather. It is therefore important to enhance understanding of space weather physics, improve forecasting capabilities and develop strategies to mitigate its effects on technological infrastructure.

5. In line with the consideration by the Scientific and Technical Subcommittee of the agenda item entitled "Space weather",[1] the objectives of the workshop were: (a) to focus on the deployment of new instruments, particularly in developing countries; (b) to discuss methods for analysing and interpreting data on space weather; (c) to focus on new research results and findings; and (d) to strengthen international coordination and cooperation on space weather products and services. The discussions at the workshop were also linked to the 2030 Agenda for Sustainable Development and to Sustainable Development Goals 4, 9 and 17.

B. Programme

6. At the opening of the workshop, welcoming remarks were made by representatives of the Federal Ministry of Innovation, Science and Technology of Nigeria, the National Space Research and Development Agency of Nigeria, the National Aeronautics and Space Administration (NASA) of the United States of America and the Office for Outer Space Affairs.

7. A keynote address on the results of the International Space Weather Initiative was delivered by an expert from NASA. The presentation covered the activities conducted under the Initiative, with a focus on the activities organized in Africa. The activities of the African Geophysical Society, formed in 2012 by scientists, were also highlighted.

8. A keynote presentation entitled "Space science, innovation, science and technology in sustainable development of a nation" was delivered by the representative of Nigeria. It was focused on the use of space science and technology for sustainable development and addressed regional and national challenges.

9. The workshop programme consisted of nine plenary sessions and two discussion sessions. Invited speakers, who came from both developed and developing countries, presented 43 papers describing their research achievements, education and outreach activities related to the International Space Weather Initiative and its instrument arrays. Discussion sessions provided participants with an opportunity to focus on specific problems and projects related to space weather, in particular instrument arrays and their status of operations and coordination and the operational use of space weather data.

10. The workshop was focused on the following topics: (a) solar physics; (b) space weather instrumentation and data; (c) space weather modelling and artificial intelligence; (d) space weather extreme events; (e) the ionosphere, the magnetosphere and the thermosphere; (f) space weather effects; (g) space weather case studies, outreach and education; (h) space weather programmes; and (i) applied space scientific research.

11. A tour of the facilities of the National Space Research and Development Agency, including the space museum and the planetarium, was organized for workshop participants.

12. In brief statements, the organizers of and participants in the workshop expressed their appreciation for the long-term, substantive contributions made to the development of the International Space Weather Initiative, in particular for the benefit of developing countries.

13. The programme of the workshop was developed by the Office for Outer Space Affairs and the National Space Research and Development Agency in cooperation with an international scientific organizing committee. The Chairs and rapporteurs

[1] A/AC.105/1338, paras. 84–92.

assigned to the plenary and discussion sessions provided their comments and notes as input for the preparation of the present report.

14. Abstracts of the papers presented, the workshop's programme and background materials were made available on the website of the Office for Outer Space Affairs (www.unoosa.org). Copies of the presentations were also made available to the workshop participants.

C. Attendance

15. Scientists, engineers and educators from developing and developed countries in all regions were invited by the Office for Outer Space Affairs to participate in and contribute to the workshop. Participants were selected on the basis of their scientific, engineering and educational backgrounds and their experiences in implementing programmes and projects in which the International Space Weather Initiative played a leading role.

16. Funds provided by the United Nations and the International Committee on Global Navigation Satellite Systems were used to cover the travel, accommodation and other costs of 15 participants from 15 countries. A total of 46 experts, 14 of whom were women, attended the workshop.

17. The following 22 Member States were represented in person or online at the workshop: Algeria, Burkina Faso, China, Côte d'Ivoire, Croatia, Egypt, Ethiopia, France, Germany, India, Indonesia, Japan, Kenya, Nigeria, Norway, Russian Federation, Rwanda, Serbia, South Africa, Uganda, United States of America and Zimbabwe. The Office for Outer Space Affairs was also represented at the workshop.

II. Observations and conclusions

18. The workshop noted that solar eruptions generally referred to coronal mass ejections and flares. Both were sources of space weather. Solar flares created sudden changes in the ionization level in the ionosphere and coronal mass ejections were associated with solar energetic particle events and geomagnetic storms. A flare with unusually high intensity and/or a coronal mass ejection with extremely high energy could be thought of as examples of extreme events on the Sun.

19. Workshop participants recalled that a number of Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) spectrometers had been deployed worldwide in the framework of the International Heliophysical Year and the International Space Weather Initiative for monitoring solar radio bursts and solar flares and together constituted the e-CALLISTO network. It was noted that the German Aerospace Centre (DLR), at Neustrelitz, was operating several CALLISTO receivers (10–80 MHz, 100–800 MHz and 1,000–1,600 MHz), with antennas following the Sun's position for best measurements, and that the original receivers had been further developed to minimize noise and ease maintenance work so that the behaviour of different propagation paths could be observed. The results were compact receivers with a built-in screen and personal computer, forming the basis for a wide range of space weather event analysis.

20. The workshop participants discussed the problem of space weather forecasting using traditional approaches, as well as the advantages of using machine-learning techniques to identify and characterize phenomena that drove space weather.

21. The workshop participants observed that artificial intelligence techniques offered significant potential for improving the prediction of geomagnetic storms. By analysing vast amounts of historical and real-time data, artificial intelligence models could identify complex patterns and relationships that might not be apparent through traditional analysis. Machine-learning algorithms, such as linear regression and

support vector machines, could be used to predict the occurrence and intensity of geomagnetic storms based on solar wind parameters and other space weather data.

22. Moreover, the use of artificial intelligence in space weather forecasting had shown promising results. For instance, long- and short-term memory networks had been successfully applied to predict geomagnetic indices such as a quasi-logarithmic index, derived from ground-based magnetic field measurements (Kp index), which quantified geomagnetic activity. Those networks had demonstrated the ability to provide more accurate and timely predictions compared with traditional methods, potentially giving operators of critical infrastructure more time to implement protective measures.

23. The workshop participants took note of the Madrigal database, an upper-atmospheric science database (http://cedar.openmadrigal.org/) that integrated multi-decade observations from over 159 instruments, including global navigation satellite system (GNSS)-based vertical total electron content (VTEC). That unique dataset provided a resource for machine-learning applications in space weather research.

24. The workshop participants were informed about the advanced capabilities of global data services from the European Space Agency (ESA), NASA and the European Earth Observation Programme (Copernicus), which provided open access to Earth observation and space physics data. Those services included the ESA space situational awareness platform, the NASA heliophysics portals and the Copernicus Data Space Ecosystem, all of which were critical for monitoring Earth, the solar system and space weather.

25. The workshop participants noted that several space weather phenomena might create disturbances in the Earth's magnetosphere and ionosphere that degraded performance and satellite tracking ability for GNSS positioning receivers. Those phenomena included high-speed solar windstreams, coronal mass ejections, large solar flares and coronal holes, which were usually (but not always) related to the 11-year sunspot or solar cycle. Two indices, the amplitude scintillation index and the rate of total electron content index, had been established to study plasma irregularities based on their impact on the GNSS signal.

26. The workshop participants also noted that GNSS receivers, originally designed for positioning, were now being used to study ionospheric irregularities. The large number of GNSS receivers had enabled significant progress to be made in studying the ionosphere, and in particular plasma irregularities.

27. The workshop participants learned that dense networks of low-cost multi-frequency GNSS receivers could be used to retrieve ionospheric information with the same level of accuracy as geodetic and/or scientific-grade multi-frequency GNSS receivers and to demonstrate that such information could be used to generate maps of retrieved ionospheric parameters for scientific studies and radio system operations. That implied the possibility of achieving global scintillation monitoring using low-cost receivers in areas of poor coverage, thereby reducing costs and increasing the density of ground receivers for the local detection and characterization of ionospheric fluctuations produced by scintillation.

28. The workshop participants noted that the twenty-fifth solar cycle was currently at its peak and consequently driving the intensification of adverse environments for orbiting satellites in low Earth orbit. The current solar activity might exacerbate the problem of atmospheric drag for low Earth orbit objects, which could lead to accelerated orbital decay and thus affect existing space debris. A detailed analysis of long- and short-term drag impact on selected catalogued low Earth orbit objects provided information on how to improve space situational awareness in the current solar cycle. Those findings underscored the importance of continuously monitoring solar activity and improving atmospheric drag models to mitigate risks associated with accelerated orbital decay and the growing challenge of managing space debris in the low Earth orbit environment.

29. From an aviation operations perspective, space weather events were causing disruptions to communications, navigation and surveillance systems. In addition, radiation dose levels at flight altitudes were elevated, as space weather events might occur on short timescales, with the effects occurring from almost instantaneously to over a few days.

30. The South African National Space Agency operated a 24/7 regional space weather centre that had been established in November 2022 and designated as such by the International Civil Aviation Organization (ICAO). The role of a regional centre was to support the four ICAO global centres in the provision of space weather information to the aviation sector. As a designated regional centre, it was important to collaborate with the other ICAO designated global centres to ensure a consistent and reliable service that served the interests of Africa. The South African National Space Agency shared its experiences of establishing and running a 24/7 operational centre and of maintaining regional partnerships for ground-based instrumentation network expansion within the African region. With its functions as a 24/7 operational, regional space weather centre, the South African National Space Agency had positioned itself to effectively participate in global efforts to address the challenges of space weather.

31. The workshop discussions helped to identify: (a) significant gaps in instrument types and coverage in the African region; (b) problems in maintaining instruments and data flow in terms of the continuity, collection, analysis and modelling of data; and (c) ways of attracting early-career scientists and supporting other ongoing international initiatives on space weather.

32. The workshop participants recognized that fundamental aspects of the International Space Weather Initiative included education, training and public outreach activities. The concept was to encourage and support space science courses, workshops and curricula in university and graduate schools that provided instrument support. There had been much success in those areas, but there was a need to continue education and training and to develop public outreach materials that were unique to the Initiative, and coordinate their distribution. It was important to provide information on the Initiative instrument arrays and results to the media, especially local media.

33. The workshop participants agreed that data from the International Space Weather Initiative's instrument arrays should be combined with space-based and other ground-based data through modelling and measurements to advance space weather science, thus leading to robust research output and the publication of scientific papers in international journals.

34. To enable effective international coordination and collaboration in space weather research and services, there should not be any barriers to data flows and communications. To that end, an open data policy, complete with rules of operation and data standards, should be promoted at the national level.

35. The workshop participants expressed their appreciation to the United Nations, the Government of Nigeria, the National Space Research and Development Agency, the co-sponsors and the scientific organizing committee for the substance, excellent organization and successful conclusion of the workshop.