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Future Opportunities for Space Weather Research in Africa

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1. Brief Space Weather Fundamentals

- **Modern society depends heavily on a variety of technologies** that are susceptible to the extremes of space weather—severe disturbances of the upper atmosphere and of the near-Earth space environment that are driven by the magnetic activity of the Sun. Some of the causes of space weather effects are:

- **Strong auroral currents** can disrupt and damage modern electric power grids and may contribute to the corrosion of oil and gas pipelines.
- **Geomagnetically Induced Currents** in power networks may shut down transformers resulting in power blackouts with huge economic consequences for many industries.
- **Magnetic storm-driven** ionospheric density disturbances interfere with high-frequency (HF) radio communications and navigation signals from Global Positioning System (GPS) satellites, while polar cap absorption (PCA) events can degrade—and, during severe events, completely black out—HF communications along transpolar aviation routes, requiring aircraft flying these routes to be diverted to lower latitudes.
- **Exposure of spacecraft to energetic particles** during solar energetic particle events and radiation belt enhancements can cause temporary operational anomalies, damage critical electronics, degrade solar arrays, and blind optical systems such as imagers and star trackers.

Industry-specific Space Weather Impacts

- **The main industries whose operations can be adversely affected by extreme space weather are: the electric power, spacecraft, aviation, GPS-based positioning industries, and oil pipelines** [Severe Space Weather Events: Understanding Societal and Economic Impacts: A Workshop Report (2008); ISBN 978-0-309-12769-1 | DOI 10.17226/12507]

- **Electric Power Companies-** collateral effects of a longer-term outage would likely include, for example, disruption of the transportation, communication, banking, and finance systems, and government services; the breakdown of the distribution of potable water owing to pump failure; and the loss of perishable foods and medications because of lack of refrigeration.

- The resulting loss of services for a significant period of time in even one region of the country could affect the entire nation and have international impacts as well.

- **Aviation Industry-** re-routing of flights to non-polar or less-than-optimum polar routes during several days of disturbed space weather. The increased flight time and extra landings and takeoffs required by such route changes increase fuel consumption and raise cost, while the delays disrupt connections to other flights e.g January 2005- United Airlines.

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- **Satellite Launching-** Under adverse space weather conditions, launch personnel may delay a launch, and satellite operators may postpone certain operations (e.g., thruster firings).
- **Satellite Industry** – outage to telecommunications satellites, thus disrupting communications services e.g the 1994 two Canadian satellites affected and recovery of recovery of took a few hours while the second satellite took 6 months and cost $50 million to $70 million.
- In August 2011 South Africa's $13m satellite SumbandilaSat failed. A solar storm caused the satellite's onboard computer to stop responding to commands from the ground station.
- **Disabling of WAAS-** the United States Federal Aviation Administration's GPS-based Wide Area Augmentation System (2003)
- **The interconnectedness of critical infrastructures** in modern society implies that the impacts of severe space weather events can go beyond disruption of existing technical systems and lead to short-term as well as to long-term collateral socioeconomic disruptions

2. Mitigating Space Weather Effects

- **Space Weather Forecasting: Capabilities and Limitations**

  - One of the important functions of a nation’s space weather infrastructure is to provide reliable long-term forecasts, although the importance of forecasts varies according to industry.
  - With long-term (1- to 3-day) forecasts and minimal false alarms, the various user communities can take actions to mitigate the effects of impending solar disturbances and to minimize their economic impact.

- **The Societal and Economic Impacts of Severe Space Weather**

  - To assess the societal and economic impacts of severe space weather, quantitatively, multiple variables must be taken into account. These include:
  - The magnitude, duration, and timing of the event; the nature, severity, and extent of the collateral effects cascading through a society characterized by strong dependencies and interdependencies; the robustness and resilience of the affected infrastructures;
  - The risk management strategies and policies that the public and private sectors have in place; and
  - The capability of the responsible agencies to respond to the effects of an extreme space weather event.

3. Global Interventions: UNCOPUOS

- **UNCOPUOS** has established a subcommittee within its subcommittee on Long Term Sustainability (LTS) of Outer Space Activities Scientific and Technical Subcommittee, an **Expert Group** on **Space Weather**

- **The UNCOPUOS** has recognized and addressed the need _to improve global preparedness through the implementation of the space weather-related approved Guidelines for the Long-Term Sustainability of Outer Space Activities (LTS) (A/AC.105/C.1/L.366).

- **Implementing global organizations** are:
  - The World Meteorological Organisation (WMO)
  - The International Space Environment Service (ISES)
  - The Committee on Space Research (COSPAR) and the Coordination Group for Meteorological Satellites (CGMS)
  - The International Civil Aviation Organization (ICAO) has issued a new *Manual on Space Weather Information in Support of International Air Navigation* (ICAO Doc 10100). This is being handled by the Meteorological panel of ICAO.

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- In the International Framework for Space Weather Services for UNISPACE+50 report (**A/AC.105/1171**), the Expert Group identified six priority areas in the "Roadmap for international coordination and information exchange on space weather events" in section III of the report, and which focus on:

- Product and service selection
- Information communication protocol
- Response procedures
- Improved understanding of fundamental physical processes which cause extreme space weather
- Promotion of capacity building for space weather in COPUOS member States.

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- The Expert Group reiterates the value of this roadmap report as a basis though which Member States and their national and international organisations can improve their global space weather preparedness. Five domains of space weather impact and action was drawn directly from the UNCOPUOS's LTS guidelines: These are:

- Mitigation of space weather including risk assessments and socioeconomic impact studies
- Space weather services and operations
- Space weather measurements and observations
- Space weather research
- Space weather capacity building

4. Space Weather Research Infrastructure in Africa

- Space weather science has been studied extensively at the Sansa Space Science (formerly Hermanus Magnetic Observatory) in South Africa since 1841 and Nigeria in the 1960s , and University of Nairobi (Kenya) in 1970s, but the focus was primarily on geomagnetism.
- It is only since the International Helio-physical Year 2007, (IHY 2007) that widespread studies of space weather began in earnest owing to international networks built that year during a meeting that was held in Addis Ababa, Ethiopia to celebrate IHY 2007.
- Principal Investigators in the fields of geomagnetism and ionosphere (US Airforce Research Laboratories, Kyushu University, and Boston College) made deliberate efforts to link up with university staff from various African universities to enable them install ground based observing infrastructure such as magnetometers, Scintillation GPS receivers, Ionosondes/Digisondes, VHF receivers, Radars, Satellite Beacon receivers among others. The beneficiary universities/institutions were (list not exhaustive):

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- Sansa Space Science (formerly Hermanus magnetic Observatory-South Africa);
- University of Zambia;
- Makerere University, Mbarara University (Uganda);
- University of Dar es Salaam (Tanzania);
- University of Nairobi, Maseno University and Jomo Kenyatta University of Agriculture and Technology ; Technical University of Kenya; Pwani University (Kenya).
- Addis Ababa university & Bahir Dar University (Ethiopia)
- Helwan University (Egypt);
- University of Lagos, Federal University of Technology, Akure and University of Ilorin (Nigeria);
- University of Cocody (Cote' d'Ivoire);
- Universite' Marien Ngouabi, Congo Brazaville;
- University of Kisangani (Democratic Republic of Congo); and
- University of Ouagadougou (Burkina Faso).

❖ **Most of these are no longer operational !!! Those operated by UNAVCO, IGS and National Mapping Agencies, CNES/AGAIE, OMNISTAR, especially GPS are ok.**

5. Continental and National Initiatives

- **African Union Commission (AUC):**
  - Developed Space Policy, Space Strategy and Statutes that establishes the African Space Agency (AfSA), with its headquarters in Egypt.
  - Created a division of Astronomy & Space Science, where Space Weather is housed.
  - Commissioned survey on Space weather (on going) in order to audit gaps in infrastructure, human resource, skills, innovations, international collaborations and funding mechanisms. This will enable the AfSA plan effectively for the future.

- **National Space Agencies** – have put emphasis on space weather, especially infrastructure development, research and innovations: These are: NASRDA (Nigeria); SANSA (South Africa); ESSTI (Ethiopia); KSA (kenya) ; EgSA (Egypt), ASAL (Algeria).
  - Innovations in technology development e.g Centre for Atmospheric Research (NASRDA)-building magnetometers. Possibility of many undisclosed innovations in the continent.

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- **Research**

- Researchers are increasingly sharing data, carrying out joint research projects, joint supervision of students, and theses examination.
- Regional workshops organized to promote capacity building.
- Robust international collaborations with researchers beyond the continent, resulting in more space weather observing infrastructure.
- Internationally competitive research outputs as demonstrated by awards e.g
- ✓ **John Bosco Habarulema (Uganda)-** 2014 Basu Early Career award in Sun- Earth System Science.
- ✓ **John Bosco Habarulema (Uganda)** - 2016 AGU Africa award for Research Excellence in Space Science
- ✓ **Joseph Olwendo (Kenya)** - 2016 Basu Early Career award in Sun-Earth system science
- ✓ **Melessew Nigusie (Ethiopia)** - 2017 AGU Africa award for Research Excellence in Space Science
- ✓ **Ferederic Outtara (Burkina Faso)** – 2018 AGU Africa award for Research Excellence in Space Science
- ✓ **Zama T. Katamzi _ Joseph (South Africa) -** 2018 Basu Early Career award in Sun-Earth system Science
- ✓ **Andrew Akala (Nigeria)** - 2018 AGU Africa award for Research Excellence in Space Science
- ✓ **Olawale S. Bolaji (Nigeria)** – 2020 AGU Africa award for Research Excellence in Space Science

6. Opportunities for Future Space Weather Research

- **The opportunities for future research will depend on:**

- The ability of researchers to produce evidence based inputs to policy (African Union Commission or national) to address local challenges and win confidence of funders.
- Sustainability of research financing mechanisms, particularly through local funding agencies or through international collaborations or foreign funding agencies.
- Contextualization of UNCOPUOS LTS guidelines on space weather to local scenarios to address space weather effects in industry. Researchers need to develop standards for space weather mitigation.
- Technology development to enable production of new products and services, especially observing infrastructure for research and commercialization as well.
- Robust research , especially in modelling in order to draw closer to forecasting space weather events.
- Ability to provide space weather advisories to various needful stakeholders to enable them take defensive measures to mitigate space weather impacts. This may ensure continued funding of research.
- Participation in global space weather initiatives.

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- Maintenance and sustainability of operations of space weather equipment acquired through donations or procured through local funding streams. Many of the facilities are dysfunctional due to poor or no maintenance or erratic power supply.
- Embrace best practices from across the world and build onto success stories in the continent of Africa e.g upscale excellent research outputs.

References

- Guidelines for the Long-Term Sustainability of Outer Space Activities (LTS) (A/AC.105/C.1/L.366).
- *Manual on Space Weather Information in Support of International Air Navigation* (ICAO Doc 10100).
- Severe Space Weather Events: Understanding Societal and Economic Impacts: A Workshop Report (2008); ISBN 978-0-309-12769-1 | DOI 10.17226/12507
- UNISPACE+50 report -**A/AC.105/1171**