

## SPACE WEATHER

### A Policy Statement of the American Meteorological Society

(ADOPTED BY THE AMS COUNCIL, 5 MAY 2008)

**SUMMARY STATEMENT.** The American Meteorological Society (AMS) recognizes the importance of space weather research and services, and the need to develop advanced forecasting and mitigation techniques. Because of our increasing reliance on technologies susceptible to space weather and the demonstrated importance of space weather to society, the AMS strongly endorses activities and investments that further our understanding of this cross-disciplinary science and its practical applications.

**SPACE WEATHER DEFINITION.** Space weather refers to the variable conditions on the Sun and in the space environment that can influence the performance and reliability of spaceborne and groundbased technological systems, as well as endanger life or health. Most space weather occurs because emissions from the Sun influence the space environment around Earth, as well as other planets. For example, space weather can significantly impact the electric power industry, aviation, Global Navigation Satellite Systems [such as the Global Positioning System (GPS)] applications, communication systems, satellites, and space flight. Space weather can also affect national security and emergency response systems.

**SOCIETAL IMPACTS OF SPACE WEATHER.** Modern society is dependent on technologies that can be vulnerable to space weather. Following are examples of some of the impacts.

*Economy.* Economists estimate that the adverse impact of space weather is \$200–\$400 million per year, and the potential exists for significantly larger losses.<sup>1,2</sup> Estimates of space weather–related losses to satellite companies range from thousands of dollars for temporary data outages up to \$200 million to replace a satellite. Economists also estimate that timely warnings of geomagnetic storms to the electric power industry would save approximately \$150 million per year. A geomagnetic storm in March 1989 caused a

failure in the Hydro-Quebec electric power system and left 6 million people without electricity for 9 hours. If a large-scale outage was avoided today, the benefits would be measured in lives saved, and monetary savings of over \$20 billion.<sup>3</sup> GPS, which plays a vital role in our nation’s economy, is also affected by space weather. According to a European Space Agency study, space weather services for the GPS industry are vital—a 1% gain in continuity and availability of GPS would be worth \$180 million per year.<sup>4</sup>

*Safety.* The influence of space weather on ground/air communications is a factor in assuring safe airline operations. Commercial airlines are rapidly increasing their use of transpolar flights, which are often rerouted during major solar storms, since impacts can be greatest in the high-latitude and polar regions. High-frequency radio signals are often degraded or lost as a result of space weather conditions, which can render emergency communications used in disaster-recovery and humanitarian operations unavailable. There are also health risks for humans in space, since solar storms and enhanced radiation belts can cause radiation sickness or even death. Human space exploration relies on timely predictions of such storms. The growing market for commercial space travel will also rely on space weather services.

*Security.* Space weather has become increasingly important in U.S. national security. Space weather events can cause immediate and severe degradation to satellite command and control, intelligence operations, precision navigation and strike operations, and defense communications systems. The U.S. Air Force relies on space weather warnings to protect over 40 satellites that provide strategic and tactical support for the armed forces.<sup>5</sup> The Department of Defense (DoD) spends \$500 million per year to mitigate the impacts of space weather to these satellite systems. Despite this, DoD estimates that unmitigated effects to government satellites still cost over \$100 million a year.<sup>6,7</sup>

Given these effects, it is in the national interest to understand space weather phenomena. With timely and accurate forecasts, industries can mitigate many of the impacts. For example, airlines may reroute flights to avoid high radiation levels and communication blackout areas; spacecraft operators may put satellites in safe mode or reschedule critical maneuvers; survey and drilling companies reliant on precise GPS measurements may cease or delay operations; and electric power transmission systems may ensure grid reliability by adding on-demand generating capacity or reducing electric current loads.

**PREDICTING SPACE WEATHER.** Accurate space weather prediction could save society hundreds of millions of dollars a year. As the modern world becomes more dependent on technologies that are vulnerable to changes in the near-Earth environment, the need for accurate forecasting only increases. Forecasters continually monitor the space environment using both space- and ground-based assets and issue alerts and warnings of a likely impact on Earth. These assets also provide the space weather community with a long-term baseline on which to base, test, and ultimately improve global prediction models.

Current space weather predictions are focused primarily on five areas: (1) solar flares and eruptions impacting communications, radar, and GPS receivers; (2) radiation storms affecting airlines, astronauts, satellites, and communications; (3) disturbances in Earth's magnetic field, impacting electric power grids, GPS, satellites, and airlines; (4) atmospheric heating from increased short wavelength radiation, which shortens the lifetime of low-Earth-orbiting satellites; and (5) ionospheric storms, which degrade navigation systems, GPS-dependent technologies, and high-frequency and satellite communications.

At present, our capability to predict space weather events is comparable to Earth weather forecasting of about a half-century ago. Many space weather events are forecasted, but with minimal lead time because of a lack of real-time data and limited model capabilities. Considering the vast volume of space involved, the environment is highly undersampled. Investments by the U.S. and the global community into space weather-related research and technologies are rapidly advancing the state of knowledge and show great promise for producing improved forecasting capabilities.

**RECOMMENDATIONS.** Research efforts, both nationally and internationally, are underway to gain a better understanding of the causes of space weather and its effects on the economy, public safety, and national security. In addition, increased collaboration between meteorological and space weather communities is showing the benefits of shared data, analysis techniques, and warnings. Commitments to observations, research, and operations will provide benefits to users who can then implement policies to reduce risks and increase cost savings. Therefore, AMS recommends the following:

*Improved Modeling and Stronger Ties Between Research and Operations.*

- Government, industry, and academia should invest additional resources to address the challenging problem of transitioning research models to operational forecast tools.
- Space weather service providers should continue to leverage research and models developed by government, academia, and the private sector. Operational forecasters need more accurate and finer-resolution models with regionalized products to satisfy critical needs identified by a fast-growing and diverse customer base.
- Universities should broaden their meteorology curricula to include space weather and its effects.

*Continuity of Observations.*

- Government agencies should develop a strategy to ensure long-term continuity of essential space weather observing systems and critical observation data. Included are the spacecraft that now acquire data at stations well beyond the orbit of the Earth to permit longer warning times. Future research and model development to improve forecast capabilities are critically dependent on these observations and the infusion of these data into research and operations centers.
- Government agencies should ensure that data from these space weather observing systems be made readily available to a broad range of users and preserved within the archives of the national data centers.
- The research community should ensure that valuable satellite data are provided to the opera-

tions community. The two communities should enhance this close cooperation.

#### *Research on Impacts & Cost–Benefit Analyses.*

Government, industry, and academia should conduct coordinated research on

- impacts of space weather on specific industries, and
- societal and economic benefits of space weather forecasts.

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