State of the Art in Space Weather Services and Forecasting

An introduction to space weather operations in the U.S.A.

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Abstract
Space weather services are an international endeavour co-ordinated by the International Space Environment Service (ISES), which sanctions nine Regional Warning Centers positioned around the globe. In the USA, the NOAA Space Environment Center’s Space Weather Operations (SWO) in Boulder plays a special role as “World Warning Agency”, acting as a hub for communication. The SWO is a joint operation of the National Oceanic and Atmospheric Administration (NOAA) and the US Air Force, that is staffed 24 hours/day, 7 days/week. The Sun is a focus of attention and is monitored in a number of wavelengths (optical and radio) by ground-based observatories around the world and instruments in space. In particular, solar monitors include the X-ray sensors on all NOAA Geostationary Operational Environmental Satellites (GOES), and optical instruments onboard interplanetary spacecraft, most notably the Japanese YOHKOH and the National Aeronautics and Space Administration/European Space Agency (NASA/ESA) SOHO spacecraft. Also of primary importance, the interplanetary medium is monitored by instruments on NASA’s ACE and WIND spacecraft. Energetic solar particles are observed on GOES, ACE and WIND. The geomagnetic field is observed by a network of ground-based observatories, and by magnetometers onboard GOES. All in all, over 2000 data streams received daily contribute to the assessment of the space environment. If the space environment is disturbed beyond preset thresholds, alerts are issued. There are alerts for solar X-ray events and energetic particle events, extraordinary radio sweeps and bursts, and geomagnetic storms. In 1999, SWO began issuing warnings (short-term, high-confidence predictions) of imminent geomagnetic activity a few minutes to a few hours in advance. Forecasts are made daily for each of the next three days for the probability of energetic flares, proton events, and geomagnetic storms, the expected value of the solar flux at a wavelength of 10.7 cm and two geomagnetic indices.
transition of new models and data into operations. In addition, SEC works with value-added vendors who use their data and products to develop commercial space weather products.

**Keywords** Forecasts, space weather services, space environment, energetic particle events, event probabilities, geomagnetic storms, verification, space environment, geomagnetic activity probabilities, solar X-ray events.

1. **INTRODUCTION TO SPACE WEATHER SERVICES**

The need for space environment services became apparent during World War II, when battlefield communications using high frequencies (HF) were compromised by a natural phenomenon that was determined to be short wave fading caused by the effects of solar x-ray emission on the dayside ionosphere. Since then space weather services have developed and have steadily grown for both military and civilian systems in concert with increasing reliance on satellites and other technological systems. Because space weather is inherently global, there has always been a need for international cooperation to acquire the necessary data and expertise needed to keep pace with technical advances. This tutorial summarizes the present services offered by the Space Environment Center (SEC), which is a United States government agency within the Department of Commerce under the auspices of the National Oceanic and Atmospheric Administration (NOAA). SEC is the official U.S. source of space weather alerts, warnings, and forecasts. These SEC services are concentrated within a division named Space Weather Operations (SWO), a joint operation of NOAA and the 55th Space Weather Squadron of the US Air Force. The Space Environment Center began this daily service in 1965 by building on the foundation originally provided by the Central Radio Propagation Laboratory under the National Bureau of Standards. As the need for space weather products and alerts grew, the service became 24/7 (around the clock, every day) in 1978. In 1998 the former Space Environment Services Center (SESC) became Space Weather Operations (SWO) and in 1999 the Center moved into a new building with new state-of-the-art data display and communication facilities.

The origin of the international component of space weather services can be traced to the International Commission on Scientific Radiotelegraphy, active in 1913-14. This commission evolved into the International Union of Radio Science (URSI) by 1919. By the 1930's, "URSIgrams" were in use as a means of rapid data exchange. General studies of the relationships between solar and geophysical phenomena were undertaken in conjunction with the