Forecasting Space Weather

Space Weather Impacts Our Nation and the World

From here on Earth, the Sun seems like an evenly-shining orb, slowly rising and setting in a steady cadence. But closer looks at the Sun show an active, turbulent surface emitting electromagnetic radiation and spewing streams of gas and particles, two types of space weather, into the Solar System.

Charged with electricity, these streaming particles, called the solar wind, can cause geomagnetic storms in Earth's atmosphere and magnetosphere—damaging the electrical grids that power our communities, interrupting radio and satellite communications, and causing our GPS navigation to fail. Predicting when and how much space weather could hit the Earth's atmosphere is important to protecting people and property. To improve the accuracy and reliability of space weather predictions, NOAA's Space Weather Observations (SWO) Office which falls under the National Environmental Satellite, Data, and Information Service (NESDIS), is set up to observe, track and understand space weather and the Sun's changing environment.

It is important to understand and monitor space weather because it threatens our economy, national security, and individual safety. Perhaps no part of U.S. infrastructure is more vulnerable to space weather than our nation's electrical generation and transmission system. The energy imparted from space weather events can ultimately generate unexpected currents in electric power transmission lines, risking the stability of those electrical grids. Protecting those grids by knowing when space weather is likely is critical. Accurate predictions of space weather can reduce or eliminate operational and service interruptions costs. Some studies estimate that extreme space weather-induced electricity blackouts could cost the U.S. more than $40 billion every day.

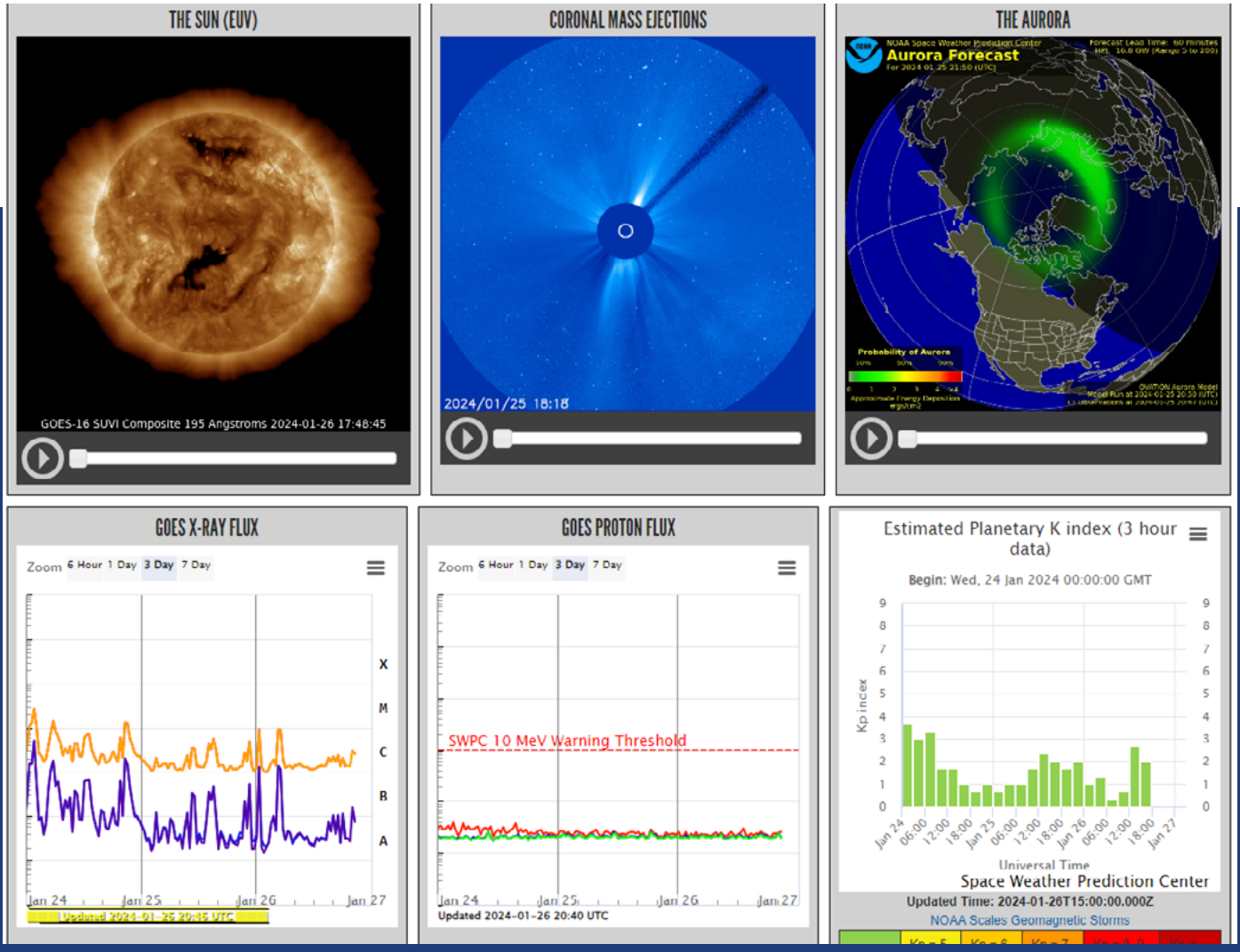
NOAA's space weather services, data management, and observations provide other societal and economic benefits across sectors including civil aviation, agriculture, satellite industry, communications, and navigation.

Space weather impacts aviation, auroras, electric power, emergency management, Global Positioning System (GPS), radio communications, satellites, and human space exploration.

To produce space weather forecasts similar to the weather forecasts predicting rain or snow here on Earth, NOAA uses real-time observations of the solar wind, space weather, and the Sun's surface. To collect these observations, NESDIS operates the Office of Space Weather Observations (SWO), which develops, deploys, and manages space weather satellite systems. NESDIS and SWO augment those observations with data from other federal science agencies, private sector companies, and our international partners.

The best way to measure space weather is from the vantage point of space. NOAA observes the Sun and space weather in the ultraviolet and x-ray spectrums from satellites carrying high-performance instruments.

Other NOAA instruments measure the solar wind, which interacts with Earth's magnetic field and can pose a danger to our near-Earth environment. Additionally, NESDIS gathers space weather data in the near-Earth environment that impacts technologies such as communications systems and GPS, and perturbs satellite orbits.



NOAA collects and provides space weather data to support agency decisions, forecasts, watches, warnings and alerts.

The data collected from platforms in various orbits is sent down to our antennas on Earth as soon as it is collected.The real-time data drive around-the-clock analysis and forecasting of space weather conditions that are then provided to the public and other government agencies by NOAA's Space Weather Prediction Center (SWPC). SWPC is the nation's official source of space weather data and information to support civil agency decisions, forecasts, watches, warnings, and alerts.

Once space weather data has been used in an alert or prediction, it is archived by NOAA's National Centers for Environmental Information (NCEI) to ensure data quality and continued access for ongoing scientific research.

How important are NOAA's space weather forecasts? Knowing of an incoming solar storm helps commercial

The Aurora Borealis is a visible manifestation of space weather. Chena Springs, Alaska.

airlines direct their pilots to avoid areas where solar wind could disrupt High Frequency (HF) communications, cause satellite navigation system errors, and risk radiation hazards to passengers and aircraft.

Solar weather also threatens the GPS used in our cell phones, the vehicles we drive, and any useful item that needs precision location measurements. Solar activity can change radio signal paths and create errors in GPS positioning information—essential to industries such as farming, construction, commercial shipping, and navigation.

When disasters such as hurricanes strike, communication is crucial. On September 6, 2017, as Puerto Rico braced for impact from Hurricane Irma, activity on the sun triggered a major coronal mass ejection--the largest solar flare detected by satellites in about a decade. A subsequent radio blackout disrupted high-frequency ground communication and aviation systems when emergency needs were critical. The outage caused a near-total communication blackout for most of that morning and early afternoon. French Civil Aviation Authority officials reported losing contact with an aircraft in the region for 90 minutes during the blackout. In situations like this, data and alerts from SWO and SWPC provide emergency response teams with information on potential space weather impacts. This gives the teams time to protect their communications equipment, to switch to alternate communications channels in order to stay in touch with each other, and to send emergency broadcasts to the public in order to save lives and protect property.

Accurate space weather data is also critical to military operations. This data can help the military determine if impacts they're experiencing are from the environment or an adversary and whether they need to leverage alternate methods of communication during the operation. SWO and SWPC are working closely with the Department of the Air Force on space weather forecast capability development to ensure that the national security sector has the data and models it needs to effectively execute its operations.

> ***"Space weather is a serious threat to the Nation, and we need to continue to advance and improve our capabilities. Our attention to space weather research, observations, and services must evolve if we are to address, at the level we need to, the support necessary to protect critical national functions and security from space weather storms."***
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> *—NOAA Administrator, Dr. Rick Spinrad*

Looking to the Future

As space commerce rapidly grows, with higher numbers of more sophisticated satellites going into orbit, so does the need for new observations and data to continually improve space weather forecasts. In 2022, 38 SpaceX Starlink satellites burned up after launch as a result of a period of prolonged, yet minor geomagnetic storm conditions. Smaller storms once unnoticed are now causing problems as we become more reliant on advanced technology and increase our activities in space, where that technology is more vulnerable to space weather.

Engineers integrate the nation's first coronagraph on the NOAA GOES-U satellite. Image Credit: Lockheed Martin

The 2024 launch of NOAA's GOES-U satellite will carry a NESDIS-developed coronagraph capable of taking images of the Sun's outer atmosphere, called the solar corona. This will help detect and characterize coronal mass ejections (CMEs) that expel plasma and accompanying magnetic field. These CMEs are potentially the most dangerous and impactful space weather events. This will be the nation's first operational coronagraph and will deliver CME imagery within 30 minutes of acquisition, an unprecedented level of monitoring that greatly exceeds the current data rate (often once in eight hours) from an aging ESA-NASA research satellite.

The SWFO team in front of the Consolidated Backup (CBU) Antenna after conducting Antenna Site Acceptance Testing (SAT). Image Credit: NASA

To ensure continuity of critical space weather data, in 2025 SWO's Space Weather Follow On (SWFO) program plans to launch a dedicated satellite to the Lagrange Point 1 position, also called L1, which is one million miles upstream of Earth. This will afford NOAA an uninterrupted view of the Sun and will provide early detection of dangerous conditions in the solar wind before it reaches Earth. To meet growing demand from users for additional space weather data and services to safeguard our nation, SWO's Space Weather Next program is developing instruments and spacecraft to collect observations from different vantage points near Earth and the Sun, in addition to expanding capabilities to new orbits using new and improved instruments. Space Weather Next's first project will be to plan for the continuity of measurements at L1. This space weather satellite constellation will be called Space weather Observations at L1 or SOL for short. It signifies a milestone for continuity and resiliency of real-time solar imagery and solar wind measurements.

> ***"NOAA is the space weather agency, just like NOAA is the ocean agency and the weather agency. NOAA embraces its mission 'from the surface of the Sun to the unknown impacts from the Sun that affect humans and our activities, the economy, and National Security.'"***
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> *—Elsayed Talaat, NOAA Space Weather Observations Director*

SWO Director, Dr. Elsayed Talaat, views the annular solar eclipse during a NOAA-NASA-NSF joint event for the public in Albuquerque, New Mexico on October 4, 2023.