

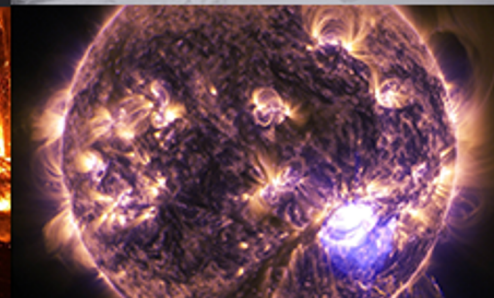
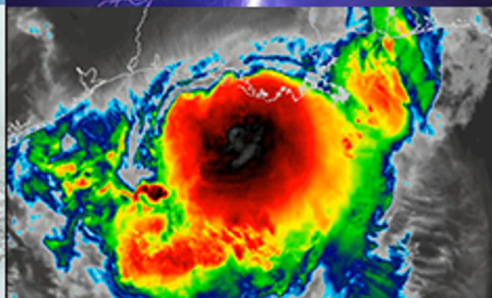
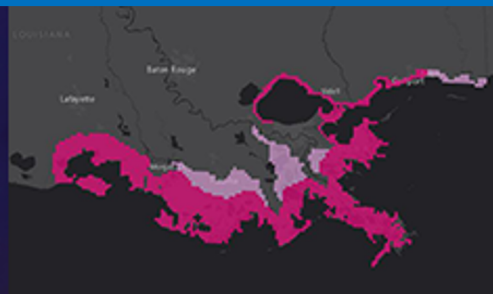
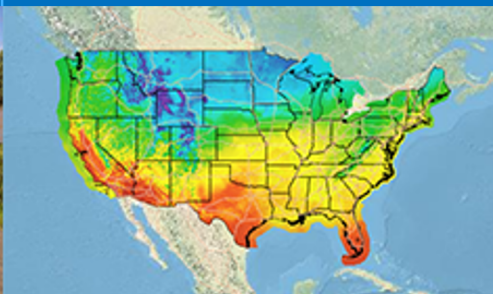


**NATIONAL
WEATHER
SERVICE**

Space Weather Products and Services for Solar Radiation

NOAA Space Weather Prediction Center

- Hazel Bain
- Rob Steenburgh
- Terry Onsager
- Bill Murtagh





NOAA Space Weather Prediction Center

The Nation's official source of space weather alerts, watches and warnings (exclusive of the responsibilities of DOD)

NOAA Space Weather Watches and Warnings are based on the NOAA Space Weather Scales:

- Geomagnetic Storms (**G-scale**)
(Magnetic field)
- Solar Radiation Storms (**S-scale**)
(Energetic charged particles)
- Radio Blackouts (**R-scale**)
(Electromagnetic radiation)



Solar Radiation Storm Scale (S-scale)

Scale	Description	Effect	Physical measure (Flux level of ≥ 10 MeV particles)
S 5	Extreme	<p>Biological: Unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.</p> <p>Satellite operations: Satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible.</p> <p>Other systems: Complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.</p>	10^5
S 4	Severe	<p>Biological: Unavoidable radiation hazard to astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.</p> <p>Satellite operations: May experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded.</p> <p>Other systems: Blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.</p>	10^4
S 3	Strong	<p>Biological: Radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.</p> <p>Satellite operations: Single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely.</p> <p>Other systems: Degraded HF radio propagation through the polar regions and navigation position errors likely.</p>	10^3
S 2	Moderate	<p>Biological: Passengers and crew in high-flying aircraft at high latitudes may be exposed to elevated radiation risk.</p> <p>Satellite operations: Infrequent single-event upsets possible.</p> <p>Other systems: Small effects on HF propagation through the polar regions and navigation at polar cap locations possibly affected.</p>	10^2
S 1	Minor	<p>Biological: None.</p> <p>Satellite operations: None.</p> <p>Other systems: Minor impacts on HF radio in the polar regions.</p>	10

S-scale is based on the GOES ≥ 10 MeV integral proton flux

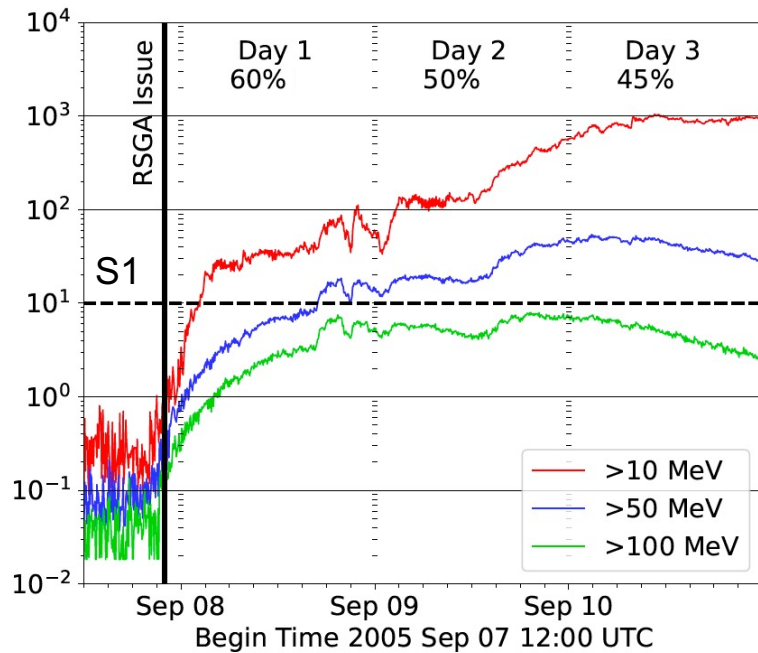
Relates the intensity of an event to the impacts on:

- Satellite systems
- HF communications
- Navigation systems
- Biological impacts to astronauts and to crew and passengers on aircraft

SWPC solar radiation storm products are used by different industries:

- All major satellite companies worldwide, for safe launch and in-orbit operations
- All airlines, especially those flying Polar (includes United, American, Delta, FedEx and UPS) to avoid radiation exposure at high latitudes, and impacts to communications and sensitive electronics

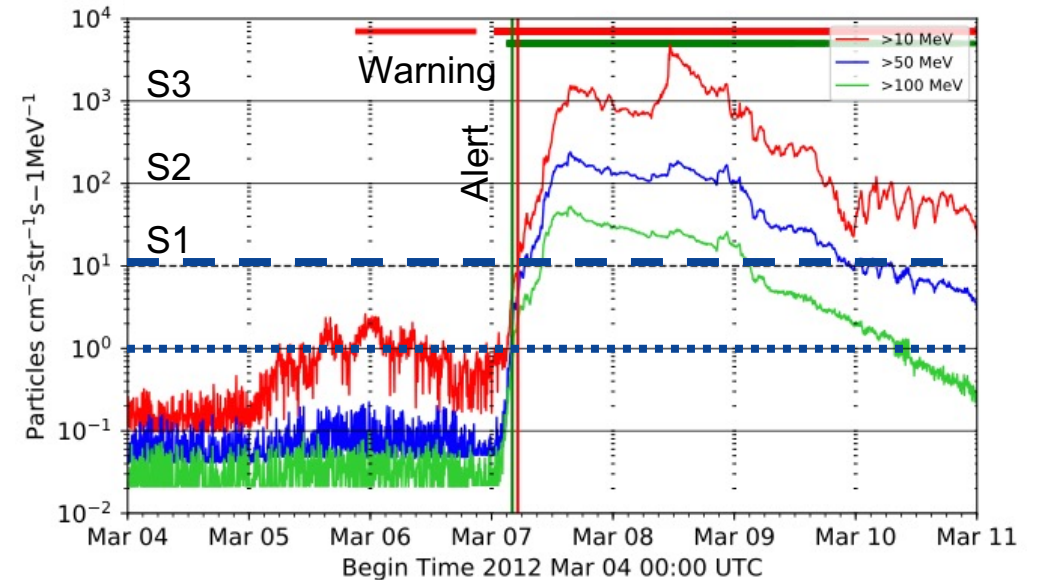
3-day Probabilistic Forecasts (days)



Probability of proton event in next 1, 2 & 3 days

S1 storm: ≥ 10 MeV protons exceeding 10 p.f.u.

Short Term Warning and Alerts (mins-hours)

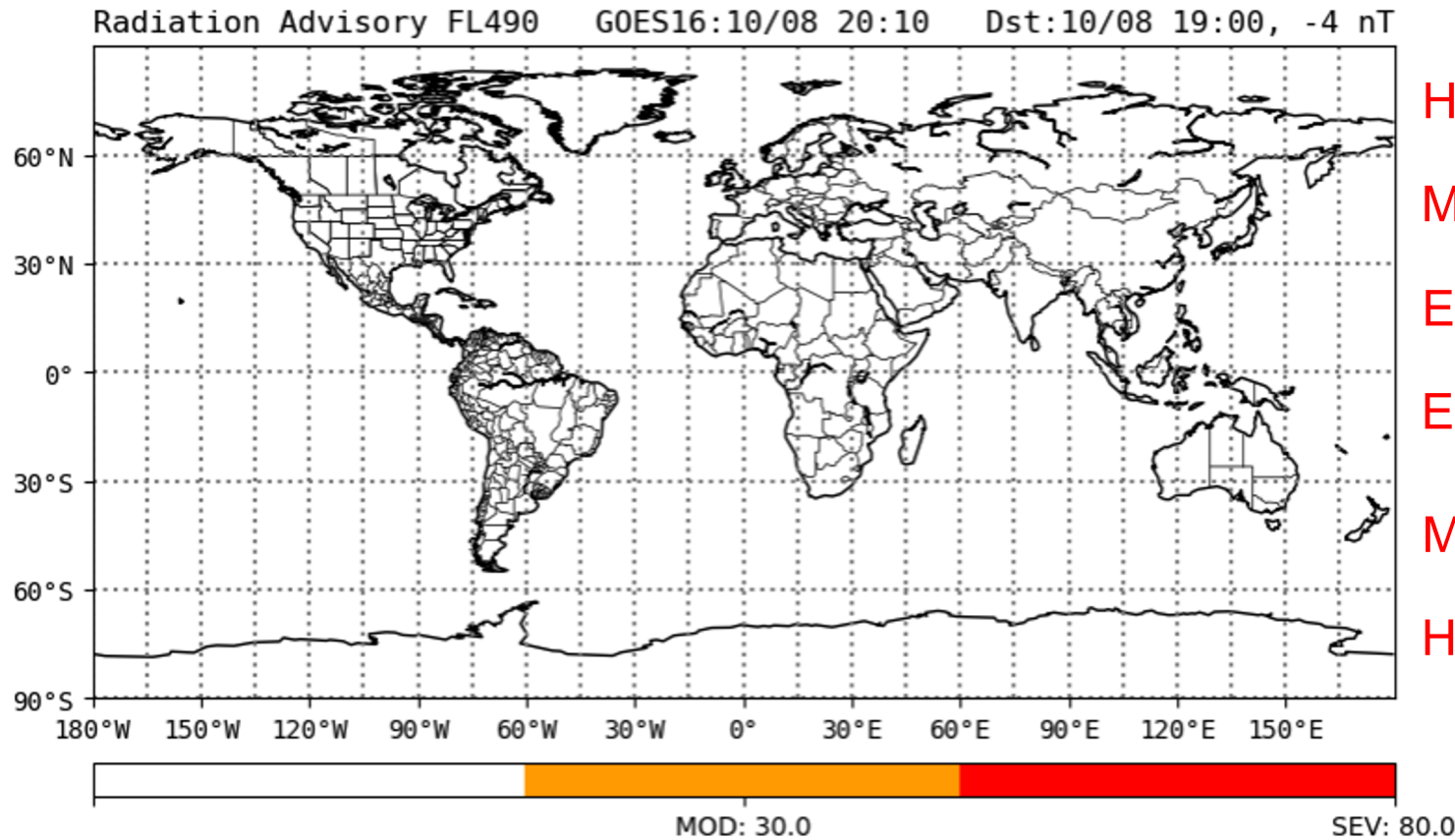


Warning and Alert ≥ 10 MeV at 10 p.f.u.

Warning and Alert for ≥ 100 MeV at 1 p.f.u.

International Civil Aviation Organization Radiation Advisories

ICAO advisory 30° x 15° grid



HNH

MNH

ENH

ESH

MSH

HSH

36 Flight Levels between 25,000 ft and 60,000 ft in 1,000 ft increments.

Thresholds:
MOD = 30 μ Sv/hr
SEV = 80 μ Sv/hr

MOD advisories only issued when the MOD threshold is reached at 46,000 ft (FL460) and below.

NOAA SWPC radiation advisories are be guided by the FAA CARI-7 dose rate model (Copeland 2017)

Human Space Exploration Forecast Requirements

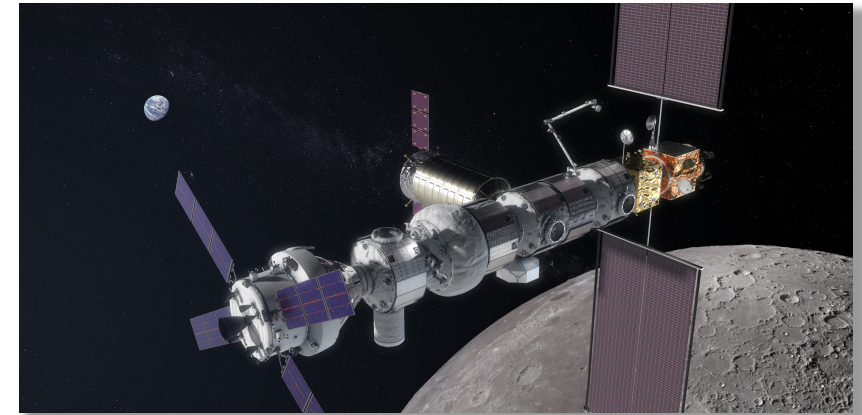


Astronauts in LEO are largely protected from SEPs by the Earth's magnetic field.

Moving beyond LEO to the Moon and Mars, astronauts are exposed to all aspects of the storm.

Enhanced forecasting will require:

- All-Clear forecasting
- Improved pre-event probabilistic forecasts
- Forecast of peak intensity
- Duration and evolution of the storm intensity





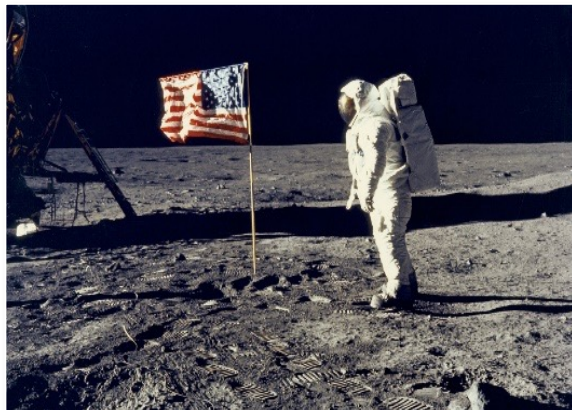
NOAA SWPC support for NASA Crewed Missions



SWPC Forecasters provide 24/7 support to SRAG.

From the Gemini and Apollo missions to the International Space Station (ISS).

- Daily briefings to SRAG.
- Communications ramp up considerably during active conditions and special activities such as launches and EVAs.
- SWPC issued 140 Alerts, Watches and Warnings to NASA JSC during the Halloween 2003 events.



NOAA SWPC support for NASA Crewed Missions

NOAA and NASA nearing completion of an Interagency Agreement on ***Space Radiation Environment Support to NASA for the Conduct of all Human Spaceflight.***

- SWPC will provide services including observations, briefings, 24-hour forecasts, and Warnings and Alerts for major solar flares, proton events, and geomagnetic storms in support of ISS, Artemis Lunar Missions and Lunar Surface Operations, and future Mars missions.

