Main Points

- Drivers of Space Weather
- Growing Space Weather Product Demand
- NOAA Observations and Research
- International Partnerships

National and international partnerships are essential for resilience to space weather
Solar Energetic Particles

- Electric power grid
- Human radiation exposure
- Communication outages
- Navigation degradation
- Satellite damage
Major Forecast Center Products

Daily Forecasts (1-3 day):
- Solar flares
- Solar energetic particles
- Geomagnetic activity
- 10.7 cm radio flux

Event-Driven Warnings and Alerts:
- Warnings: geomagnetic storms, proton events
- Alerts: solar flare, proton event, geomagnetic storm, electron event, solar radio burst

Numerical Models:
- WSA-Enlil – background solar wind and CMEs
- Relativistic Electron Forecast Model
- D-Region Absorption Product
- U.S. Total Electron Content
- Ovation Aurora Model
Customer Growth
NOAA Space Weather Prediction Center – Product Subscription Service

Customers Include:
- Electric power industry
- All major airlines
- Drilling and oil exploration
- Satellite companies
- Transportation sector
- Emergency responders

Subscription service began
Sweden:
- Power outage
- Transformer heating in nuclear plant

South Africa:
- 14 transformers damaged
- $60 million impact
- Basic commerce and security impaired

United States:
- Power reduced to mitigate impact on generation facilities
Alert Issued for Airline Radiation

**ALERT:** Solar Radiation Alert at Flight Altitudes Conditions Began: 2003 Oct 28 2113 UTC

**Comment:** Satellite measurements indicate unusually high levels of ionizing radiation, coming from the sun. This may lead to excessive radiation doses to air travelers at Corrected Geomagnetic Latitudes above 35 degrees north, or south.

*(Federal Aviation Administration)*

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**Research Article**

Economic impact and effectiveness of radiation protection measures in aviation during a ground level enhancement

Daniel Matthiä¹, Martin Schaefer², and Matthias M. Meier¹

- Radiation dose reduced by 42% with 5% fuel increase and 30 min flight delay
- Prompt changes in altitude and velocity not compliant with Air Traffic Mgmt System
Overarching Goal: Strengthen Resilience Through Improved Services

Four elements needed to improve space weather capabilities:

1. User Needs: Understand the risks and the actions that need to be taken
2. Targeted Services: Develop useable capabilities from basic science knowledge
3. Observing Infrastructure: Shared approach for long-term continuity
4. Global Coordination: Consistent, accurate message
• Launched: February 11, 2015
• To replace operational use of NASA ACE spacecraft
• Space weather measurements:
  - Solar wind density, velocity, temperature
  - Solar wind magnetic field
• High-reliability warnings of geomagnetic storms
• Requires international real-time data network
• Follow-on mission in planning
Geostationary Operational Environmental Satellite Series
GOES-R

- Launched planned: October, 2016
- Space weather measurements:
  - Solar EUV
  - Solar X-rays
  - Energetic particles
  - Magnetic field
• *Taiwan-U.S.* 12-satellite constellation
• 6 low- and 6 high-inclination satellites
• First launch (6 low-inclination) planned for 2017
• GNSS Radio-Occultation
  - Ionospheric electron density profiles
  - Ionospheric scintillation
• Ionospheric ion velocity
• NOAA is working with international partners to host/operate data-receiving ground stations
Components of NOAA’s Numerical Space Weather Modeling Effort

Solar /Solar Wind

Magnetosphere/ Ionosphere

Atmosphere/ Ionosphere

L1 Satellite Location – ACE and now DSCOVR
International Organizations Involved in Space Weather Services

International Space Environment Service – Global network of space weather service providers since 1962

World Meteorological Organization – Leverage global infrastructure and membership, build capacity and increase service providers

UN Committee on Peaceful Uses of Outer Space – Promote high-level awareness of space weather

Coordination Group for Meteorological Satellites – Satellite observations, user needs, and anomaly reporting

International Civil Aviation Organization – Defining civil aviation requirements and space weather service needs
Summary

• Demand is increasing for space weather services – electric power, aviation, satellites, navigation, communication

• NOAA’s role is to provide forecasts, warning, and alerts to protect critical infrastructure, society, and economic vitality

• User needs, targeted services, observations, and service coordination are essential elements

• NOAA provides key space-based observations and works with NASA and other partners to utilized space-based and global ground-based data

• Improvements to numerical models and services rely on cooperation with national (NASA, NSF, DoD, industry) and international research efforts

• National and international partnerships are essential for improving resilience to space weather