

NOAA's Space Weather Prediction Center Update

Howard J. Singer

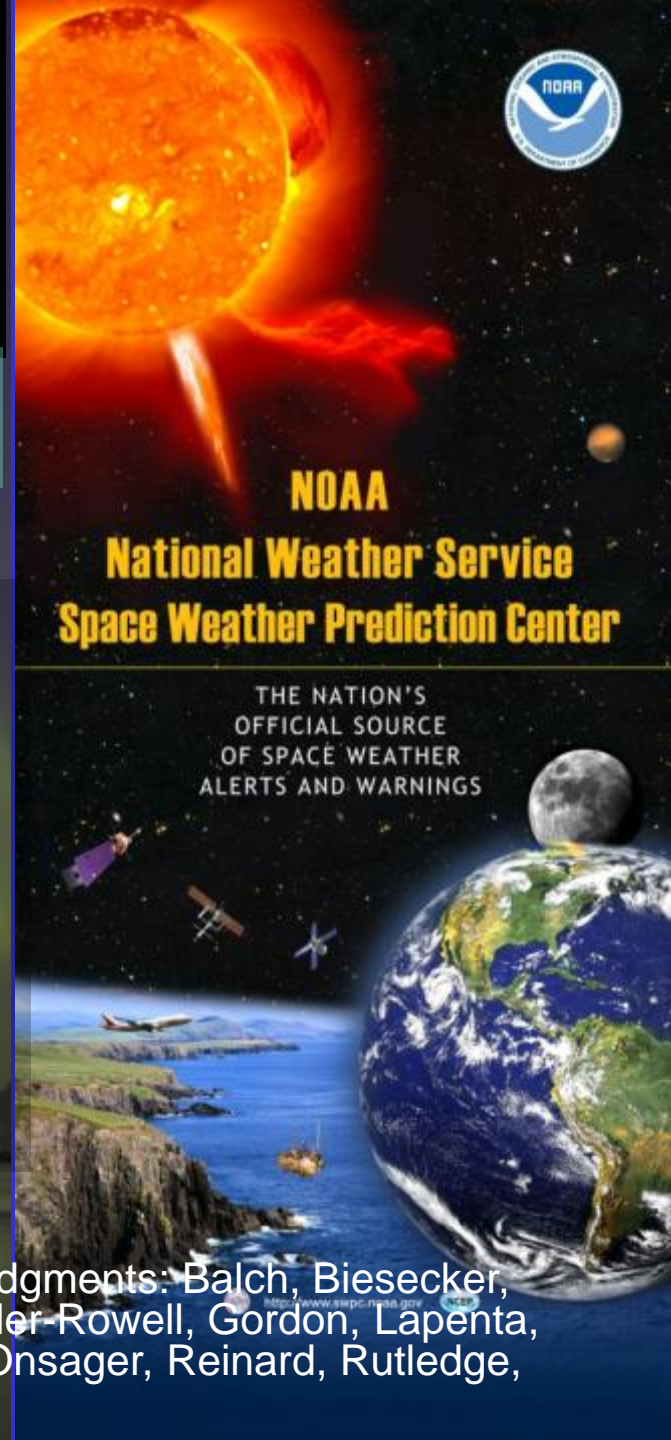
NOAA Space Weather Prediction Center

Outline:

- SWPC and Solar Cycle
- Advances in Forecasting
 - Observations and Models
- International Partnerships
- Research to Operations and Operations to Research
- Conclusions

COMMITTEE ON SOLAR AND SPACE PHYSICS
March 28-30, 2017

Acknowledgments: Balch, Biesecker,
Denig, Fuller-Rowell, Gordon, Lapenta,
Murtagh, Onsager, Reinard, Rutledge,
Vioreck



Established 1946 as part of Central Radio Propagation Laboratory

A photograph of a control room or observatory. In the foreground, a person is seated at a desk with multiple computer monitors. The background wall is covered with large projection screens displaying various astronomical data, including green and red circular images, spectra, and a large blue image. The room is dimly lit, with the primary light source being the screens.

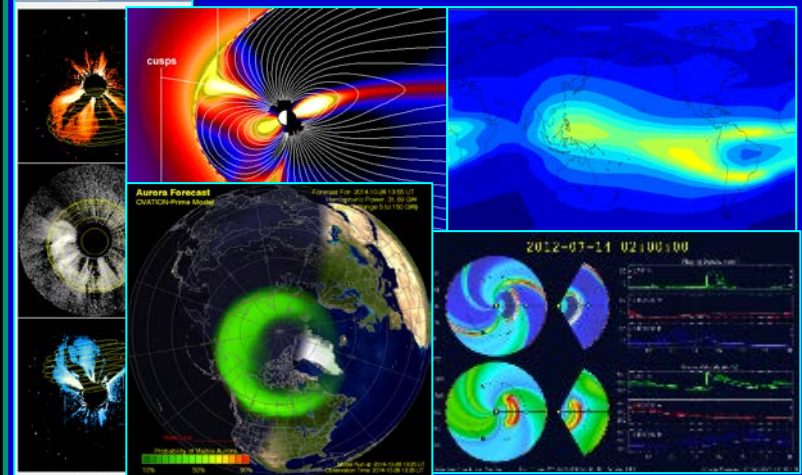
- Specifications;** Current conditions
- Forecast;** Conditions tomorrow
- Watches;** Conditions are favorable for storm
- Warnings;** Storm is imminent with high probability
- Alerts;** observed conditions meeting or exceeding storm thresholds

R20

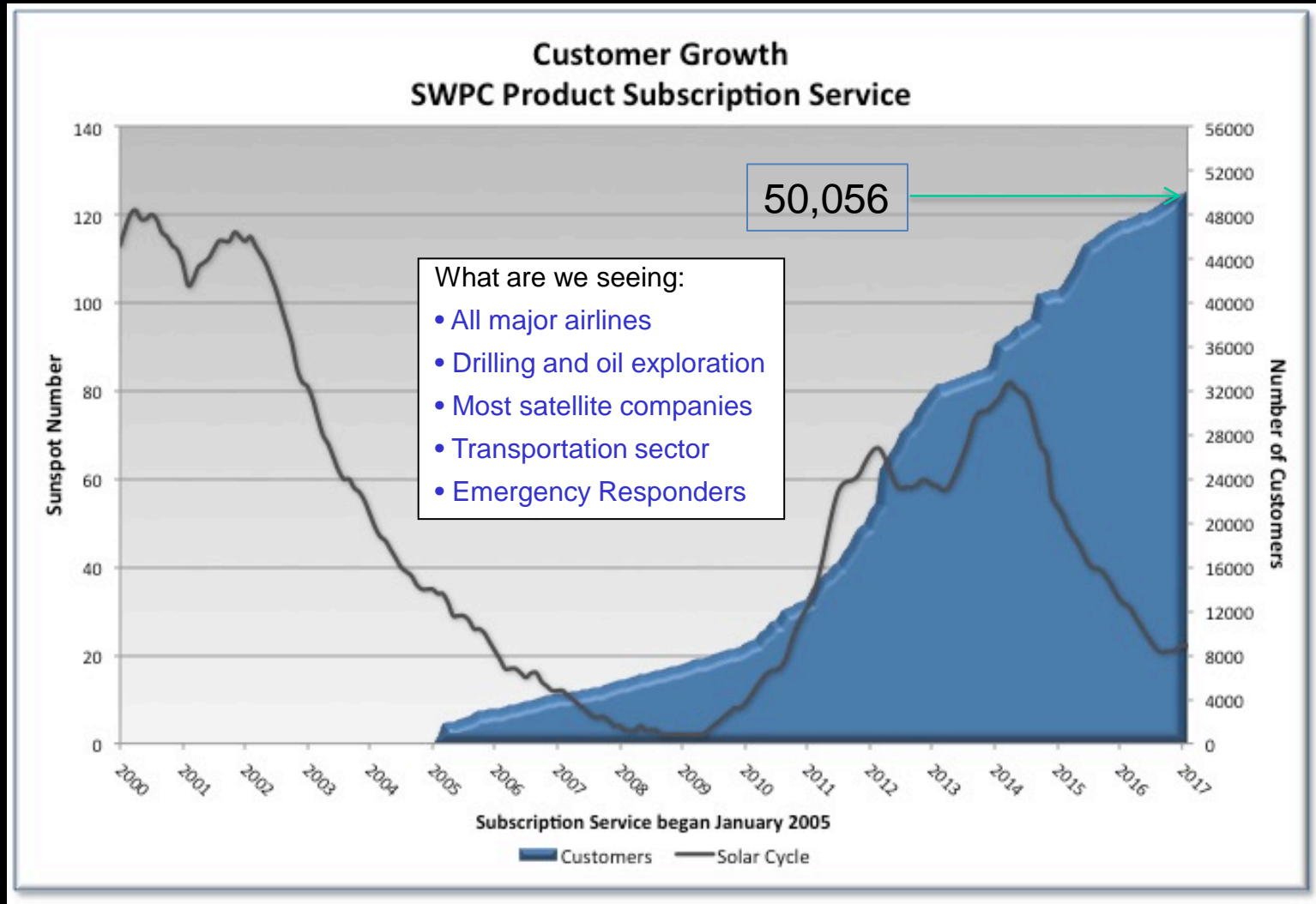
- Applied Research
- Model Development
- Model Test/Evaluation
- Model Transition
- Operations Support

- Customer Requirements
- Observation Requirements
- Research Requirements

O2R



Customer Subscriptions Skyrocket... (through February 2017)



Small solar cycle, but the largest geomagnetic storms on record occurred during smaller than average cycles (e.g. 1859, 1921)

GOES-R Launch November 19, 2016

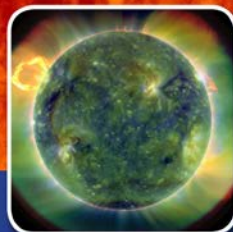


GOES-R Series Space Weather Instruments

Solar imaging.

Space weather monitoring.

Geomagnetic storm warnings.



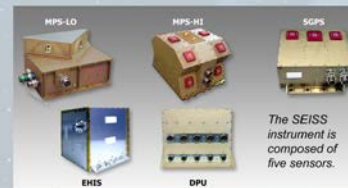
What is space weather?

The changing environmental conditions from the sun's atmosphere are known as space weather. Space weather is caused by electromagnetic radiation and charged particles being released from solar storms. Changes in the magnetic field and a continuous flow of solar particles during a powerful storm headed to Earth can cause disruption to communications, navigation, and power grids as well as result in spacecraft damage and exposure to dangerous radiation.

How will GOES-R monitor space weather?

The GOES-R series of satellites will host a suite of instruments that provide significantly improved detection of approaching space weather hazards. Two sun-pointing instruments will measure solar ultraviolet light and x-rays. The Solar Ultraviolet Imager (SUVI) will observe and characterize complex active regions of the sun, solar flares, and the eruptions of solar filaments which may give rise to coronal mass ejections. The Extreme Ultraviolet and X-ray Irradiance Sensors (EXIS) will detect solar flares and monitor solar irradiance that impacts the upper atmosphere.

The satellites will also carry two instruments that measure in-situ. The Space Environment In-Situ Suite (SEISS) will monitor proton, electron and heavy ion fluxes in the magnetosphere. The Magnetometer (MAG) will measure the magnetic field in the outer portion of the magnetosphere.



The SEISS instrument is composed of five sensors.

WWW.NESDIS.NOAA.GOV | WWW.GOES-R.GOV | TWITTER: NOAA.SATELLITES | FACEBOOK: GOES-R

What benefits will the GOES-R space weather mission provide?

Solar eruptions can cause geomagnetic and solar radiation storms, which can disrupt power utilities, communication and navigation systems, damage satellite electrical systems, and may cause radiation damage to orbiting satellites, high-latitude aircraft, and the International Space Station. The GOES-R

series SUVI and EXIS instruments will provide improved imaging of the sun and detection of solar eruptions, while SEISS and MAG will provide more accurate monitoring, respectively, of energetic particles and the magnetic field variations that are associated with space weather. Together, observations from these instruments will enable NOAA's Space Weather Prediction Center to significantly improve space weather forecasts and provide early warning of possible impacts to Earth's space environment and potentially disruptive events on the ground.



Astronauts working outside the International Space Station are especially vulnerable to radiation from solar storms.

- ✓ Improved detection of coronal holes, solar flares and coronal mass ejection source regions
- ✓ More accurate monitoring of energetic particles responsible for radiation hazards
- ✓ Improved power blackout forecasts
- ✓ Increased warning of communications and navigation disruptions

Learn more:

<http://www.goes-r.gov/>
<http://www.goes-r.gov/spacesegment/exis.html>
<http://www.goes-r.gov/spacesegment/suvi.html>
<http://www.goes-r.gov/spacesegment/seiss.html>
<http://www.goes-r.gov/spacesegment/mag.html>
<http://www.swpc.noaa.gov/>



GOES-13, -14, -15 and new GOES-16

- **Currently, GOES-13 and -15 operational; GOES-14 on-orbit storage**
- **GOES-16 undergoing post-launch testing; first of four satellites in the GOES-R series that extends into 2030's**
- **In addition to continuing magnetometer, integrated X-ray and EUV, and an extensive range of energetic particles observations, GOES-16 includes new capabilities:**
 - **Ions and electrons down to 30 eV**
 - **Heavy ions 10-200 MeV/nucleon**
 - **Improved energetic particle energy resolution**
 - **shifts current x-ray imagery to the ultraviolet for improved solar feature characterization with wavelength bands comparable to SDO/AIA**
 - **Faster sampling rate for magnetometer (10 Hz).**

After DSCOVR: Space Weather Follow On

Highlights of the planned mission are:

- Total 10-year operational mission
- Two identical spacecraft for long-term continuity
 - Launches planned for 2022 and 2027
- Addition of a coronagraph – Compact Coronagraph (CCOR)
- Addition of a suprathermal ion sensor (e.g. ACE/EPAM)
10 keV - 2 MeV
- Improved plasma measurements for meeting more stringent user requirements – high plasma velocity ($V=2500$ km/s)

European Space Agency at December 2016 Ministerial approved and provided funding for starting L5 mission (For launch in 2023)

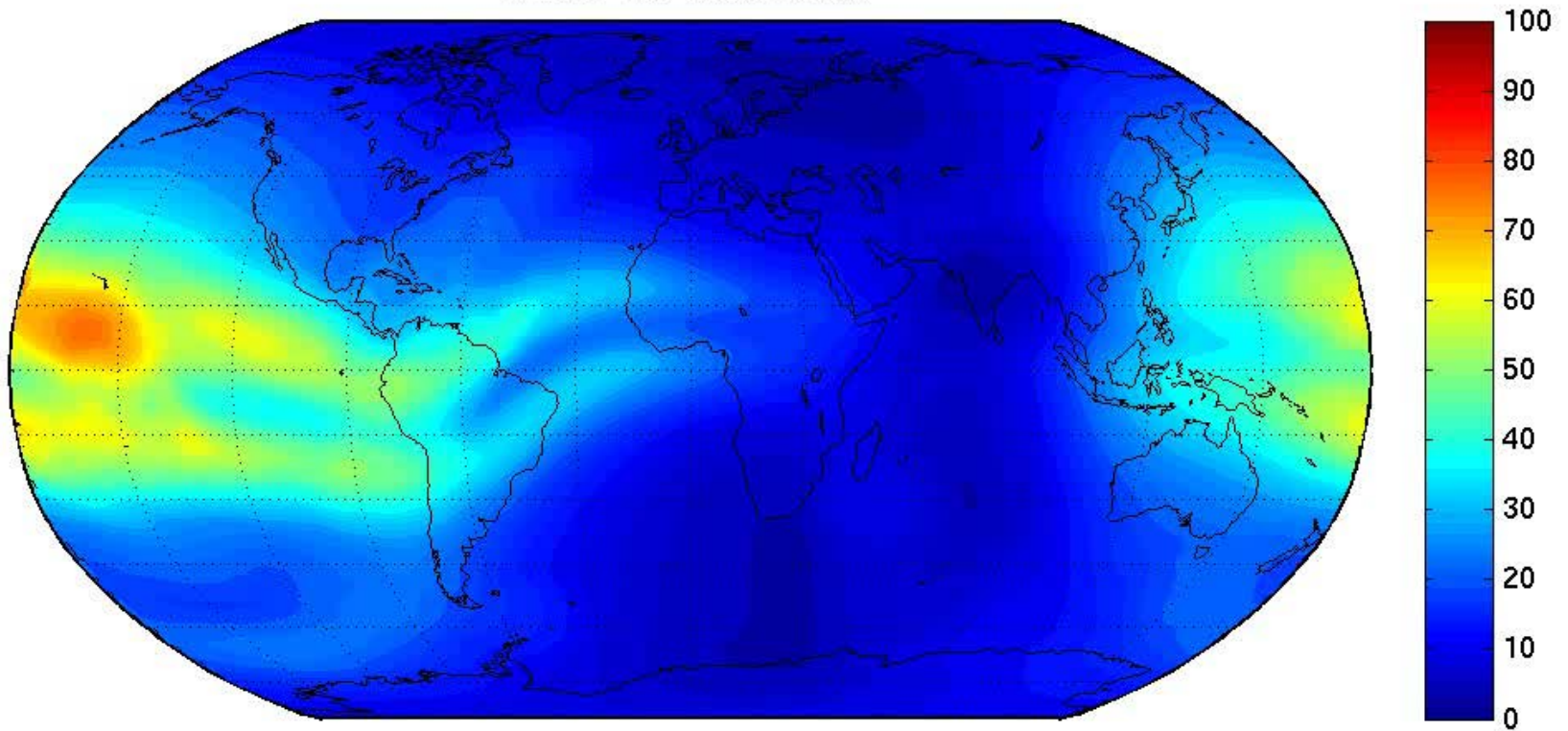
- Two studies for Phase A/B1
- Down select to one to complete Phase B
- Final go ahead at 2019 Ministerial
- L5 will be an operational mission
- Payload priorities still TBD, but Coronagraph, Heliospheric Imager, and Magnetograph at the top of everyone's list

Using COSMIC II Data Global TEC (GloTEC) Specification Model

- **Input Data**
 - **Space-based GPS radio occultation data ionospheric electron density profiles**
 - **Ground based GPS line-of-site TEC**
- **Kalman Filter**
- **2.5 deg lat x 5 deg lon by 10 km alt**
- **Background provided by IRI**
- **Developed by Xinan Yue (NCAR now Chinese Academy of Sciences)**

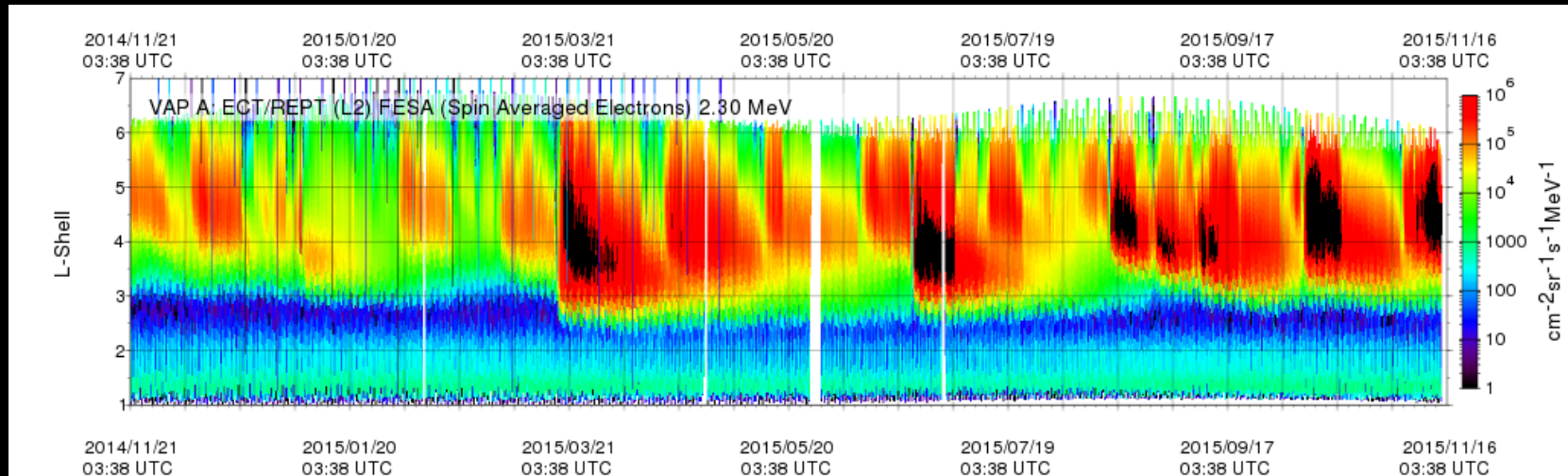
Global TEC (GloTEC)

Assimilation 2013 072 00:0
Min: 2.7113 Max: 77.1236



Radiation Belt Products: New and Future

New SWPC Experimental Product: Radial profile of Radiation Belts – in collaboration with Johns Hopkins University, NASA and Van Allen Probe Scientists



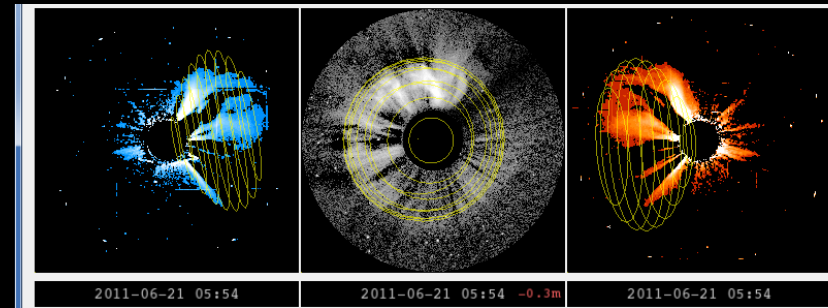
Radial Profile of Radiation Belts with Assimilative Model - in collaboration with Los Alamos and Korean Space Weather Center



Solar-Heliosphere

Upgrades to the WSA-Enlil Model

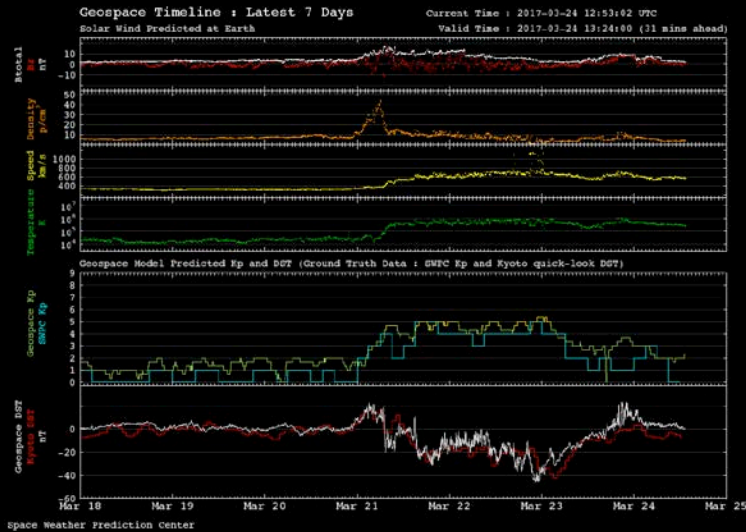
- Improve the accuracy of Geomagnetic Storm Forecasts
- Current Activity
 - Upgrade CME Analysis Tool
 - Evaluate methods for computing CME mass for individual events
 - Improve CME parameterization
 - Additional forecaster training
 - Upgrade Enlil Model
 - Upgrade WSA
 - ADAPT: Improved background solar wind with continuous updates
 - Explore ensemble modeling for improved forecast accuracy
 - At SWPC and working with international partners running WSA-Enlil operationally
 - Working with CCMC to validate the performance of the WSA – Enlil Adapt upgrade



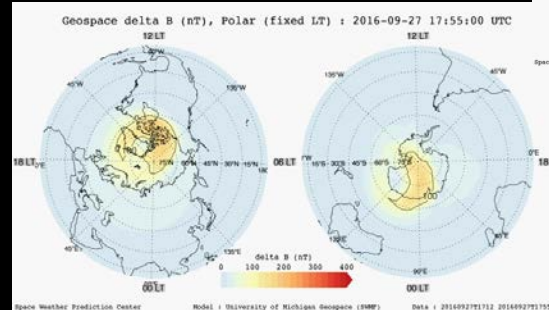
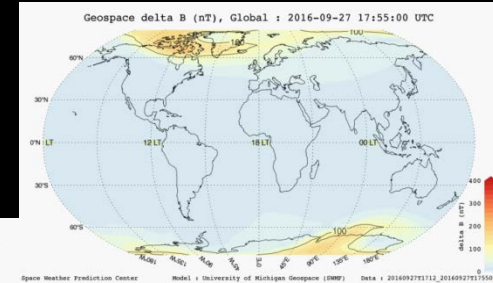
Initial Geospace Products

<http://www.swpc.noaa.gov/experimental>

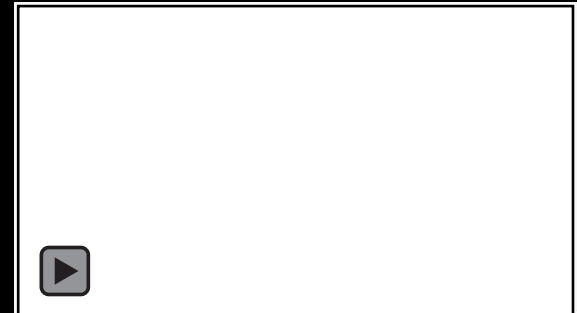
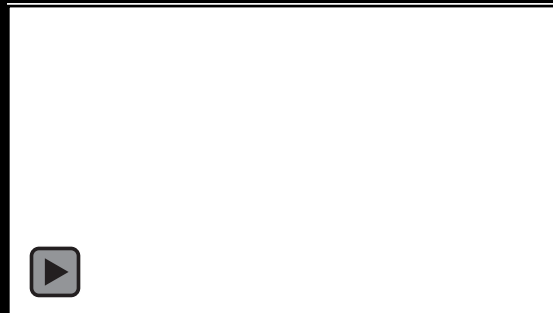
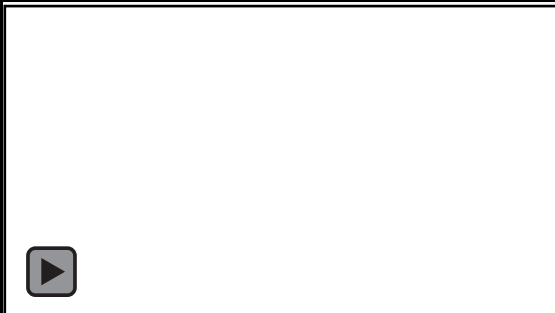
Geomagnetic Activity Plot



Ground Magnetic Perturbation Maps



Magnetosphere Views

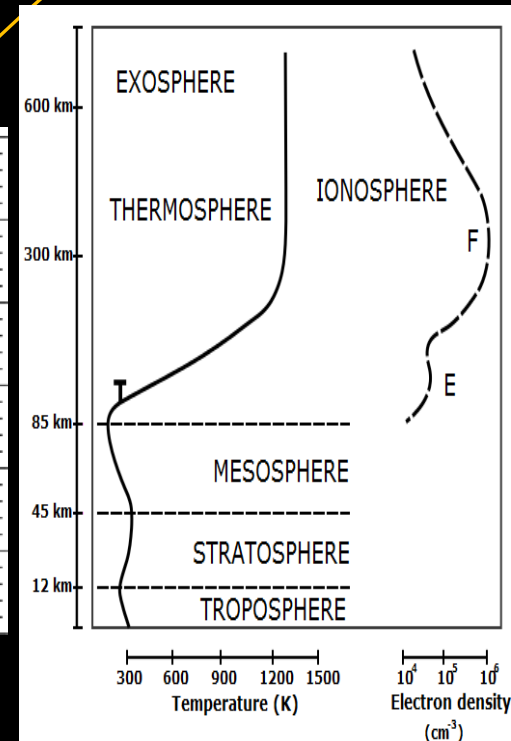
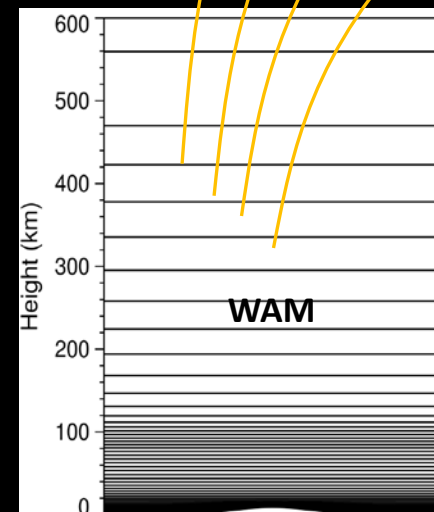
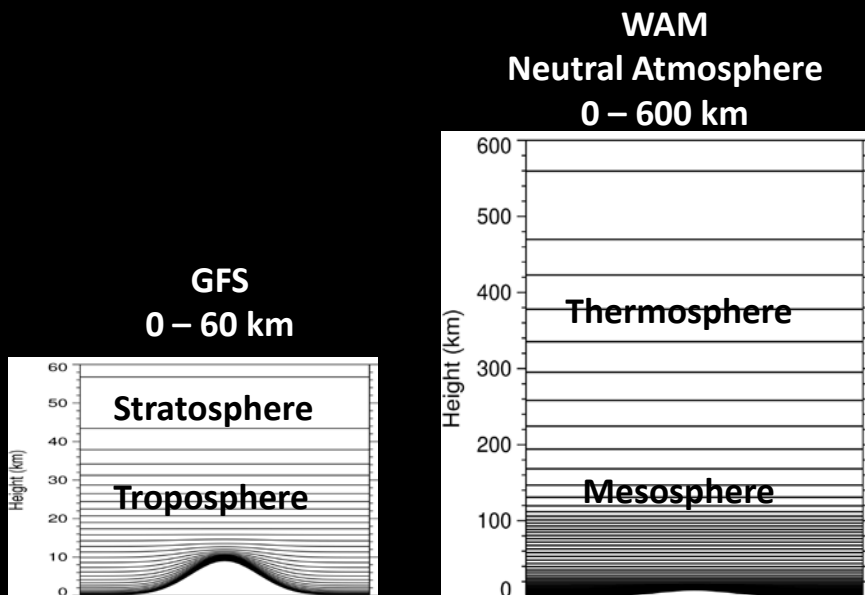


Model Development in the Thermosphere-Ionosphere: Integrated Dynamics in Earth's Atmosphere (IDEA)

Whole Atmosphere Model (WAM = Extended GFS) +
Ionosphere Plasmasphere Electrodynamics (IPE) =
Integrated Dynamics in Earth's Atmosphere (IDEA)

- Multi-day forecasts for GPS/GNSS and radio communication customers
- FY17 Deliverable: Execute Real-time run of one-way coupled WAM->IPE on NOAA WCOSS

Ionosphere
Model

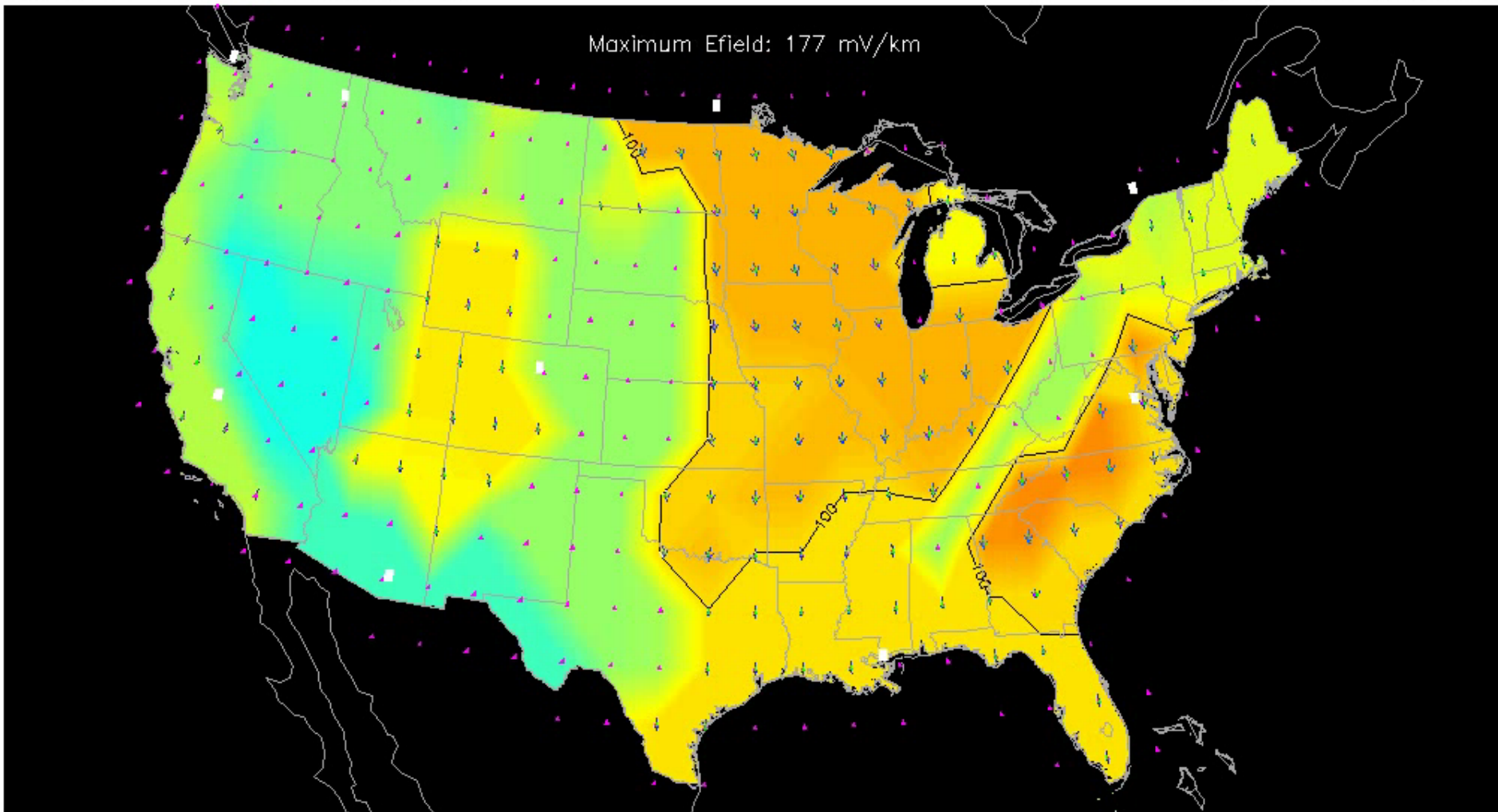


Geoelectric Field: 13-14 March 1989 Storm

Geoelectric Field Map Prototype V6

1989/03/13 01:29:30UTC

Maximum Efield: 177 mV/km



1

10

100

1000

10000

Intensity Scale (mV/km)

One-minute averaged values — 2×2 degree grid

Map Creation Time: Simulation UTC

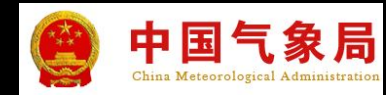
Number of Stations Reporting: 9

C. Balch

U.S. Bilateral Space Weather Activities

China: China Meteorological Administration

- Discuss monitoring and service plans



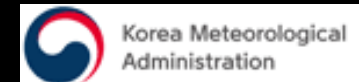
Korea: Korean Space Weather Center

- DSCOVR, ACE, STEREO data reception
- Model/data exchange and forecaster interchange



Korea Meteorological Administration

- Model exchange



Japan: National Institute of Information and Communications Technology

- DSCOVR, ACE, STEREO data reception



Germany: German Aerospace Center

- DSCOVR, ACE data reception



UK: Met Office

- Model exchange, forecaster interaction



International Organizations Involved in Space Weather Services



International Space Environment Service – Global network of 18 space weather service providers



World Meteorological Organization – Four-year plan for space weather cooperation approved June, 2016



Coordination Group for Meteorological Satellites – Coordinate operational space-based measurements



International Civil Aviation Organization – Defining civil aviation requirements for space weather services



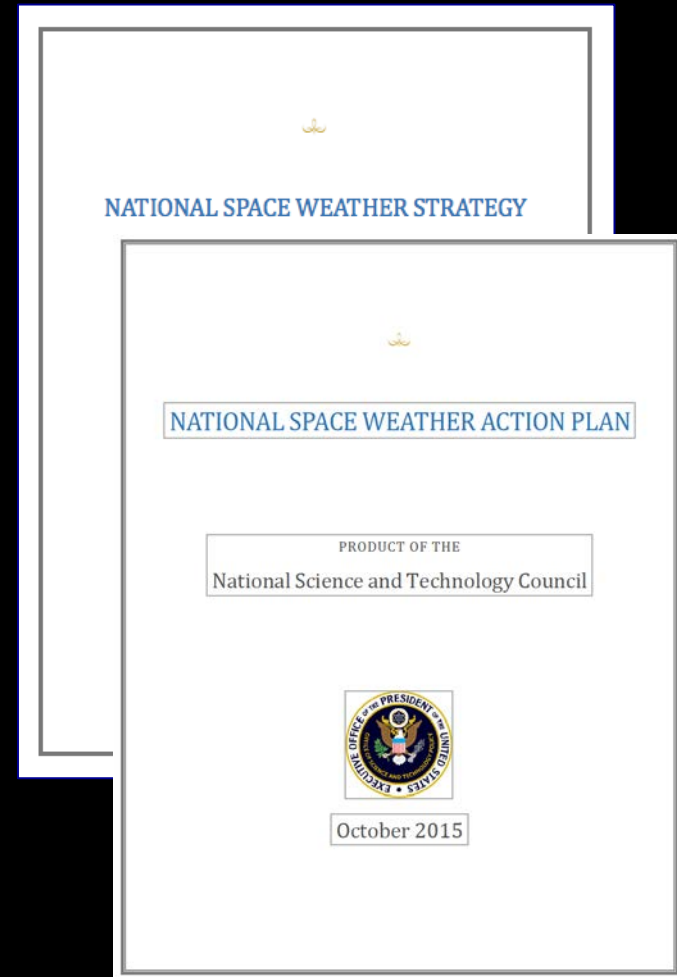
UN Committee on Peaceful Uses of Outer Space – Developing a roadmap for coordinated space weather services to 2030

National Space Weather Strategy and Action Plan

(Released October 2015)

Identifies Needs for Research and Observations

- Chartered under White House Office of Science & Technology Policy (OSTP)
- Ensuring that this Nation is prepared to respond to and recover from severe space weather storms
- Evaluate potential impact space weather may have on key infrastructures and technologies
- Chapter 5 of Space Weather Action Plan (SWAP) addresses observations and research to sustain and improve prediction of space weather events



National Space Weather Strategy and Action Plan

Operations to Research and Research to Operations

- DOC and DOD in collaboration with NASA and NSF will develop a plan (which may include a virtual or physical center) that will ensure the improvement, testing, and maintenance of operational forecasting models.
- First Space Weather O2R Workshop 16-17 August 2016, Boulder CO
- O2R Plan emphasizes
 - Coupling between R2O and O2R
 - Open source and community models
 - Communication and collaborations, between government agencies and academia, private enterprise, space weather customers, and international
 - Connections between fundamental research and the needs and requirements of the operational space weather community
- O2R Plan Public Comment Period ended March 20
- Next steps: How to best implement opportunities in presented in O2R Plan

Conclusions

Forecasting Space Weather will advance through:

- new and sustained **Observations**
- improved and accurate **Models**
- advances in space science understanding and **Research**
- and the transition and improvement of tools and models through effective **R20/O2R**

These actions, along with an understanding of user needs, will enable SWPC to serve customers with consistent, accurate, and actionable information.

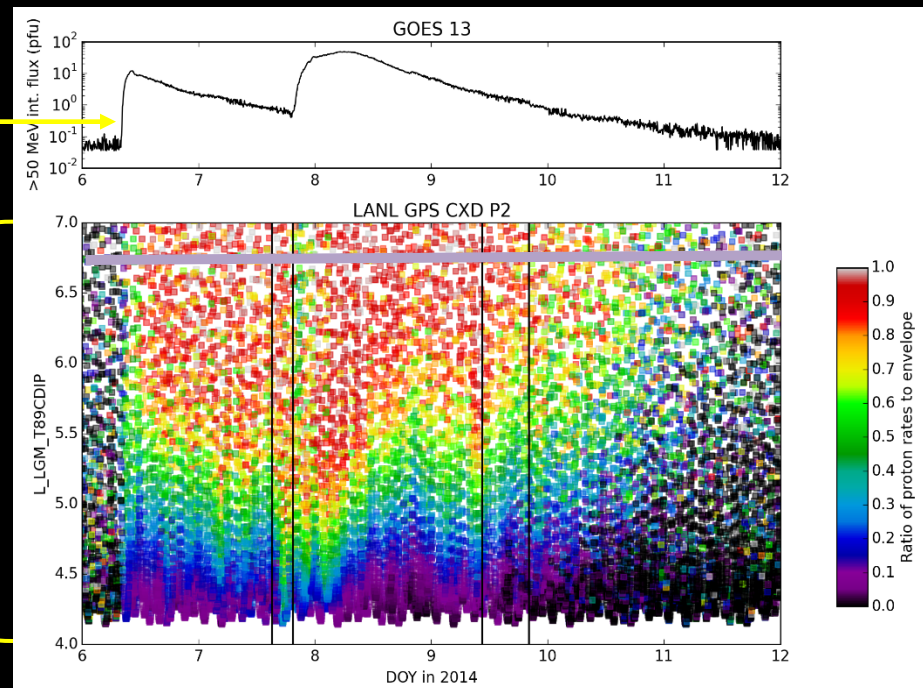
Backup

Comparison of GOES and GPS Protons

During Solar Energetic Particle Events (SEPs) in January 2014

LANL GPS Data now available at NOAA NCEI

- NOAA GOES observations in Earth's equatorial plane about 6.6 Earth radii from center of Earth
- GPS observations of energetic particles that follow Earth's field lines and reaching locations from about 4 Earth radii to beyond geosynchronous
- GPS observations complement GOES by providing a broad, time-evolving, radial profile of Earth's radiation environment that affect satellites
- During the event shown, on Jan 8, 2014, there was a launch delay of re-supply ship to ISS due to SEPs



Top: GOES 13 > 50 MeV protons
Bottom: Ratios of 10-50 MeV proton rates to interplanetary levels observed between about 7 and 4 Earth radii as measured by GPS CXD on 13 satellites at 4-min cadence. Purple bar shows approximate GOES location.