NOAA's Space Weather Prediction Center Update

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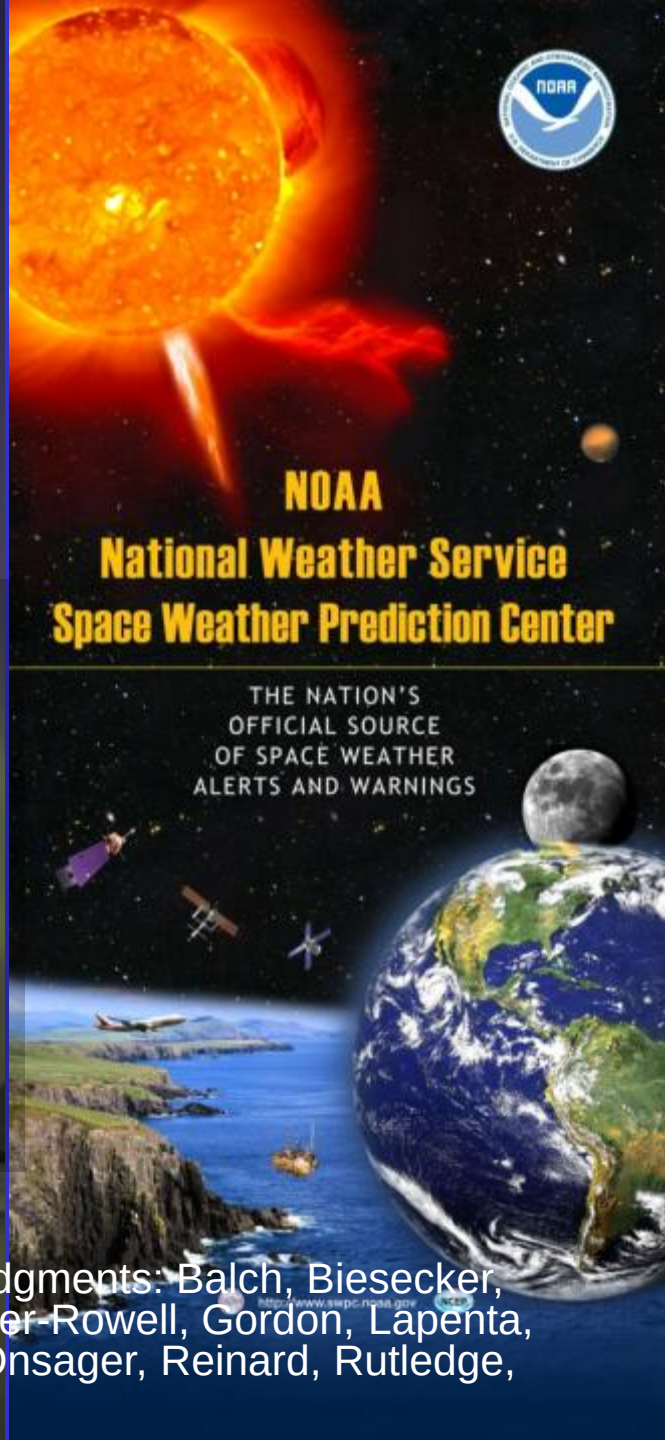
NOAA Space Weather Prediction Center

Outline:

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



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

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

Space Weather Prediction Center

Established 1946 as part of Central Radio Propagation Laboratory

Operations – Space Weather Forecast Office

Daily forecast since 1965.

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

R & D – Space Weather Prediction Testbed

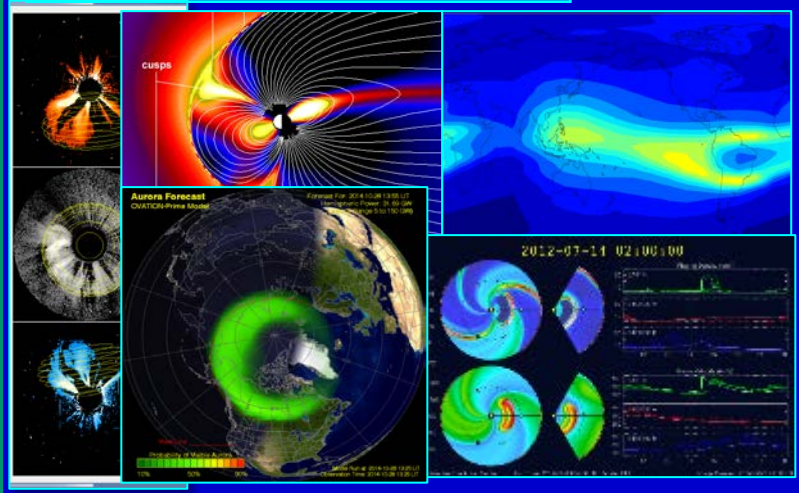
Transitioning models into operations

R2O

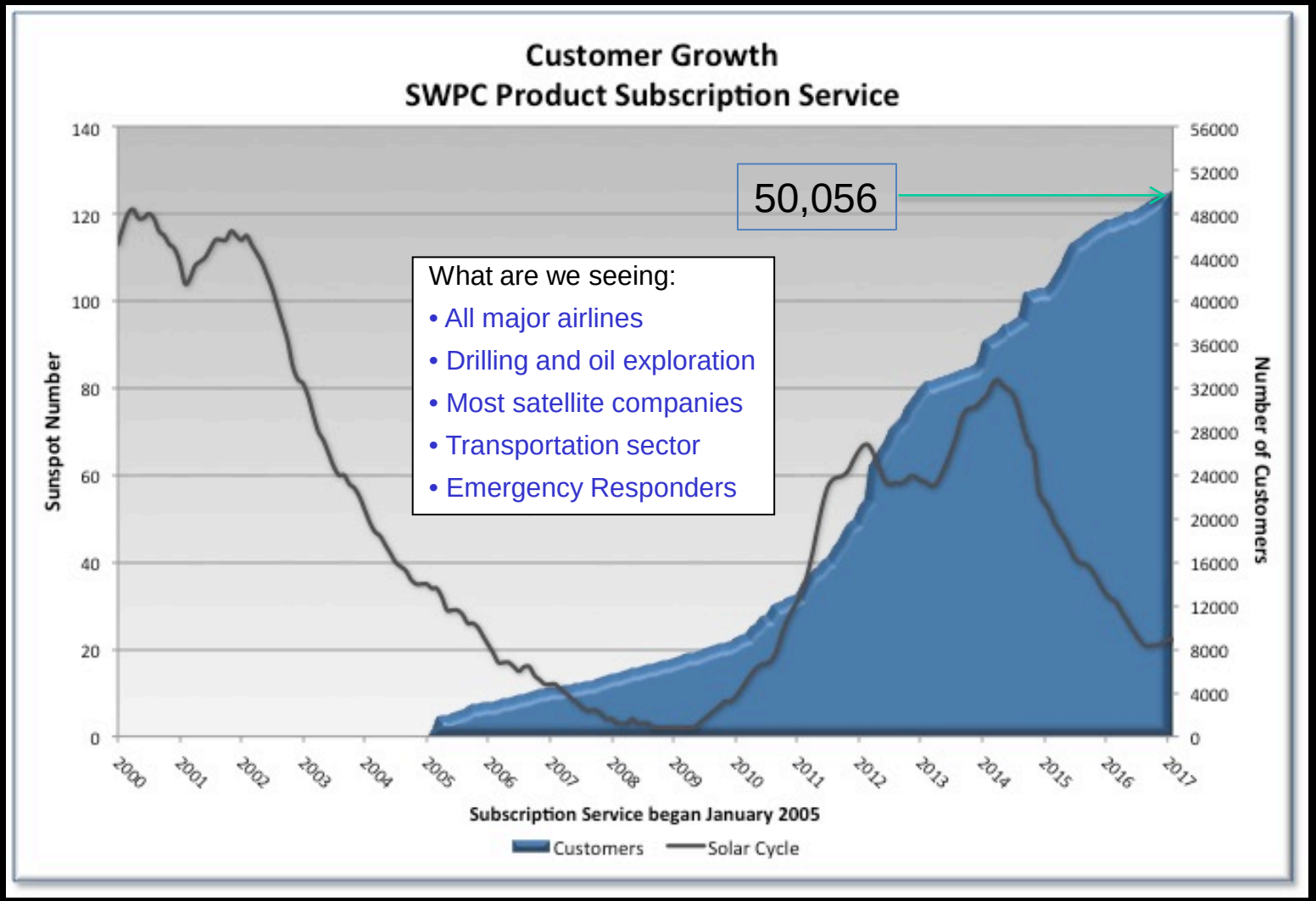
Research-to-Operations
- Applied Research
- Model Development
- Model Test/Evaluation
- Model Transition
- Operations Support

Operations-to-Research
- Customer Requirements
- Observation Requirements
- Research Requirements

O2R

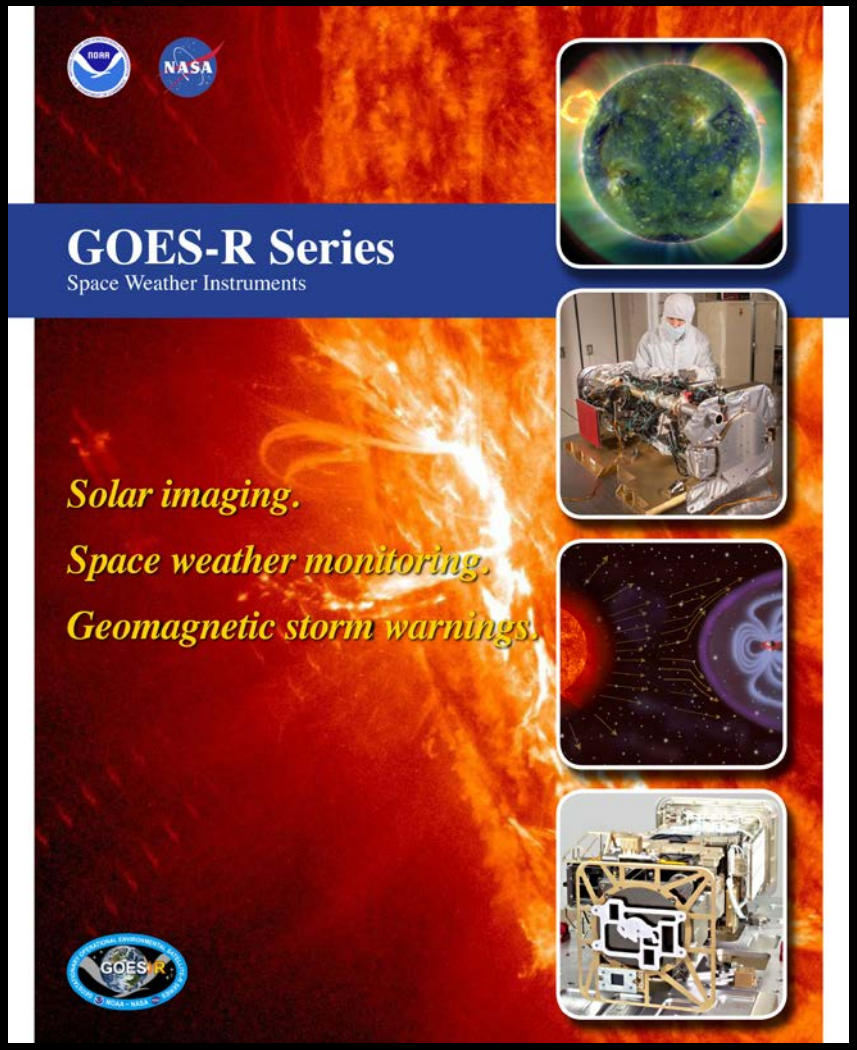


Customer Subscriptions Skyrocket… (through February 2017)



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-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)

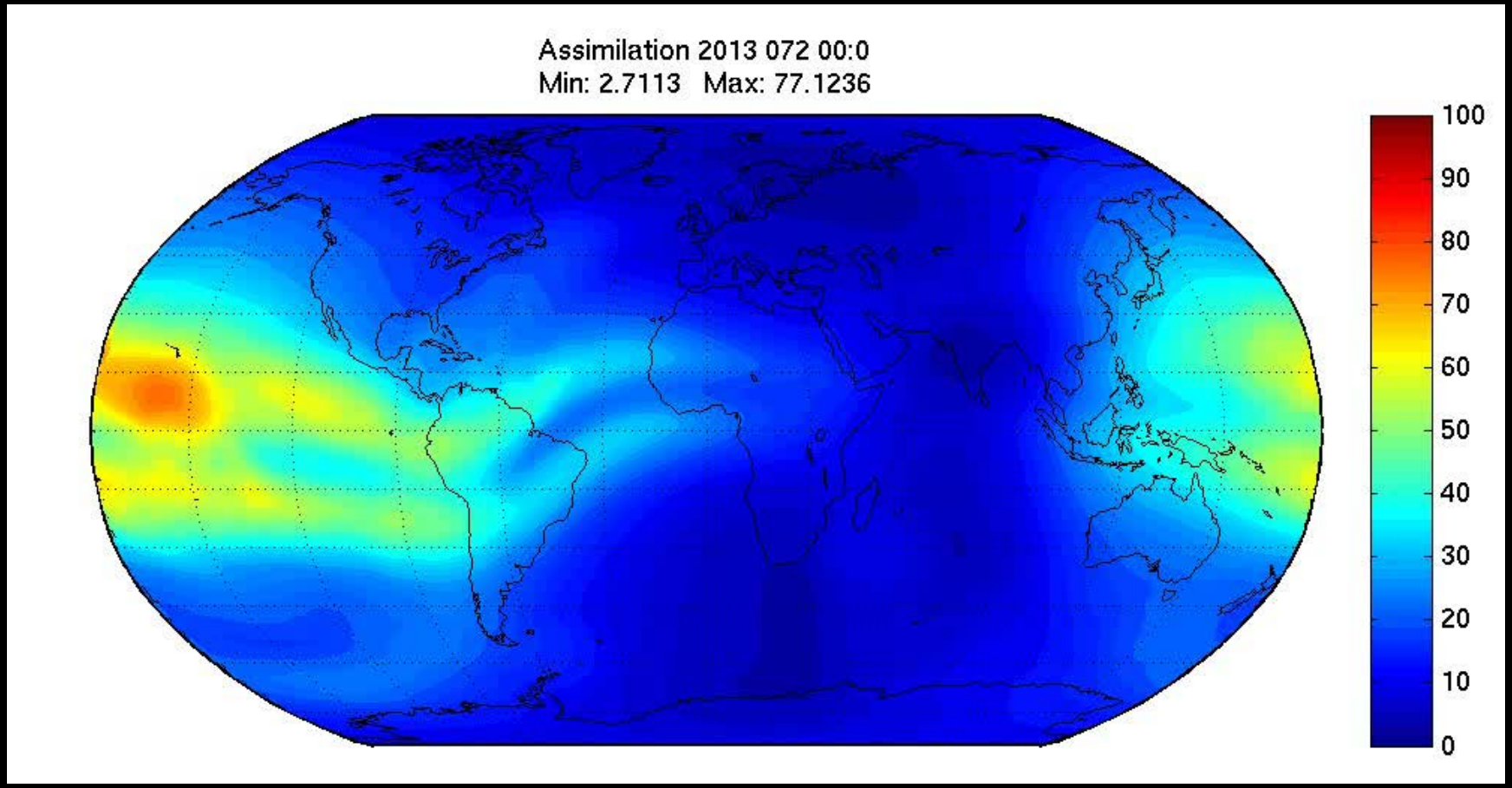
- Two studies for Phase A/B1
- Down select to one to complete Phase B
- Final go ahead at 2019 Ministerial
- L5 will be an operational mission
- Payload priorities still TBD, but Coronagraph, Heliospheric Imager, and Magnetograph at the top of everyone's list

Biesecker

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)**

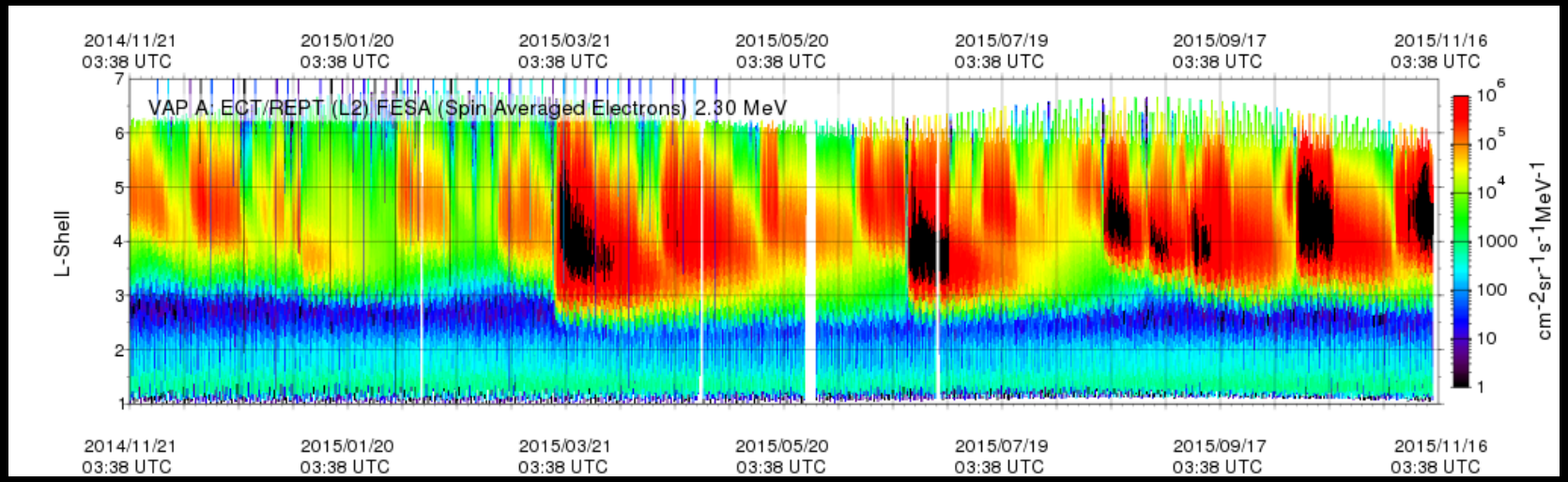
Global TEC (GloTEC)



Dominic Fuller-Rowell

Radiation Belt Products: New and Future

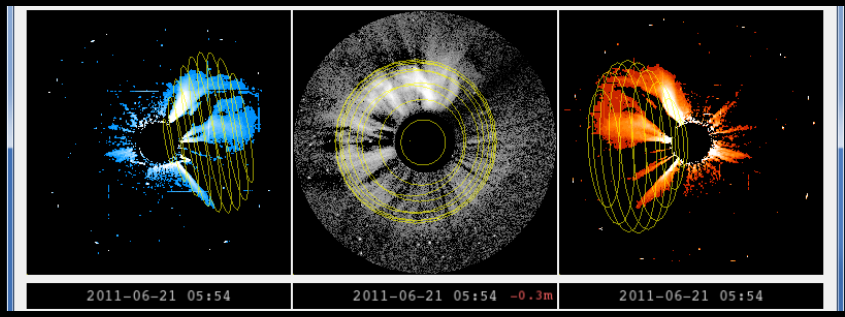
New SWPC Experimental Product: Radial profile of Radiation Belts – in collaboration with Johns Hopkins University, NASA and Van Allen Probe Scientists



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

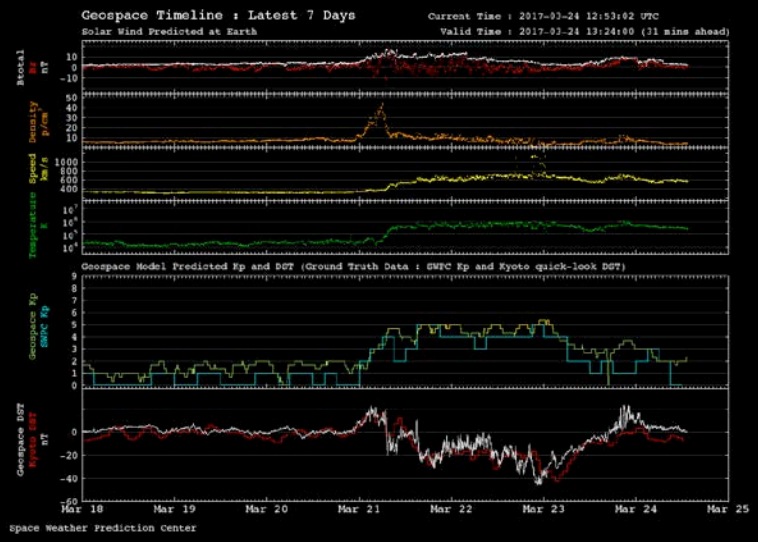
- **Improve the accuracy of Geomagnetic Storm Forecasts**
- **Current Activity**
  - **Upgrade CME Analysis Tool**
    - Evaluate methods for computing CME mass for individual events
    - Improve CME parameterization
    - Additional forecaster training
  - **Upgrade Enlil Model**
  - **Upgrade WSA**
    - 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**



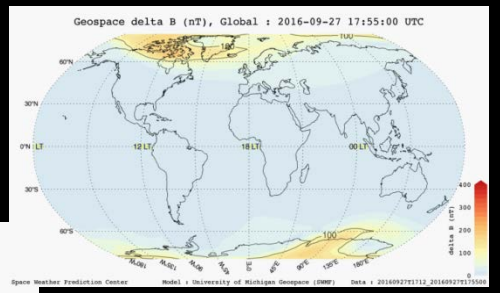
Initial Geospace Products

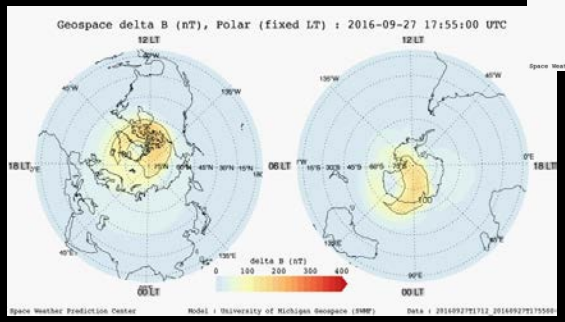
http://www.swpc.noaa.gov/experimental

Geomagnetic Activity Plot

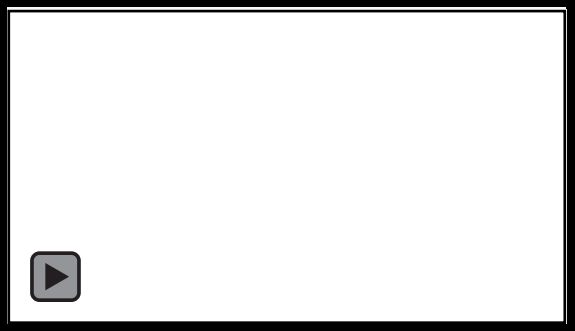


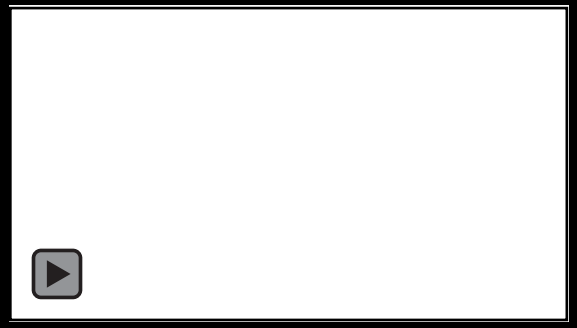
Ground Magnetic Perturbation Maps

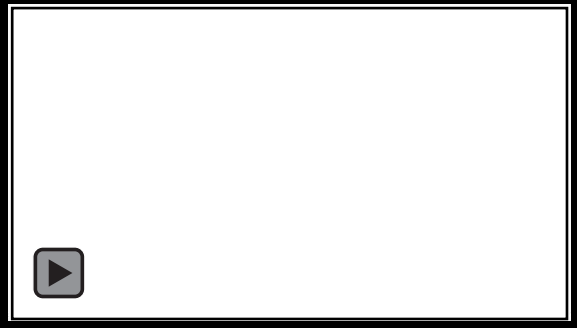




Magnetosphere Views







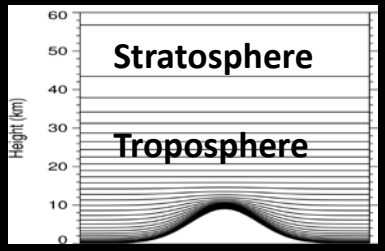
Model Development in the Thermosphere-Ionosphere: Integrated Dynamics in Earth's Atmosphere (IDEA)

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

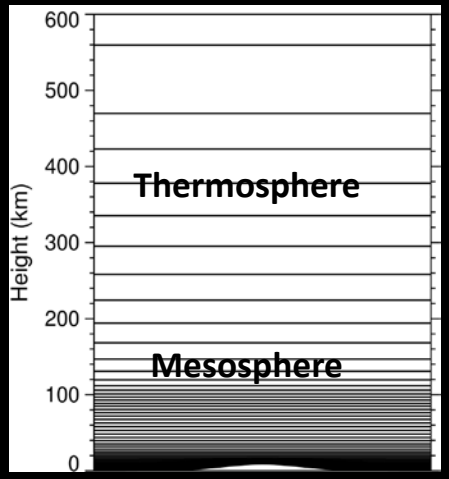
- Multi-day forecasts for GPS/GNSS and radio communication customers
- FY17 Deliverable: Execute Real-time run of one-way coupled WAM->IPE on NOAA WCOSS

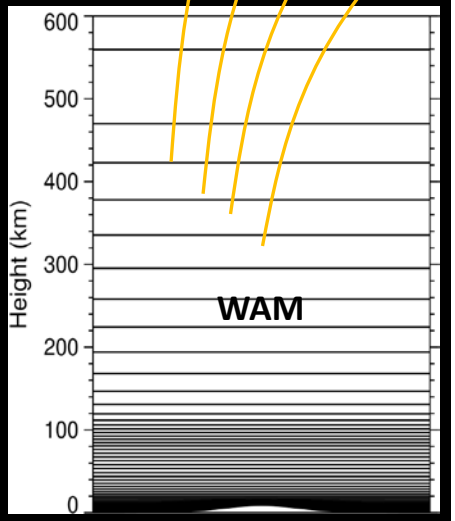
Ionosphere Model

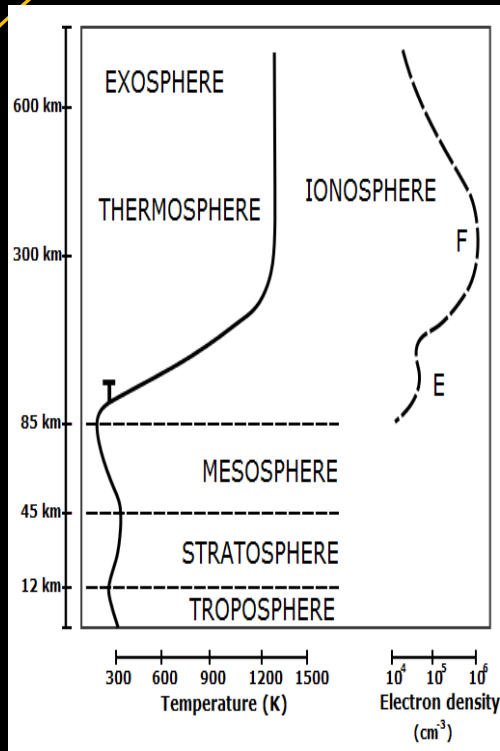
GFS
0 – 60 km



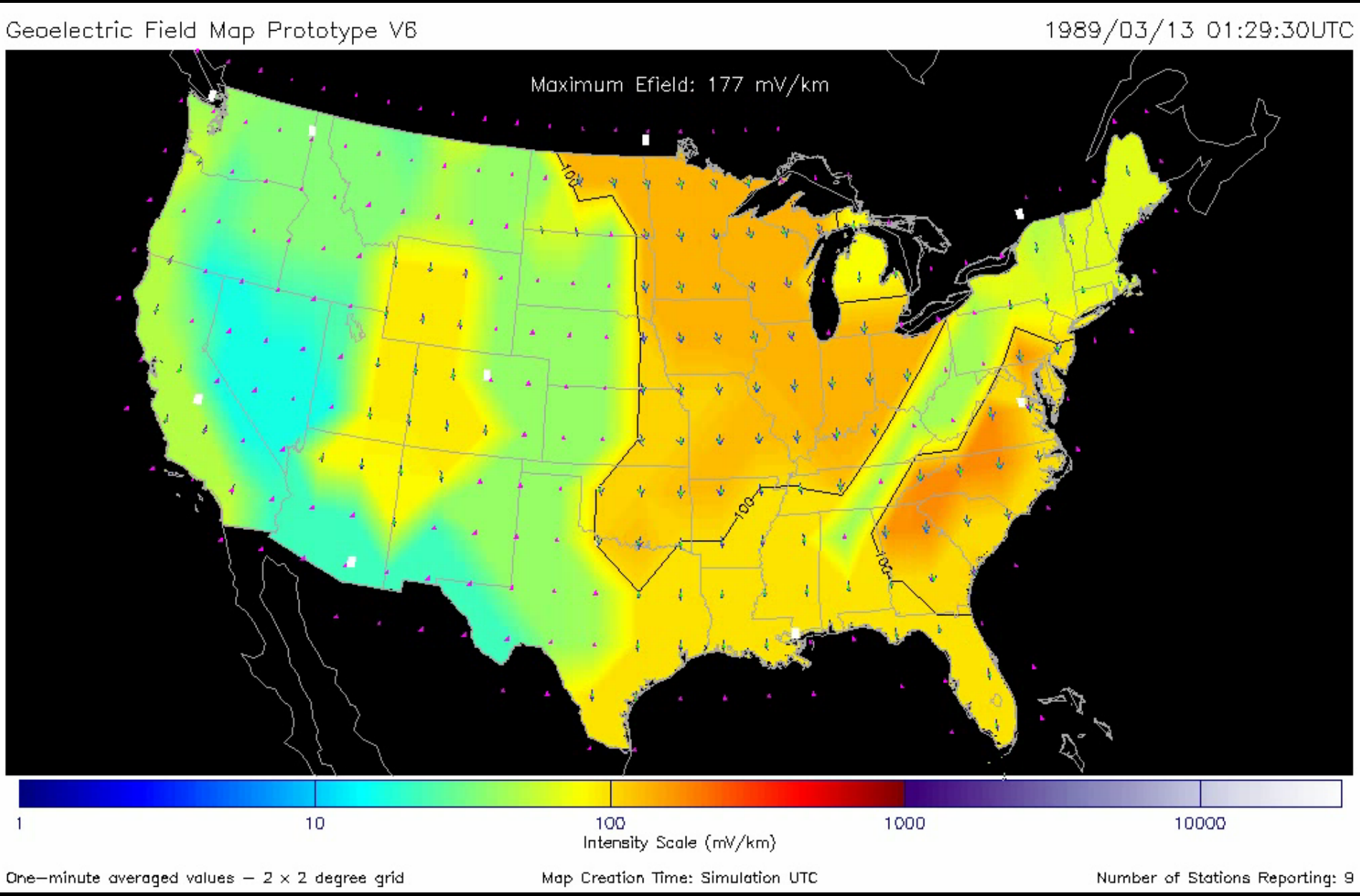
WAM
Neutral Atmosphere
0 – 600 km







Geoelectric Field: 13-14 March 1989 Storm



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

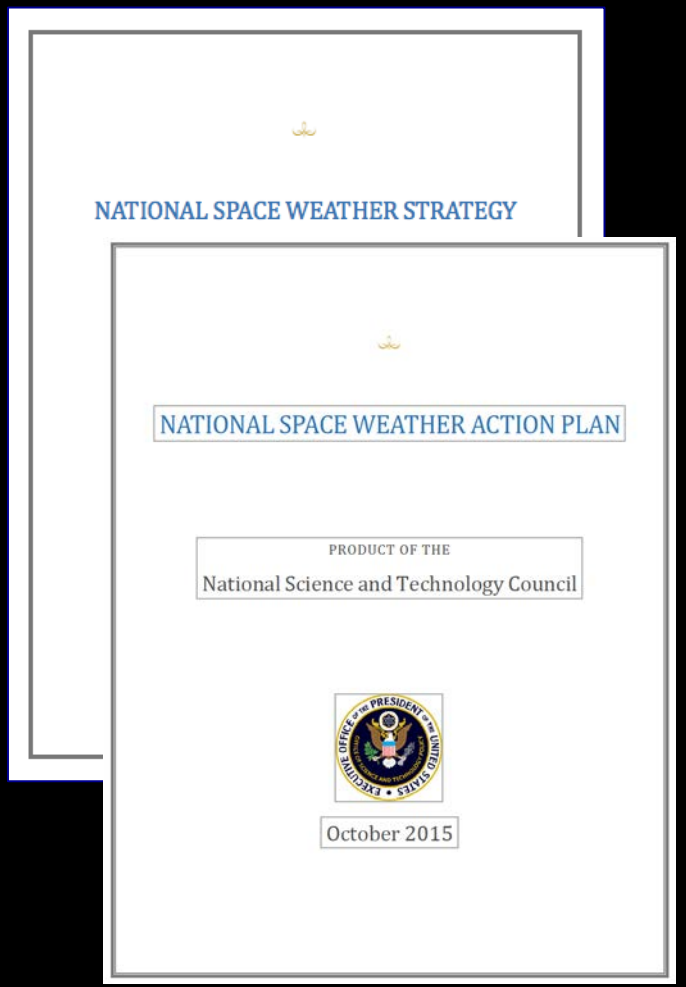
Coordination Group for Meteorological Satellites – Coordinate operational space-based measurements

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 R20 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:

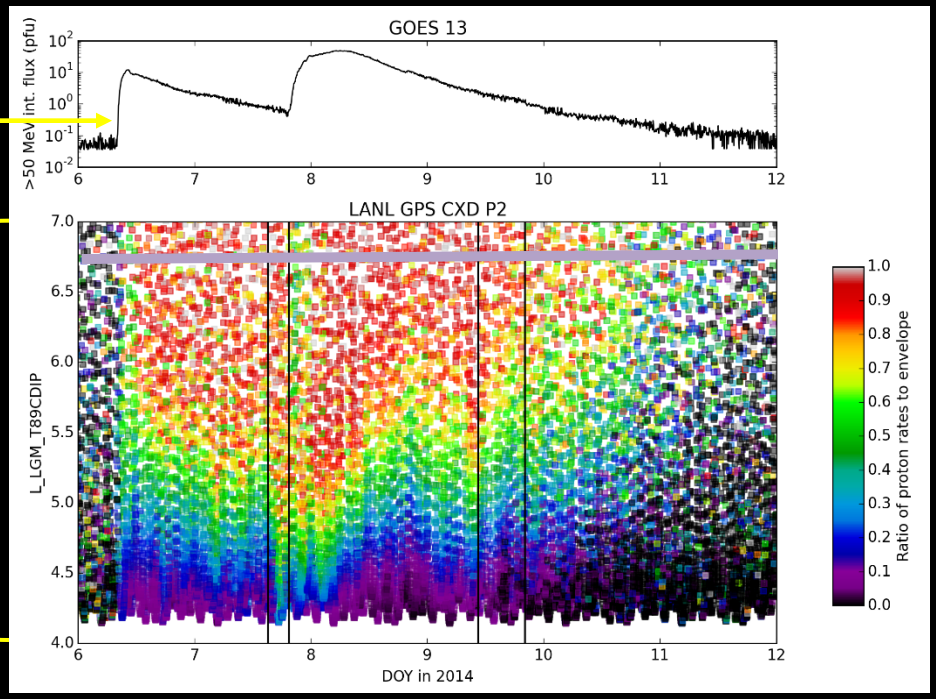
- **new and sustained Observations**
- **improved and accurate Models**
- **advances in space science understanding and Research**
- **and the transition and improvement of tools and models through effective R20/O2R**

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.

Rodriguez, Singer and Onsager