NOAA's Space Weather Prediction Center Update

Howard J. Singer
NOAA Space Weather Prediction Center

Outline:

- **SWPC, Customers, & Recent Events**
- **Advances in Forecasting**
  - **Observations and Models**
- **Policies and Plans**
- **Conclusions**

COMMITTEE ON SOLAR AND SPACE PHYSICS
March 27, 2019

Acknowledgments:Adamson, Biesecker, Murtagh, Onsager, Redmon, Steenburgh, Talaat, Zanetti

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

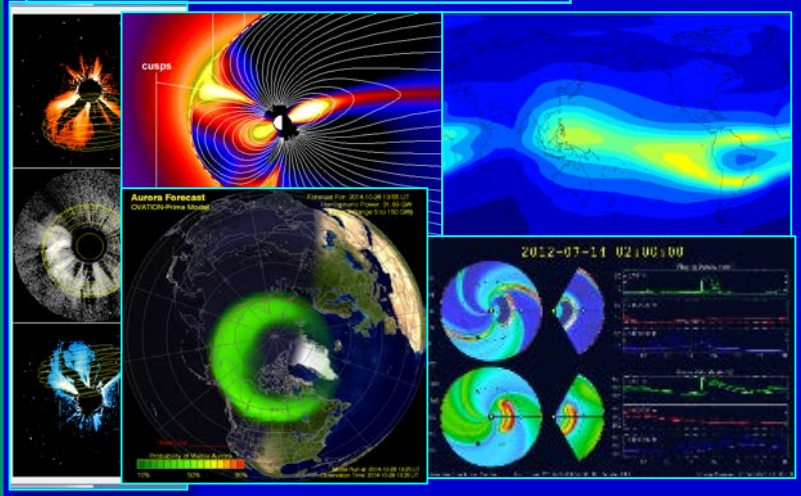
Transitioning models & data into operations

R2O

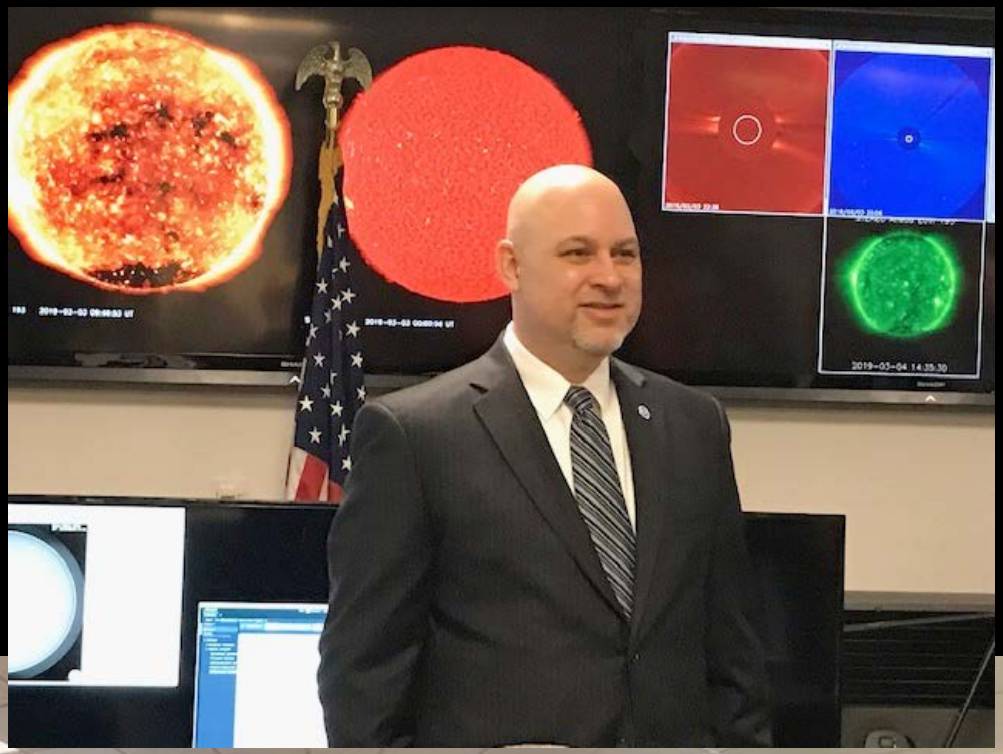
Research-to-Operations
- Applied Research
- Model Development
- Model Test/Evaluation
- Model Transition
- Operations Support

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

O2R

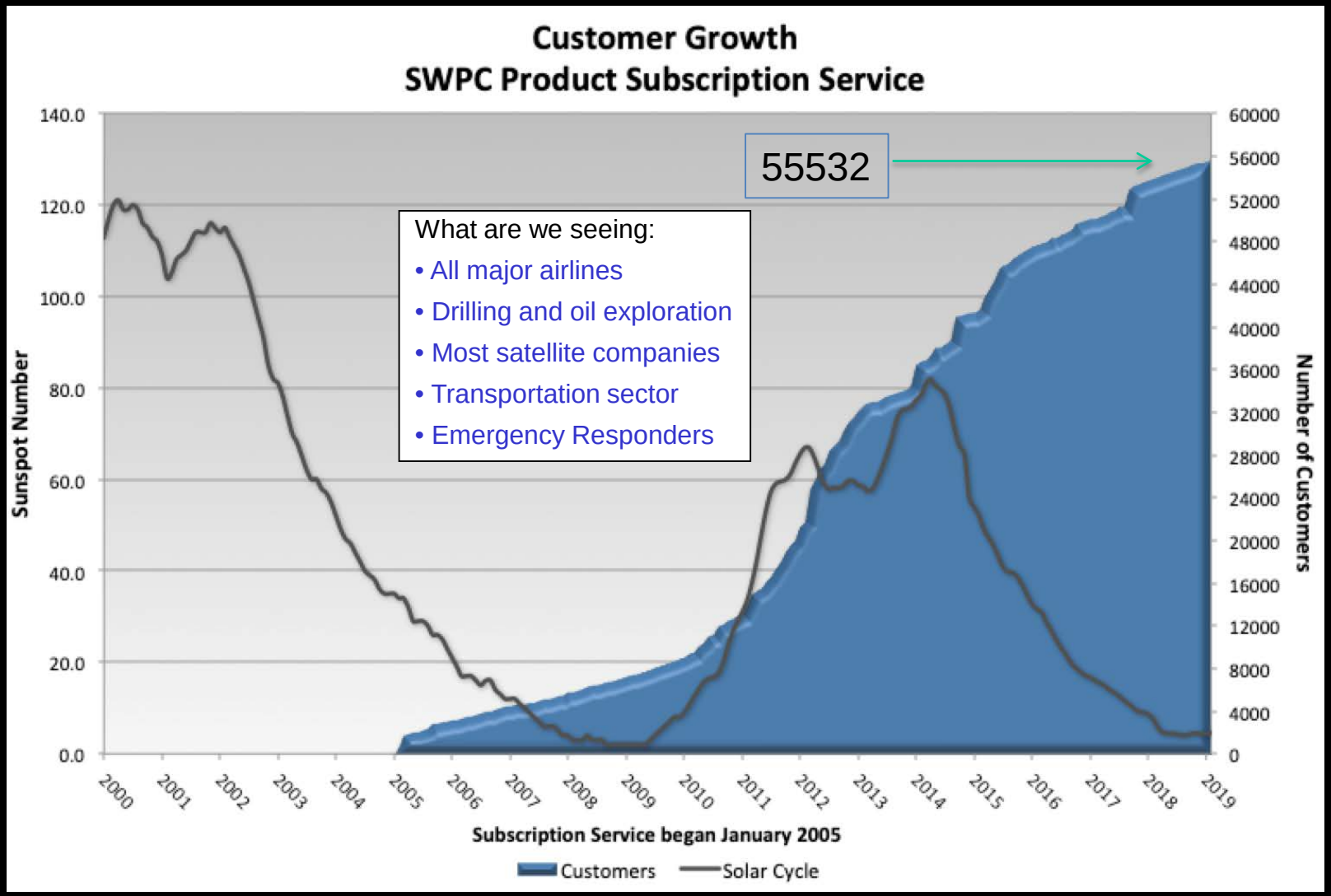


Clinton Wallace
New SWPC Director



- March 4, 2019 sworn in by Bill Lapenta
- Brings new Leadership experience and ideas
- Extensive experience in:
  - Aviation weather R&D
  - Operations
  - R2O2R
  - National and international partnerships
- Since 2010 was Deputy Director of NCEP's Aviation Weather Center

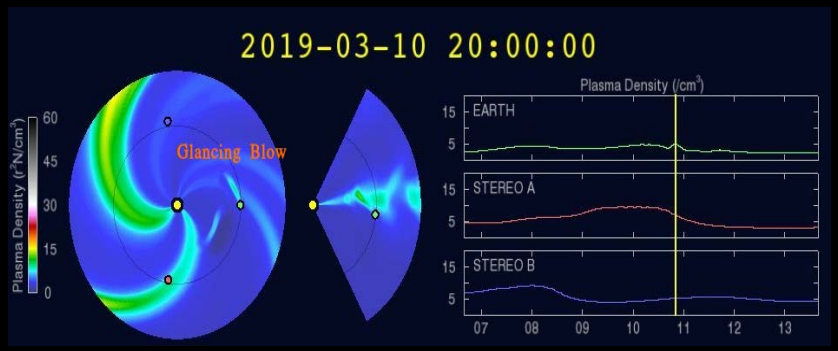
Customer Subscriptions Skyrocket… (through February 2019)



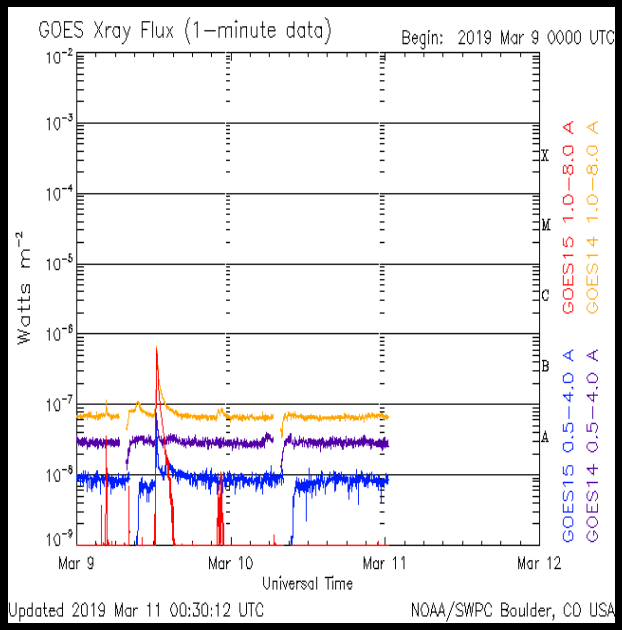
Registrations continue to rise, even as we head toward solar minimum

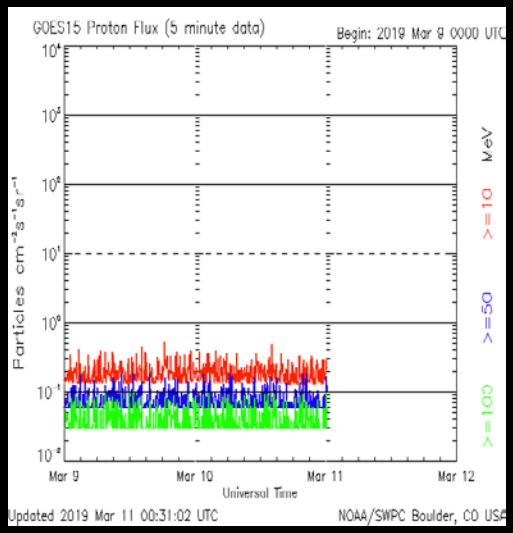
SWPC Provides FEMA with Routine Space Weather Summary/Outlook

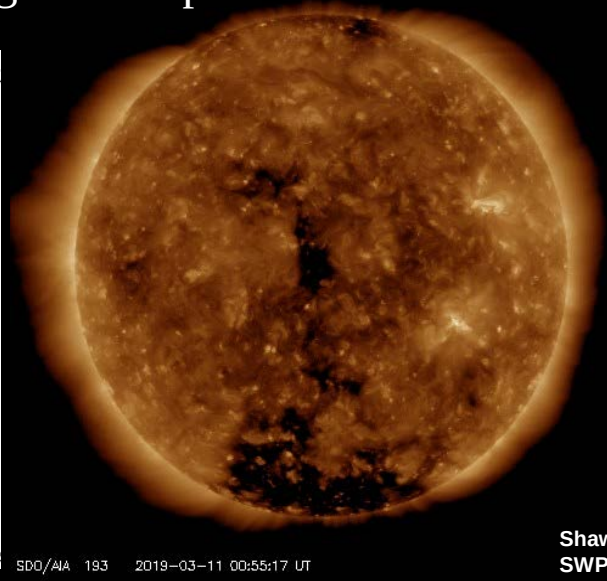
Space Weather Summary Mar 11th 2019	Past 48 Hours	Forecast: Mar 12th	Forecast: Mar 13th
Radio Blackouts (R Scale)	None	R1-R2: 1% R3-R5: 1%	R1-R2: 1% R3-R5: 1%
Solar Radiation Storms (S Scale)	None	S1 or >: 1%	S1 or >: 1%
Geomagnetic Storms (G Scale)	G1	None	None



Benign solar and particle environment.
Glancing blow expected from 8 March CME.





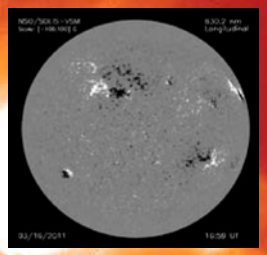


Shawn Dahl
SWPC
Mar 11th, 2019

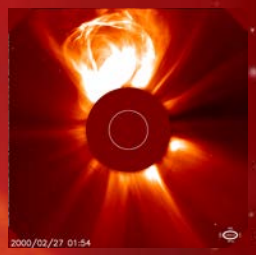
OBSERVATIONS
And
MODELS

Space Weather Forecast Data and Models

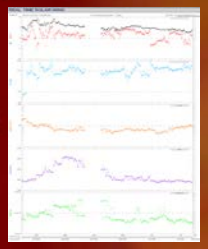
GONG Magnetograms



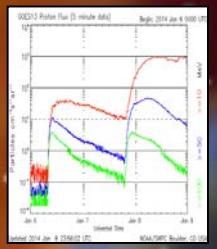
SOHO LASCO Coronagraph

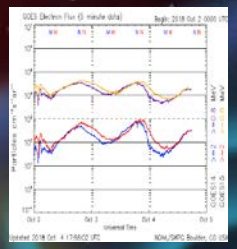


DSCOVR Solar Wind and Mag Field at L1

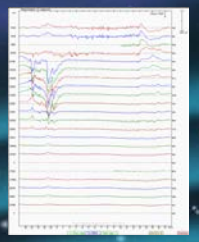


GOES Protons and Electrons

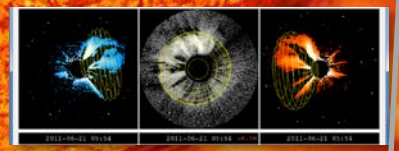




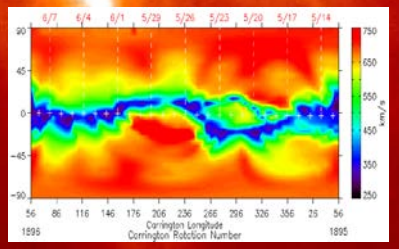
Mag Field from USGS



CME Parameters from CAT

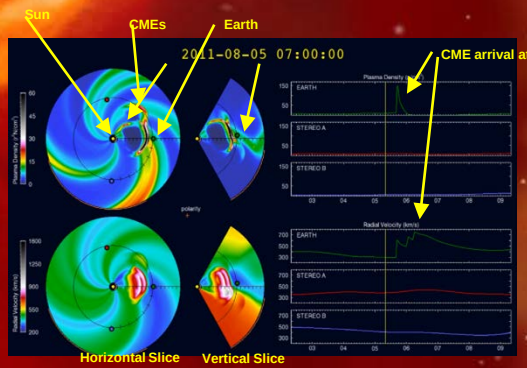


Solar Wind from WSA



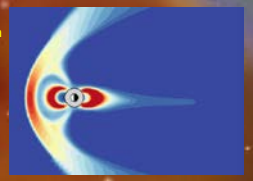
WSA Developed by SWPC and AFRL

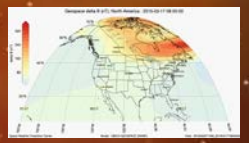
Enlil Model of CME Arrival



Enlil Developed by SWPC and G. Mason U. NSF CISM …

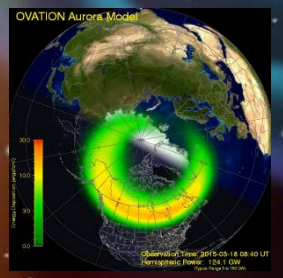
Geospace Model of Magnetosphere (Regional Impacts)





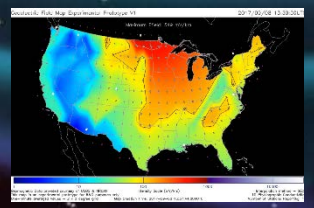
Geospace Model Developed by U. Mich.

Ovation Model of Aurora



Aurora Model Developed by APL Johns Hopkins

Regional Electric Field Model



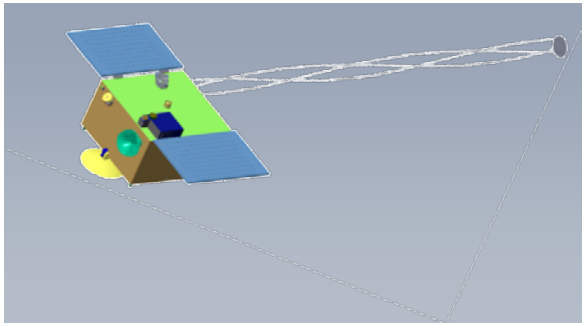
E-Field Model Developed by SWPC, NASA, USGS NRCAN

NESDIS Space Weather Follow On (SWFO) Status 2019

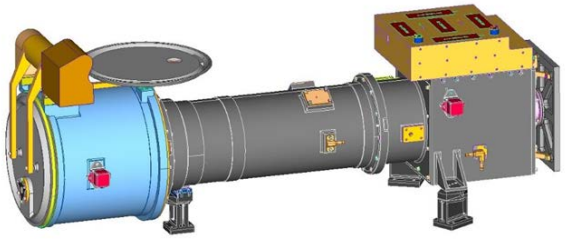
- The Consolidated Appropriations Act 2019 allows the SWFO Program to complete formulation activities and initiate development
- Key technical components
  - Compact CORonagraph (CCOR) with Naval Research Laboratory as NOAA partner
  - Host CCOR on the GOES-U spacecraft planned for launch in early 2024
  - Establish NOAA/NASA partnership for rideshare to L1 with NASA's Interstellar Mapping and Acceleration Probe (IMAP) launch late 2024; NOAA spacecraft will have CCOR, in-situ solar wind and possible instrument of opportunity
- Ongoing negotiations with ESA with regard to planned L5 mission
- NOAA Satellite Observing System Architecture (NSOSA) calls for sustained Space Weather in-situ observations at L1 and CME imaging capability
- Maintain archives at NCEI for space-based data which are essential for model development and benchmarking

Program Description: Key Technical Components

3-Axis Stabilized ESPA Class Spacecraft

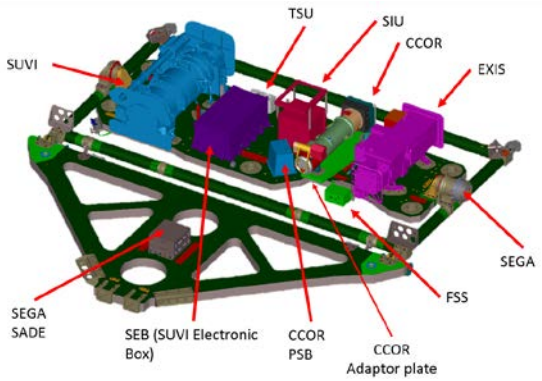


Compact Coronagraph (CCOR)



GOES-U Solar Pointing Platform (SPP)

CCOR + SUVI + EXIS



SWFO-L1 Mission Overview

- Space Weather Operational Observation at Earth-Sun Lagrange Point 1
- NASA to procure an ESPA Grande compatible spacecraft and a SWIS (Solar Wind Instrument Suite)
- NOAA ground system
- Rideshare with NASA IMAP
- Nominal orbit: L1
- Nominal launch: 2024
- SWFO-L1 Instruments: CCOR, SWIS and a potential instrument of opportunity
- Potential ESA contributed instrument (X-Ray flux monitor)

Coronagraph Project

- Compact coronagraphs under development by NRL
- CCOR for SWFO-L1 Satellite, deliver 2021
- CCOR for GOES-U, deliver 2021
- Potential CCOR for ESA-L5 Satellite, deliver 2023

Coronagraph Accommodation on GOES-U

- CME imaging from geostationary orbit
- CCOR Integrated onto GOES-U SPP
- Commanding and data flow through GOES-R ground system
- Nominal launch: 2024

STP SpWx Satellite Services: DSCOVR, GOES, POES, GPS & LANL GEO, DMSP

STP's comprehensive Space Environmental Data Services

Satellite Data: DSCOVR, GOES, LANL, POES/Metop, DMSP

https://www.ngdc.noaa.gov/stp/satellite/

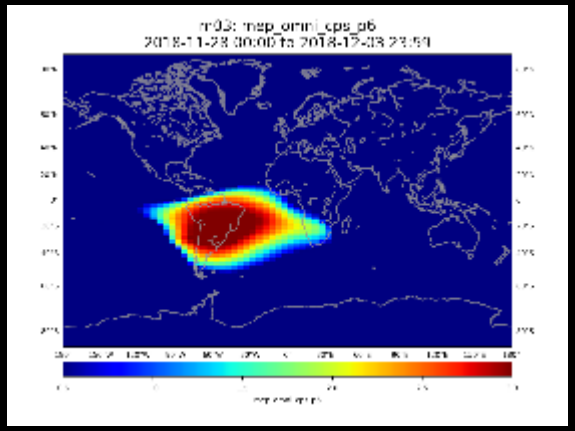
Metop-C SEM-2 Launched in Nov - Final in series

Contact NCEI for pre-release data.

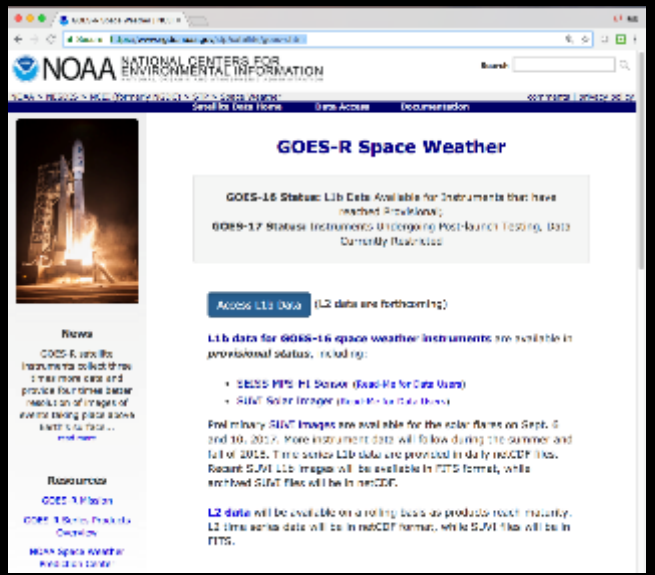
Watch for GOES-R SpWx product updates here:

GOES-R – SUVI, SEISS, EXIS, MAG, early data, docs

https://www.ngdc.noaa.gov/stp/satellite/goes-r.html



Metop-C SEM first light.



We're hiring!

NOAA CU Boulder Partnership CIRES:

Magnetometer Space Physicist

Contact: Paul.Lotoaniu@noaa.gov

Contact: Rob.Redmon@noaa.gov,

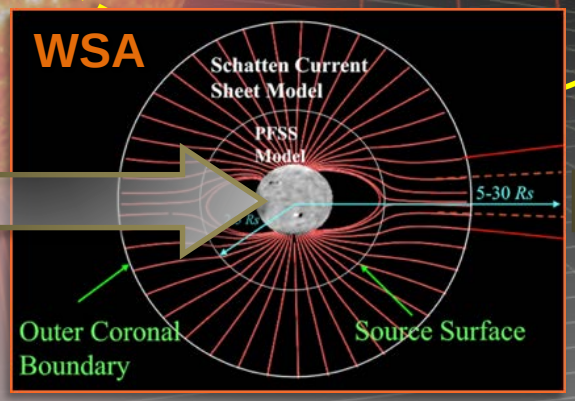
WSA–Enlil Heliospheric Model

Coupled modeling framework: WSA (corona) + Enlil (Heliospheric MHD) affording predictive knowledge of geomagnetic storm onset (~ +/- 6hrs):

- **Operational since 2011**
- **Enlil upgrade in transition (delivered to NCO 2/21)**
- **Progress:**
  - ***Validating WSA upgrade***
  - ***Ongoing NASA/NOAA MOU – (ADAPT/time-dep)***
  - ***O2R funded efforts***

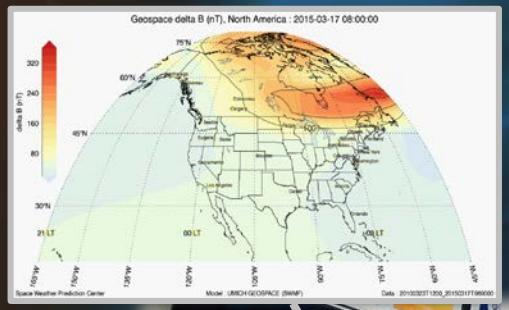
GONG Magnetogram

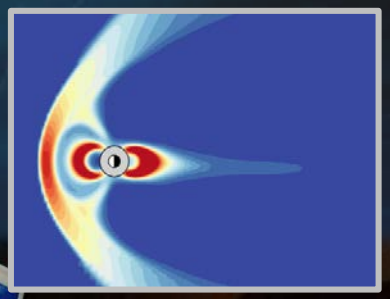
CME Characterization

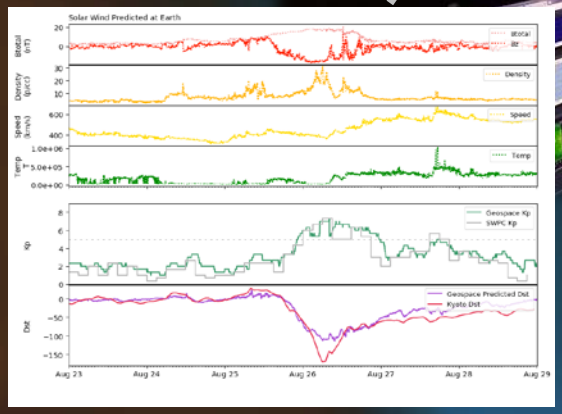


Michigan's Geospace Model

Predicting Regional Disturbances in Earth's Magnetic Field







Validation underway to better establish confidence levels for forecasters and web-based customers and to provide feedback for improvements (O2R)

Operational At NOAA's Space Weather Prediction Center Since 2016

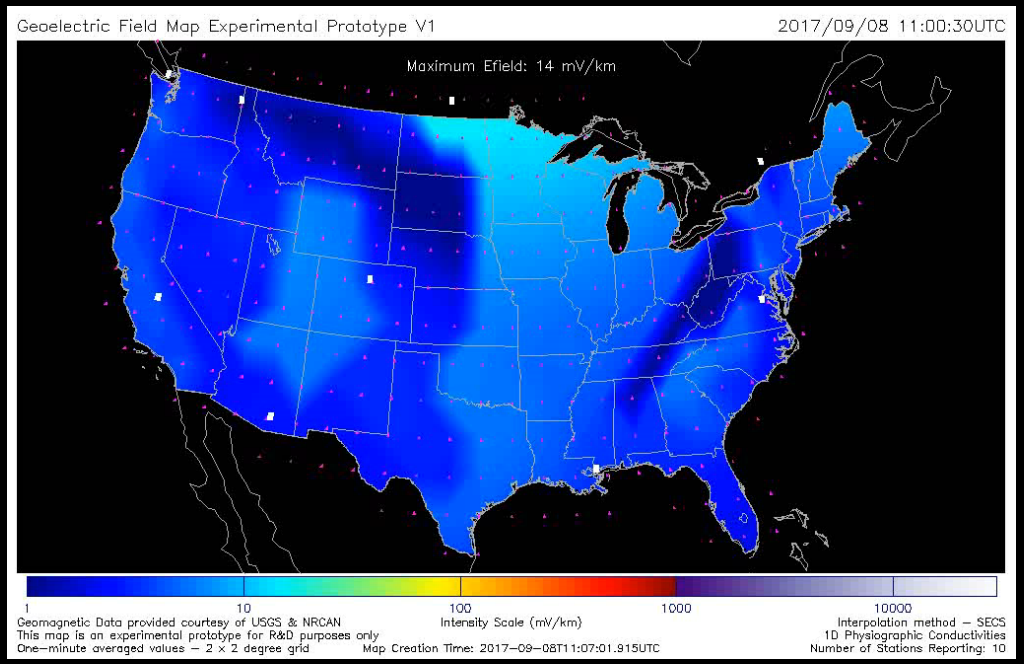
Geospace products displayed in the Forecast Office at the Space Weather Prediction Center support forecasters and external customers, including power grid operators

Geoelectric Field

- Computed from ground-based magnetometer data and ground-conductivity maps
- Upgrade for map products in progress
- Grid resolution increase from 2 degree to ½ degree
- Conductivity models improve from 1D (Fernberg) to 3D based (Earthscope) – in regions where surveys have been completed
- Validation work with user community is underway

Collaborators: USGS, NASA, NRCAN, NSF-Earthscope Project

September 7, 2017

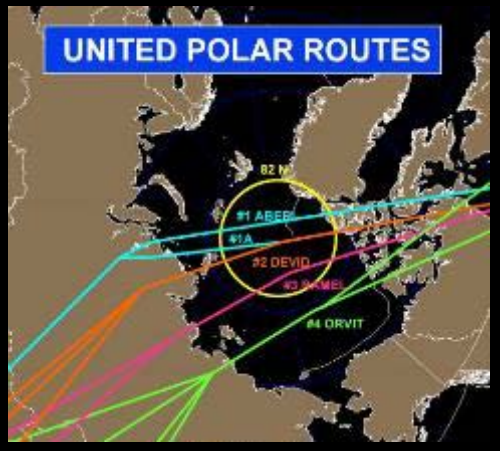


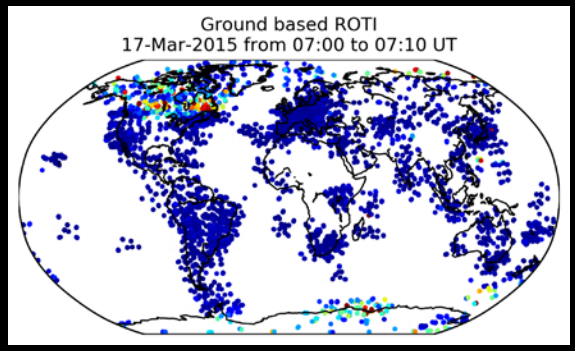
- 2-degree grid example above
- Plans to drive Geoelectric Field model in a predictive mode with Geospace model magnetic perturbations

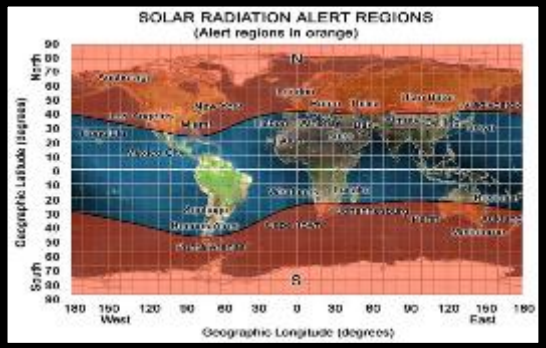
Adapted from C. Balch

Aviation Space Weather Products
Models in Transition/Development

- Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics (CTIPe)
  - HF Communications – Maximum Usable Frequency
  - Ionosphere Total Electron Content-GNSS accuracy
- Global Total Electron Content (GloTEC)
  - Ionosphere Total Electron Content-GNSS accuracy
- Rate of TEC index (ROTI)
  - Ionospheric scintillation-GNSS accuracy and availability
- FAA Solar Radiation Model
  - Dose rates at avaiation altitudes







POLICIES AND PLANS

Decadal Survey Applications Recommendations

Enabling Effective Space Weather and Climatology Capabilities:

[To be implemented only if it does not impinge on the recommended research program]

A1.0 Recharter the National Space Weather Program

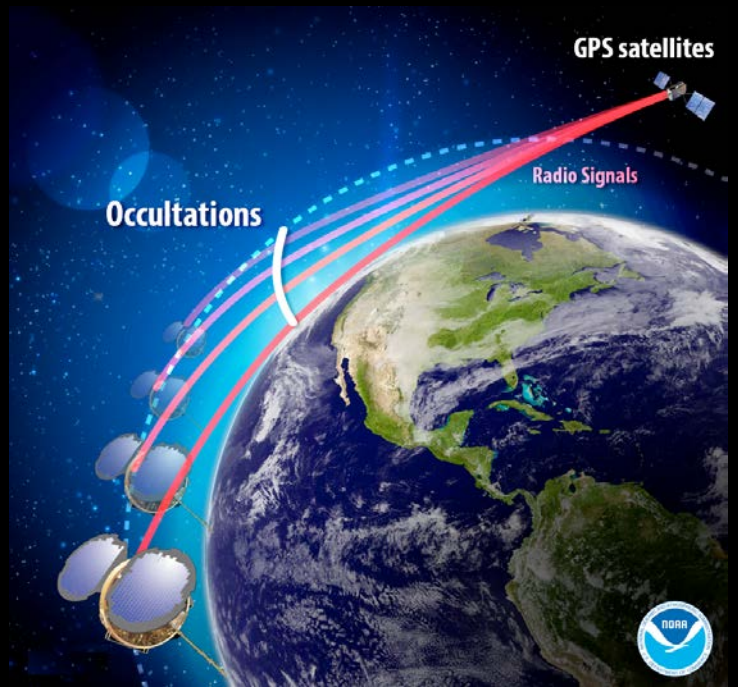
A2.0 Multi-agency partnership for continuity of solar and solar wind observations

- A2.1 Continue solar wind measurements – DSCOVR and IMAP
- A2.2 Continue space-based coronagraph
- A2.3 Evaluate new observations and alert dissemination systems
- A2.4 NOAA research program to transition research to operations
- A2.5 Distinct funding lines for basic research and specifications/forecasts

From Terry Onsager presentation to Decadal Survey mid-term review committee

NOAA's Commercial Weather Data Pilot

- NOAA will evaluate commercial GNSS radio occultation data to demonstrate the quality, impact to forecast models, and to inform NOAA's process for ingesting, evaluating, and utilizing commercial data in the future.
- Contracts awarded to Spire, PlanetIQ and GeoOptics
- For space weather, these data can fill the gap that was left when COSMIC-2 polar orbits were not funded
- SWPC is supported to assess the data quality for fulfilling operations needs; including assimilation into a global total electron content product (GloTEC) and comparisons to US TEC and other models; also working with UCAR and their Model Evaluation Tools (MET)



Space Weather Support for International Civil Aviation*

Purpose: ***To provide information on space weather and to avoid the risks posed to flight safety regarding communications, Satellite-based navigation surveillance, and avionics, as well the risk to the health of aircraft occupants (i.e.flight crew and passengers) due to radiation exposure***

Participants: **PECASUS (Finland (Lead), Belgium, UK, Poland, Germany, Netherlands, Italy, Austria, and Cyprus), ACFJ (Australia, Canada, France, Japan), SWPC (United States), Regional Centers (South Africa, China, Russia)**

Products: **Space weather advisories: ionospheric scintillation (amplitude and phase), and TEC for GNSS; effective dose for radiation; and Kp, PCA, Solar X-ray flux (or equivalent), and MUF for HF.**

Practicalities: 2 wks/Centre as primary provider, daily & real-time coordination, established consistency procedures, initial implementation: November 7, 2019

***International Civil Aviation Organization (ICAO), a UN specialized agency, established by States in 1944**

Solar Cycle 25 Prediction

NASA Funded- NOAA Led

Objective Required:

Predict peak intensity and phasing of Solar Cycle 25, including error bars and onset of Cycle 25/solar minimum

Objective Ideal:

Predict north/south hemispheres independently (intensity/phase); F10.7/F30; flare/CME rates

Co-chairs:

Douglas Biesecker (NOAA)

Lisa Upton (Space System Research Corp)

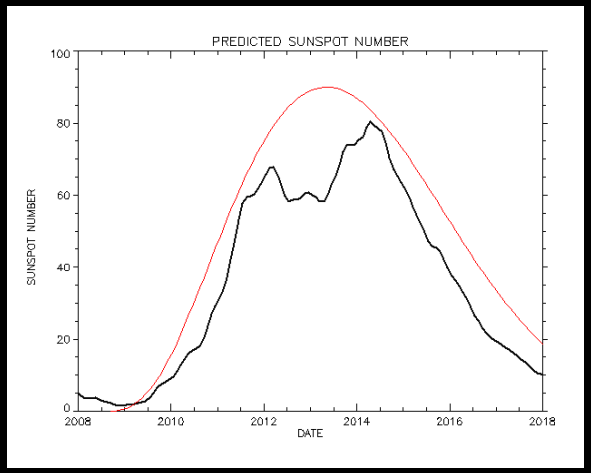
International Team:

US, Germany, Belgium, UK, Japan, China, Sweden

Methods:

Climatology, Dynamo, Machine Learning, Precursor, Spectral, Statistical, Flux Transport, Other…

Solar Cycle Panel
Boulder March 2019



Solar Cycle 24
Prediction and Observed

Coordinated Interagency Space Weather Applied Research Funding – And the Next Challenge

January, 2018 – Pilot funding opportunity for Operations-to-Research
- NASA/NOAA joint opportunity; NSF released separate announcement
- **Target: Improved geomagnetic activity forecasting**

(9 of 11 Awardees Speaking at Space Weather Workshop)

March, 2018 – First applied research opportunity released
- NASA/NOAA coordinated research announcement
- **Target: Satellite radiation environment**

(8 of 9 Awardees Speaking at Space Weather Workshop)

November 2018- Second applied research opportunity released
- NASA/NOAA/NSF coordinated research announcement
- **Target: energetic proton and/or heavy ion conditions in the heliosphere due to solar eruptions**

- **New funding for R2O/O2R Research is enabling the development of models and tools that can be made available for space weather customer support**

- **Next challenge: select and transition new and improved models and capabilities to operations**

Space Weather Workshop – 2019

Next Week

- UCAR organized (+ Steering Committee)
- Co-sponsored NOAA, NASA, NSF
- Brings together: researchers, space weather service providers, and users of space weather services
- Over 300 registered as of March 22;
- Banquet speaker: Nicky Fox, NASA Heliophysics Div Dir
- Boulder (Embassy Suites)
- Mon Aft: Open ICAO mtg.
- Tue-Fri regular meeting

Program Highlights:

ICAO, Satellite Impacts, Arctic Region, Human Expansion Across Solar System, O2R2O, Extreme Space Weather Benchmarks, Power Grids, Aviation, Observations, Models Research and more…