



**NATIONAL
WEATHER
SERVICE**

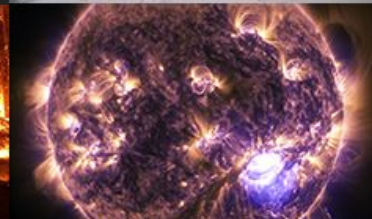
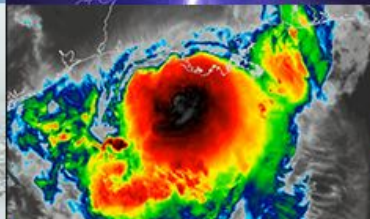
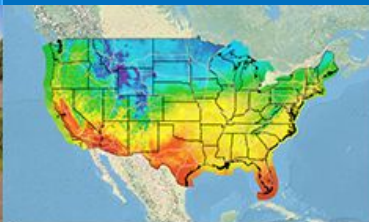
Building National Resilience for Space Weather Storms

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Working Group, National Science and Technology Council

September 9, 2020



Outline

- Building capacity to advance space weather policy - the inception and construction of a National Space Weather Strategy and Action Plan
- Accelerating growth in NOAA and the Enterprise's space weather services
 - Identify and sustain fundamental observations to support operations
 - Provide timely, accurate, and relevant models and forecast products
 - Transition scientific and technological advances into operations (R2O2R)
 - Support growing private sector activities to fill data and technology gaps and provide value-added services and products
- Integrating approach and collaboration



Driving Operational and Strategic Changes in the National Space Weather Program



Transformation of space weather from a research-focused activity to a National operational priority



2005: Space Environment Center in NOAA's Office of Atmospheric Research becomes Space Weather Prediction Center and transitions to National Weather Service (NWS)



2013: NWS space-weather vision presented to OSTP and President's Council of Advisors on Science and Technology (PCAST). NWS objectives identified:

- Increase the accuracy and timeliness of space-weather observations and forecasts
- Supporting decision-making to enhance the resilience of critical infrastructure to the adverse effects of space weather on the people, economy, and security of the Nation



2014 - 2016: White House charts Space Weather Operations, Research, and Mitigation (SWORM) Task Force - develops a National Space Weather Strategy and Action Plan - releases Executive Order



2019: White House releases new Strategy and Action Plan and Executive Order directing NOAA and DOD, working with private sector as appropriate, to provide operational observations and forecasts of space weather

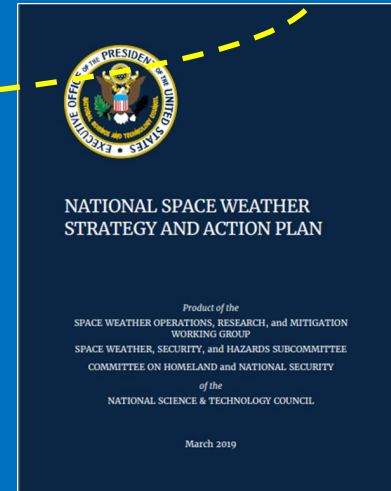


The 2019 Strategy and Action Plan seeks to achieve three objectives to enhance the Nation's resilience to space weather:

- Enhancing the protection of national security, homeland security, and commercial assets and operations against the effects of space weather
- Developing and disseminating accurate and timely space weather characterization and forecasts
- Establishing plans and procedures for responding to and recovering from space weather events.



Driving towards a resilience-based outcome!



The Strategy and Action Plan (NSW-SAP)

Identifies strategic objectives and high-level actions necessary to achieve a space-weather-ready Nation

NSW-SAP		
Objective 1 Actions	Objective 2 Actions	Objective 3 Actions
8	11	5

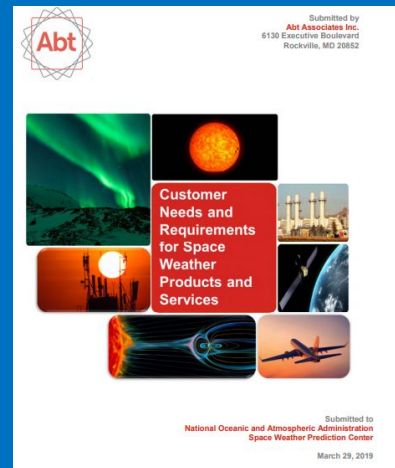
The SWORM Interagency Working Group, comprised of 34 departments and agencies, developed an internal Implementation Plan with deliverables and timelines

NSW-SAP Implementation Plan		
Objective 1 Actions	Objective 2 IP Actions	Objective 3 IP Actions
34	41	13

88 actions in the Implementation Plan that support the 24 high-levels actions in the NSW-SAP – many interdependencies between the 88 actions

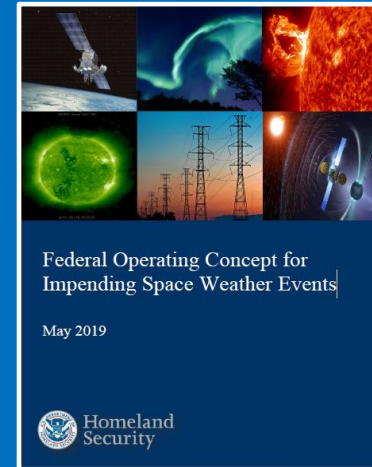
SWORM - Important Progress

- Conducted socioeconomic analysis of the consequences of a space weather event
- Surveyed and documented customer needs and requirements for space weather services
- Developed space weather benchmarks that quantify the intensity of an extreme space weather event
- Linked together:
 - *Mitigation needs* to operations, services, forecasts
 - Research and modeling to *forecast needs*
 - *Observation requirements* for operations and research



SWORM - Important Progress

- Space weather included in national risk assessment documents
 - National Threat and Hazard Identification and Risk Assessment
- FEMA releases Federal Operating Concept for Impending Space Weather Events
 - Federal agencies must develop operational plans to prepare for space weather events
- Space weather incorporated into:
 - International, national, state, and local EM exercises
 - Aviation, daily operations of electric-grid, ...



SWPC now supporting a space weather paradigm similar to terrestrial weather to address user needs

Observations: Collecting and providing critical, real-time, continuous, operationally-dedicated space weather data and imagery for alert, watch, and warning services, and predictive modeling systems

Modeling and R2O2R: Introducing a formal framework that incorporates the contributions from industry, agency, and academic partners

- Test and evaluate emerging science that may contribute to operations
- Accelerate the transition of new models/research results into operations
- Enable the improvement and maintenance of existing operational models

Forecasts, Watches, and Warnings: Providing regional and local specification and forecasts of space weather hazards, using indices and products suitable for objective decision-making



Providing the Nation with space weather forecasts, warnings, and data critical to public safety, disaster preparedness, and the protection of the Nation's critical infrastructure

Old paradigm
Reliance on research observations
R2O2R to ad hoc, no formal work, lacked input
Reliance on global indices

Critical Observations to Support Operations and Validate Research

GONG – NOAA now supporting the operations and maintenance of the six GONG observatories

- SWPC working with NSF/NSO to operationalize processing of GONG data

Ground-based Magnetometers - USGS

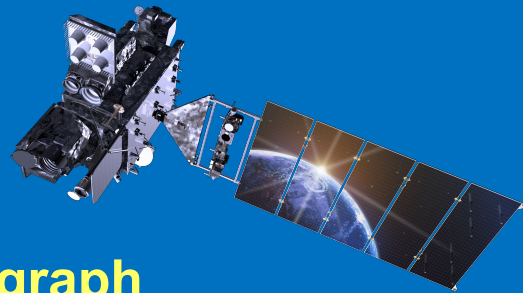
- Critical input to SWPC's geomagnetic storm warnings and alerts
- Funding for the magnetotelluric (MT) survey was included in the USGS Geomagnetism Program's FY 2020 appropriation; funding for the second year of the survey is included in the President's FY 2021 budget request - on course for 2023 completion
- New NOAA-USGS Geoelectric Field model relies on MT data

Critical Observations to Support Operations and Validate Research

GOES-16 operational as of Dec 2019

GOES-17 operational mid-FY21

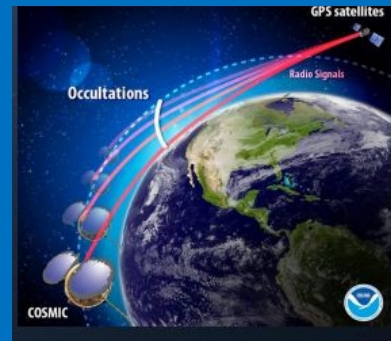
- instruments: EXIS, MAG, SEISS, SUVI



Space Weather Follow-On + Operational Coronagraph

- Rideshare to L1 with NASA's Interstellar Mapping and Acceleration Probe (IMAP) mid-2024
- FY20 appropriation bill includes \$64 million
- Host coronagraph on GOES-U, launch in 2024

COSMIC-2A - six satellites in low-inclination orbits launched in June 2019



More tomorrow from Steve Volz, NOAA Assistant Administrator for Satellite and Information Services

Critical Observations to Support Operations and Validate Research (Continued)

NOAA Commercial Weather Data Pilot

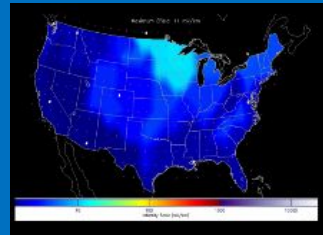
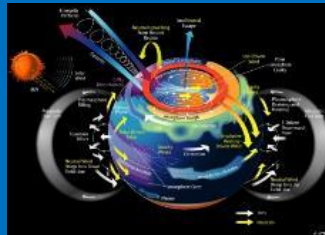
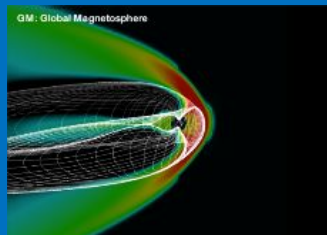
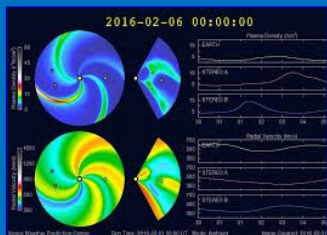
- June 2020 - NOAA concluded that commercial sector is able to provide radio occultation data that can support NOAA's operational products and services
- Aug 2020 - NOAA released a Request for Proposal for the first purchase of space-based commercial RO data

More tomorrow from Steve Volz, NOAA Assistant Administrator for Satellite and Information Services

Identified and released underutilized data sets

- 2017: The DOD and DOC made historical particle data from the GPS constellation publicly available
- 2020: *Working now to release LANL particle data from DOD geo satellites and LANL TEC data from GPS satellites*

Operational Space Weather Modeling at NOAA – A Sun-to-Earth Continuum



GMU/AFRL
WSA/Enlil

Understand the structure of the solar wind as it propagates from the Sun to Earth

Operational 2011
Upgraded 2019

U. Michigan
Geospace

Understand the geomagnetic response to changes in solar wind; provide regional predictions of geomagnetic storms

Operational
Sept 2016

NOAA/CIRES
WAM-IPE

Understand details in the mesosphere, exosphere, and ionosphere, to understand links between the lower and upper atmosphere

Now in real-time
(experimental)

NOAA/USGS
E-field

Characterize and predict the regional electric field and the associated currents that impact electric power grids

Operational
Sept 2019

The space weather community working together on a modeling framework that captures critical domains of the Sun-Earth system, beginning at the Sun and ending at the Earth's surface..

Supporting a space weather watch/warning paradigm similar to terrestrial weather...



Build off successes in the development of research models in the academic community and transition to operations

May 2019: SWPC implemented WSA-Enlil heliospheric model v2.0 (the first upgrade since the initial implementation in late 2011)

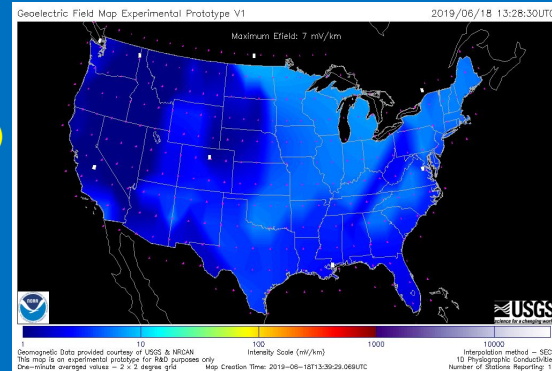
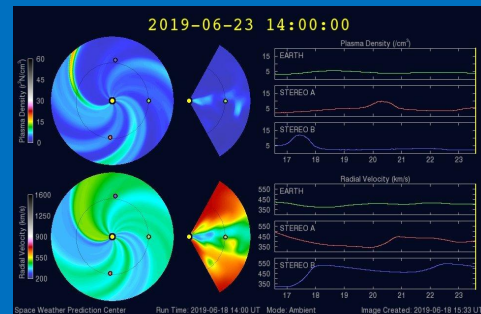
- Improved accuracy of the ambient solar wind = improved CME forecast

Jun 2020: SWPC introduced 3-D conductivity joint NOAA-USGS Geoelectric-field model

- Improves geographic granularity of geoelectric field evolution

“This will allow us to start developing tools for the control room; exactly what we needed” - PJM Interconnection (serving 65 million customers)

Nov 2020: Geospace Model v2.0 will be implemented and will provide higher resolution and better regional predictive capabilities



Research-to-Operations-to-Research (R2O2R)

SWORM Action: “Identify mechanisms for transitioning and sustaining models and observational capabilities from research to operations...that will include academic, private sector, and international partnerships”

Identify an effective R2O2R process for space weather:

- Partnerships with Government Agencies (NOAA, NASA, and NSF), Academia, Private Sector, International Partners
- Includes Community Coordinated Modeling Center (CCMC) at NASA GSFC in R2O partnership, priorities, and process
- New Space Weather Capabilities Research-to-Operations (R2O)
 - Evaluate, Prototype, Transition within space weather testbed at SWPC
- Operations-to-Research (O2R)
 - Continuous improvement of the existing operational models
 - Informs future capabilities
 - Establishes research priorities



NASA
CCMC

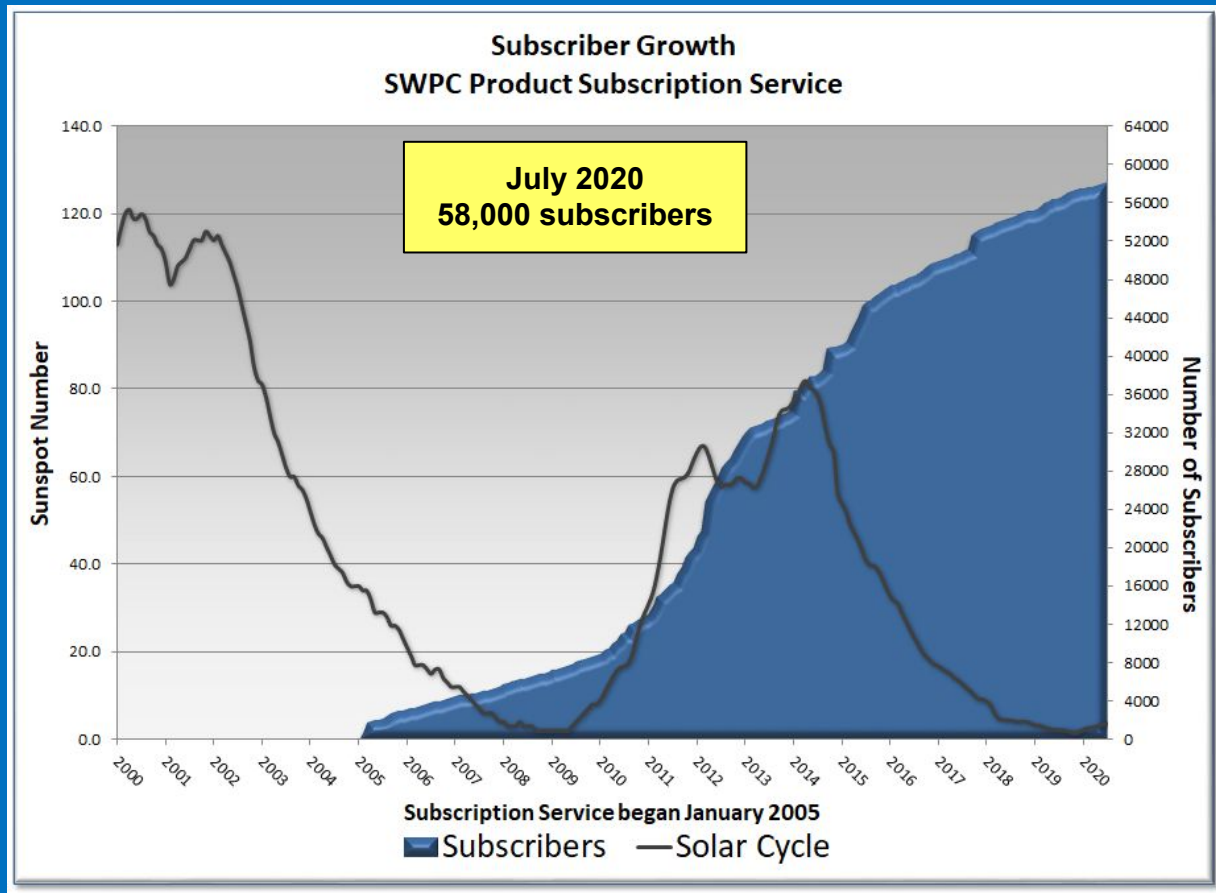
NWS
SWPC



Capabilities

- ✓ Products
- ✓ Models
- ✓ Observations
- ✓ Applications
- ✓ Techniques

SWPC Product Subscription Service - Subscriber Growth



Average 130 new subscribers per month through solar minimum

Interest surges during space weather outbreaks, e.g., Sep 2017, 4 large flares = 1550 new subscribers

A Space Weather-Ready Nation

Building a Nation Ready, Responsive, and Resilient to Space Weather

*Continued research,
Improved understanding
with new modeling
and R2O2R capability*

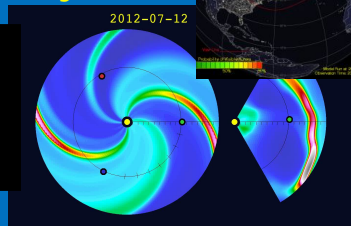
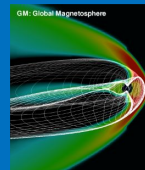
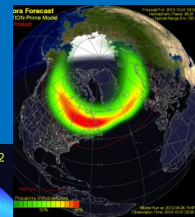
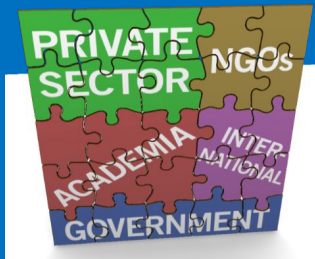


Critical observations



Operationally Supported

*Partnerships –
Involves the entire
US Space Weather
enterprise working
together*



*Better information connected to key stakeholders
for better decisions - enhance National resilience*



Thank you!





Additional Slides

Impacts and preparedness drove the need for a National Strategy

The initiation of the Space Weather Observation, Research, and Mitigation (SWORM)

1. Establish **Benchmarks** for Space-Weather Events
2. Enhance **Response and Recovery** Capabilities
3. Improve **Protection and Mitigation** Efforts
4. Improve Assessment, Modeling, and Prediction of **Impacts on Critical Infrastructure**



Understand, prepare, and mitigate



5. Improve Space-Weather Services through **Advancing Understanding and Forecasting**
6. Increase International Cooperation



Facilitate operational readiness and improve decision making



Driving towards a resilience-based outcome!

“The focus of space weather activities must evolve as the Nation reinvigorates its human space exploration program, reinforces the importance of space-based capabilities for critical national functions and security, and enhances its overall resilience.” - *Kelvin Droegemeier, Director, Office of Science and Technology Policy, March 2019*

26 March 2019

- Updated National Space Weather Strategy and Action Plan
- New Executive Order on Coordinating National Resilience to Electromagnetic Pulses
 - With over 50% of 2015 action plan complete - time for update
 - Better defines some of the remaining 2015 actions
 - Aligns with new policy and priorities (e.g., Space Policy Directives)
 - Executive order also released covering both adversarial and natural (geomagnetic storm) electromagnetic pulse

