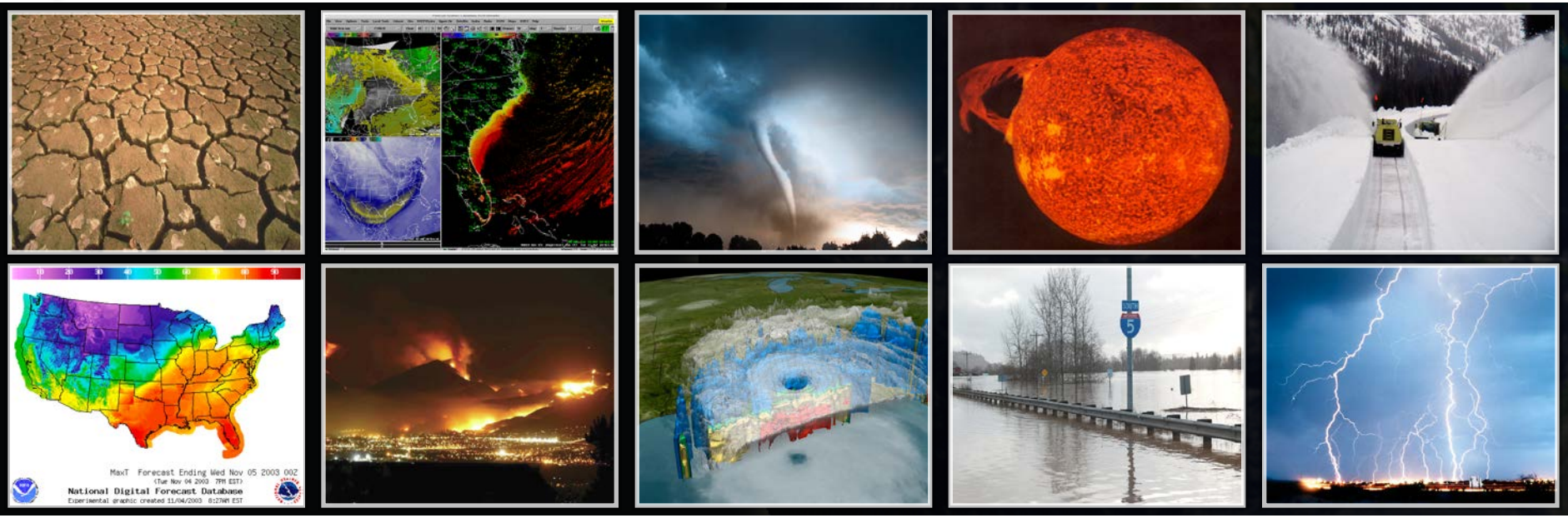
The National Weather Service:
Space Weather Prediction Center Update



Dr. William M. Lapenta
Director, National Centers for Environmental Prediction
NOAA/National Weather Service
Committee on Solar and Space Physics
06 October 2016

NWS Strategic Outcome:
A Weather- and Water-Ready Nation

"Ready, Responsive, Resilient"

Becoming a Weather-Ready Nation is about
building community resiliency in the face of increasing vulnerability to extreme weather, water and climate events

Better forecasts and warnings

Consistent products and services

Actionable environmental intelligence

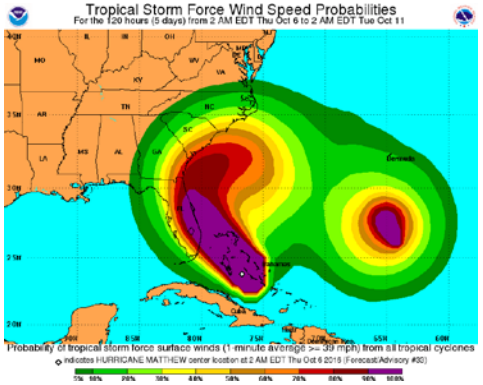
Connecting forecasts to decisions

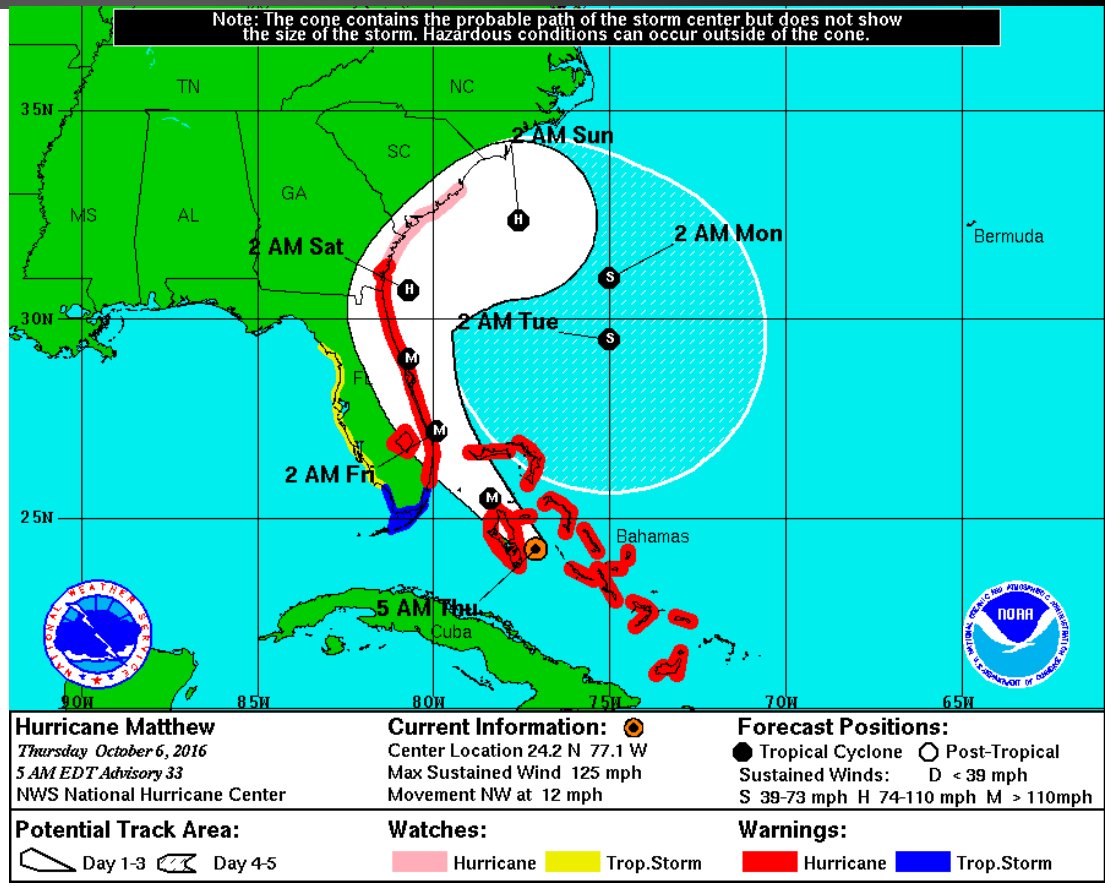
Involves the entire US Weather, Water and Climate Enterprise WORKING TOGETHER

We have 3460 WRN Ambassadors

Tom Geyer: The $$ Chart

- What's happening?
- What's the impact?
- What are the proposed courses of action?
- What are the risks?





- **COMMUNICATION** with decision makers: "we don't want a map discussion"
- Impact-based Decision Support Services (IDSS): going the last mile!

The Job Doesn't End with Forecasts and Warnings

"What is a Good Forecast? An Essay on the Nature of Goodness in Weather Forecasting"

by Allan H. Murphy; Weather and Forecasting (June 1993)

"First, it should be understood that forecasts possess no intrinsic value. They acquire value through their ability to influence the decisions made by users of the forecasts."

January 2016 Blizzard & Costal Storm: Connecting All of the Pieces

Jan 15 - 18

Medium range products begin identifying heavy snow threat for the end of next week

NWS offices begin briefing partners on potential storm

Jan 19

Confidence increasing

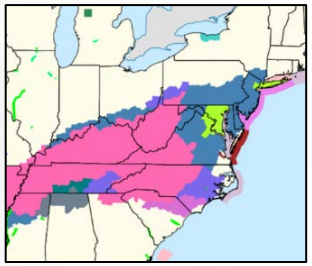
Partner Coordination/ Briefings

Media interviews

Jan 20

Partner Coordination/ Briefings

Blizzard Watches Issued



Media interviews

Jan 21

Fed./state/local govts make critical decisions ***before*** the snow begins

State of Emergency Declared:
- North Carolina
- Virginia
- West Virginia
- District of Columbia
- Maryland
- Pennsylvania
- New Jersey
- New York

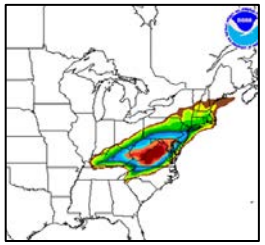
Blizzard Warnings Issued

1 pm: Press Briefing

Jan 22

Snow begins in the Mid-Atlantic

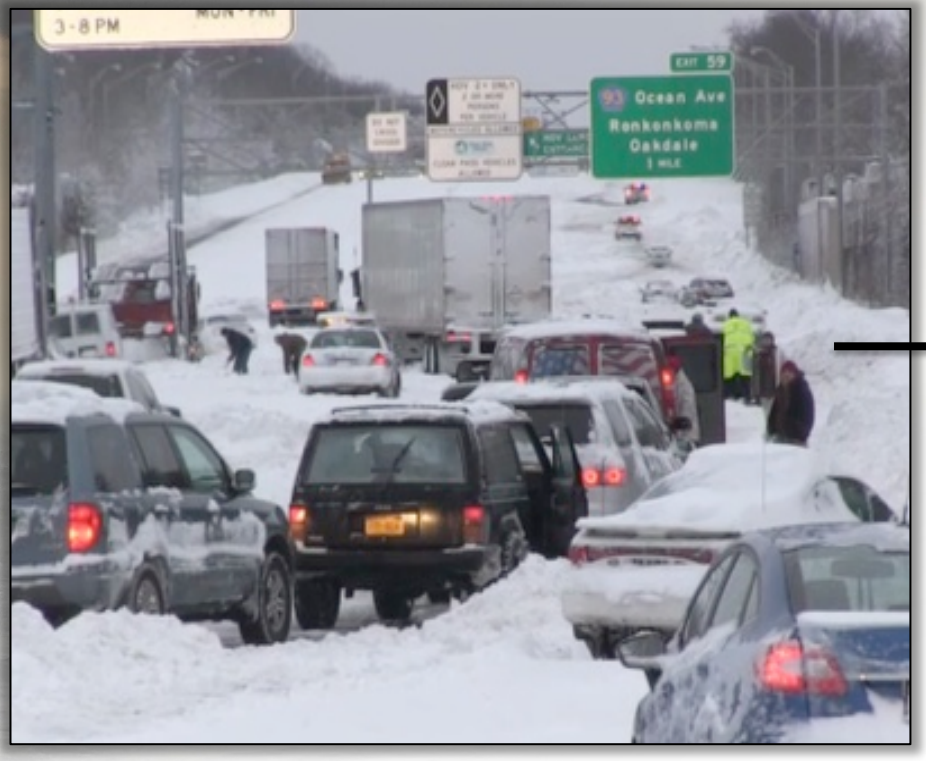
Snow forecast adjusted to include NYC in Blizzard Warning



Schools/Govt Close
Flights Canceled
Roads Closed

January 2016 IDSS Example: Long Island Expressway comparison to 2013

2013 Snowstorm



2016 Snowstorm

The Past

With NWS Impact-Based Decision Support Services (IDSS)

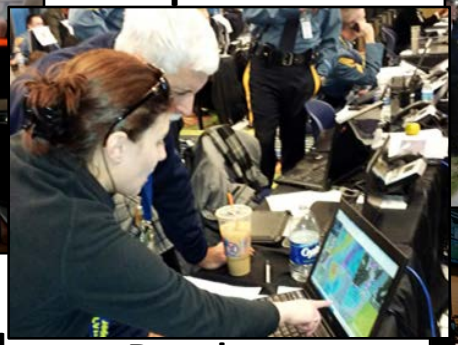
Realizing Intrinsic Value

Intrinsic Value is realized through providing Impact-Based Decision Support Services (IDSS)

Generating forecasts and warnings + Connecting those forecasts/warnings with impacts = IDSS

The best hydrometeorological forecasting in the world

Practice, practice, practice!



Develop relationships/ know partner needs

Trust

"Ready, Responsive, Resilient"

Operational Space Weather Forecasting

SWPC Space Weather Scales:

Radio Blackouts

			GOES X-ray peak brightness by class and by flux*	Number of events when flux level was met; (number of storm days)
R 5	Extre	HF Radio: Complete HF (high frequency**) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector.	X20 ($2x10^{-3}$)	Fewer than 1 per cycle
R 4	Sever			
R 3	Strong			
R 2	Mode			
R 1	Minor			

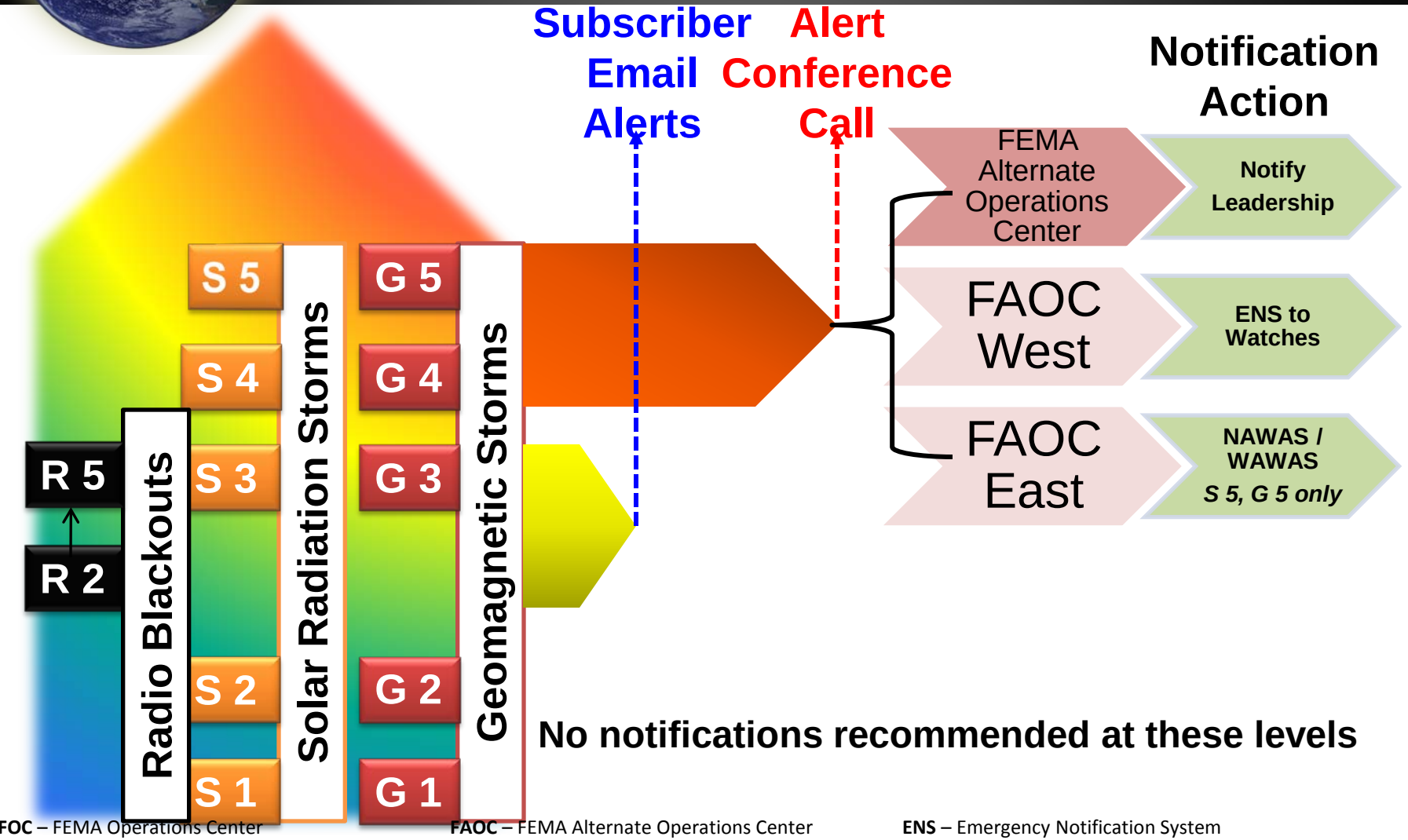
Solar Radiation Storms

			Flux level of ≥ 10 MeV particles (ions)*	Number of events when flux level was met**
S 5	Extreme	Biological: unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. ***	10^5	Fewer than 1 per cycle
S 4	Severe	Biol high Sate prob Othe over		
S 3	Strong	Biol airc Sate pane Othe		
S 2	Moderate	Biol risk. Sate Othe poss		
S1	Minor	Biol Sate Othe		

Geomagnetic Storms

Category		Effect	Physical measure	Average Frequency (1 cycle = 11 years)
Scale	Descriptor	Duration of event will influence severity of effects		
			Kp values* determined every 3 hours	Number of storm events when Kp level was met; (number of storm days)
G 5	Extreme	Power systems: widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. Spacecraft operations: may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. Other systems: pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.).**	Kp=9	4 per cycle (4 days per cycle)
G 4	Severe	Power systems: possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. Spacecraft operations: may experience surface charging and tracking problems, corrections may be needed for orientation problems. Other systems: induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.).**	Kp=8	100 per cycle (60 days per cycle)
G 3	Strong	Power systems: voltage corrections may be required, false alarms triggered on some protection devices. Spacecraft operations: surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. Other systems: intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.).**	Kp=7	200 per cycle (130 days per cycle)
G 2	Moderate	Power systems: high-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. Spacecraft operations: corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. Other systems: HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.).**	Kp=6	600 per cycle (360 days per cycle)
G 1	Minor	Power systems: weak power grid fluctuations can occur. Spacecraft operations: minor impact on satellite operations possible. Other systems: migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine).**	Kp=5	1700 per cycle (900 days per cycle)

FEMA Alerts and Notifications



FOC – FEMA Operations Center
NAWAS – National Warning System
FAOC – FEMA Alternate Operations Center
WAWAS – Washington Metropolitan Area Warning System
ENS – Emergency Notification System

SWPC Impact-based Decision Support Services & Partners

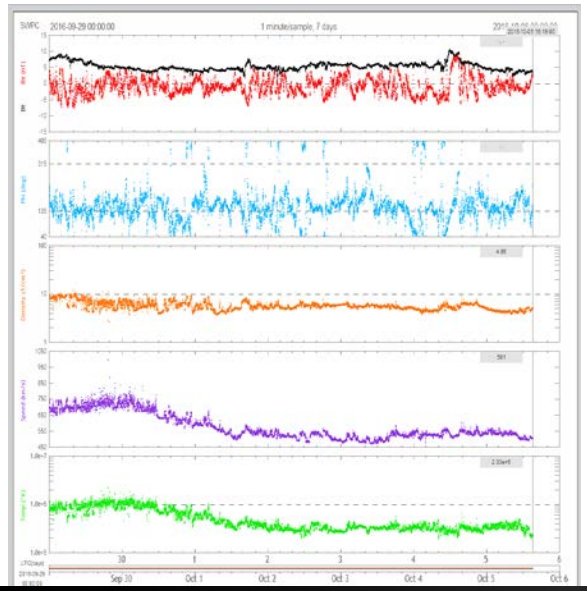
- **Government:** SWPC interacts closely with FEMA, North American Electric Reliability Corporation (NERC), USAF, NASA, FAA, USGS and regional emergency mangers for DSS
- **Electric Power Grid Operators:** Use geomagnetic storm detection and warning system to maximize power grid stability and to mitigate power grid component damage and large-scale blackouts.
- **Communications Operators:** Anticipate and react to space weather over a wide range of communications frequencies used by emergency management officials, search and rescue systems, and many others.
- **Aviation:** Use crucial information on space weather impacts, such as communication outages, potentially harmful radiation, and navigation errors to adjust routes and altitudes.
- **Spacecraft Operations:** Rely on space weather products to ensure spacecraft survival from electronic problems.
- **Navigation Systems:** Users need space weather data as a critical input to ensure the integrity and safe use of electronic (i.e., GPS) based navigational systems.

Deep Space Climate Observatory (DSCOVR) Update

DSCOVR was declared operational by NOAA on 27 July 2016

All Instruments now performing nominally

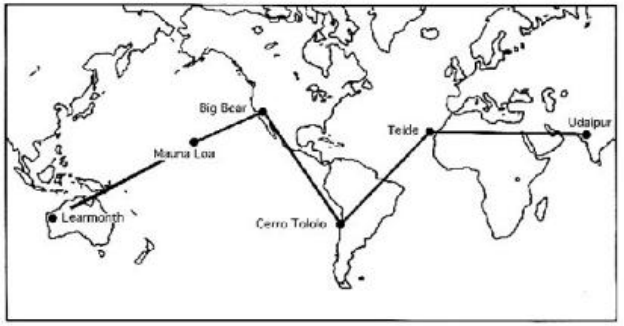
- Magnetometer continues to provide very good data
- Faraday cup now performing very well after additional calibration and signal processing efforts – This is what we wanted to get right before declaring operational



- NOAA/SWPC has been utilizing DSCOVR in its forecast operations and models since the 27 July 2016 switch from ACE
- ACE data continue to be made available from DLR (Germany) and NOAA Wallops on a best effort basis
  - SWPC has committed to process and make available ACE data whenever it is delivered to us in real-time
  - We do experience 8+ hour outages over the Pacific sector

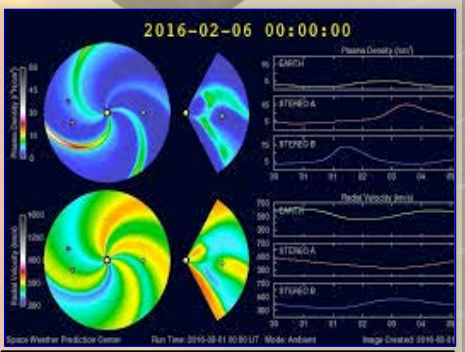
Global Oscillation Network Group (GONG): Transition to Operations

- GONG is operated by the NSO and funded by the NSF for research (not operational)
- The Global Oscillation Network Group (GONG) solar data is critical for SWPC operations
  - Critical magnetogram data set for WSA-Enlil
  - Important H-alpha imagery for forecasters
- NWS is funding NSF and NSO to keep real-time GONG data flowing
- SWPC will take over the real-time data processing and move it to an operationally supported environment



SWPC Operational Model Suite

Tracking solar storms from "Sun to Mud"



GMU/AFRL WSA/Enlil

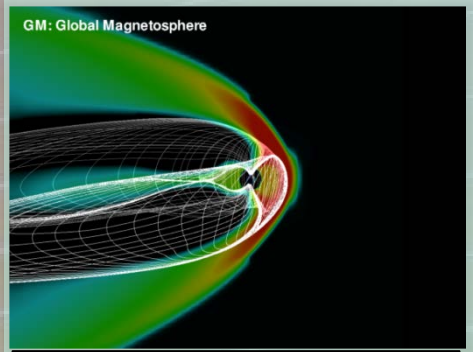
Inputs:

1. GONG solar magnetic field data
2. SOHO/LASCO coronagraph CME images from L1

Validation:

1. DSCOVR solar wind character at L1
2. GOES magnetometer shock arrival

Operational



U. Michigan Geospace

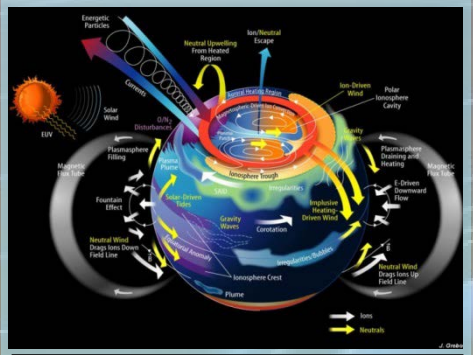
Inputs:

1. DSCOVR solar wind density, temp, speed, mag field at L1
2. Solar F10.7 radio flux measurements

Validation:

1. GOES vector magnetic field
2. USGS magnetometer network

Operational



NOAA/CIRES WAM-IPE

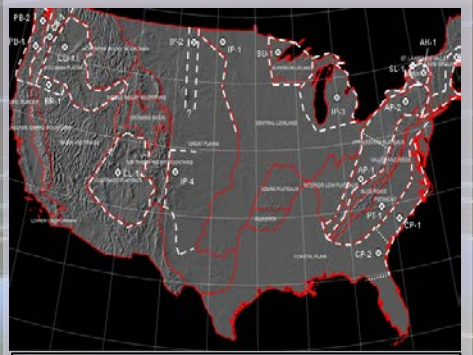
Inputs:

1. GFS Tropospheric weather model inputs
2. GOES Solar EUV flux
3. COSMIC-2 RO electron density
4. Geomagnetic storm data from Geospace

Validation:

1. GPS receiver network TEC measurements

Operational FY17-19



USGS/NOAA E-field

Inputs:

1. USGS lithospheric conductivity model
2. USGS magnetometer network

Validation:

1. USGS geoelectric field measurements.

Operational FY16-17

Note: all models developed with NASA and/or NSF funding at some level.

GOES R: Space Weather Sensor Improvements

- **Solar Imagery:**
  - Moving from X-ray to EUV wavelengths, higher resolution, higher cadence (Improved identification of solar features and better forecasts of impacts at Earth)

- **Solar X-Ray and EUV Irradiance:**
  - Larger dynamic range (won't saturate for large flares. Extreme event capabilities)
  - Higher accuracy (calibrated at NIST for improved specification and forecasts of impacts)
  - Flare location (Quad diode provides fast identification of flare location for improved inputs into models)
  - Broader spectral coverage at higher spectral resolution (more accurate inputs into atmosphere/ionosphere models)

- **Energetic Particle Sensor:**
  - Expanded energy range (diagnosing spacecraft surface charging)
  - Improved electron energy and angular resolution (diagnosing satellite internal charging)
  - Improved solar proton energy resolution (Improved Solar Radiation Storm Characterization)
  - Heavy ion coverage expanded (diagnosis of satellite single event upsets)

- **Magnetometer:**
  - Higher sampling rate and lower frequency cut-off (more accurate data to use in models)

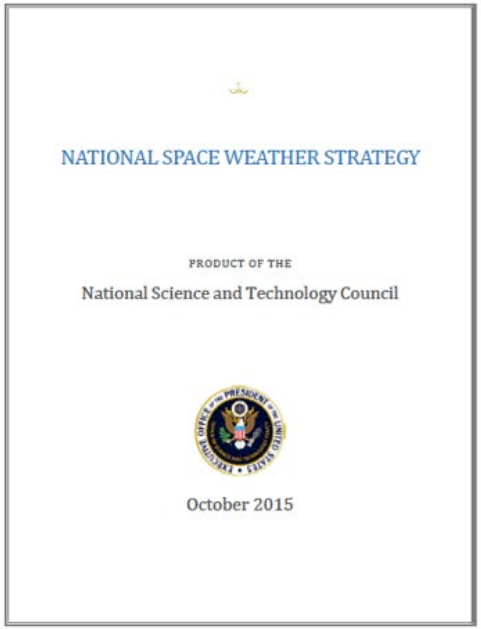
- **Launch Date – 04 November 2016**

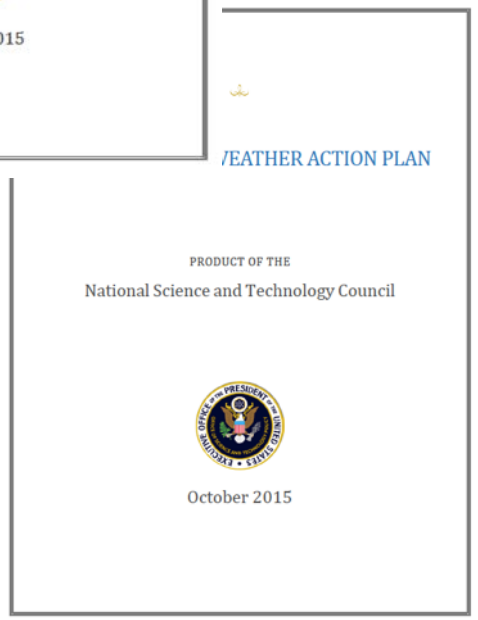
Space Weather Follow On (SWFO)

- Intended replacement of DSCOVR plus an operational coronagraph
- NOAA FY17 Budget Blue Book (http://bit.ly/2dtvMD9)
  - Two satellites, two launch vehicles
    - Solar wind instruments: magnetic field; thermal plasma; suprathermal ions
    - Compact coronagraph (NRL - CCOR)
  - Program total budget ($757M)
  - First launch 2022
- Independent Study Team (IST)
  - Assisting NESDIS by providing findings on concepts developed in 2014
  - Report delivery due in Dec 2016
  - 2017 NESDIS to make decision on procurement
- Coronagraph mitigation plans
  - Concerns about SOHO lifetime and coronagraph continuity
  - NOAA investigating but not yet budgeted for a stop-gap coronagraph
  - IST reviewing NRL plans for CCOR development as well as stop gap flight options
    - CCOR in Phase A – completion March 2017
    - NOAA RFI (http://bit.ly/2dvlemq) for CCOR hosted payload opportunities by 2019
    - Responses due 17 Oct 2016

Summary of Space Weather Action Plan (SWAP)

- **SWAP specifies 96 total actions**
- **NOAA involved in 73 of 96 actions**
  - **NWS/SWPC is involved in all 73 these to varying degrees**
- **SWPC has the lead on 30 actions due within 6—36 months (or continuing activity)**



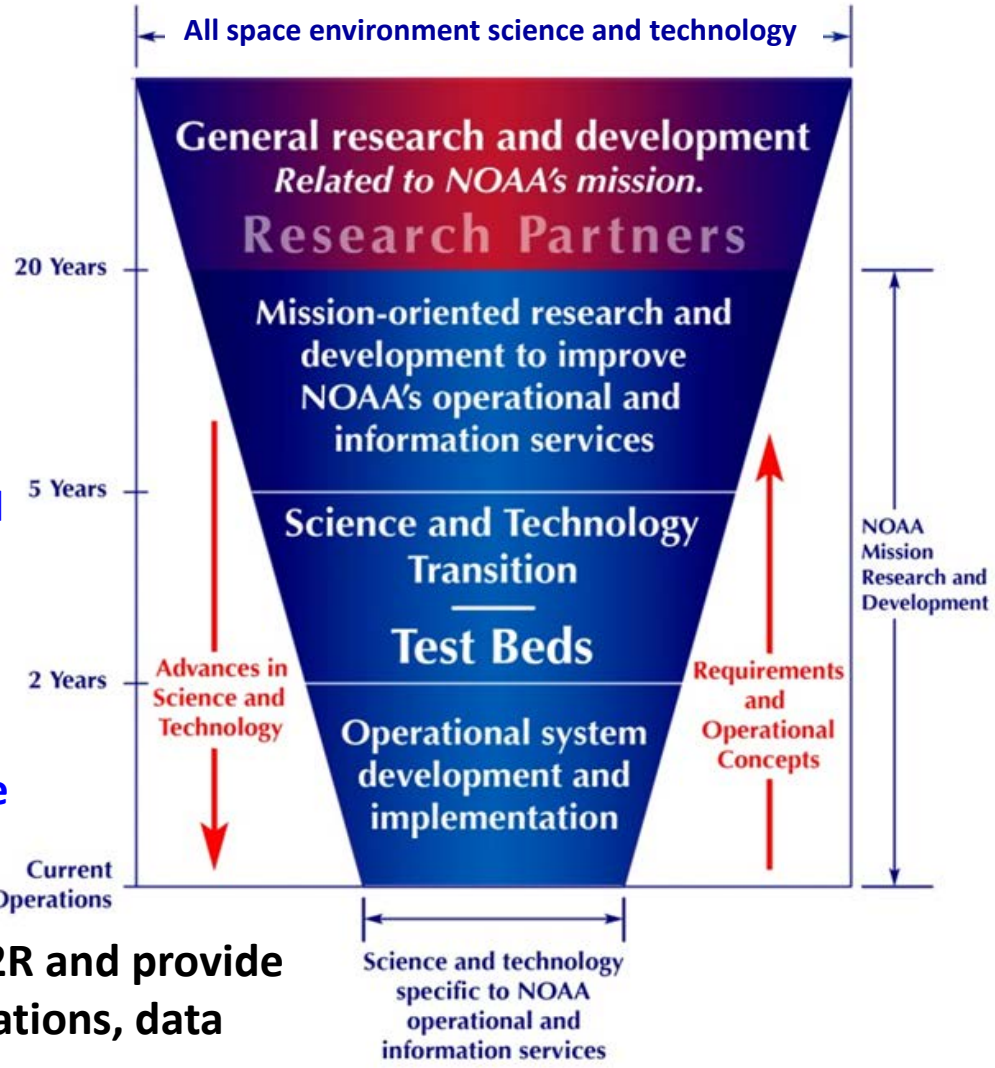


[SWAP Action 5.6]

Example: The NOAA Research to Operations Funnel

Basic Research Applied Research Operations

- **The R2O Funnel:**
  - Enhances the transfer of scientific advances and technology into operational and information services
  - Leverages research and development from multi-agency programs
  - Establish and improve operational observations and modeling/prediction systems
  - Enables NOAA operational requirements and concepts to inform research priorities atop the funnel



To accelerate R2O, need to support O2R and provide research access to operational observations, data assimilation and modeling system.