Headquarters U.S. Air Force

Fly – Fight – Win

Space Weather Enterprise Forum 2009

AF/A3O-W

Dr Fred Lewis

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Overview

- **Bottom Line Up Front**
- **Space Weather Information Flow**
- **Space Weather Impacts**
- **Space Weather Roadmap / Initiatives**
- **What We Still Need**
- **Summary**

National Partners working to provide timely & actionable space weather support for the warfighters and the Nation

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Bottom Line Up Front (BLUF)

- **Space environment mission improvements to support SSA**
  - **AFSPC and AF/A3O-S/W working in partnership to address needs across AFSPC SSA and AF Wx Weapon System (AFWWS)**
    - **AFSPC SSA: Space based sensors & Data exploitation (ISSA)**
    - **AFWWS: Ground-based sensors, models, net-centric database**
  - **Exploit data from existing infrastructure & national/international partners**
  - **Formalize space weather training and professional development**
- **A3O-W published Space Wx Implementation Plan in Mar 08**
- **AFSPC, A3O-W, A3O-S, 14AF, AFWA, and National Partners concluded ICT to develop end-to-end implementation plan for way ahead … Plan documented in SSA Interim Architecture**
- **OFCM leading interagency CSESMO (Committee for Space Environment Sensor Mitigation Options) effort for OSTP … developing options for DMSP and ACE space sensors plus analysis/forecast model software**

BLUF: Space Wx Capability for SSA

Today & Circa 2017

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Today: Space-Based & Ground-Based Measurement Plus Modeling Capabilities

1 DMSP
2 ACE/SOHO
3 GOES
4 GPS
5 DSP
6 NPOESS
7 C/NOFS
8 SOON
9. RSTN
10 DISS
11TEC
12 SCINDA
13 Geomag

Space Weather Parameter (% Space-based / Ground-based contribution)	Example Mission Supported	Observing Capability (Threshold SSA)	Forecasting Capability (Objective SSA)
Ionospheric Electrons (50%/50%) 1, 2, 7, 10, 11, 12 ,13	Geolocation		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 10, 11, 12 ,13	Communications		
Energetic Particles (80%/20%) 1, 2, 3, 4, 5, 6, 7, 13	Satellite Ops		
Radiation & Disturbances (70%/30%) 1, 2, 3, 4, 5, 6, 7, 10, 11, 12 ,13	Space Track		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 10, 11, 12 ,13	Navigation		

Good (>75%) Moderate (50-75%) Marginal (25-50%) Little or None (0-25%)

Circa 2017: Fund both Space-Based & Ground-Based Measurement Plus Modeling Capabilities

1 DMSP/SES*
2 ACE/SOHO FO
3 GOES
4 GPS
5 DSP
6 NPOESS
7 C/NOFS
8 ISOON/GONG
9 RSTN II
10 NEXION
11TEC
12 SCINDA
13 Geomag

Space Weather Parameter (% Space-based / Ground-based contribution)	Example Mission Supported	Observing Capability (Threshold SSA)	Forecasting Capability (Objective SSA)
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*SES– SSA Environment Sensing … DMSP Space Wx Sensor Follow-on

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Space Weather Warfighter Impacts

X-Rays, EUV, Radio Bursts

- SATCOM Interference
- Radar Interference
- HF Radio Blackout
- Geolocation Errors
- Satellite Orbit Decay

Scintillation

- Degraded SATCOM
- Dual Frequency GPS Error
  - Positioning
  - Navigation
  - Timing

Proton Events

- High Altitude Radiation Hazards
- Spacecraft Damage
- Satellite Disorientation
- Launch Payload Failure
- False Sensor Readings
- Degraded HF Comm (high latitudes)

Geomagnetic Storms

- Spacecraft Charging and Drag
- Geolocation Errors
- Space Track Errors
- Launch Trajectory Errors
- Radar Interference
- Radio Propagation Anomalies
- Power Grid Failures

Space Weather Information Flow

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Environmental Inputs (DoD, Civil, International)

Observations Requirements

Data Received

AFWA – weather data ingest/analysis/prediction and product flow to the warfighter!

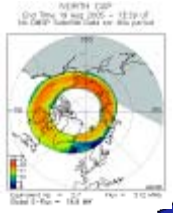
SWPC

Data & Products Provided

Space / Space Wx Operators

Teamwork

Tailored Products



AFWA: Space Wx support provider

2 WS Space Weather Flight

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Space-Based Sensor Options

Exploit current satellite systems space wx observing capabilities

- GOES, GPS, and other satellites
- C/NOFS and COSMIC follow-on operations

NPOESS Mitigation

- SSA Environmental Monitoring (SSAEM) proposed by AFSPC
  - Looking to buy sensors for rides-of-opportunity
  - DoD identifying funding … AFSPC leading requirements/concept development
- Currently enhancing NPOESS space environment monitor (SEM-N)… METOP component of NPOESS may not fly SEM

Advocacy to NOAA, NASA, etc.

- Need partnerships to collect from the rest of the space domain
- Need ACE replacement … OFCM/NOAA/NASA/DoD considering options for OSTP … CSESMO

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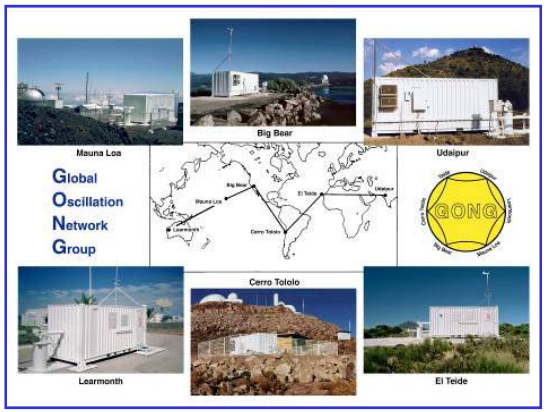
Ground Sensor Upgrades

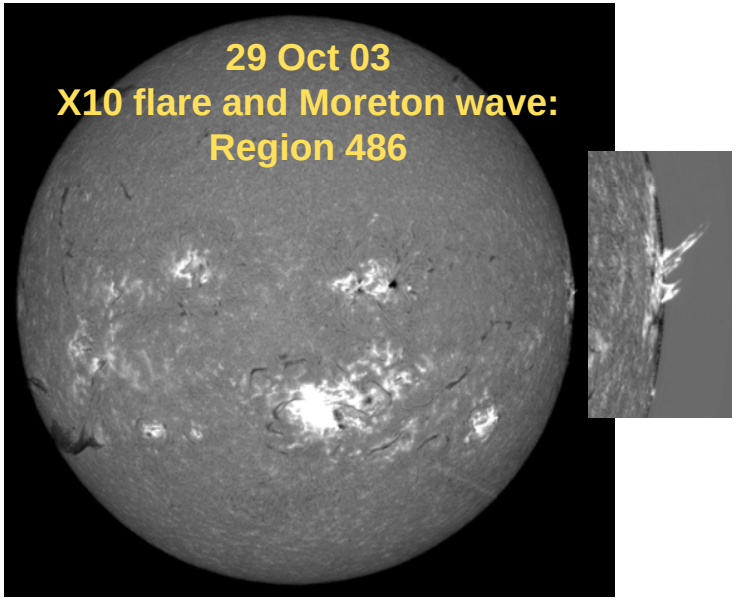
Ionosphere

- NEXION replaces DISS
- Leverage NSF, NOAA, international ionosondes
- Continue to use NASA JPL Total Electron Content (TEC) data

Solar Observing

- ISOON replaces SOON
- Radio solar sensor R&D
- Automate solar observing sites
- Leverage NSF GONG





ISOON

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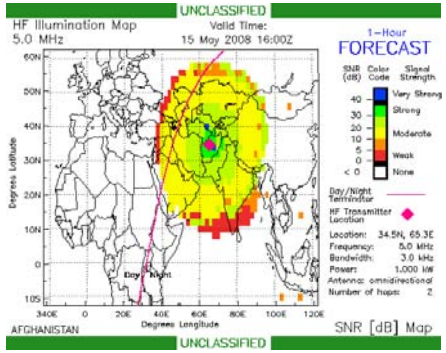
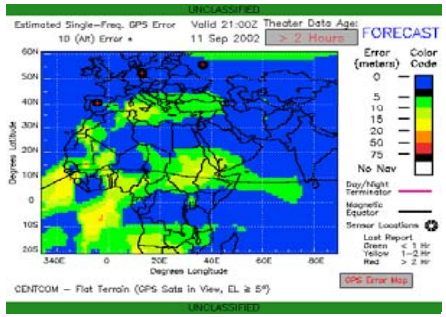
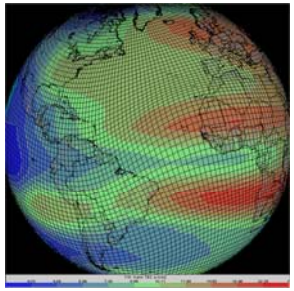
Modeling and Exploitation S/W Upgrades

- **Additional investments accelerate space wx analysis, forecast & exploitation capabilities … Directly enhances SSA for warfighters**
  - **Substantially increased investment in Space Weather Analysis and Forecast System (SWAFS)**
  - **AFSPC funding SSA Environmental Effects Fusion System (SEEFS) to provide JSpOC tool set to support ops assessments**
  - **Accelerating GAIM to enable full physics utilization of ionospheric data & produce more realistic forecasts**

GAIM Output







- **Investments provide Models, Apps, Graphics, Data Fusion, & Decision Aids to improve operational space weather support**

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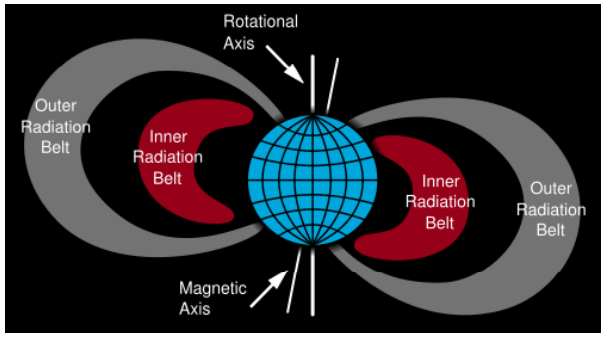
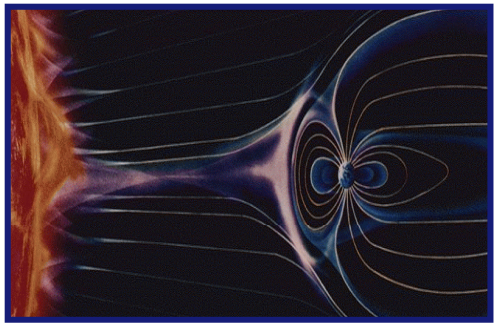
What We Still Need

- Physics-based models for scintillation, magnetosphere
- Improved flare forecast tool/model
- Improved CME forecast tool/model



- Improved proton prediction and dual frequency GPS error models
- Improved radiation exposure model (use with SWPC)
- Needed collections:
  - Top-side Ionosphere (DMSP follow on)
  - Solar wind (ACE follow-on)
  - Radiation storm belt probe and SDO



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Summary

- **Accelerated actions to prepare for solar max … and beyond**
- **OFCM, NOAA, NASA, DoD, and other National Partners working to determine way forward to support national space wx needs and SSA … CSESMO and other efforts**
- **Increased investment in ground-based sensor, modeling and exploitation capabilities**
- **Must ensure AF space wx expertise available in future**

Working with National Partners to support National Space Wx needs

Questions?

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Space Wx Training & Personnel Initiatives

Space Weather Training

- **Formalize internal AFWA space weather training course – already available to outside agencies**
- **Continue to provide space weather overview during Weather initial skills training**

Personnel

- **Revitalizing Advance Academic Degree program for space weather modeling and exploitation**
- **Space weather officers/enlisted will now participate in AFSPC Space Professional Development**

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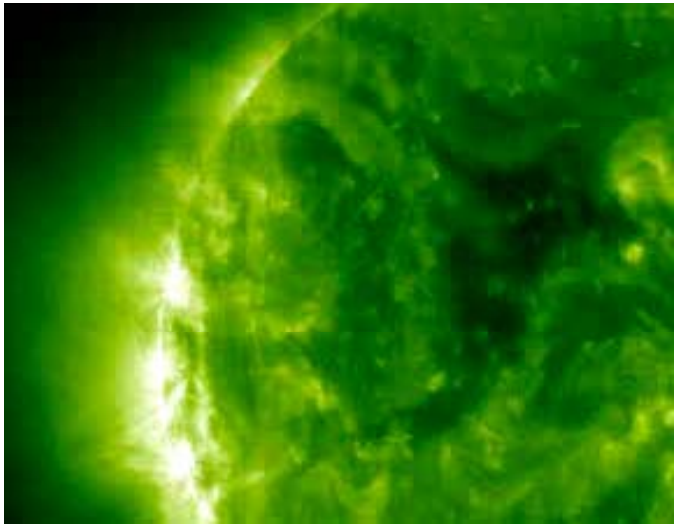
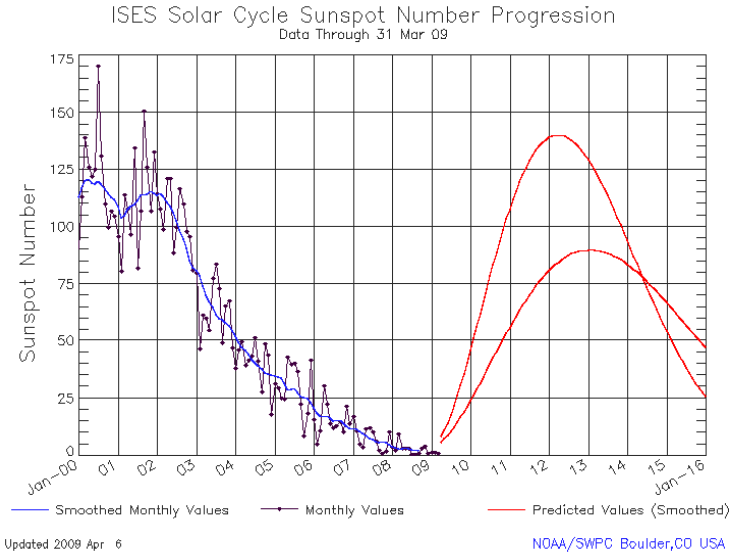
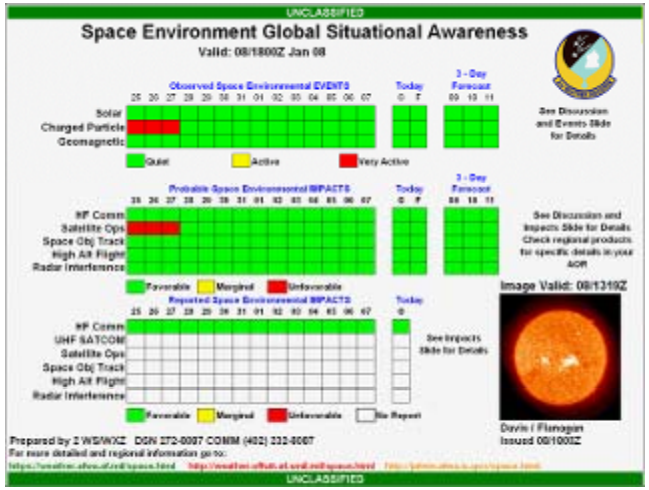
Space Weather Operations



2 WS/WXZ Space Wx Product



Halloween storms 2003



Solar Cycle 24

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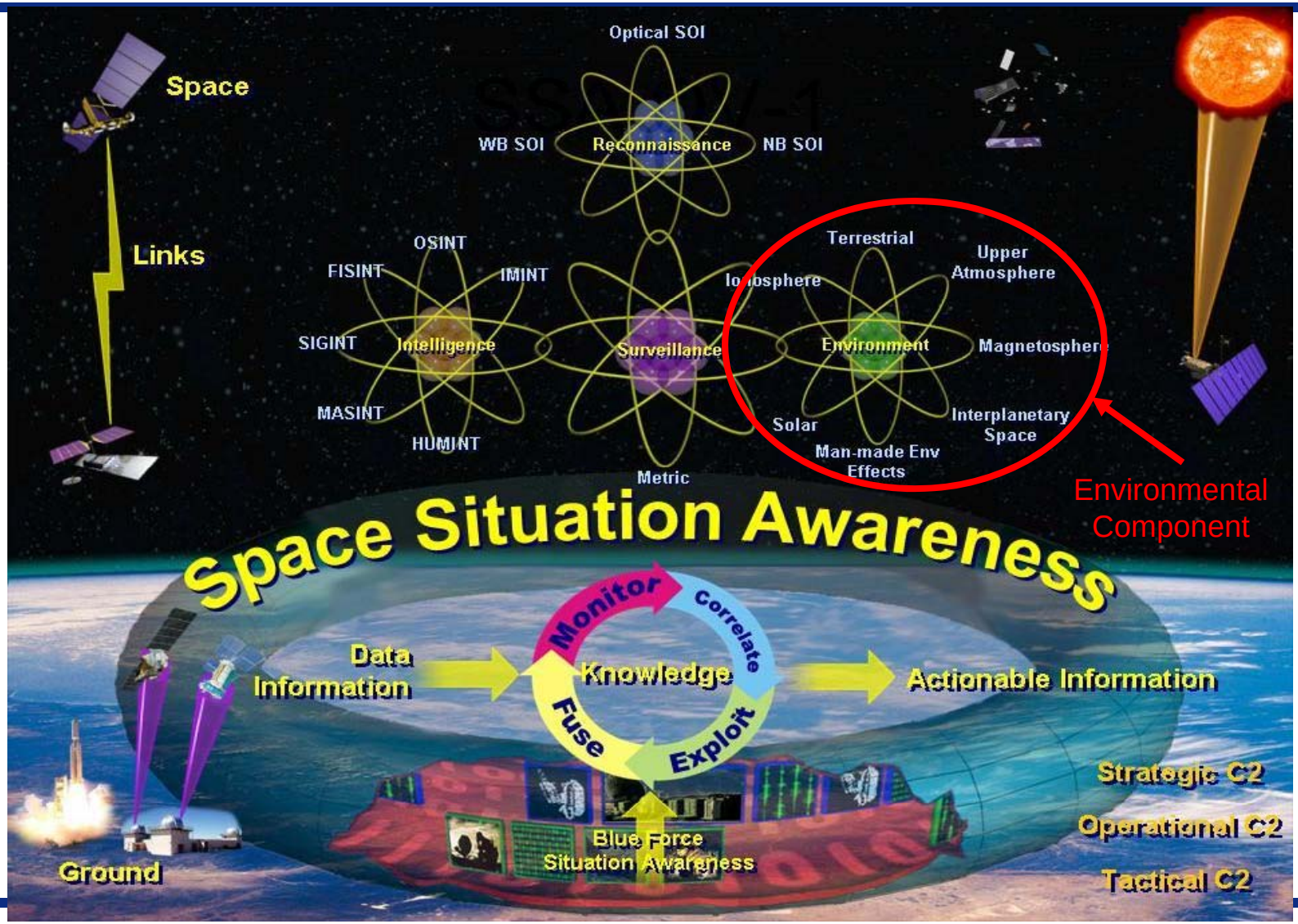
Space Situational Awareness Operational View



SSA: Space Weather Roadmap

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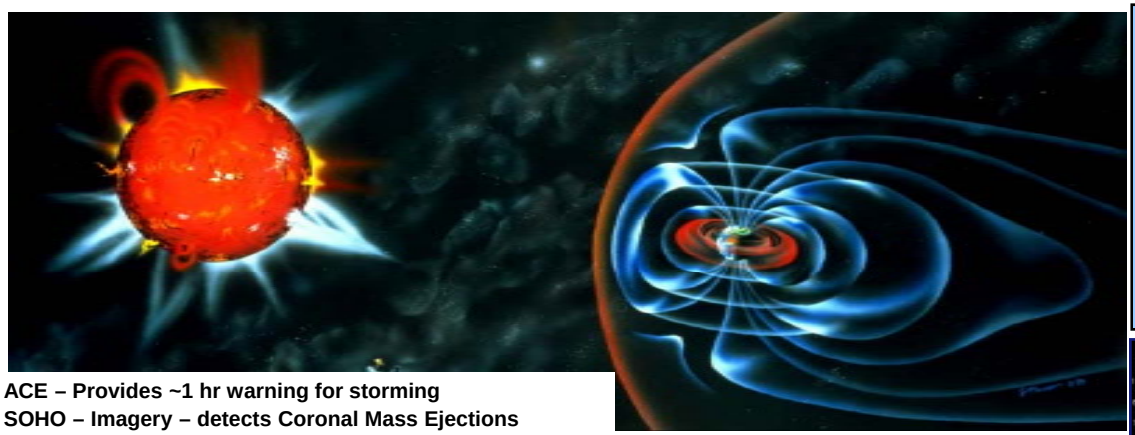
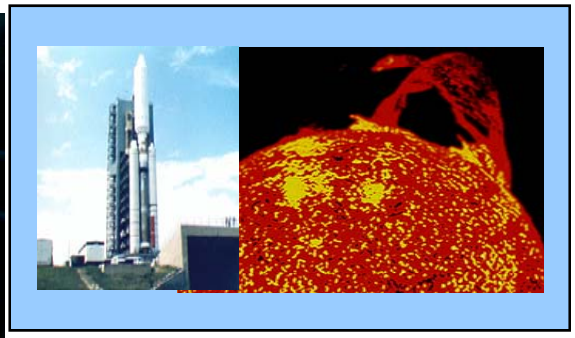
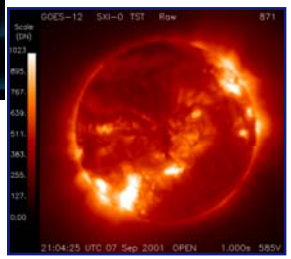
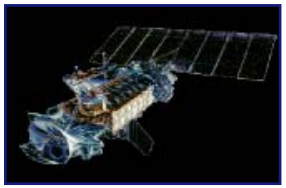
- **Improve analysis, forecasting, & effects capabilities … FY08-17+**
- **Collaborate with U.S. & Allied government/civilian agencies to increase sensing capability & reduce costs … NASA, NOAA, NSF, USGS, LANL, and others**
- **Modernize ground-based sensing capabilities … FY08-17+**
- **Follow-on to DMSP space weather sensing capabilities … FY12-17**









ACE – Provides ~1 hr warning for storming
SOHO – Imagery – detects Coronal Mass Ejections
GOES – Energetic particles, X-Ray flux and X-Ray images
POES/DMSP – LEO space wx ionospheric sensors
SEON – Ground-based solar observatories
DISS – Ground-based ionospheric measurements
TEC – GPS-derived ionospheric measurements

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Current Status

- **Space-Based Space Wx Sensors**
  - **DMSP sunset program, NPOESS Nunn-McCurdy restructure de-manifested space environment sensors – follow on capability being worked by AFSPC to avoid gap in ~2016**
  - **ACE (Advanced Composition Explorer) – replacement planning being worked as part of CSESMO for ~ 2016-2018**
- **Ground-Based Space Wx Sensors … Current sensors need replacement**
  - **AFWA & SMC working RSTN SLEP (System Lifecycle Extension Program) and SOON modernization**
  - **Using some R&D sensors (SCINDA & TEC) for ops – will continue to support**
- **Space Environment Models**
  - **AFWA w/ National Partners making progress … increased $s in FY08-15**
  - **AFRL, NRL, NASA, NSF, and others R&D progressing, working funding for transition programs**
- **System Effects Products**
  - **AFSPC funding ops software capability; Additional R&D funding needed**

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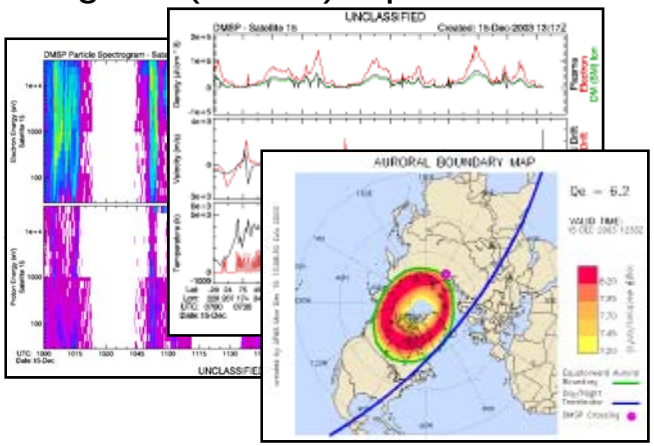
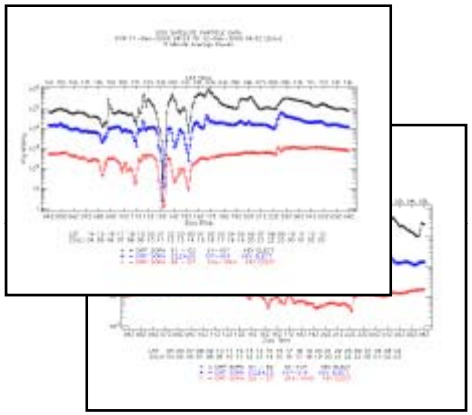
Space Weather

Space-Based Sensing

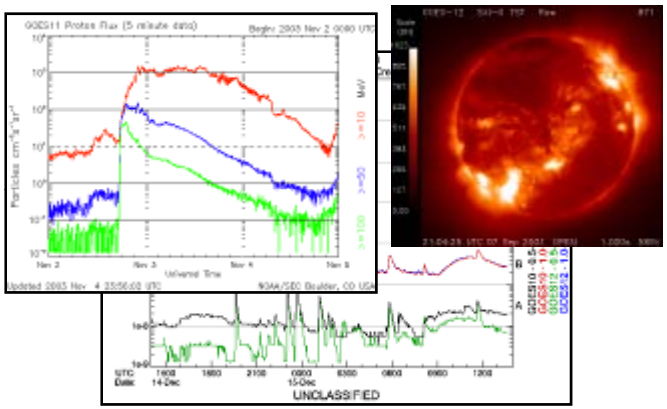
Defense Meteorological Satellite Program (DMSP) – particles/fields



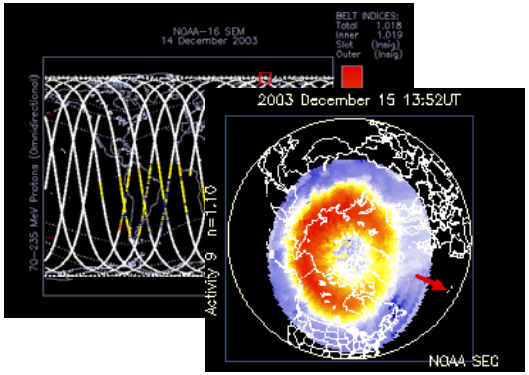
Defense Support Program (DSP) - particles



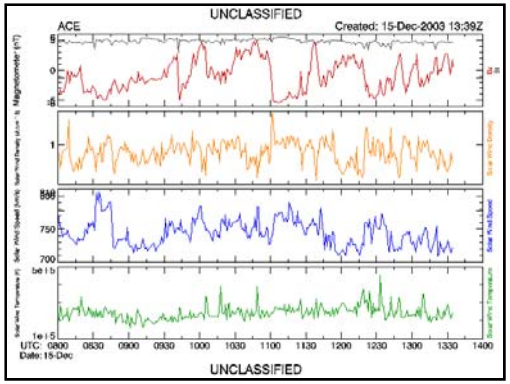
Geostationary Operational Environment Satellite (GOES) – X-ray, particles and fields



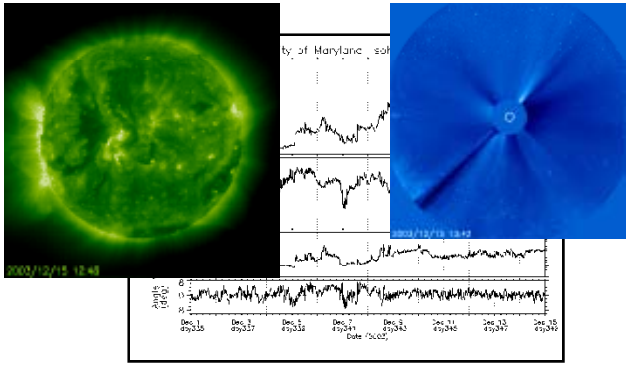
Polar-Orbiting Environmental Satellite (POES) - particles



Advanced Composition Explorer (ACE) – solar wind



Solar Heliospheric Observatory (SOHO) - solar wind/radiation



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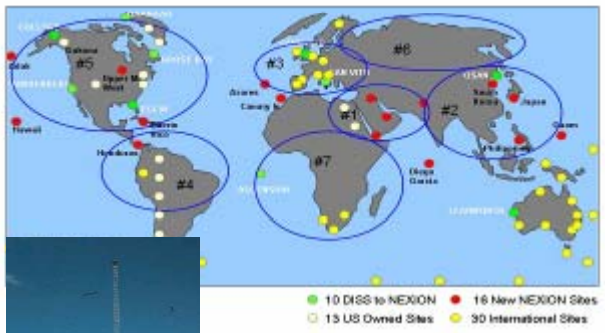
Space Weather
Ground-Based Sensing Examples

AF and other agencies collect space weather data from ground-based sensors

- **Sensors include SOON, RSTN, DISS, NEXION, USGS Magnetometer, SCINDA, TEC, and others**
- **Data from many government & non-government sources … Data partnerships are crucial**

All Sites



DISS

SOON

RSTN

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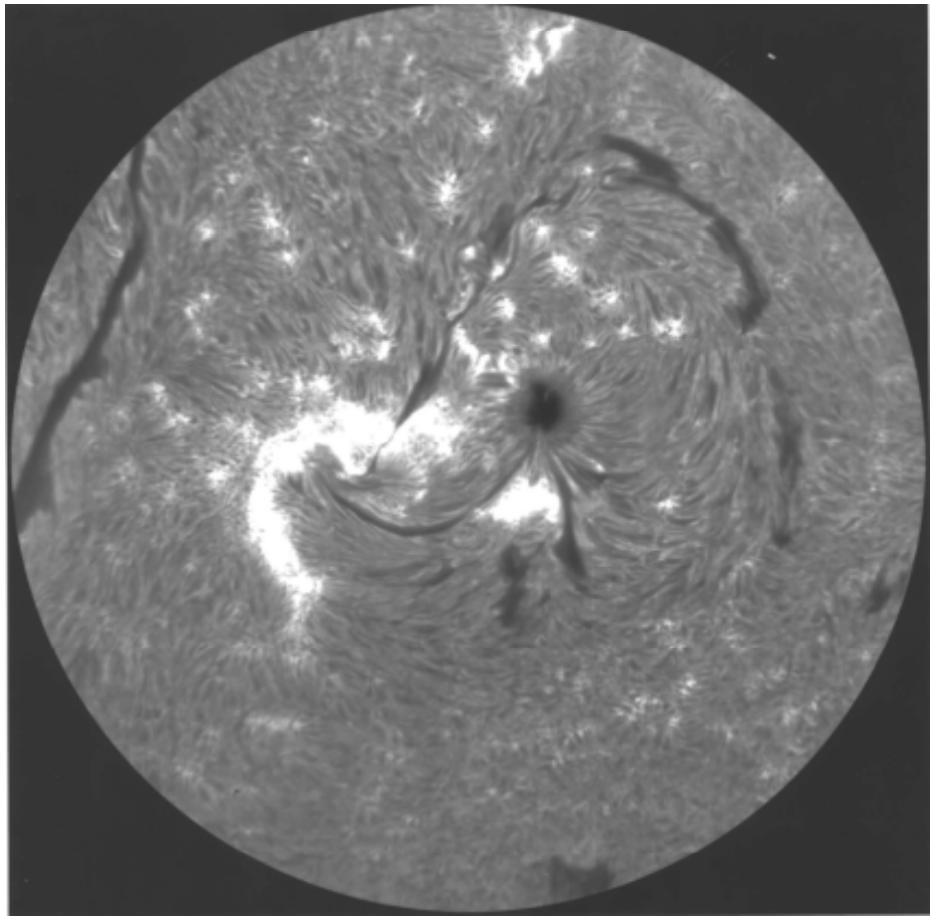
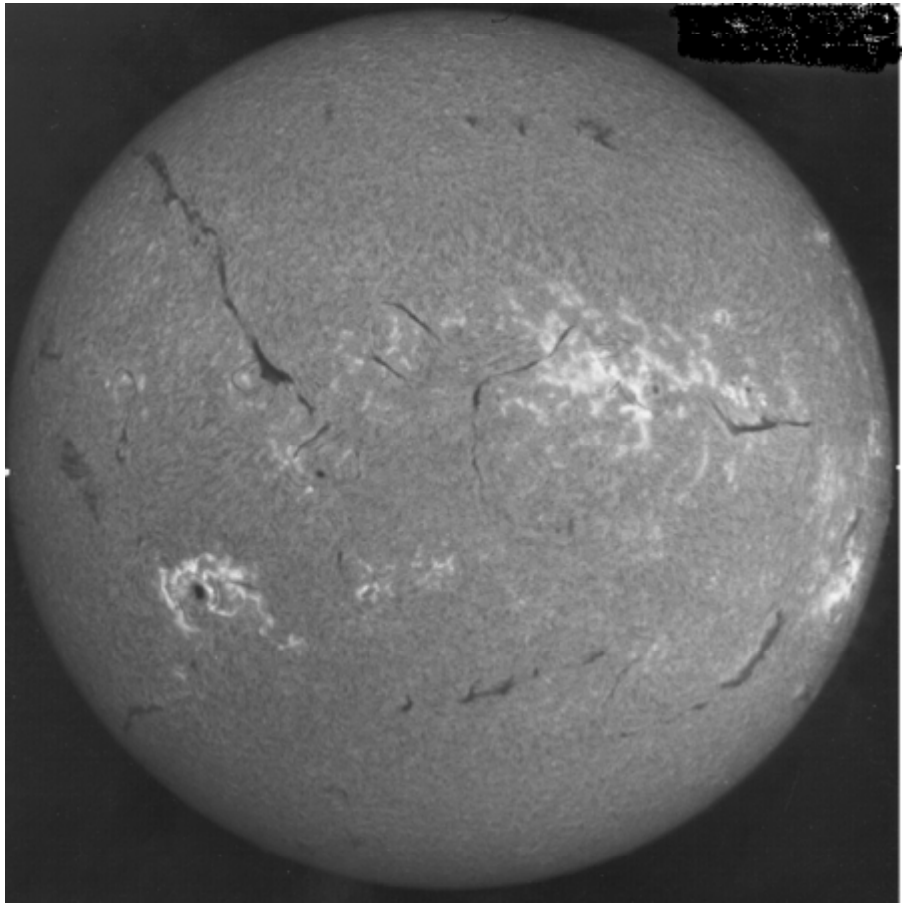
Improving Ground-based Obs Before Solar Max

ISOON

SOON





Note: Not the same date and time

Ground-Based Space Wx Sensor Opportunities
NSF

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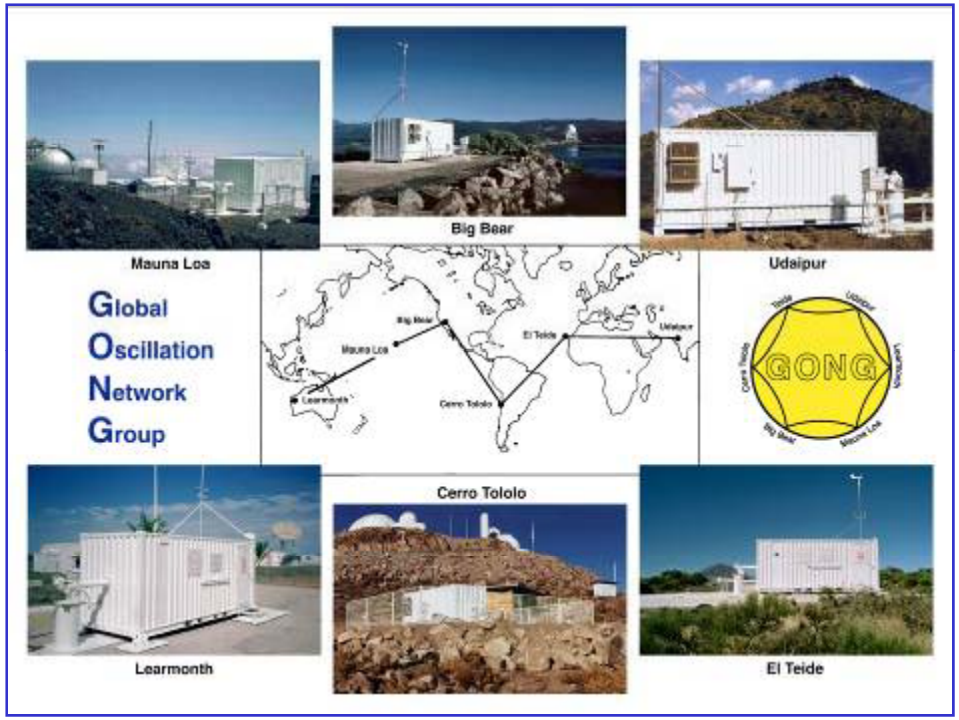
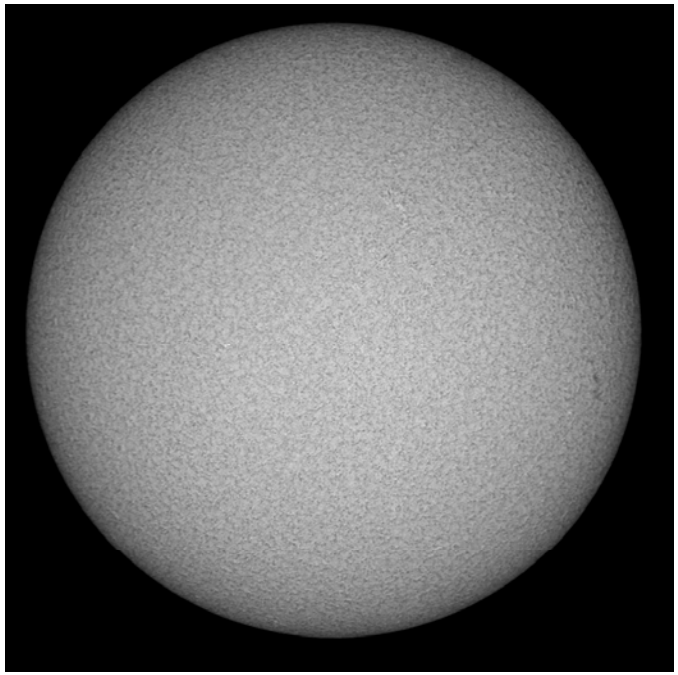
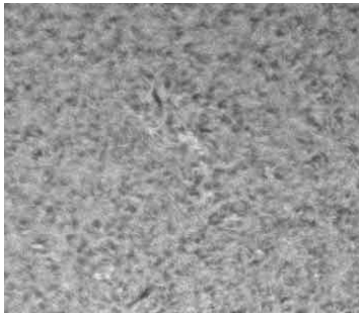
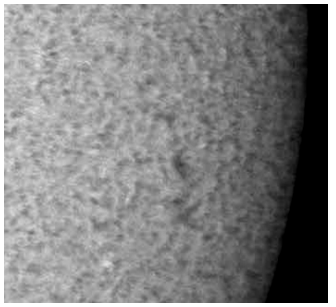




GONG

Upgrade to provide H-alpha capability … data products every minute





GAIM Plan & Deliverables

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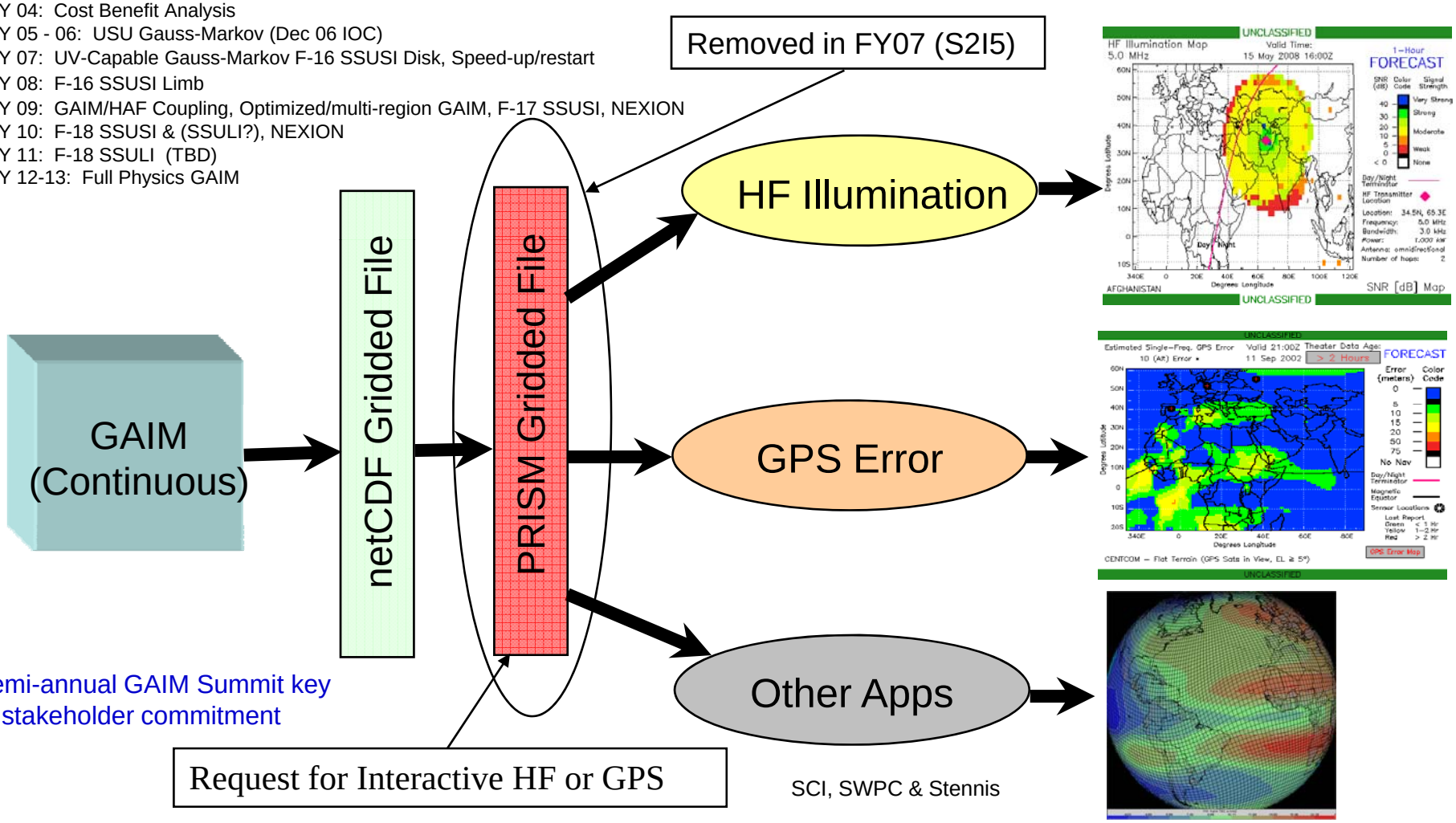
Global Assimilation of Ionospheric Measurements (GAIM) – 8-9 year effort

- FY 04: Cost Benefit Analysis
- FY 05 - 06: USU Gauss-Markov (Dec 06 IOC)
- FY 07: UV-Capable Gauss-Markov F-16 SSUSI Disk, Speed-up/restart
- FY 08: F-16 SSUSI Limb
- FY 09: GAIM/HAF Coupling, Optimized/multi-region GAIM, F-17 SSUSI, NEXION
- FY 10: F-18 SSUSI & (SSULI?), NEXION
- FY 11: F-18 SSULI (TBD)
- FY 12-13: Full Physics GAIM



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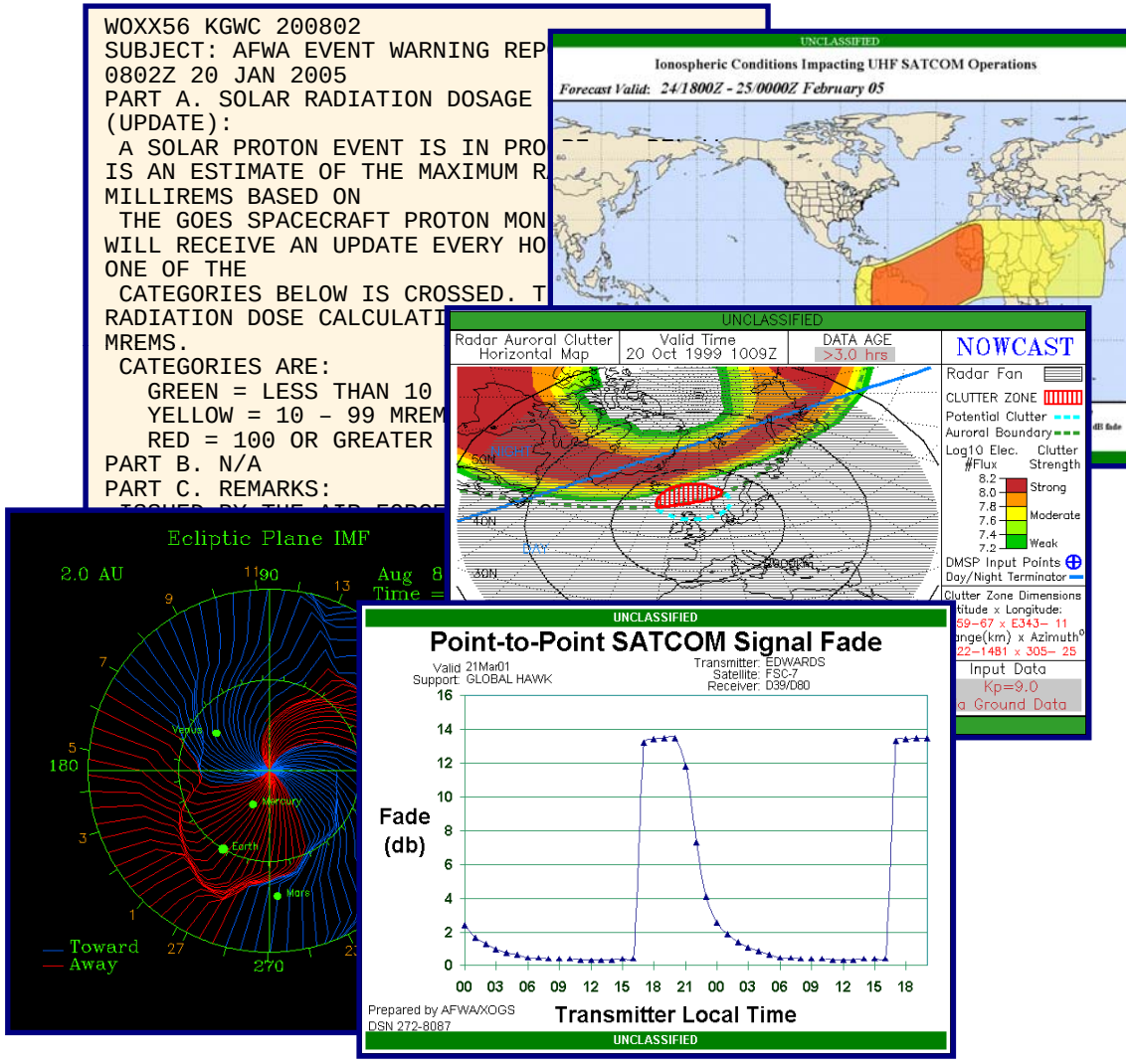
Mitigation of Impacts

- **Warnings**
  - Geomagnetic Activity
  - Solar Event, Flare, Radio Burst
  - Energetic Particle/Charging
  - Short Wave Fade
- **Specification & Forecast**
  - Ionosphere
  - Magnetosphere
  - Solar Wind
- **Products**
  - Radar Auroral Clutter
  - HF Illumination
  - GPS Error
  - HF/UHF Point-to-Point
  - Ap/F10 Forecast
  - Anomaly Assessments
  - UHF SATCOM Scintillation



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Space Wx Capability for SSA

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Space Wx Capability for SSA

Circa 2017

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Do not fund Ground-Based or Space-Based Measurement & Modeling Capabilities

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Ionospheric Disturbances (50%/50%) 10, 11, 12 ,13	Navigation		

Good (>75%) Moderate (50-75%) Marginal (25-50%) Little or None (0-25%)

Fund Ground-Based and not Space-Based Measurement & Modeling Capabilities

1 DMSP
2 ACE/SOHO
3 GOES
4 GPS
5 DSP
6 NPOESS
7 C/NOFS
8 ISOON/GONG
9 RSTN II
10 NEXION
11TEC
12 SCINDA
13 Geomag

Space Weather Parameter (% Space-based / Ground-based contribution)	Example Mission Supported	Observing Capability (Threshold SSA)	Forecasting Capability (Objective SSA)
Ionospheric Electrons (50%/50%) 8, 9, 10, 11, 12, 13	Geolocation		
Ionospheric Disturbances (50%/50%) 8, 9, 10, 11, 12, 13	Communications		
Energetic Particles (80%/20%) 3, 4, 5, 6, 8, 9, 13	Satellite Ops		
Radiation & Disturbances (70%/30%) 3, 4, 5, 6, 8, 9, 10, 11, 12, 13	Space Track		
Ionospheric Disturbances (50%/50%) 8, 9, 10, 11, 12, 13	Navigation		

U.S. AIR FORCE

Space Wx Capability for SSA

Circa 2017

Fund Space-Based and not Ground-Based Measurement & Modeling Capabilities

1 DMSP/SES*
2 ACE/SOHO FO
3 GOES
4 GPS
5 DSP
6 NPOESS
7 C/NOFS
8 SOON/GONG
9 RSTN
10 NEXION
11TEC
12 SCINDA
13 Geomag

Space Weather Parameter (% Space-based / Ground-based contribution)	Example Mission Supported	Observing Capability (Threshold SSA)	Forecasting Capability (Objective SSA)
Ionospheric Electrons (50%/50%) 1, 2, 7, 10, 11, 12 ,13	Geolocation		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 10, 11, 12 ,13	Communications		
Energetic Particles (80%/20%) 1, 2, 3, 4, 5, 6, 7, 13	Satellite Ops		
Radiation & Disturbances (70%/30%) 1, 2, 3, 4, 5, 6, 7, 10, 11, 12 ,13	Space Track		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 10, 11, 12 ,13	Navigation		

Good (>75%) Moderate (50-75%) Marginal (25-50%) Little or None (0-25%)

Fund both Space-Based and Ground-Based Measurement & Modeling Capabilities

1 DMSP/SES*
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Space Weather Parameter (% Space-based / Ground-based contribution)	Example Mission Supported	Observing Capability (Threshold SSA)	Forecasting Capability (Objective SSA)
Ionospheric Electrons (50%/50%) 1, 2, 7, 8, 9, 10, 11, 12, 13	Geolocation		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 8, 9, 10, 11, 12, 13	Communications		
Energetic Particles (80%/20%) 1, 2, 3, 4, 5, 6, 7, 8, 9, 13	Satellite Ops		
Radiation & Disturbances (70%/30%) 1 - 13	Space Track		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 8, 9, 10, 11, 12, 13	Navigation		

*SES– SSA Environment Sensing … DMSP Space Wx Sensor Follow-on