*Headquarters U.S. Air Force*

*Fly – Fight – Win*

# Space Weather Enterprise Forum

Year of the Air Force Family

**AF/A3O-W**

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# *Way Ahead*

- **Preparing 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 sensor, modeling, and exploitation capabilities**

Working with National Partners to support National Space Wx needs – TEAM BALL!

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# Overview

- **Space-Based Collections Modernization**
- **Ground-Based Collections Modernization**
- **Modeling Efforts**
- **Other Partnerships**

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

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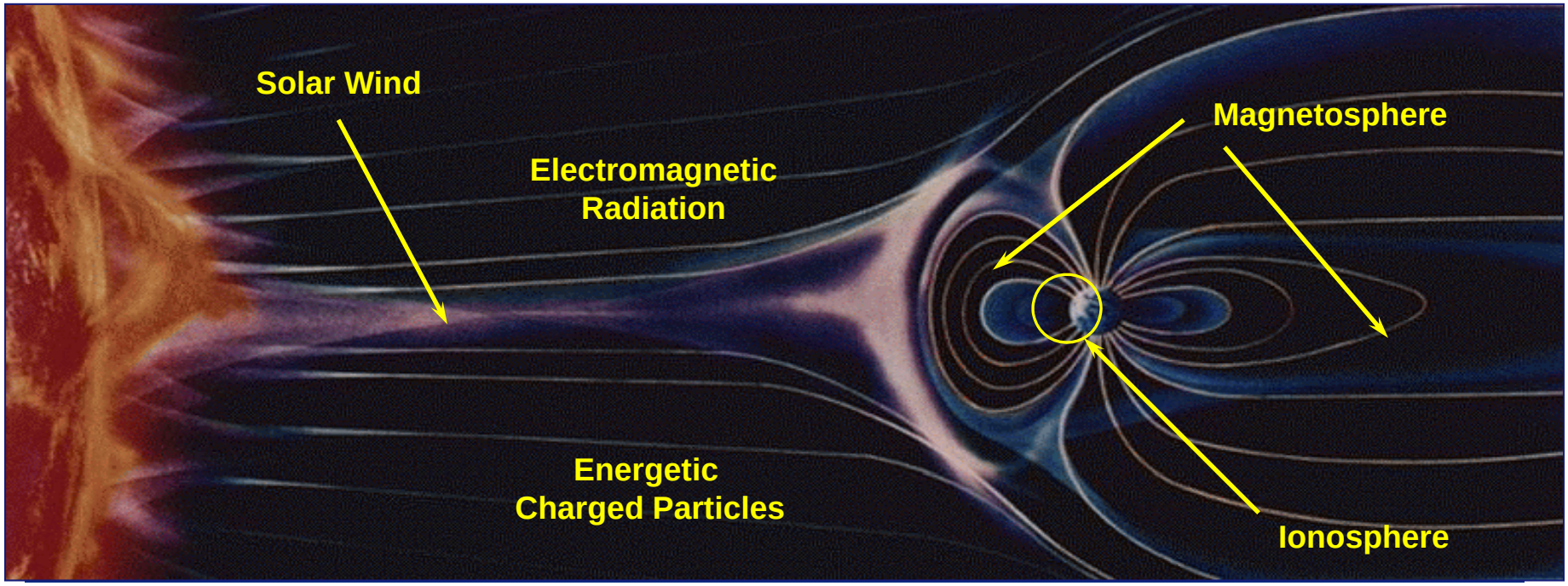
# AF Space Weather Mission

**Provide mission-tailored analyses and forecasts of the solar environment and warnings for mission limiting space weather events to Department of Defense warfighters and decision makers**

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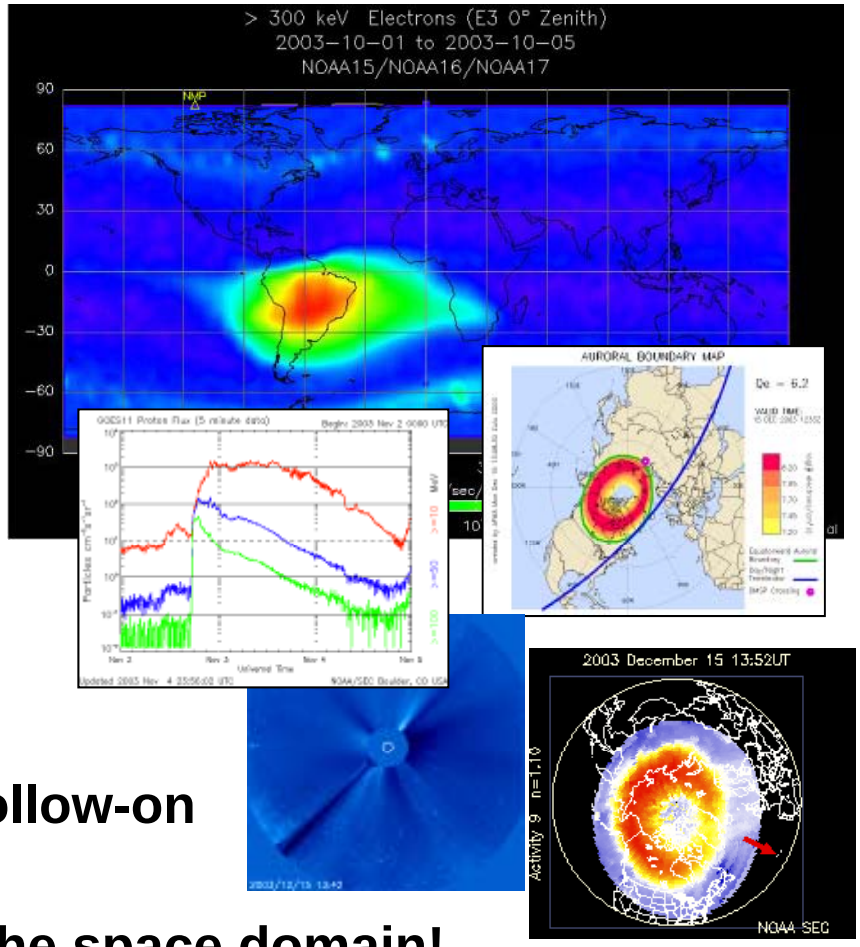
# Space-Based Sensor Options

## Exploit Current Capabilities

- DMSP, GOES, POES, SOHO, ACE
- C/NOFS, STEREO,SDO & GPS-RO/COSMIC
- Non-traditional sources

## Future Options

- SEM-N
- COSMIC-II & DSCOVR
- SSAEM
- Radiation Belt Storm Probe
- AMPERE
- DoD continuity mission or DMSP follow-on




## Advocacy and Partnering

- Need partnerships to collect from the space domain!
- CSESMO … proposed national space-based sensing architecture

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# Space Weather
## Ground-Based Sensing

***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


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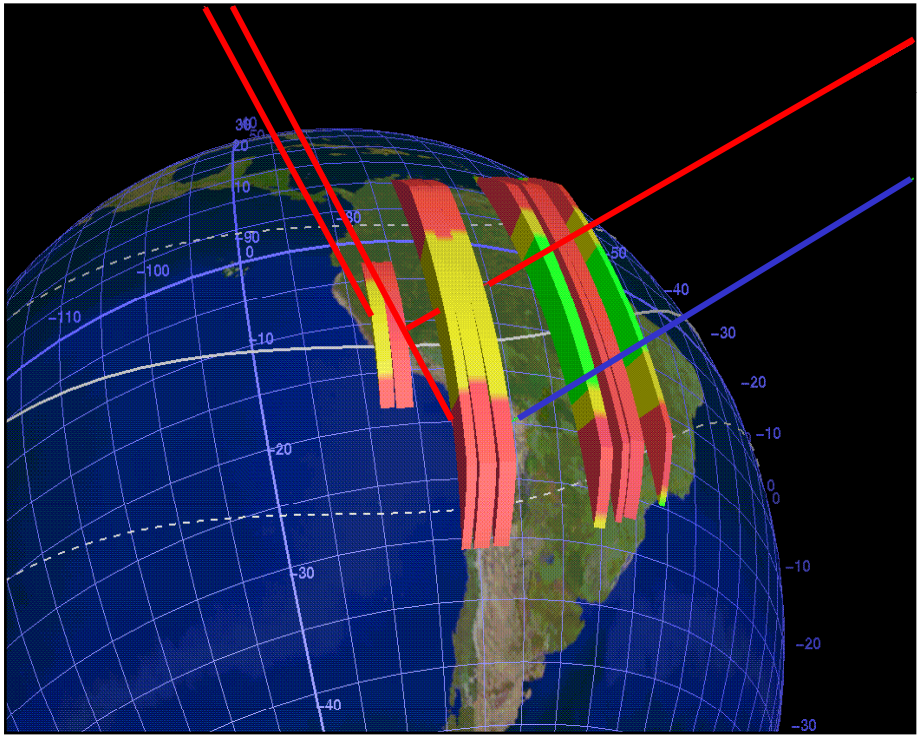
# SCINTILLATION NETWORK DECISION AID (SCINDA)

**A regional nowcasting system to support users of space-based communication and navigation systems**



Real-time to 2-Hr Forecasts of equatorial scintillation

- **Ground-based sensor network**
  - **Passive UHF / L-band / GPS scintillation receivers**
  - **Measures scintillation intensity, eastward drift velocity, and TEC**
  - **Automated real-time data retrieval via internet**
- **Data supports SATCOM users**
  - **In theater and reach back support**
- **Future: multi-frequency GPS error work**

***Partners: AFRL, SMC, DoS***

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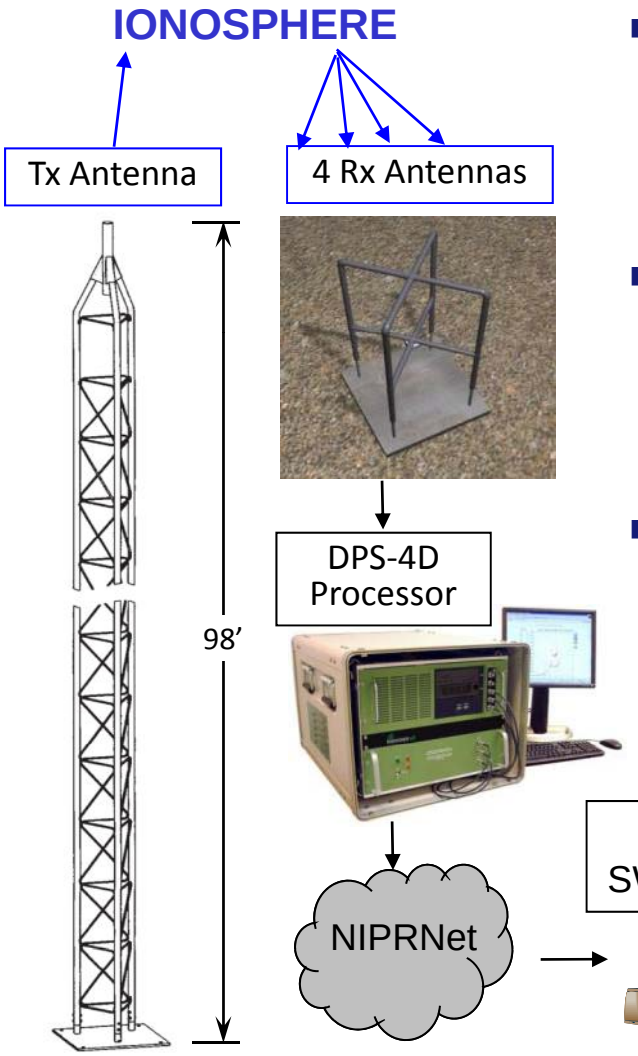
# Next Generation Ionosonde NEXION




- **Replacement for Digital Ionospheric Sounding System (DISS)**
  - Ionospheric data feeds AFWA's ionospheric model
  - Generates products critical to space situational awareness
- **Advantages**
  - Reduced footprint -- 5 acres for DISS/1 acre for NEXION
  - Characterizes ionosphere over 1000 km radius
  - Improved spatial resolution
  - Modernized network and remote sustainment functions
- **NEXION network will consist of at least 30 sites**
  - 3 sites currently operational
  - Install 3 sites per year: worldwide fielding

*Partners: UMass - Lowell, SMC*

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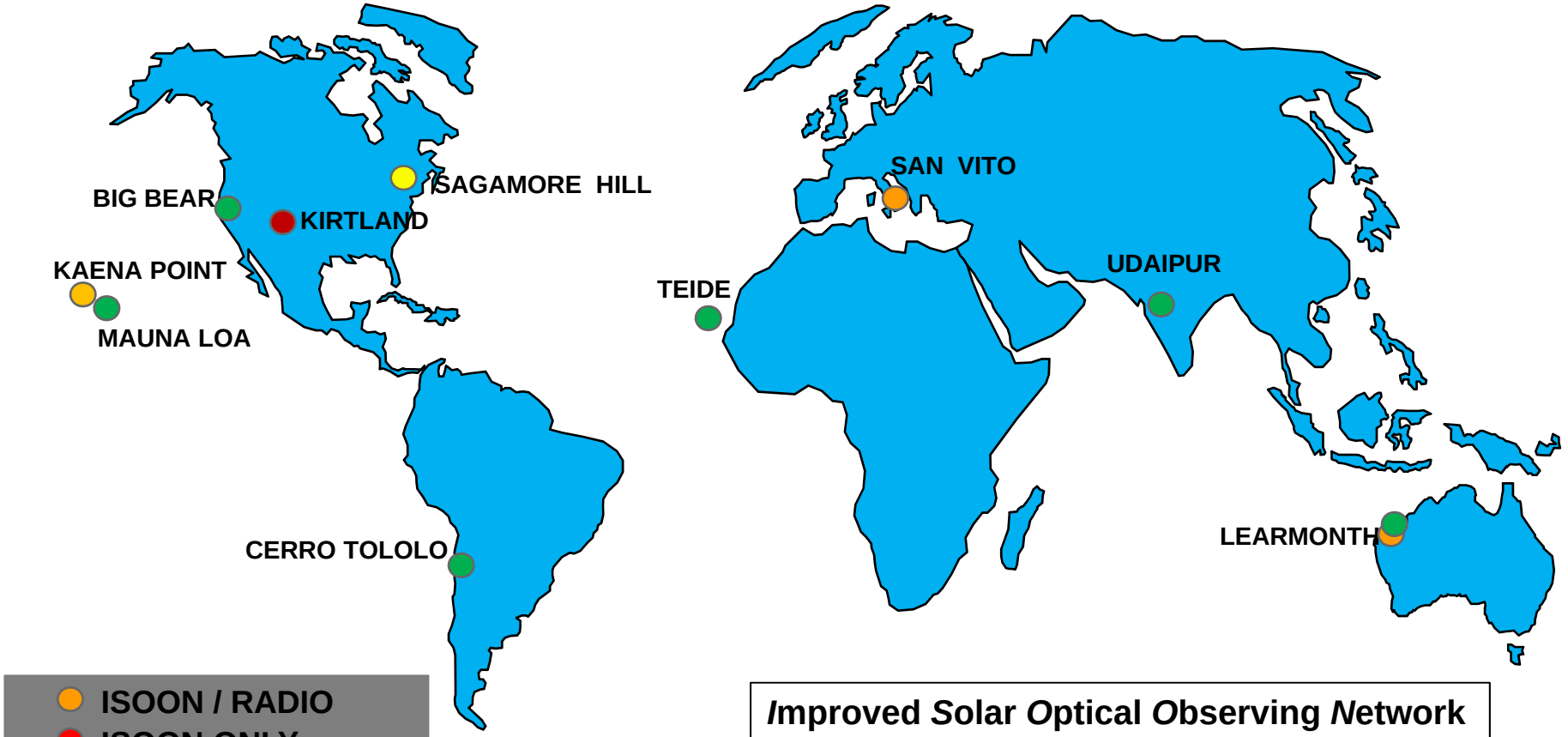
# Investing in a Global Observing Network




- ISOON / RADIO
- ISOON ONLY
- RSTN (RADIO) ONLY
- RESEARCH ISOON
- GONG

***I**mproved **S**olar **O**ptical **O**bserving **N**etwork*
- Upgrades finished by 2015

***Global Oscillation Network Group***
***Radio Solar Telescope Network***
- Remoting finished by 2015



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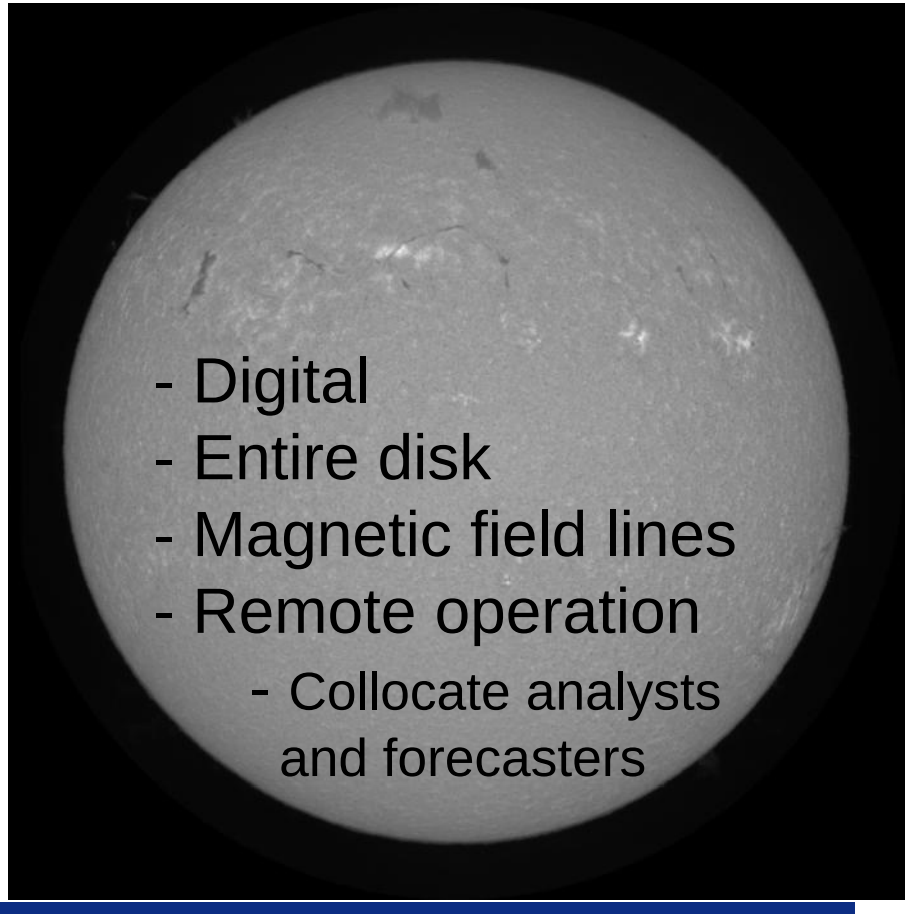
# Improved Optical Observations

SOON vs ISOON
08 Apr 2010
Hα 14:29UT

*Partners: AFRL, SMC*

SOON

ISOON



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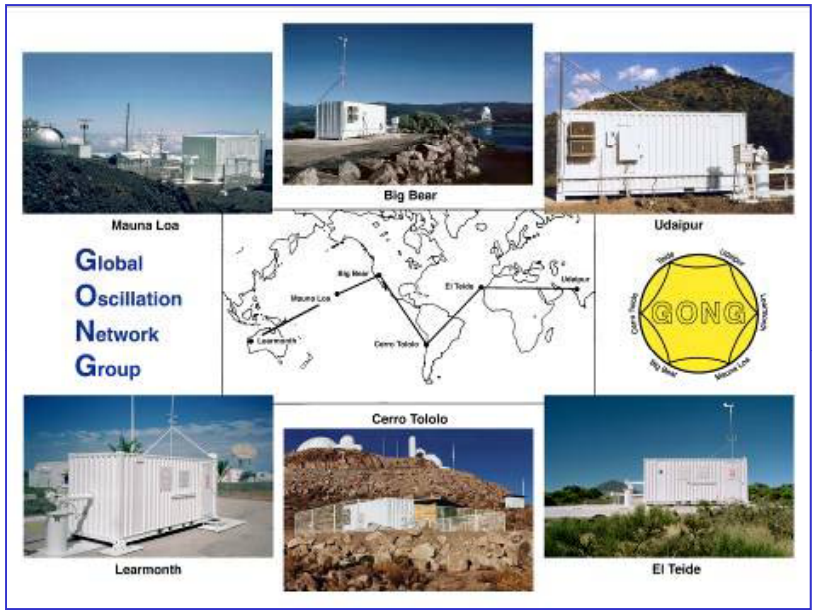
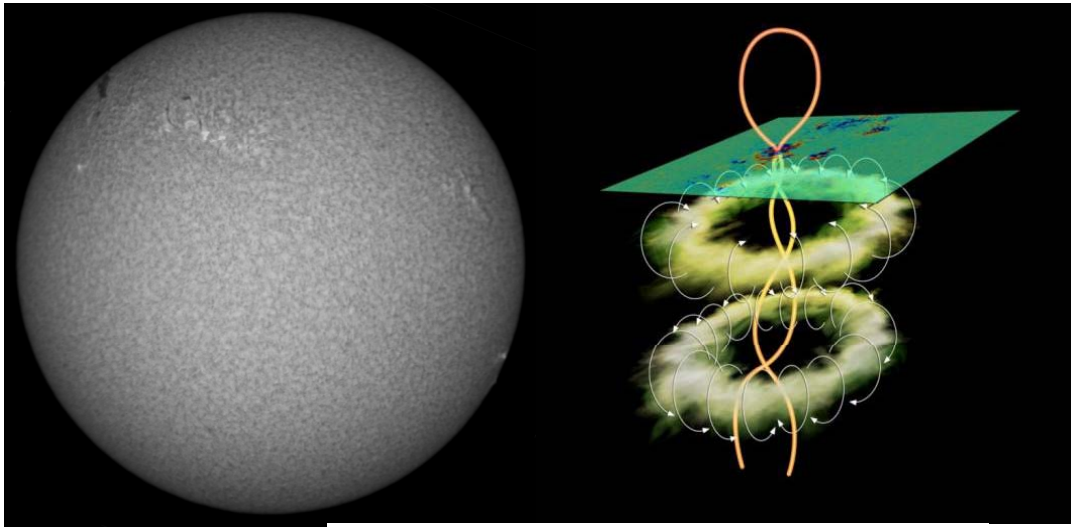
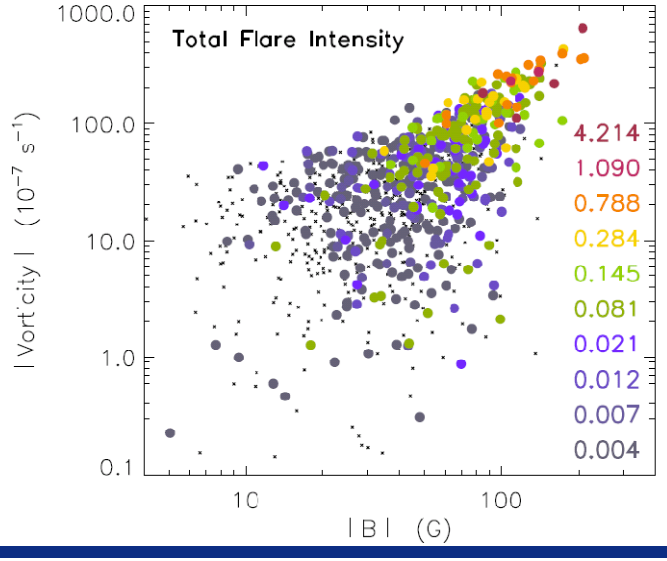
# USAF Cooperation with Global Oscillation Network Group (GONG)






**Upgrading to provide H-alpha capability to USAF…**
**data products every minute, 24/7**

**Potential flare forecast tool …**
**Magnetic field + Vorticity**

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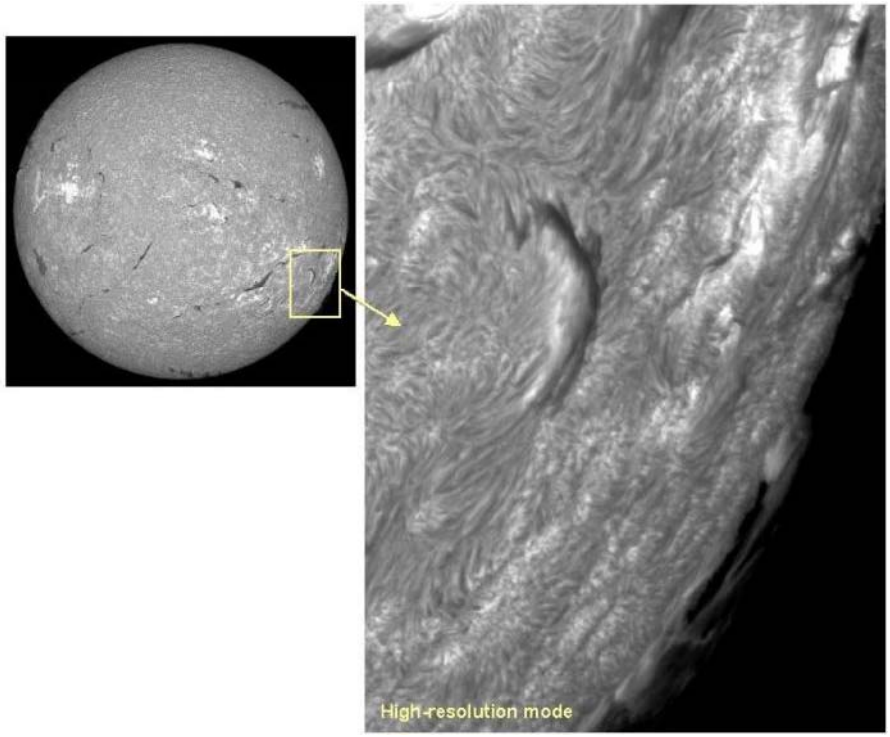
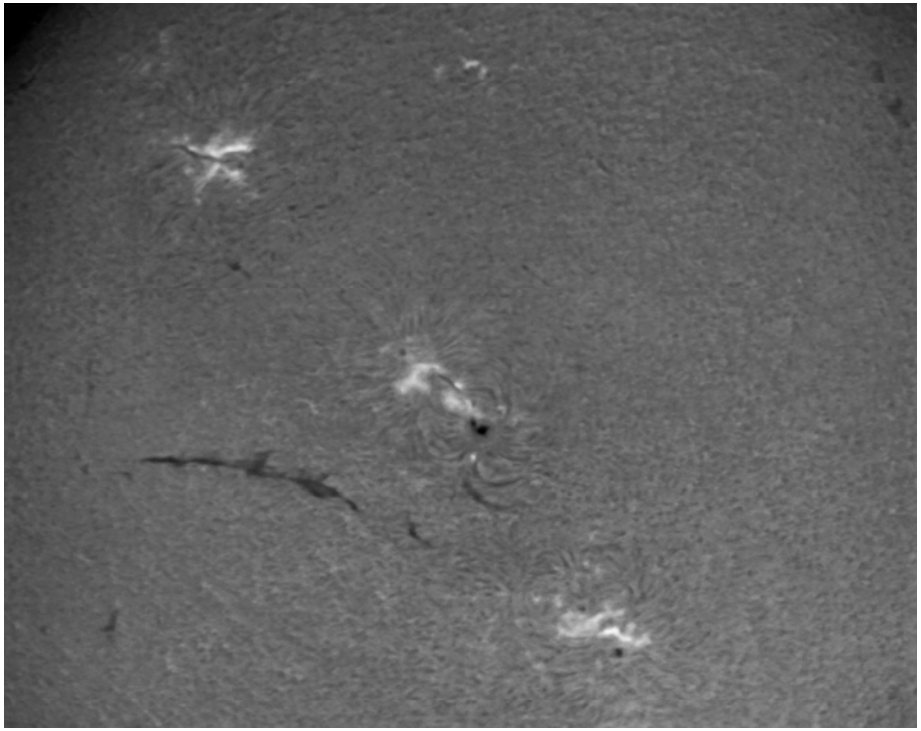
# ISOON – GONG Operational Integration

**ISOON**




- 1 arc/sec resolution
- Meets AFSPC and NEPC requirements
- Remote operation will collocate solar analysts with space wx forecasters

**GONG**



- 2.5 arc/sec resolution
- Flare patrol during gaps in ISOON coverage
- 6-site network assures eyes on Sun
- Data to be integrated into analyst workstation at AFWA

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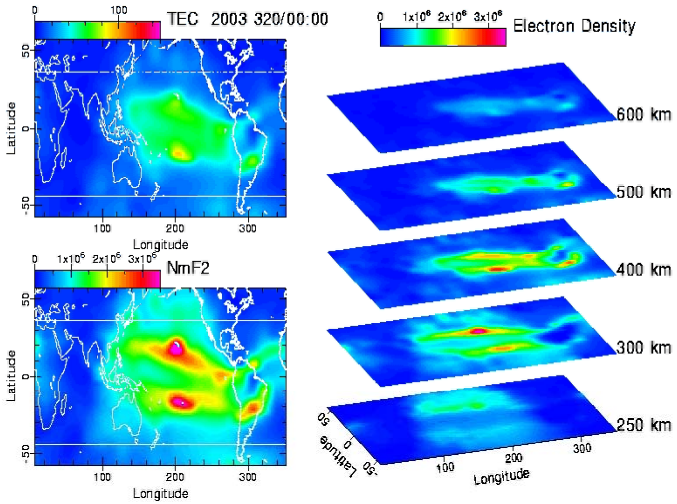
# Space Weather Analysis and Forecast System (SWAFS)

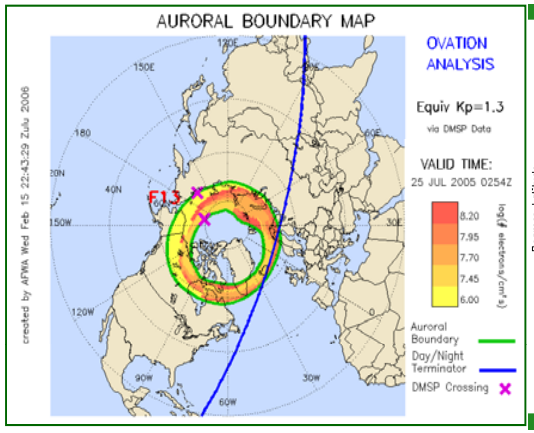
## Dec 09

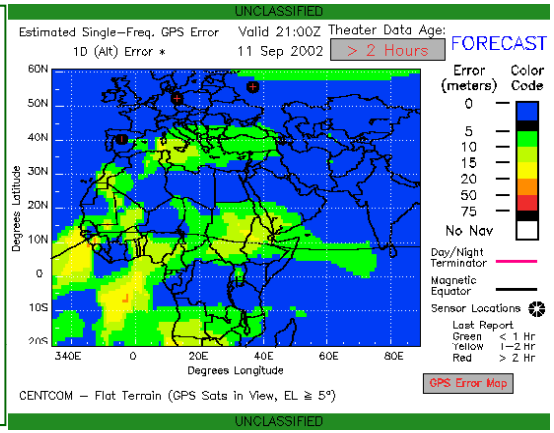
- Add NEXION SAO V4.3 data
- Replace SWPC IDS Adapter with E-SWDS
- Add GOES 13 & 14 Data – Delayed

## Jun 10

- Add NEXION SAO V5.0 XML data
- *Implement real-time Dst*
- Integrate non-SWAFS applications
- ICF (Pave Paws, ROTHR & IONPRO)
- *Integrate regional Gauss-Markov GAIM*
- *Add DMSP F-17 SSUSI disk & limb data*




## FY10-11 (Planned)

- *Begin development of net - centric JMSESS (JMBL)*
- *Add DMSP F-18 SSM/J/IES & SSUSI data*
- *Add Radio Occultation data to GAIM*
- Continue re-engineering of non-SWAFS spreadsheets
- Integrate remaining non-SWAFS applications
- ISOON & GONG integration

*Partners: NRL / AFRL/ SMC / Utah State & academia / CCMC / NGIT*

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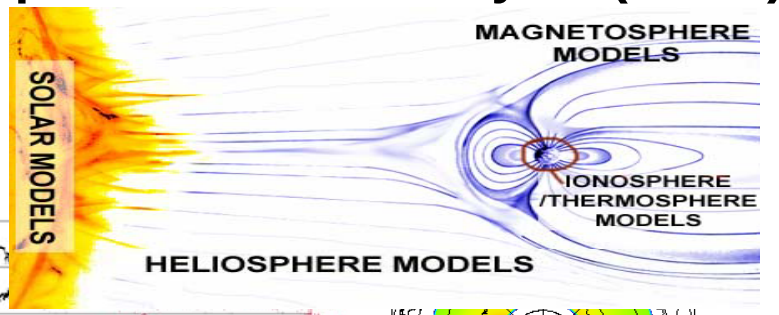
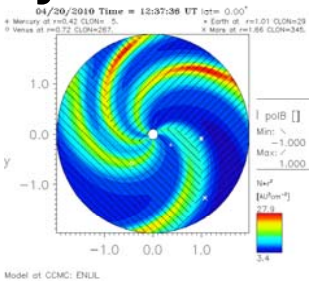
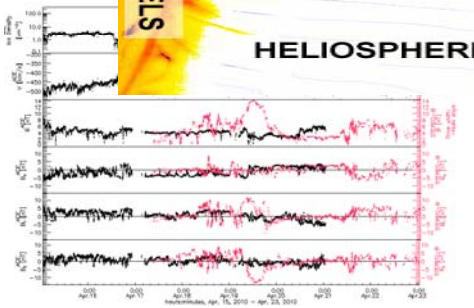
# Other Partnerships

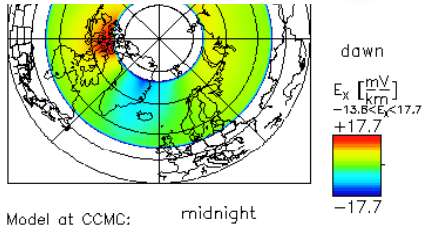
- **Collaboration with CCMC: Integrated Space Weather Analysis (iSWA)**
  - **User-friendly data/model displays**
  - **Model Comparisons/Validation**
  - **"Ensemble" displays**




Community Coordinated Modeling Center

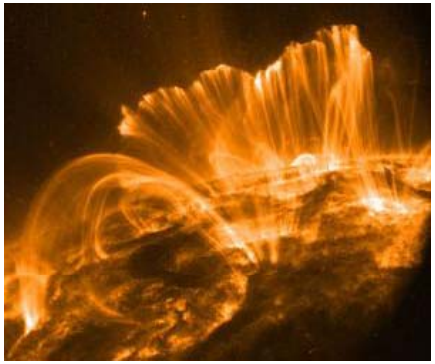







- **Collaborations: AFRL SWFL, AFSPC,SMC, ESC, NRL**

- **And our partner in operations**



# Working with National Partners to support National Space Wx needs

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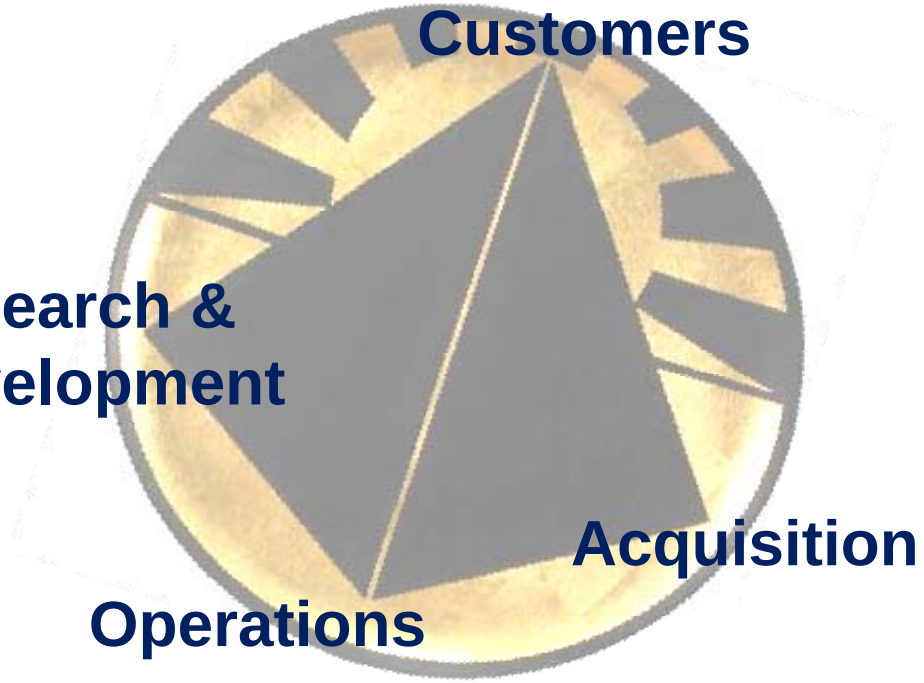
## Questions?

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*Rising Sun Over Pyramid* (painting) – Paul Greco, 2009

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# Space Weather Warfighter Impacts

## X-Rays, EUV, Radio Bursts

**Arrival: 8 min / Duration: 1-2 days**

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

## Scintillation

**Daily / ionospheric disturbance**

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

## Proton Events

**Arrival: 15 min to hours / Duration: days**

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

## Geomagnetic Storms

**Arrival: 2-3 days / Duration: days**

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

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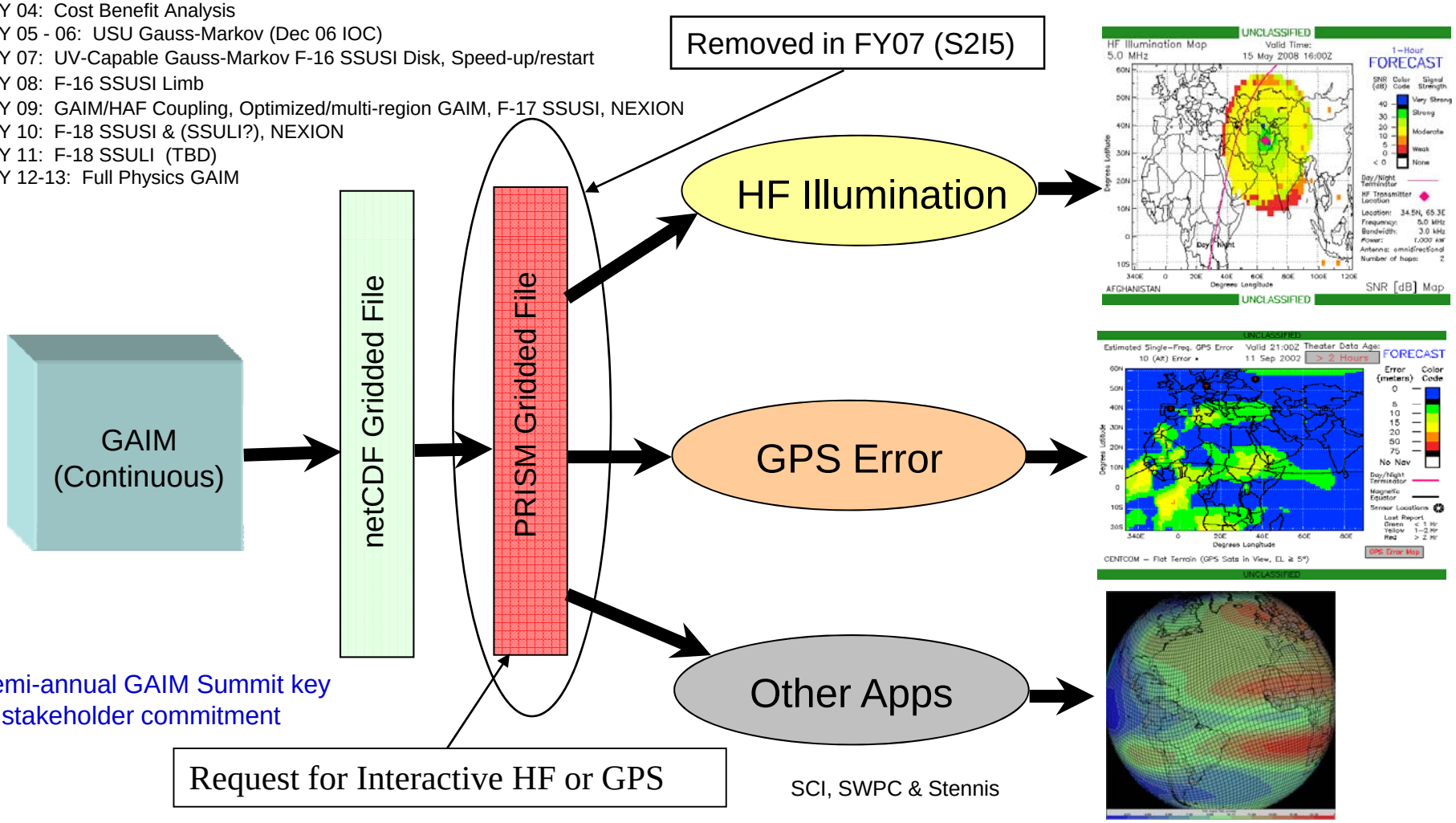
# GAIM Plan & Deliverables

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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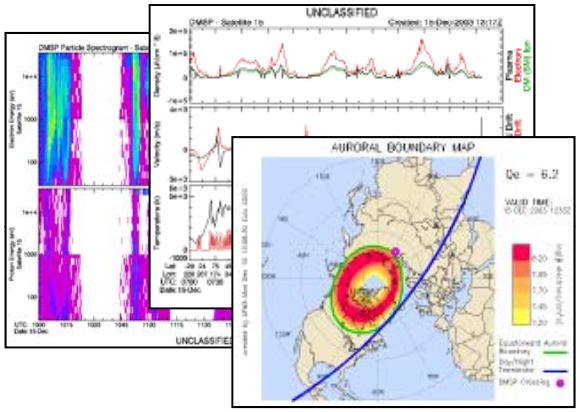
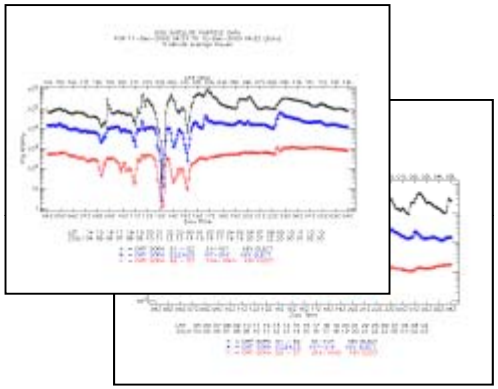
# Space Weather

## Space-Based Sensing

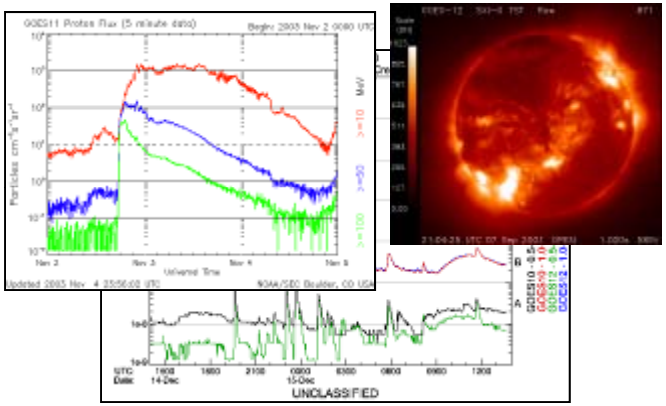
Defense Meteorological Satellite Program (DMSP) – particles/fields



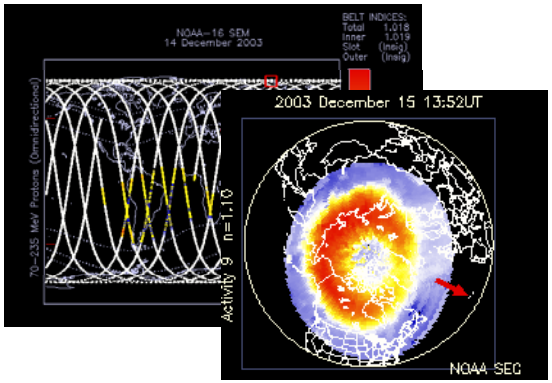

Defense Support Program (DSP) - particles



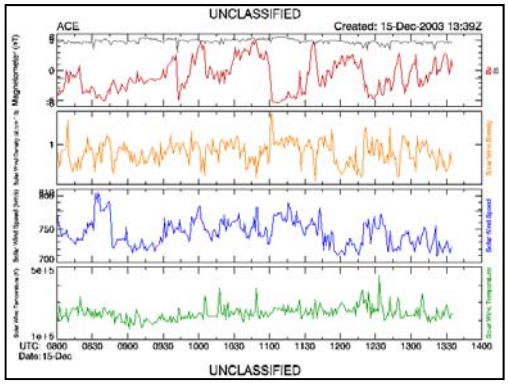
Geostationary Operational Environment Satellite (GOES) – X-ray, particles and fields



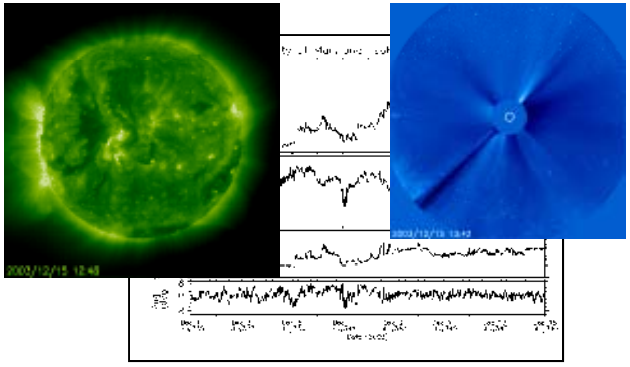

Polar-Orbiting Environmental Satellite (POES) - particles




Advanced Composition Explorer (ACE) – solar wind




Solar Heliospheric Observatory (SOHO) - solar wind/radiation



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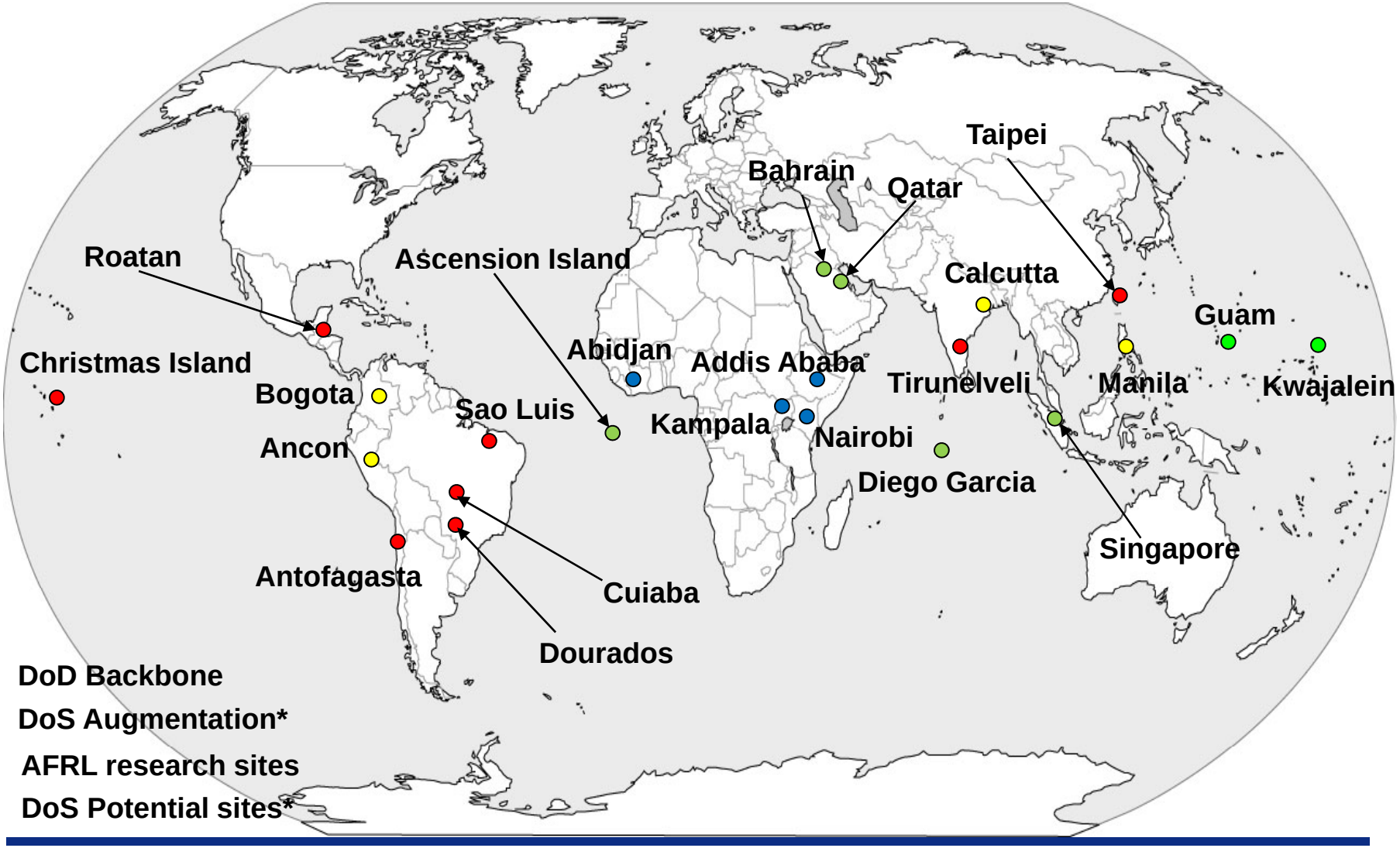
# SCINDA Locations



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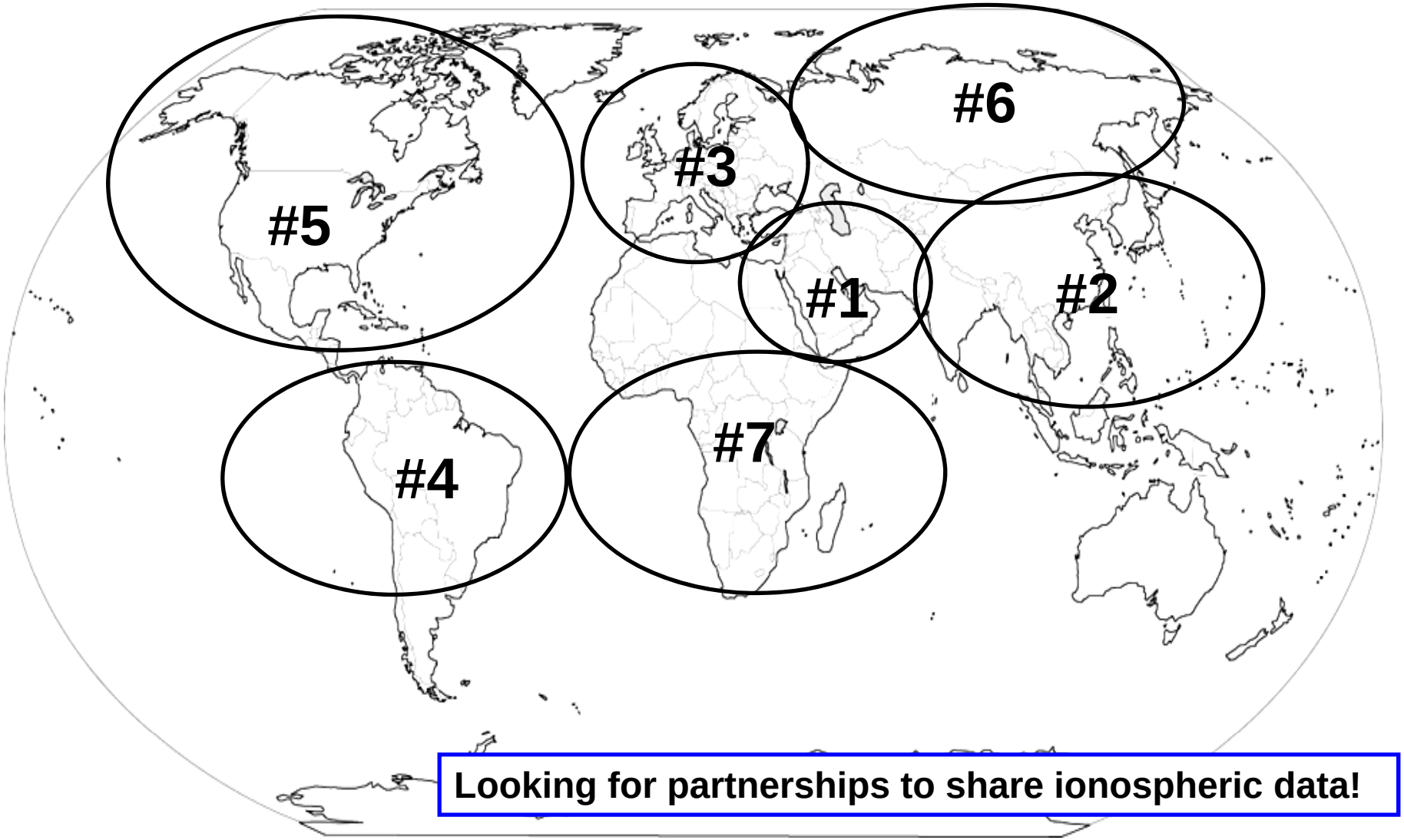
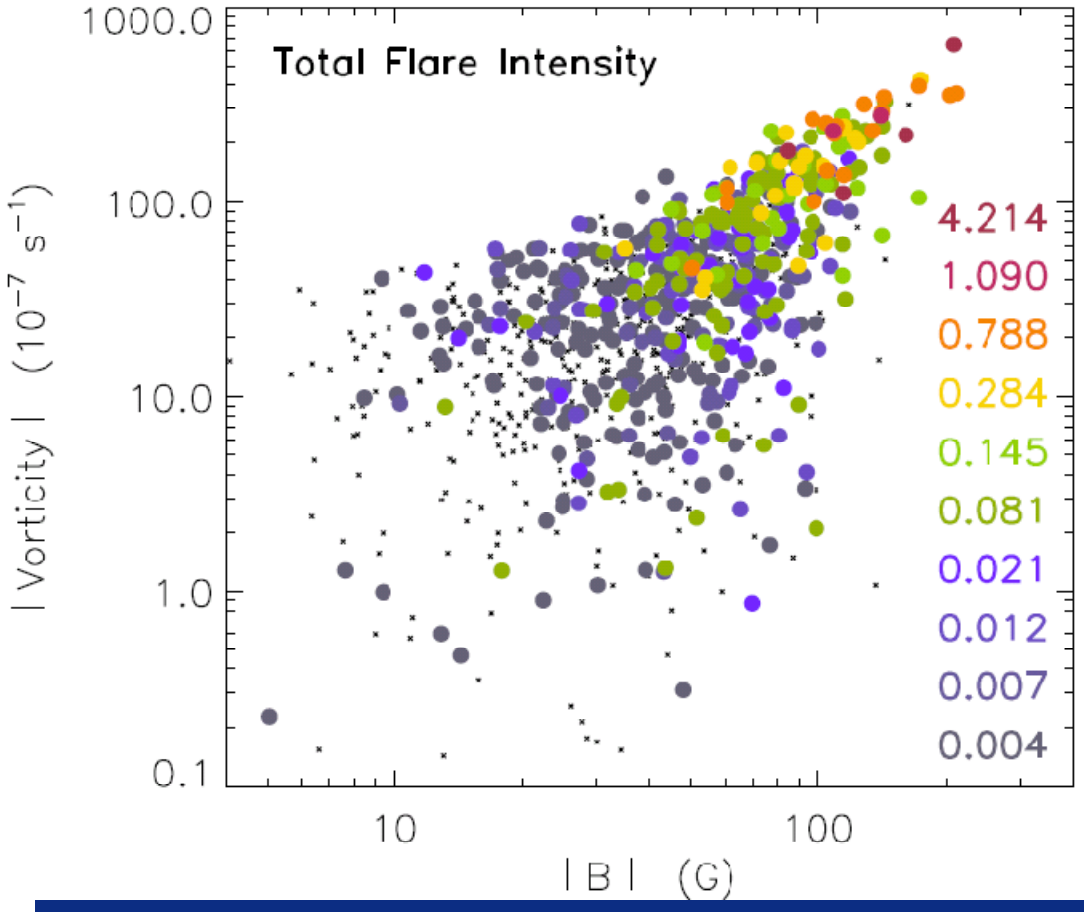
# NEXION Siting Strategy

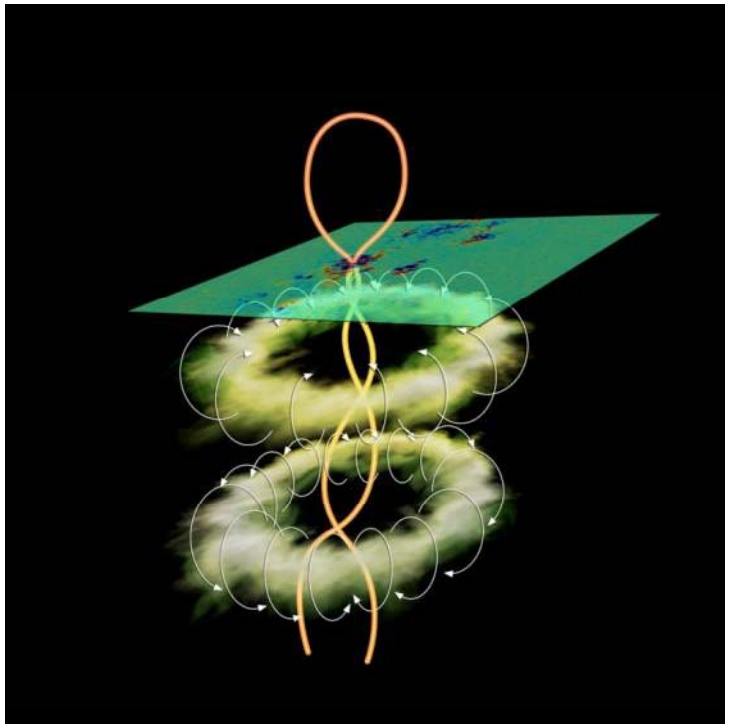



**Looking for partnerships to share ionospheric data!**

# GONG
## Development of New Flare Prediction Algorithms

Large magnetic field + large vorticity = larger flares



Courtesy of GONG

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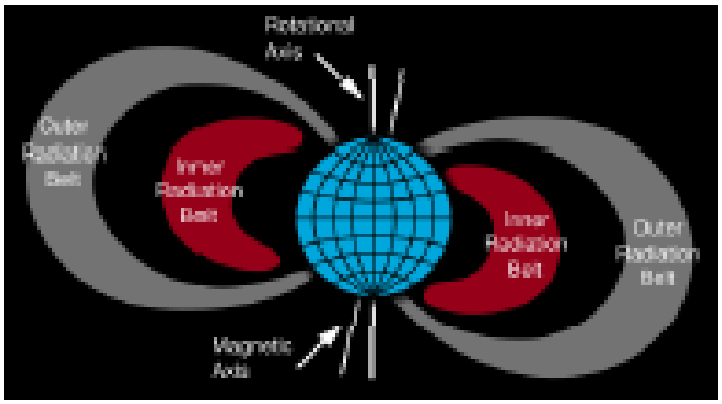
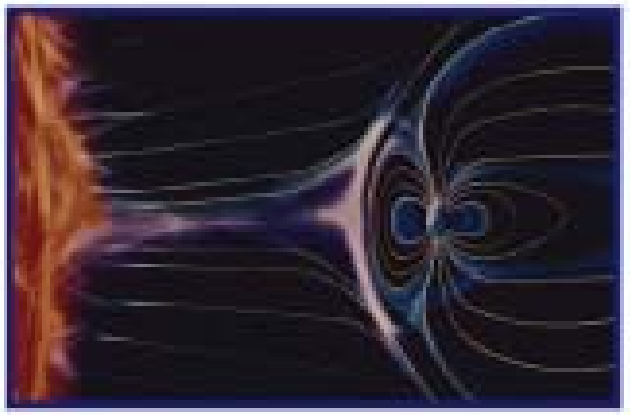
# What We Still Need

- 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
- Needed collections:
  - ✓ Top-side ionosphere
  - ✓ Solar wind (ACE follow-on)
  - ✓ Radiation belt storm probe and SDO



✓ Mentioned today / work in all areas

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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 Wx Capability for SSA

## Today & Circa 2017

### Today's Space-Based and Ground-Based Measurement & 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%)

### Fund both Space-Based and Ground-Based Measurement & 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) |
|---|---|---|---|
| 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

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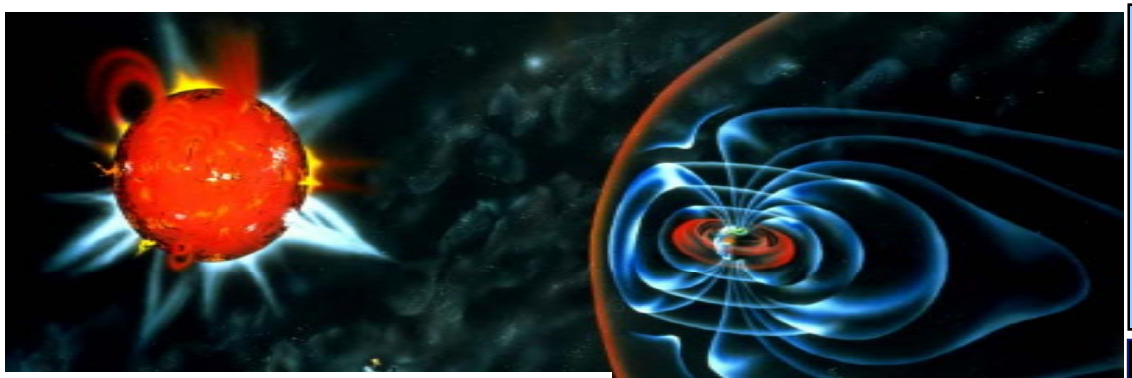
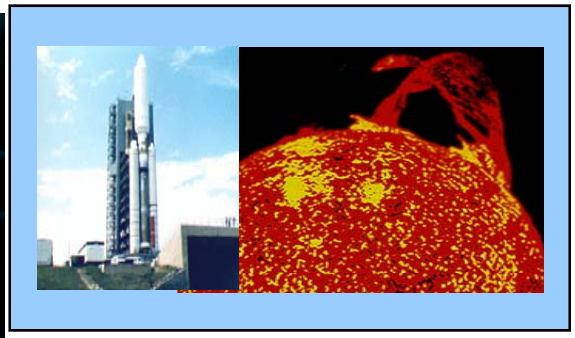
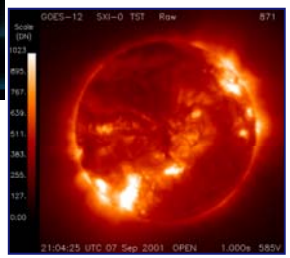
# SSA: Space Weather Roadmap

- 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