



Geospace Environmental Research at the Air Force Research Laboratory

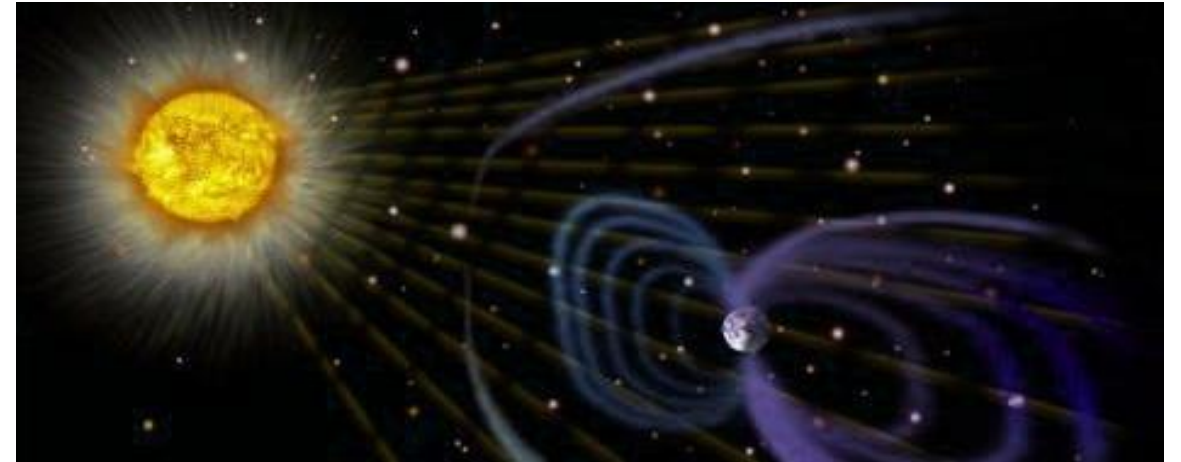
Ron Caton
Air Force Research Laboratory
Space Vehicles Directorate

20-24 May 2019 – International Space Weather Initiative Workshop
Abdus Salam International Center for Theoretical Physics

AFRL Space Vehicles Directorate – Geospace Environment Branch

Outline

- AFRL & ISWI
- Who we are
 - ✓ AFRL Heritage & Mission
- Basic Research Opportunities
- AFRL Science & Technology Needs



Basic and Applied R&D to better understand the Sun-to-Earth environment



AFRL Space Vehicles Directorate – International Heliophysical Year & International Space Weather Initiative

IHY Sponsored SCINDA Workshops

2006 – Cape Verde

- 20 participants representing 7 nations

2007 – Addis, Ethiopia

- ~50 participants from 12 nations at 2007 IHY in Ethiopia

2009 – Livingston, Zambia

- 116 delegates from 27 nations including 19 African countries

Led to installation of space weather sensors at >20 sites



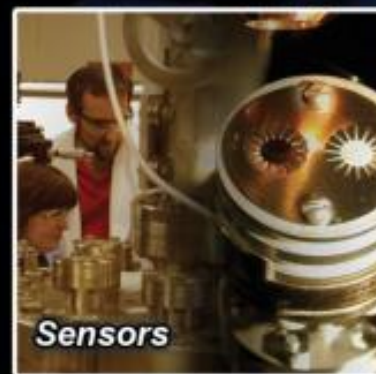
2010 – ISWI Summer School - Bahir Dar, Ethiopia

- Hardware demos & lectures on ionospheric dynamics

2010 – ISWI Workshop – Helwan University

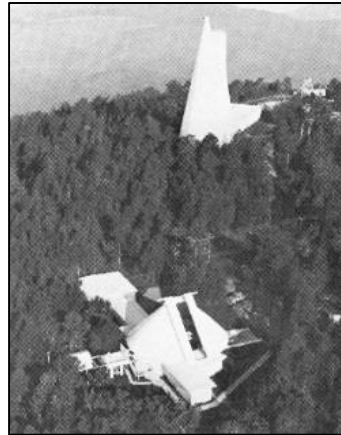
- Hosted sessions on scintillation and ionospheric modeling

Air Force Research Laboratory Nine Technical Directorates



AFRL Space Weather Heritage

Going back to 1949 with observations from solar telescopes at Sacramento Peak



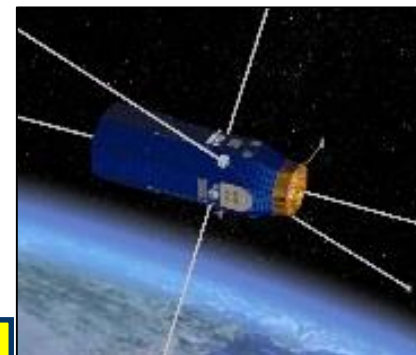
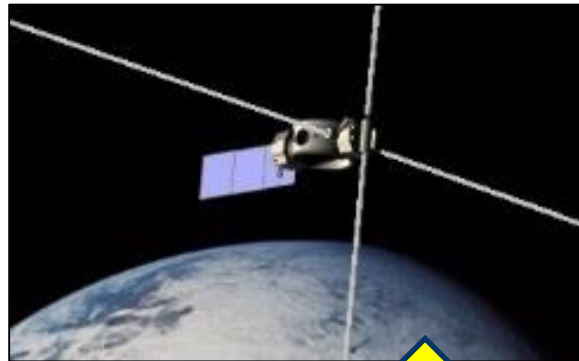
To supporting **IGY** science in 1957-1958 from Greenland



To Ionospheric observations with DMSP beginning in the 1970s



To the Demonstration and Science Experiment (DSX) high power VLF experiment scheduled to launch next month!



To the C/NOFS mission from 2008-2015

AFRL's Role in Space Weather

AFRL invests in, creates, and matures Space Wx technology

- In-house research with Gov't scientists
- Grants, contracts and other agreements

- Basic & Applied Research – Space Vehicles Directorate

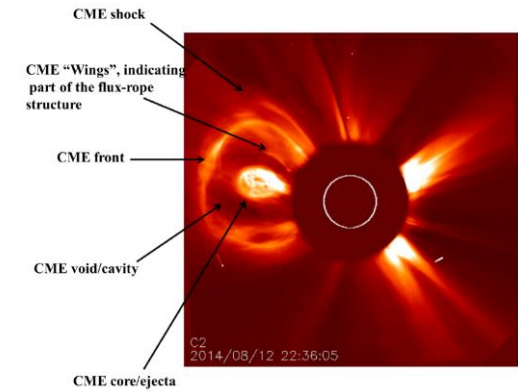
- Basic Research – Air Force Office of Scientific Research
 - Domestic & Int'l Grants for Basic Research
 - International Offices of Aerospace Research & Development
 - ✓ Japan: Asian Office – AOARD
 - ✓ London: European Office – EOARD
 - ✓ Chile: Southern Office – SOARD

ISWI Goal: *develop the scientific insight necessary to understand the science, and to reconstruct and forecast near-Earth space weather*



AFOSR International Office - Space Environment R&D

- Basic Research Grants
- Topic areas include Space Sciences, Space Technology, Quantum Sciences, and more
- Focus on research areas with significant and comprehensive benefits to AFRL programs – Highlighted in USAF 2030 S&T Strategy!



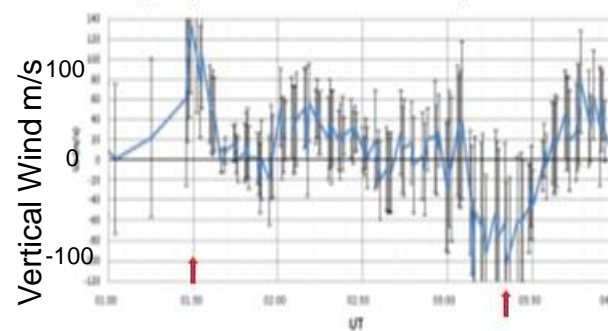
Solar wind / Interplanetary
Coronal Mass Ejections

Rutherford-Appleton Laboratory, UK



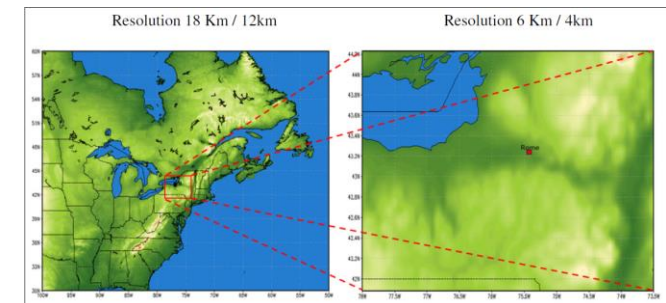
AGU 2017 African Award for Research
Excellence in Space Science

Melessew Nigussie, University of Bahir Dar, Ethiopia



UT (hour)
Ionosphere-Thermosphere
Physics and Chemistry

University College London, UK



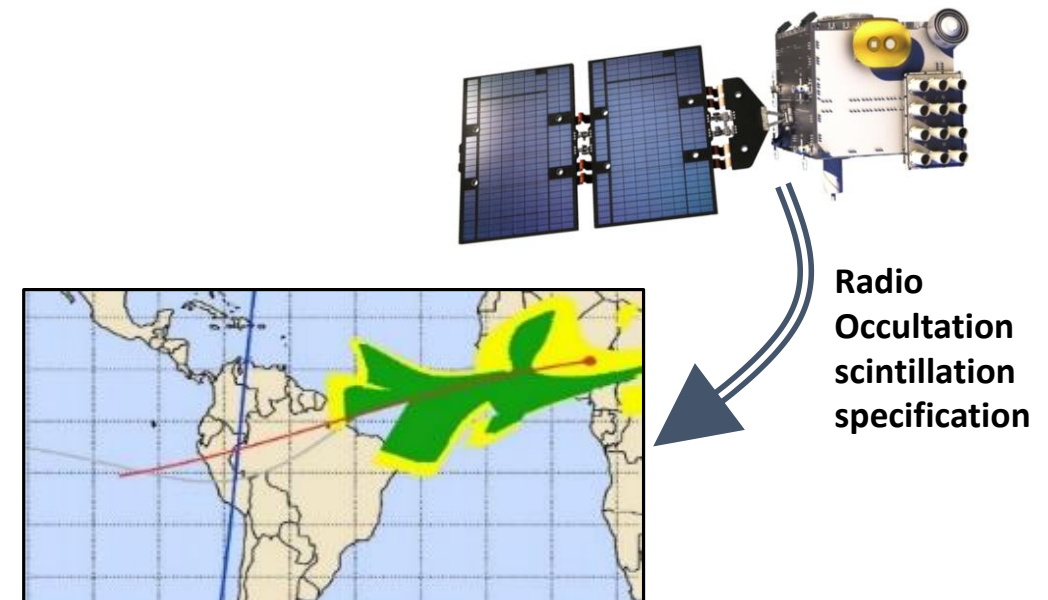
Tropospheric effects on
satellite communication

University of Rome, Italy

AFRL Space Vehicles – Int’l Cooperation for Space Weather

- Global space weather monitoring requires increased interoperability
- **Sharing of observations & models with the global community**
 - AFRL is working to release more of our observational data
 - Necessary to build better models & improve fundamental understandings
- Interested in working together to mature promising technologies to support space weather specification & forecasting
- **Communicate our S&T needs to the community**

We need a partnership with international space weather research community to work the hard research problems



AFRL Geospace Environment Research & Development

Communicating our S&T needs to the community

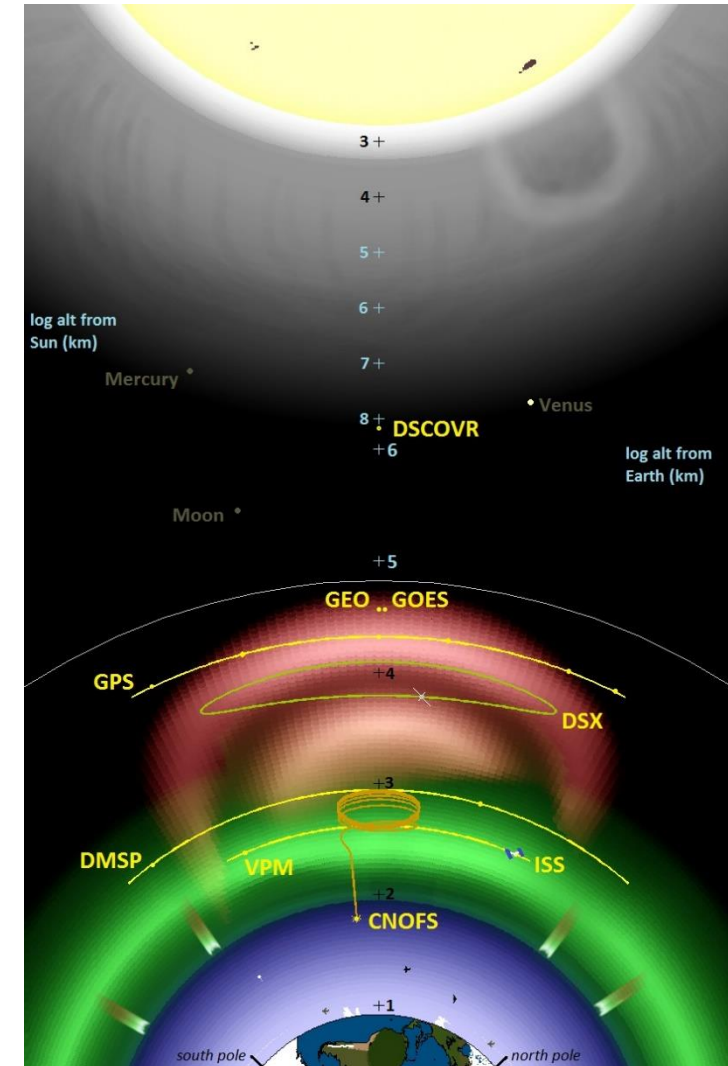
AFRL interests span the full range of the geospace environment from the sun to the earth

BASIC RESEARCH

- Solar processes
- CME propagation
- Radiation belt processes
- Magnetosphere-Ionosphere coupling
- Wave-particle interactions
- Ionospheric processes
- Plasma chemistry
- Thermospheric modeling

APPLIED RESEARCH

- Solar flare forecasting
- CME prediction
- Energetic charged particle sensors
- Spacecraft/plasma interactions
- Ionospheric modeling and data assimilation
- Scintillation impacts
- HF propagation modeling



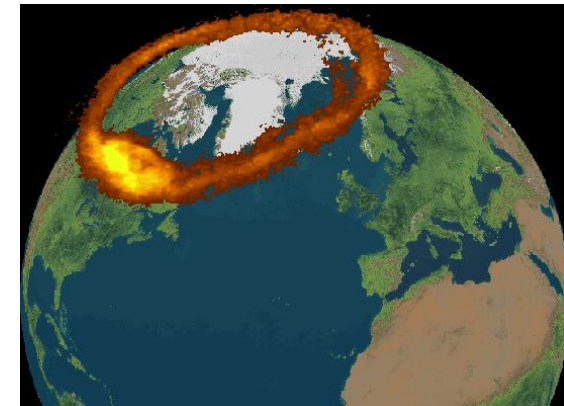
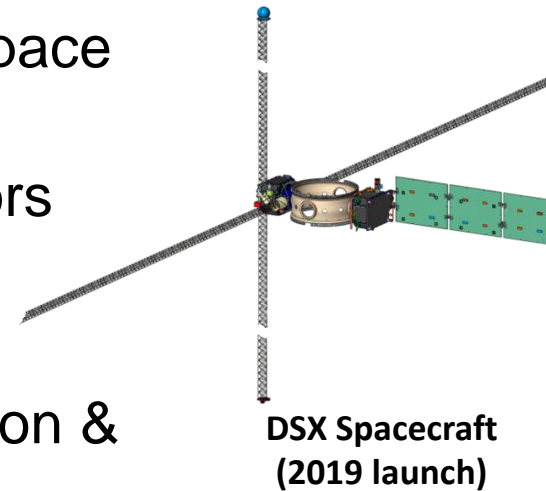
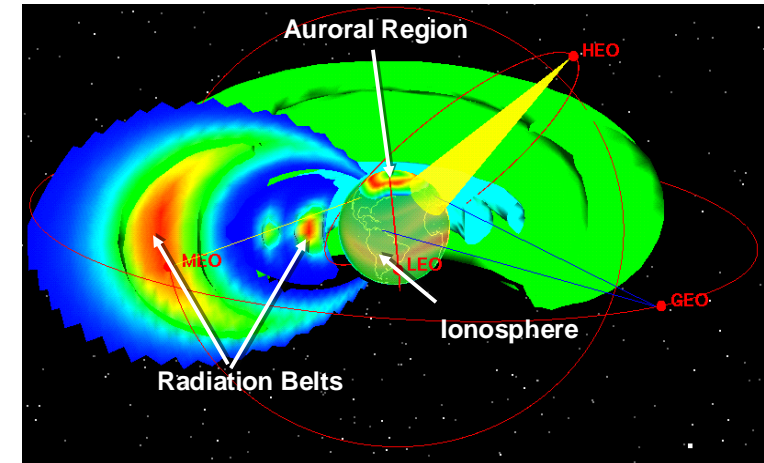
AFRL Geospace Environment R&D – Magnetospheric Communicating our S&T needs to the community

Need:

Novel space environment sensing techniques, specification models, and forecast models; modern climatologies; improved understanding of space environment interactions with space systems

R&D Challenges:

- Remote sensing techniques to specify the space environ
- Advanced Energetic Charged Particle sensors
- Radiation environment and solar particle specification models
- Auroral oval/precipitating electron specification & forecast models
- Spacecraft-plasma interaction models



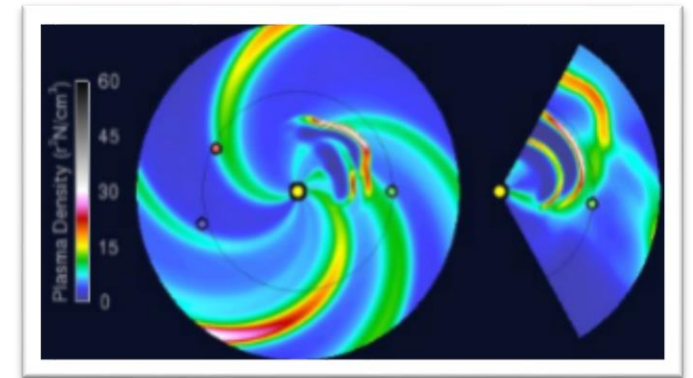
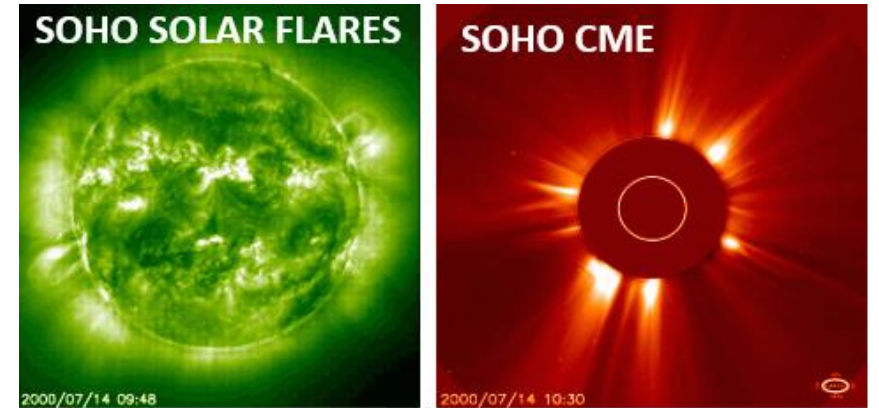
AFRL Geospace Environment R&D – Solar Communicating our S&T needs to the community

Need:

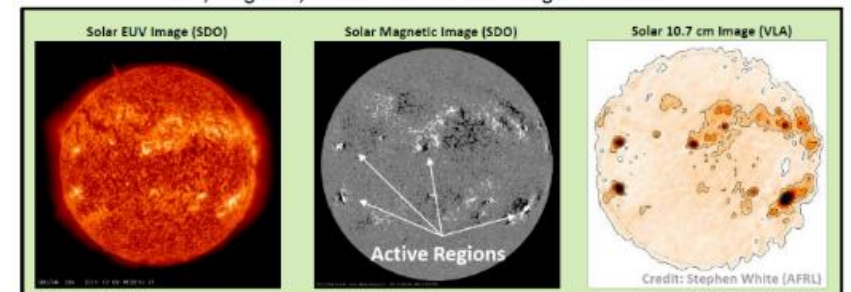
Understanding and forecasting solar driven mechanisms impacting space systems from CMEs to solar flares and the interaction of the solar wind with Earth’s magnetic field

R&D Challenges:

- Next-gen ground-based solar observing networks
- Automated probabilistic forecasting of solar events
- Post-eruption forecast of timing, peak fluxes, fluences, & spectral hardness
- Development of coronal and solar wind modeling providing accurate 3-day forecasts (particularly Bz)
- 3-day forecasts of solar radio bursts (timing, frequency, & intensity)



EUV, Magnetic, and 10.7 cm Full-Disk Images of the Sun



AFRL Geospace Environment R&D – Ionospheric

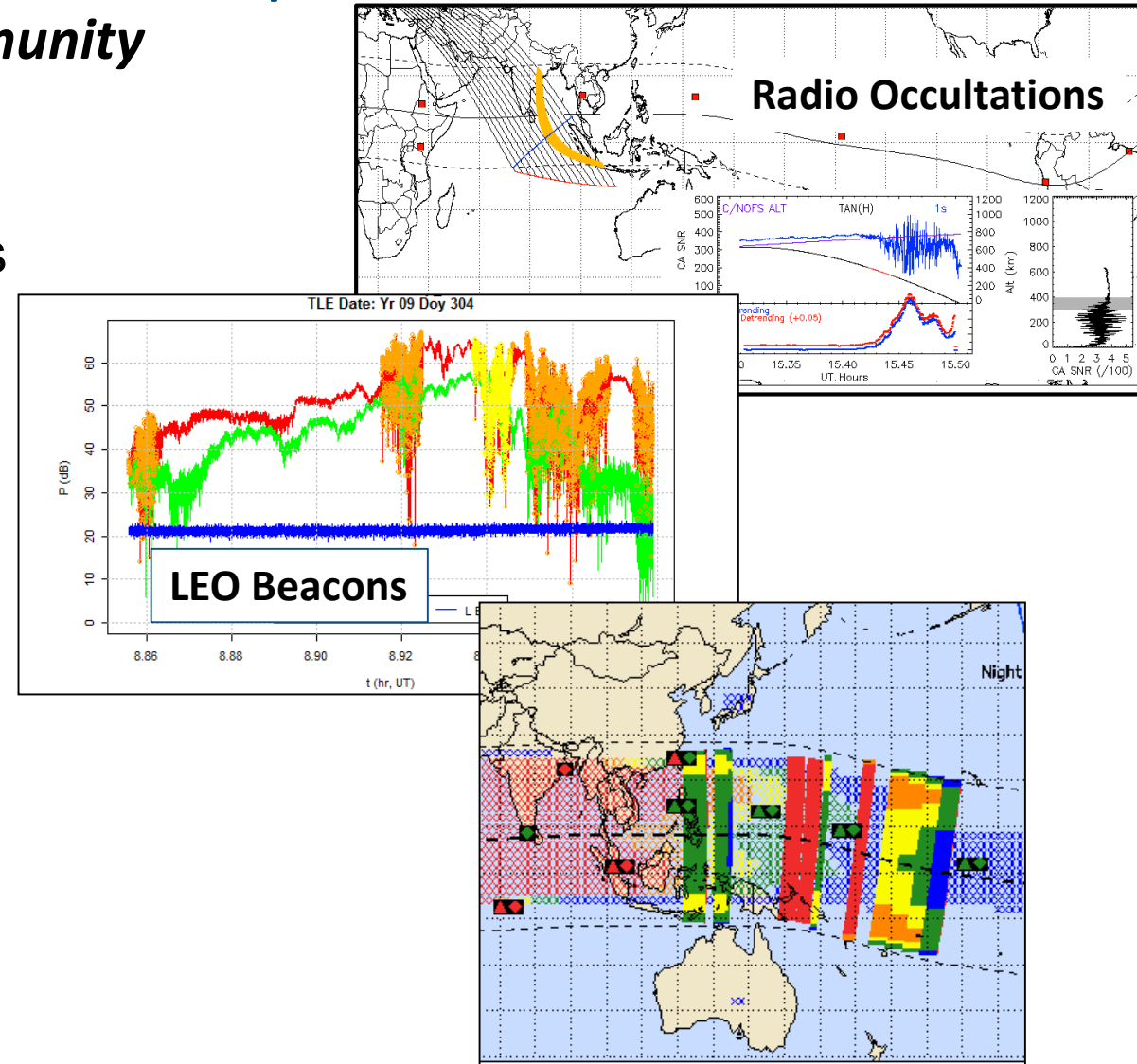
Communicating our S&T needs to the community

Need:

Monitoring, predicting, & characterizing the natural space environment and mitigating its effects on space systems

R&D Challenges:

- Understanding the fundamental drivers that control the ionospheric phenomena
- Physics-based models of the ionosphere: densities, winds, irregularity development, response to environmental drivers
- Coupled assimilation models for new and disparate data sources



AFRL Geospace Environment R&D – Ionospheric

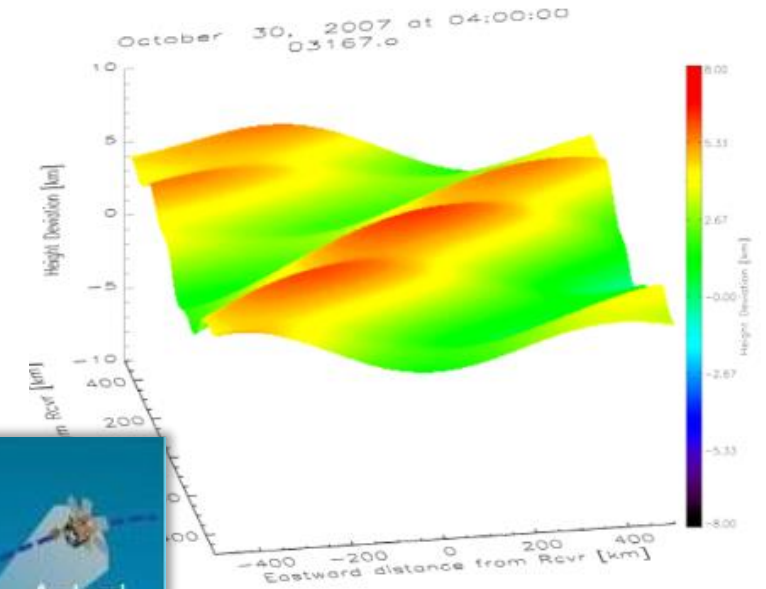
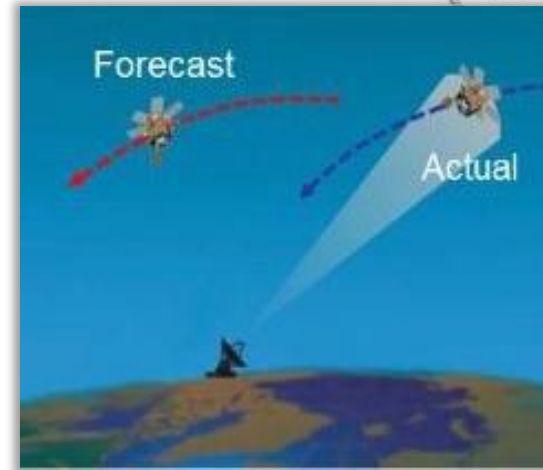
Communicating our S&T needs to the community

Need:

Monitoring, predicting, & characterizing the natural space environment and mitigating its effects on space systems

R&D Challenges:

- Bottomside ionospheric specification
- Global mapping of sporadic-E with available sensors, eg. Radio Occultation
- Physics-based neutral density models for precise orbit determination



Courtesy of G. Crowley, ASTRA



Questions?