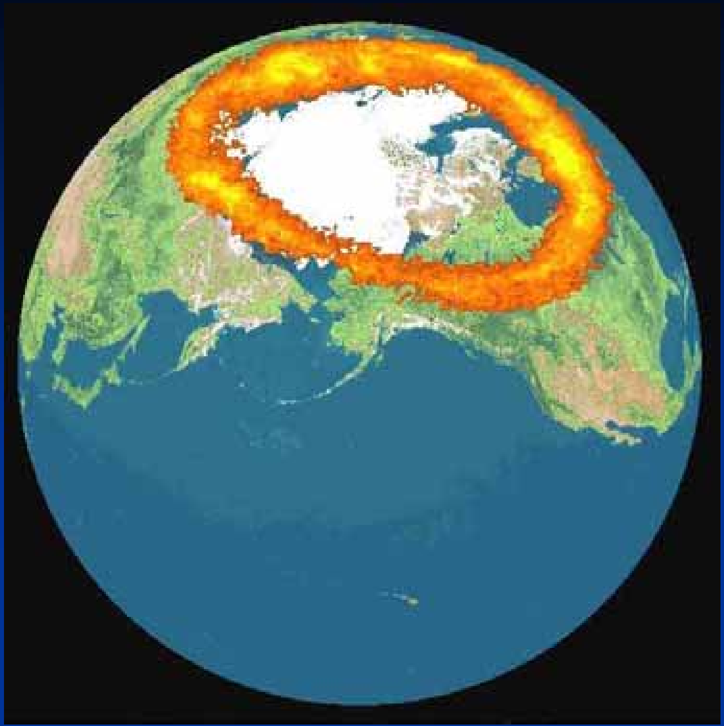
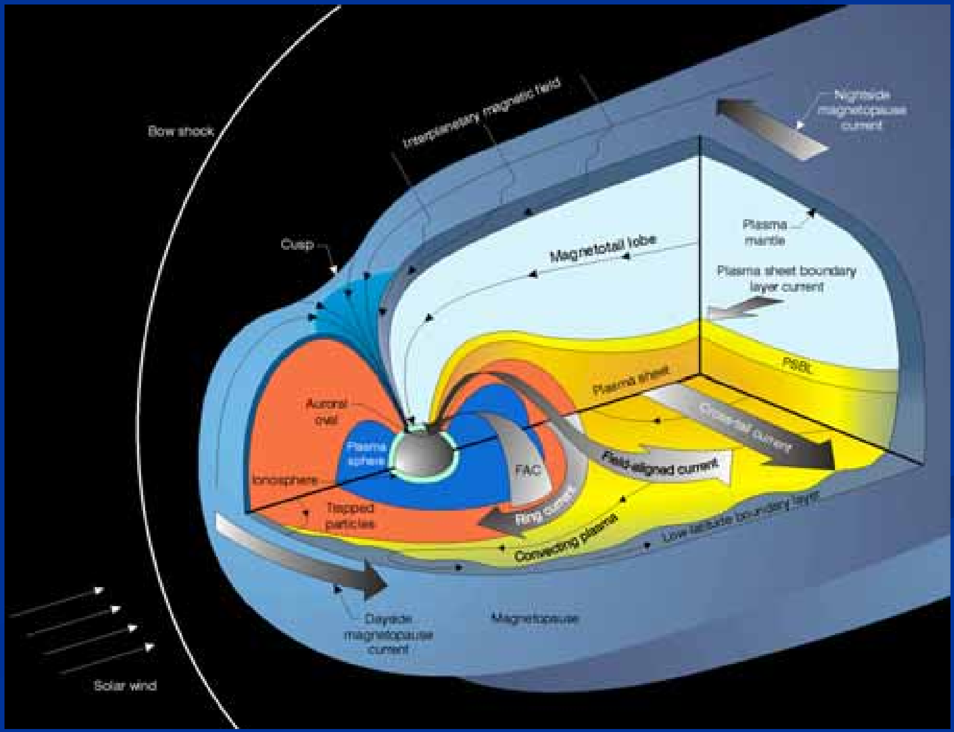
MIT

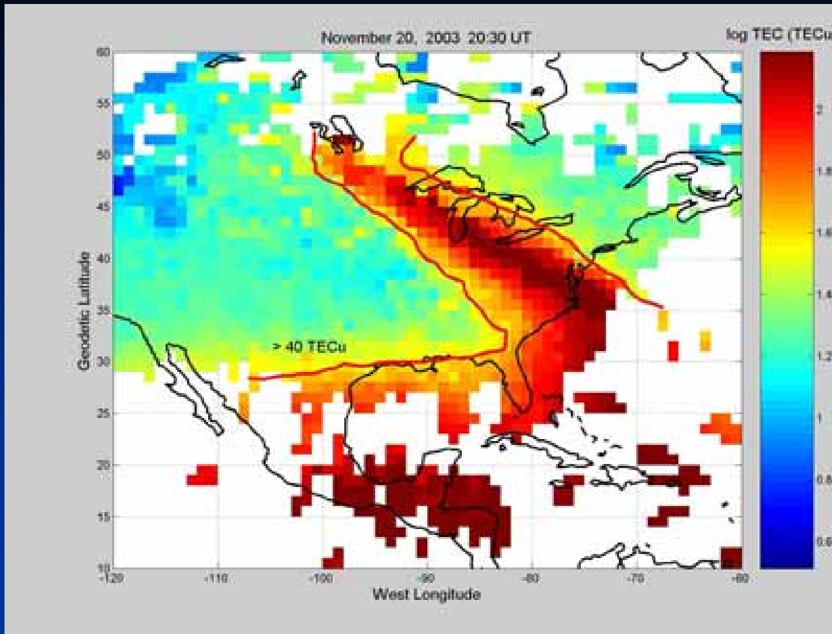
Millstone Hill Observatory

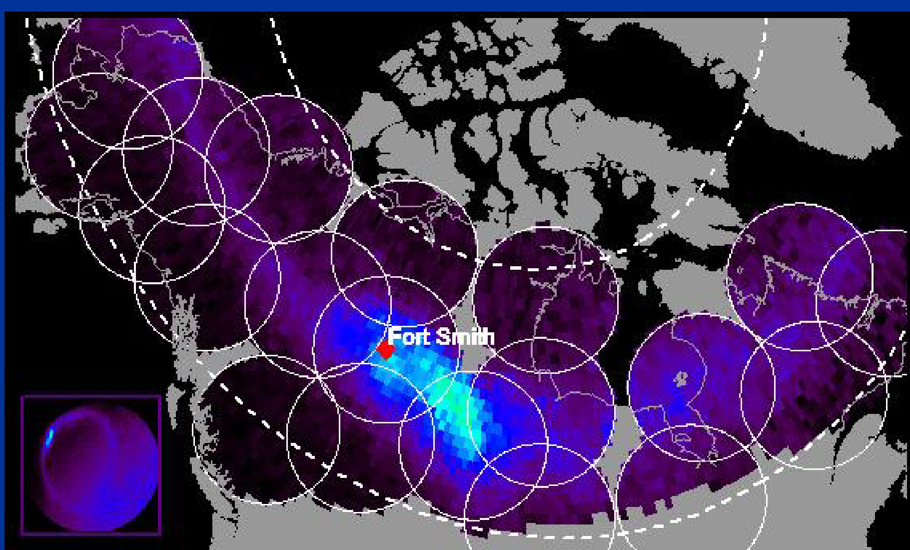


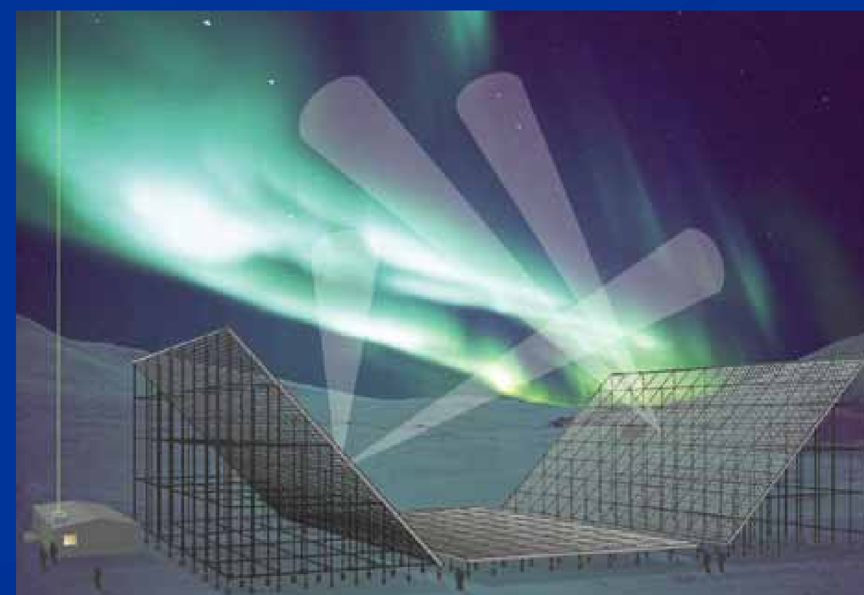
The Role of Ground-Based Observations in M-I Coupling Research

John Foster
MIT Haystack Observatory







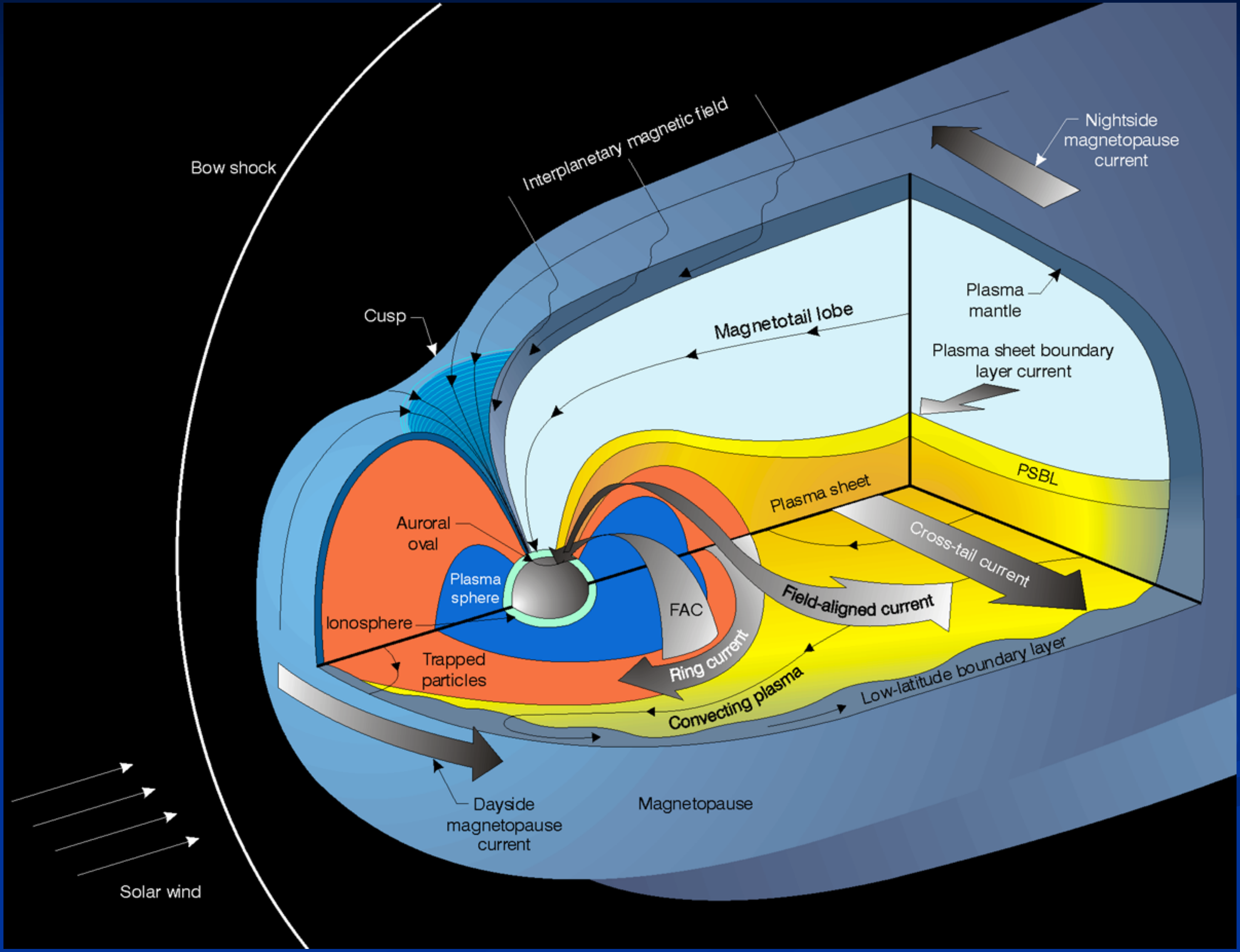


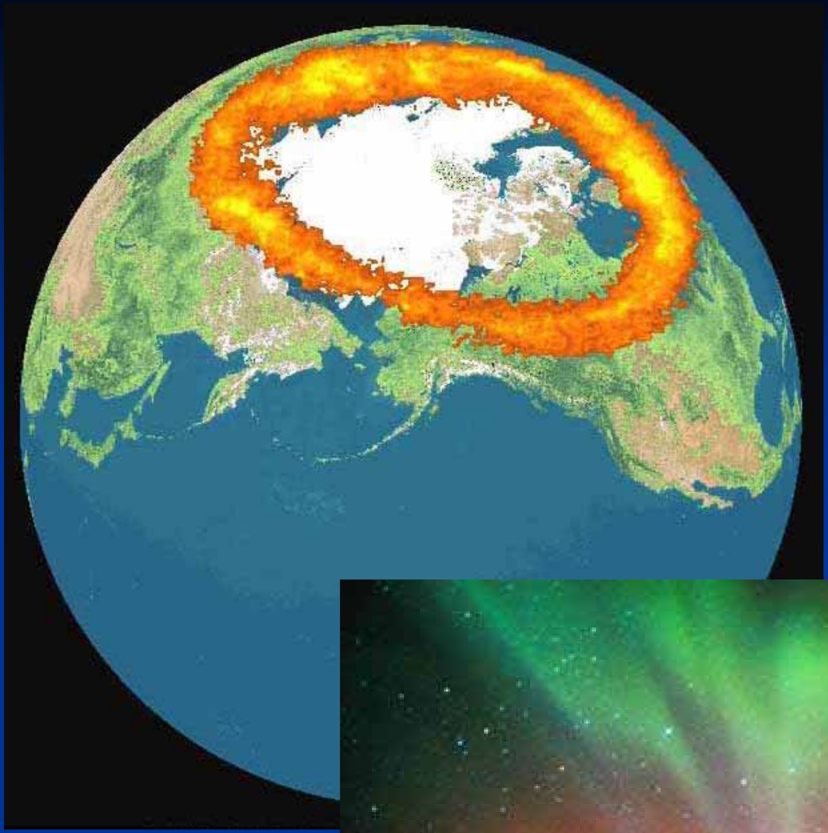
CEDAR/GEM Student Workshop

Outline

- Some Definitions: Magnetosphere, etc.
- Space Weather
- Ionospheric Disturbances
  (M-I Coupling Effects)
- Class I Facilities
- DASI: Distributed Arrays
- Multi-Technique System Studies

Earth's Magnetosphere



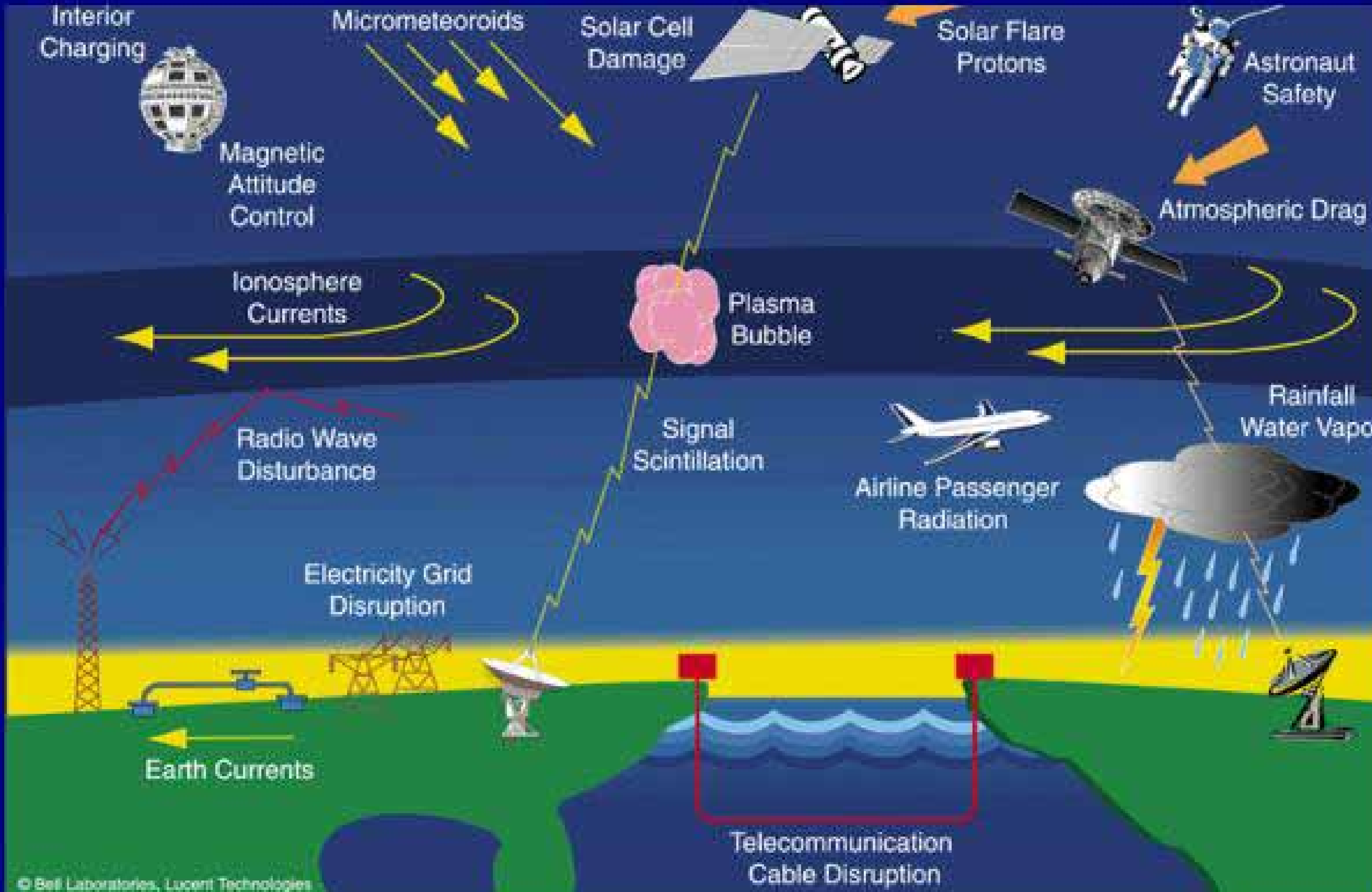


Aurora:
Energized Particles from Magnetosphere Enhance Ionospheric Conductivity within Auroral Oval

Weather in Earthspace

- Earth's Magnetosphere – Ionosphere – Atmosphere form a **Coupled System**
- The **medium consists of magnetized plasmas** whose dynamics are controlled by electric fields and currents
- Distributed ground-based instruments and space-based imaging are providing **new perspectives and understanding**
- Severe Space Weather effects arise from **processes** which **span these upper-atmosphere regions**
- A **predictive capability is needed** to protect our assets in space

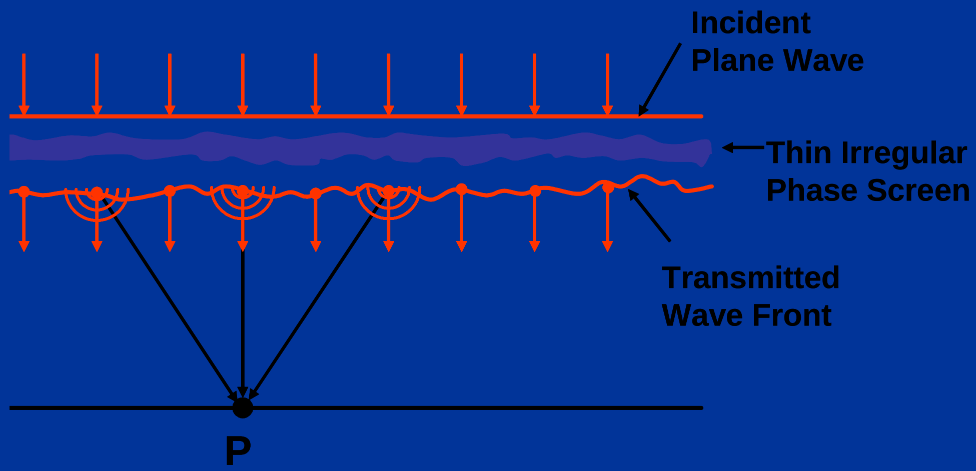
Space Weather Effects

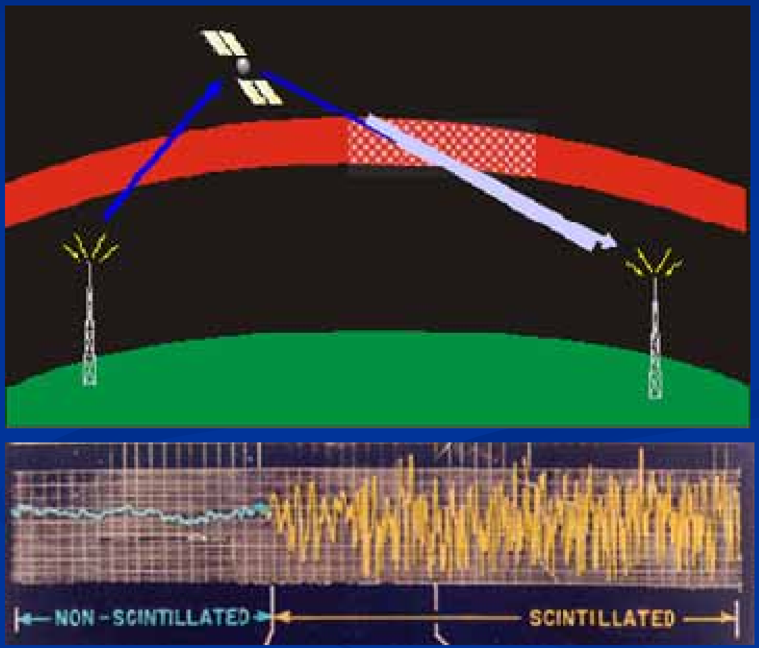


Space Weather: Ionospheric Scintillation

(One Person's Noise Is Another's Data)

Scintillations disrupt signals important for communications/navigation systems.





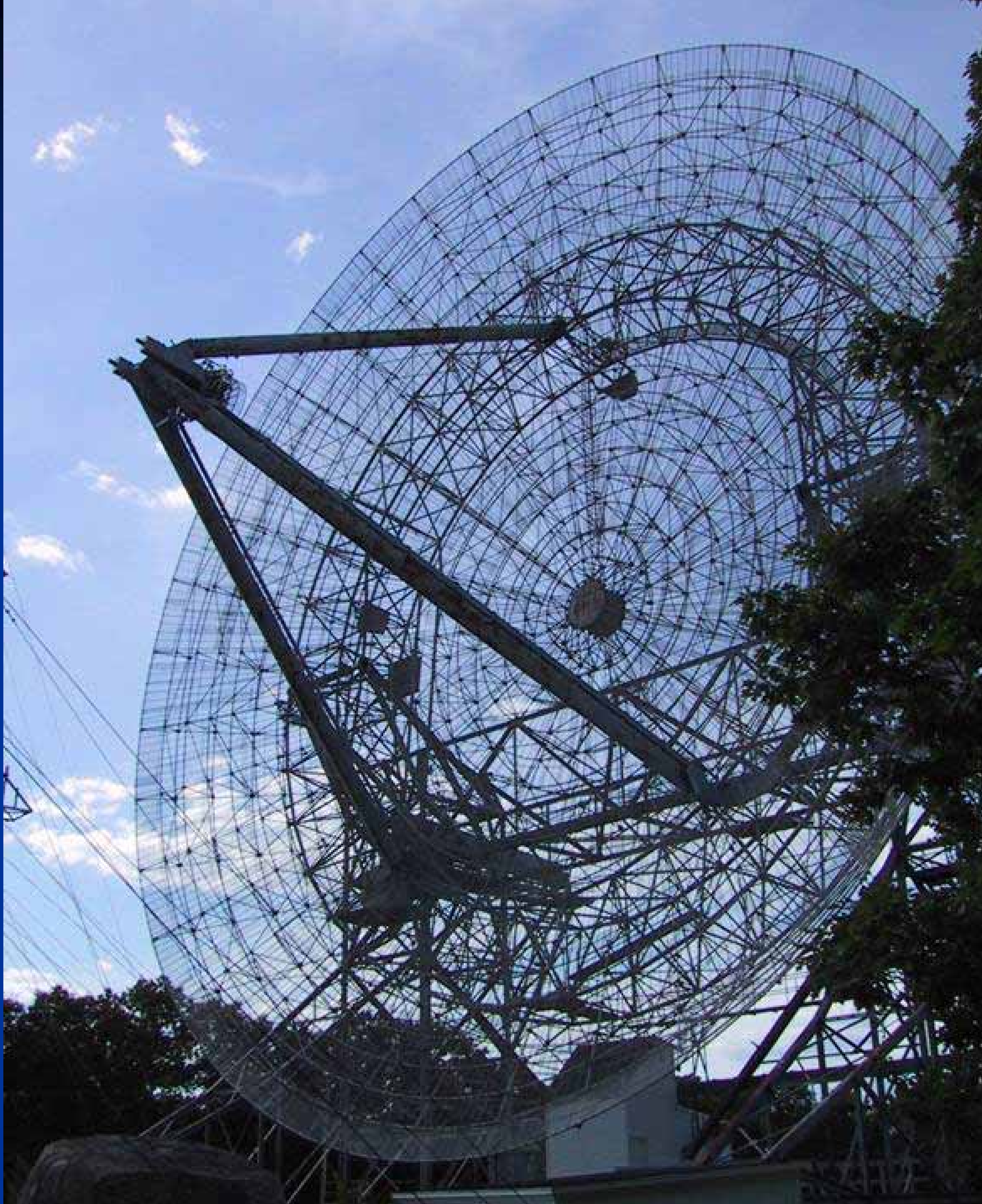
Unstable plasma within the Earth's ionosphere results in irregularities in refractive index

Scintillations occur when radio waves pass through a turbulent ionosphere, reducing signal quality

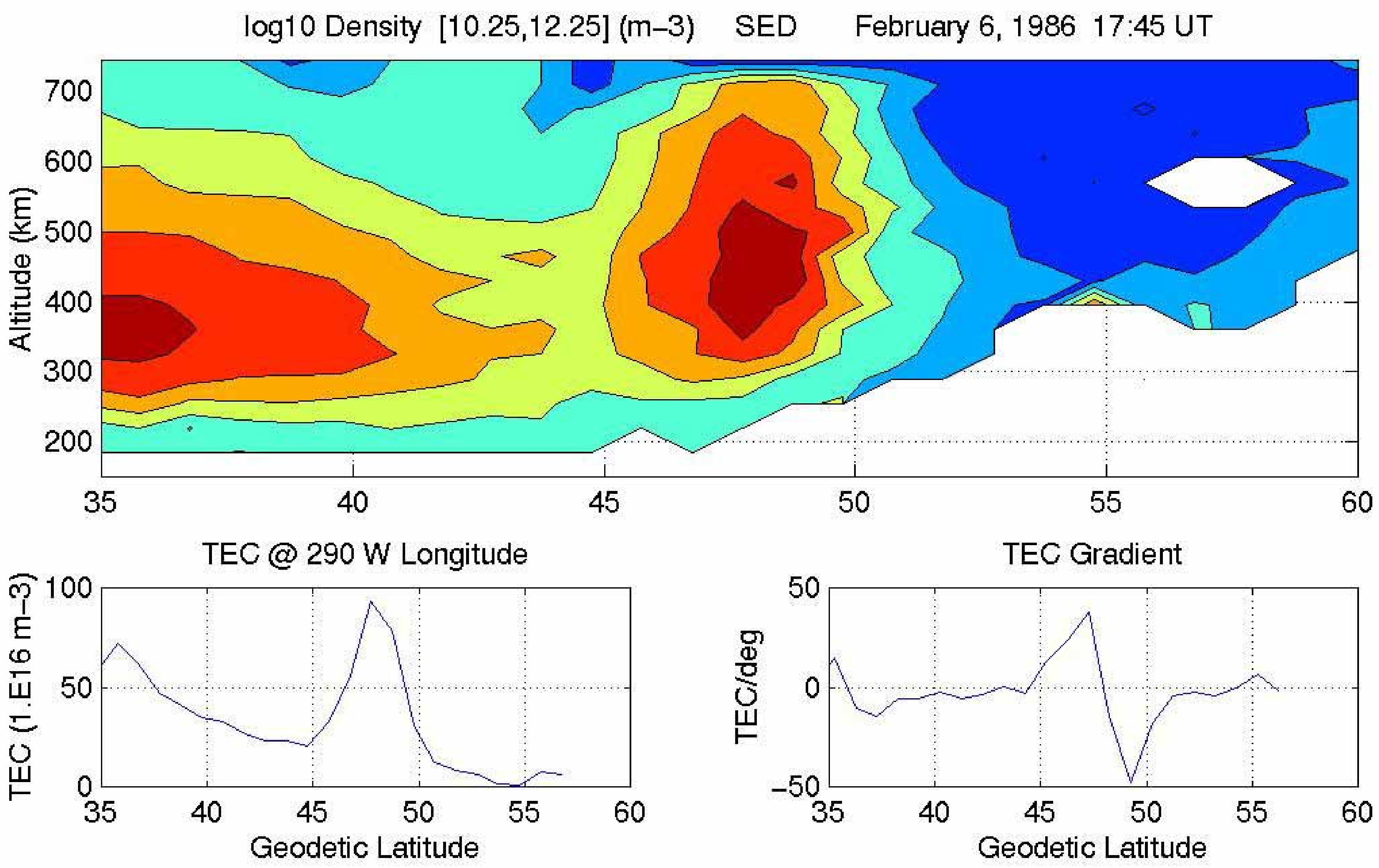
MIT Millstone Hill Incoherent Scatter Radar

Scanning Radar Probes Ionosphere and Space Weather Disturbances

Radio-Wave Remote Sensing



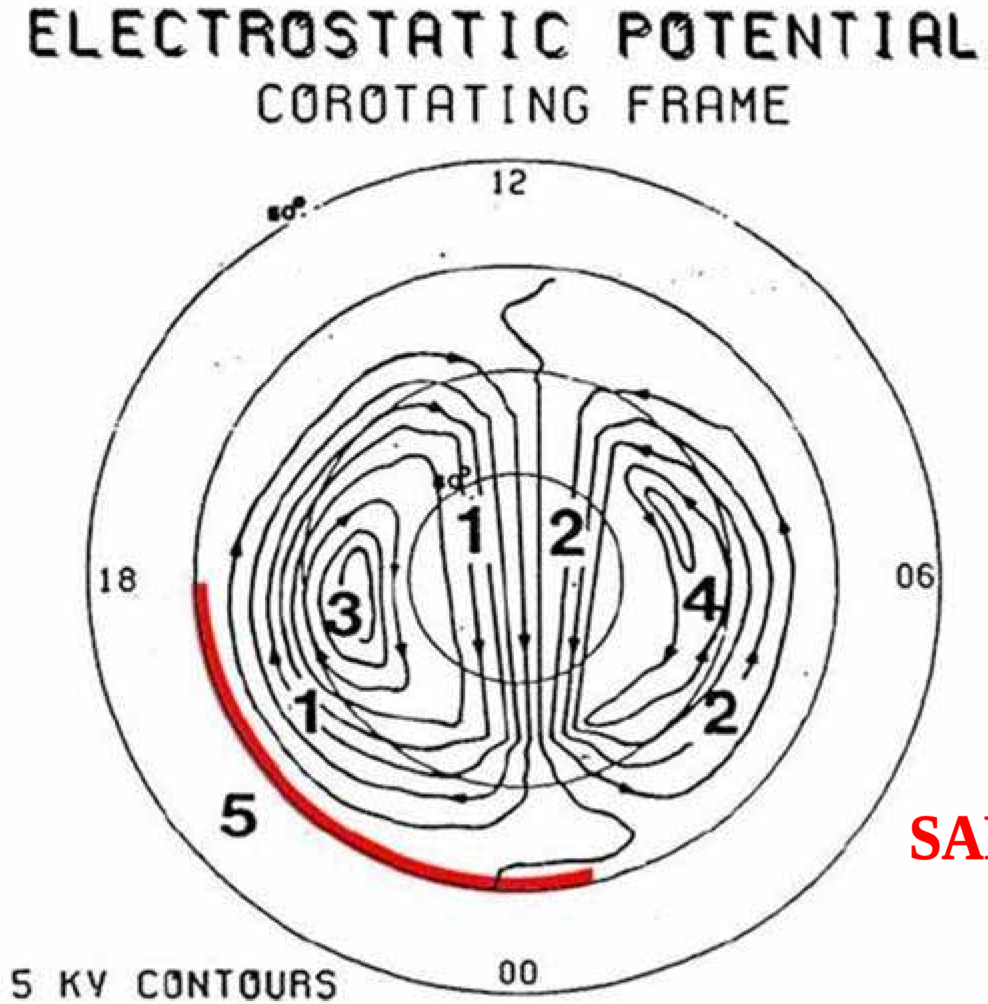
ISR Observes Storm Enhanced Density



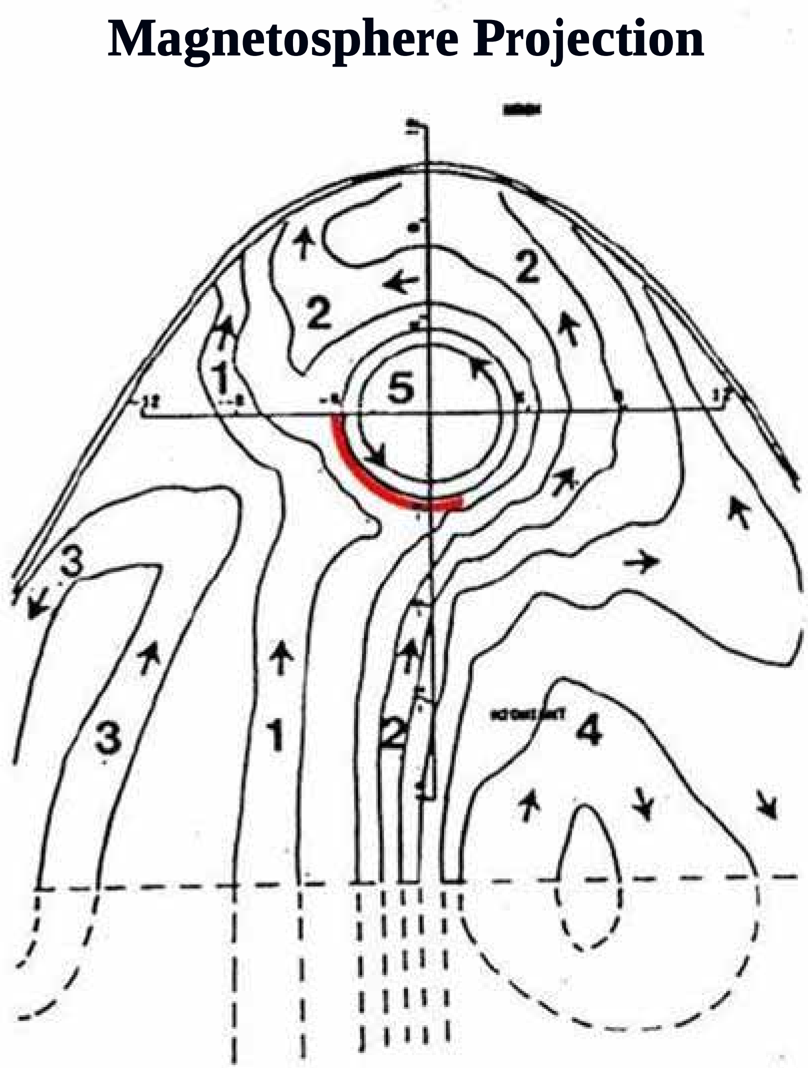
[Foster, JGR, 1993]

Millstone Hill IS Radar

Radars Measure Ion Velocity and Map Convection Electric Field (V ~ E x B)

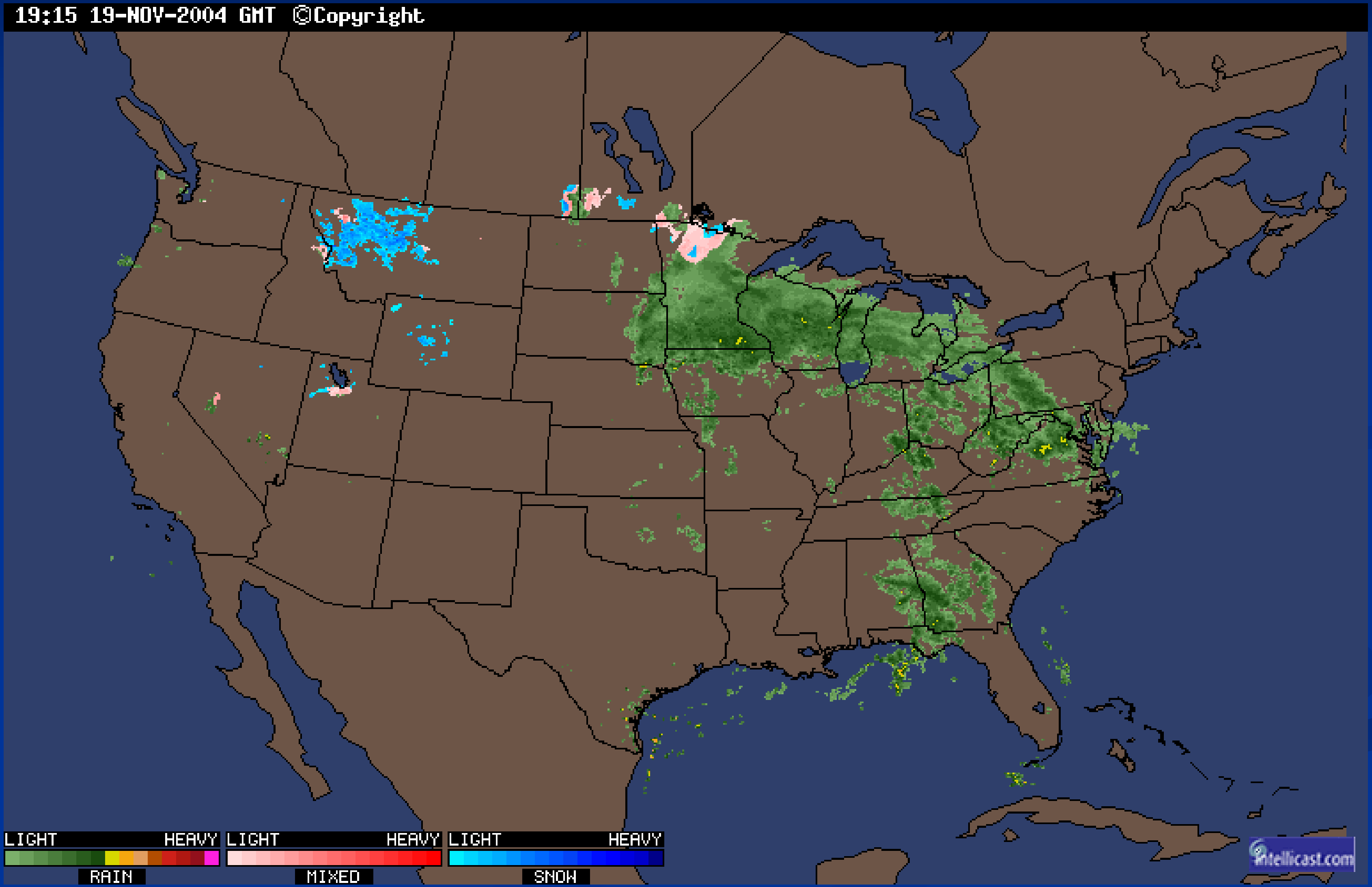


SAPS

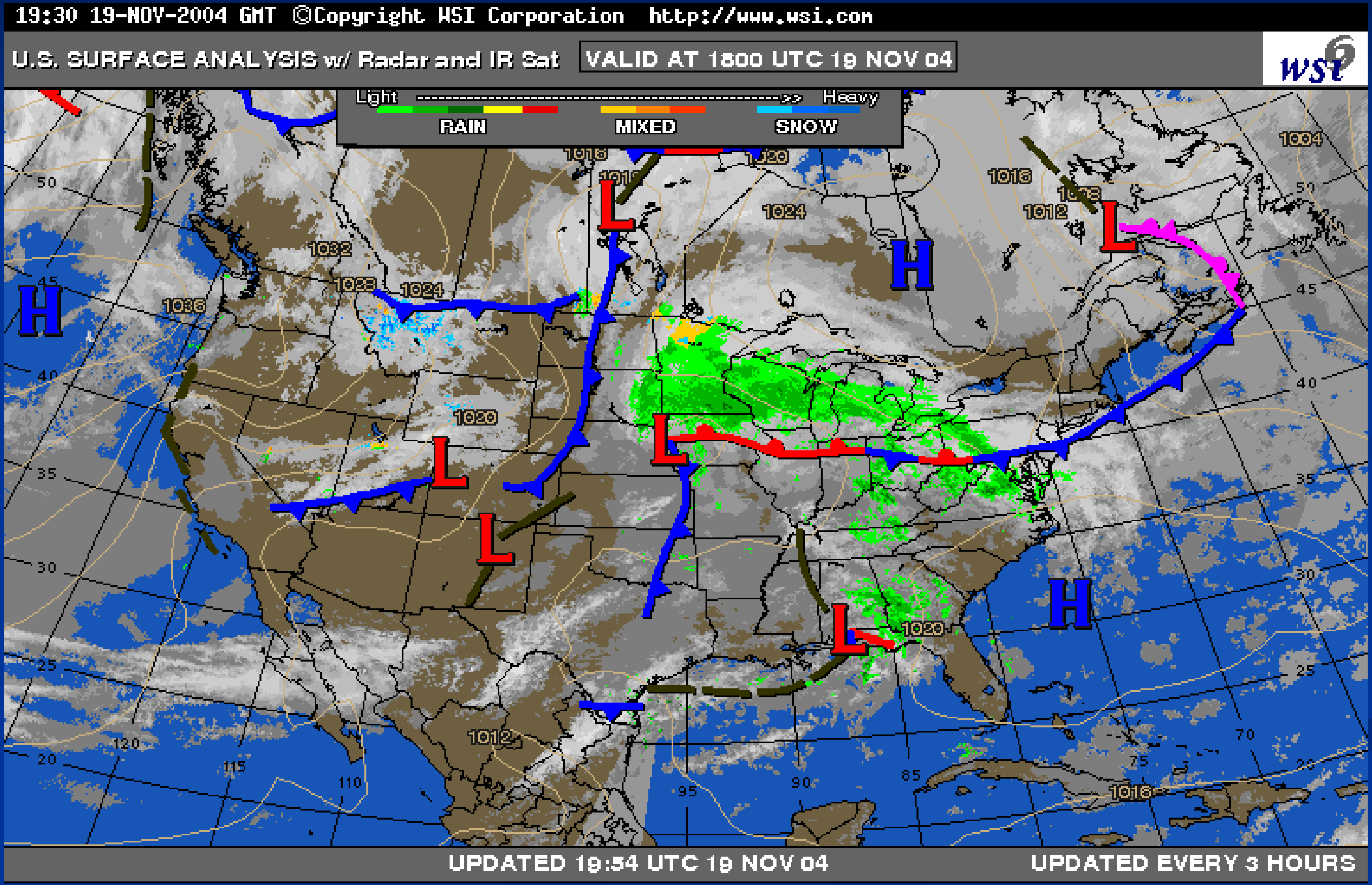


Electric Field Maps Between Ionosphere and Magnetosphere

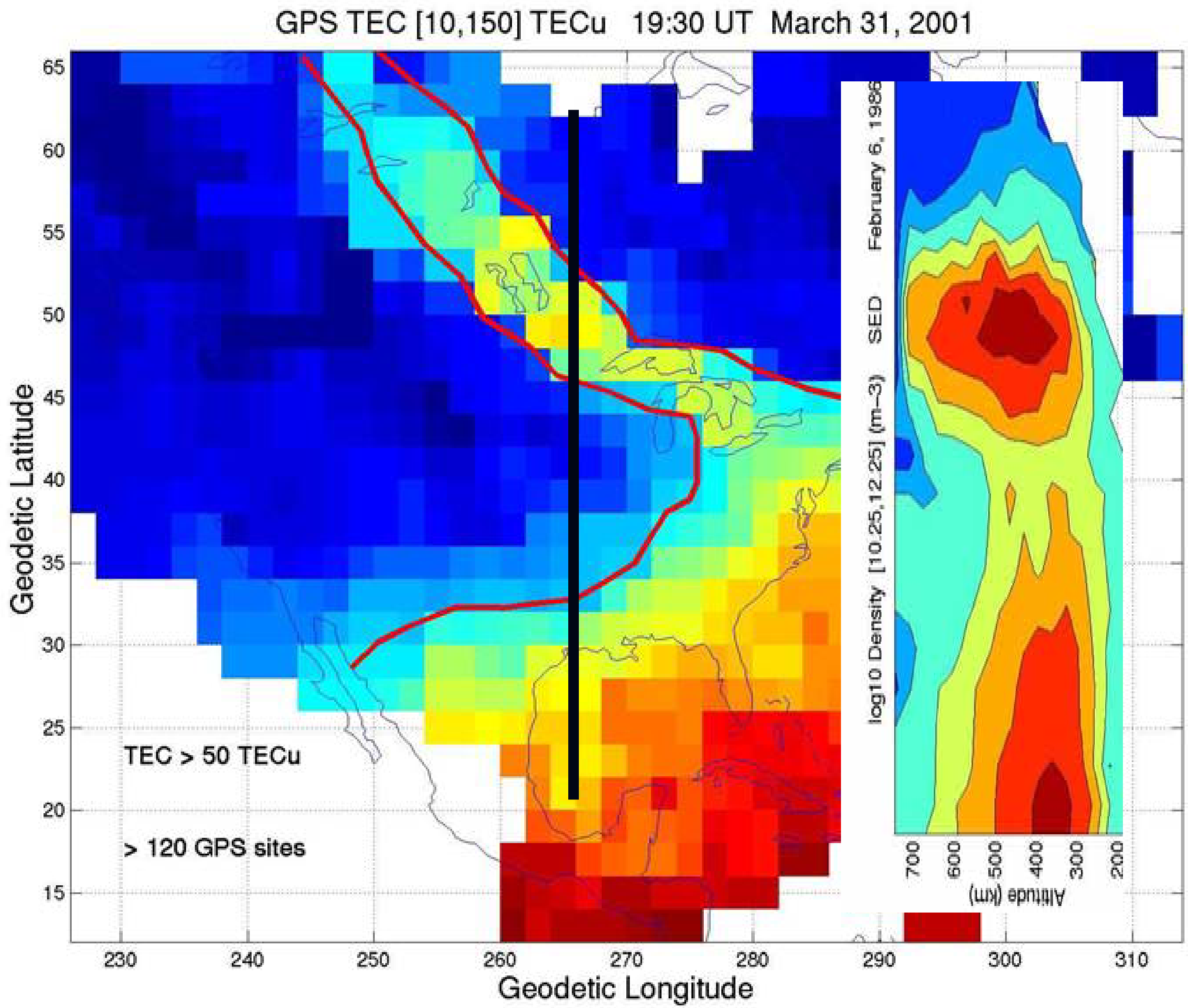
Today's Weather: NEXRAD Observations of Storm Front over N. America



Analysis & Understanding are Well Developed

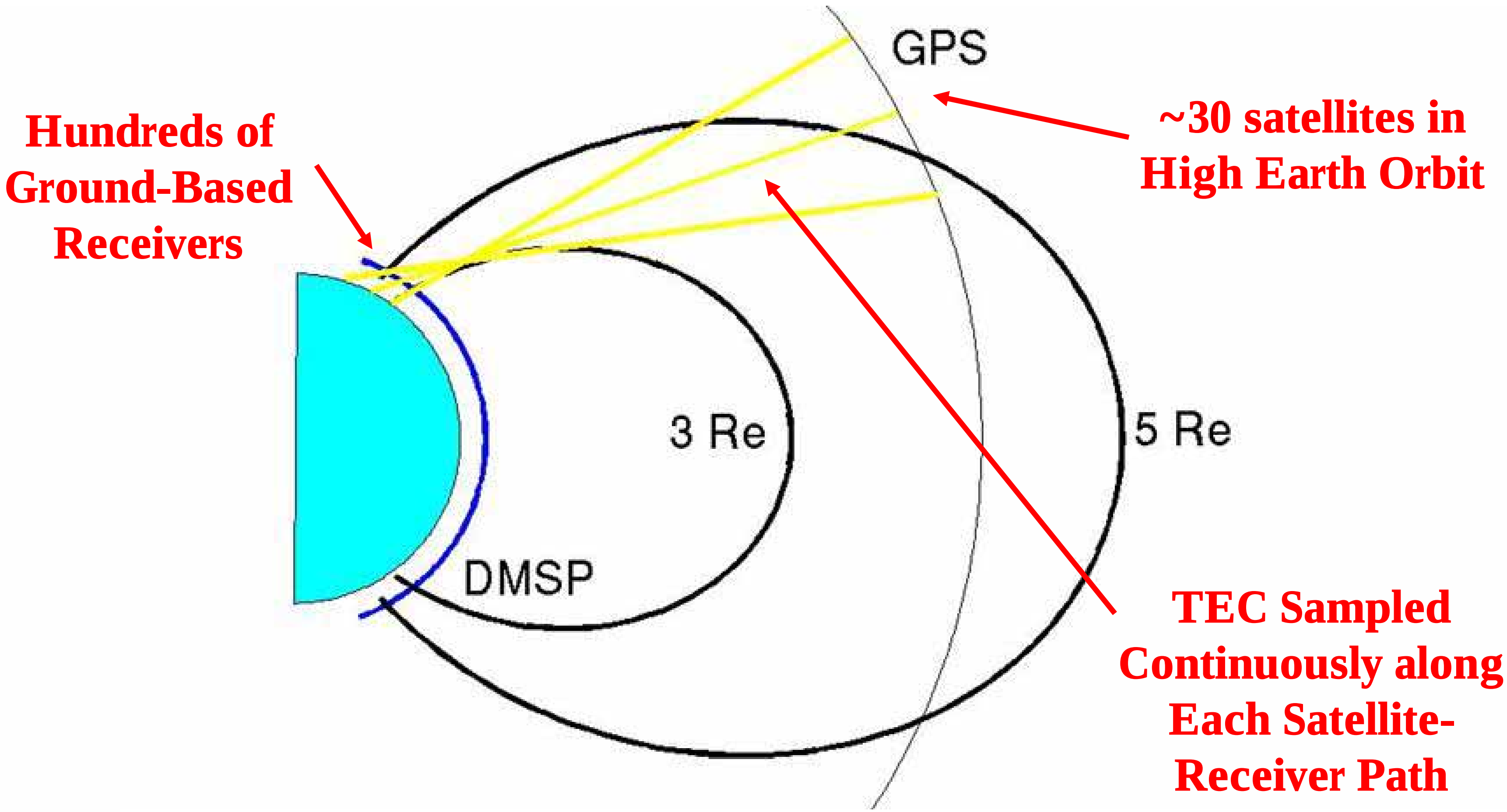


Ground-Based Observations using GPS TEC Image Space Weather Storm Fronts



[Foster et al. GRL 2002]

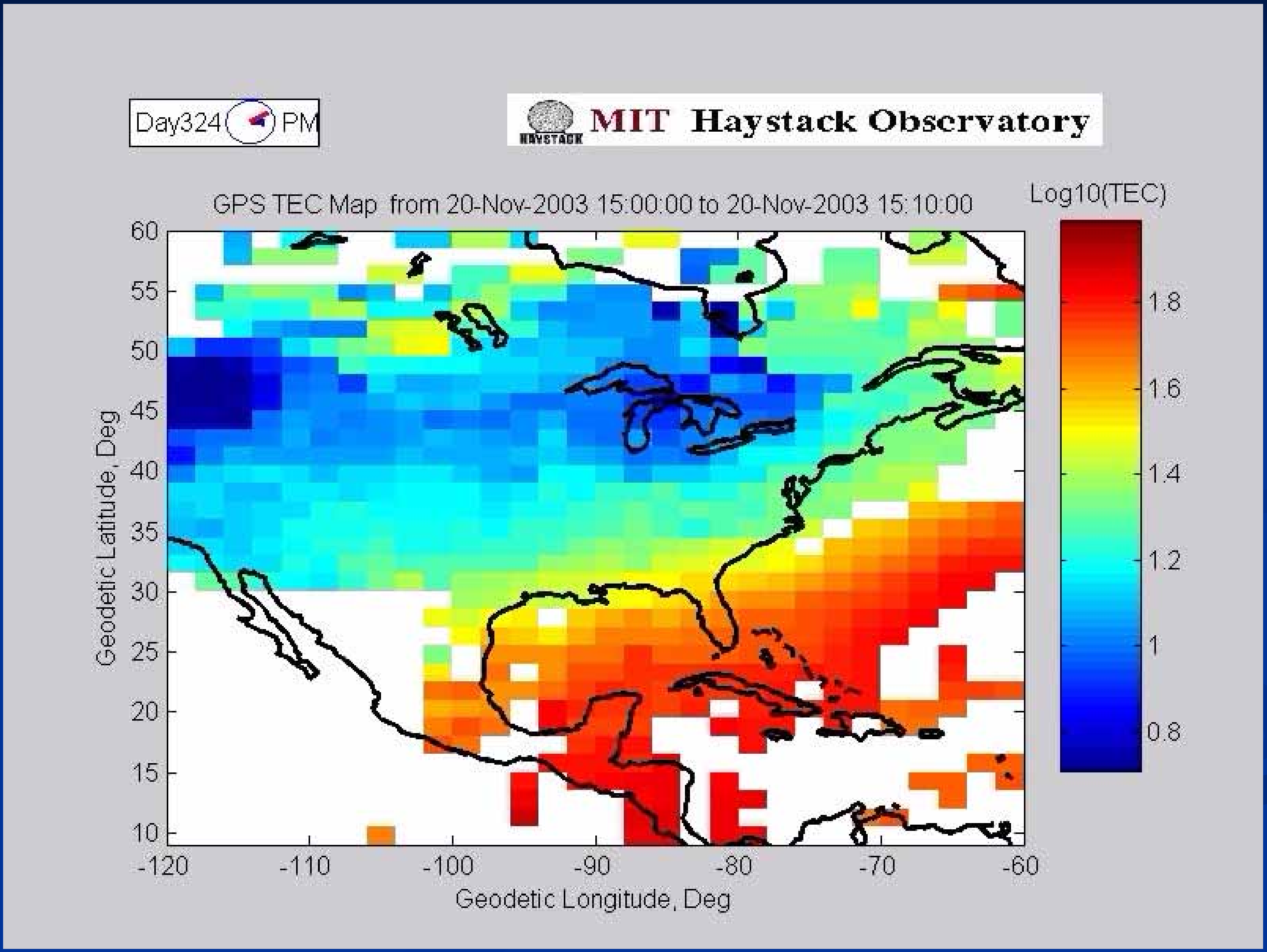
GPS samples the ionosphere and plasmasphere to ~20,000 km. Dual-frequency Faraday Rotation Observations give TEC (Total Electron Content)



TEC is a measure of integrated density in a 1 m^2 column

1 TEC unit = 10^{16} electrons m^{-2}

Observations: GPS TEC



Plasmasphere & Ring Current

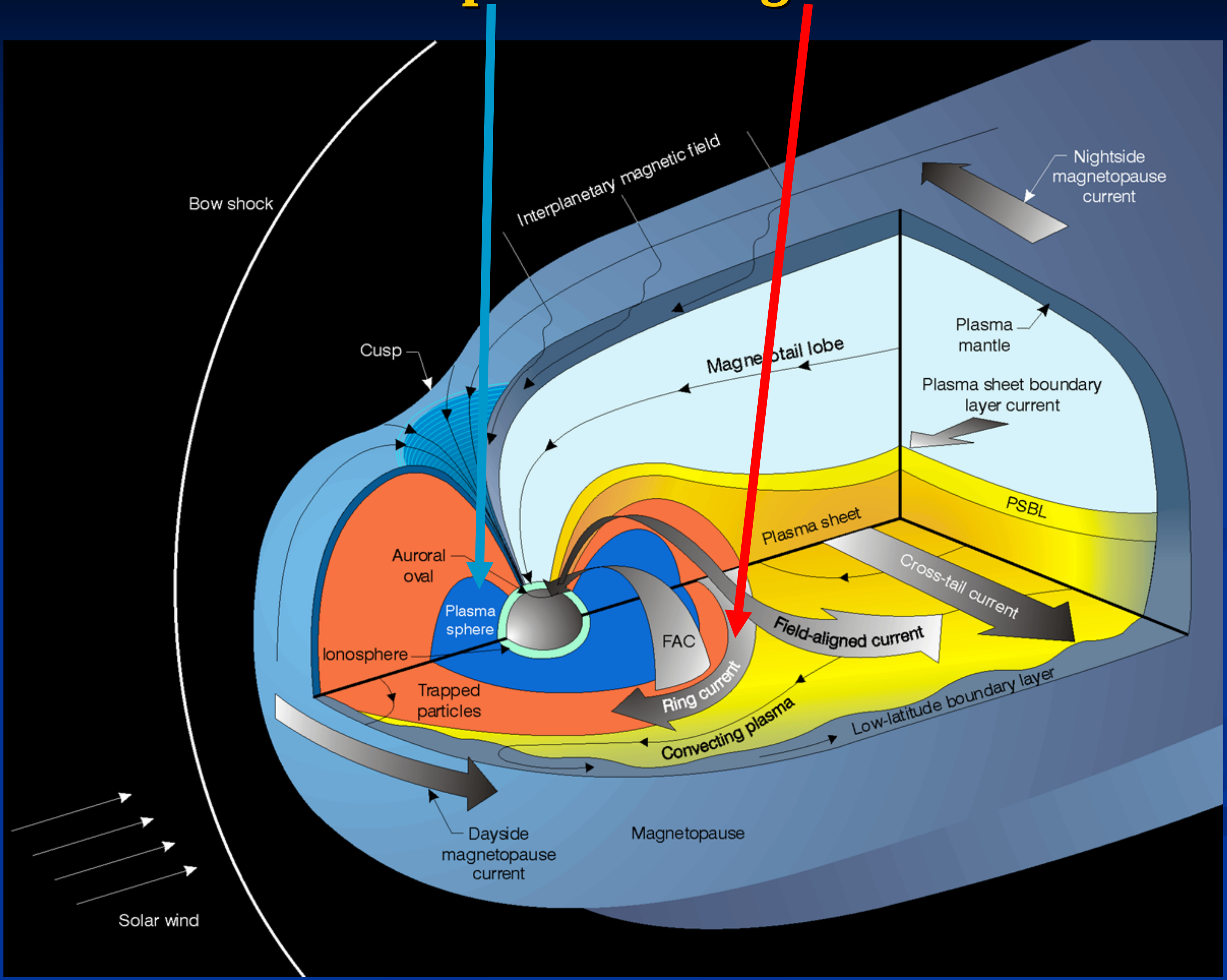


IMAGE EUV

Observations of the Plasmasphere

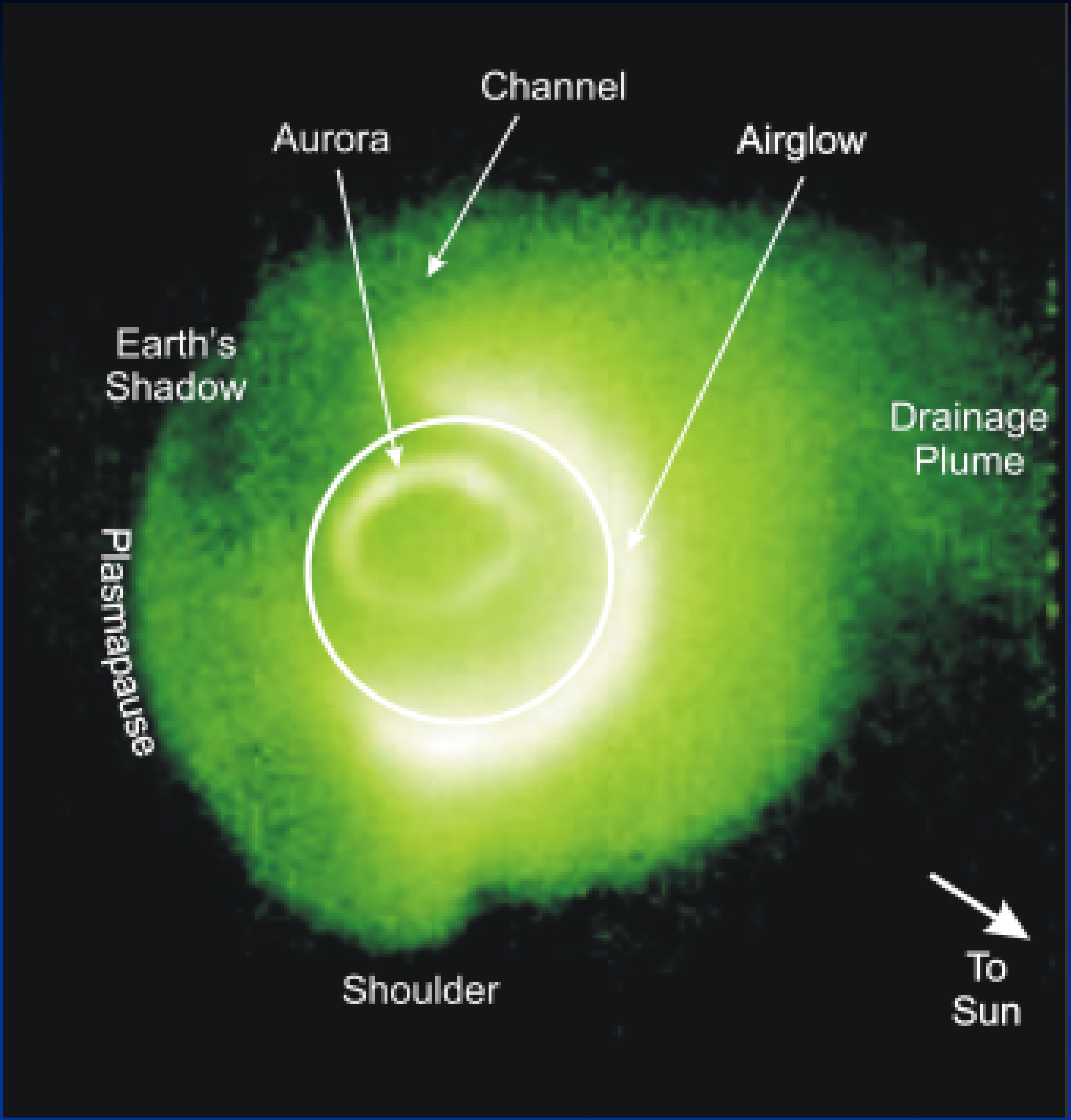
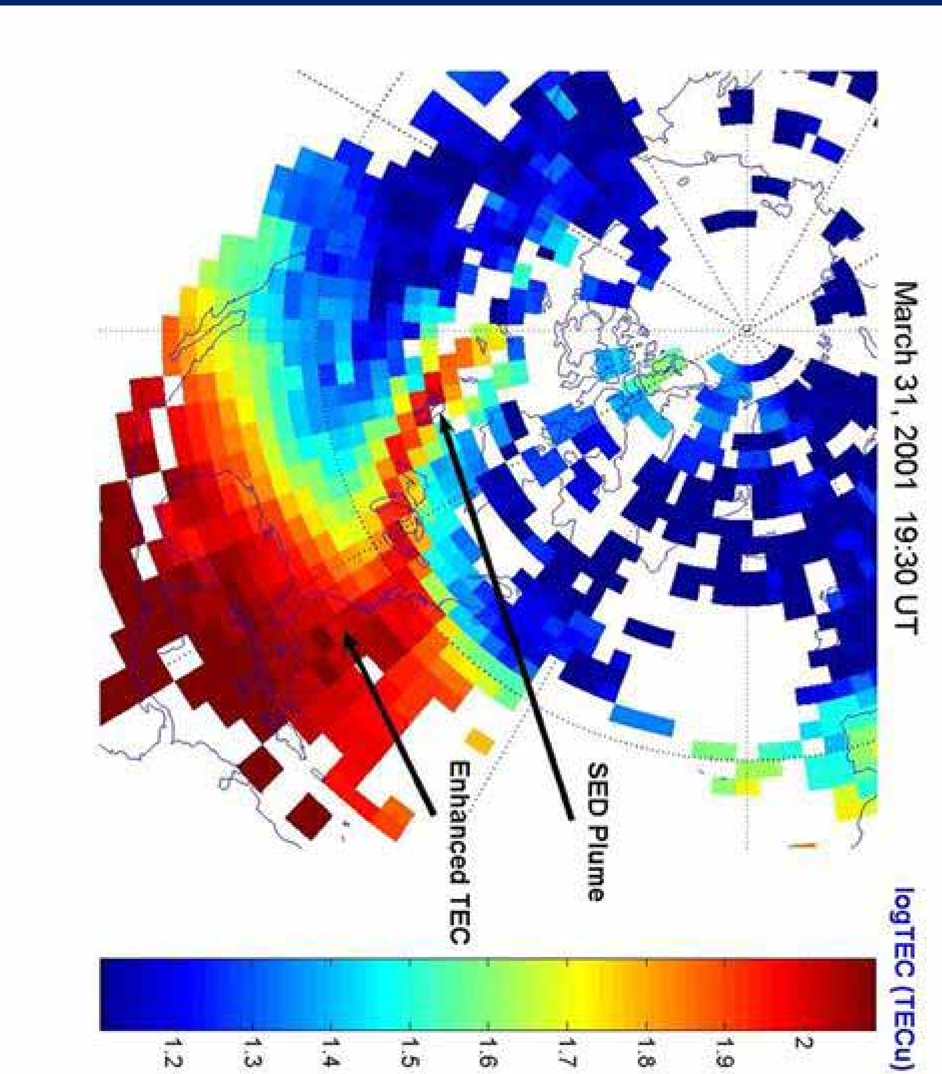


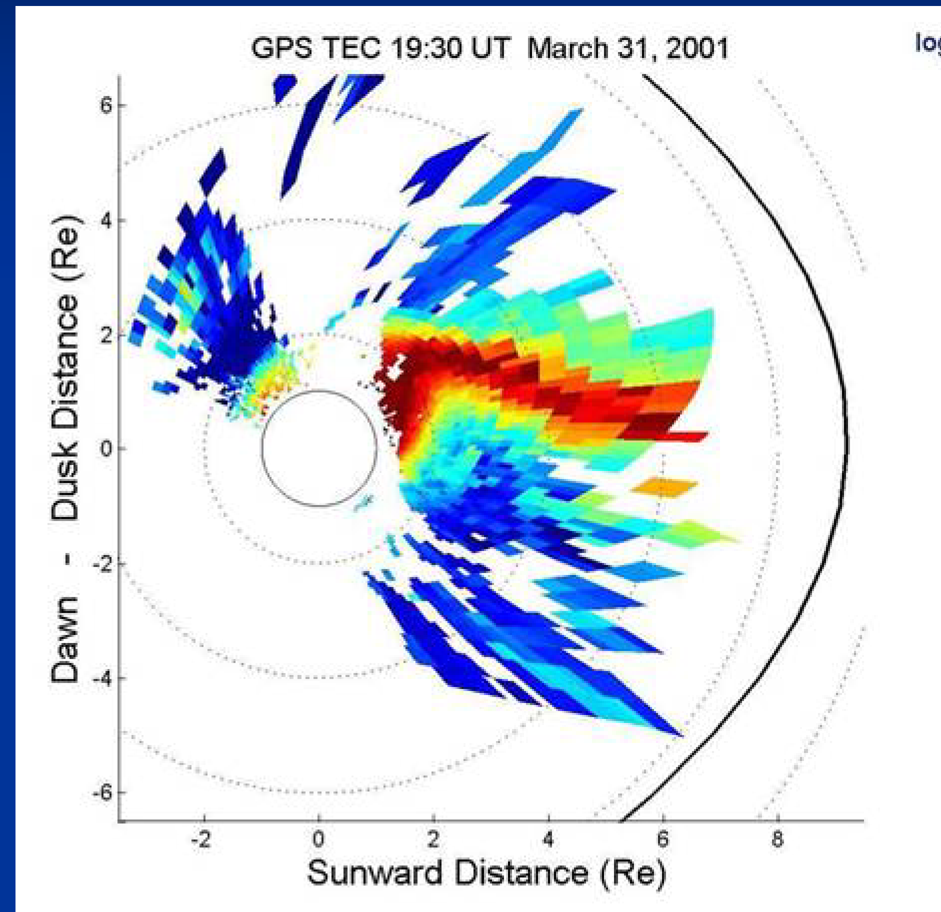
IMAGE EUV observations:
SED Plumes accompany Plasmasphere Erosion

April 11, 2001

Sun

Footprint of Erosion Plume in the Ionosphere & Magnetosphere





(Tsyganenko Mapping to Equator)

CEDAR Class I Facilities

Modern Instruments (Radar/Lidar: AMISR)

DASI

Distributed Arrays of Small Instruments

- GPS Receivers
- Optical Imagers
- Interferometers
- Ionosondes
- Scintillation and VLF Rx
- Tomography Receivers
- Solar Observations
- Magnetometers
- Passive & Active Radar
- Radio Receivers
- Riometers
- Neutron Monitors
- IPS Arrays
- Earth Current Monitors

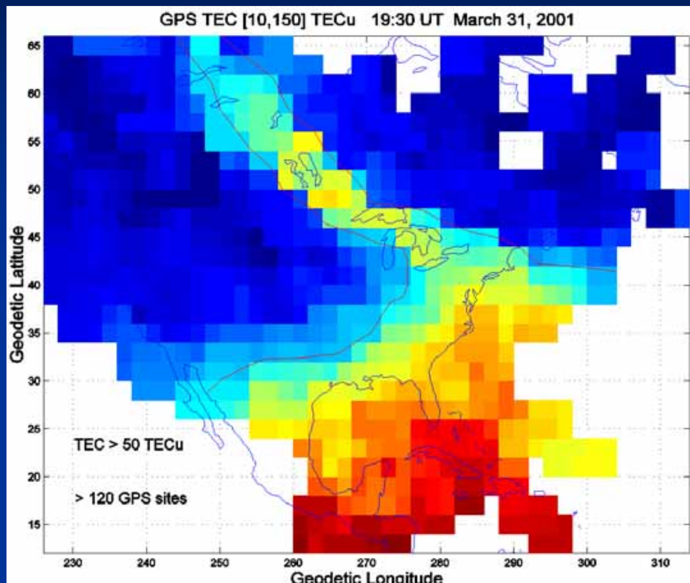
Technology: ITR, Miniaturization

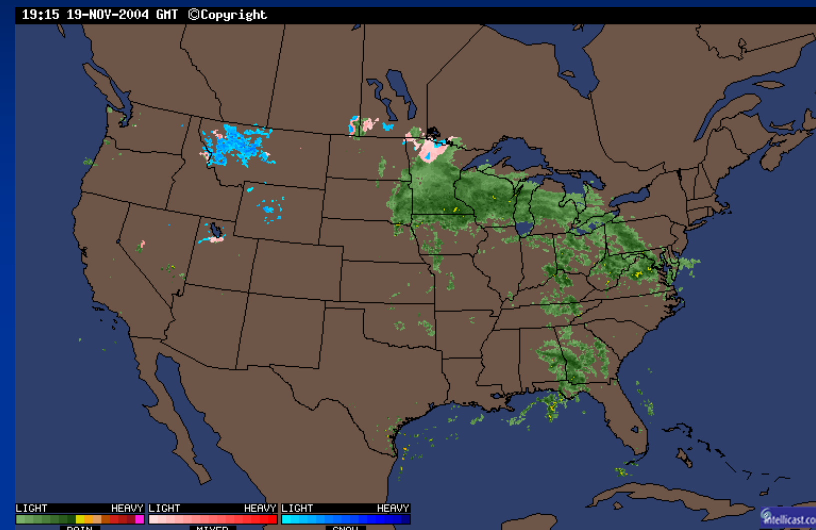
EPO Opportunities

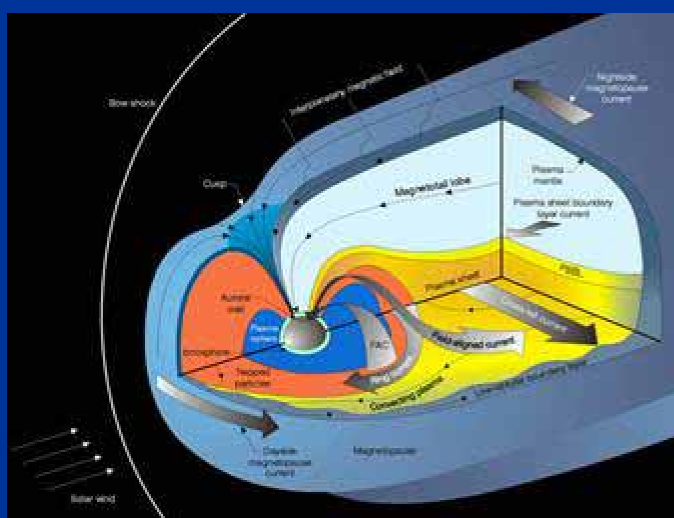
DASI Overview

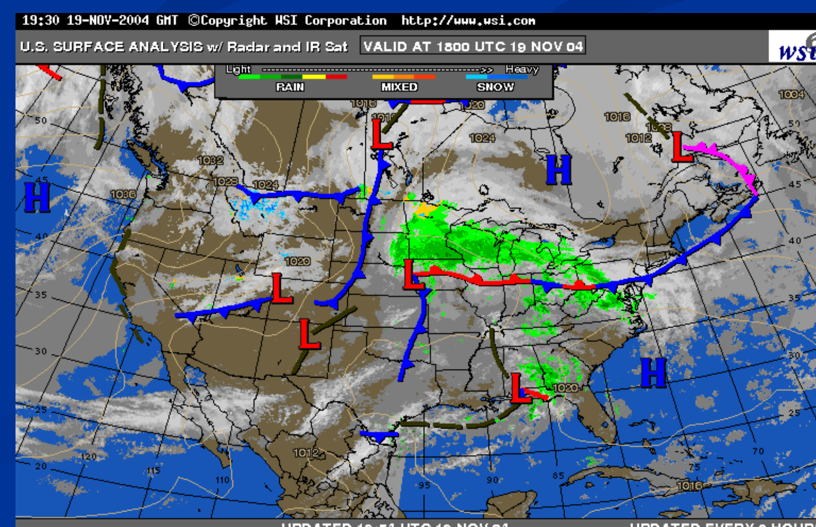
- The NAS Solar and Space Physics Decadal Survey has recommended that the **next major ground-based instrumentation initiative** be the deployment of arrays of space science research instrumentation
- DASI arrays will provide **continuous real-time observations** of Earthspace with the resolution needed to resolve mesoscale phenomena and their dynamic evolution
- Ground-based arrays will address the need for observations to support the next generation of **space weather data-assimilation** models
- The **time is right for DASI**: developing technology and IT systems support a new science capability

Imaging Meso-Scale Phenomena with Distributed Observations





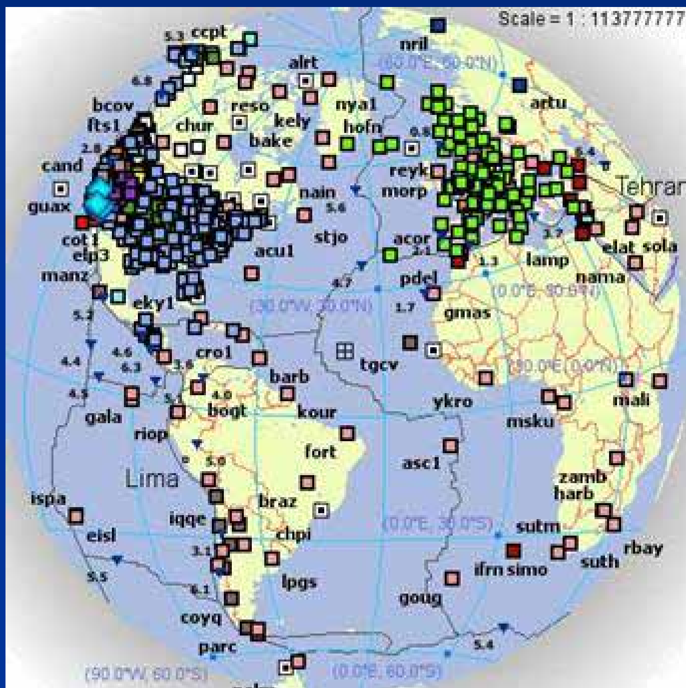


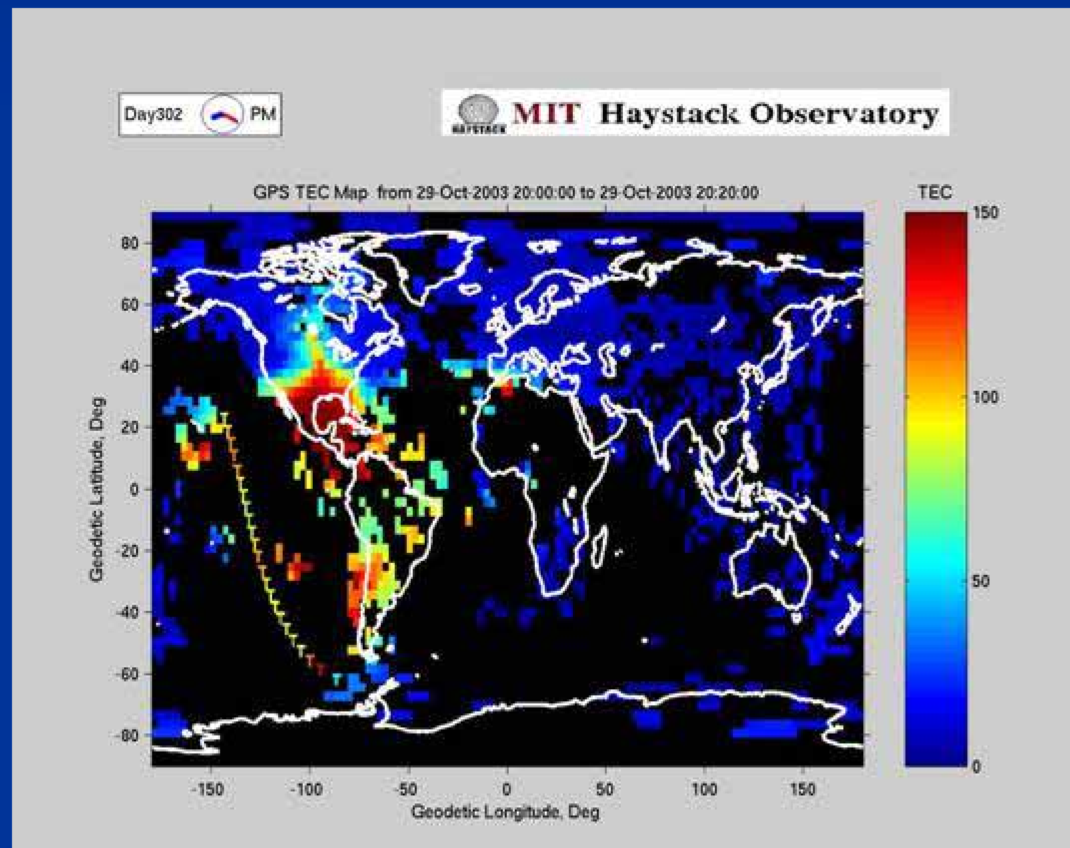


Persistent Themes

- 1 ***Insufficient Observations***
  Observational space physics is data-starved, producing large gaps in our ability to both characterize and understand important phenomena. This is particularly true for Space Weather events, which often are fast-developing and dynamic, and extend well beyond the normal spatial coverage of our current sensor arrays.
- 2 ***Geospace as a System***
  Geospace processes involve **significant coupling across atmospheric layers** and 'altitude boundaries', as well as coupling across **multiple scale sizes** from global (1000s km), to local (10s km), to micro-scale (meter-scale and smaller).
- 3 ***Real-Time Observations***
  *E*lucidation of the fundamental coupling processes requires **continuous real-time measurements** from a distributed array of diverse instruments as well as physics-based data assimilation models.

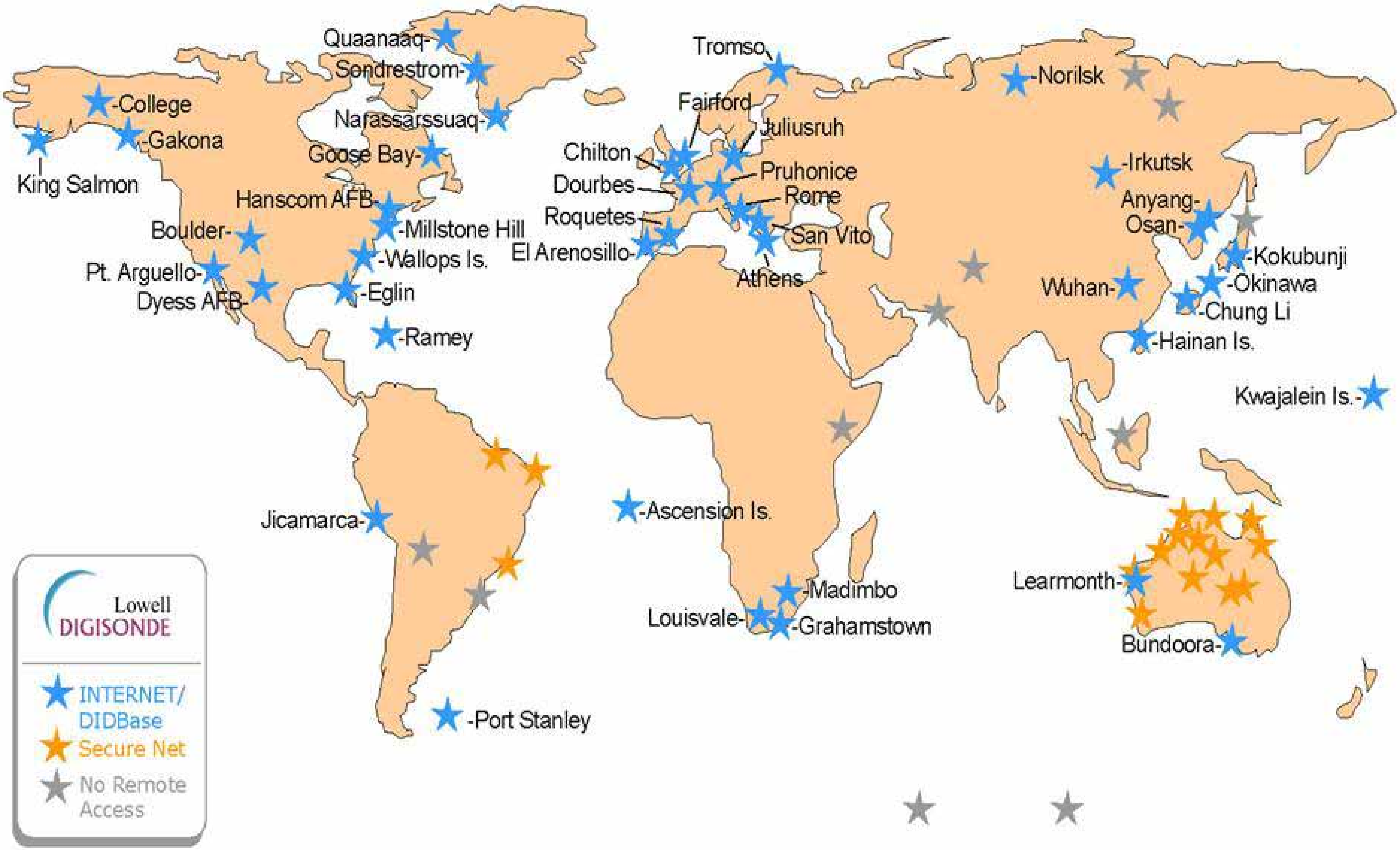
Current Arrays: Limits on Global Coverage & Real-Time Access (e.g. GPS Receivers)

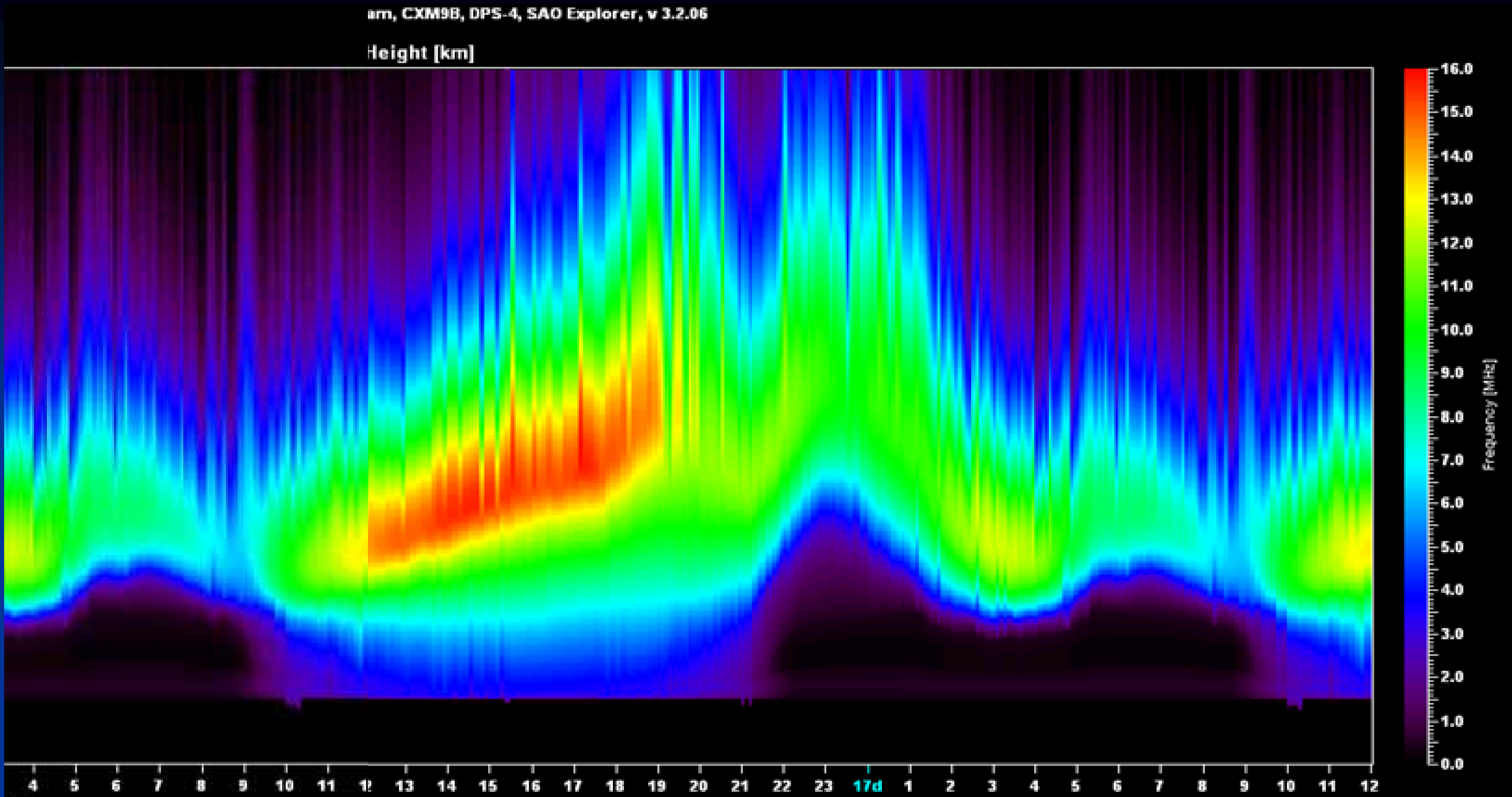


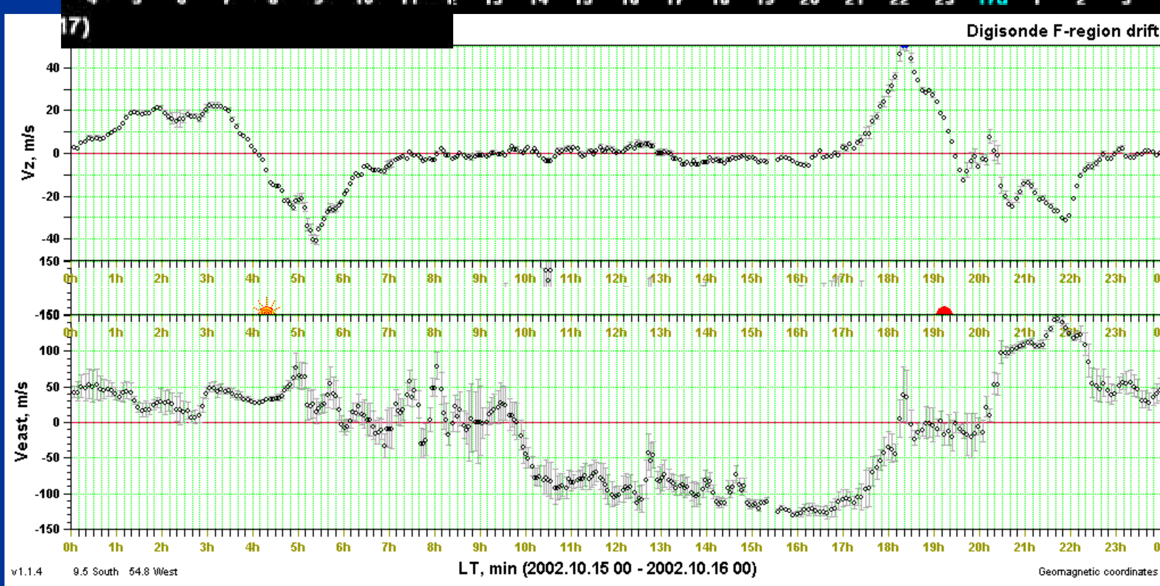


Issues:
Logistics & International Participation

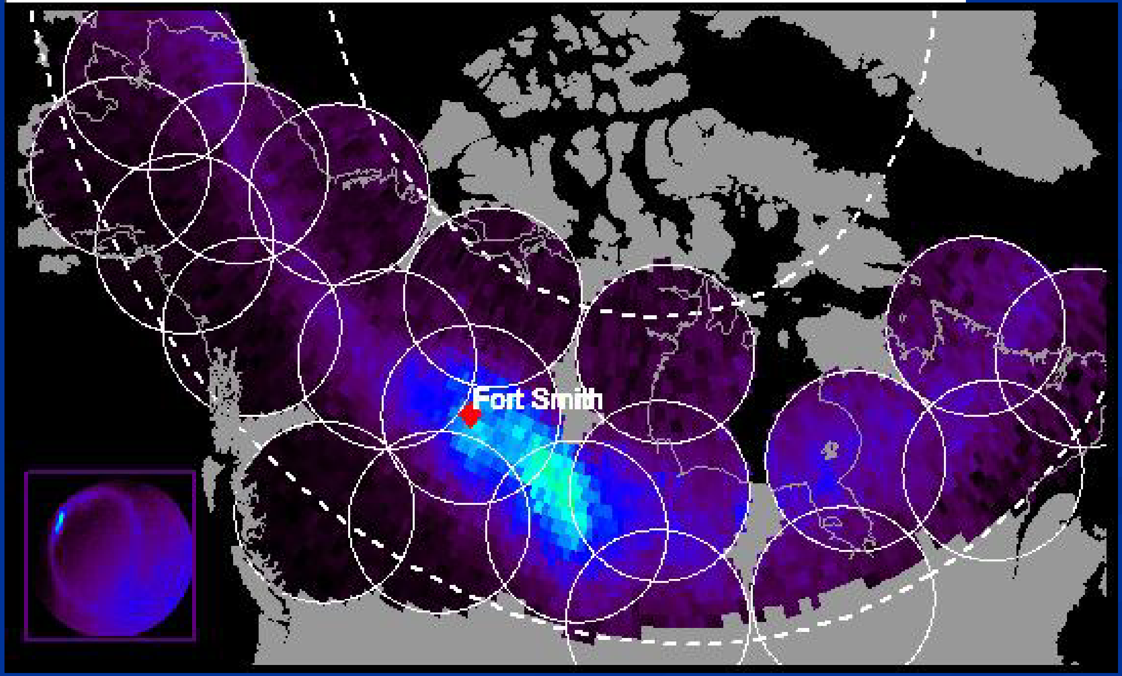
Digisonde Network





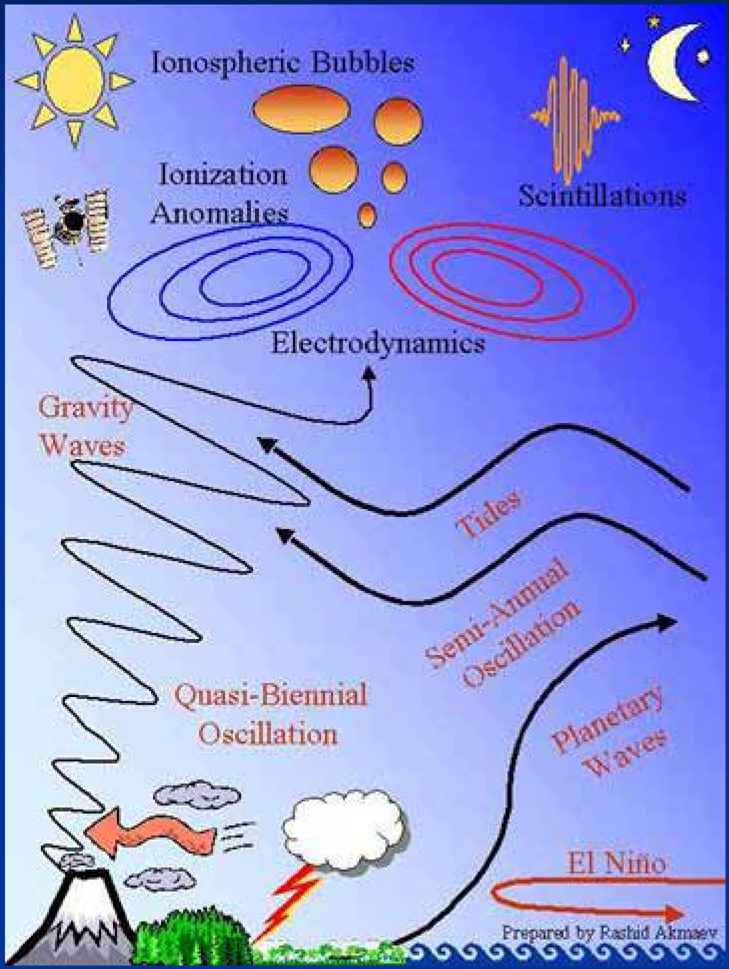


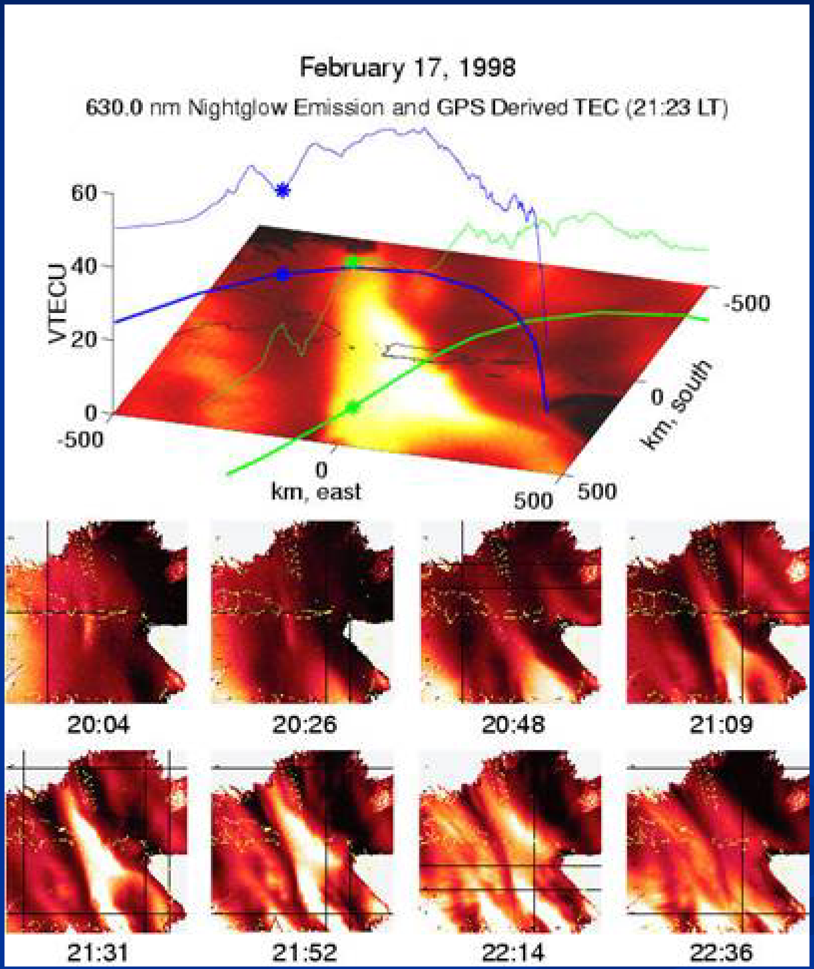
Lowell Digisonde October 15-16, 2002 Cachimbo



Auroral Processes: Distributed Imagers (Themis)

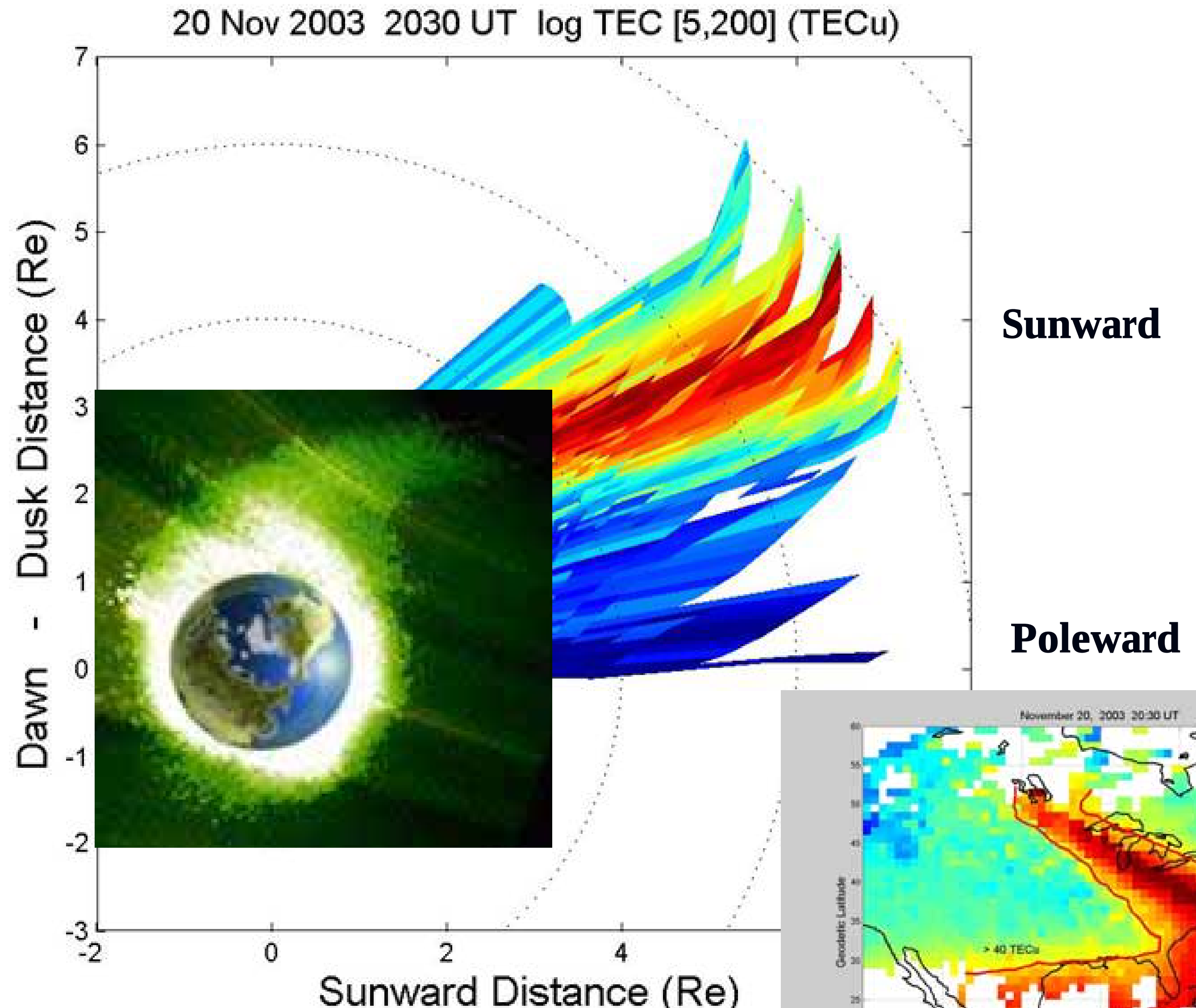
Thermosphere-Ionosphere Coupling

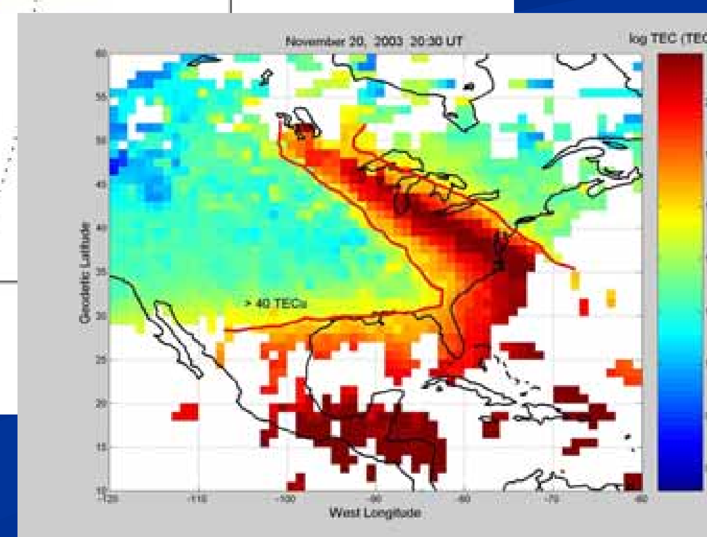




Optical Imagers View Atmospheric Waves

Distributed Instruments (HF Radar: SuperDARN)

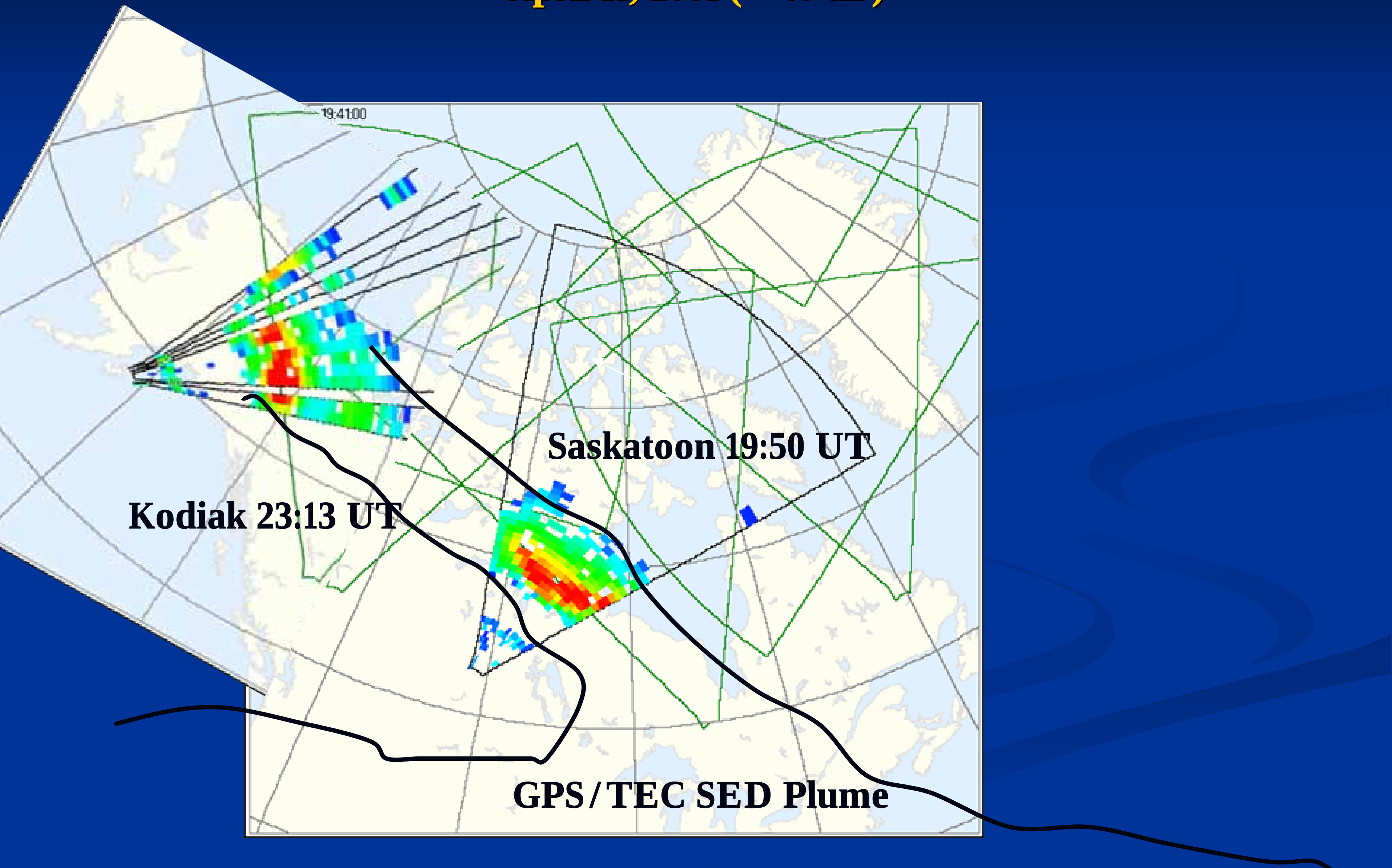




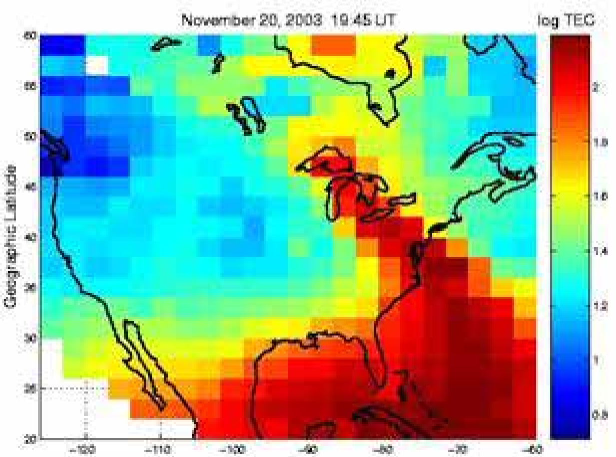
TEC Plume Mapped to Equatorial Plane
Ground-Based Imaging of Magnetosphere

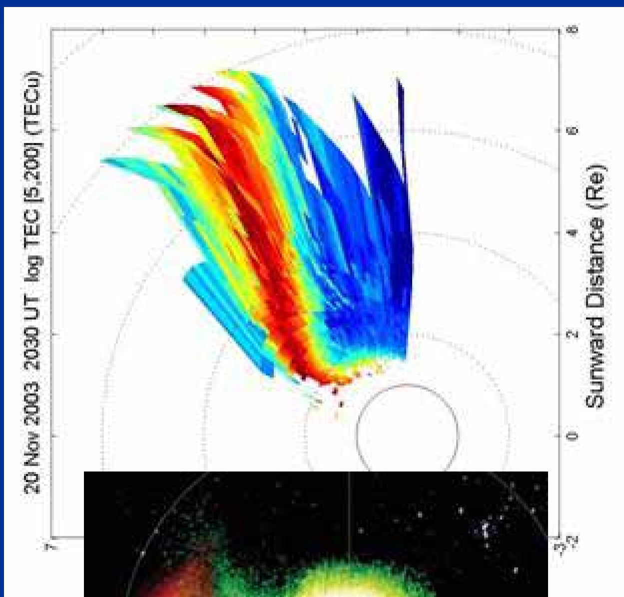
SED Plumes generate
Strong SuperDARN HF Backscatter

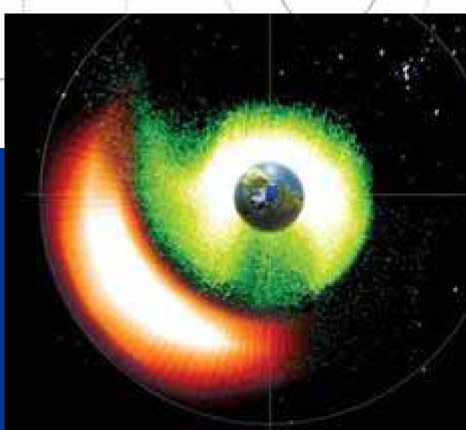
April 11, 2001 (> 40 dB)

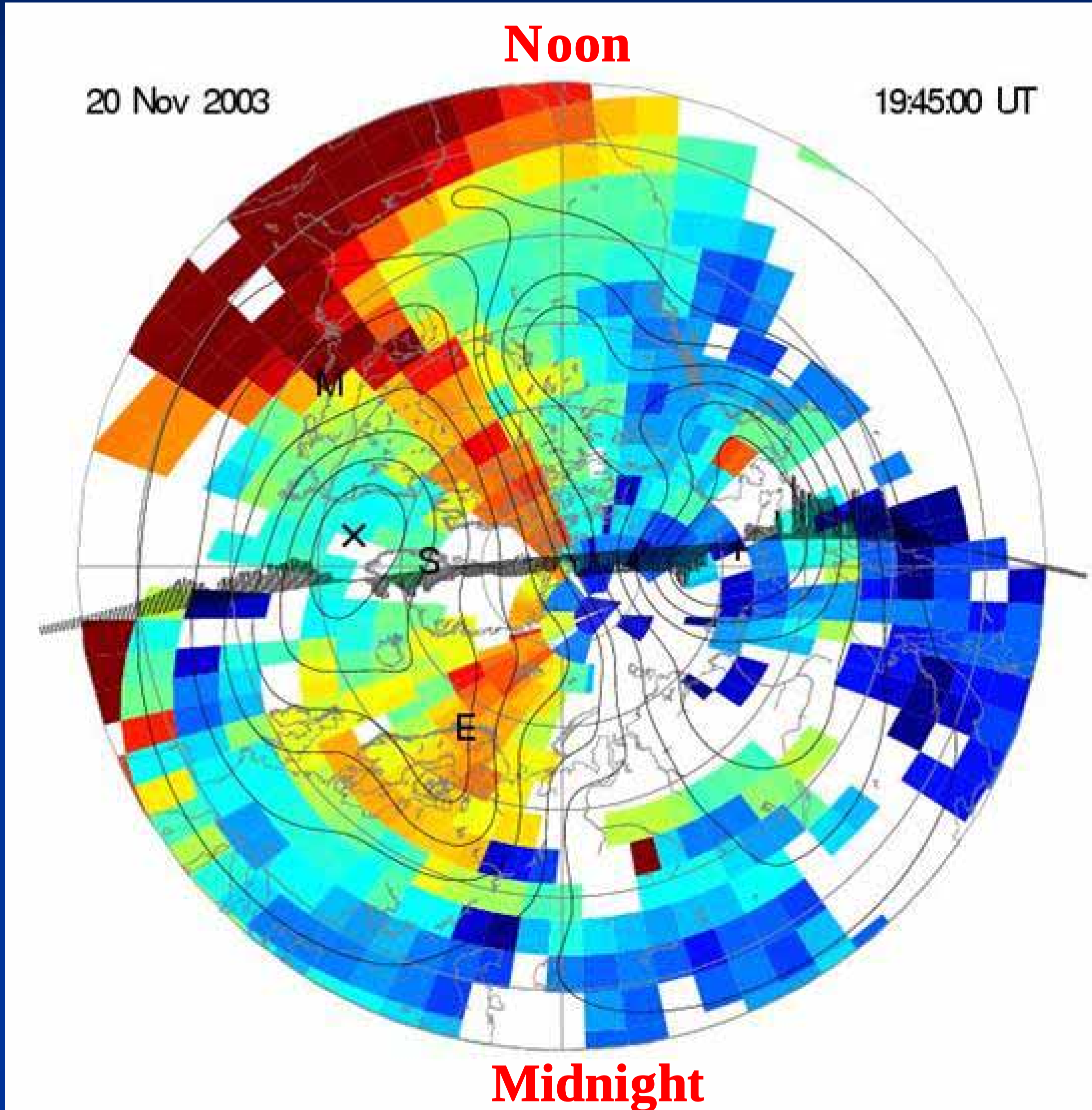


Ground-Based Observations: Polar Tongue of Ionization

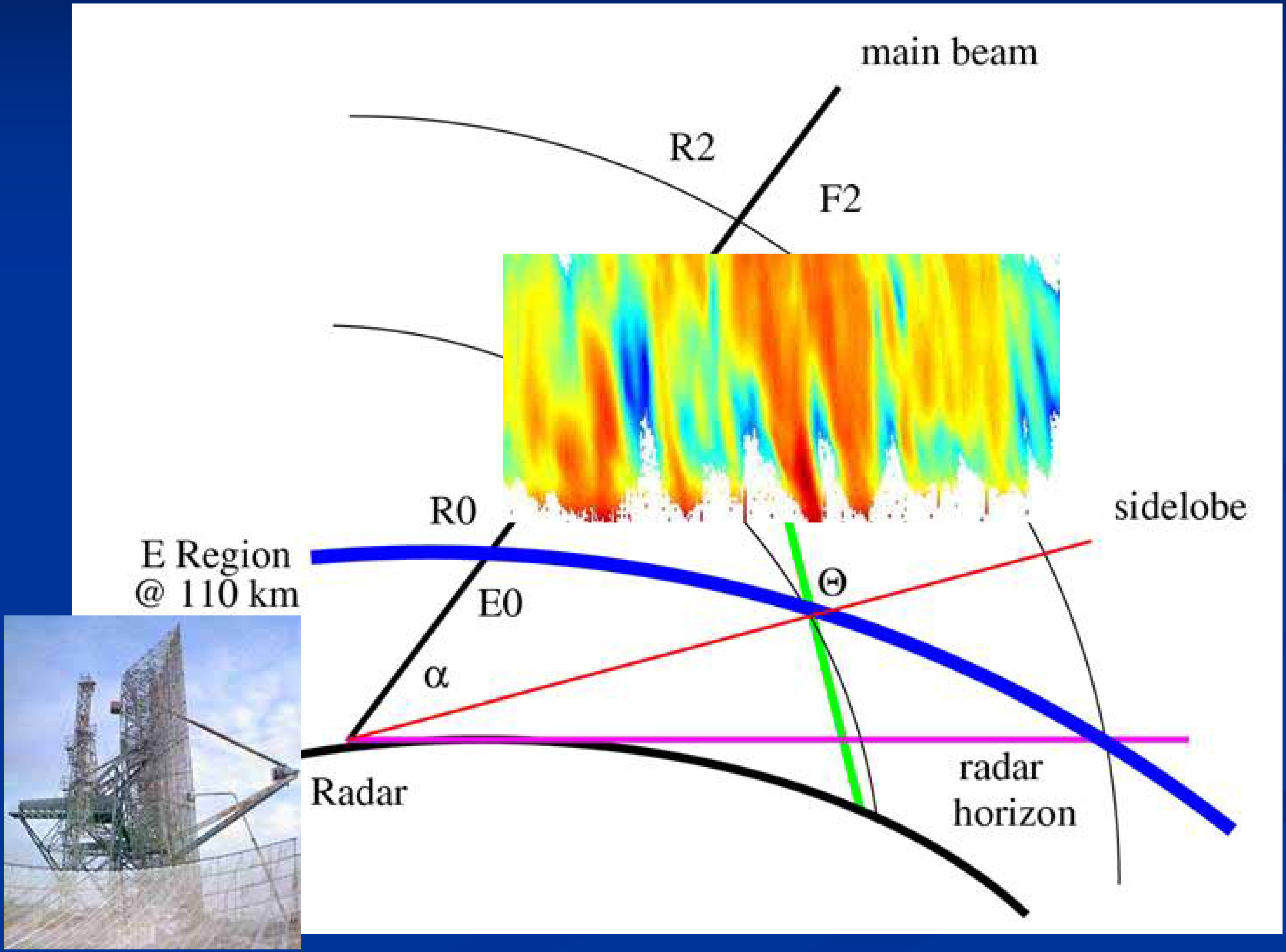








Coherent Radar Backscatter: Plasma Processes and Ionospheric Variability



Intercepted Signals for Ionospheric Science

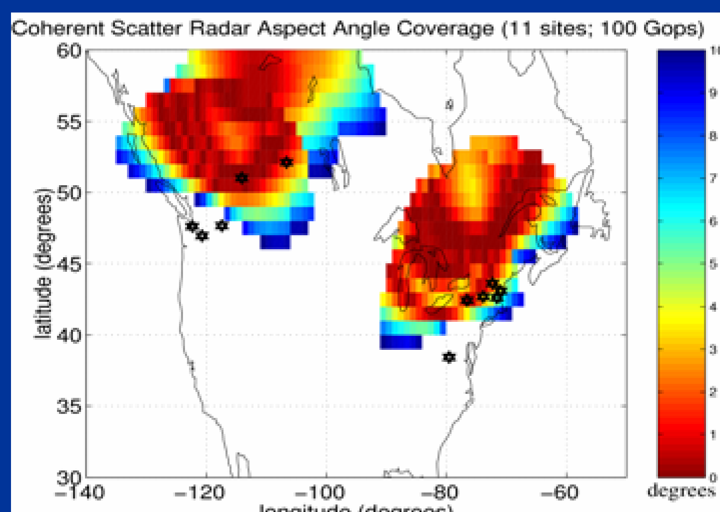
Multirole Coherent Software Radio Network

Multistatic Active and Passive Radar,
Radio Scintillation Studies, RF monitoring

Cluster Computer Operational!

ISIS Array Node Assembly Has Started!

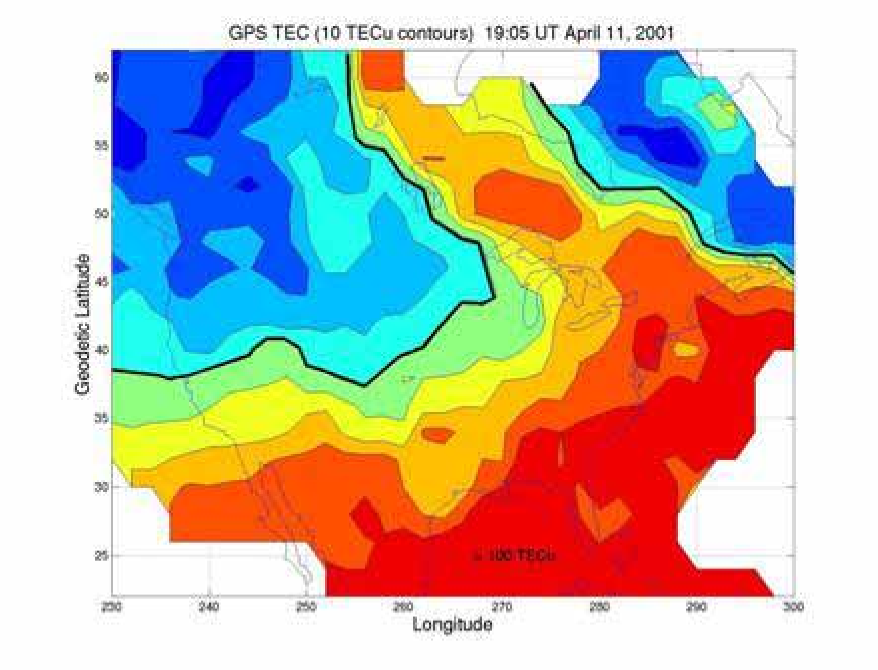
First Node Deployment to Greenbank Radio Observatory
- Summer 2005; Deployment Supported by MIT Lincoln Lab
- Multistatic Active Radar with MIT Millstone Hill Radar
- 140 Foot Telescope at Greenbank

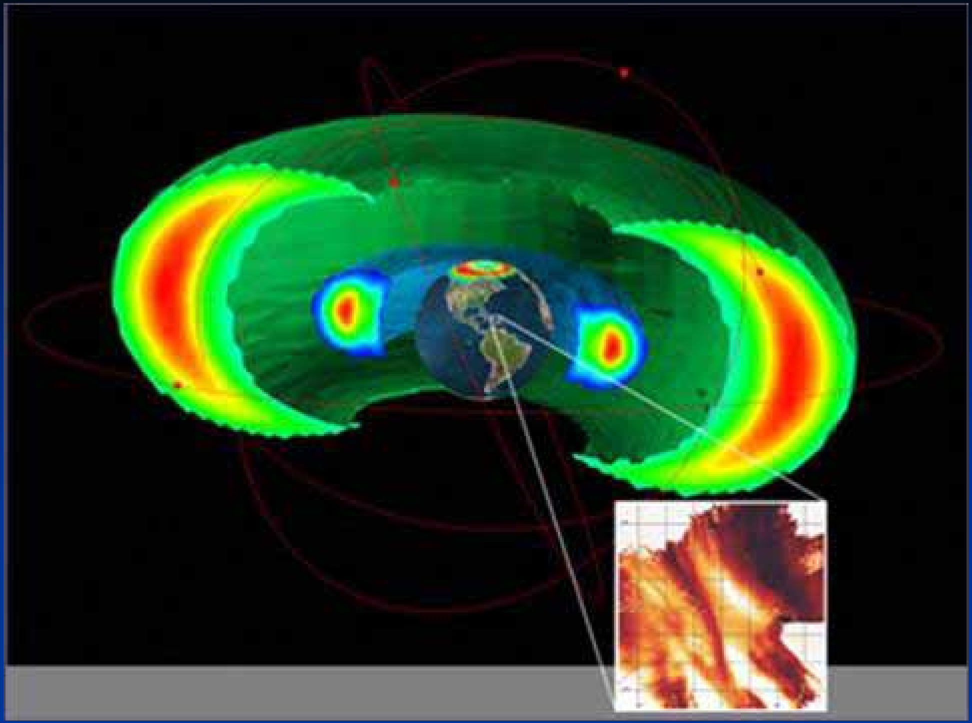


MIT Haystack Observatory

DASI Report: Important Issues

- **Education**: Distributed instruments and R-T publicly-accessible data provide **extensive opportunities**.
- **State of the art IT systems** will be needed to realize the DASI architecture
- SYNERGY: RT access to **different types of data** will enable new science arising from their **combination**.
- Instrument types and their Deployment should be **driven by the needs of the science**





Magnetosphere Ionosphere Atmosphere Coupling