



ATMOSPHERIC & SPACE TECHNOLOGY RESEARCH ASSOCIATES

SCIENCE + TECHNOLOGY + APPLICATIONS // *Bringing it all together*

Introduction to the Ionosphere

- For atmospheric scientists
- Including ionospheric models as tools for the RO community

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ASTRA Overview

❖ Science

❖ Technology

❖ Applications

Bringing It All Together



Modeling

Physics-Based
Modeling
(TIMEGCM)

Real-Time
Specification
of
Ionosphere/
Thermosphere

Data Assimilation

High-latitude
Electrodynamics
(AMIE)

Global Ionosphere
(IDA4D)

Thermospheric
Neutral Density
(ADAM)

Satellite Drag &
Ballistic
Coefficients

Data Services

Space Based
Data

Ground Based
Data

Forensic
Space Weather
Analysis

Space weather
Phone Apps

Ground-based Instrument Development

GPS-based Space
Weather Monitor

Ionospheric
Wave Mapper

Low Power
Ionospheric
Sounder

Laser Systems

Space Systems

CubeSat Missions
NSF 'DICE' Cubesat

AF 'DIME' Cubesat

NASA 'SORTIE'

Plug-N-Play Avionics

CubeSat Instruments

Scanning
UV Photometer

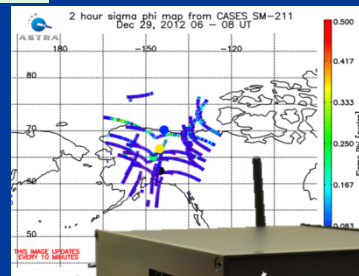
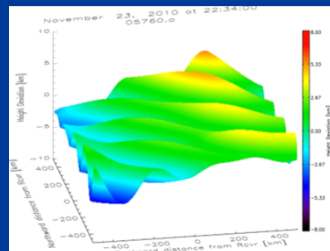
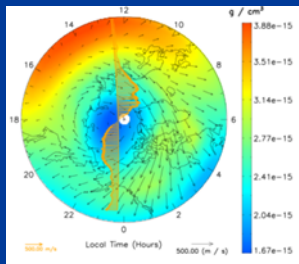
E-field Double Probe

Topside Sounder

Wind Profiler

GPS-based Space
Weather Monitor

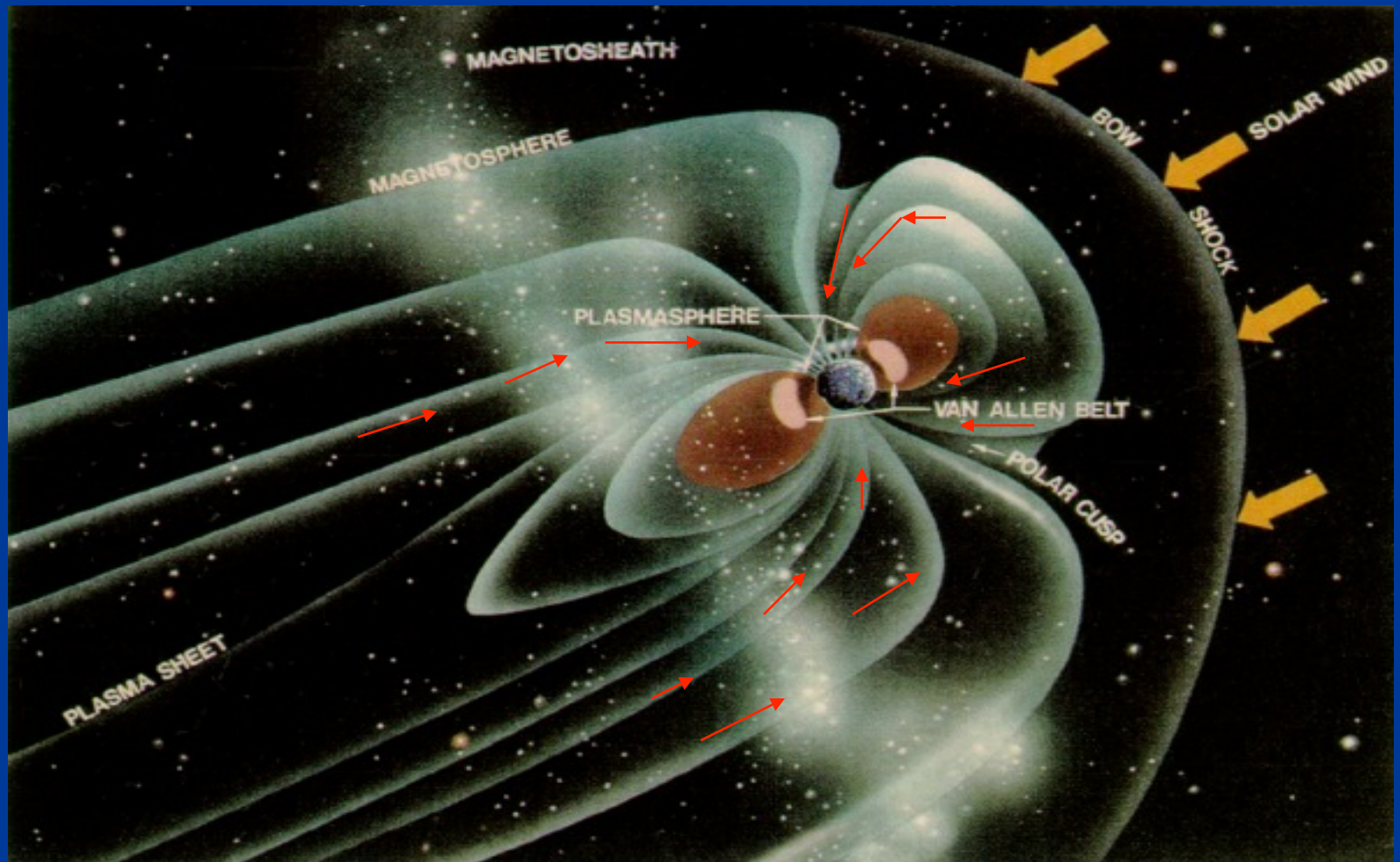
Satellite
Aerodynamics

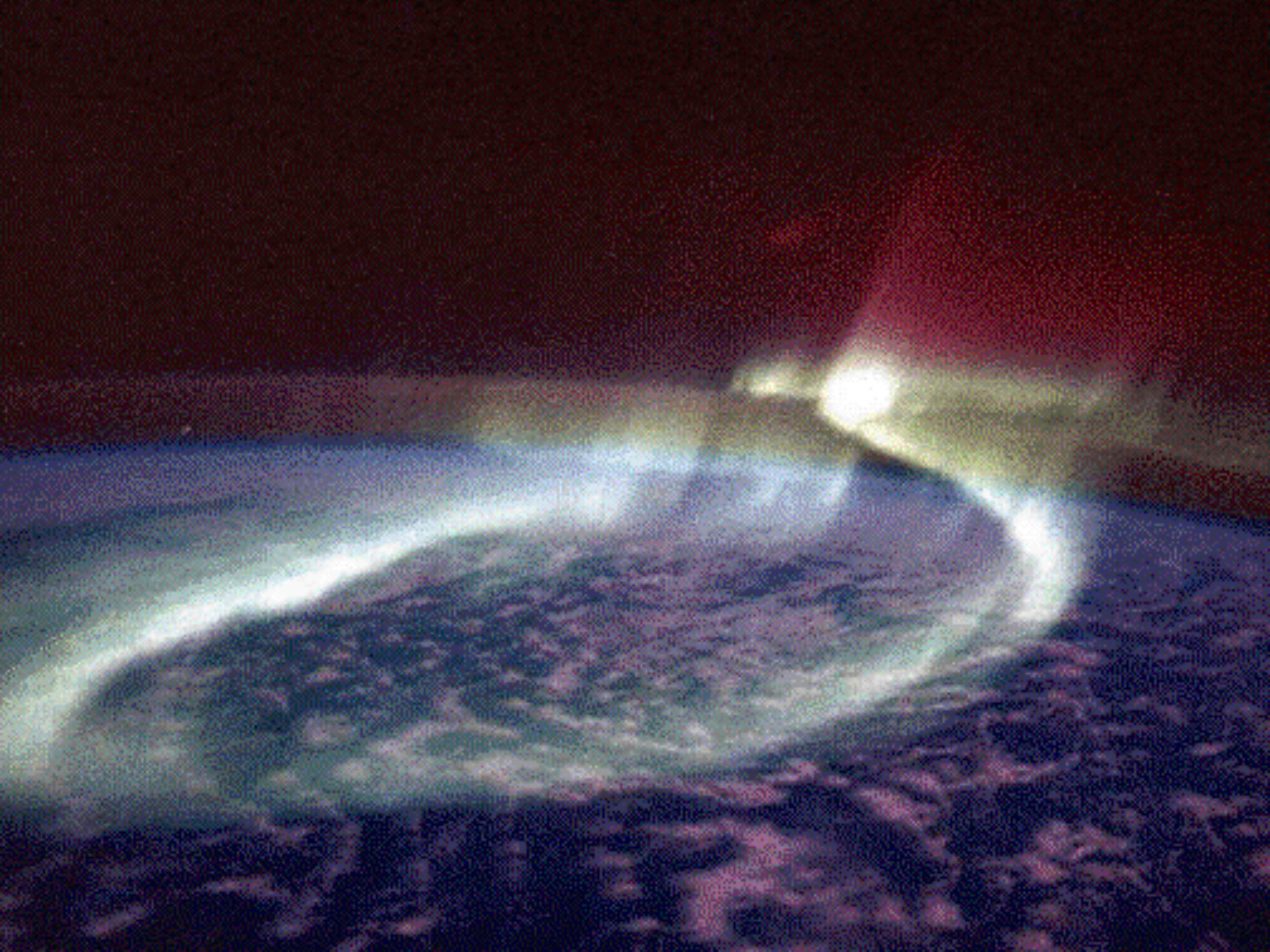


Outline

- What ionospheric features and tools have we seen this week that affect RO?
“One man’s noise is another man’s data”
- Ionospheric background structure
 - ✧ Vertical and Horizontal Structures
 - ✧ F-region, E-region
 - ✧ Low, middle and high latitudes
 - ✧ Time variation (daily, solar cycle)
 - ✧ Geomagnetic storms and their effects
- Models
- Supporting instruments

What is Space Weather ?







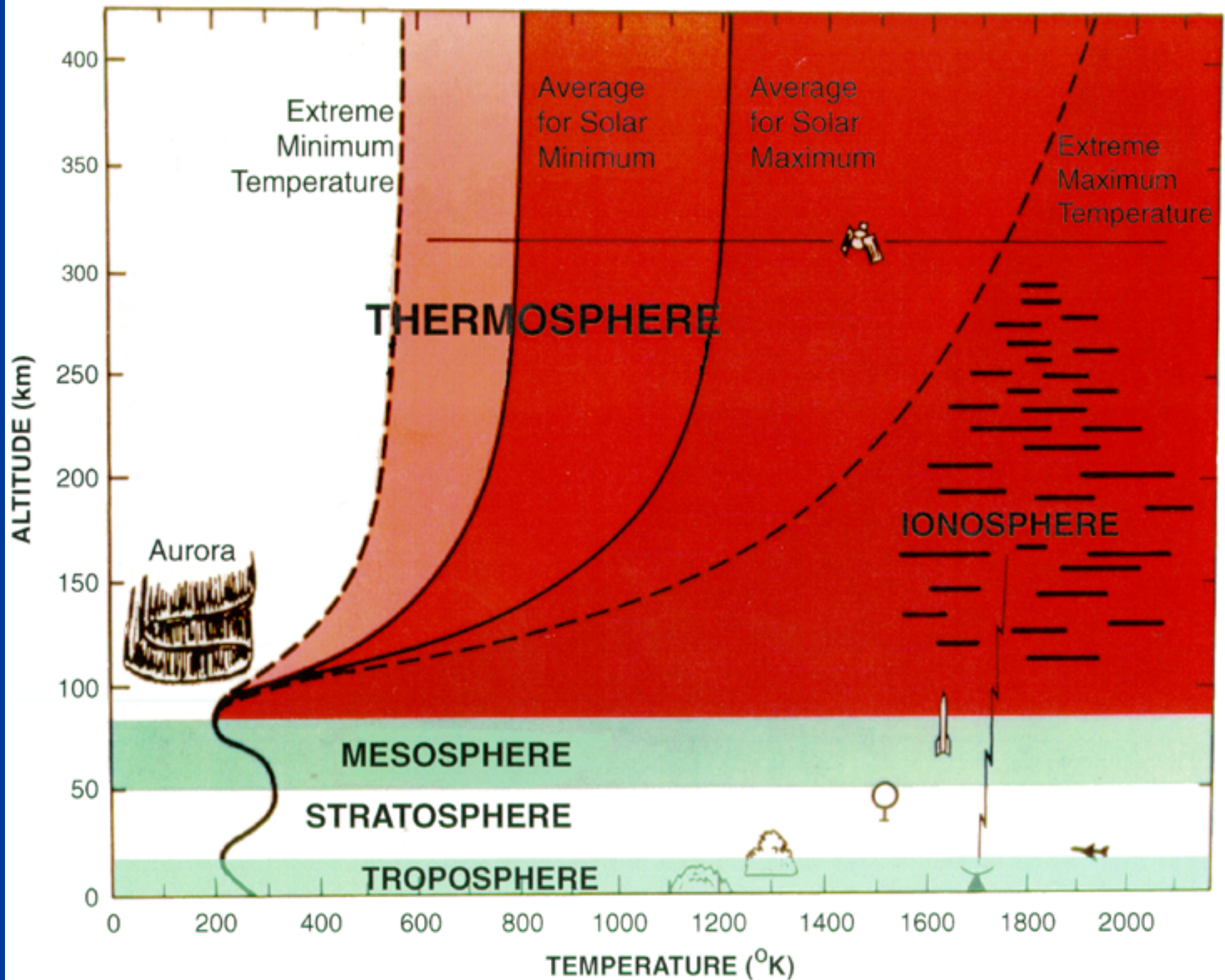


Figure 1c: Typical profiles of neutral atmospheric temperature

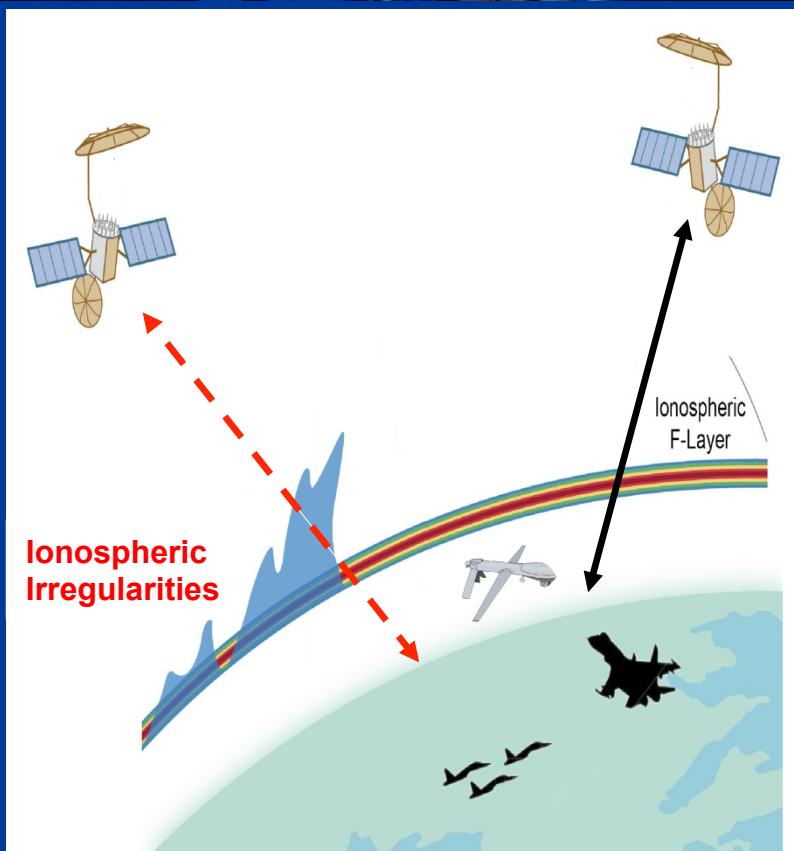
Who Cares About the Ionosphere?

❖ Science

❖ Technology

❖ Applications

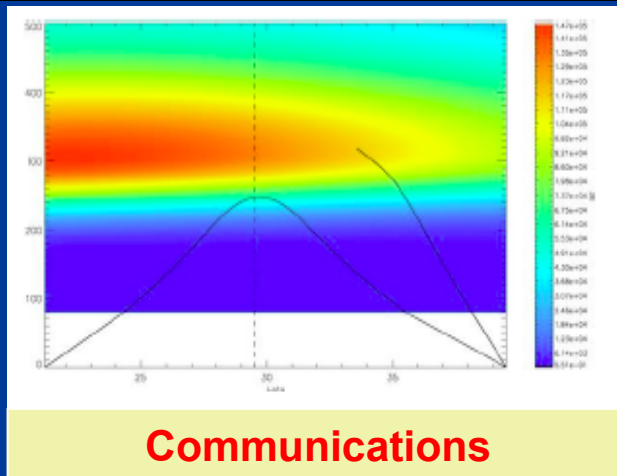
Bringing It All Together



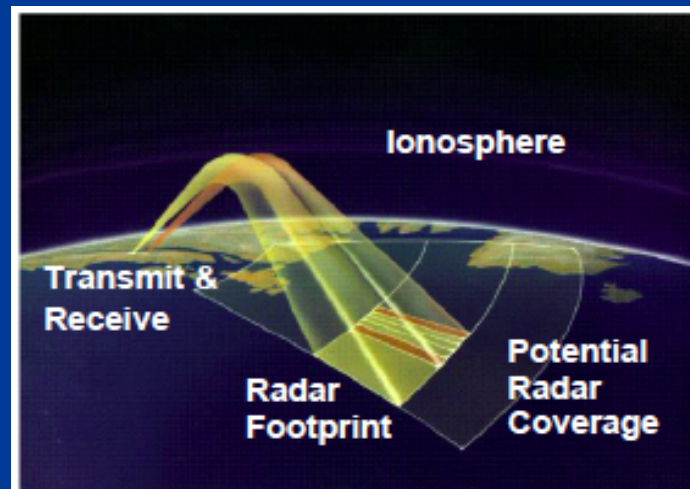
**Ionospheric
Irregularities**

Ionospheric
F-Layer

**Positioning, Navigation,
Communications**



Communications



Surveillance Radars

Systems that depend on the ionosphere are affected by Space Weather

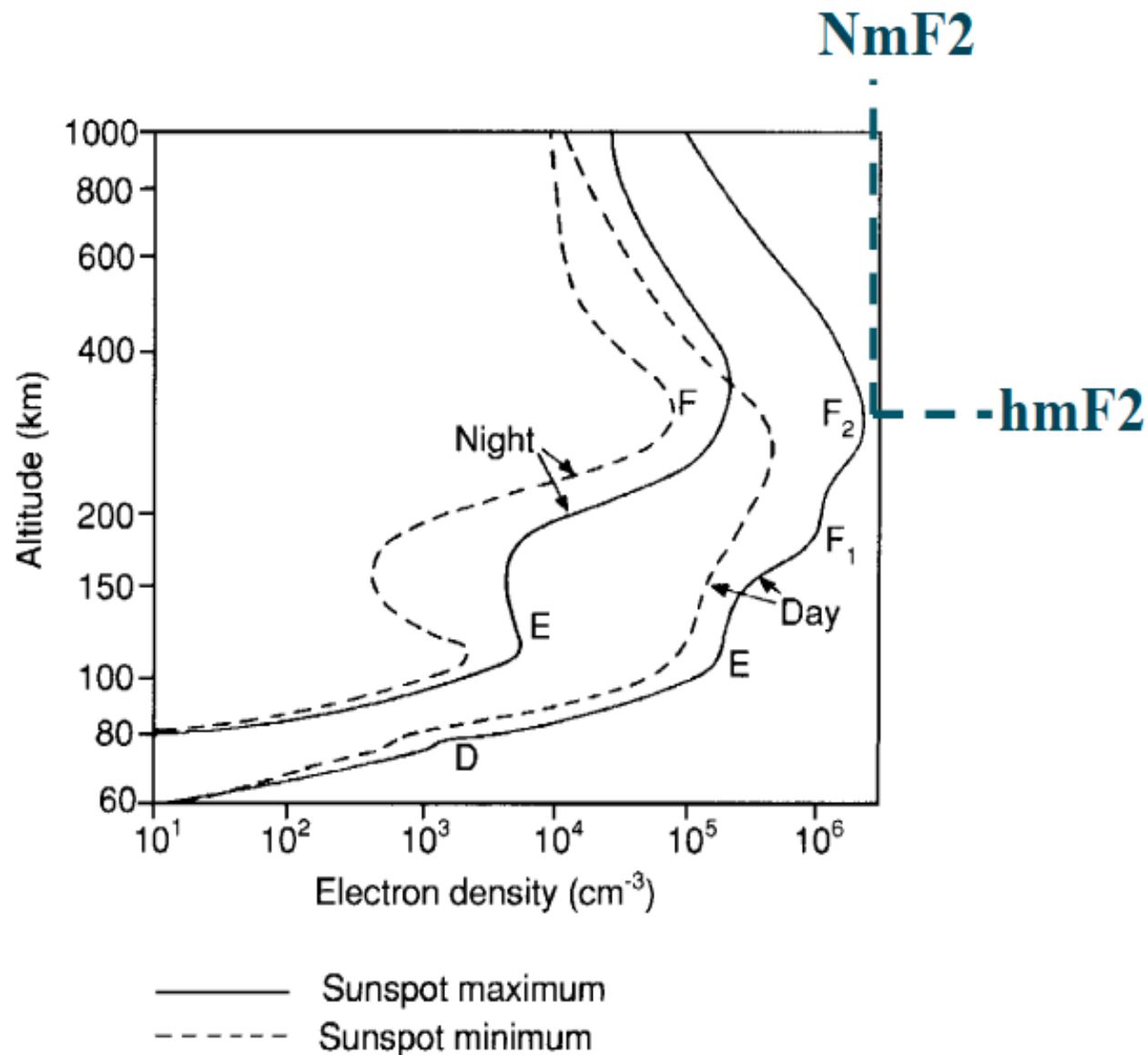
Vertical Structure

❖ Science

❖ Technology

❖ Applications

Bringing It All Together



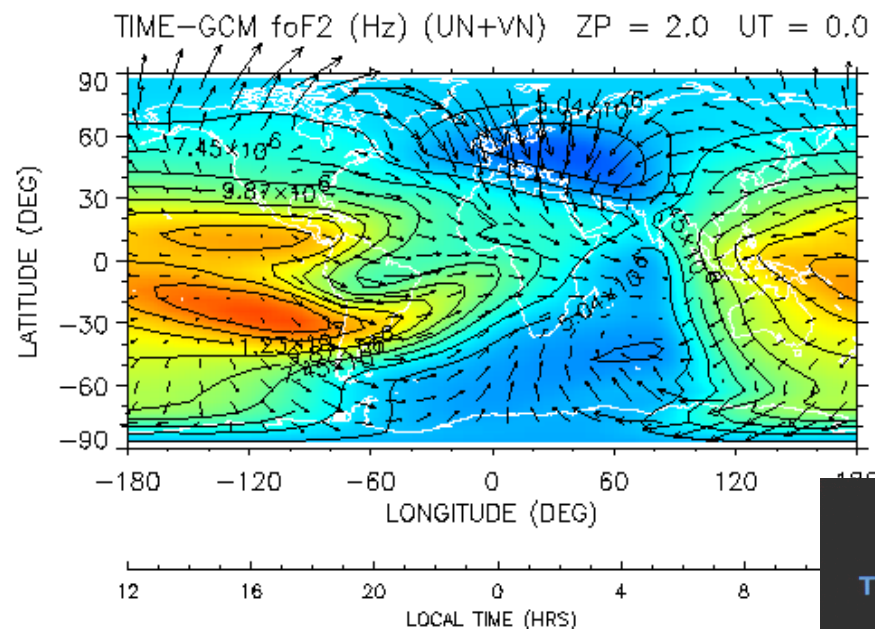
Horizontal Structure

❖ Science

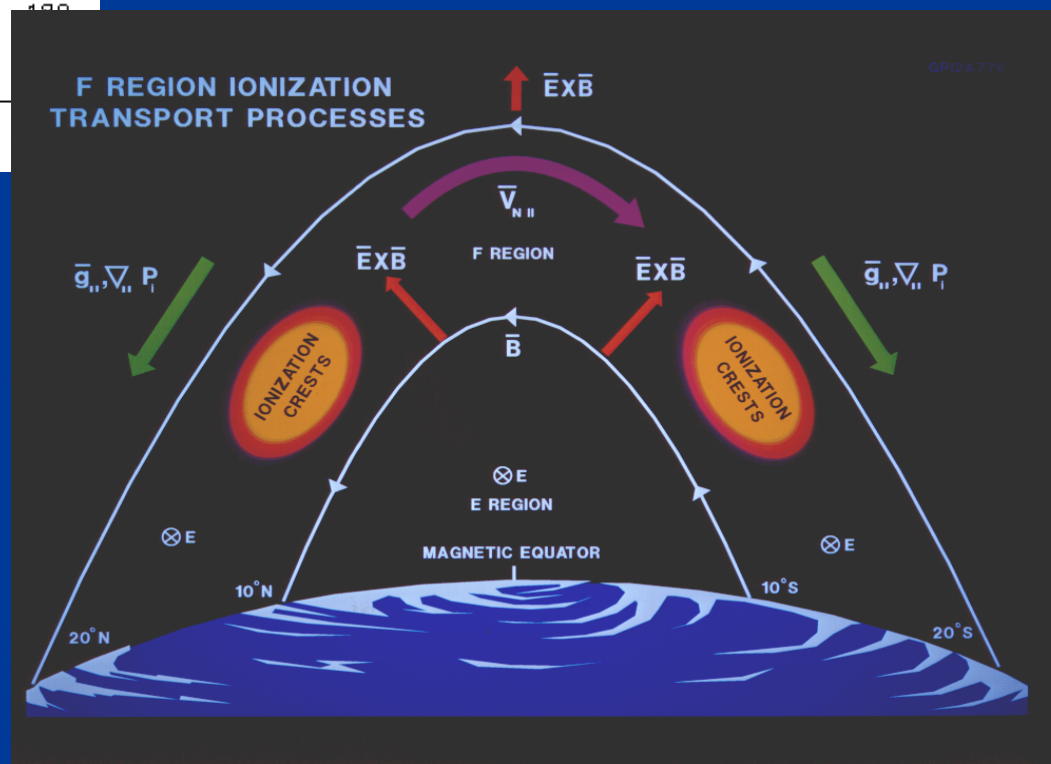
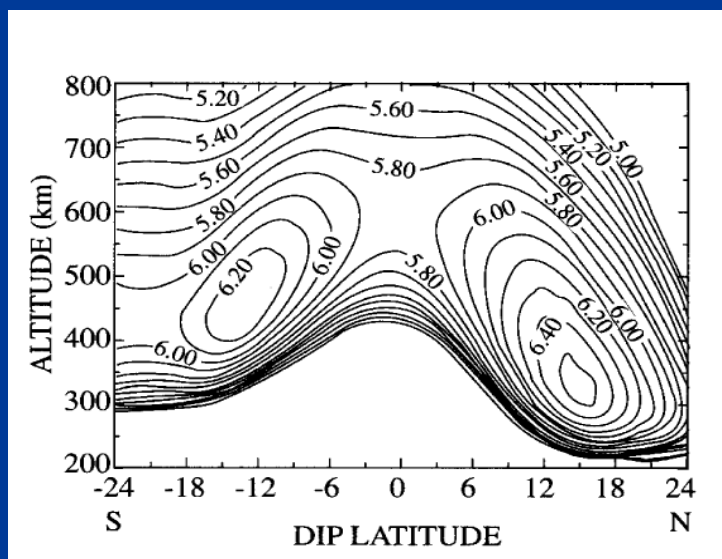
❖ Technology

❖ Applications

Bringing It All Together

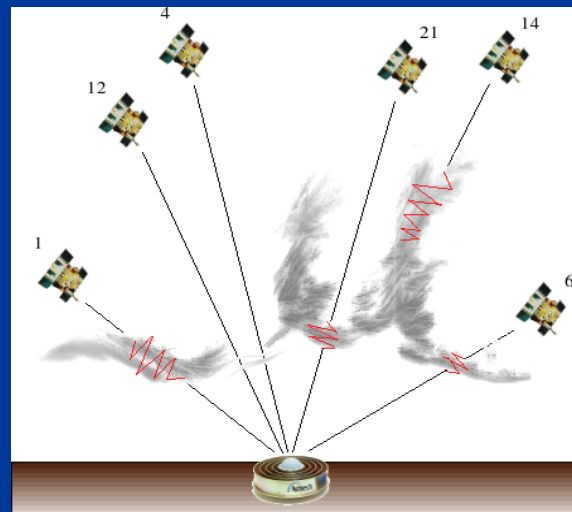
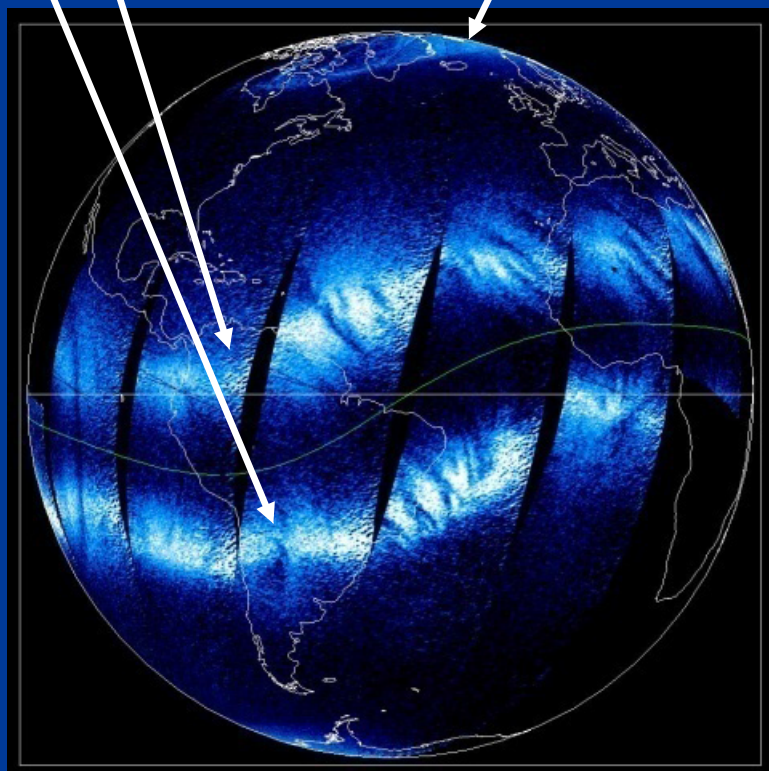


Equatorial Ionization Anomaly or Appleton Anomaly (Fountain Effect)

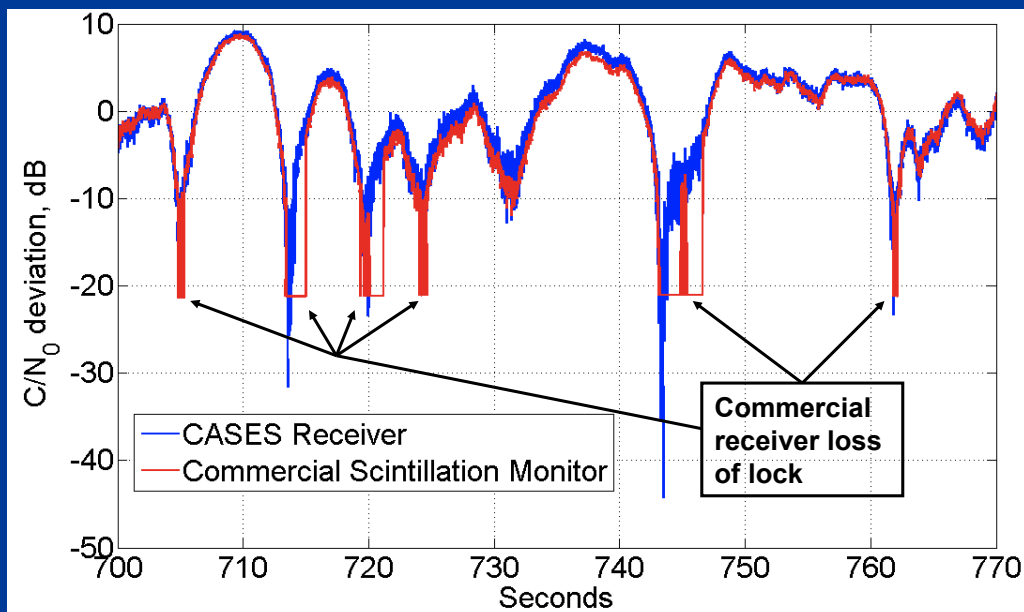


Appleton
Anomaly

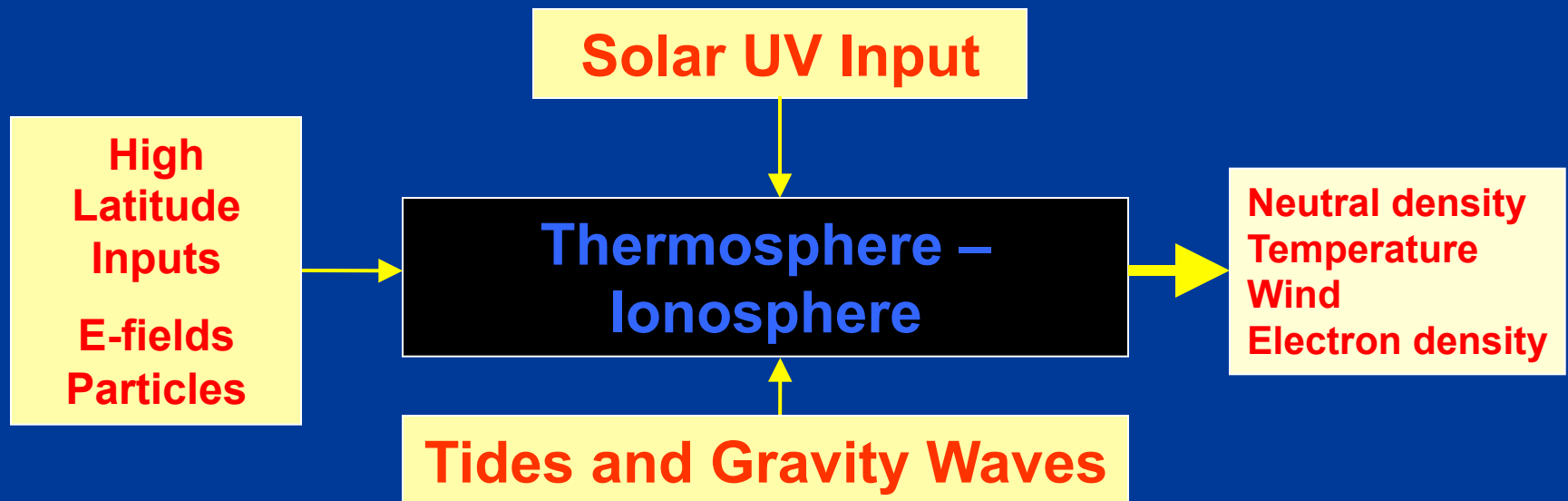
Aurora

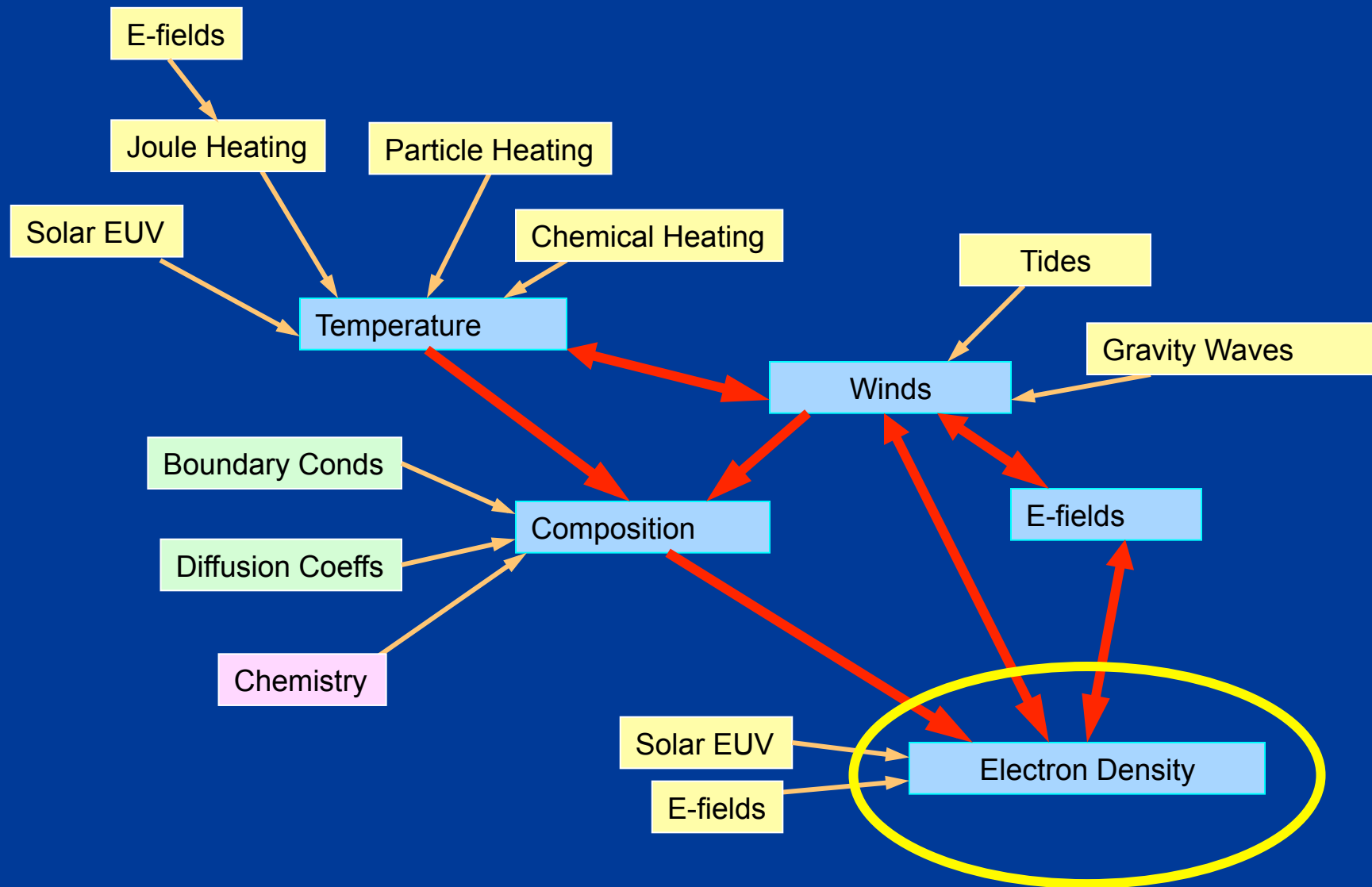


Scintillation effects on GPS

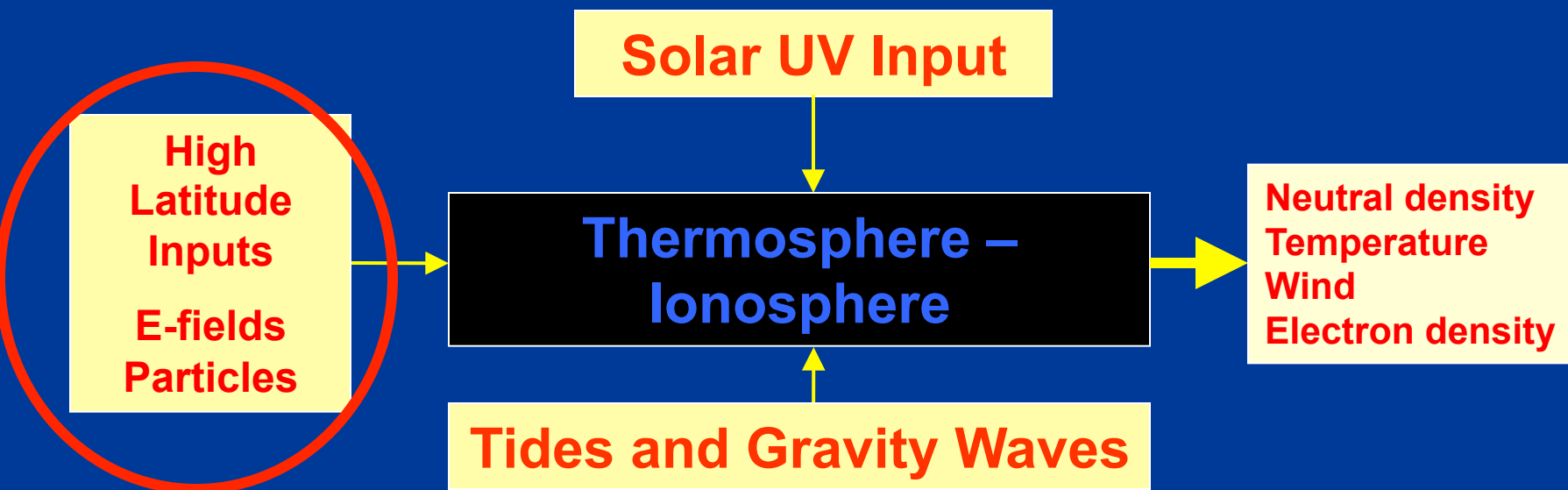


Important Inputs to the Thermosphere – Ionosphere System





Important Inputs to the Thermosphere – Ionosphere System



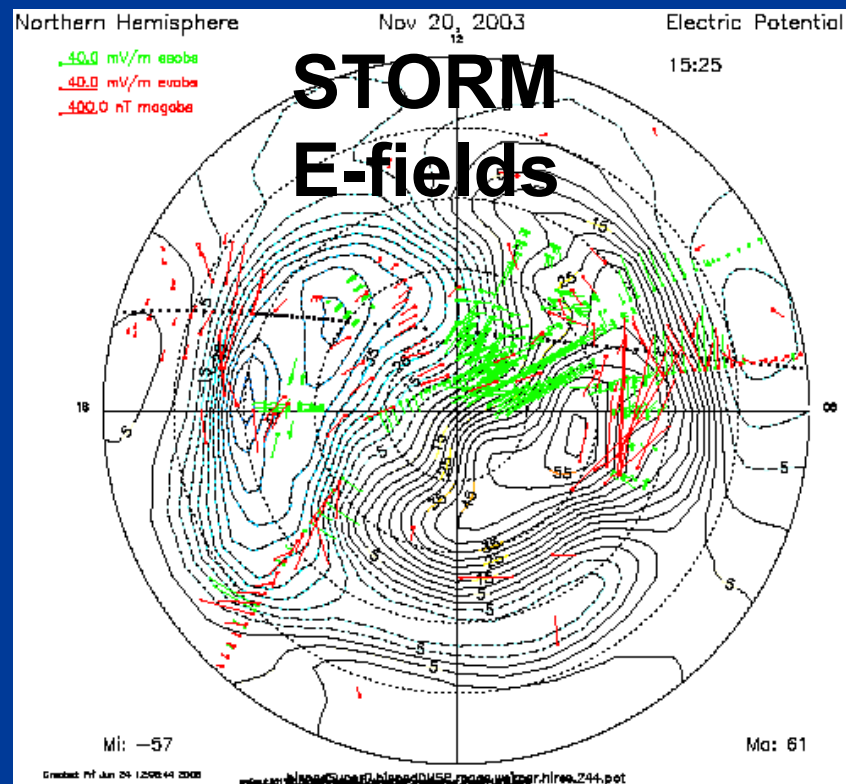
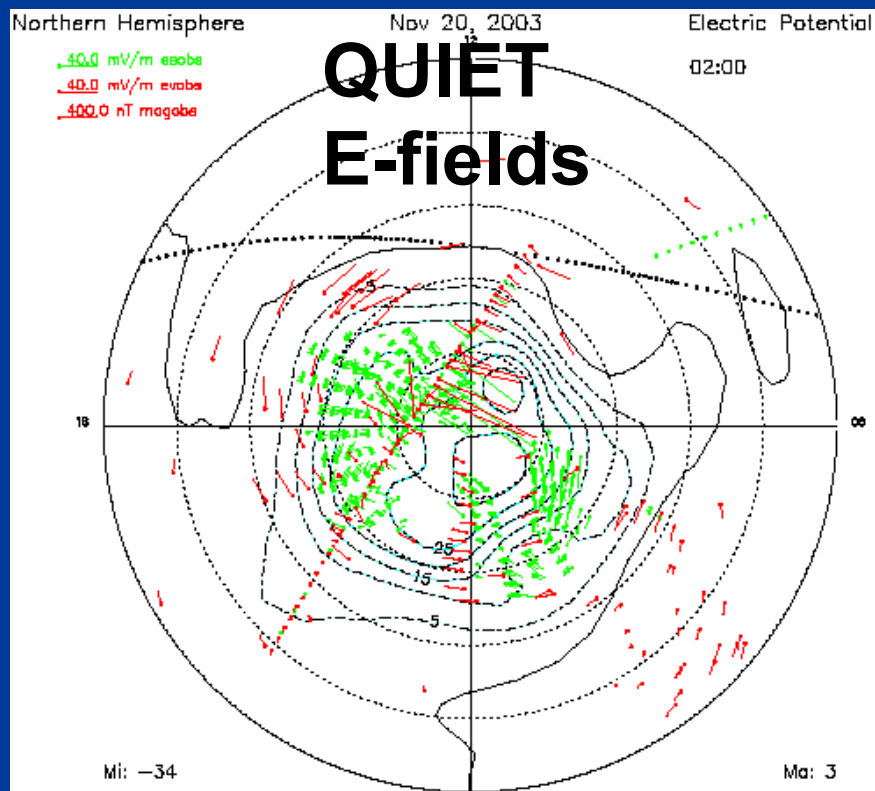
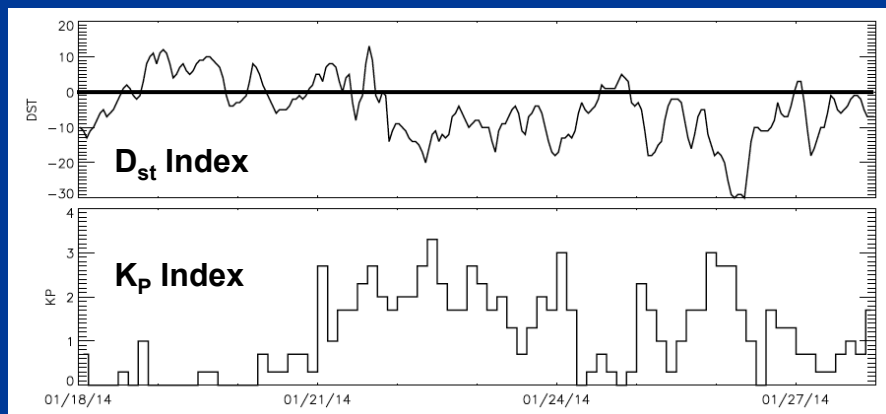
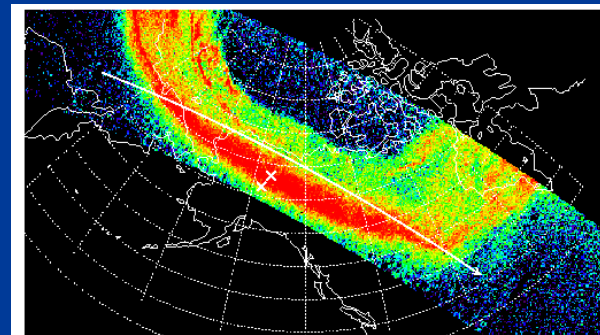
Geomagnetic storm

❖ Science
❖ Technology
❖ Applications

Bringing It All Together



Enhanced particle input



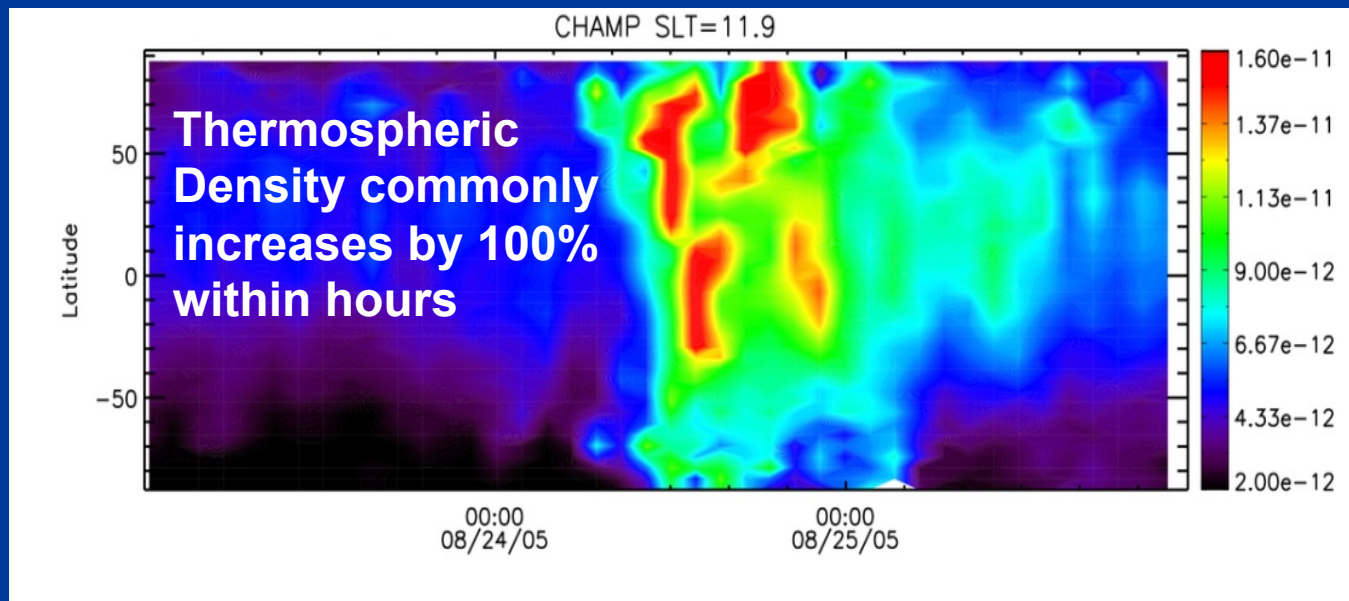
Geomagnetic storm

❖ Science

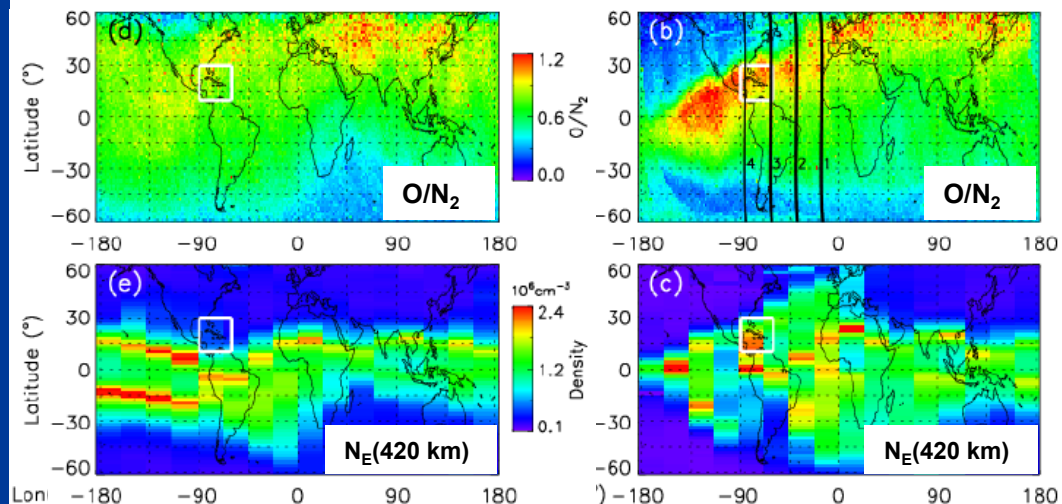
❖ Technology

❖ Applications

Bringing It All Together



Global composition change affects ionospheric electron density



Mid-latitude Ionospheric Structure

❖ Science

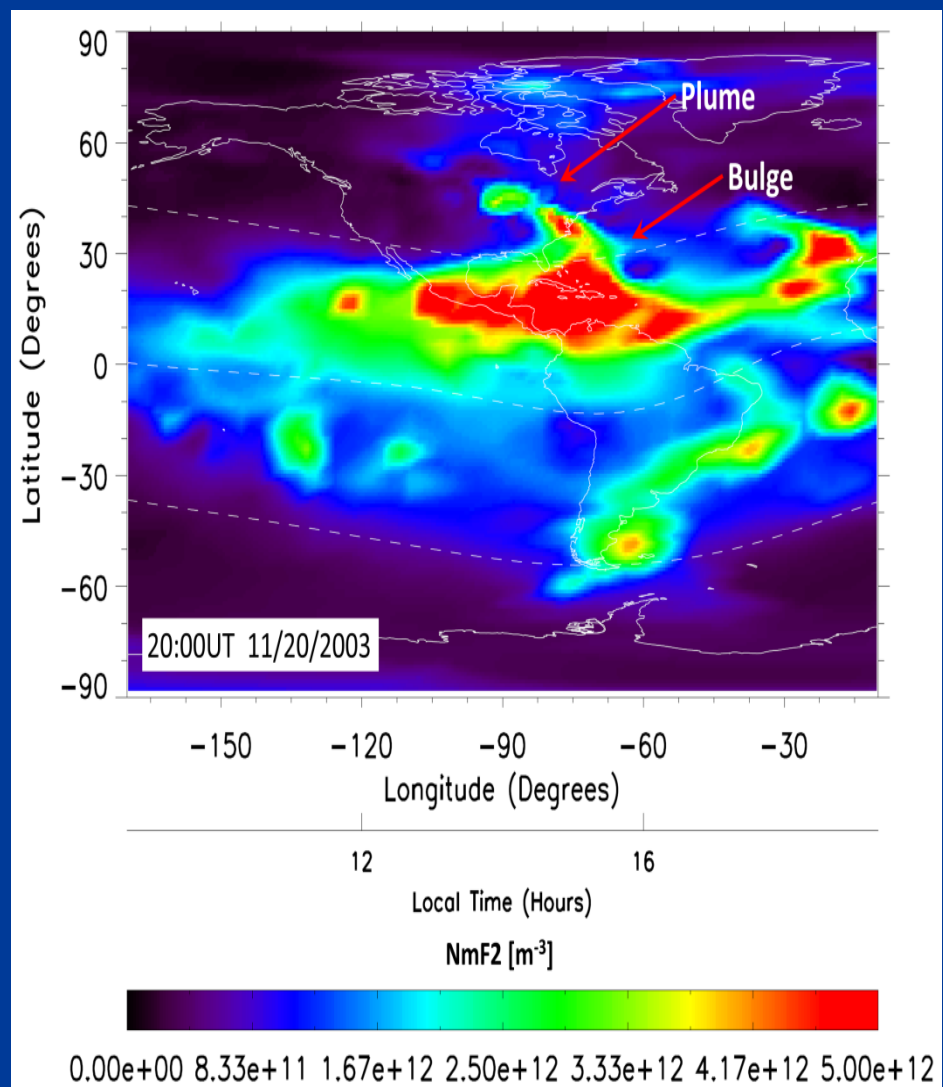
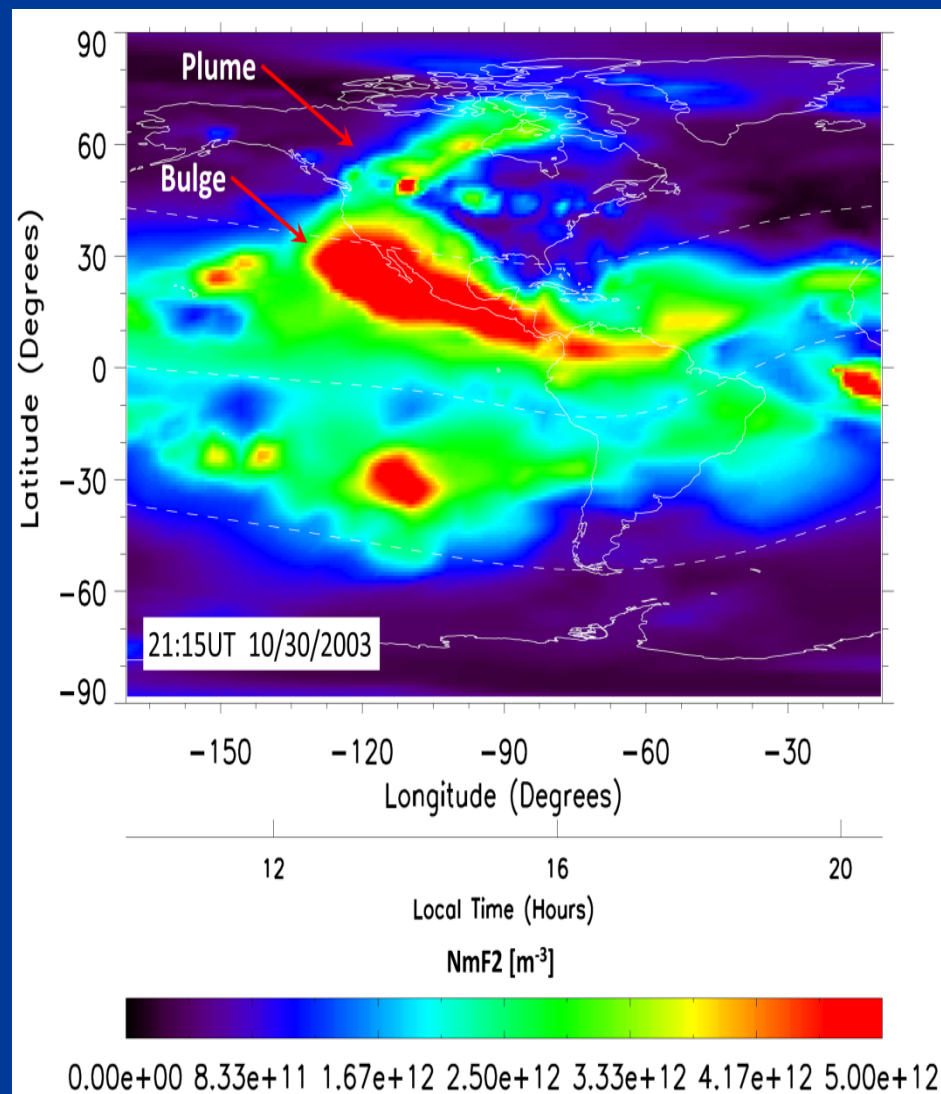
❖ Technology

❖ Applications

Bringing It All Together



- Storm Enhanced Density (SED) 250 TEC units
- ASTRA's Ionospheric Data Assimilation Algorithm (IDA-4D)
- **Effect:** FAA's WAAS System not usable



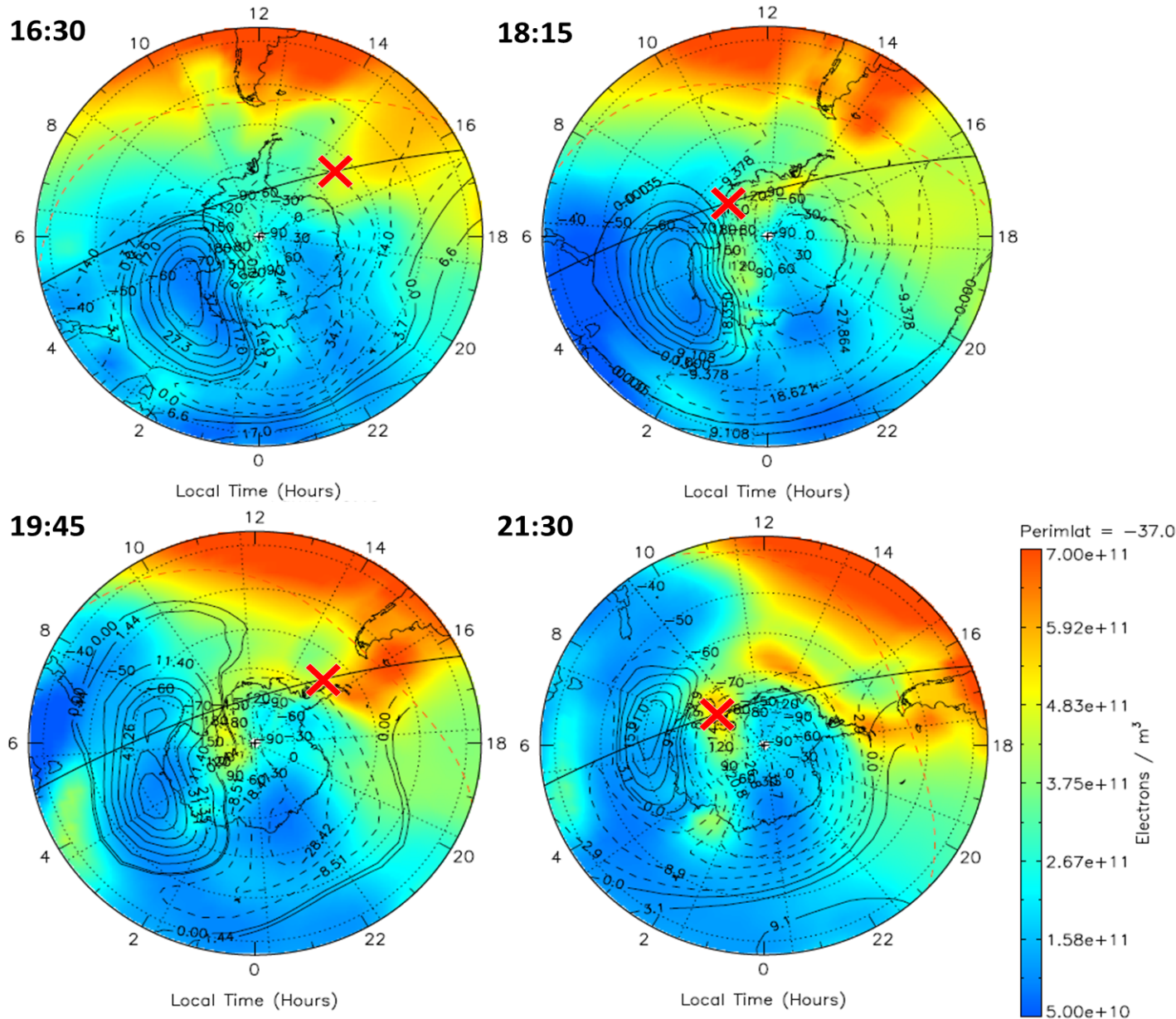
Tongue of Ionization & Polar Cap Patches

❖ Science

❖ Technology

❖ Applications

Bringing It All Together



11 year solar cycle

27 day solar rotation

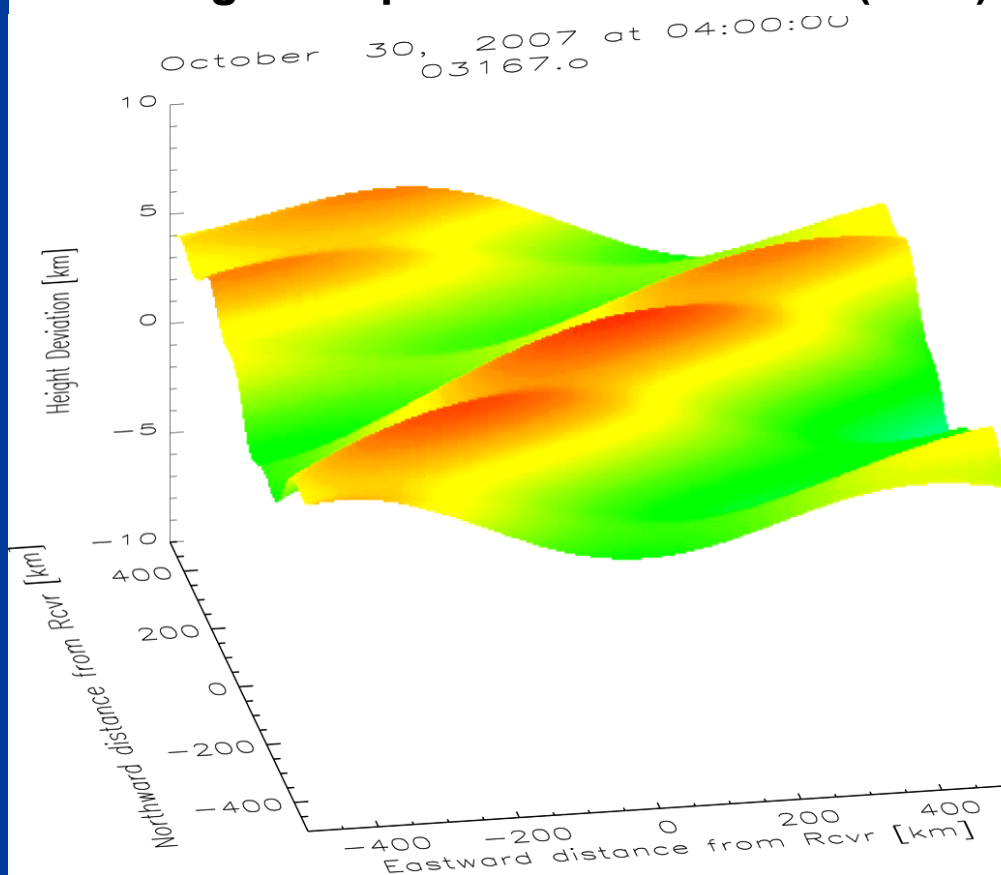
Solar Maximum

Solar Minimum

28-SEP-91 12:55 (a)

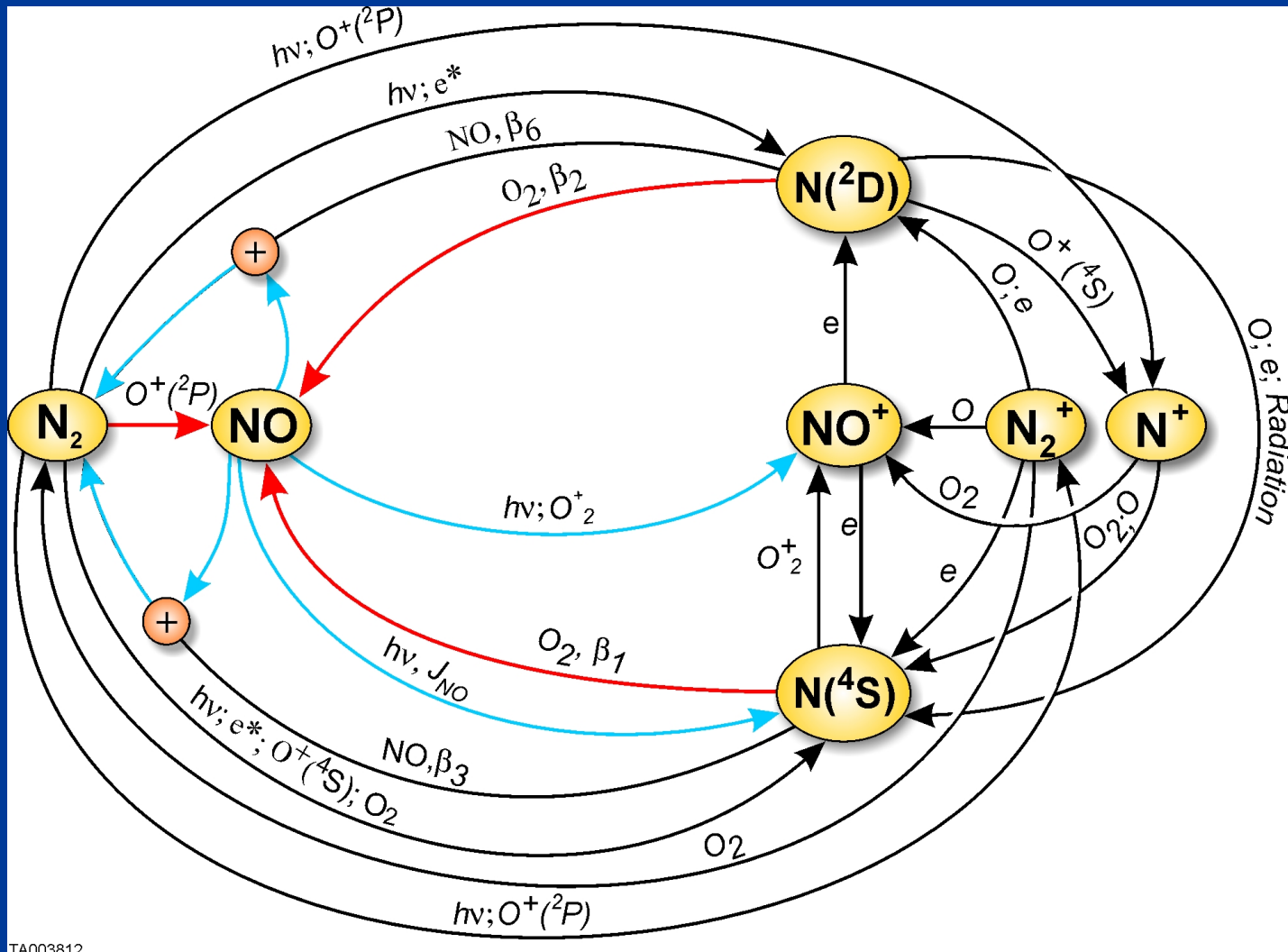
7-APR-95 14:57 (b)

Traveling Ionospheric Disturbances (TIDs)



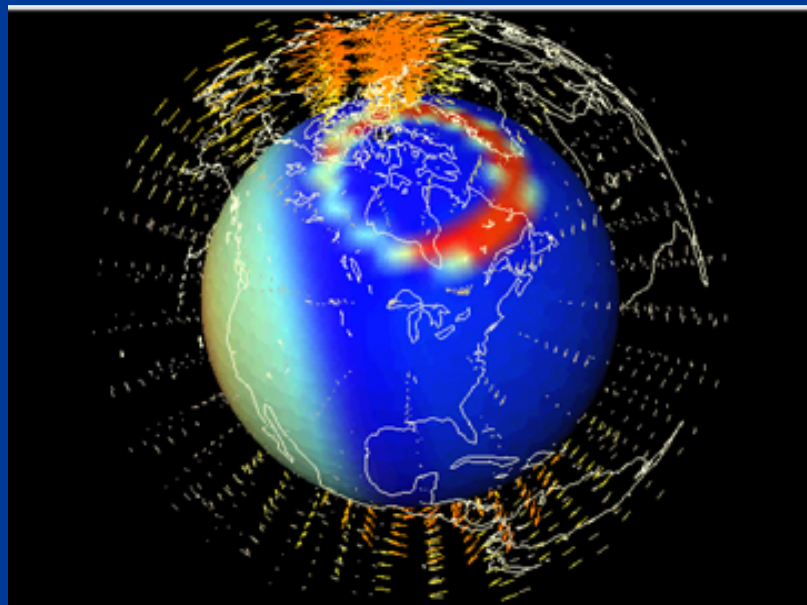
ASTRA “TIDDBIT” TID MAPPER

Nitrogen Chemistry (Simplified for This Talk)



TA003812

Each species equation includes horizontal and vertical advection, photochemical production and loss, and vertical molecular and eddy diffusion.



**Goal:
Specify or
Predict the
Atmosphere**

Data

Equations

**Equations
and Data**

**Empirical
Model**

IRI, MSIS, HWM

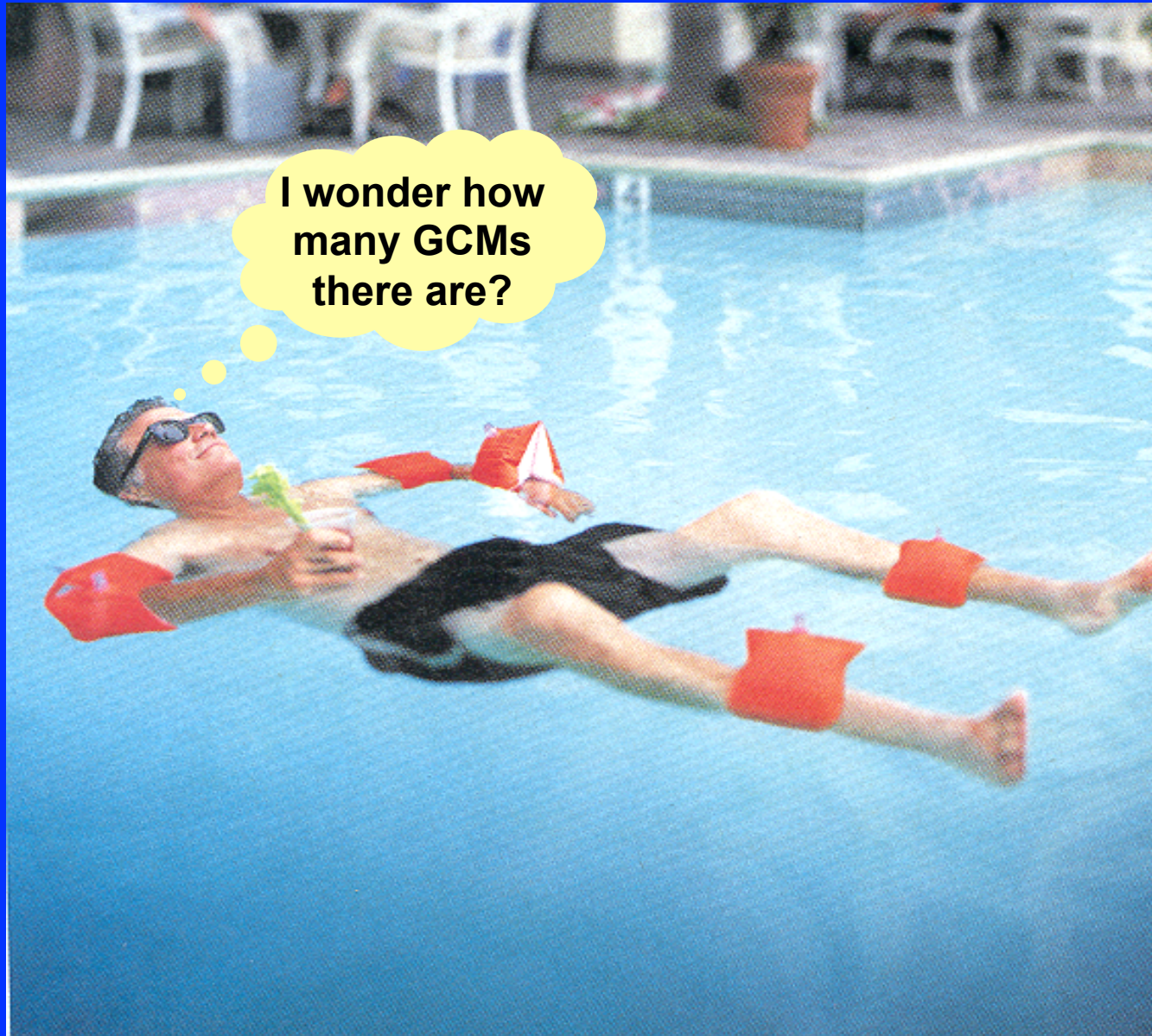
**First-
Principles
Model**

**TIMEGCM, TIEGCM,
CTIPe, SAMI3**

**Assimilative
Model**

IDA4D, GPSII, GAIM (2)

But Why Do We Need So Many Models?



Super-Ensemble Approach

❖ Science

❖ Technology

❖ Applications

Bringing It All Together

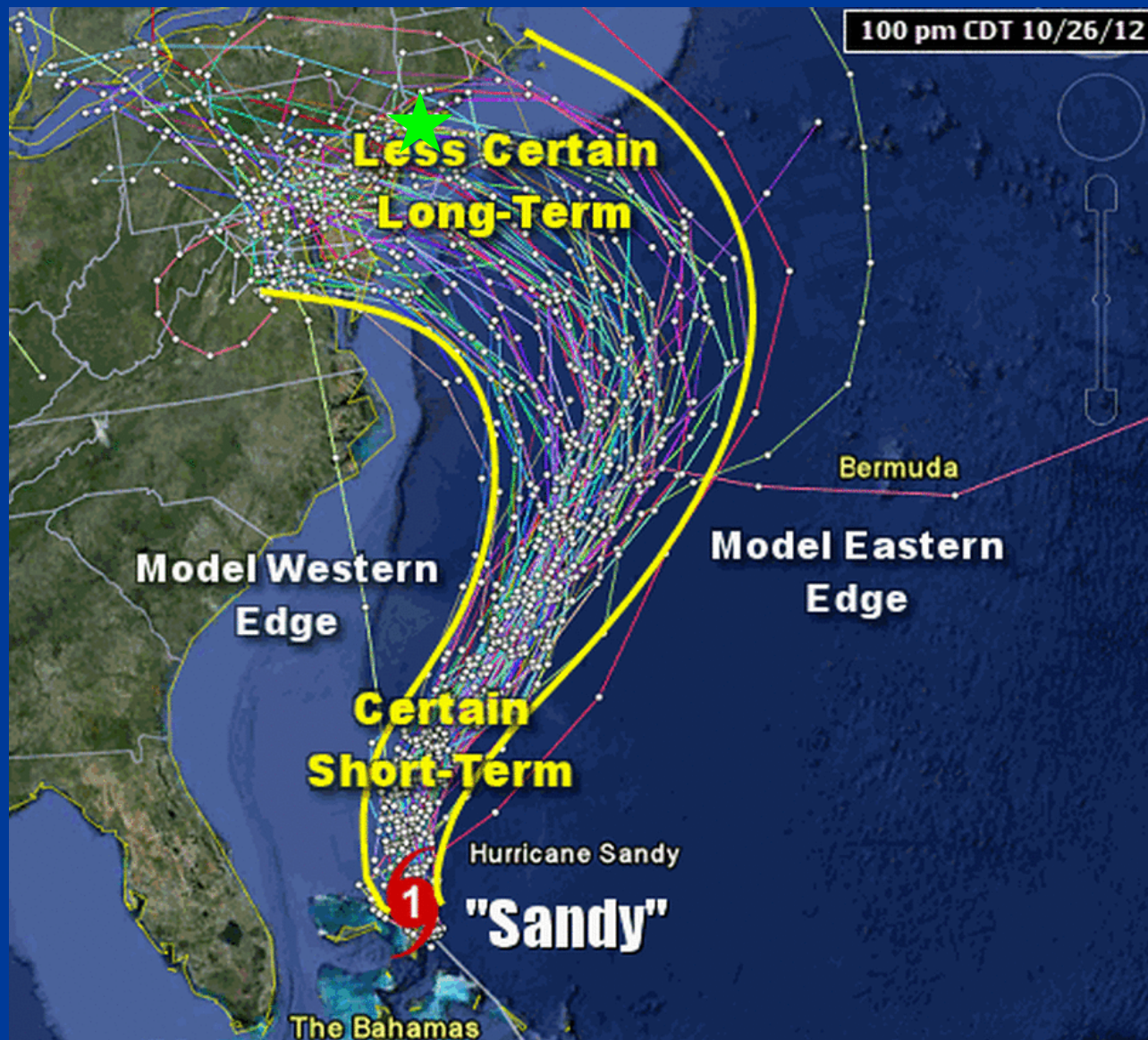
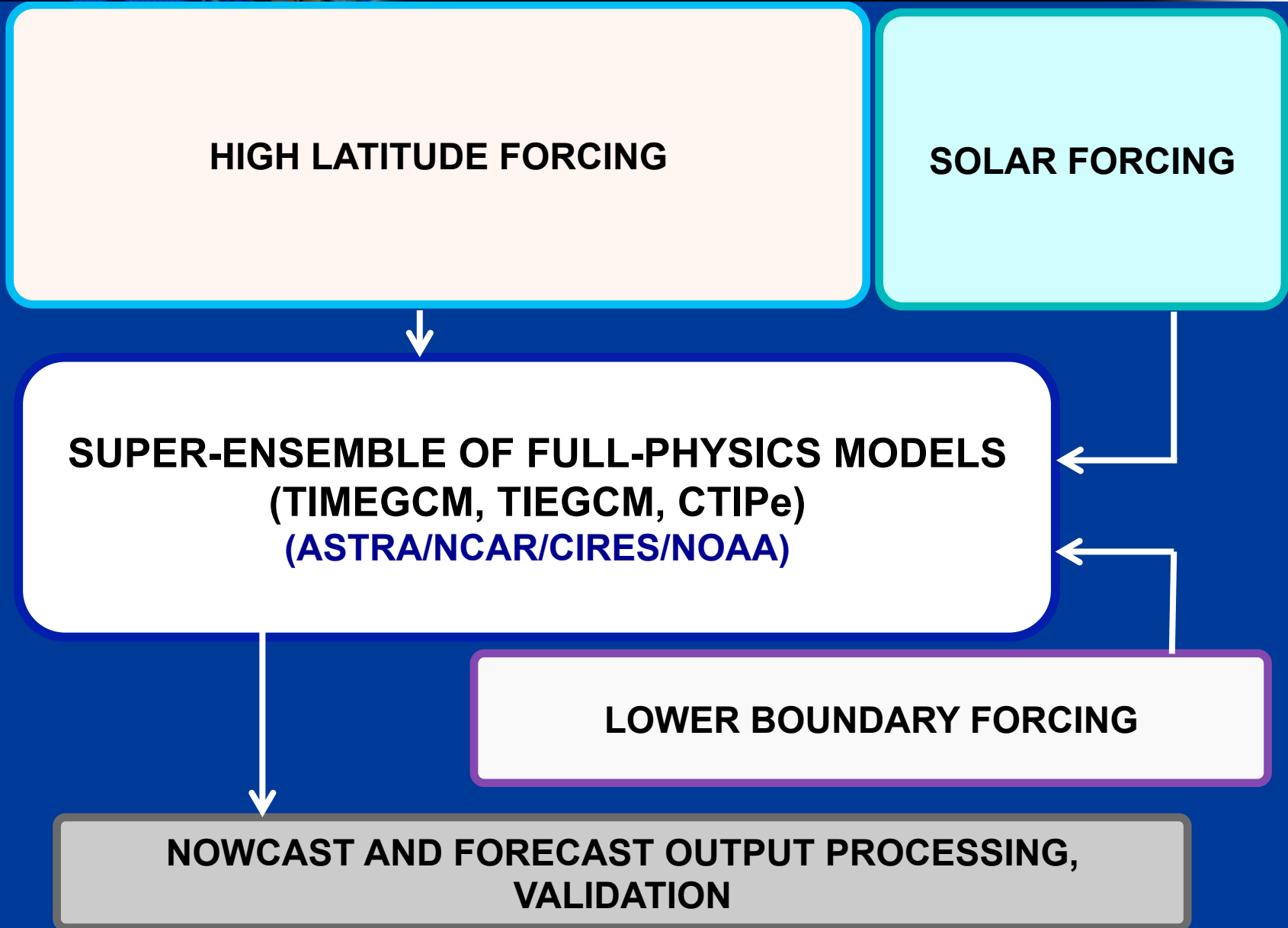
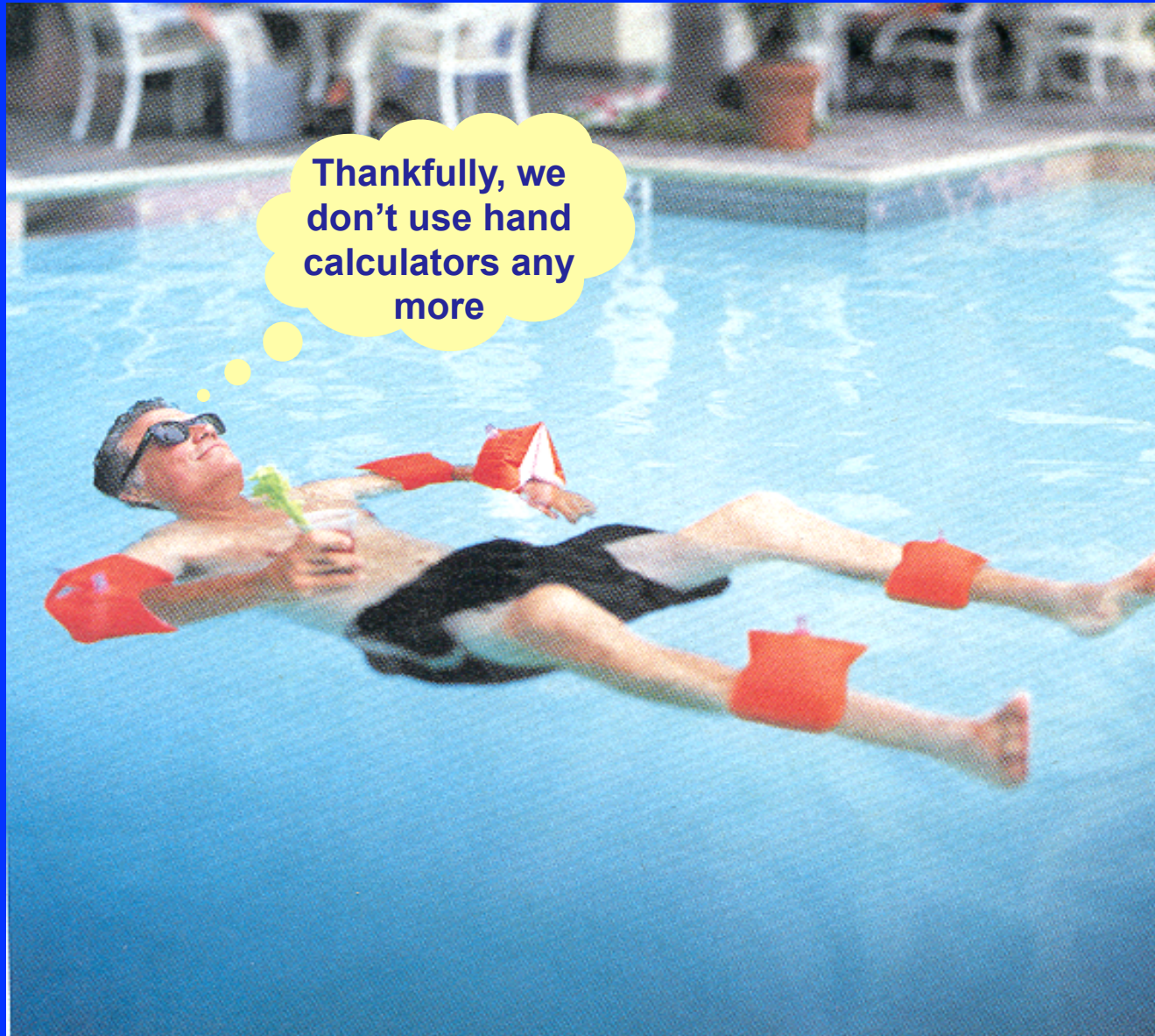


Image credit: TerraMetrics, Google

Super-Ensemble Approach



Modeler Stays Busy While Computer Runs GCM



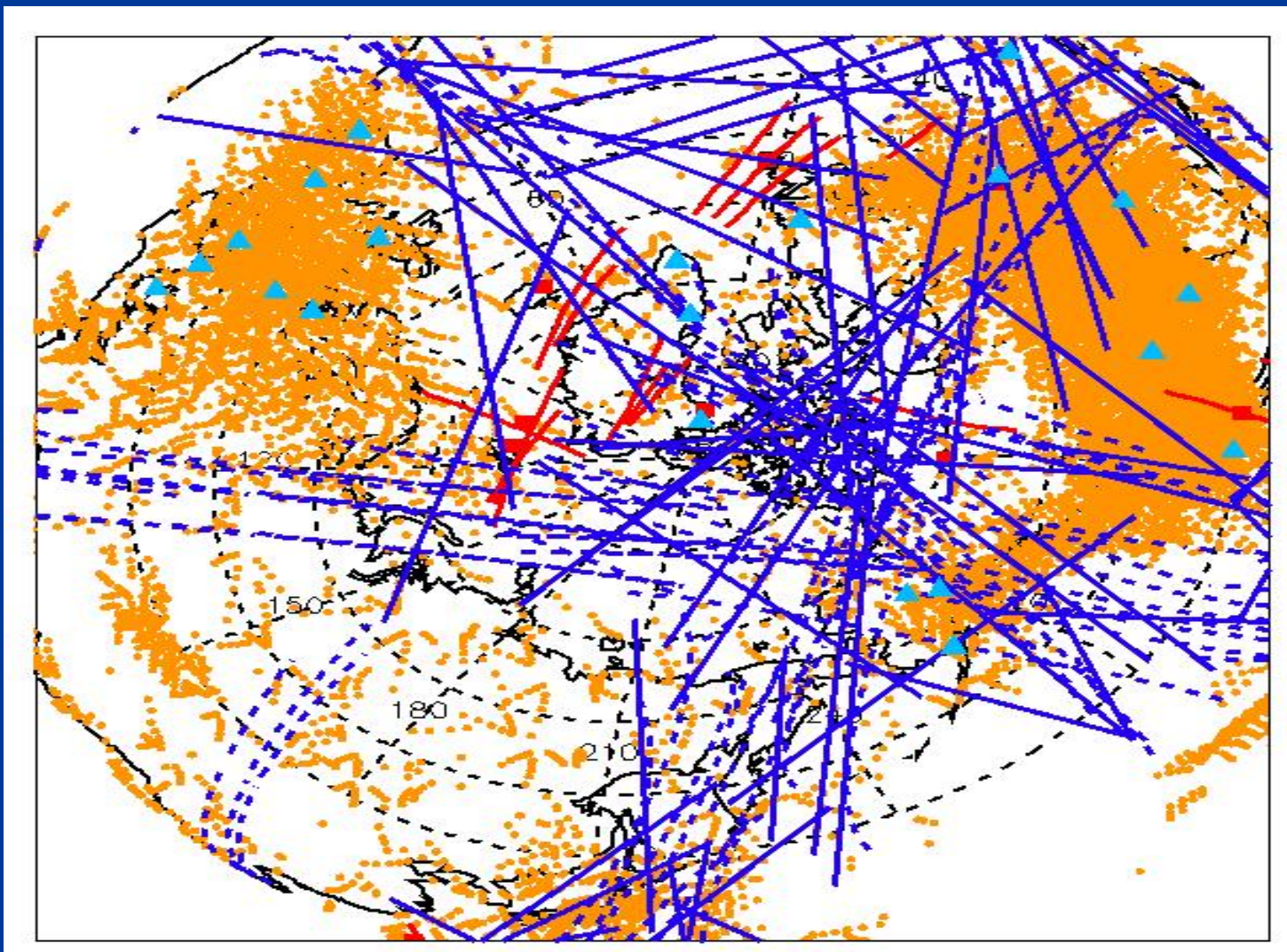
Other Ionospheric Instruments

❖ Science

❖ Technology

❖ Applications

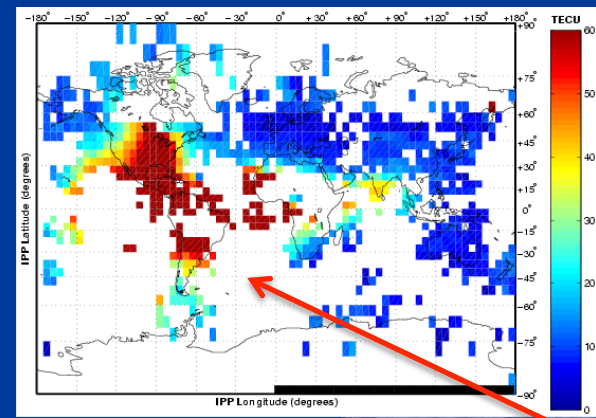
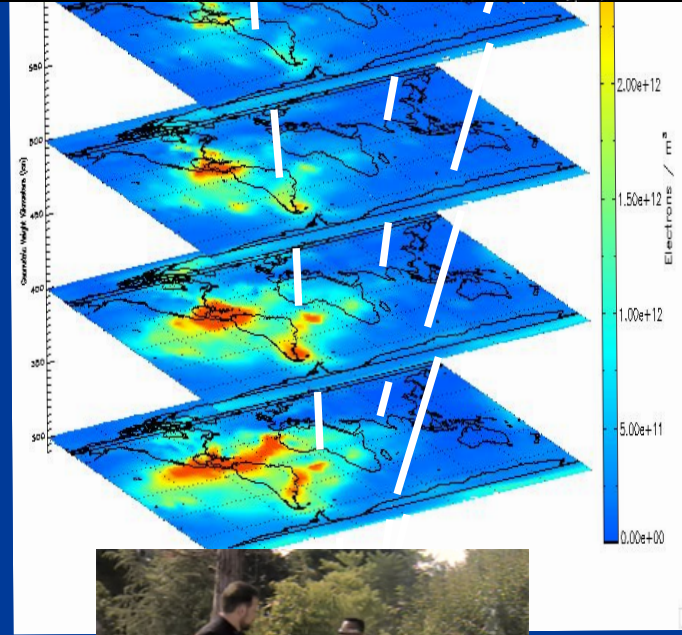
Bringing It All Together



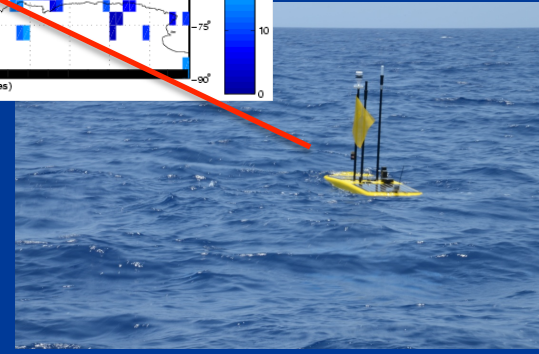
Ionospheric data are available from a number of instruments



ASTRA builds GPS scintillation and TEC monitors for rugged environments including oceans and Arctic/Antarctica.



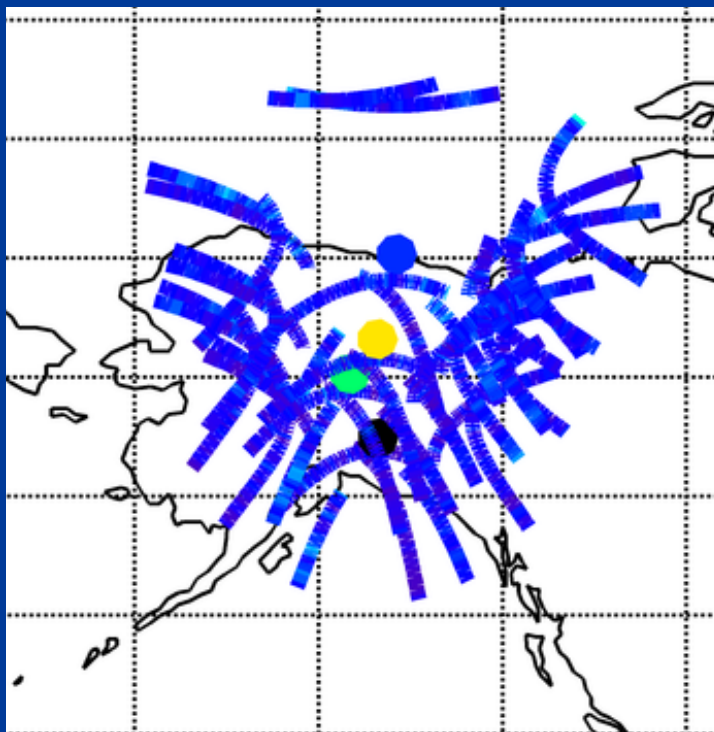
Scintillation can disrupt satellite-based navigation and communications systems



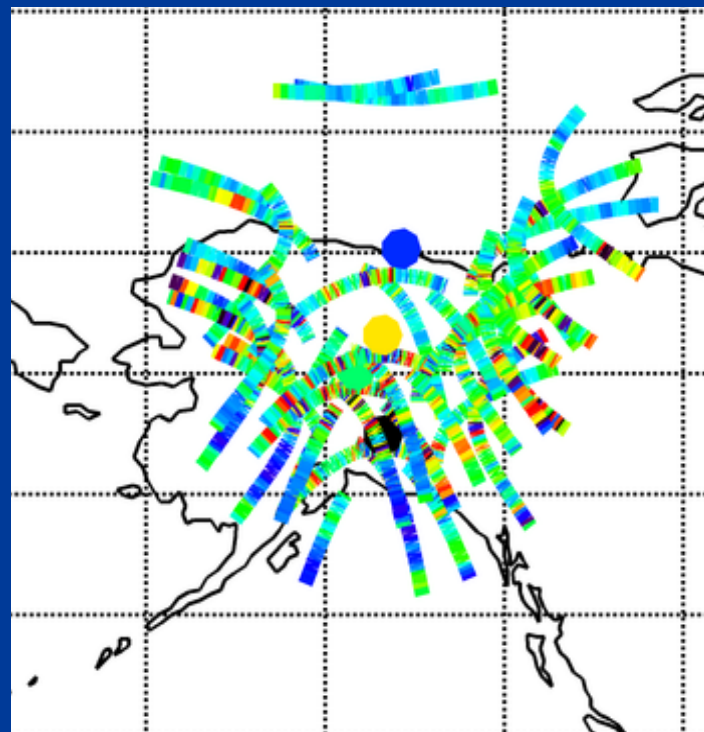


ASTRA's GPS Monitoring Networks

QUIET



ACTIVE



Alaskan scintillation monitoring service in realtime
<http://astraspace.net/news-2/cases-alaska/>

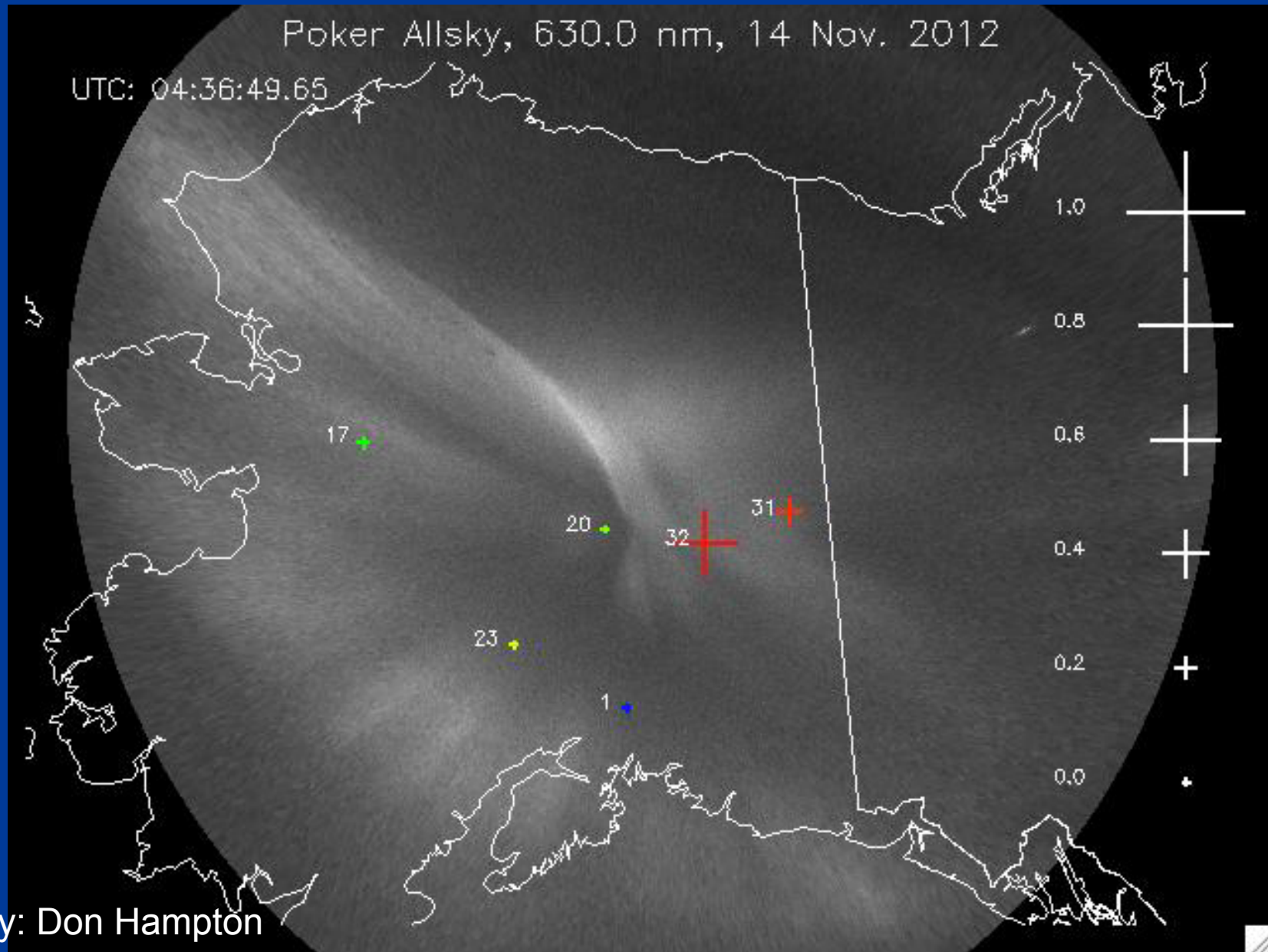
Ground-based All-Sky Images of Aurora

❖ Science

❖ Technology

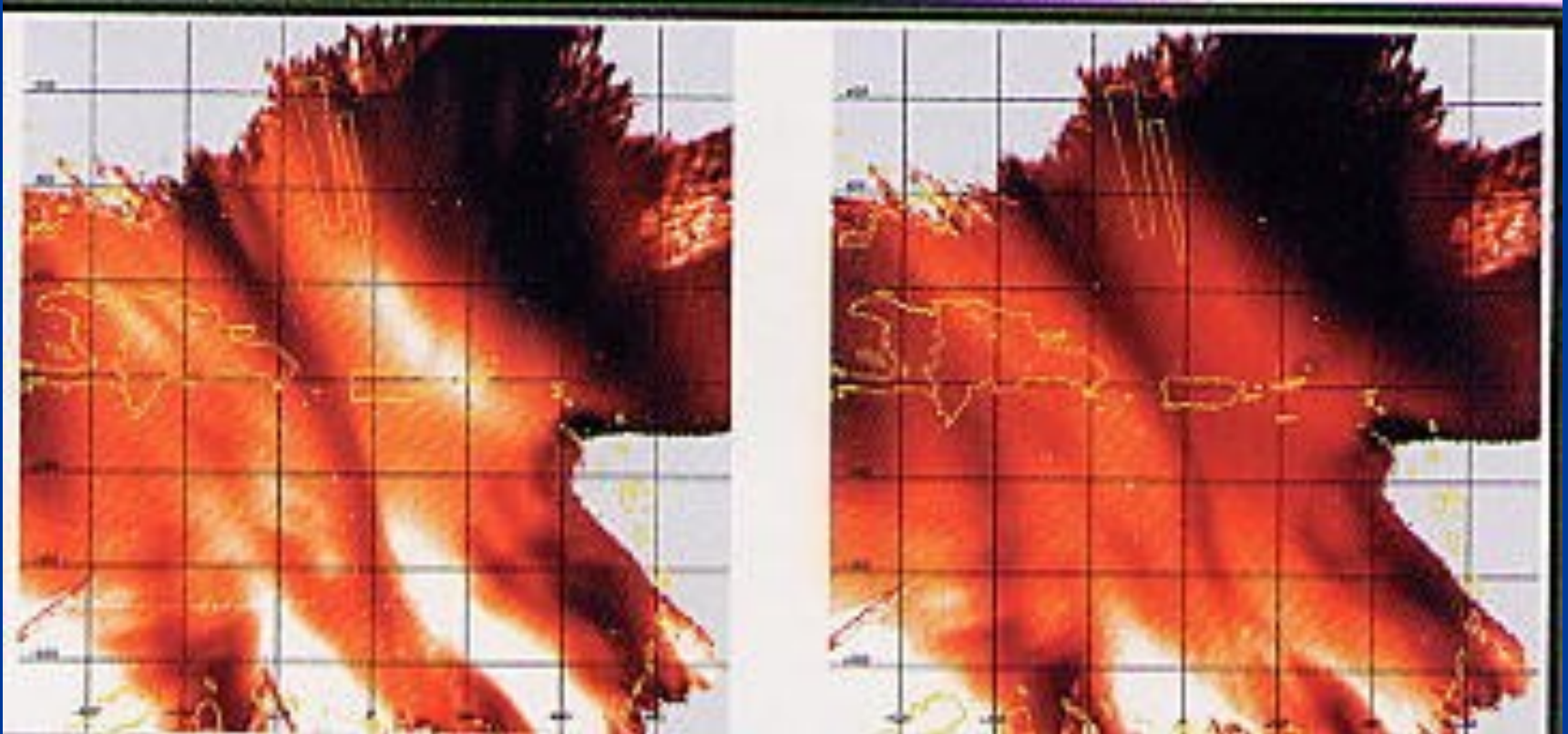
❖ Applications

Bringing It All Together



Courtesy: Don Hampton

Ground-based All-Sky Images of Midlatitude TIDs and Irregularities



Kelly, et al. "Caribbean Ionosphere Campaign, Year One: Airglow and plasma observations during two intense mid-latitude spread-*F* events." *Geo. Res. Let.* 27 2825-2828

Incoherent Scatter Radars

❖ Science

❖ Technology

❖ Applications

Bringing It All Together



AMISR at Resolute Bay, Canada

Sondrestrom Research Facility



Other ISR Facilities include:

Poker Flat (PFISR)

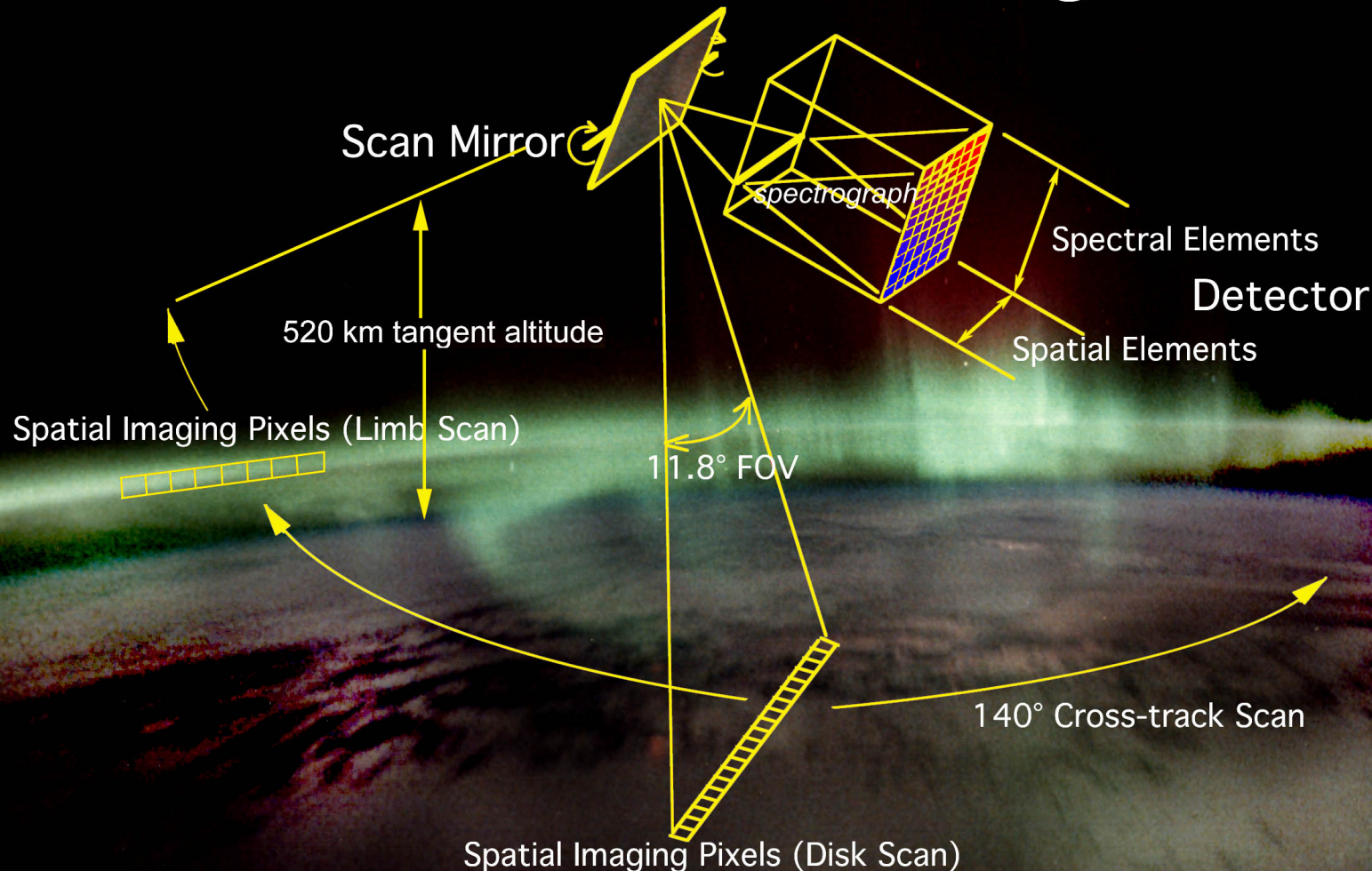
Millstone Hill

Arecibo

Jicamarca

EISCAT

Global Ultraviolet Imager (GUVI)



Scan operation of the GUVI instrument on TIMED. The slit dimension is along the satellite track and is subdivided into 14 pixels. The cross-track scan is initiated every 15 s.

DICE Cubesat: Dynamic Ionosphere Cubesat Experiment

❖ Science

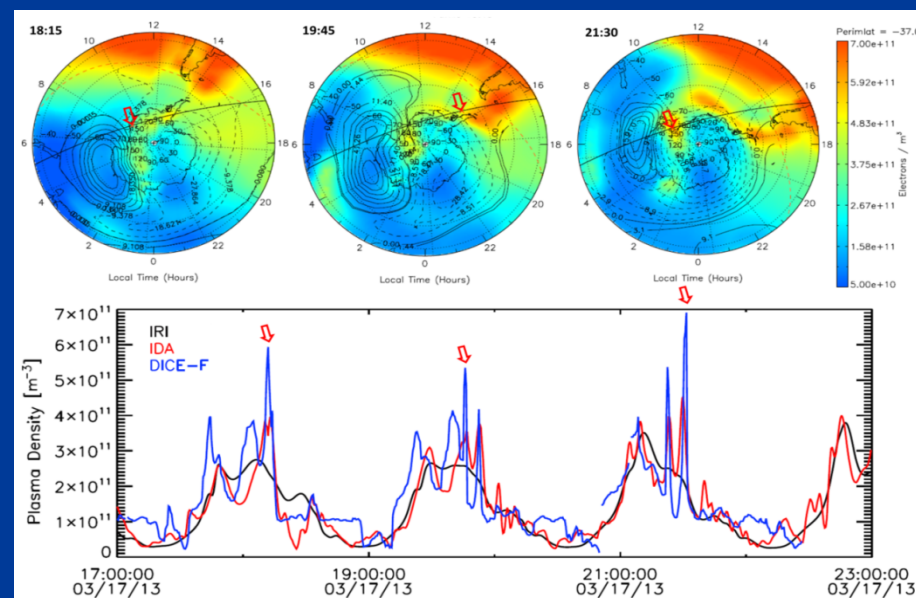
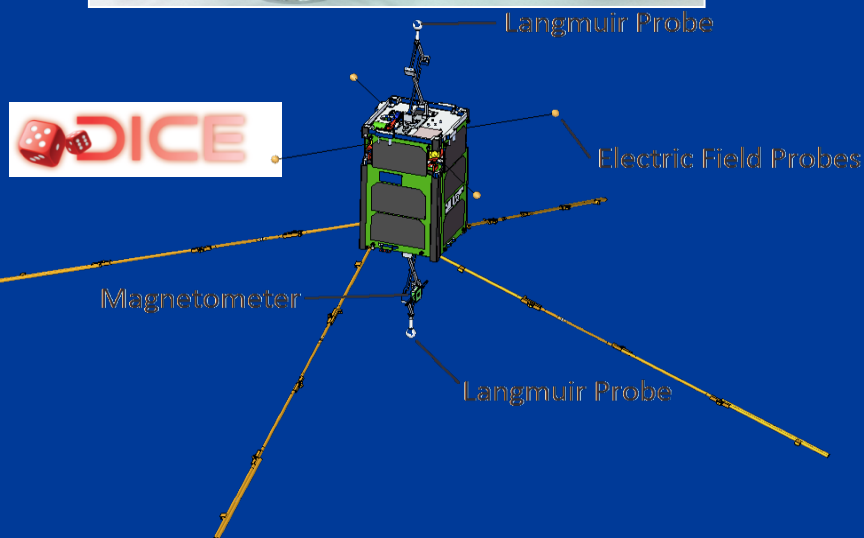
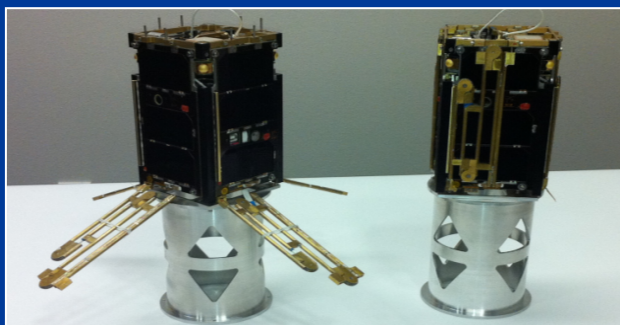
❖ Technology

❖ Applications

Bringing It All Together



- Objectives:
 - Characterization of Storm Enhanced Densities (SEDs) in the ionosphere,
 - Detection of Field Aligned Currents (FACs) at high latitudes.
- Funded by NSF
- ASTRA was the PI institution
- Team members: Space Dynamics Laboratory, USU, Embry-Riddle, and Clemson
- Both DICE satellites were deployed into the same orbit in October 2011.



Above: DICE plasma density observations compared with IDA4D assimilation of the south polar ionosphere. Note that the enhanced densities observed by DICE (red arrows in the bottom plot) correspond to when the DICE satellite passes through a tongue of ionization during successive passes (red arrows).

SORTIE: Scintillation Observations and Response of The Ionosphere to Electrodynamics

❖ Science

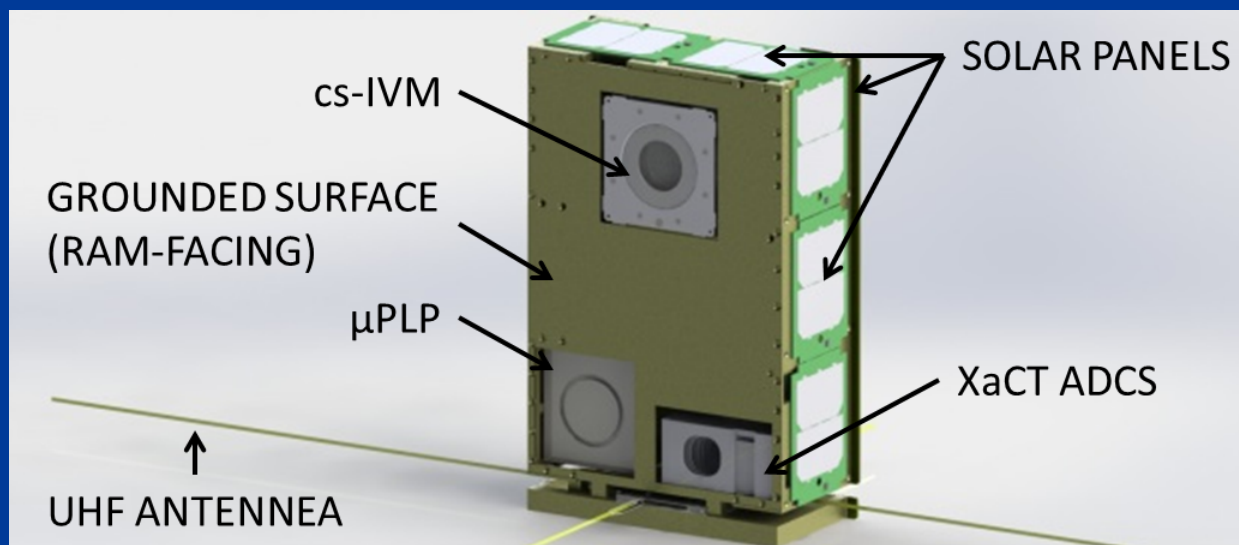
❖ Technology

❖ Applications

Bringing It All Together



- Objectives:
 - Describe the distribution of wave-like structures in the plasma density of the ionospheric F-region and to connect these variations to wave sources in the troposphere and in the high latitude thermosphere
 - Construct an atlas of ionospheric variability
 - Collect data over the course of 6 months
- Funded by NASA (HTIDeS)
- ASTRA is the PI institution
- Team members: COSMIAC, AFRL, University of Texas at Dallas and Boston College
- Will weigh just 5kg and be no larger than a cereal box
- Includes miniature Ion Velocity Meter (mini-IVM) built by The University of Texas at Dallas
- Includes a micro Planar Langmuir Probe (μ PLP) built by the Air Force Research Laboratory



- What ionospheric features and tools have we seen this week that affect RO?
“One man’s noise is another man’s data”
- Ionospheric background structure
 - ✧ Vertical and Horizontal Structures
 - ✧ F-region, E-region
 - ✧ Low, middle and high latitudes
 - ✧ Time variation (daily, solar cycle)
 - ✧ Geomagnetic storms
- Models
- Supporting instruments

You are now all ionospheric experts!