Solar Storms in the Ionosphere and the NASA GOLD Mission

GOLD
Global-scale Observations of the Limb and Disk

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NCAR

Outline

- Brief overview of Space Weather
- Brief overview of the ionosphere-thermosphere
- Review of the Global-scale Observations of the Limb and Disk (GOLD) Mission
- What we hope to observe
- What we hope to learn

Solar Eclipse of 21 August 2017 (with image enhancement)

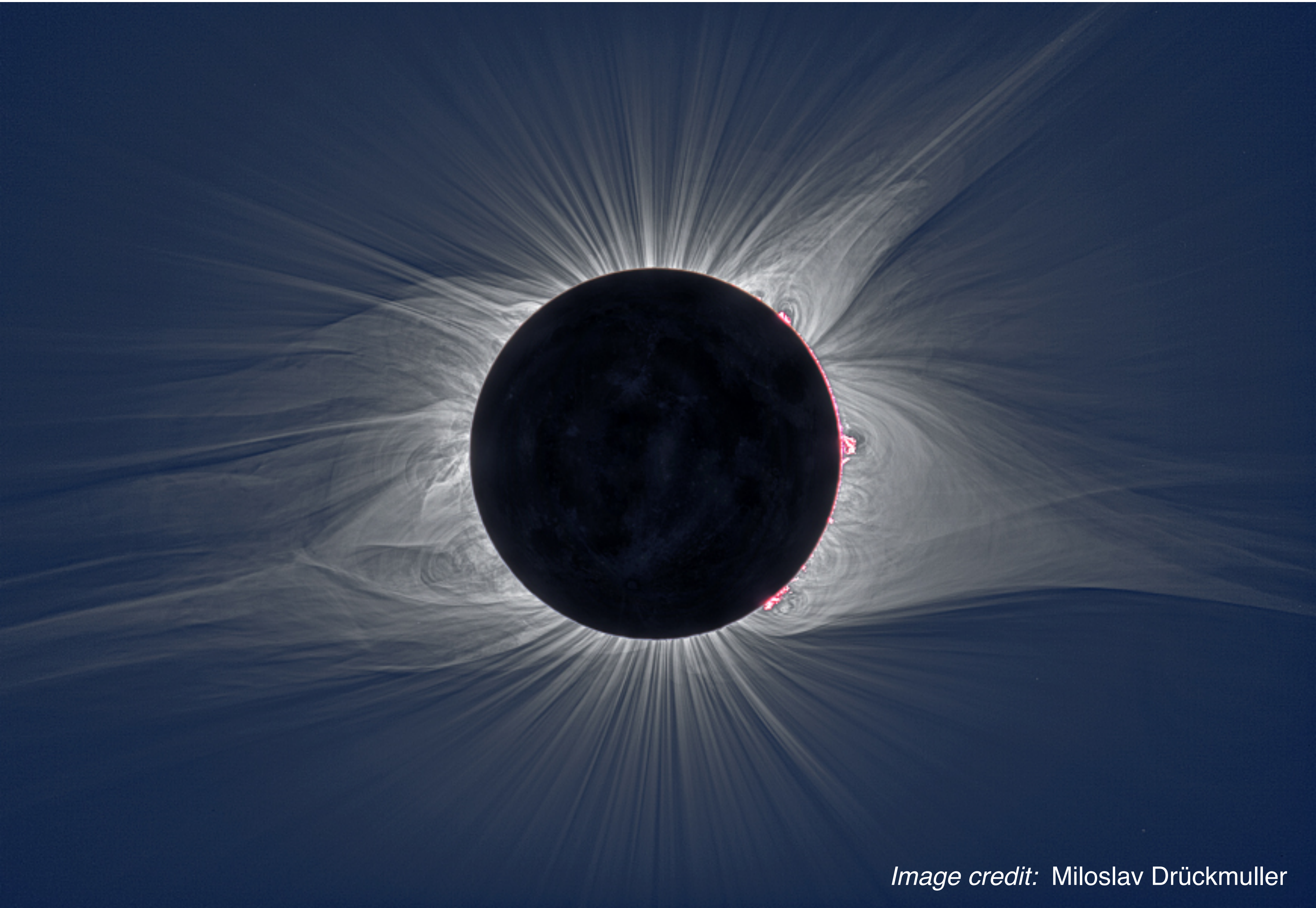
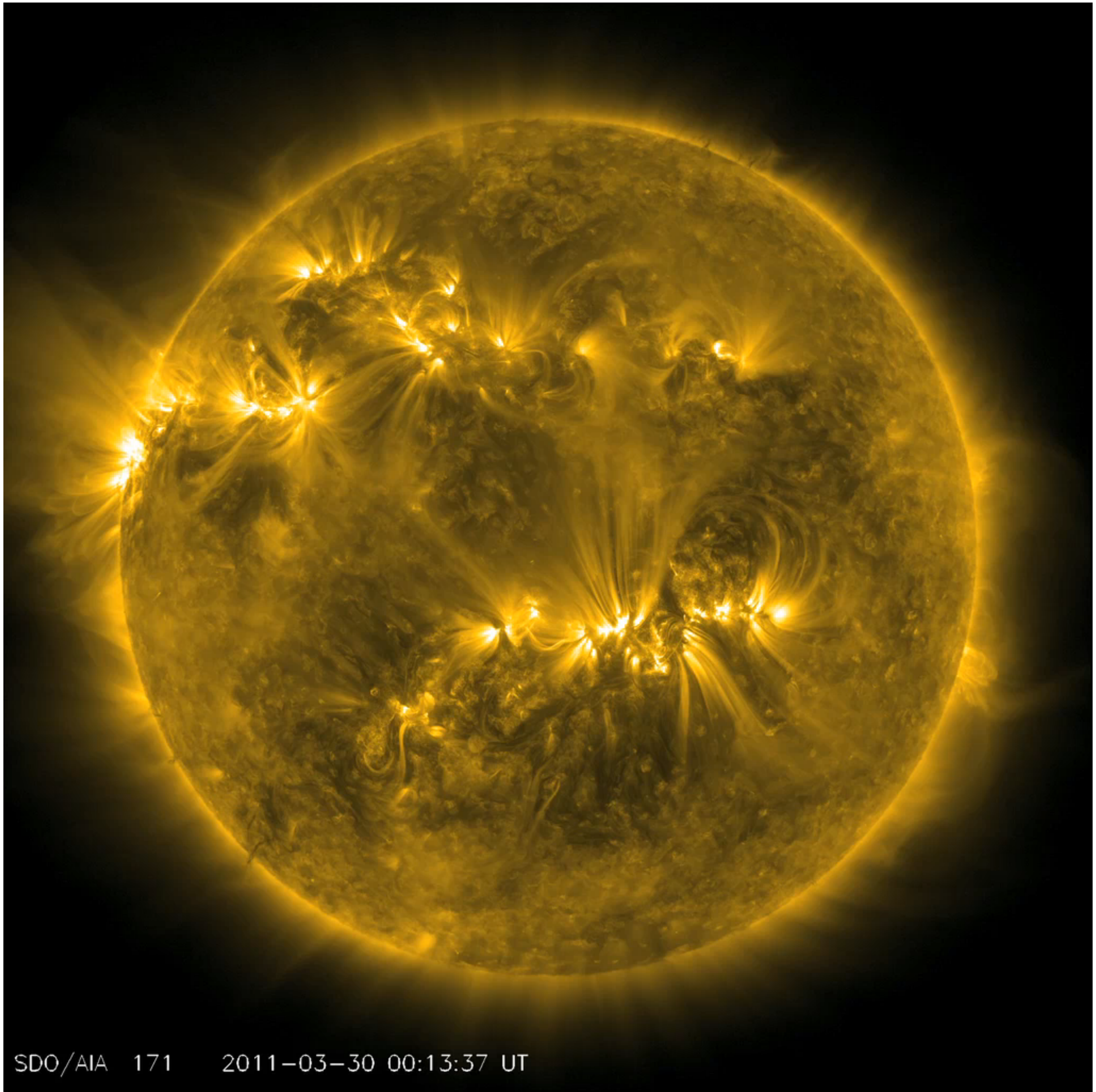


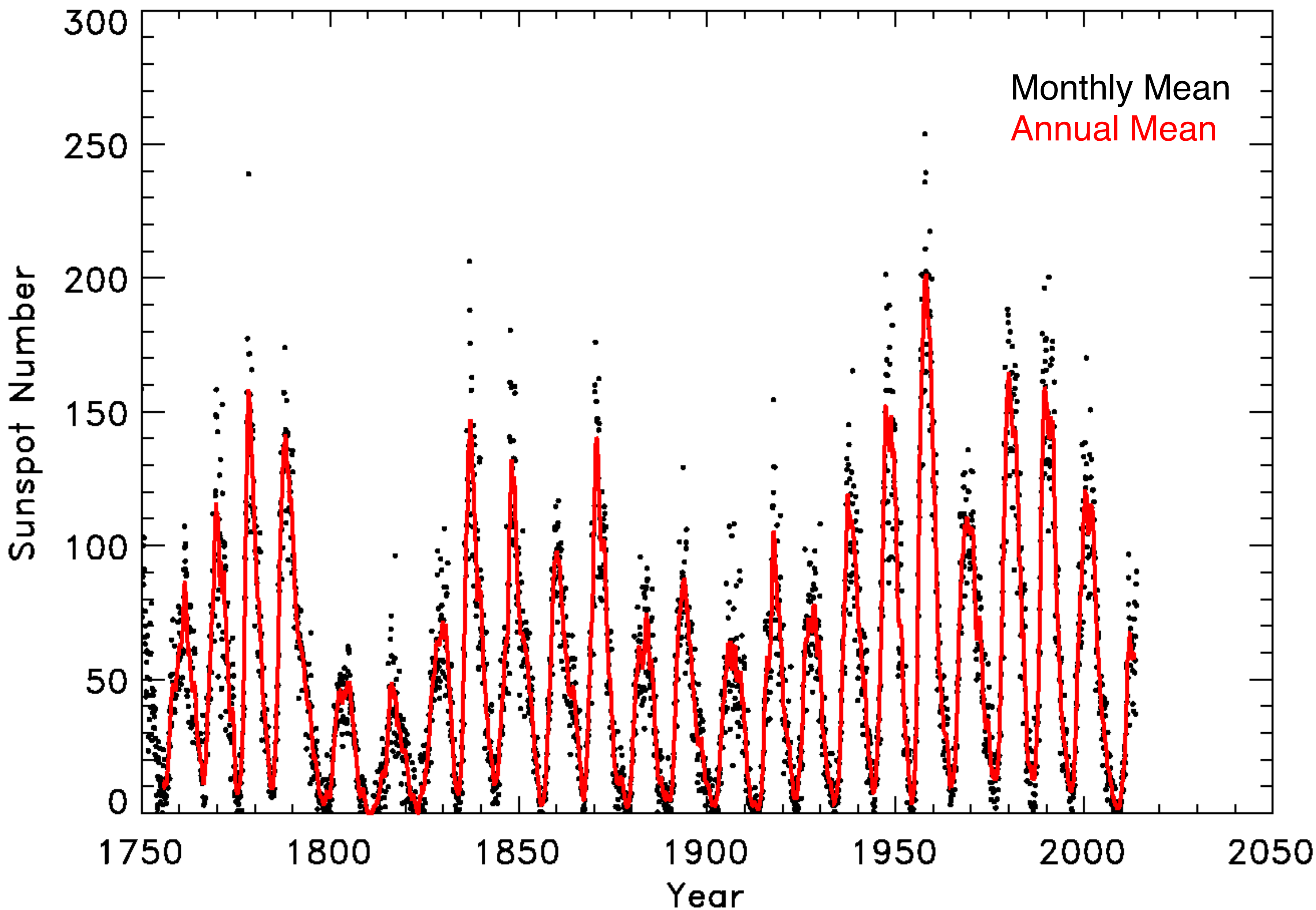
Image credit: Miloslav Drückmuller

Solar Eclipse of 21 August 2017 (wide view)

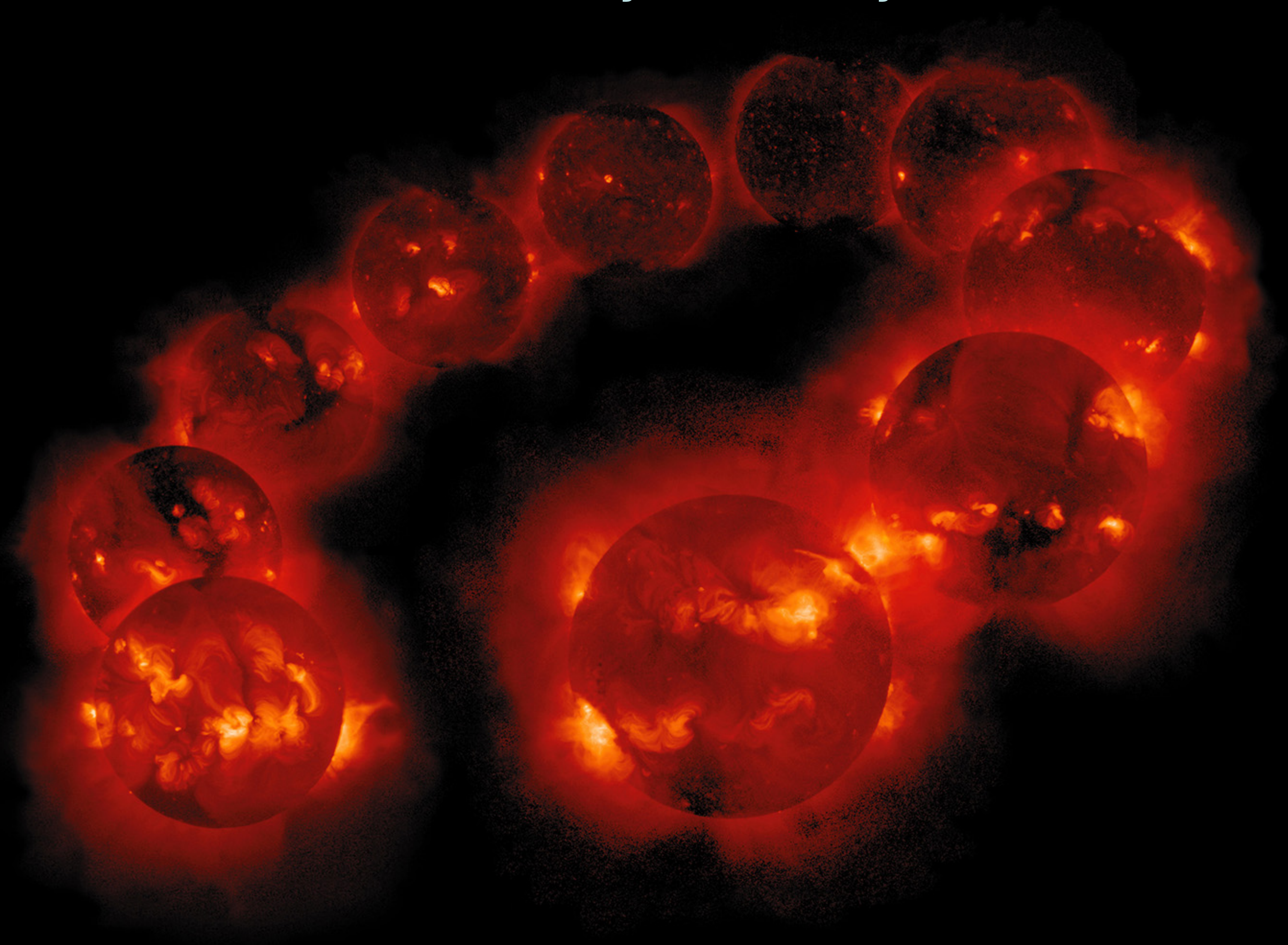
Active Regions on the Sun Generate Space Weather



The Solar Cycle in Sunspots



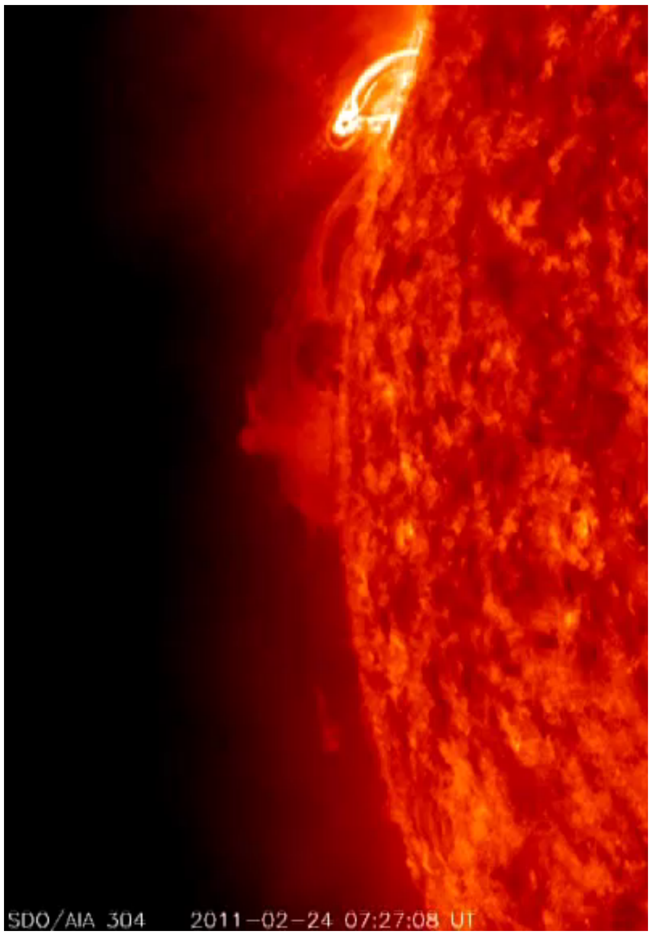
The Solar Cycle in X-rays

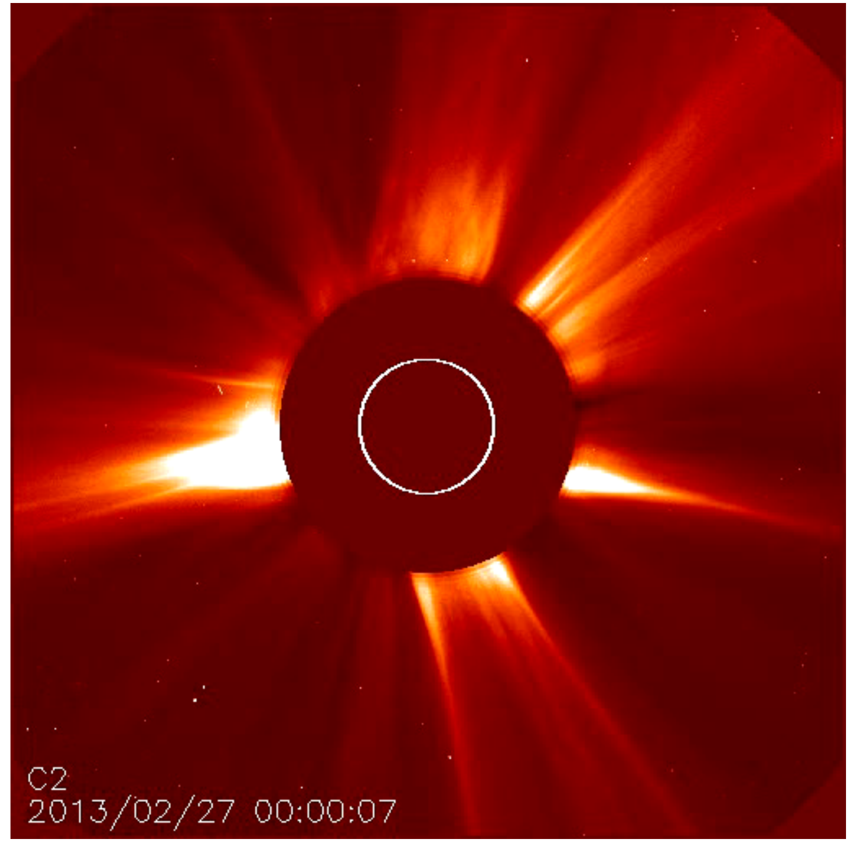


Solar Eruptions

Solar flares produce electromagnetic radiation:

- Travel time to Earth: 8 min
- From gamma-ray to radio

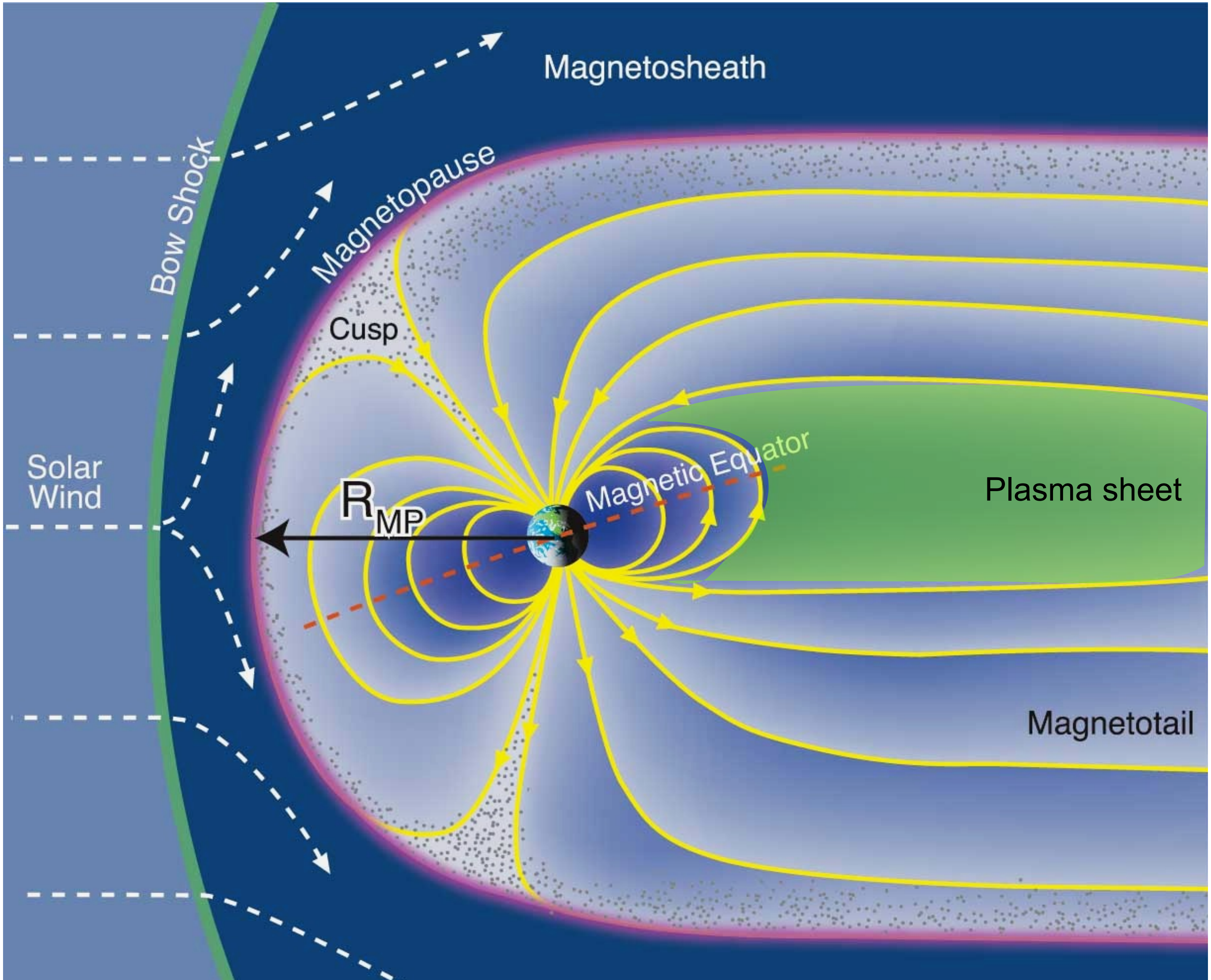




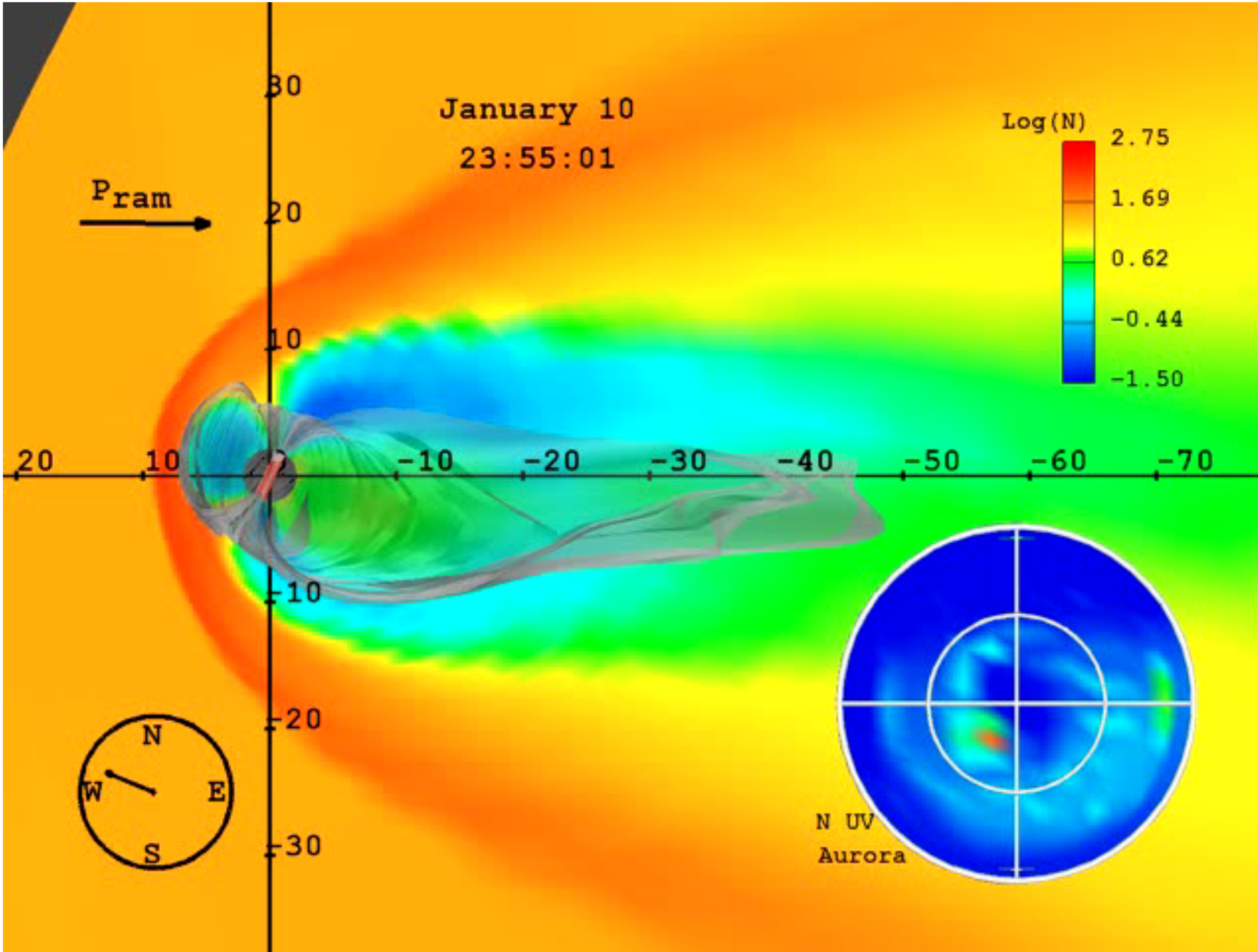
Flares & coronal mass ejections (CMEs) also produce solar energetic particles:

- Travel time to Earth: 15 min – hours
- protons, electrons, heavier nuclei
- tens of MeV to few GeV

The Magnetosphere Responds to Solar Eruptions

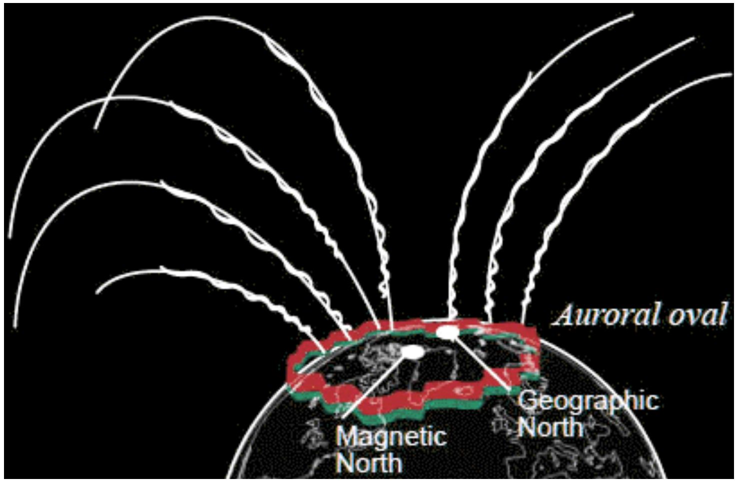


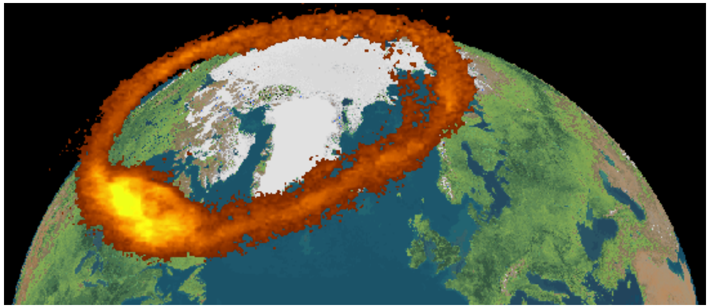
The Magnetosphere Responds to Solar Eruptions



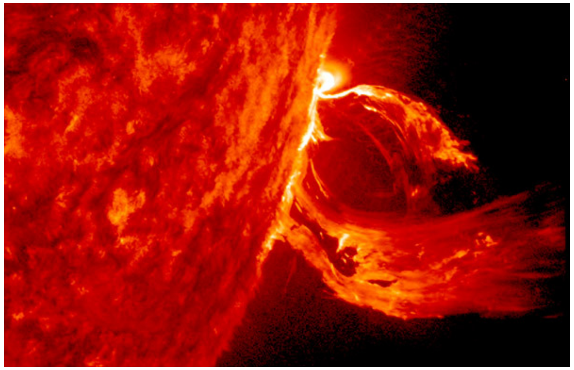
Magnetosphere-Ionosphere Interactions Cause the Aurora

- Energetic electrons stream down the polar cusp, collide with atmospheric O, O_2, N_2, excite bound electrons, which decay & emit photons…





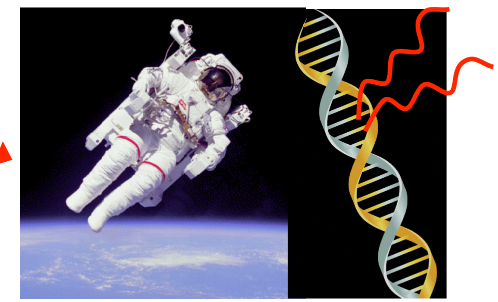
Space Weather Impacts



Impacts from space weather are wide-ranging, with potentially significant consequences

Satellite Operations

GPS



Human Space Flight

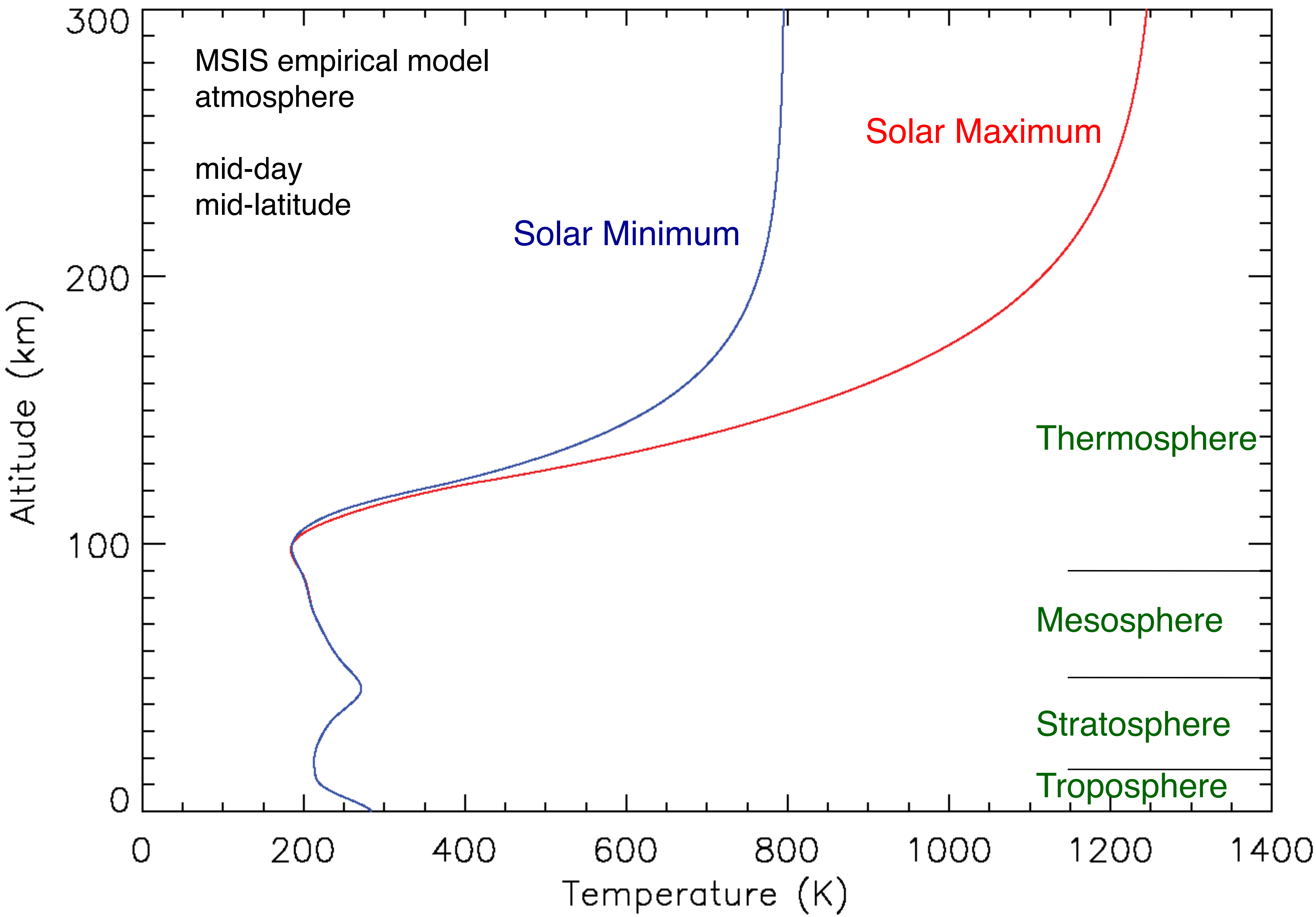
Power Grid Operations

Aircraft Operations

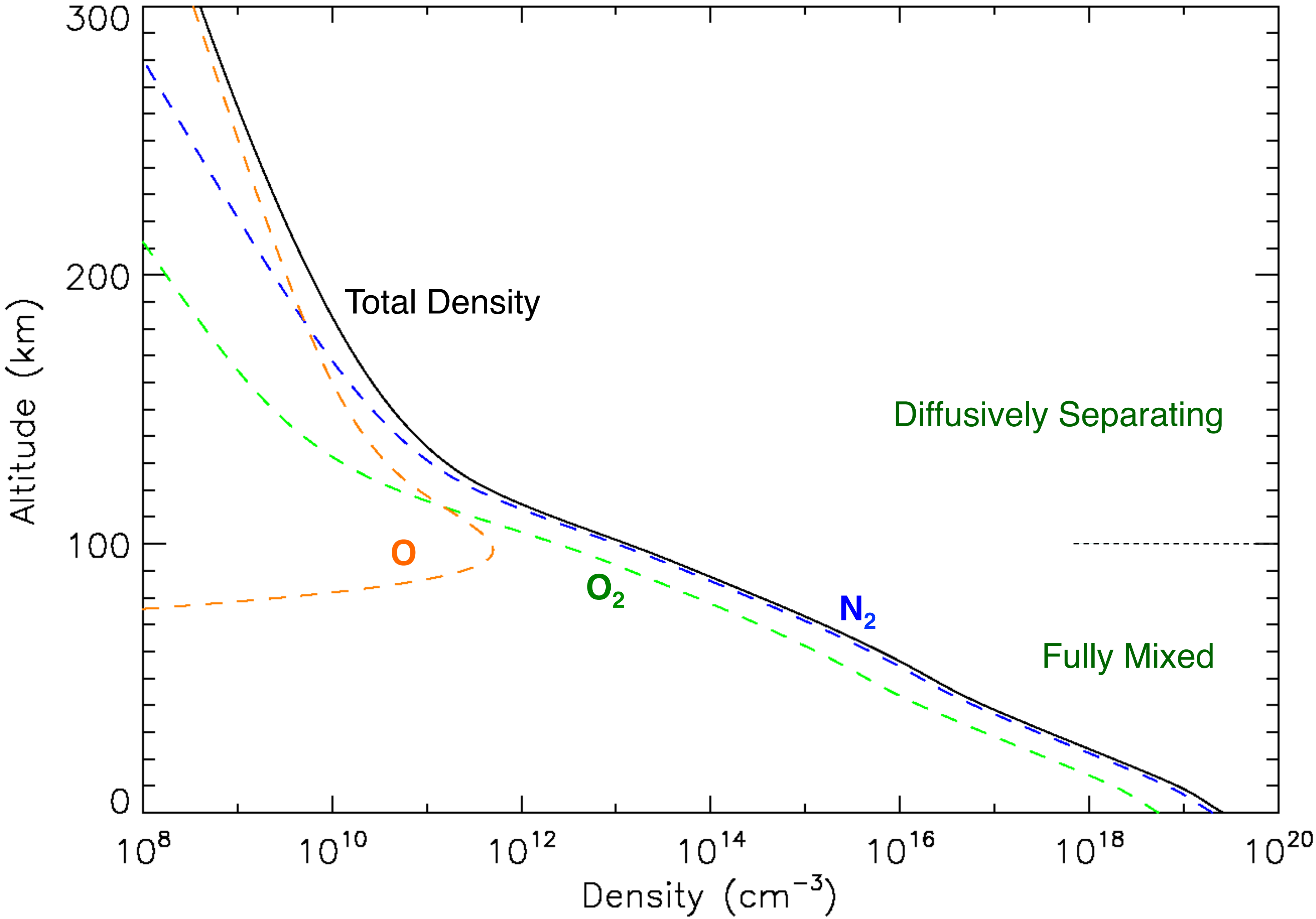
Communications

Brief Overview of the Ionosphere-Thermosphere

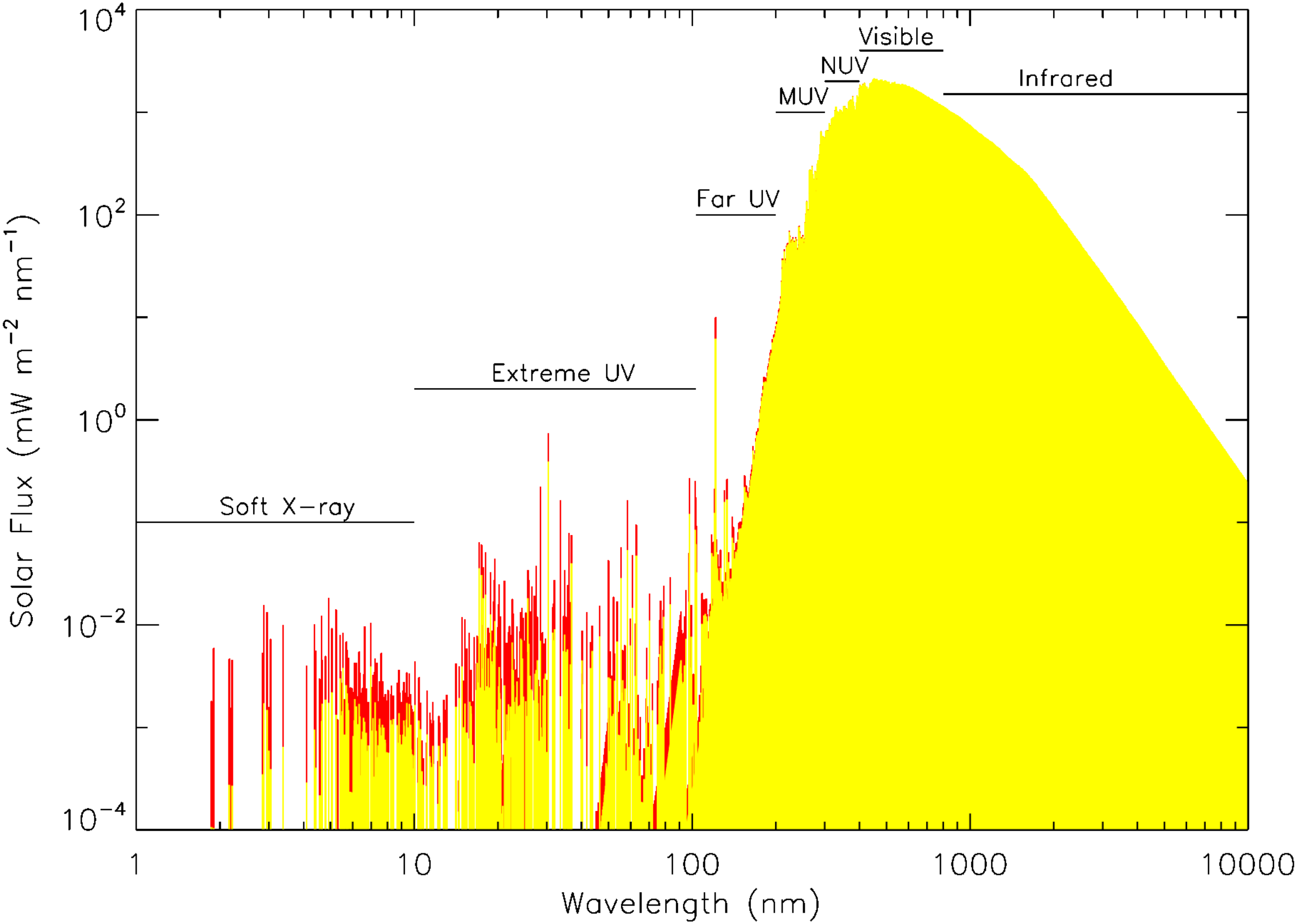
Temperature Structure of the Atmosphere



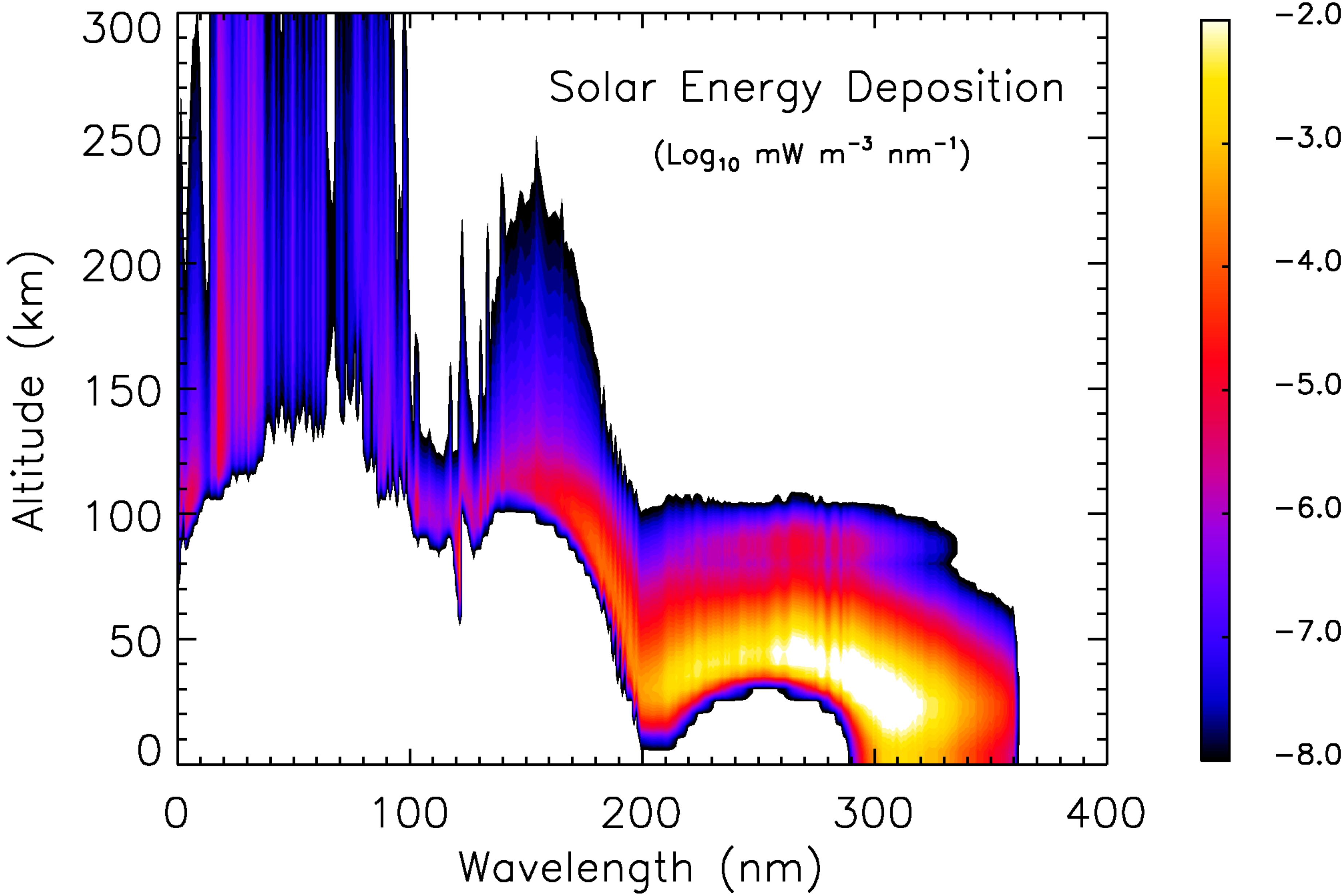
Major Species Density Structure of the Atmosphere



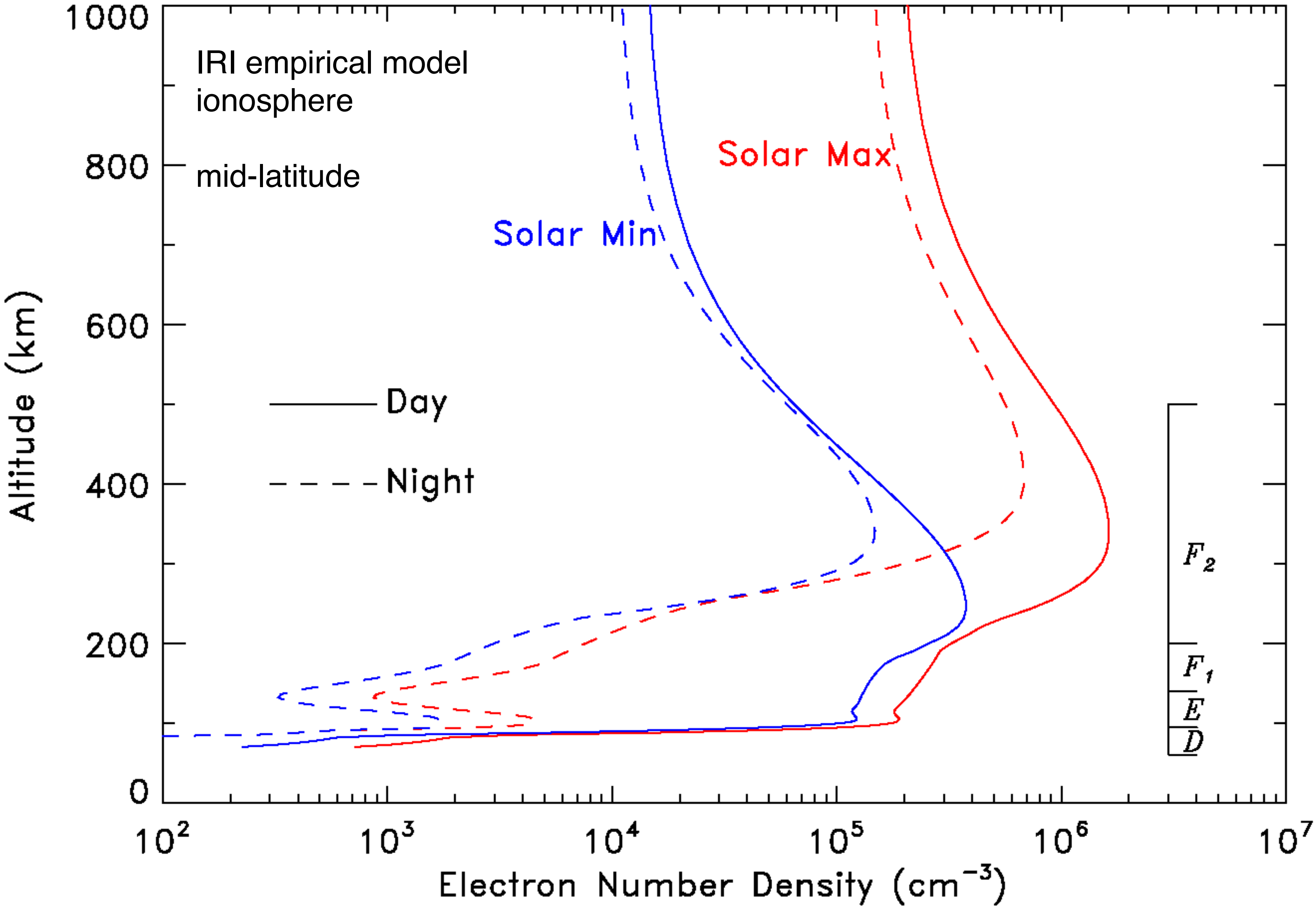
The Solar Spectrum



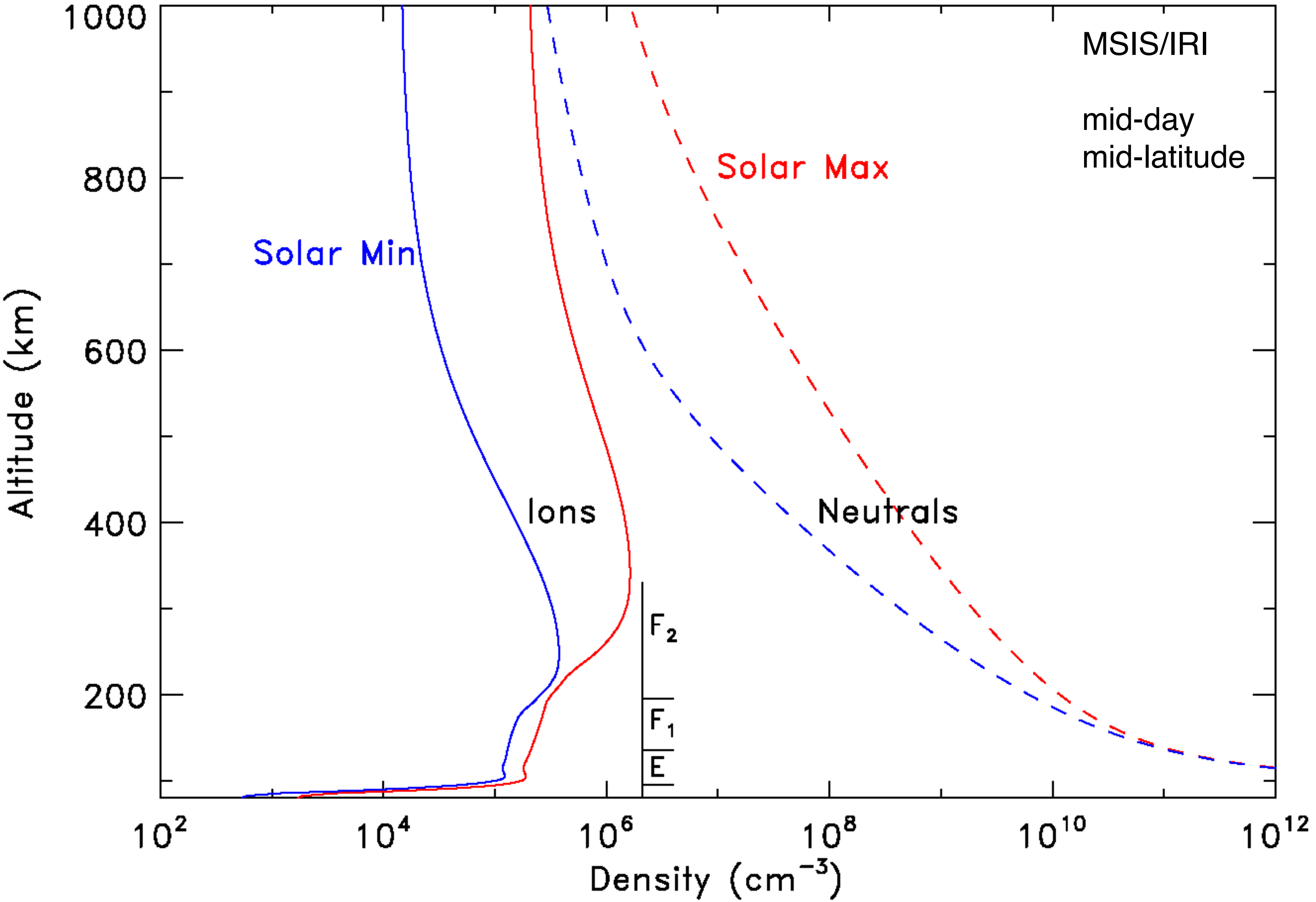
Altitude Dependence of Solar Energy Deposition

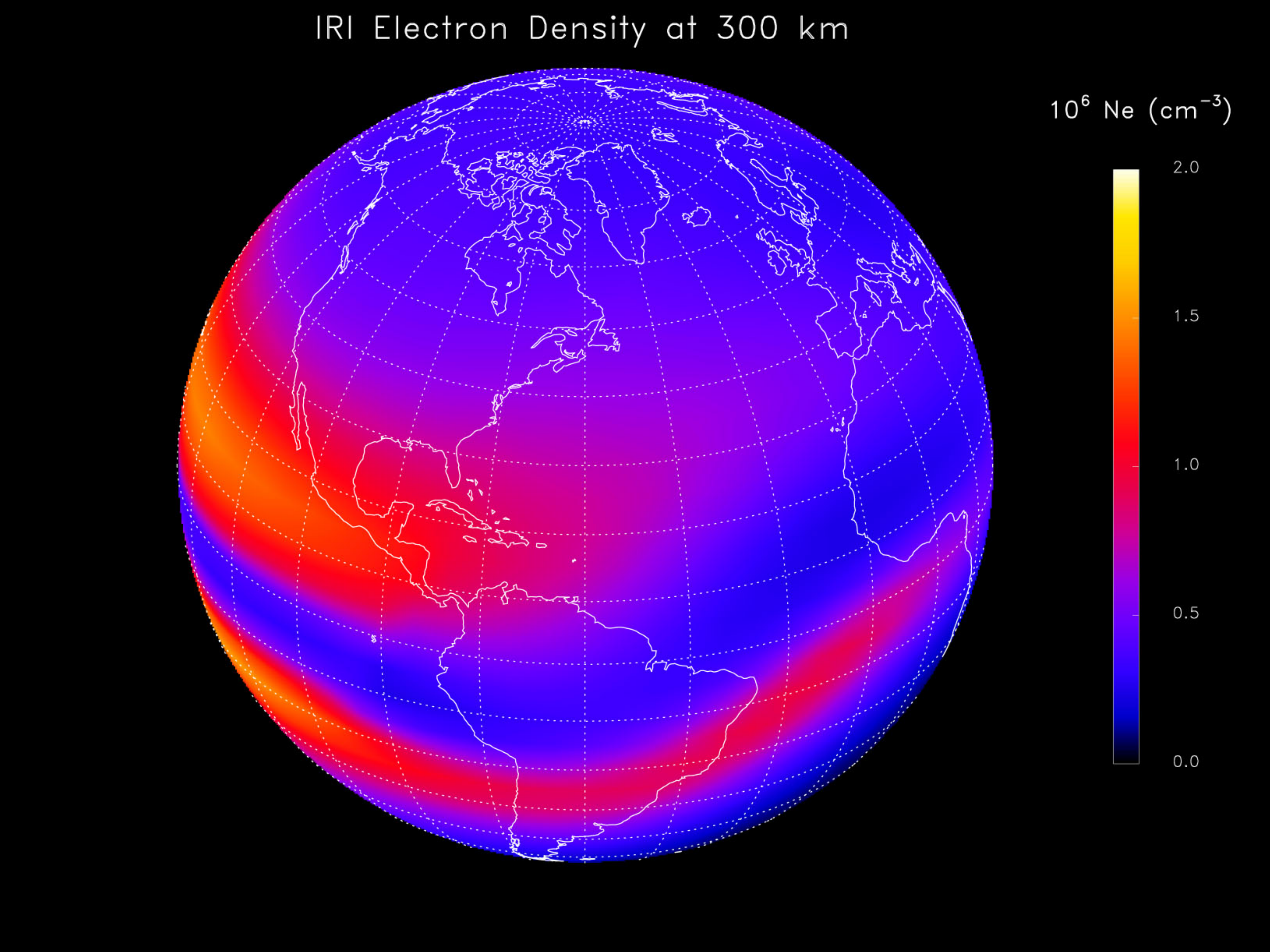


Ionosphere Basic Altitude Structure



Thermosphere-Ionosphere Variability

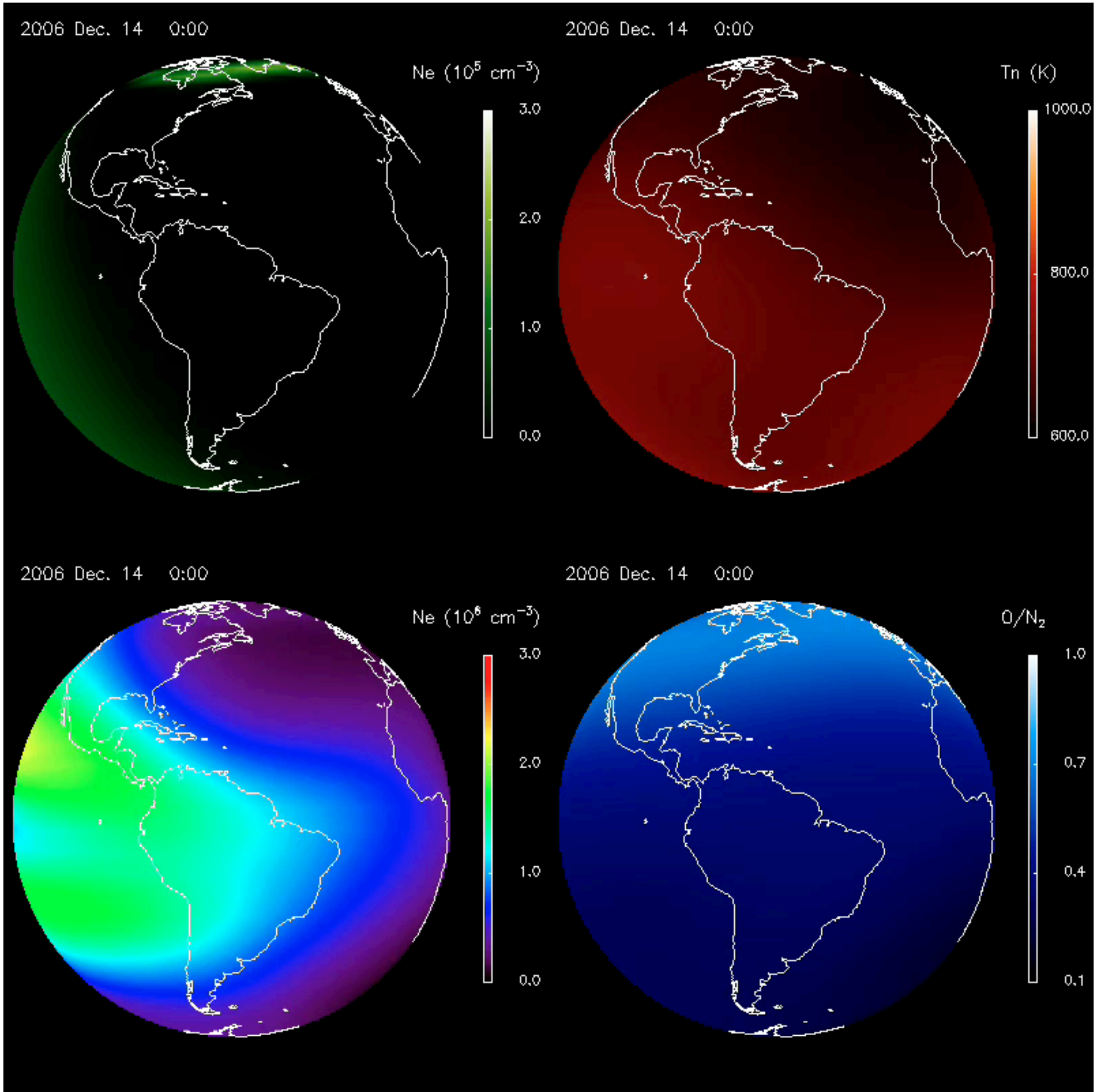



IRI Electron Density at 300 km
10^6 Ne (cm^{-3})
2.0
1.5
1.0
0.5
0.0

Thermosphere-Ionosphere Modeling during Storms

E-region Electron Density (~110 km)

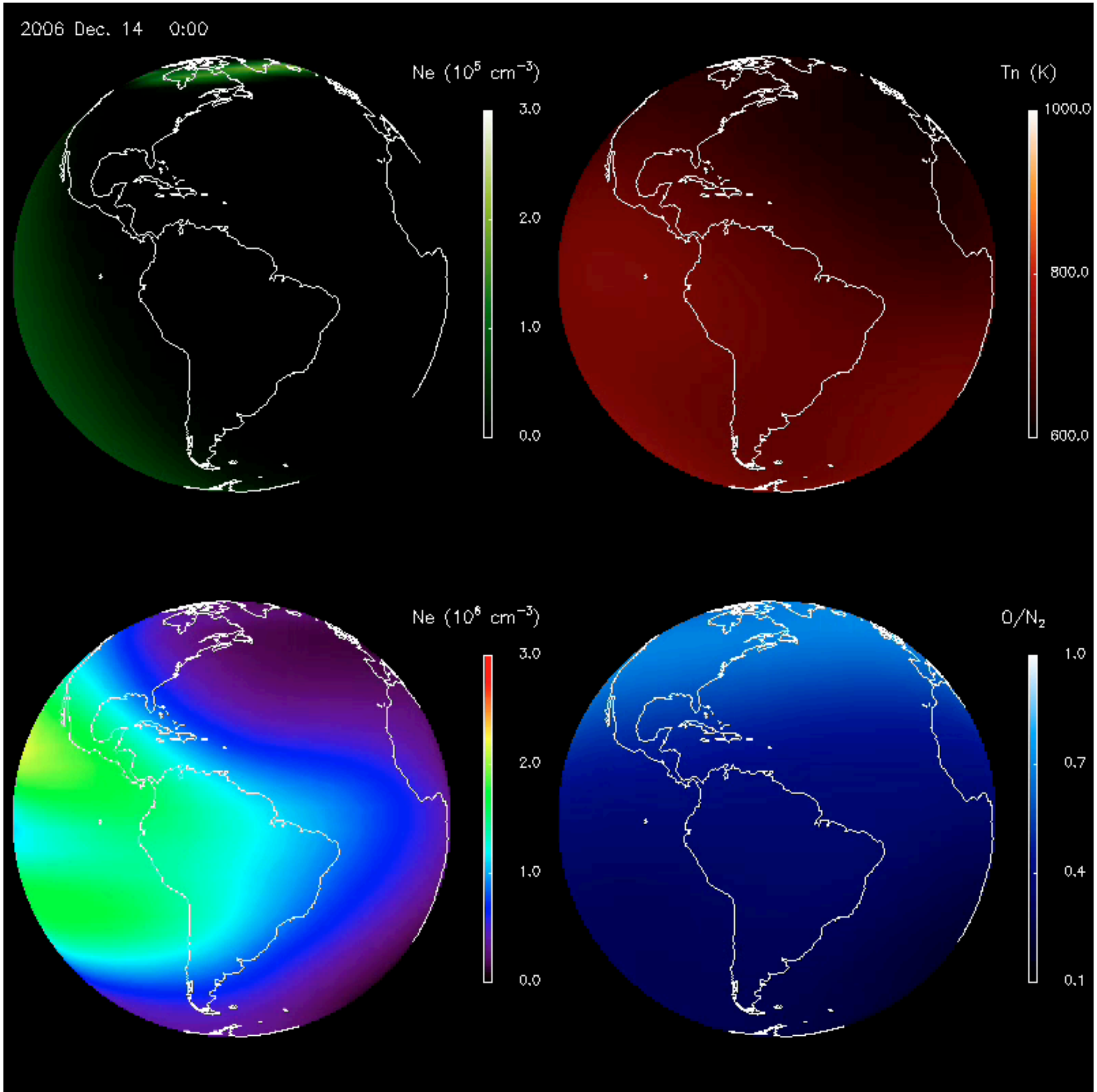
F-region Electron Density (~300 km)



Neutral Temperature (~160 km)

O/N_2 Ratio (~160 km)

Thermosphere-Ionosphere Modeling during Storms



E-region Electron Density (~110 km)

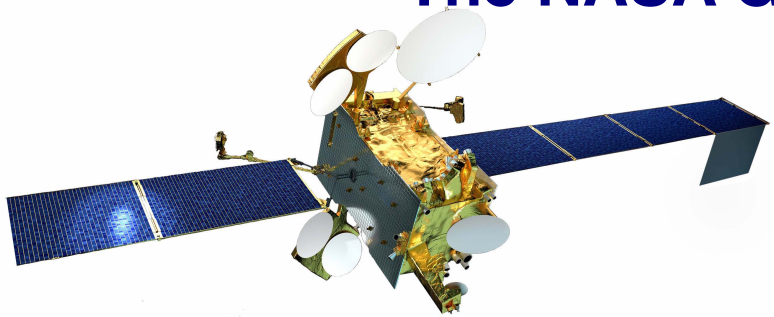
Neutral Temperature (~160 km)

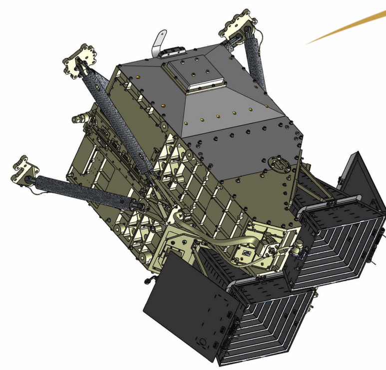
F-region Electron Density (~300 km)

O/N_2 Ratio (~160 km)

Review of the Global-scale Observations of the Limb and Disk (GOLD) Mission

The NASA GOLD Mission

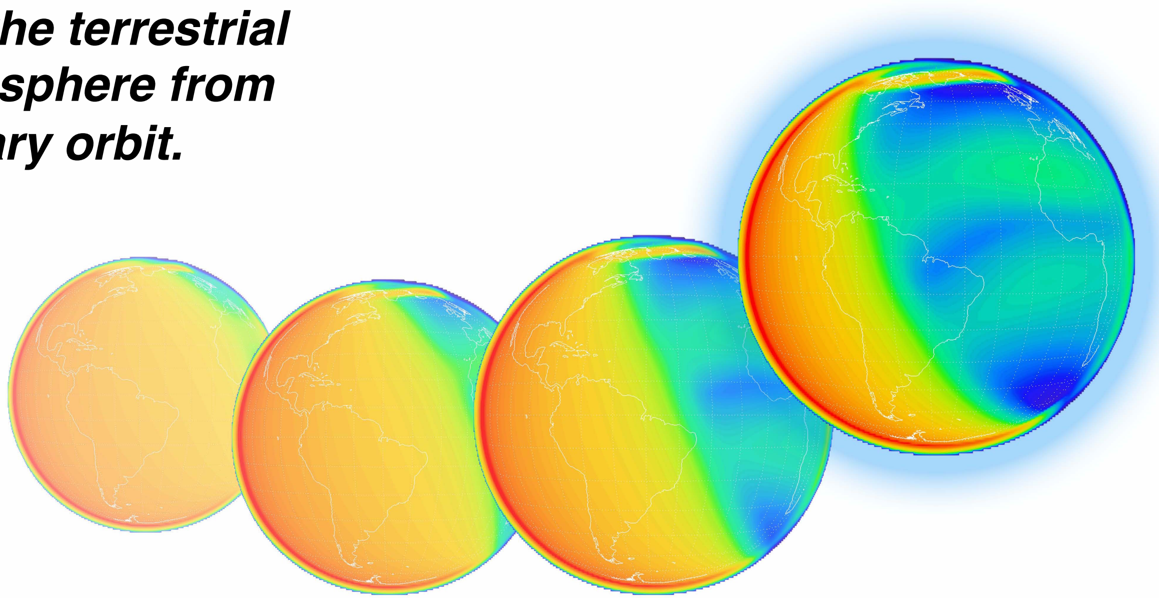




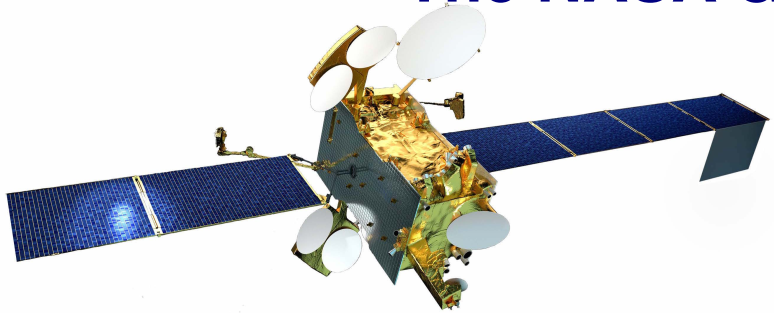
GOLD

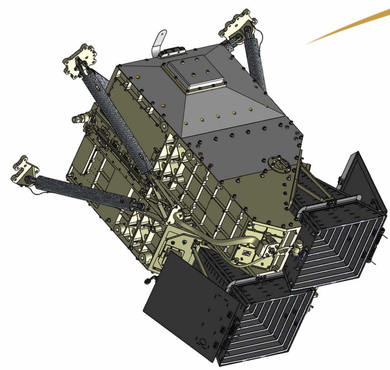
Global-scale Observations of the Limb and Disk

GOLD is an ultraviolet imaging spectrograph to measure the temperature, composition, and electron content of the terrestrial upper atmosphere from geostationary orbit.



The NASA GOLD Mission





GOLD

Global-scale Observations of the Limb and Disk

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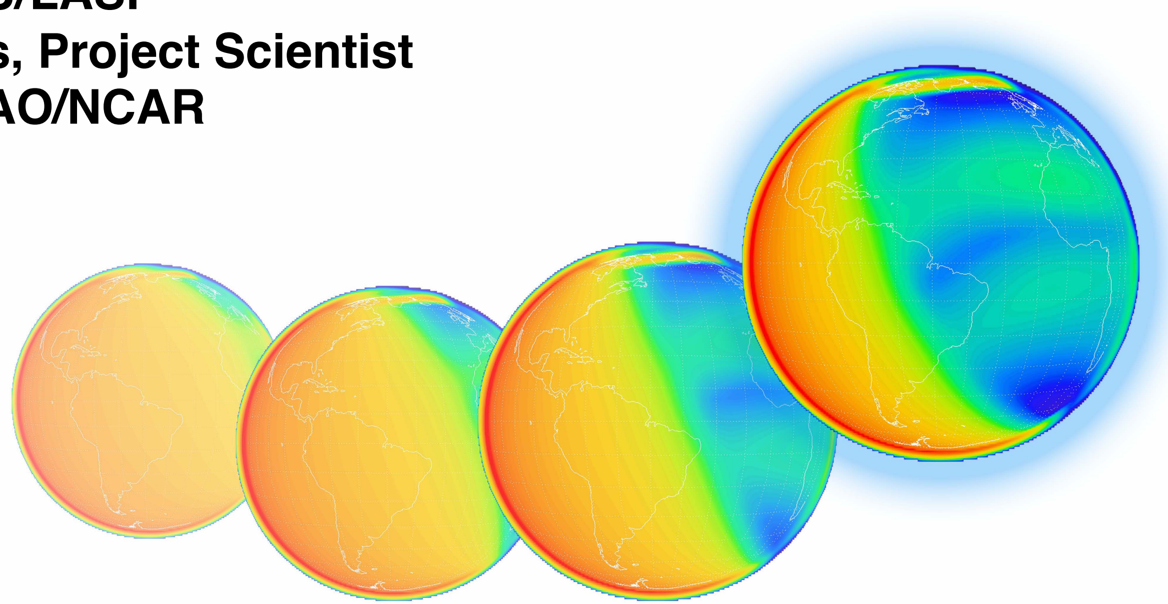
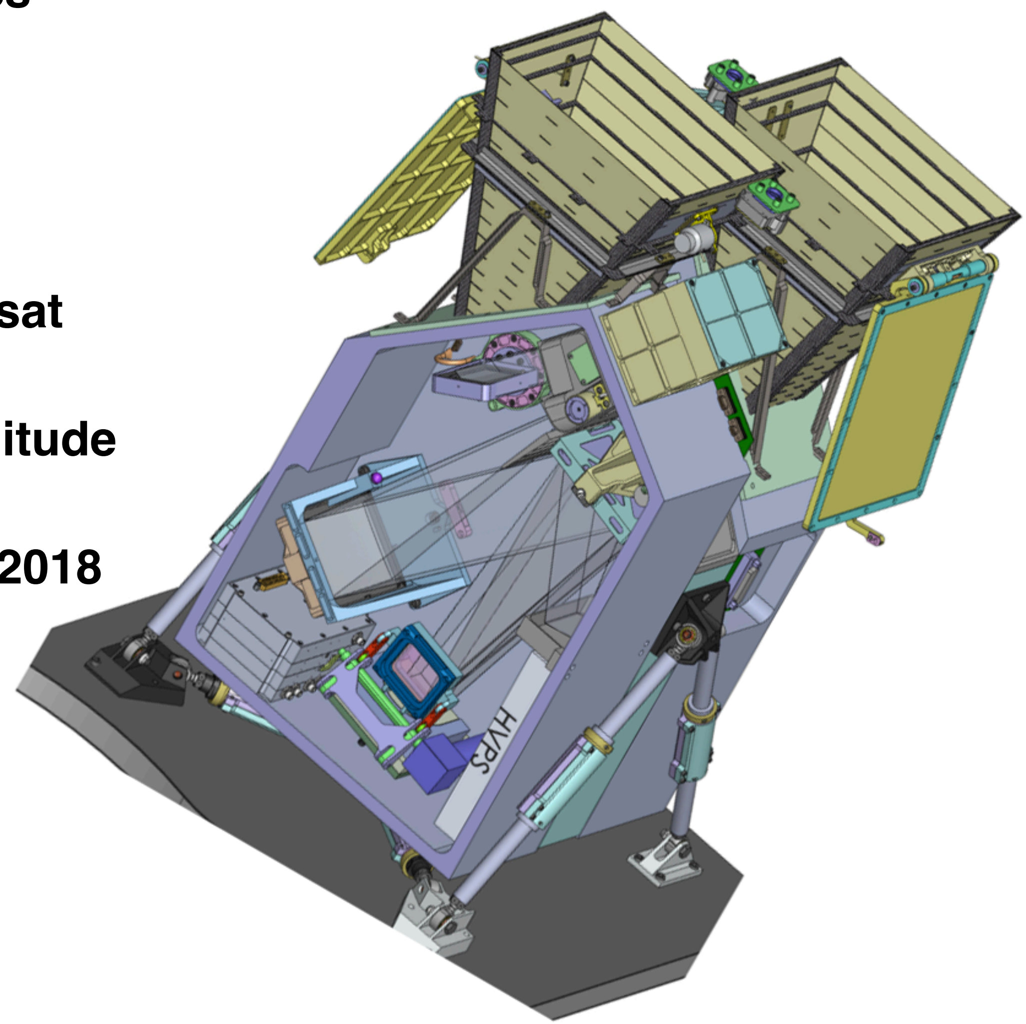
CU/LASP
Alan Burns, Project Scientist
HAO/NCAR



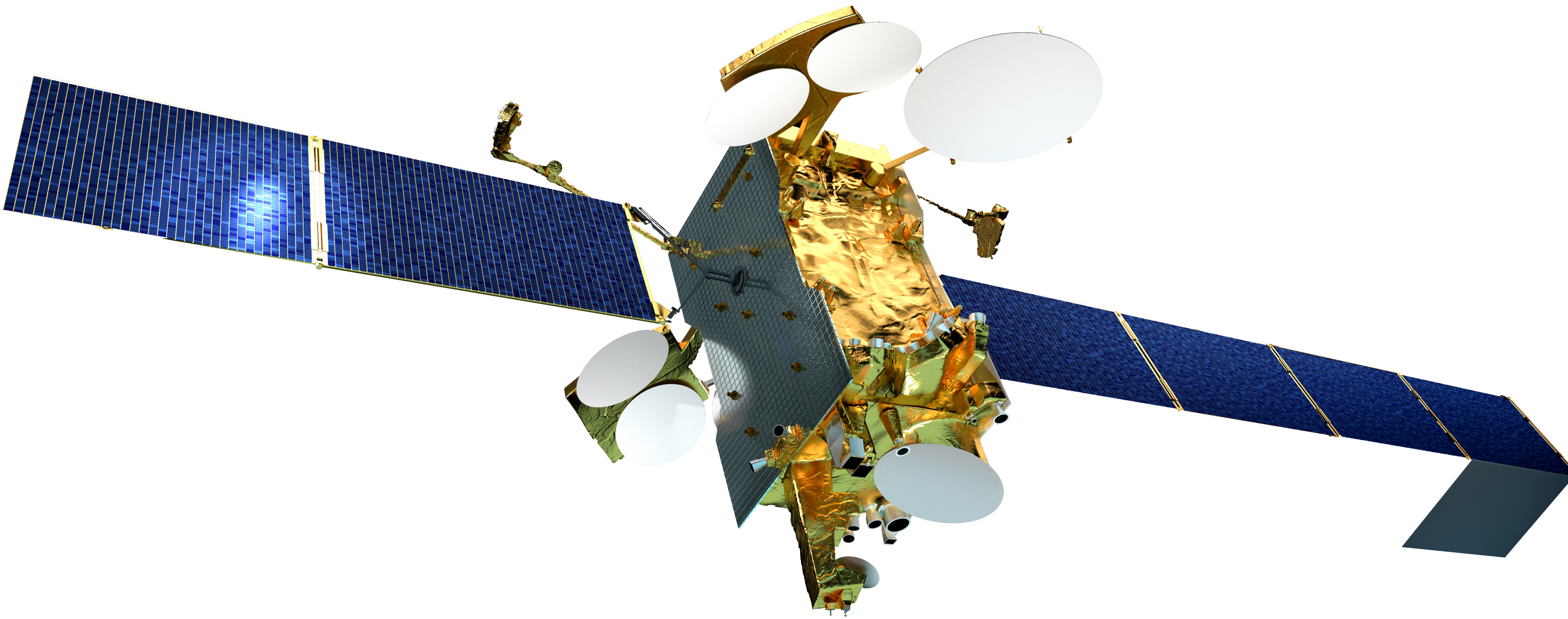
GOLD Ultraviolet Imaging Spectrograph

- Two identical channels
- Fully independent observing modes
  - Disk images and limb scans
    - Dayside: T and O/N_2
    - Nightside: O^+ density
  - Stellar occultation
- Deployed on a Geostationary Comsat
  - — Provided by SES-GS
  - — Airbus SES-14 at 47.5 W longitude
  - — Launched January 2018
  - — Observations begin October 2018



Instrument Summary	
Volume	51×55×69 cm^3
Mass	33 kg
Power	53 W
Data Rate	3.3 Mbit/sec

The SES-14 Communications Satellite

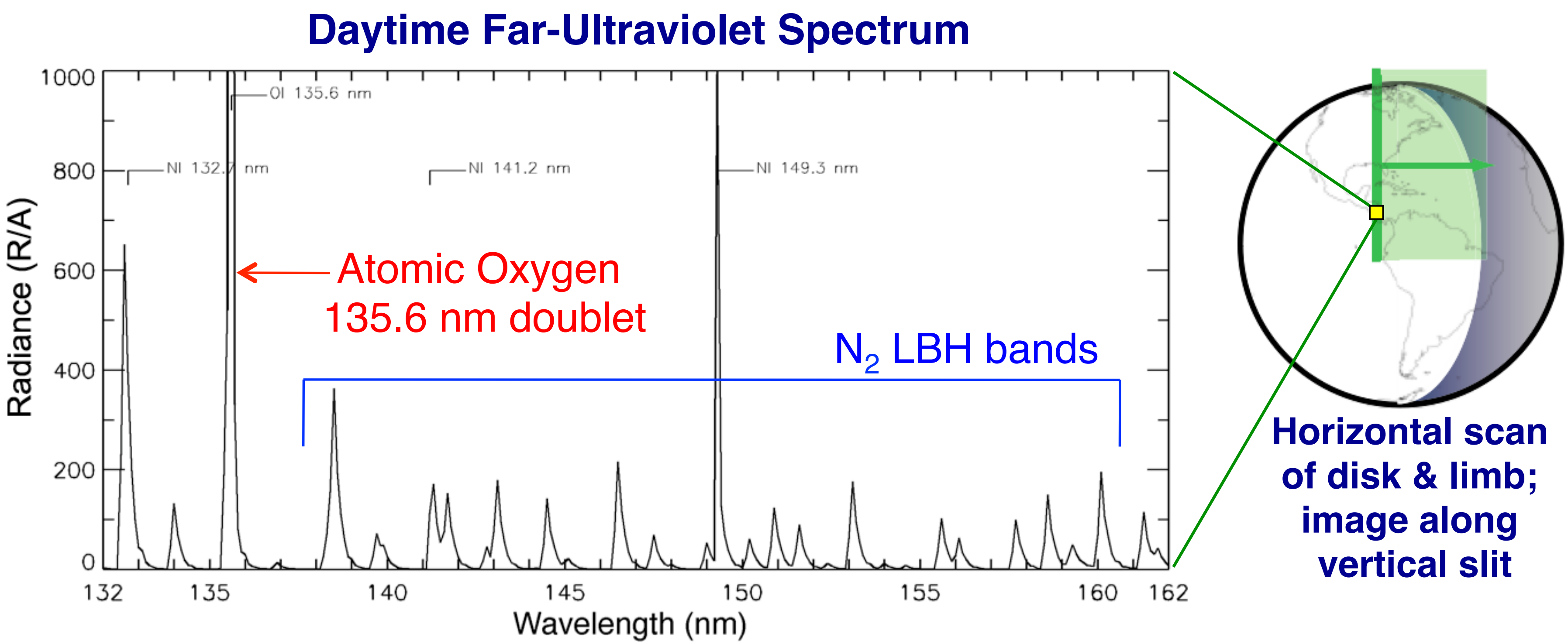


Airbus vehicle positioned at 47.5° west longitude, carries C and Ku-band transceivers.

Launched into GTO, 25 January 2018; electric propulsion to GEO; arrived July 2018.

Ariane 5 Launch, 25 January 2018

GOLD Measurement Technique



- Temperature obtained on disk from rotational shape of N_2 LBH bands
- O/N_2 composition measured using ratio of 135.6 doublet to LBH bands
- Temperature on limb determined by slope of emission altitude profile
- O_2 profile on limb from stellar occultations
- O^+ at night observed using 135.6 recombination emission

What We Hope to Observe

Airglow Simulations

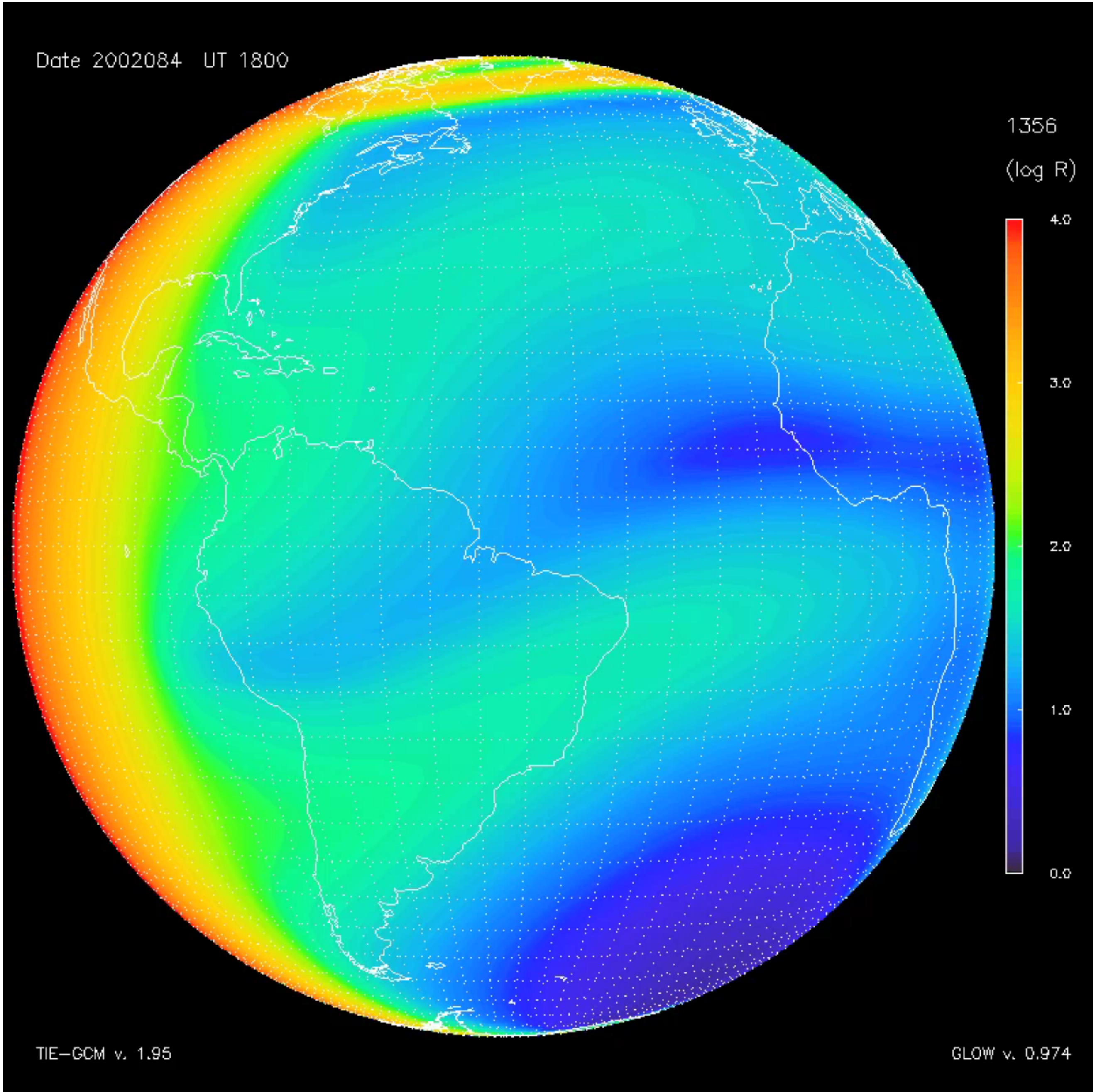
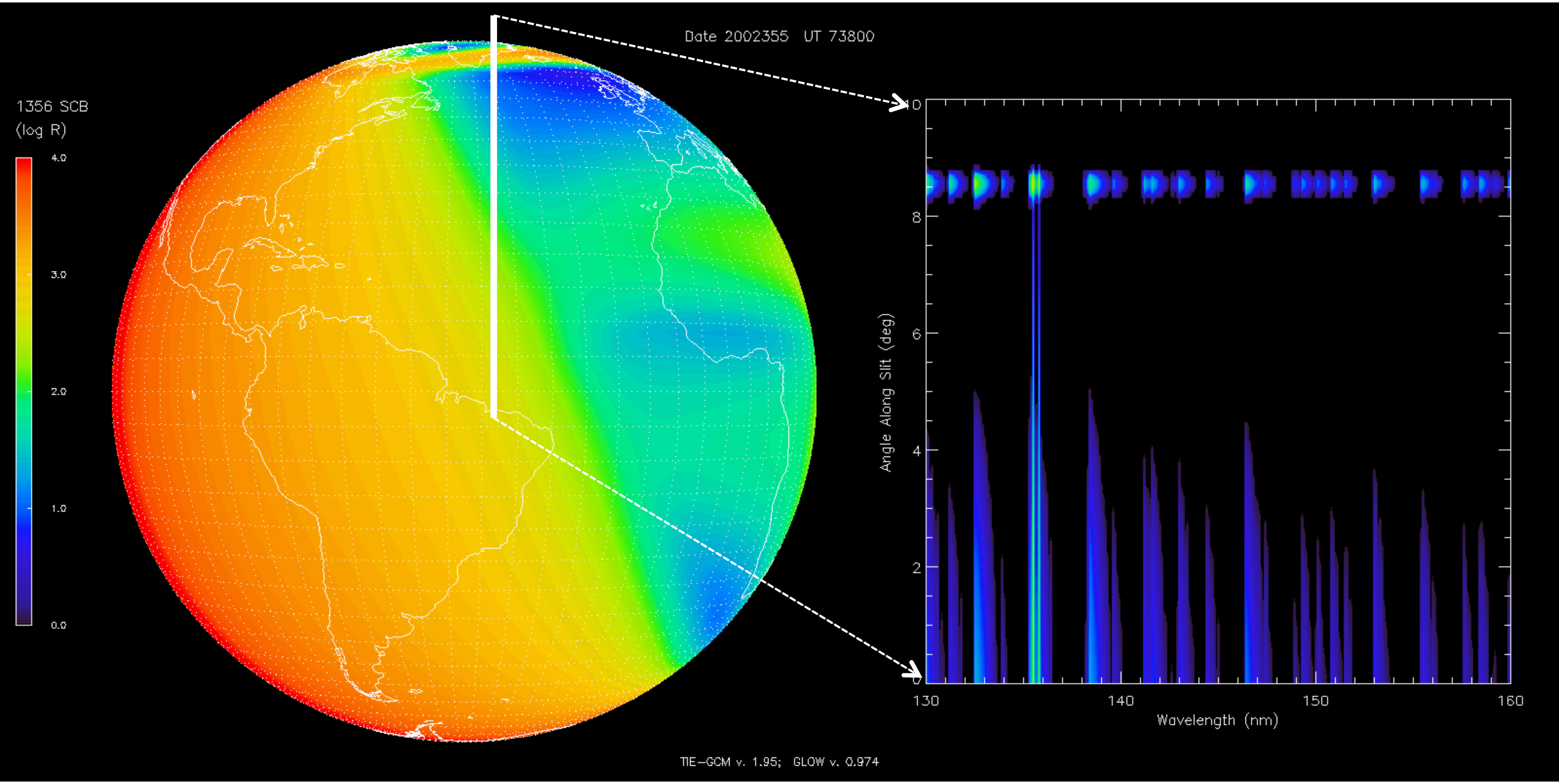


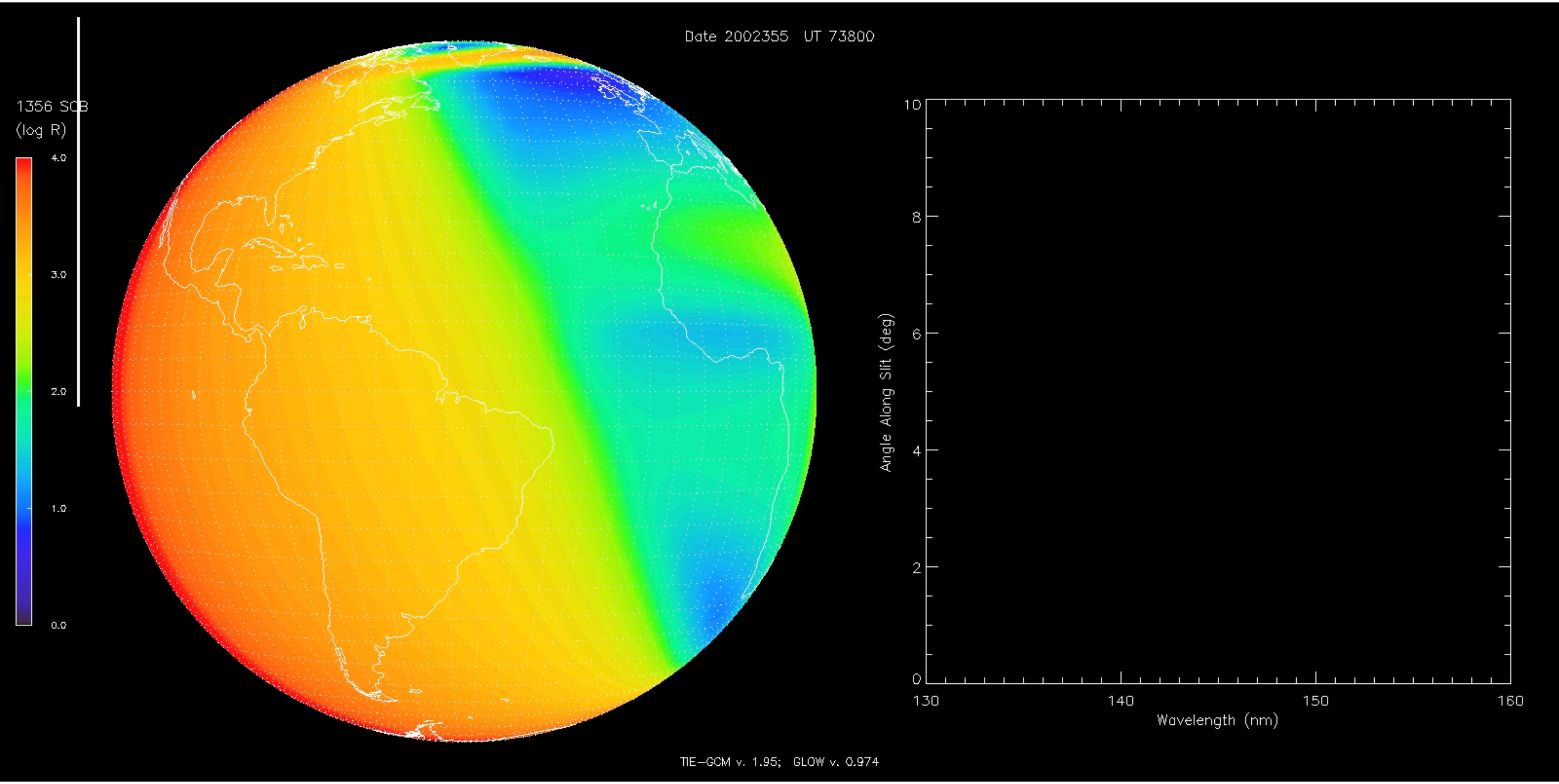
Image Cube Simulation



Disk Image

Detector Image

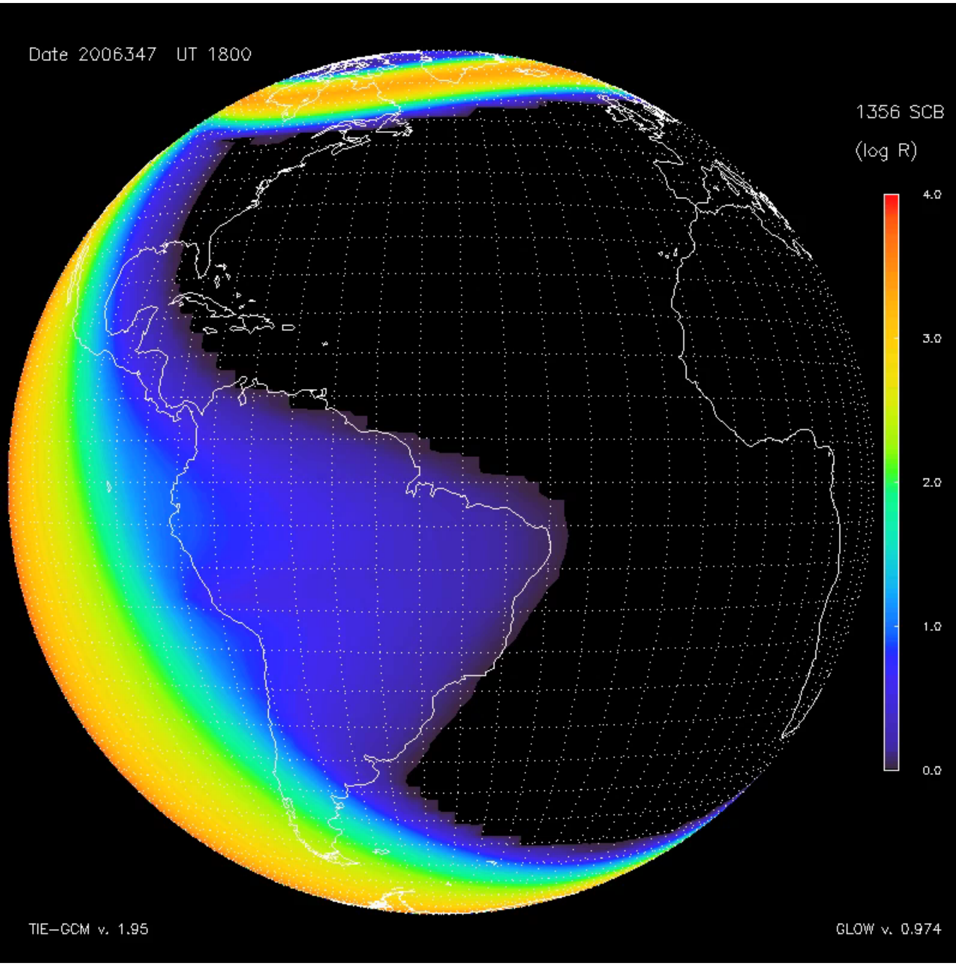
Image Cube Simulation

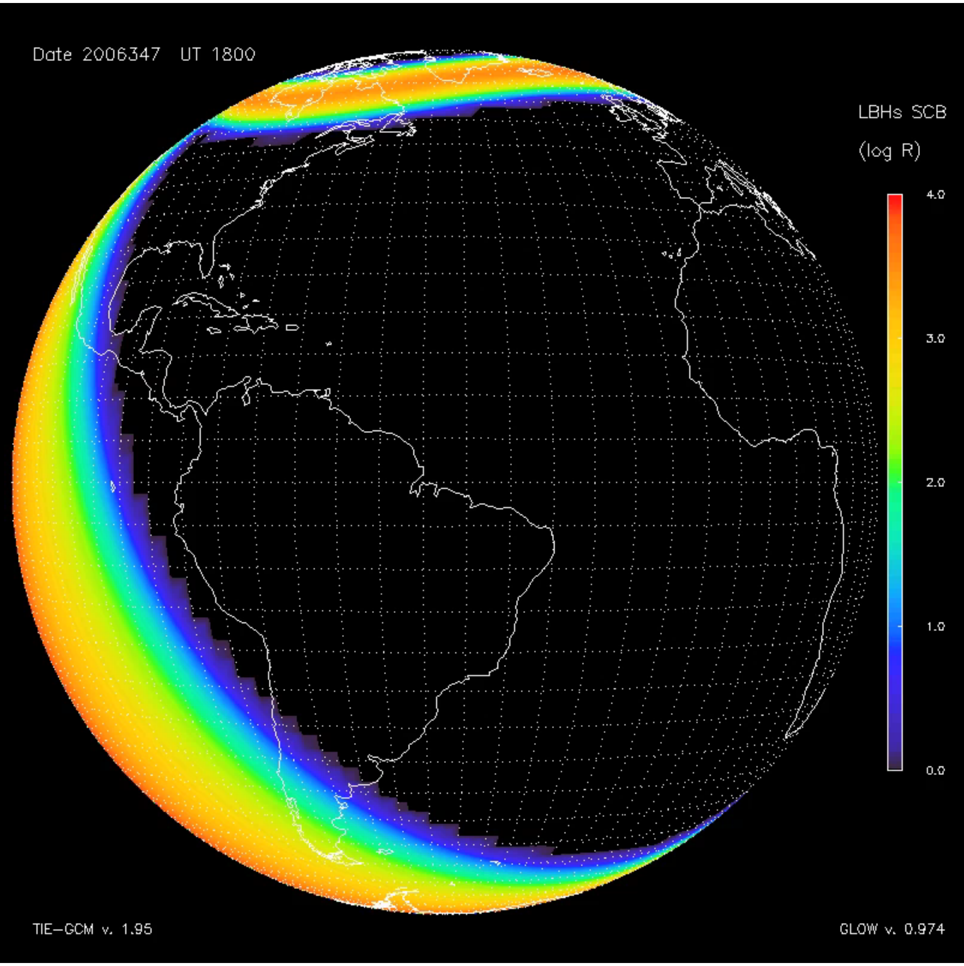


Disk Image

Detector Image

The December 2006 “AGU Storm”

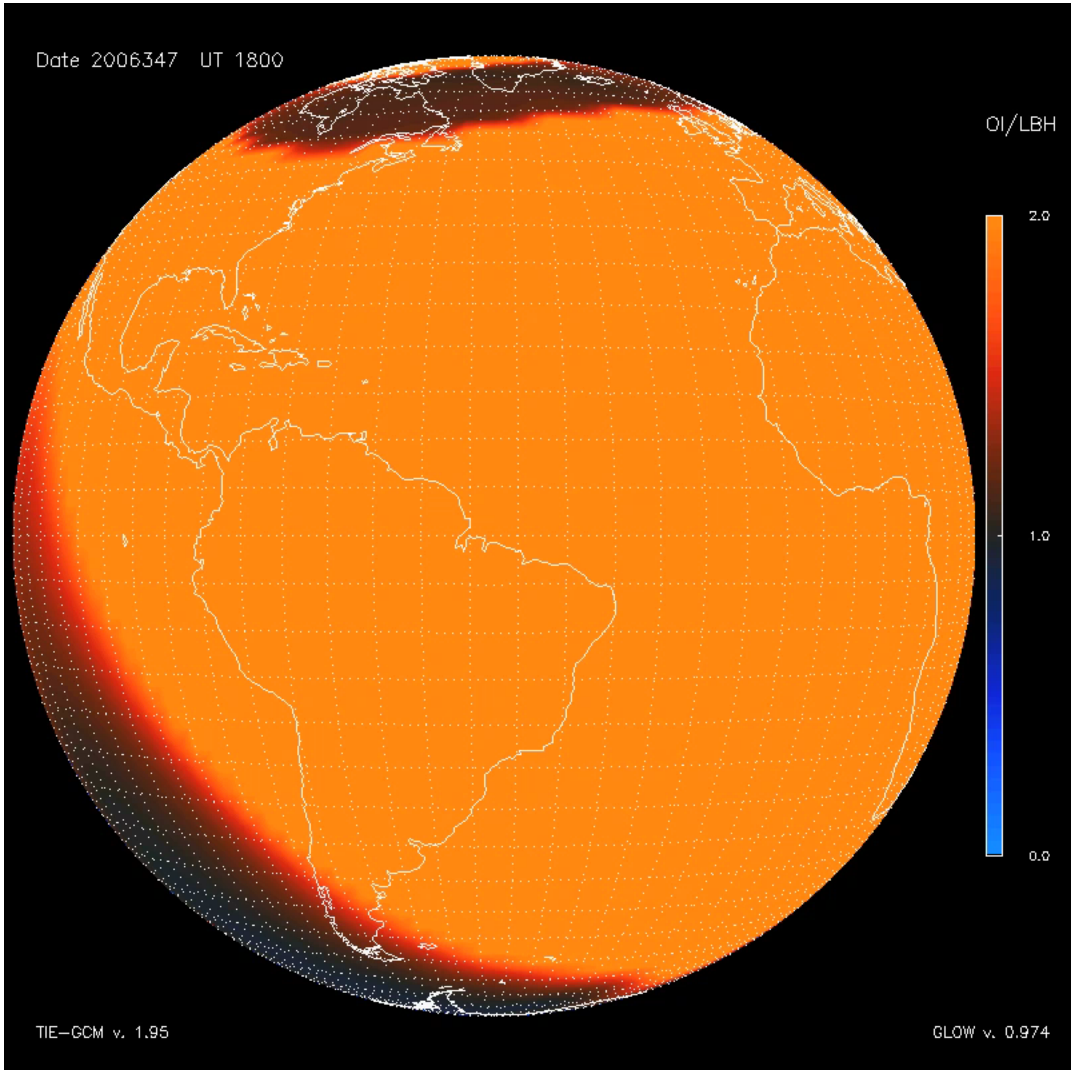




O (^{5}S) 135.6 nm doublet

N_2 LBH “short” (138–148 nm)

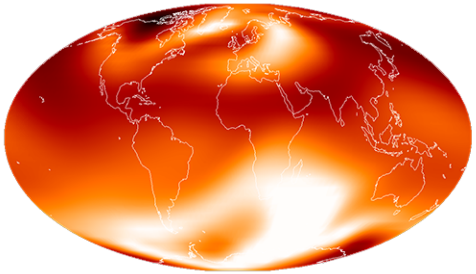
The December 2006 "AGU Storm"



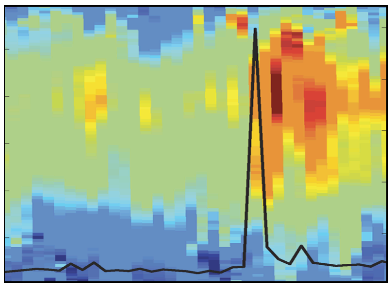
O(^{5}S) / N_2 LBH ratio

What We Hope to Learn

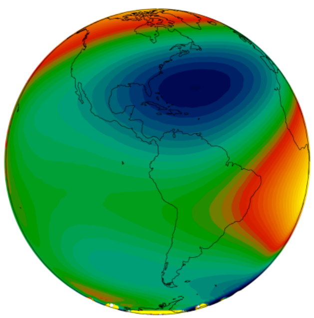
GOLD Scientific Objectives



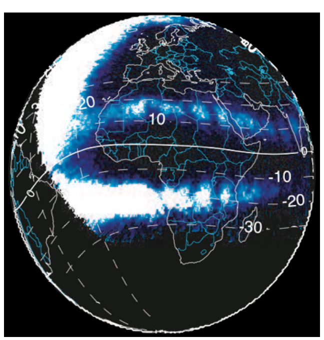
1. How do geomagnetic storms alter the temperature and composition structure of the thermosphere?



2. What is the global-scale response of the thermosphere to solar extreme-ultraviolet variability?



3. How significant are the effects of atmospheric waves and tides propagating from below on thermospheric temperature structure?



4. How does the nighttime equatorial ionosphere influence the formation and evolution of equatorial plasma density irregularities?

Why is the Atomic Oxygen to Molecular Nitrogen Ratio Important?

• The thermosphere consists mostly of atomic oxygen (O) and molecular nitrogen (N_2) so the O/N_2 ratio indicates the overall atomic-to-molecular composition.

• Because of diffusive separation, the lower thermosphere is mostly N_2 and the upper thermosphere is mostly O.

• Therefore, the O/N_2 ratio is diagnostic of vertical winds.

• Vertical winds, in turn are diagnostic of the horizontal circulation pattern.

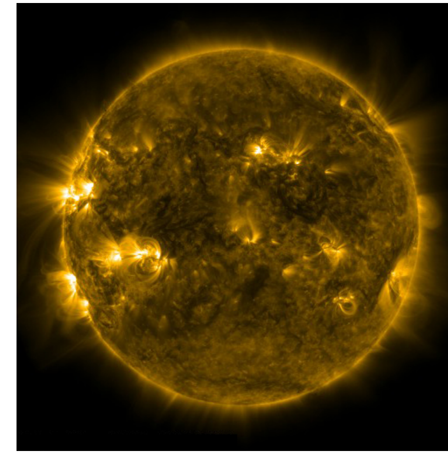
• The ionosphere is strongly influenced by the atomic-to-molecular composition as well, because molecules react with ions, depleting the ionosphere.

• Meanwhile, the winds push the ions around, changing the density of the ionosphere.

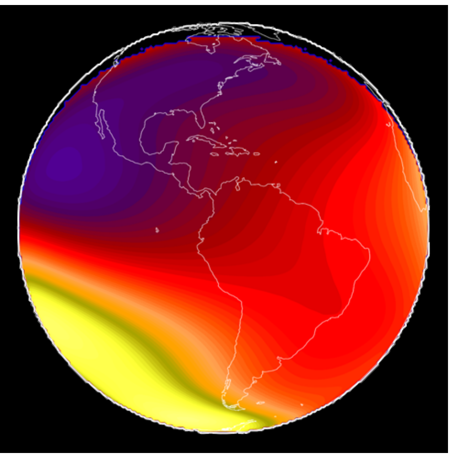
• And, electric fields from the magnetosphere interact with the electric fields caused by atmospheric circulation, and the ions are also moved around by these fields.

• Our numerical models contain all of these processes, but in order to improve them, we need measurements that are diagnostic of the global dynamical system.

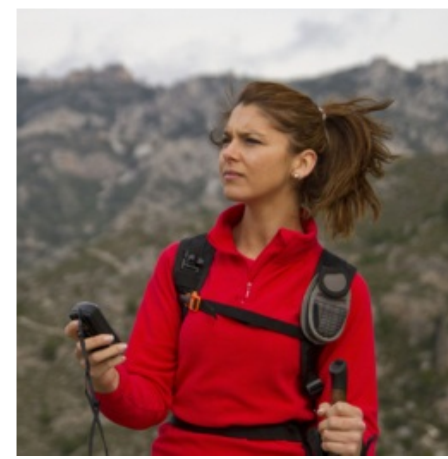
Scientific and Societal Benefits



Advance Heliophysics science by linking solar observations to thermosphere-ionosphere physics



Develop of the next generation of upper-atmosphere models



Address operational challenges in space-based communication, navigation, and orbital tracking

Engage the public by providing near-real-time global images of aurora and space weather

So What?

- Most space weather happens in the ionosphere-thermosphere system, where it affects radio communications, GPS navigation, and satellite orbits.

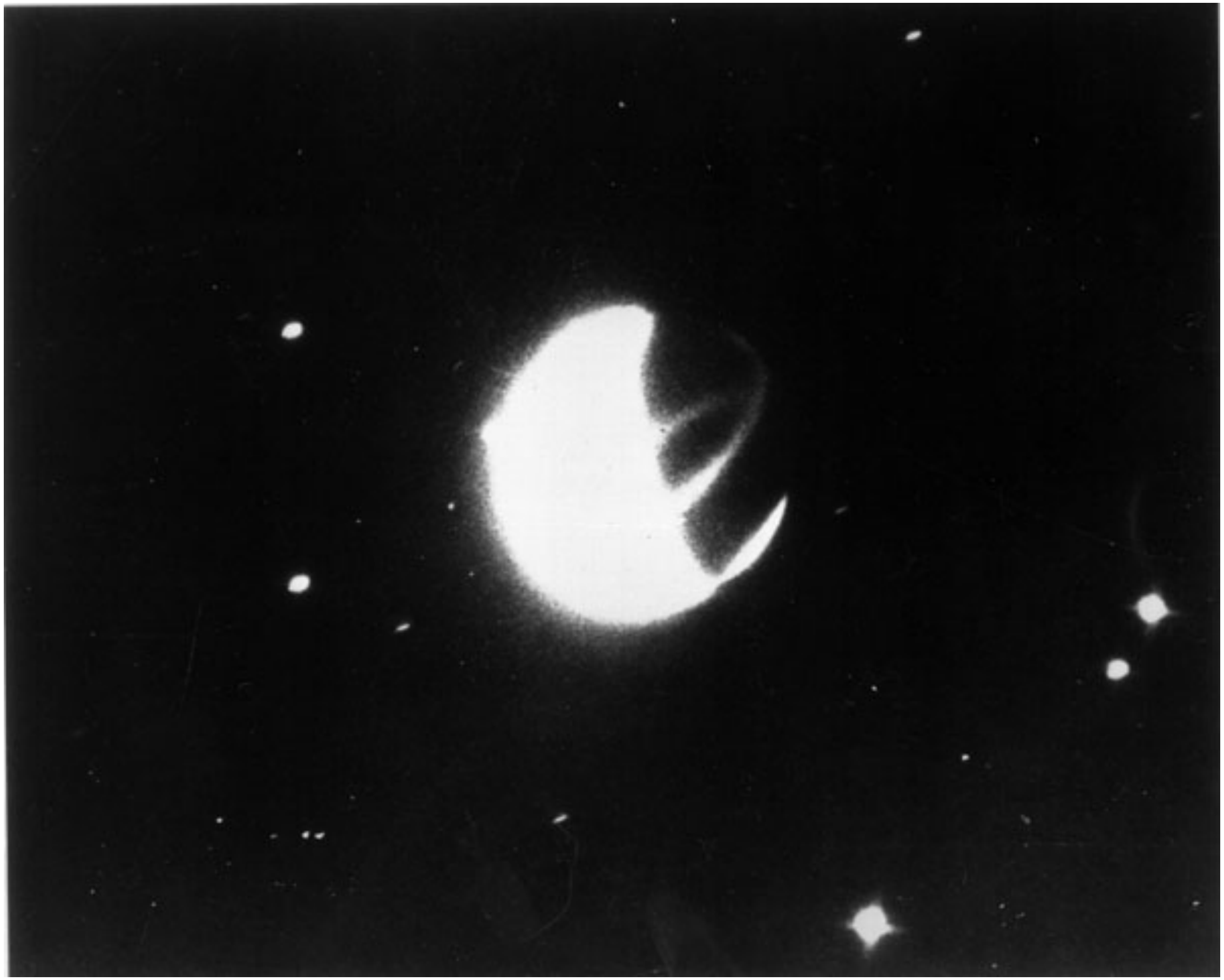
- We would like to be able to nowcast and forecast the ionosphere, using numerical models, in the way that we can nowcast and forecast tropospheric weather..

- We would like to be able to nowcast and forecast thermospheric density, using numerical models, to enable better tracking of functioning satellites and space debris.

- We have made a lot of progress on this in recent years, but in order to make the models better, we need to understand how thermospheric energy and dynamics respond to geomagnetic storms, and how the thermosphere controls the ionosphere.

- We have learned a lot from low-Earth-orbit satellites which perform local measurements of thermosphere-ionosphere variability, but in order to take the next step, we need global measurements.

Thank You



Questions Welcome