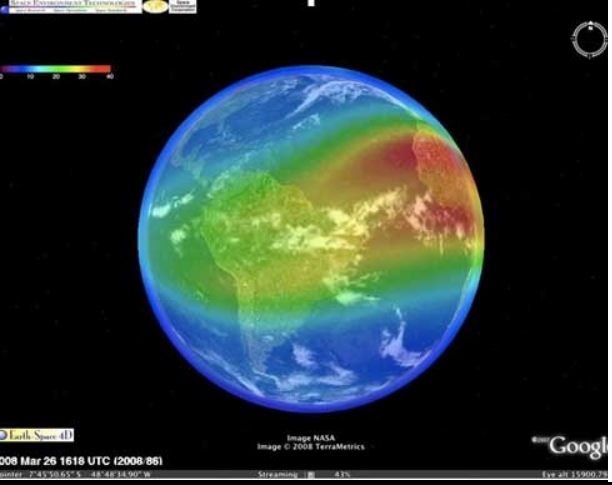
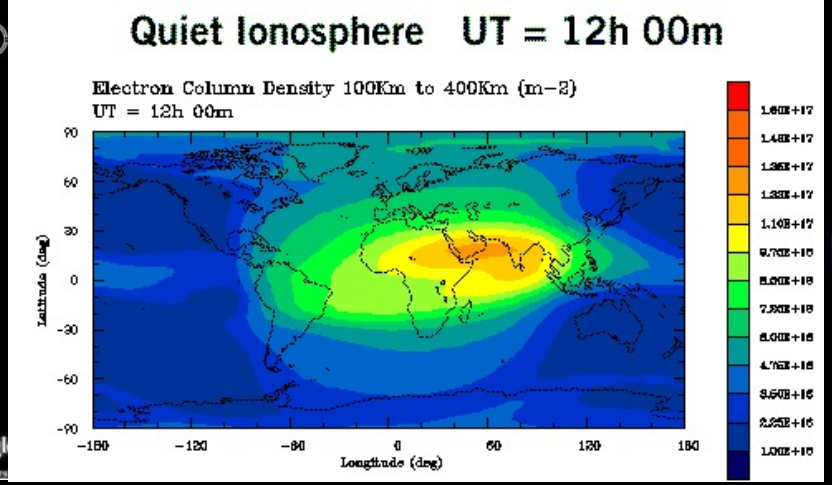
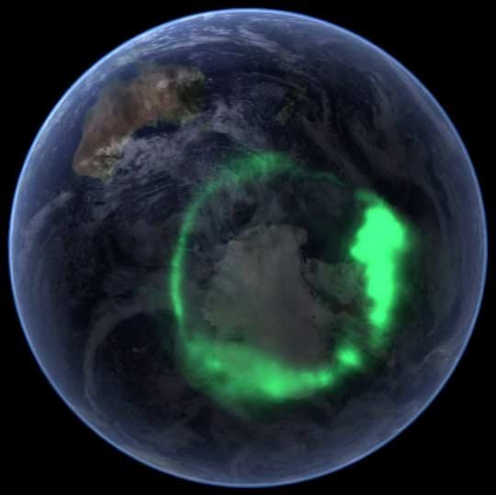
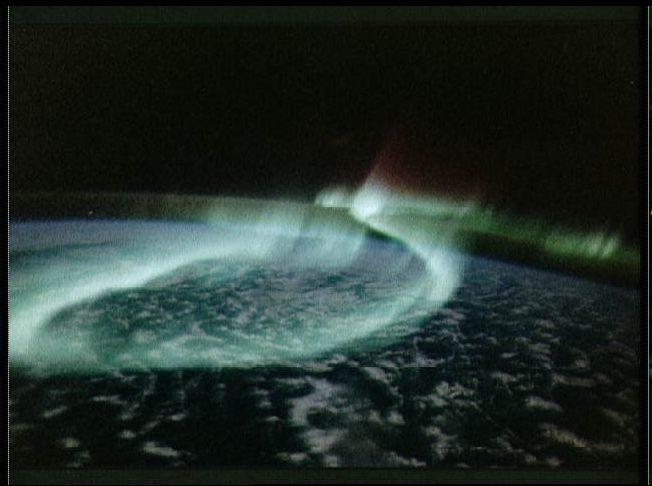


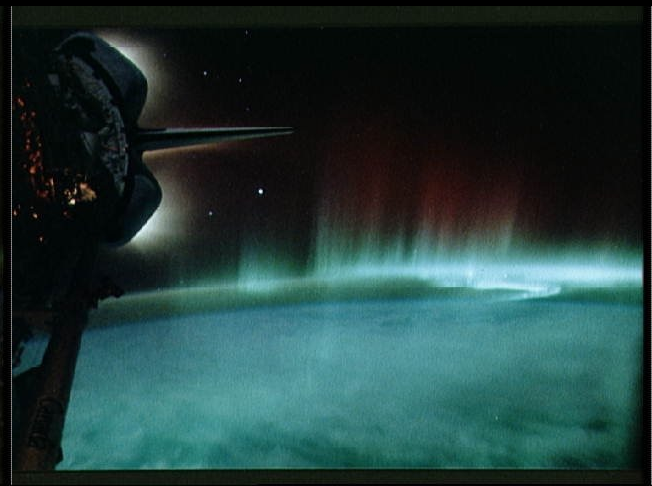




Julie A. Feldt
CEDAR-GEM workshop
June 26th, 2011

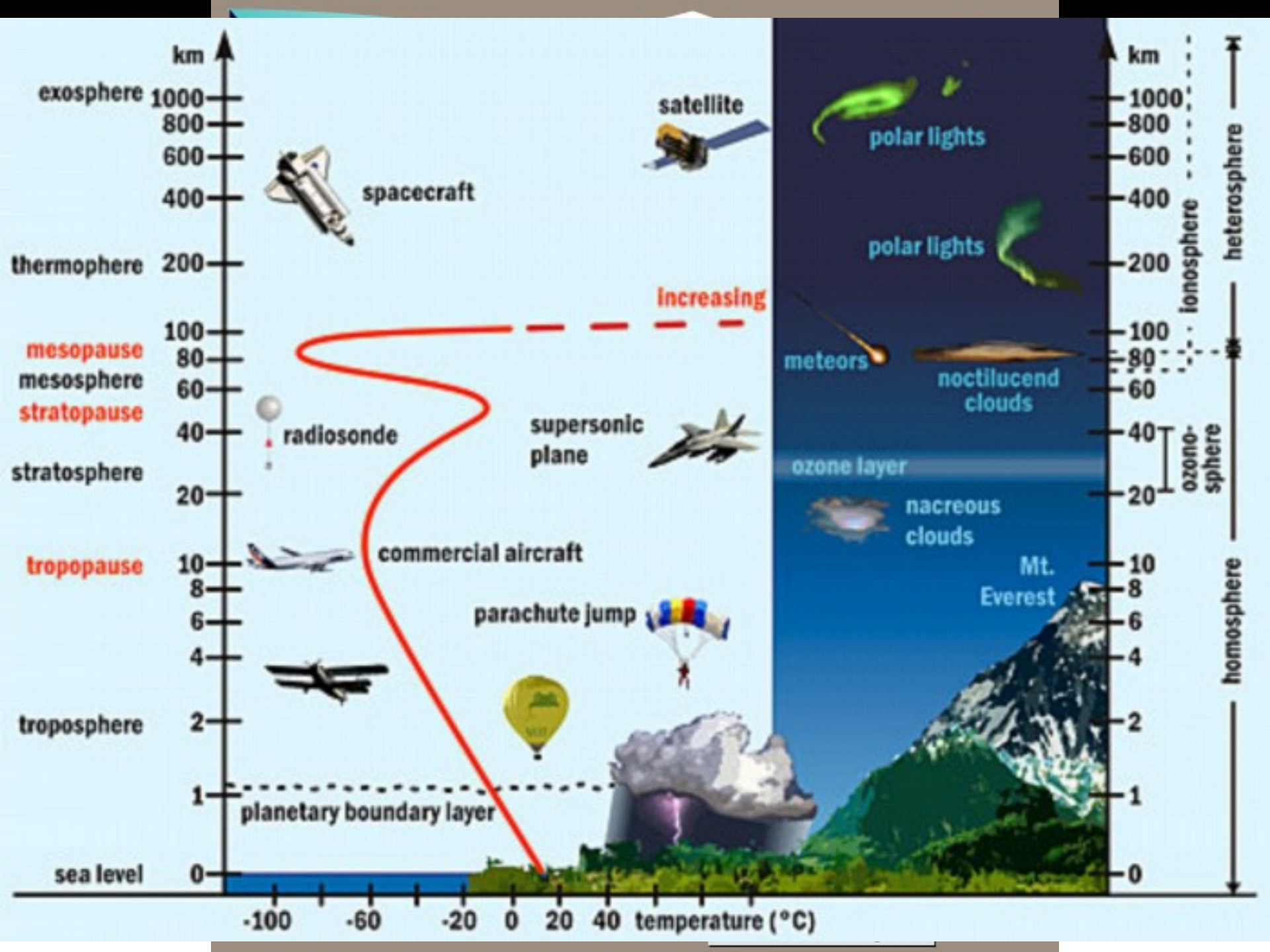
Introduction to the Ionosphere





Summary

- Earth's atmosphere
- Ionosphere facts
- Structure
  - Altitude
  - Latitude
- Processes
- Further Reading

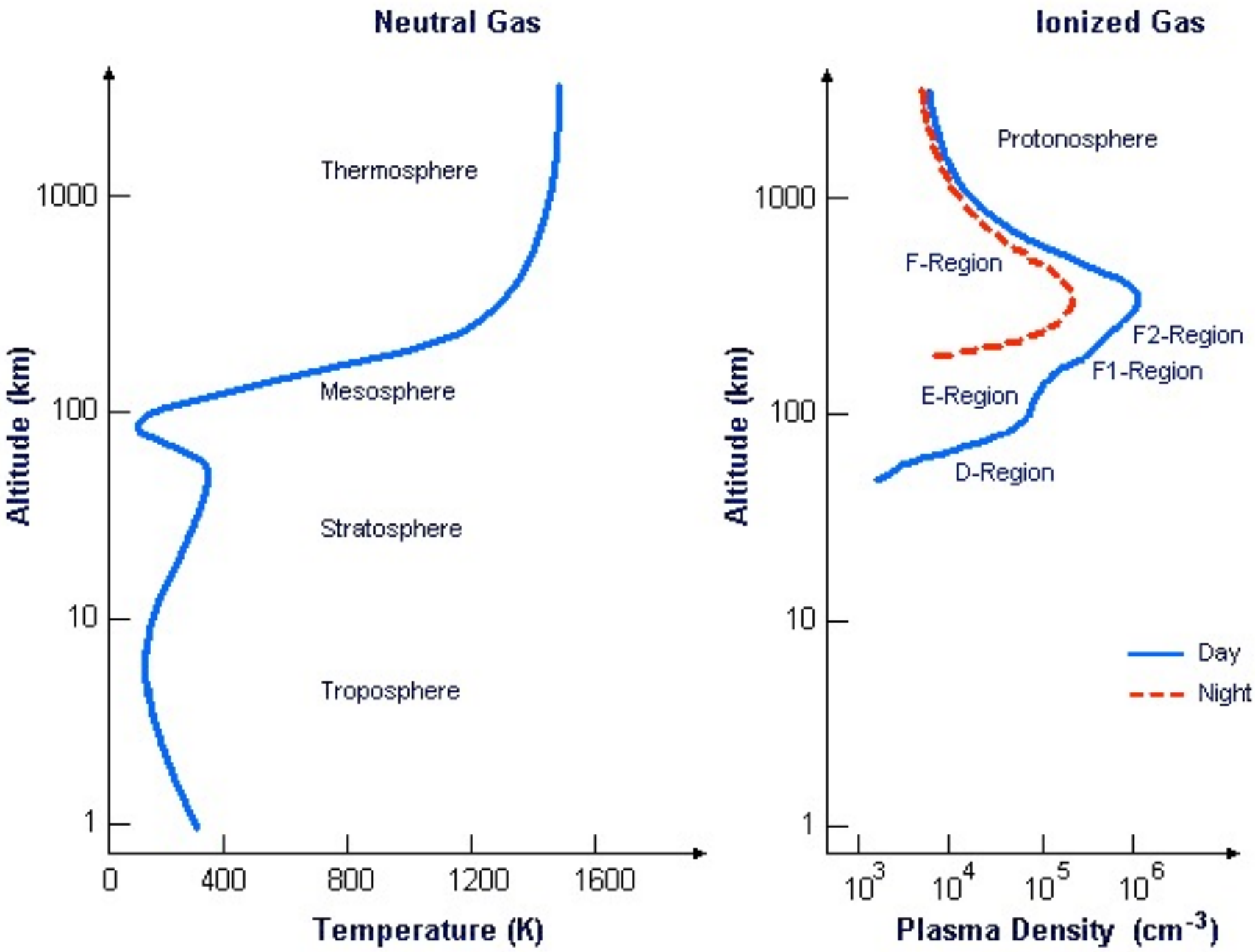

km
exosphere
1000
800
600
400
thermophere
200
100
mesopause
80
mesosphere
60
stratopause
40
stratosphere
20
tropopause
10
8
6
4
troposphere
2
1
sea level
0
satellite
spacecraft
increasing
radiosonde
supersonic plane
commercial aircraft
parachute jump
planetary boundary layer
-100
-60
-20
0
20
40
temperature (°C)
polar lights
polar lights
meteors
noctilucend clouds
ozone layer
nacreous clouds
Mt. Everest
ionosphere
heterosphere
ozono-sphere
homosphere

Ionosphere Facts

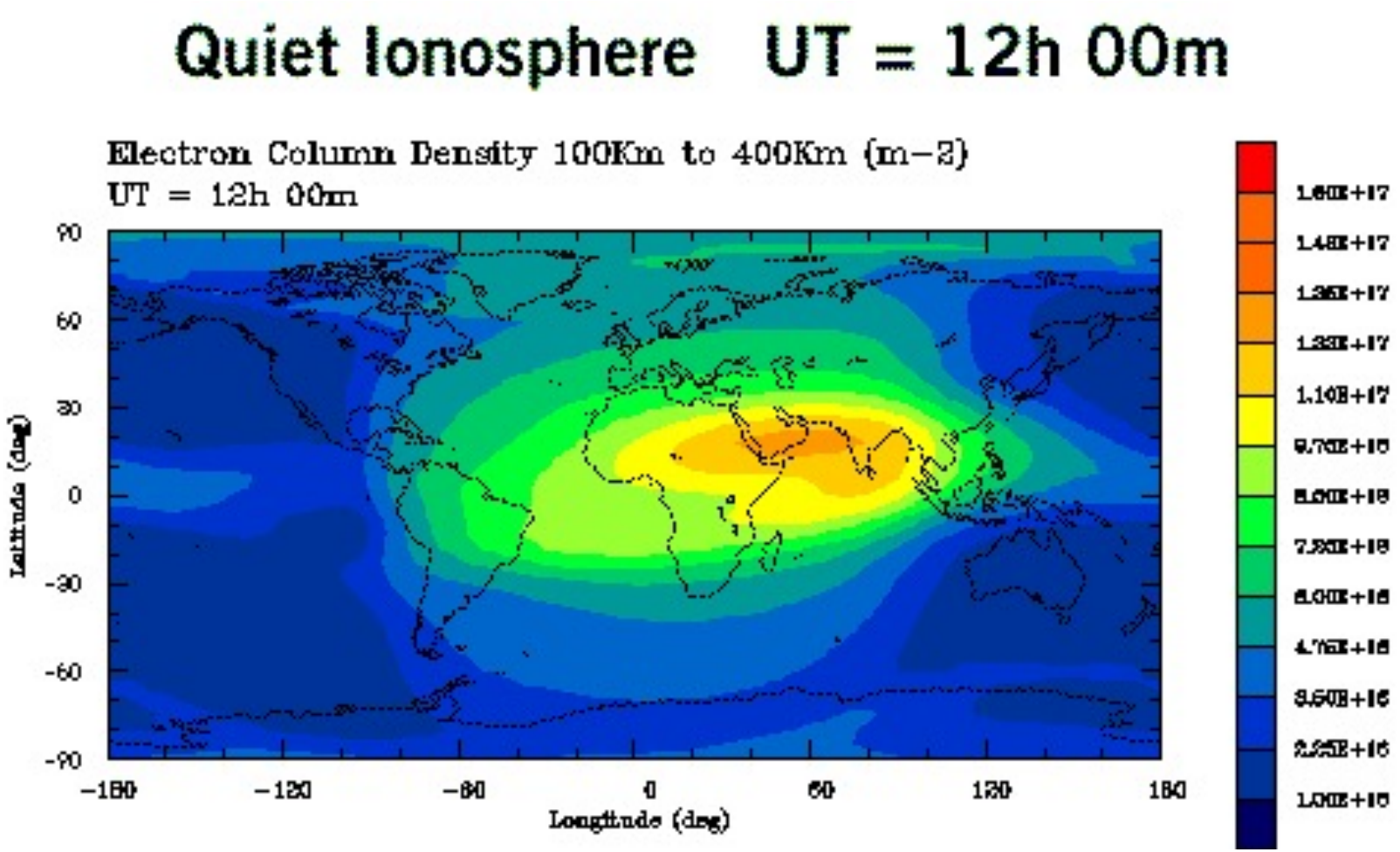
- Ionized upper atmosphere that acts as the interface between earth and space environments.
- Closely coupled to the thermosphere and magnetosphere
- Located at ~60 to 1000+ km
- Altitude structure is separated into regions
  - D region (60 – 100 km)
  - E region (100 – 150 km)
  - F_1 region (150 – 250 km)
  - F_2 region (250+ km)
  - Topside Ionosphere (above F_2 peak)

Ionosphere Facts

- Latitude structure is defined by processes that occur due to Solar EUV effects, Earth's magnetic field, Solar wind, IMF and Geomagnetic storms interactions
- Boundary Definitions
  - Lower Boundary: $\frac{dn}{dt} + \nabla \cdot n\vec{u} = S - L$
  - Upper Boundary: start of the plasmasphere, where H^+ becomes dominant

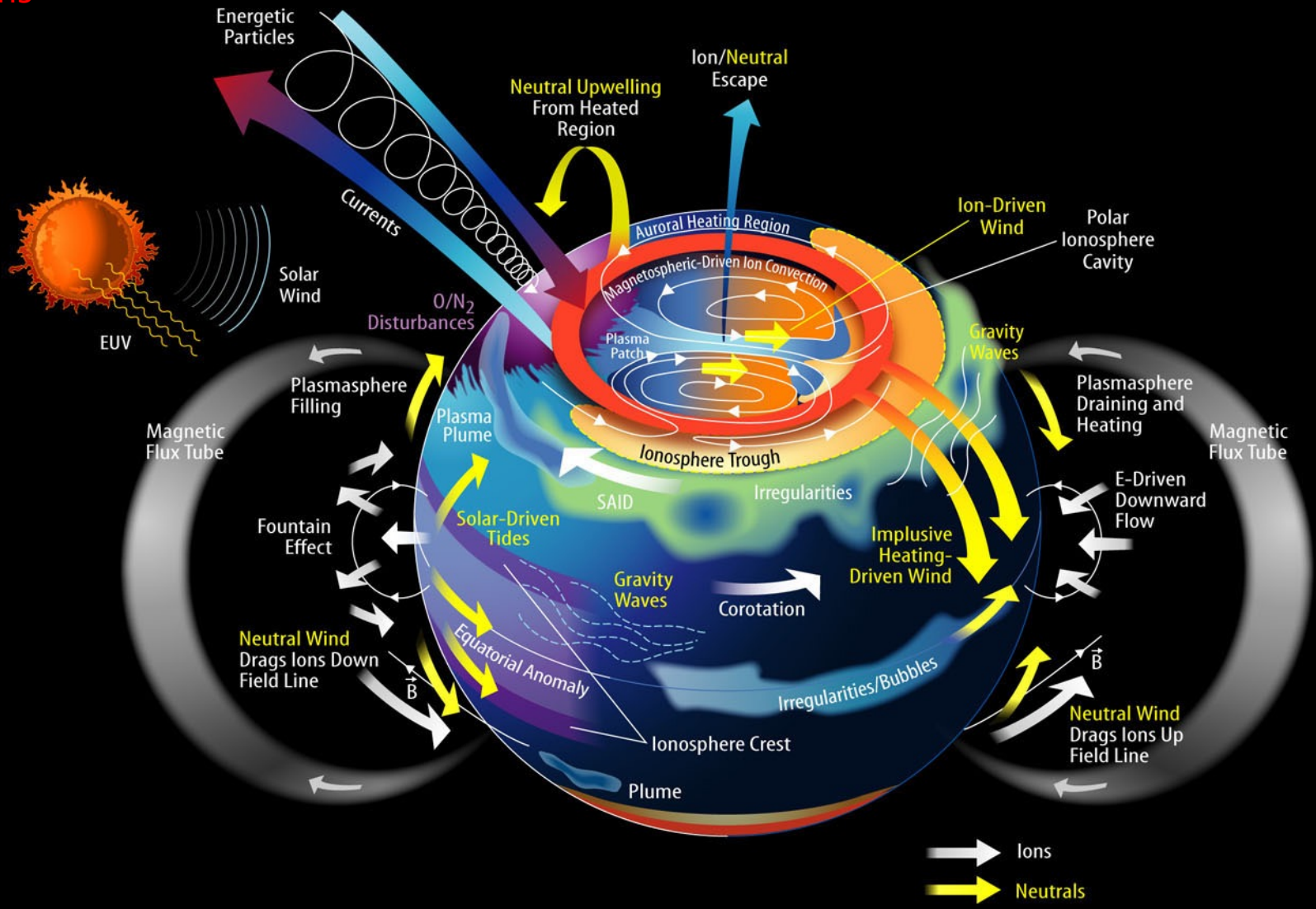

Neutral Gas
Thermosphere
Mesosphere
Stratosphere
Troposphere
1000
100
10
1
Altitude (km)
0
400
800
1200
1600
Temperature (K)
Ionized Gas
Protonosphere
F-Region
F2-Region
F1-Region
E-Region
D-Region
Day
Night
1000
100
10
1
Altitude (km)
10^3
10^4
10^5
10^6
Plasma Density (cm^{-3})

Latitudinal Structure



Ionospheric Processes

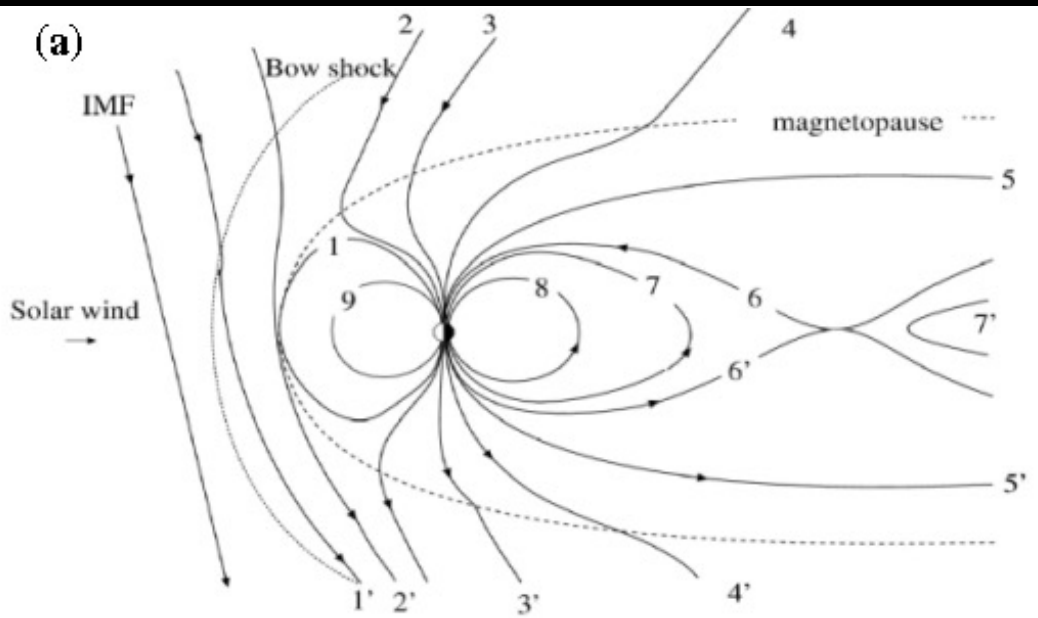
Addition of Geomagnetic Storms

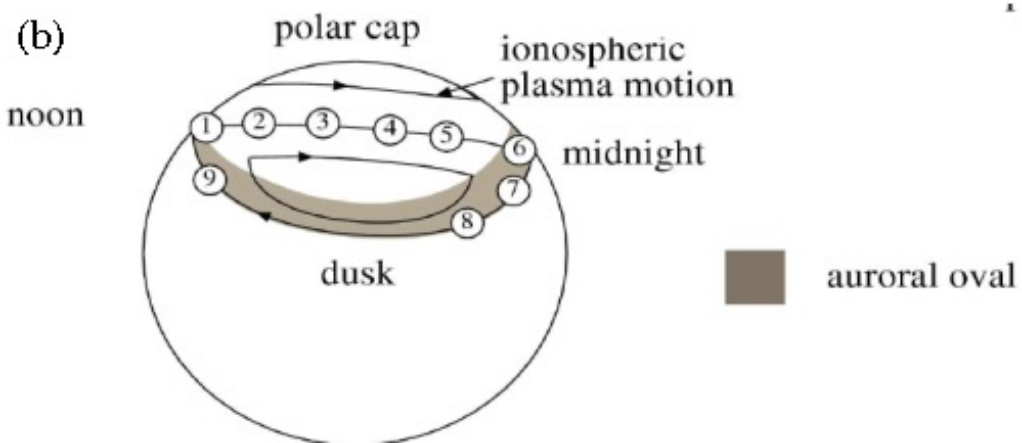


Polar wind

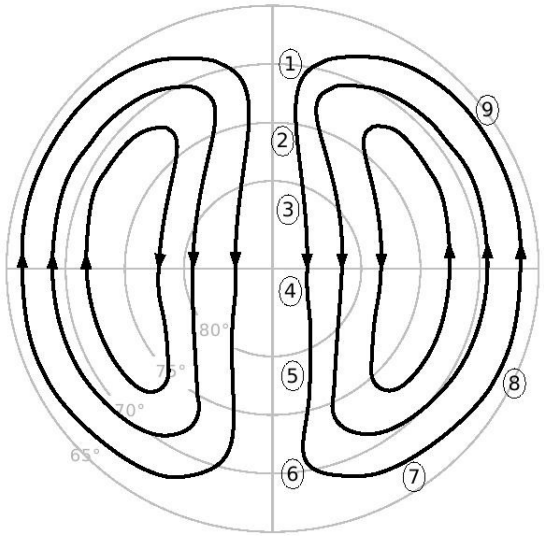
- The escaping of thermal plasma along the open field lines at the poles in the topside ionosphere.
- Important transitions
  - Chemical to diffusion dominance
  - Subsonic to supersonic flow
  - Collision-dominated to collisionless regimes
  - Heavy to light ion composition

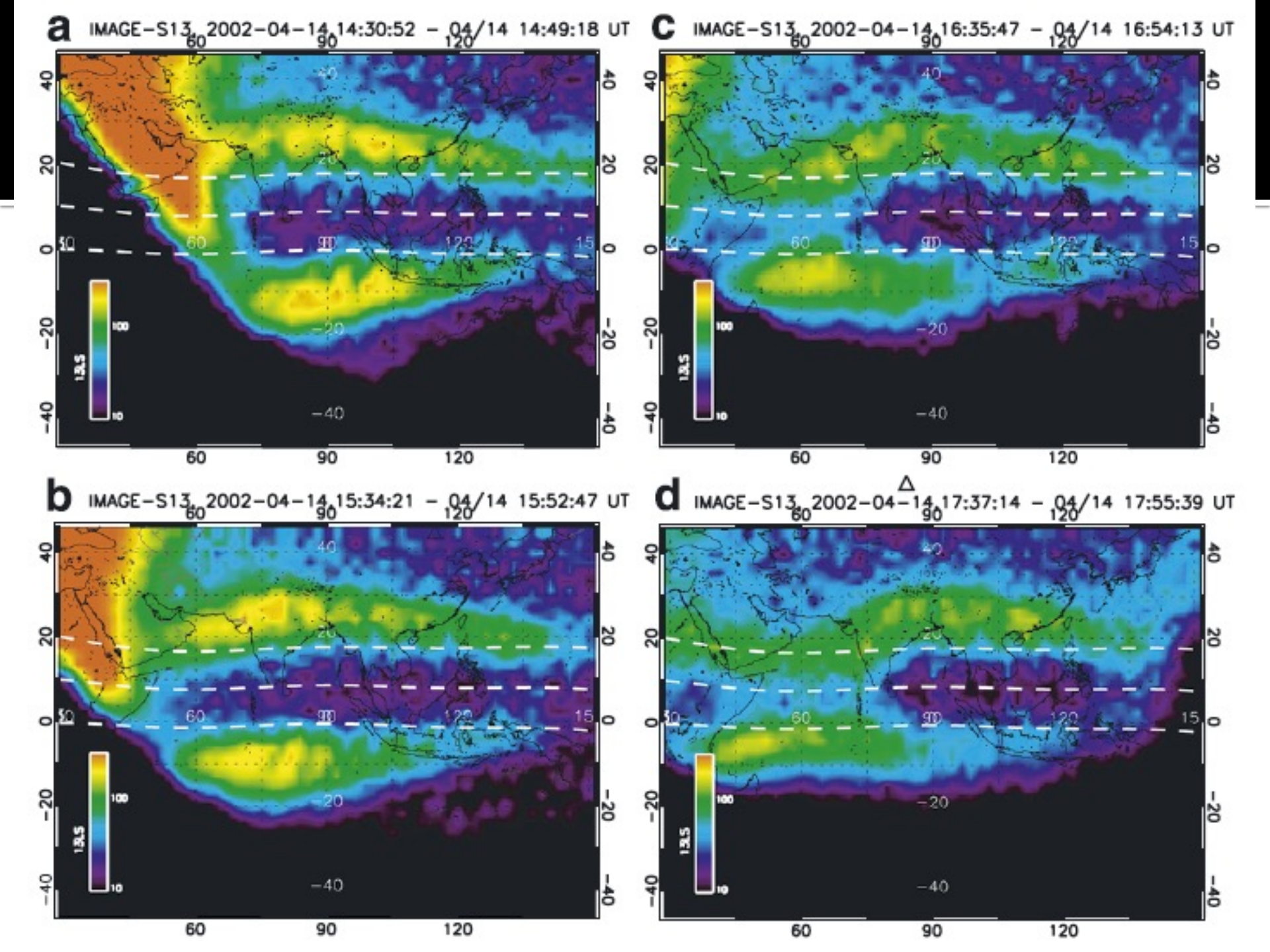
Polar two-cell plasma flow



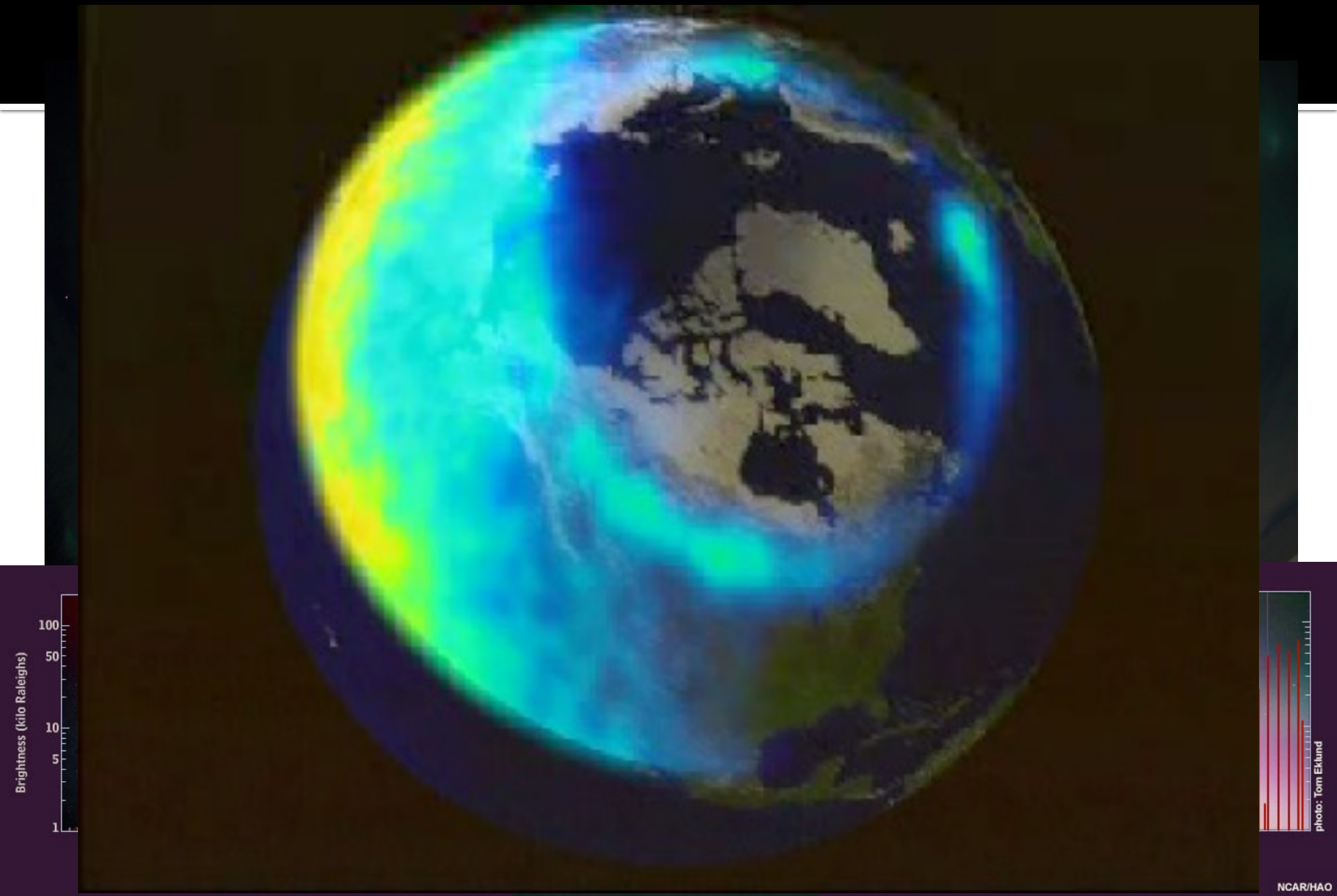


- Flow pattern at the poles due to solar wind-magnetosphere interactions

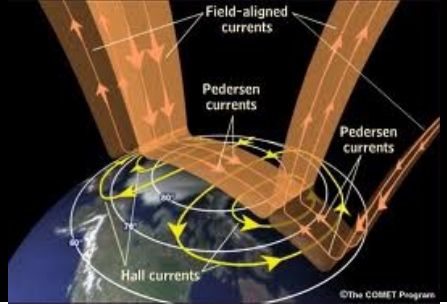



a
IMAGE-S13 2002-04-14 14:30:52 - 04/14 14:49:18 UT
b
IMAGE-S13 2002-04-14 15:34:21 - 04/14 15:52:47 UT
c
IMAGE-S13 2002-04-14 16:35:47 - 04/14 16:54:13 UT
d
IMAGE-S13 2002-04-14 17:37:14 - 04/14 17:55:39 UT
60
90
120
40
20
0
-20
-40
135
100
10

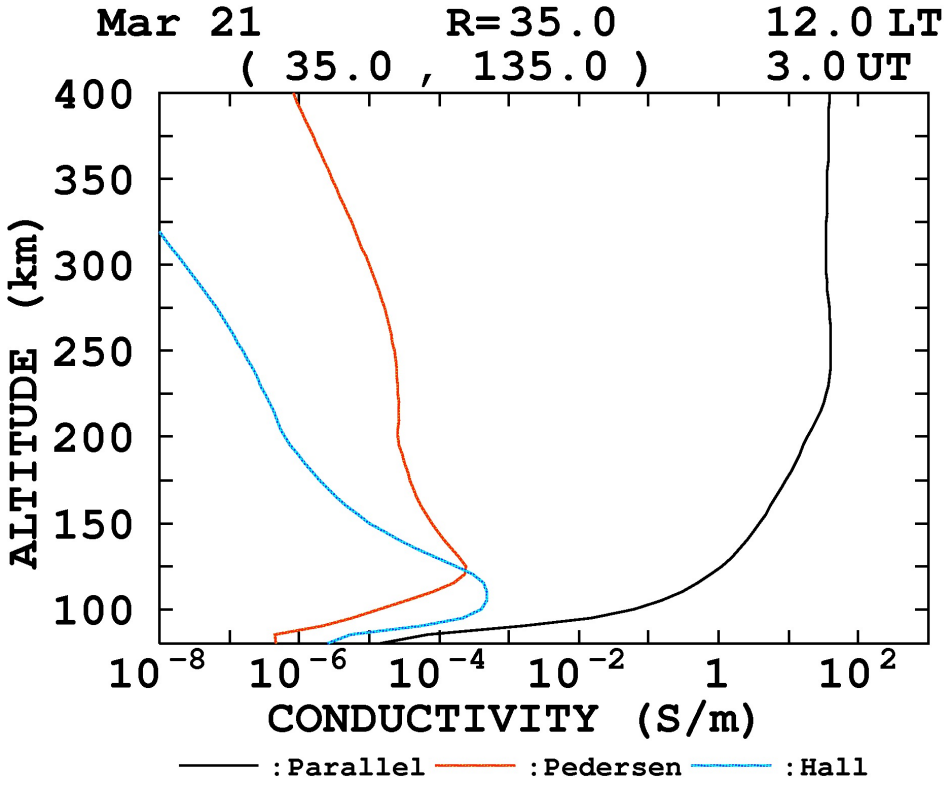
Aurora


Brightness (kilo Raleighs)
100
50
10
5
1
photo: Tom Eklund
NCAR/HAO

Conductivities



- **Pedersen conductivity** is the electrical conductivity parallel to the electric field in the Earth's ionosphere.
- **Hall conductivity** is that which is perpendicular to the electric field. In the ionosphere this conductivity is due to the drift motion of the electron (ExB drift) and maximum in the E region where only electrons drifts in the direction of ExB. Hall currents are how the auroral electrojet forms.
- **Specific conductivity** is a scalar conductivity that depends only on the collision frequencies; parallel electrical conductivity.

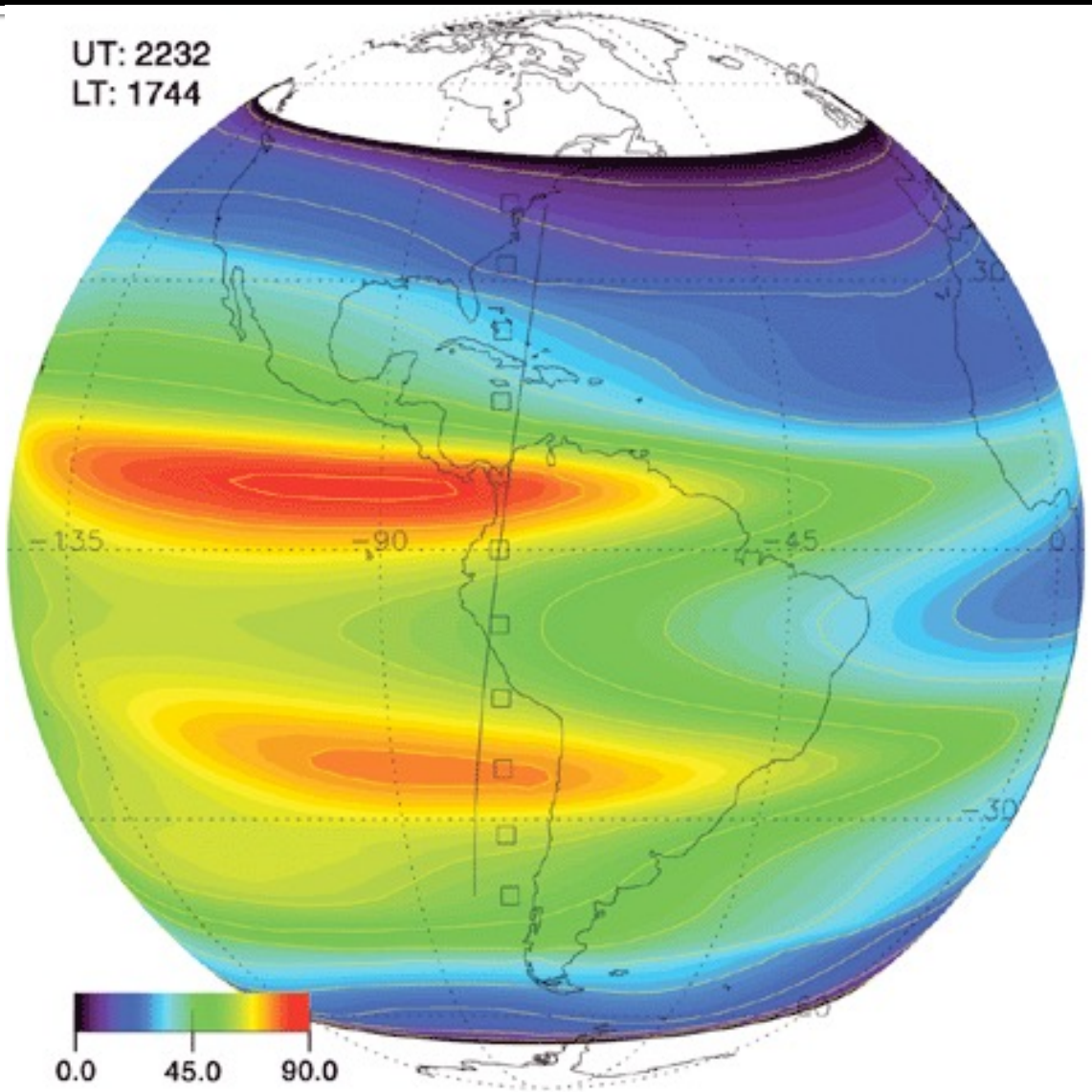


From the plot above, it can be seen that Pedersen currents dominate the F-region while Hall currents dominate the E-region. This is important for Magnetospheric-Ionospheric coupling.

Anomalies

Equatorial anomaly (arcs)

Dayside formation of peaks on either side of the magnetic equator due to the fountain effect.

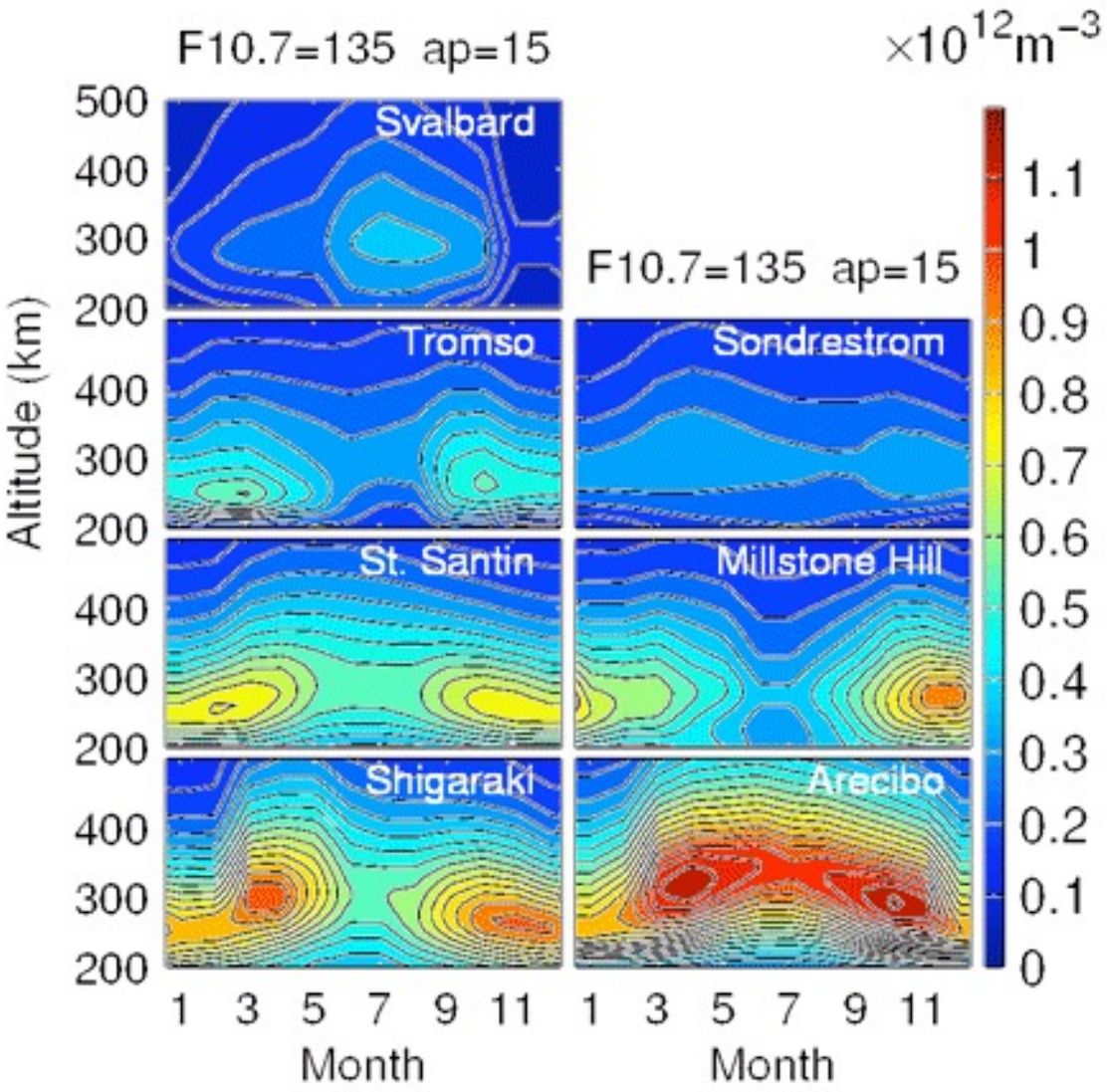


Anomalies

Seasonal anomaly

NmF2 in the winter is greater than NmF2 in the summer despite the fact that the solar zenith angle is smaller in summer, which occurs because of the seasonal changes in the neutral atmosphere.

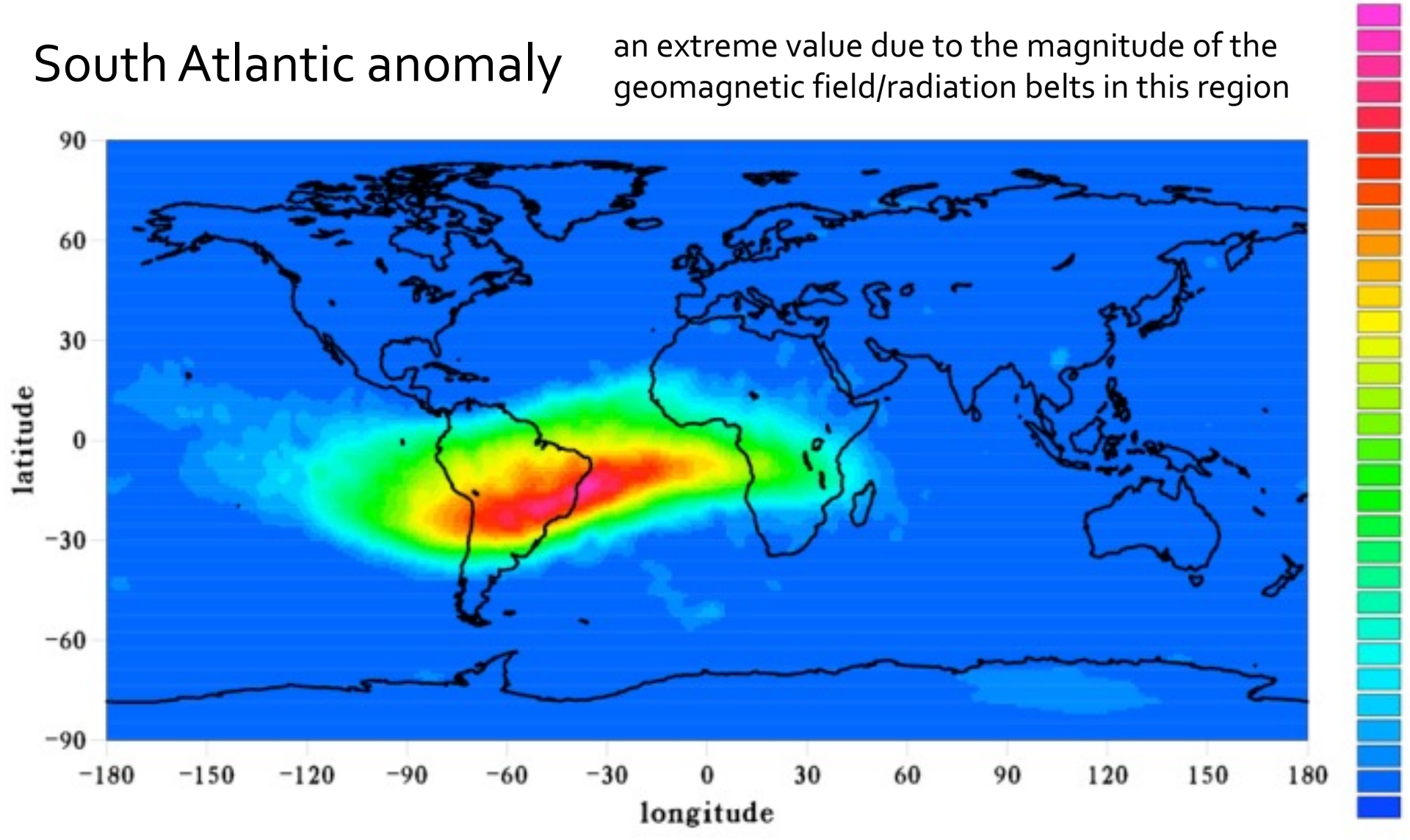
Station	Lat., deg	Lon., deg
Svalbard	78.1	16.0
Sondrestrom	67.0	309.0
Tromsø	69.6	19.2
Millstone	42.6	288.5
St. Santin	44.6	2.2
Arecibo	18.3	293.2
Shigaraki	34.8	136.1



Anomalies

South Atlantic anomaly

an extreme value due to the magnitude of the geomagnetic field/radiation belts in this region



References and Suggested Further Reading

- Ganguli, S. B. (1996), The Polar Wind, Rev. Geophys., 34(3), 311-348.
- Kelley, M. C. (2009), The Earth's Ionosphere: Plasma Physics and Electrodynamics, Second Edition ed., 556 pp., Academic Press, San Diego.
- Schunk, R. W., and A. F. Nagy (2009), *Ionospheres: Physics, Plasma Physics, and Chemistry*, Second Edition ed., 628 pp., Cambridge University Press, Cambridge.
- Zhang, S.-R., J. M. Holt, A. P. van Eyken, M. McCready, C. Amory-Mazaudier, S. Fukao, and M. Sulzer (2005), Ionospheric local model and climatology from long-term databases of multiple incoherent scatter radars, Geophys. Res. Lett., 32, L20102, doi:10.1029/2005GL023603.
- http://www.igpp.ucla.edu/public/ekassie/ionosphere.html
- www.haystack.mit.edu/edu/pcr/Astrochemistry/4%20-%20ATMOSPHERE/ionosphere%20as%20plasma.ppt
- http://www.igpp.ucla.edu/public/rwalker/ess7_2008_fall/ESS%25207%2520Atmosphere%2520and%2520Ionosphere.ppt

Questions?

Ionospheric Variations

- Diurnal – related to the change in solar zenith angle and change in solar radiation flux due to the rotation of the Earth
- Seasonal – related to a solar zenith angle change
- Solar Cycle – related to a change in the solar EUV and X-ray radiation fluxes