Global Response of the I-T system to Magnetic Storms

-- Composition changes/upwelling

-- Penetration Electric Fields, large plasma density variations

-- High Latitude winds driven to mid/low latitudes

-- Joule Heating

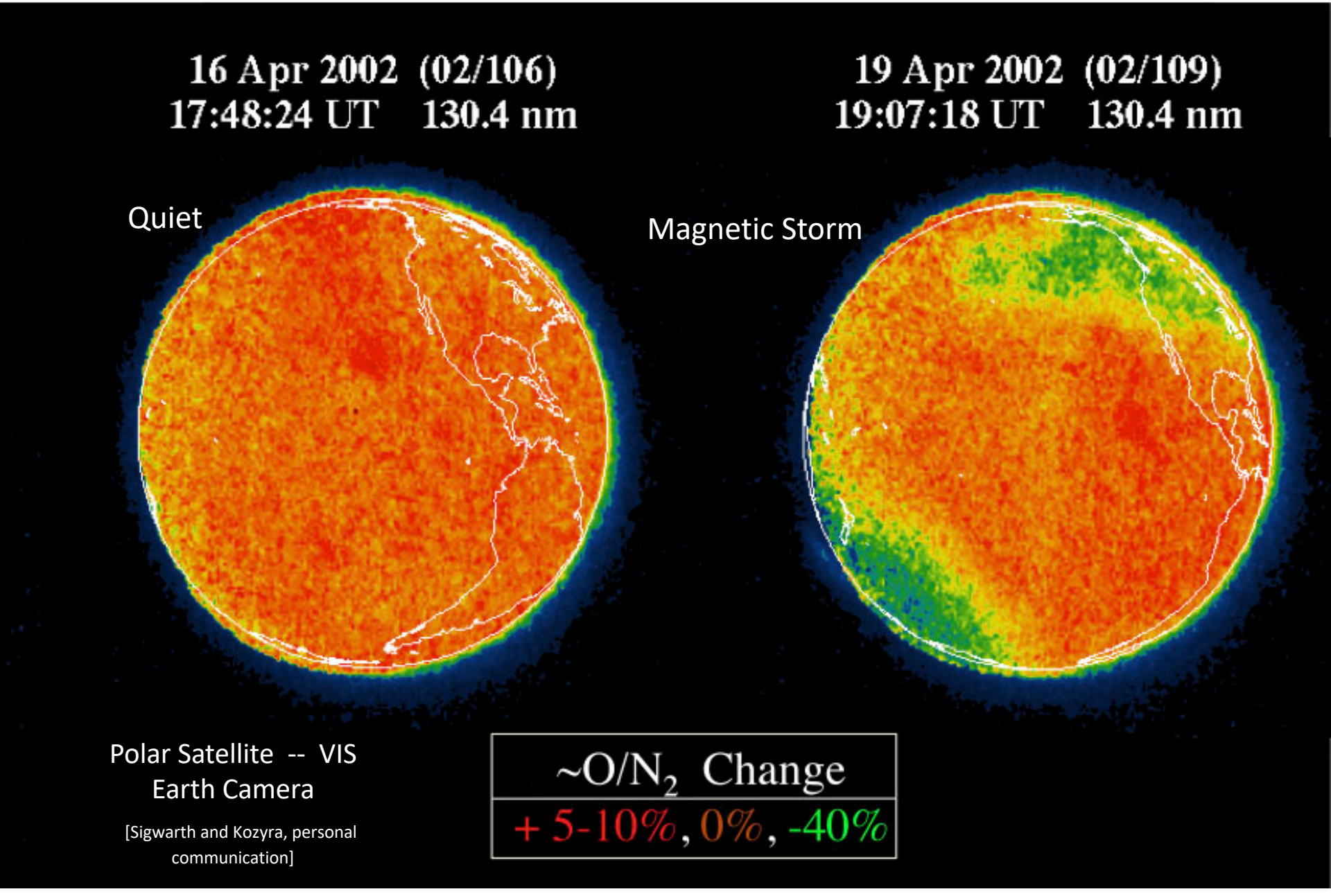
-- Disturbance Dynamo

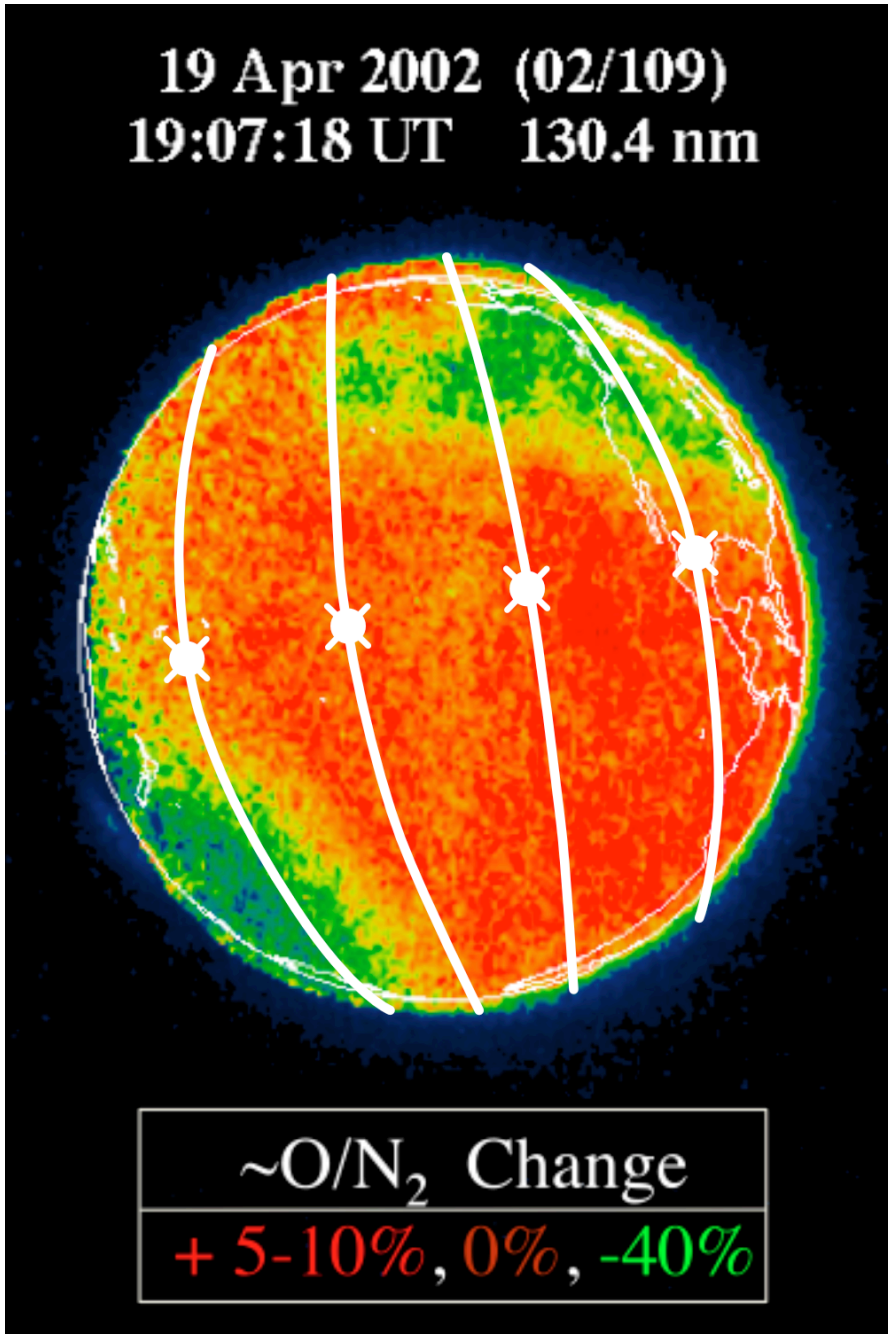
-- Irregularities at all latitudes

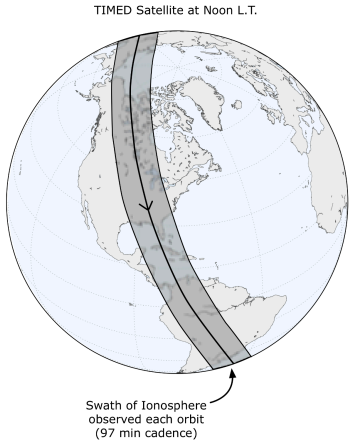
Input to GDC STDT

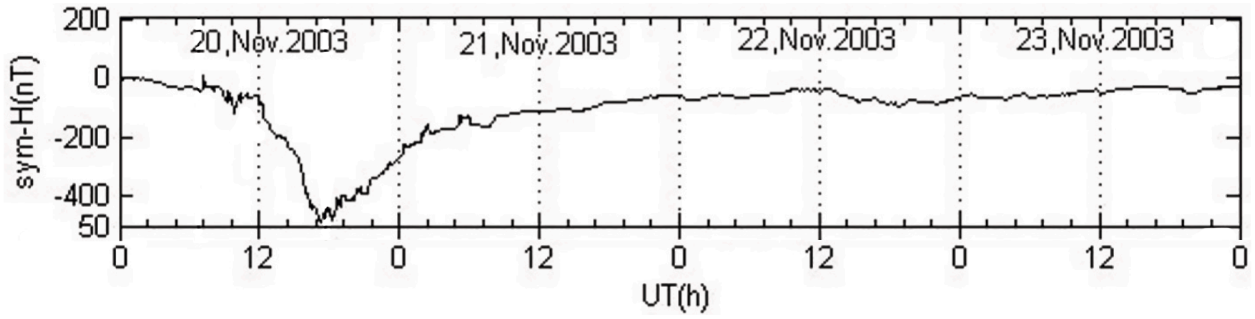
Rob Pfaff, NASA GSFC

August 1, 2018


16 Apr 2002 (02/106)
17:48:24 UT 130.4 nm
19 Apr 2002 (02/109)
19:07:18 UT 130.4 nm
Quiet
Magnetic Storm
Polar Satellite -- VIS Earth Camera
[Sigwarth and Kozyra, personal communication]
~O/N2 Change
+ 5-10%, 0%, -40%


19 Apr 2002 (02/109)
19:07:18 UT 130.4 nm
~O/N2 Change
+ 5-10%, 0%, -40%

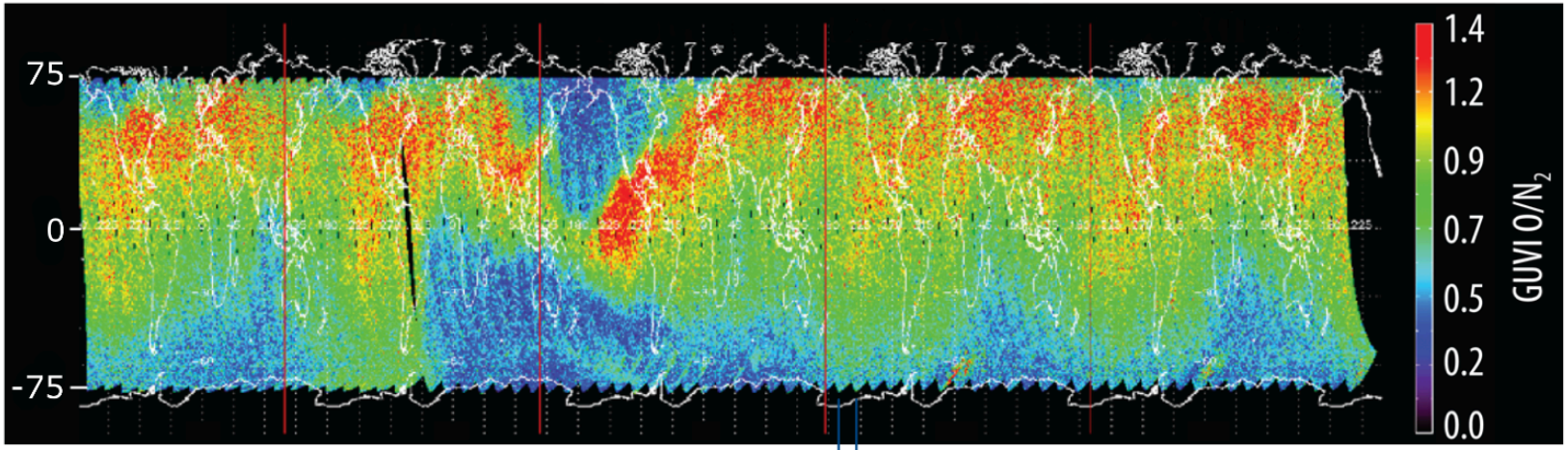




Yang et al., 2003

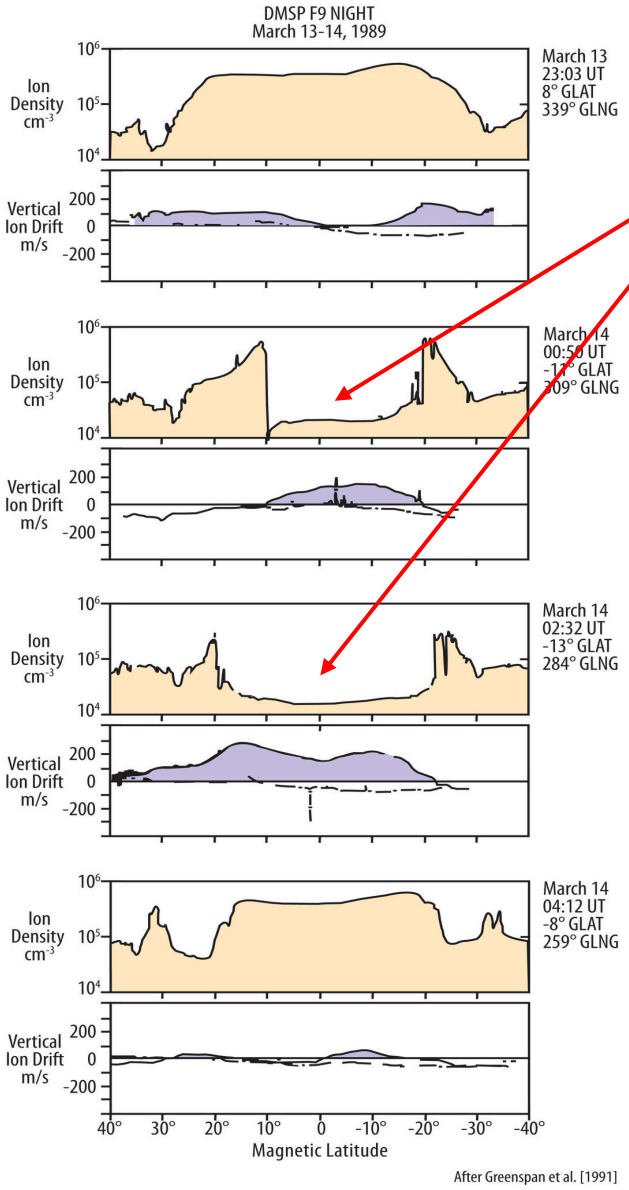
TIMED GUVI Observations near Noon L.T.

Nov. 18 - 22, 2003



[Meier et al., 2005]

During magnetic storms, the low latitude ionosphere often rises above 840 km (as shown by DMSP satellites), at least at 21:30 LT



Ionosphere "disappears" at low latitudes

→ Why? Penetration Electric fields?

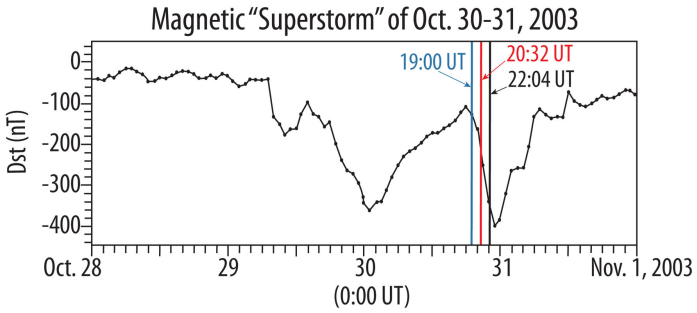
→ What happens at other local times?

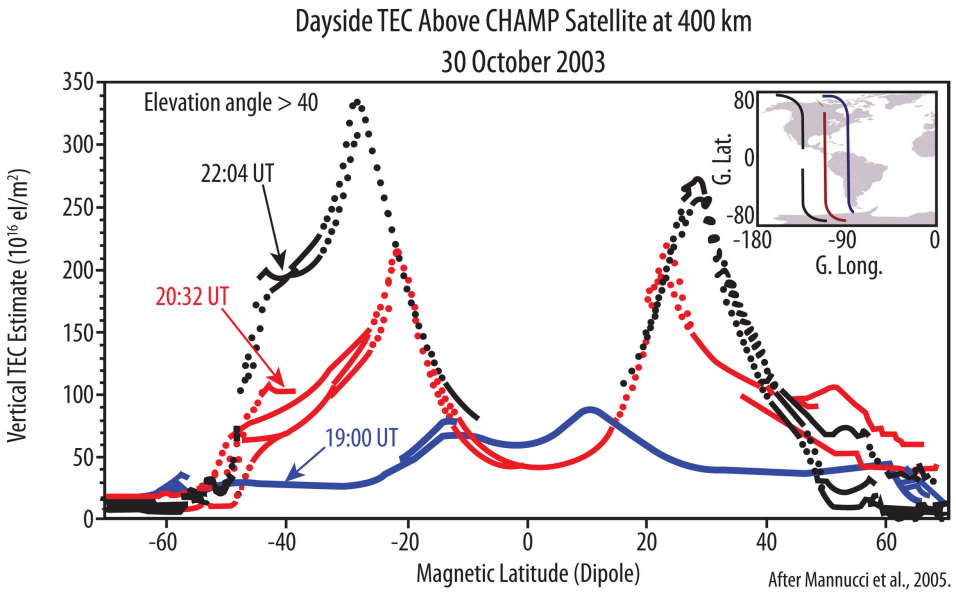
→ What about the upper atmosphere?

4 consecutive DMSP passes (100 minutes apart) near 21:30 L.T. show ionosphere rising above 840 km during magnetic storm

[Greenspan et al., 1991]

GDC will reveal how the mid and low latitude ionosphere responds to magnetic activity and storms, including extreme events.

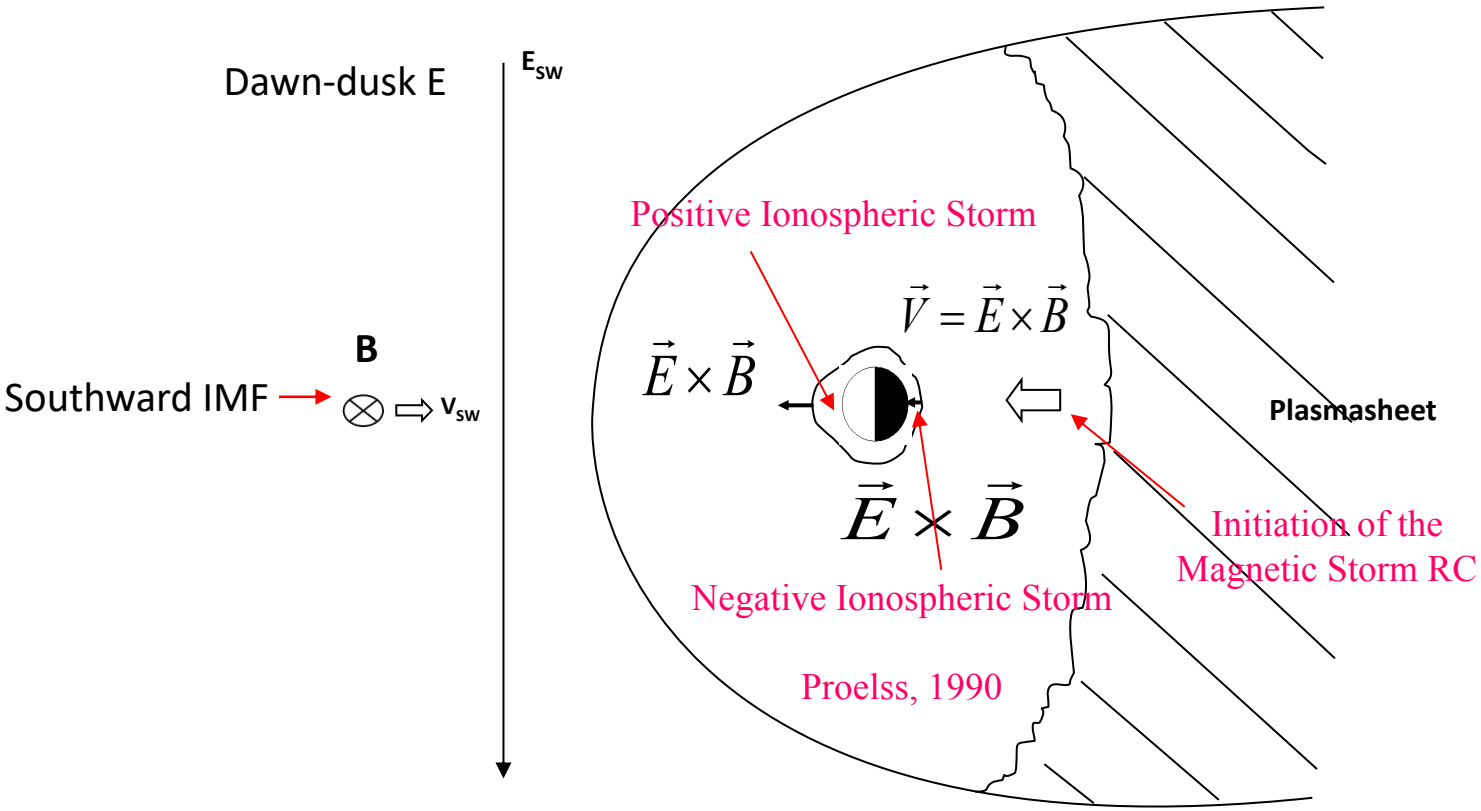




Local times of these orbits -- 12:30 to 13:30 L.T.

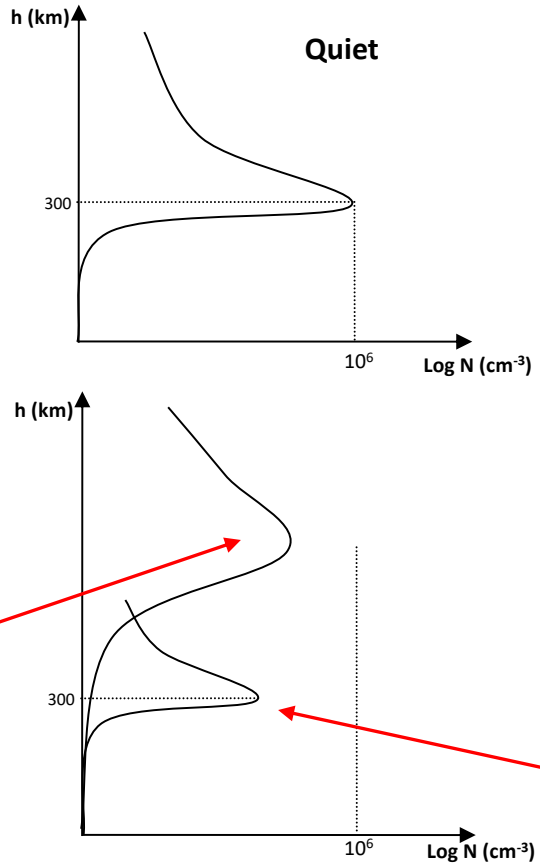
TEC measurements (above 400 km) by GPS receiver on CHAMP
on 3 successive orbits during magnetic "superstorm" of Oct. 30-31, 2003

Prompt Penetration Electric Fields(PPEFs) and Their Effects: A Global Scenario



Tsurutani et al., JGR, 2004, 2008

Why Ionospheric Uplift Leads to TEC Enhancements



Creation of a new ionosphere:
TEC enhancement

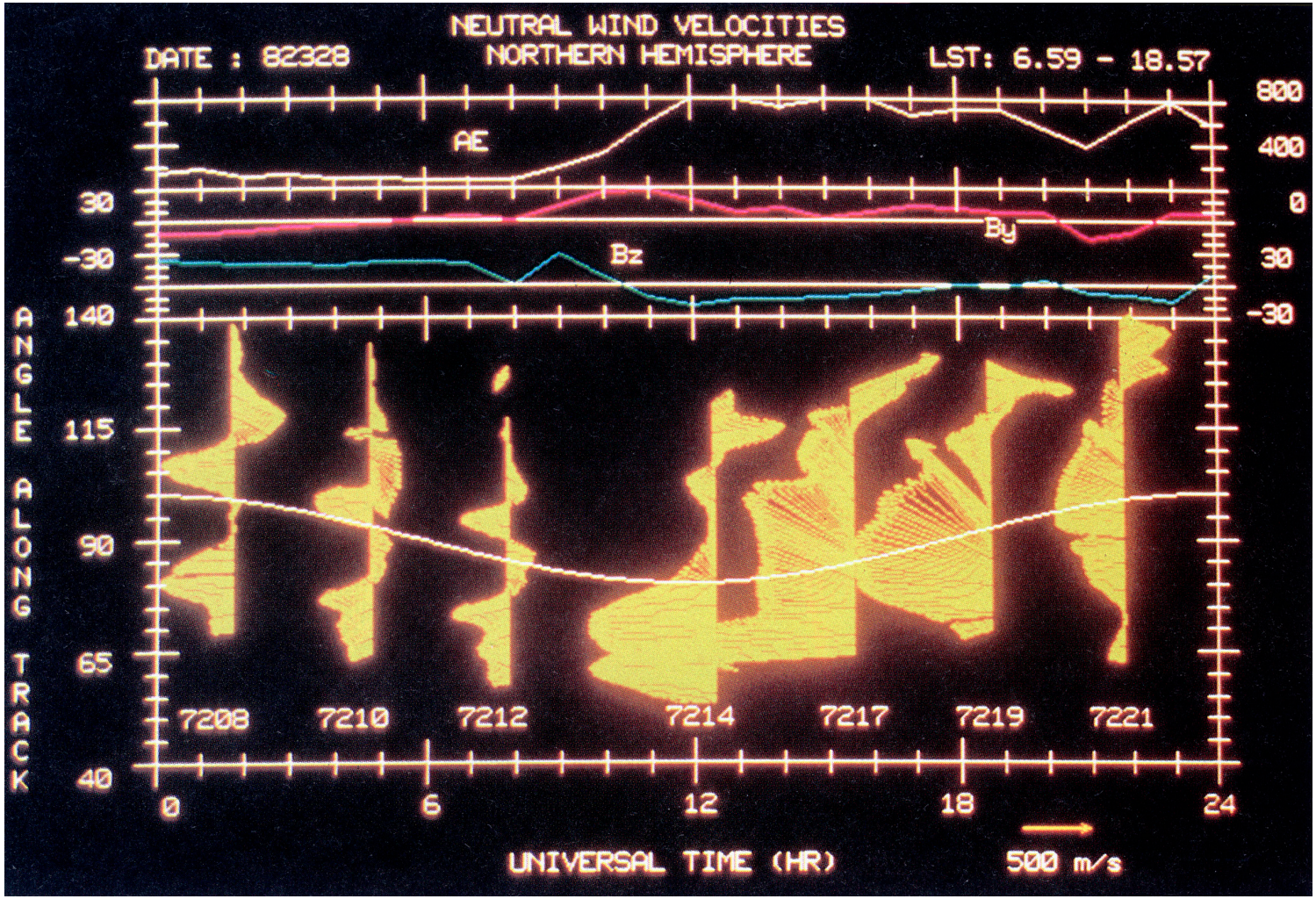
Uplifted plasma moved to region of lower recombination time scales, i.e., longer plasma lifetimes

Solar photoionization creates a new ionosphere

Tsurutani et al. Ann. Geo. 2013

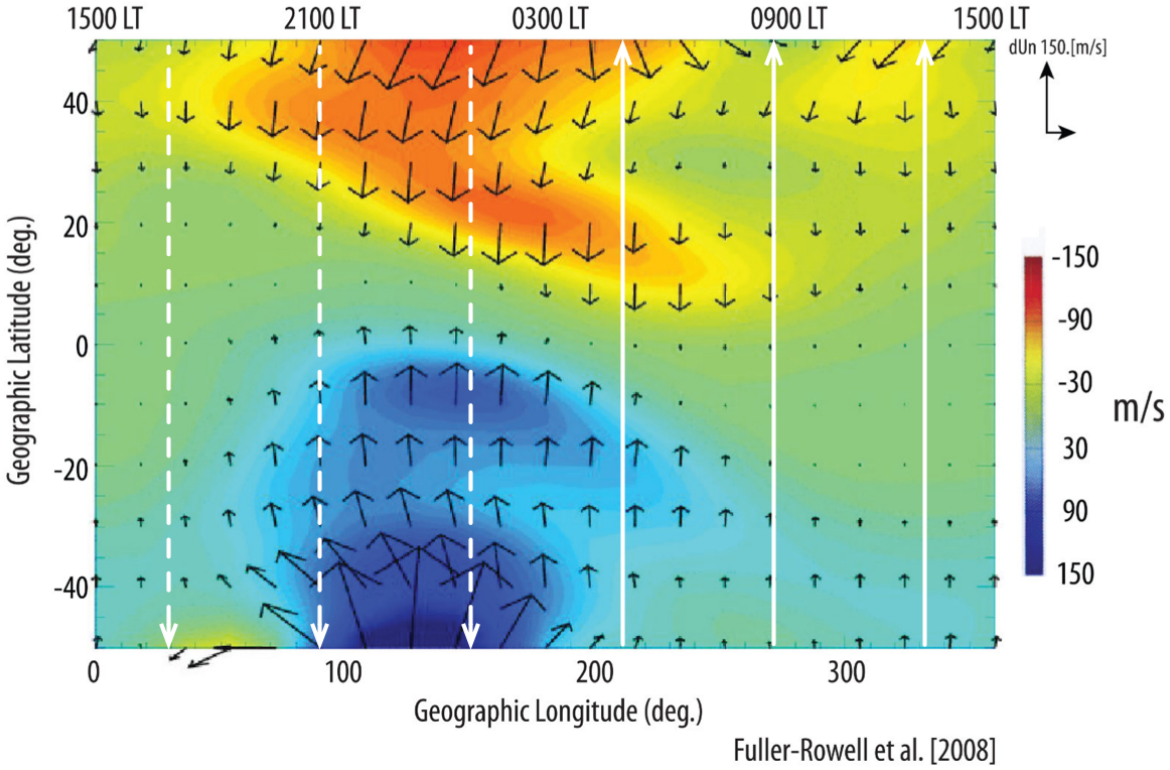
Earth's Upper Atmosphere is thrust into motion by the magnetosphere!

Particularly in response to Geomagnetic Storms!



[Killeen and Roble, 1988]

Neutral atmosphere is not only set in motion by the magnetosphere electric fields, but flows to lower latitudes!

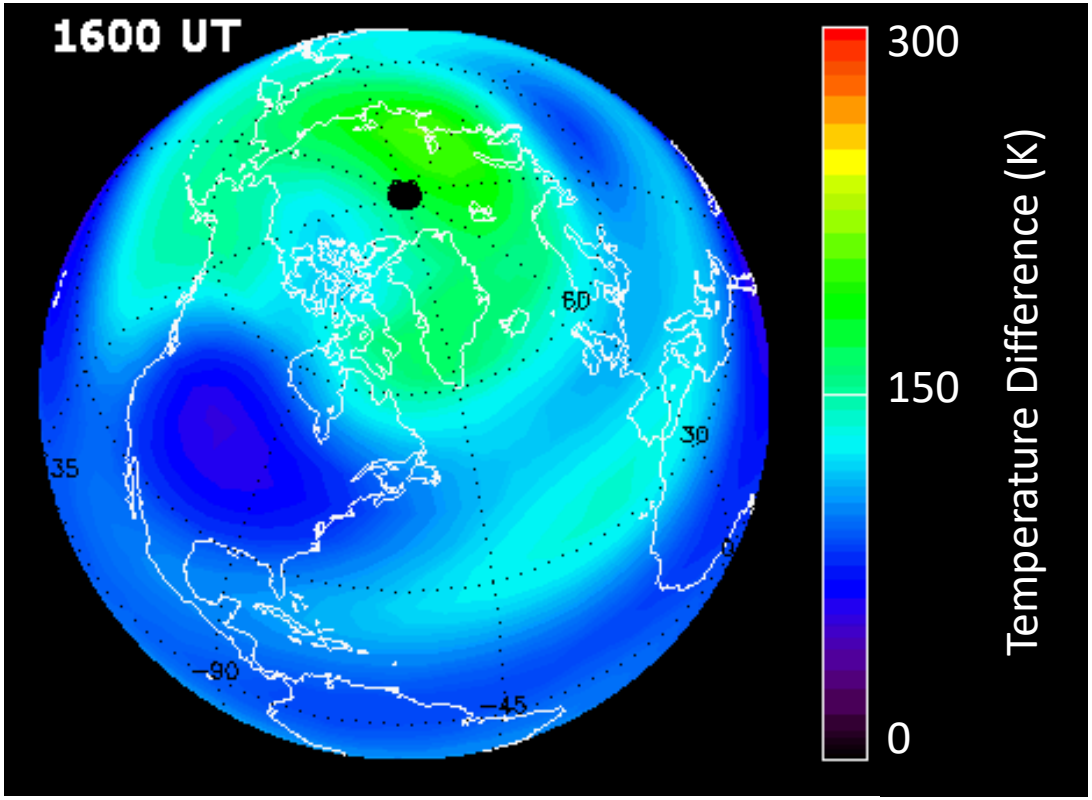


Equatorward winds (Model results at 253 km) driven by auroral heating -- note the strong variations with local time (longitude)

GDC will reveal how the mid and low latitude ionosphere/thermosphere respond to magnetic activity and storms, including extreme events

Global Response of IT System to Magnetic Storms

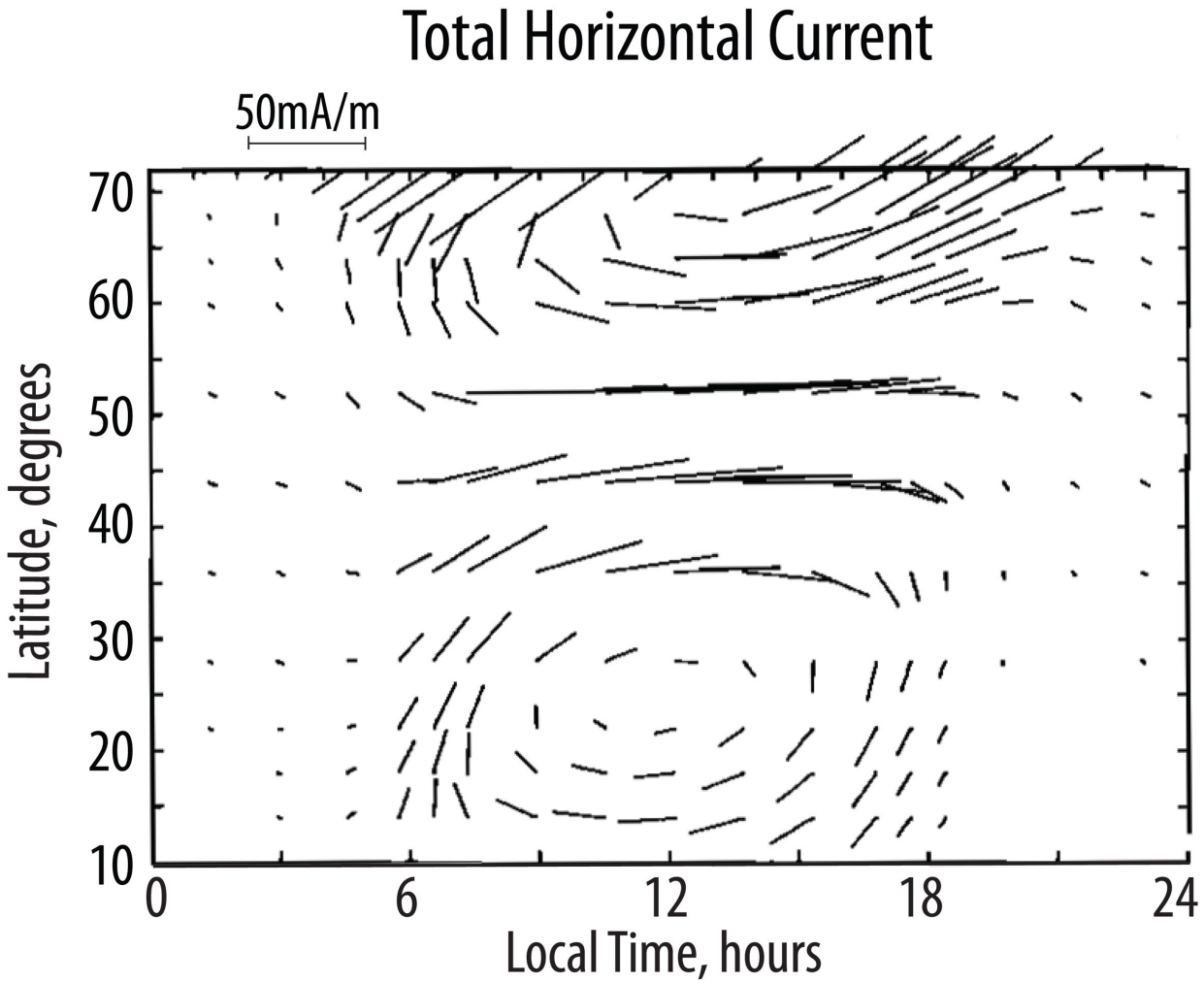
- Both observations and models show that the IT system responds globally to magnetic storms.
  - The response we observe is a consequence of many interconnected processes which result from ion-neutral, chemical-dynamical, and electrodynamic coupling.
  - Global responses vary with local time and are asymmetric between hemispheres.
- Current understanding is based on climatologies.
  - Insufficient to unravel the array of coupling and feedback processes that produce the global scale responses and their relationships to solar wind conditions.



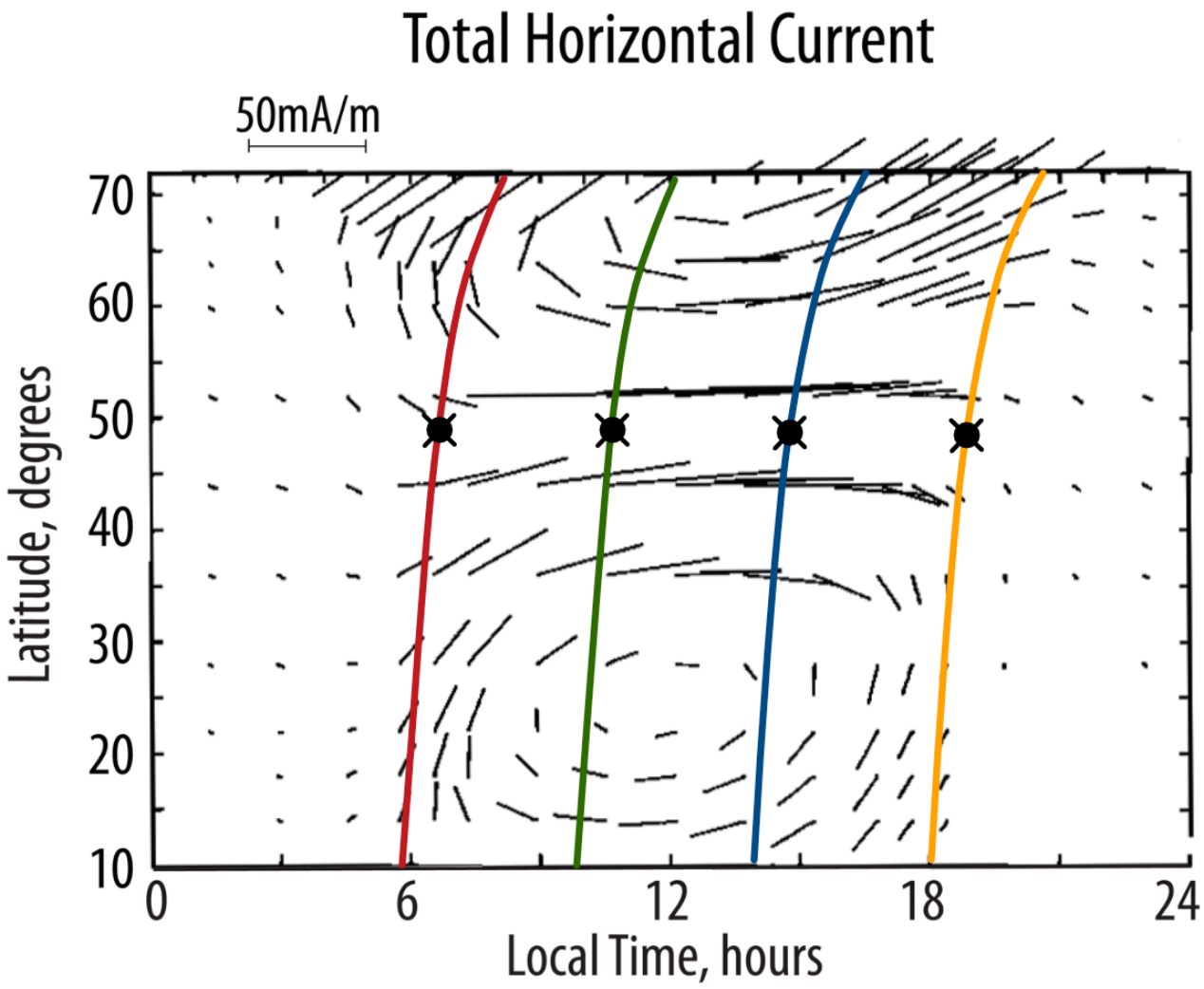
Global Simulation of Magnetic Storm
Temperature at 350 km Altitude

Courtesy G. Lu

Currents, Winds and Plasma Velocity (Electric Fields) are Driven in Unknown ways during Magnetic Storms

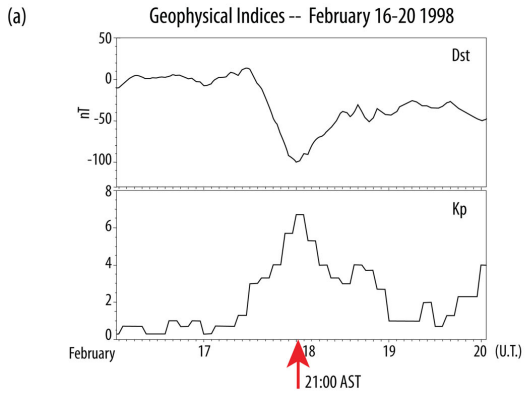


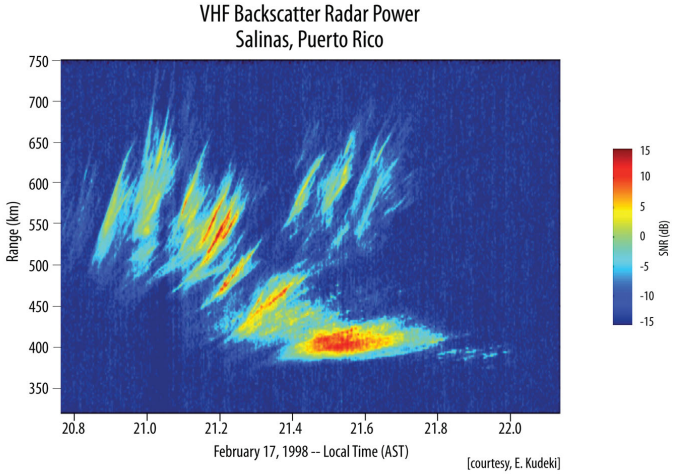
Blanc and Richmond, 1980

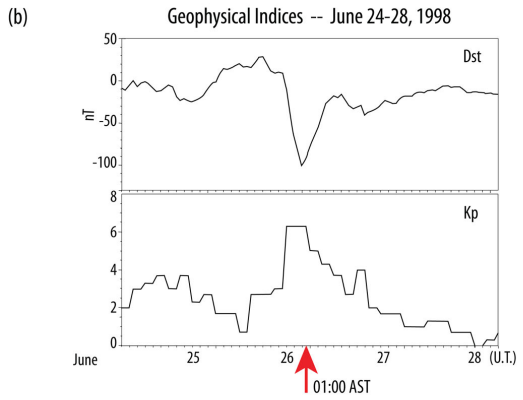


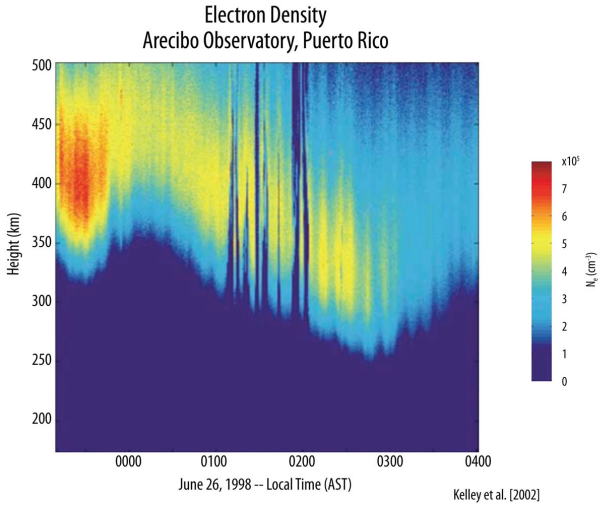
Adapted from Blanc and Richmond, 1980

Mid-latitude “irregularities” associated with geomagnetic storms





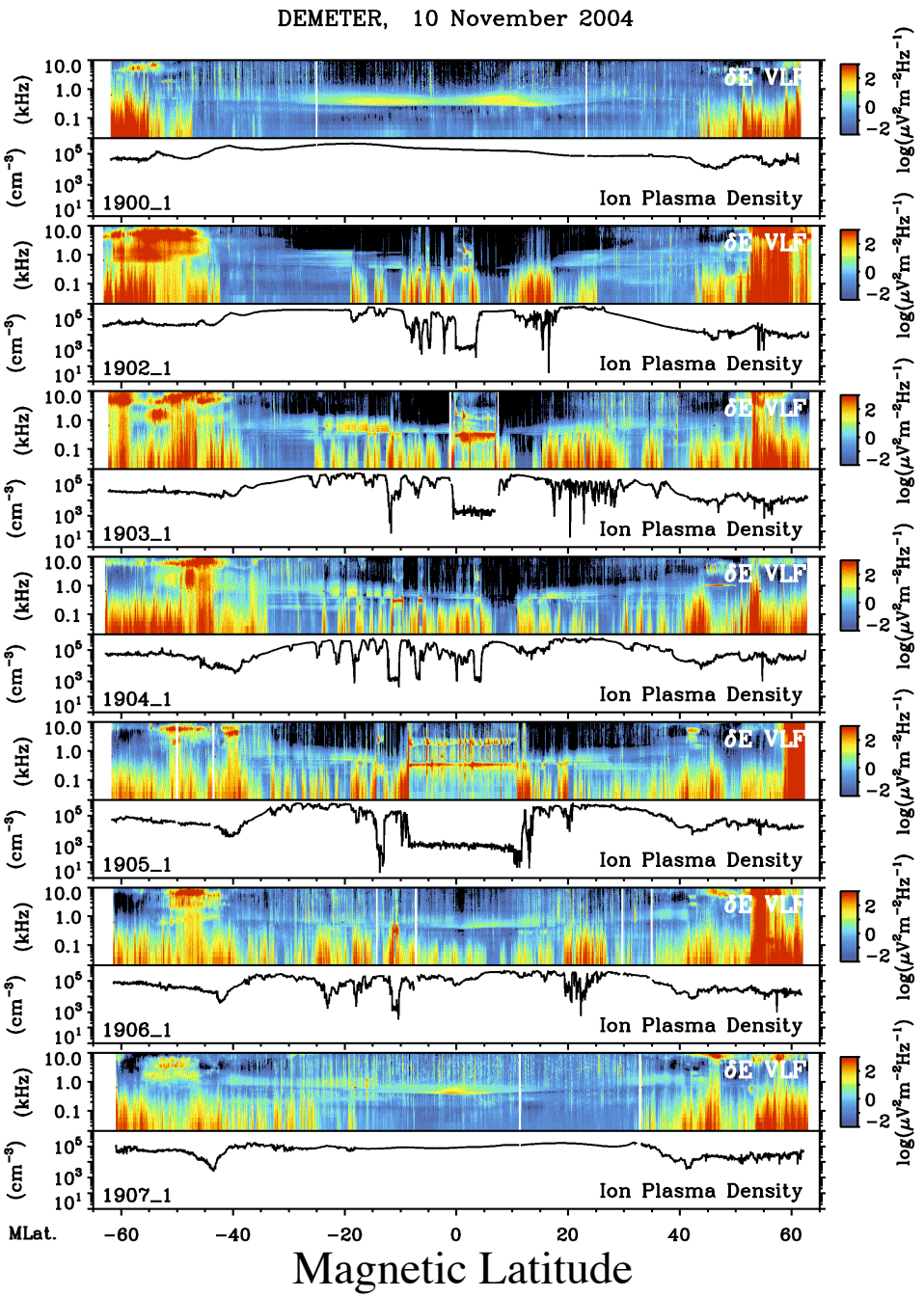




GDC will reveal how the mid and low latitude ionosphere develops large scale irregularities

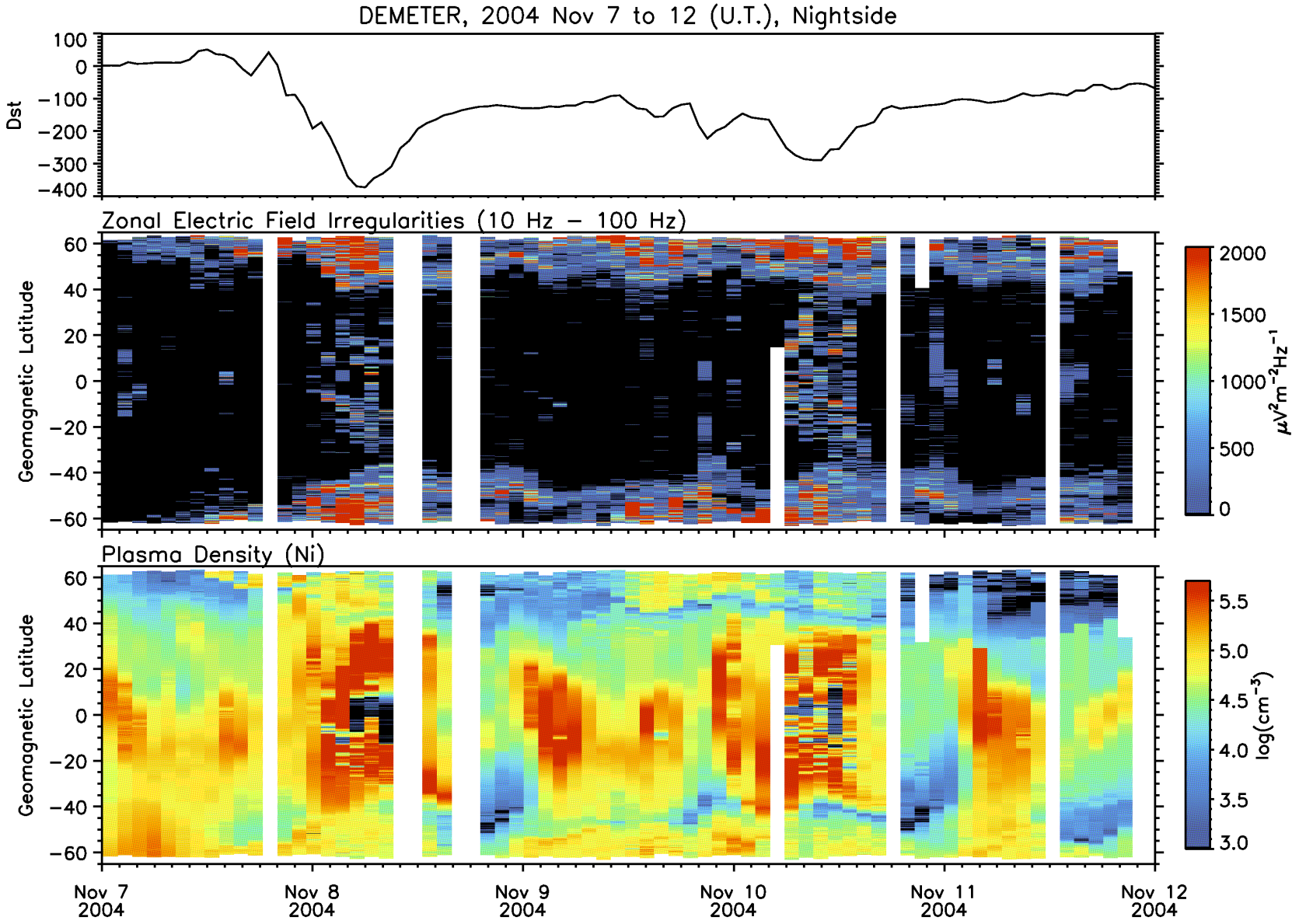
Consecutive DEMETER orbits at 22 h L.T. during major storm.

(~ 700 km)

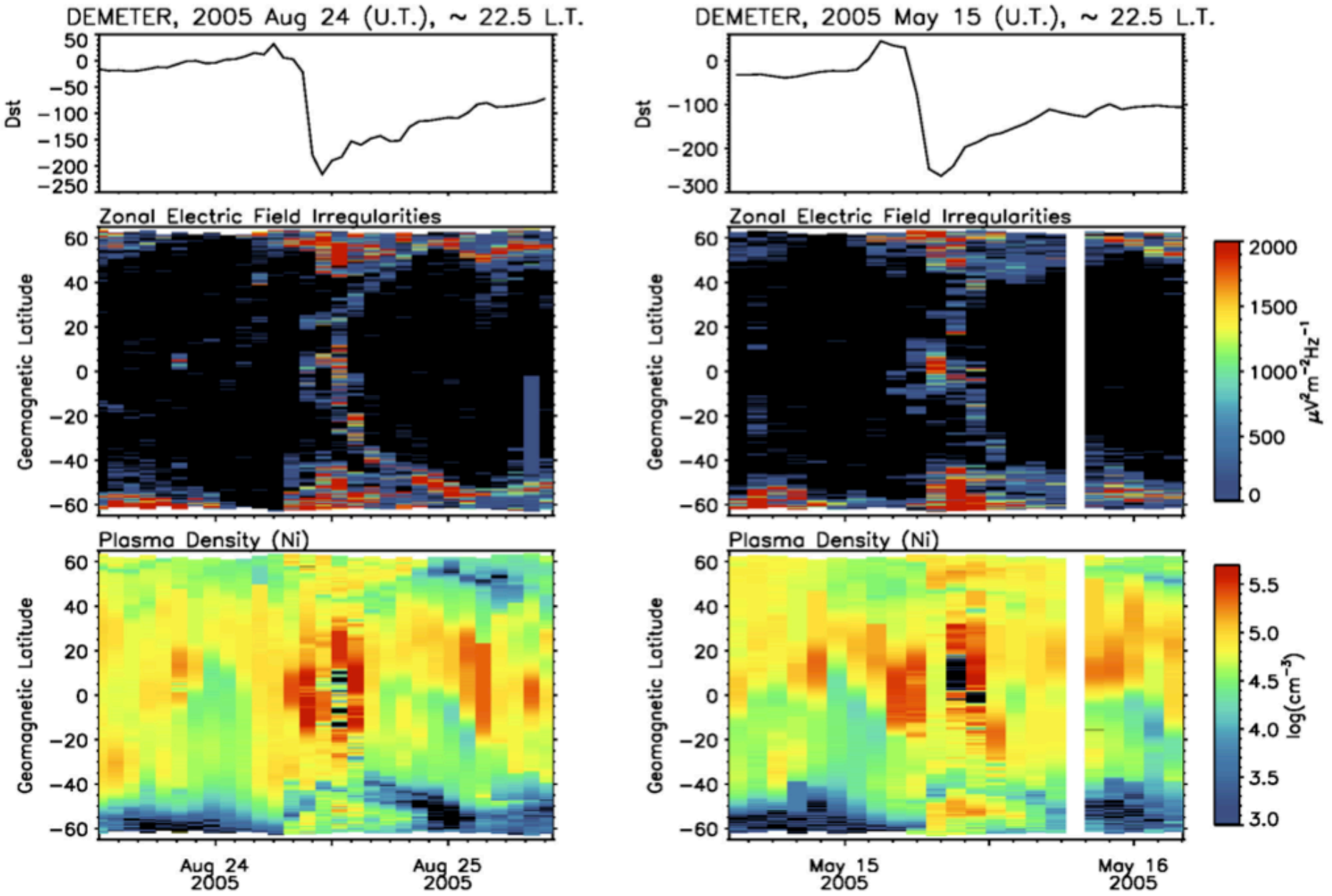


Missing one orbit.

Pfaff et al. 2008



Pfaff et al. 2008



Pfaff et al. 2008