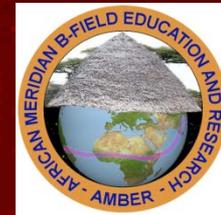


Imaging the global vertical density structure from the ground and space

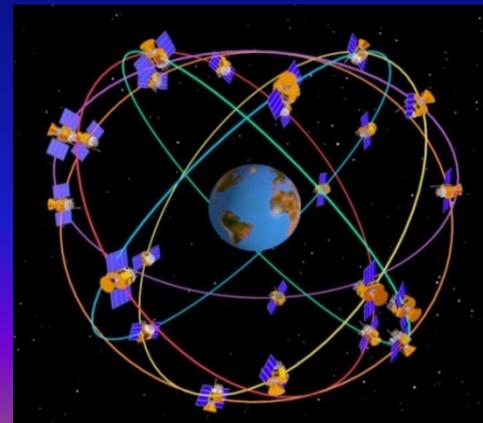
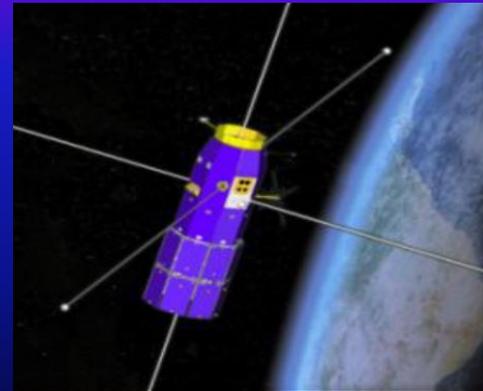
Endawoke Yizengaw

Institute for Scientific Research, Boston College

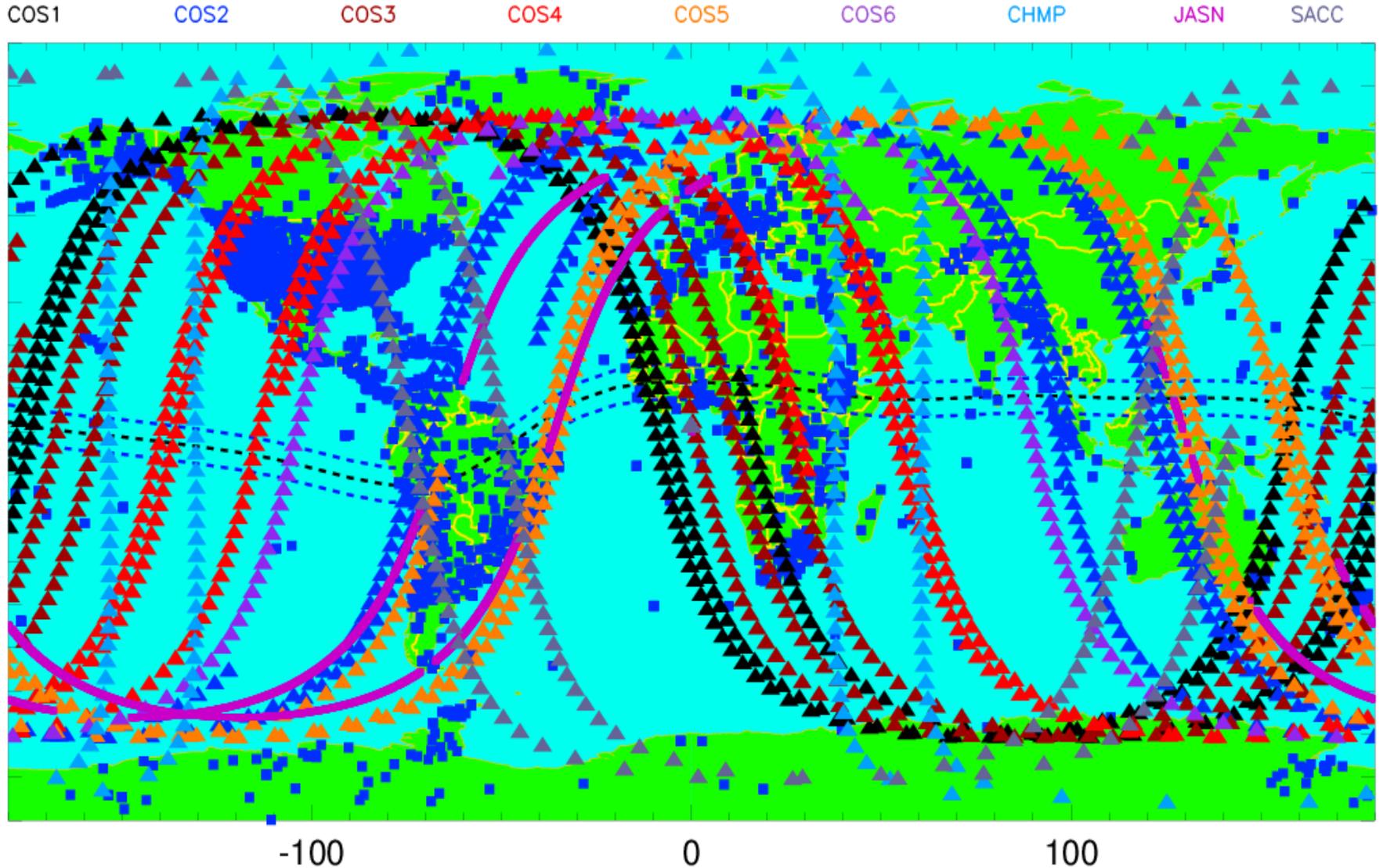


Outline

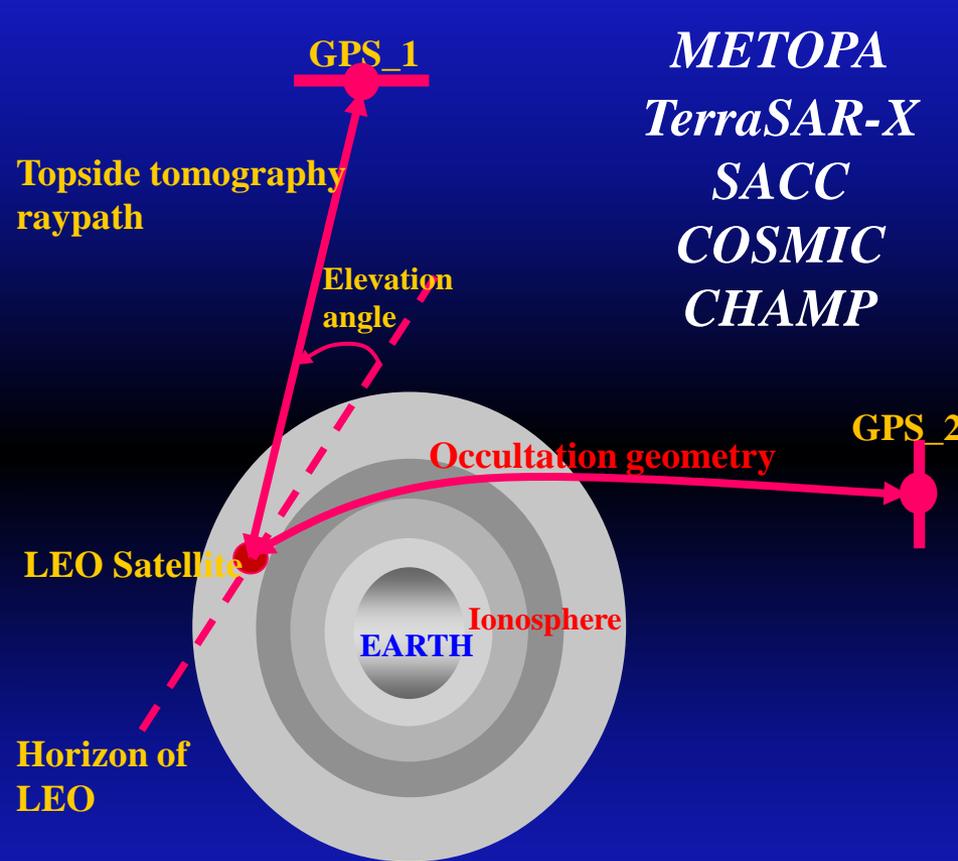
- Global Data Coverage
- Occultation density and its validation with different data sets
- Topside tomographic reconstruction
- Desired Future LEO Satellites' Data



Global Ground- and Space-based GPS data coverage

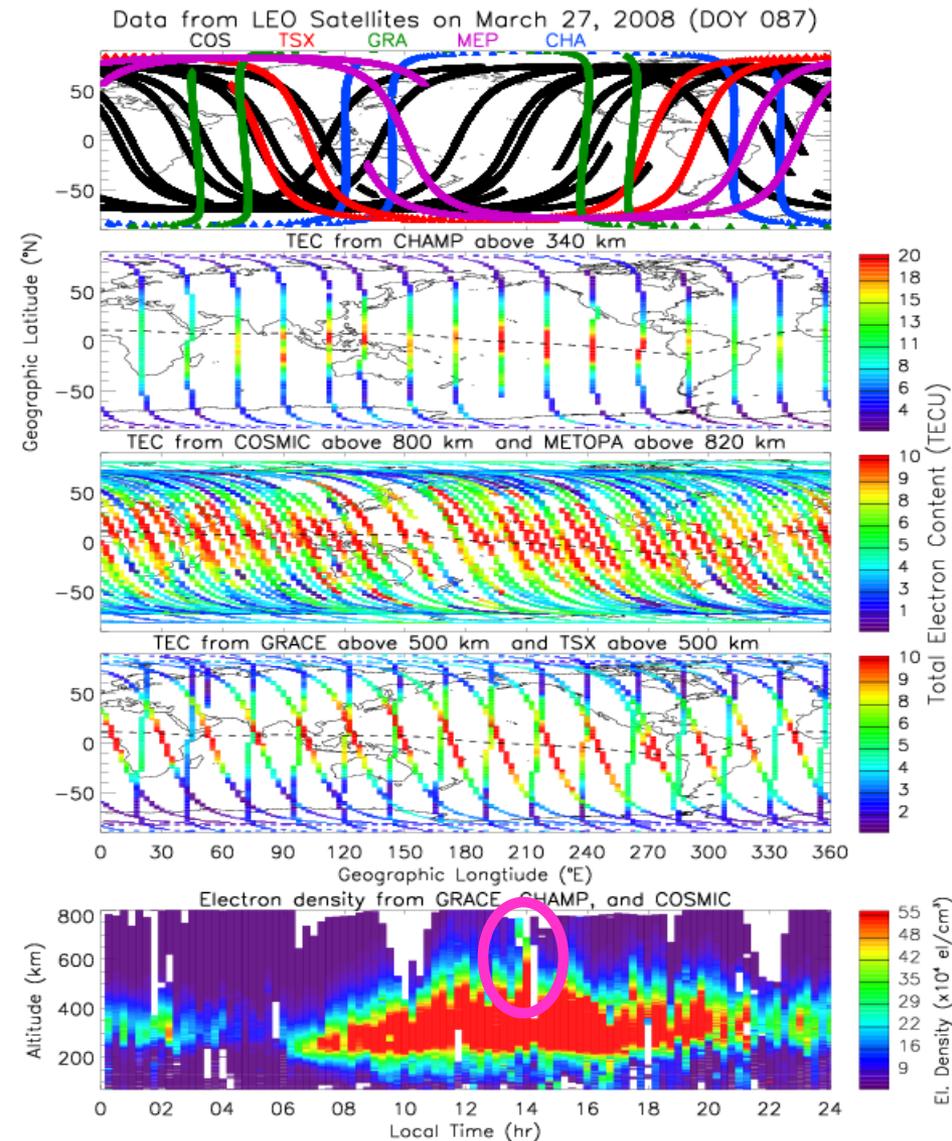


The two most important type of LEO GPS observations

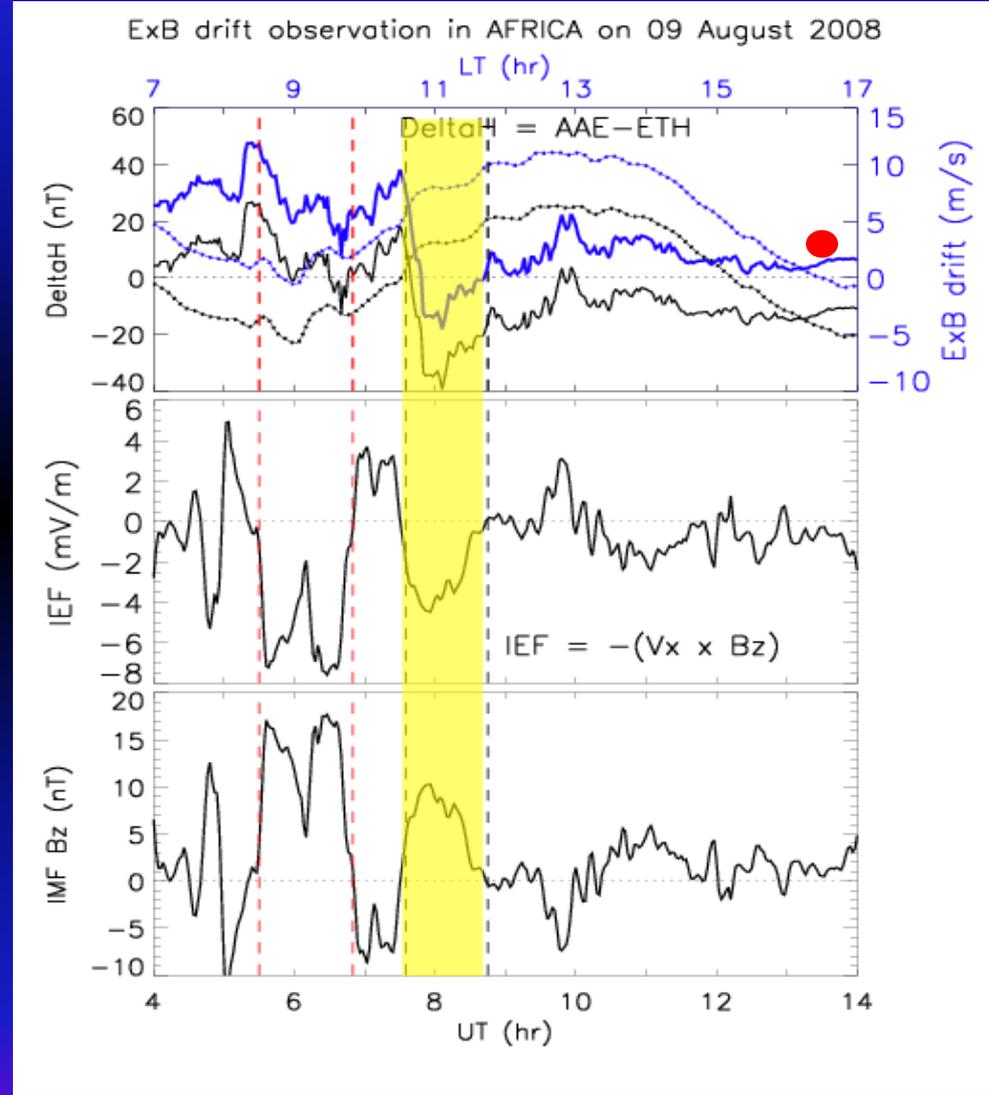
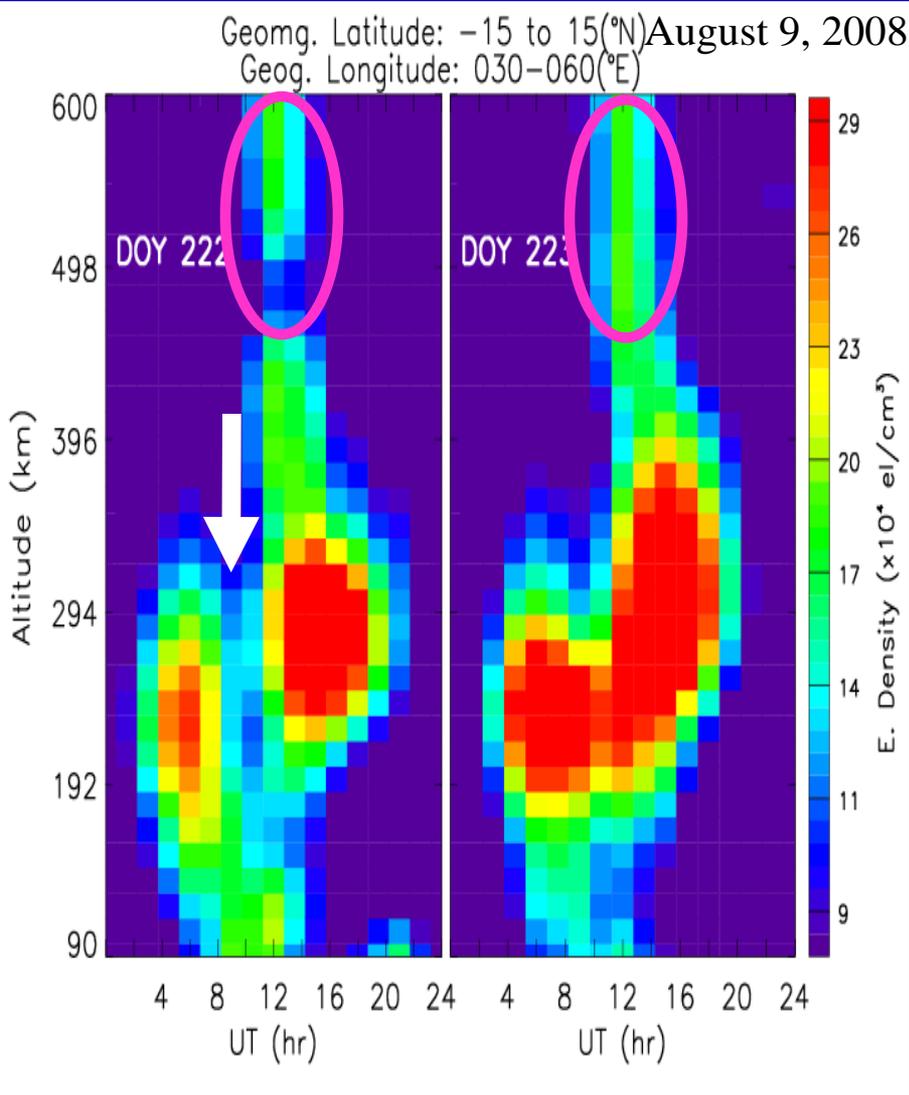


METOPA
TerraSAR-X
SACC
COSMIC
CHAMP

Yizengaw and Carter, 2016

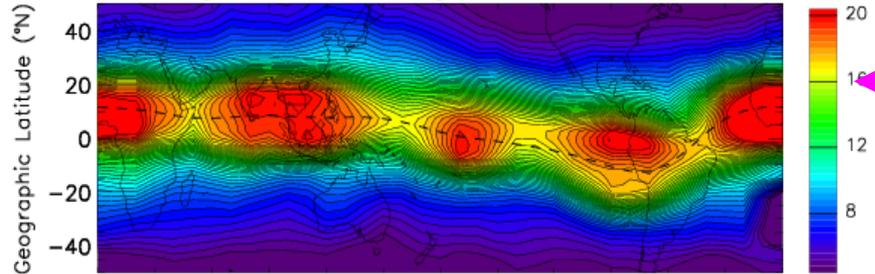


LEO GPS Occultation Data

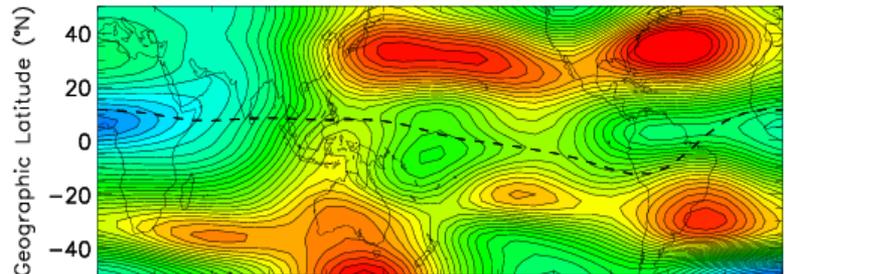


Global Statistical Studies using LEO Occultation

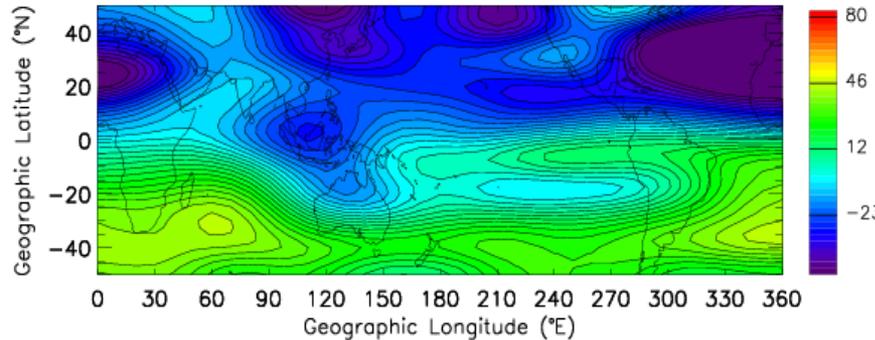
CHAMP Average TEC Map during 244–304, 2008 at 15–17 LT



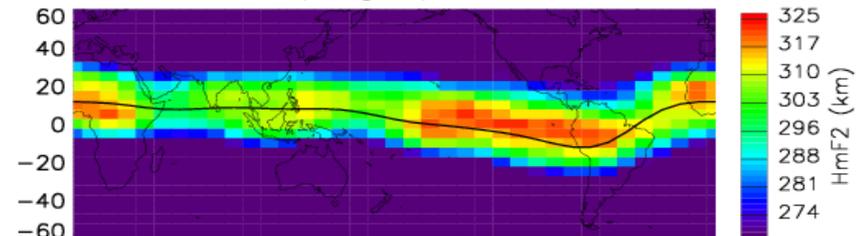
TIMED TIDI Zonal wind: 244–304, 2008 at 15–17 LT



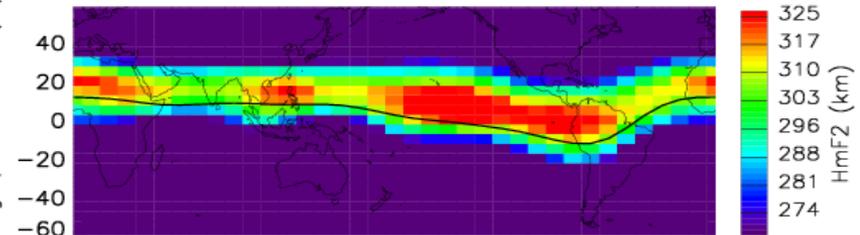
TIMED TIDI Meridional wind: 244–304, 2008 at 15–17 LT



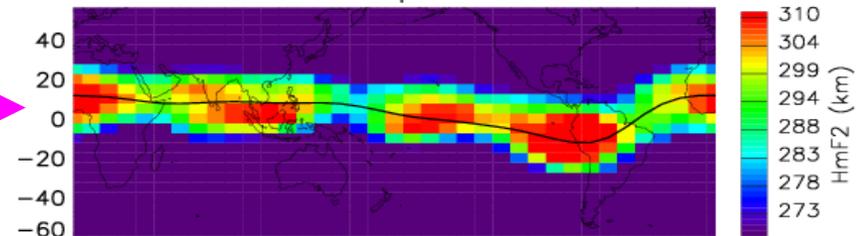
Global HmF2 at 15:00–17:00 LT in 2008
Spring Equinox



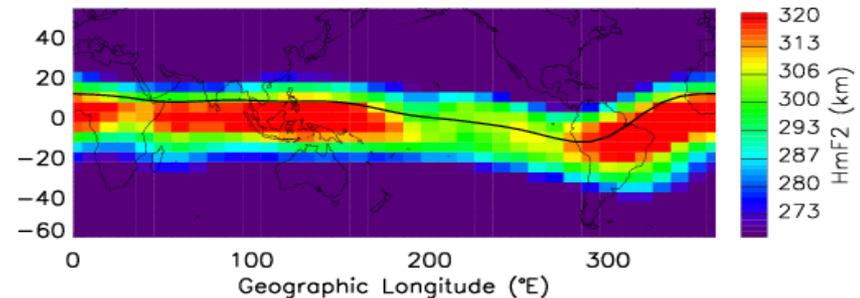
Summer



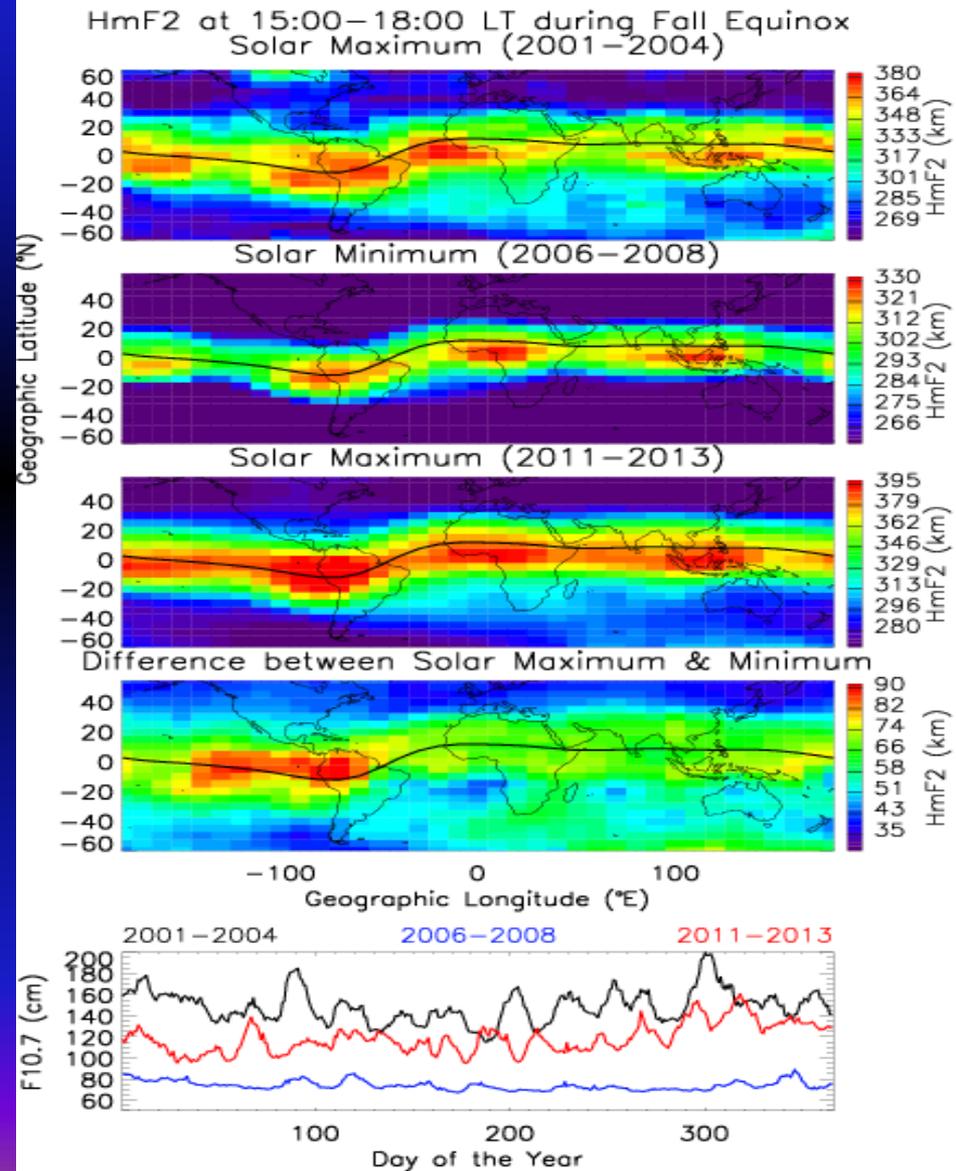
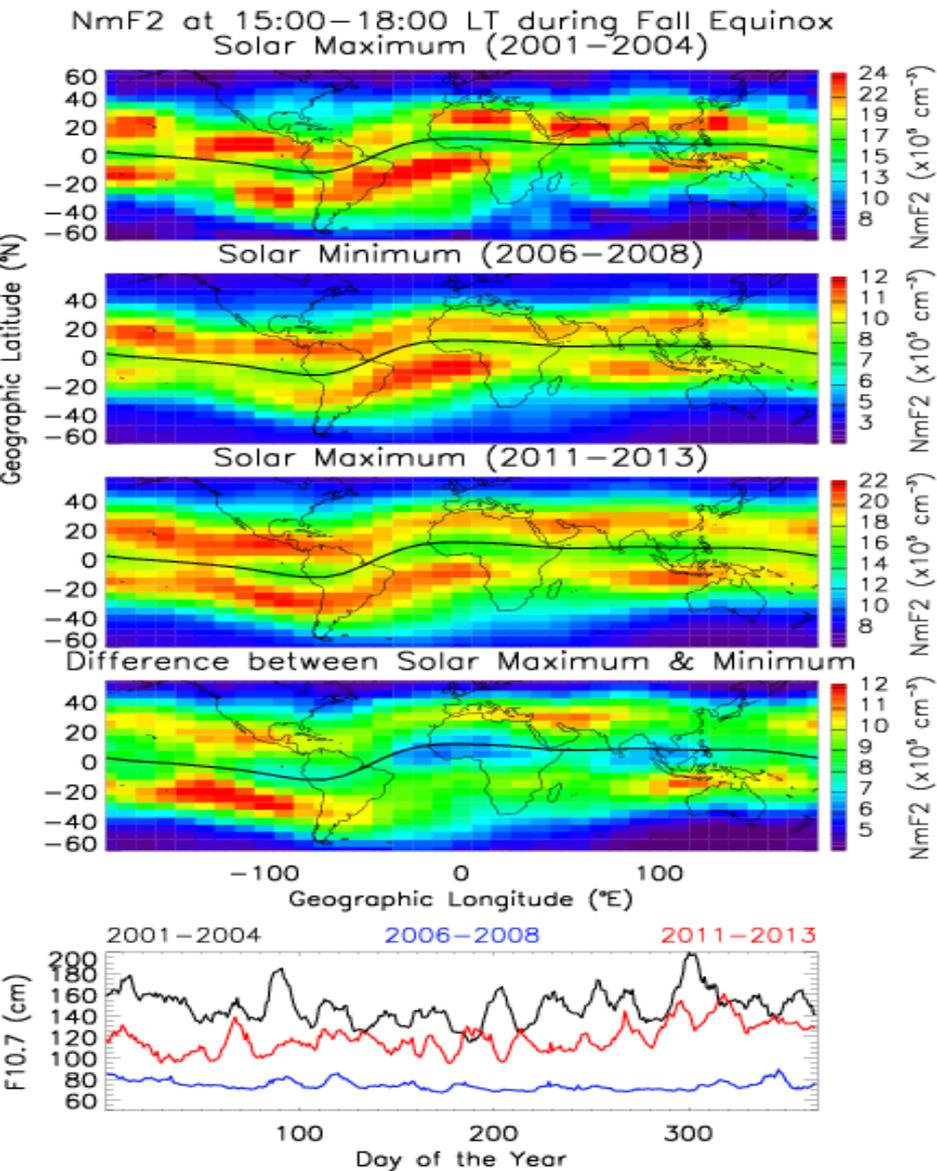
Fall Equinox



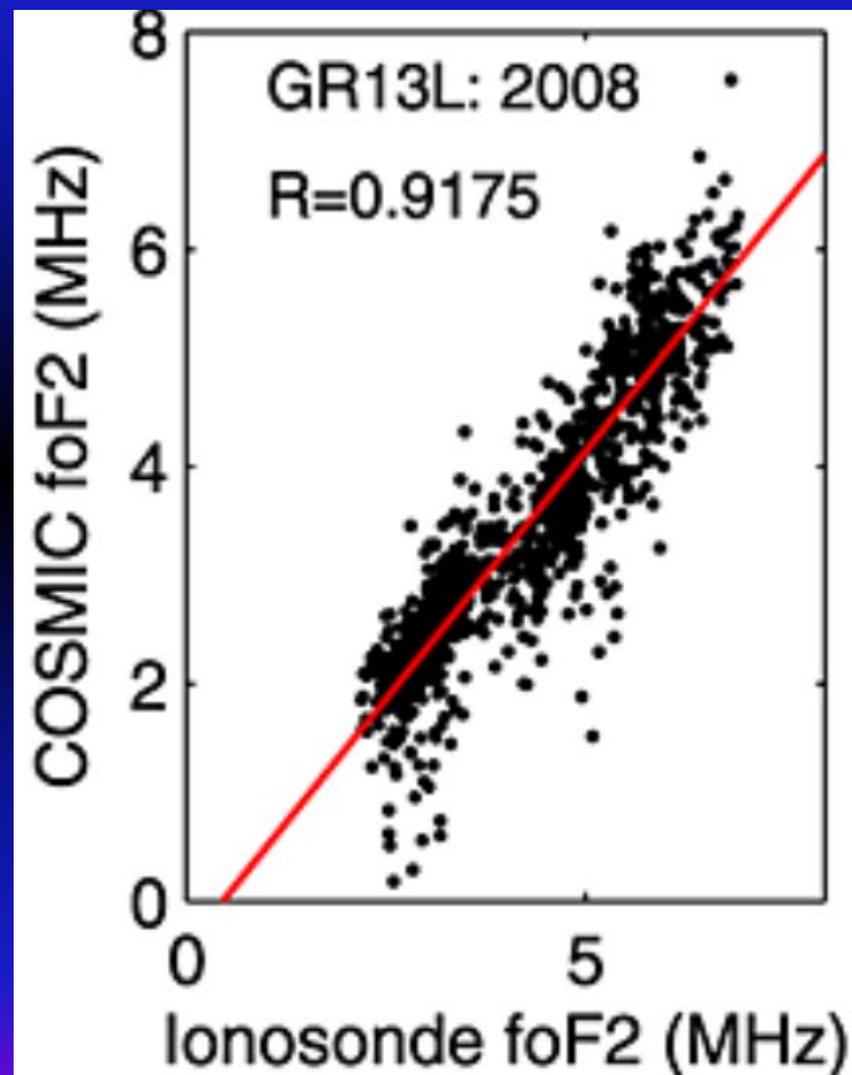
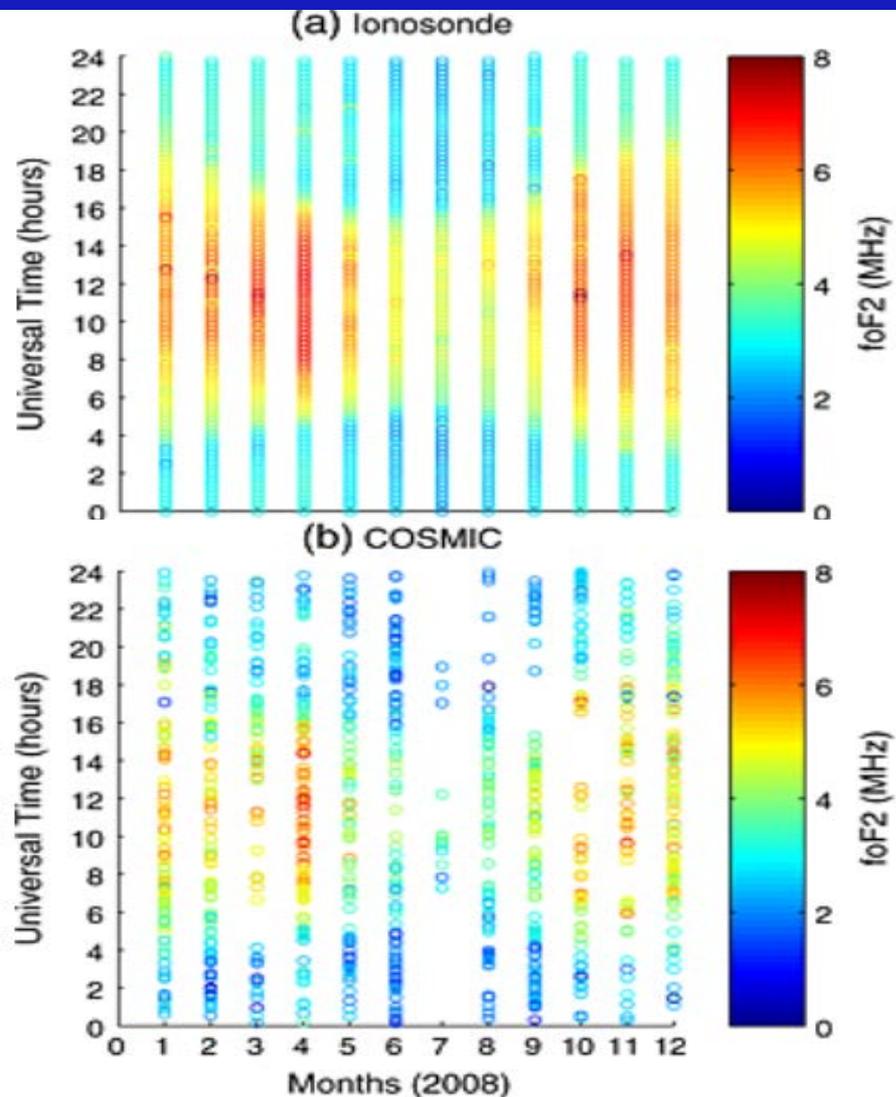
Winter



Global Statistical Studies using LEO Occultation

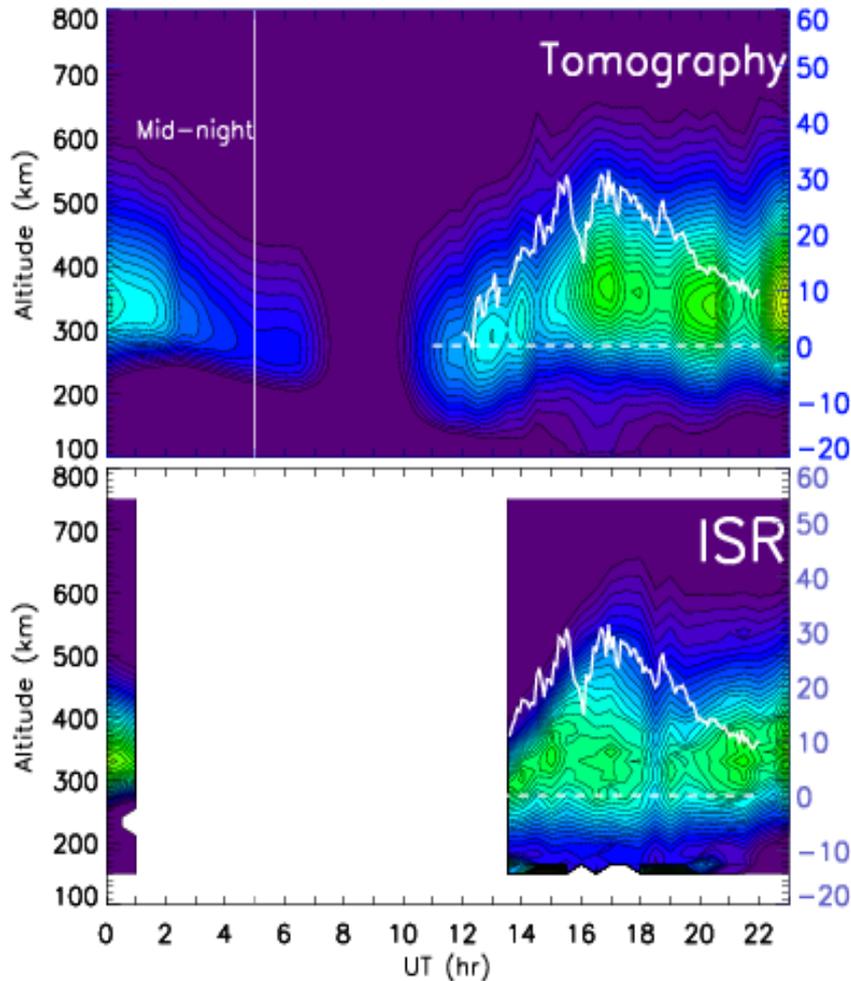


Validation of LEO Occultation Profiles with Ionosonde Measurements

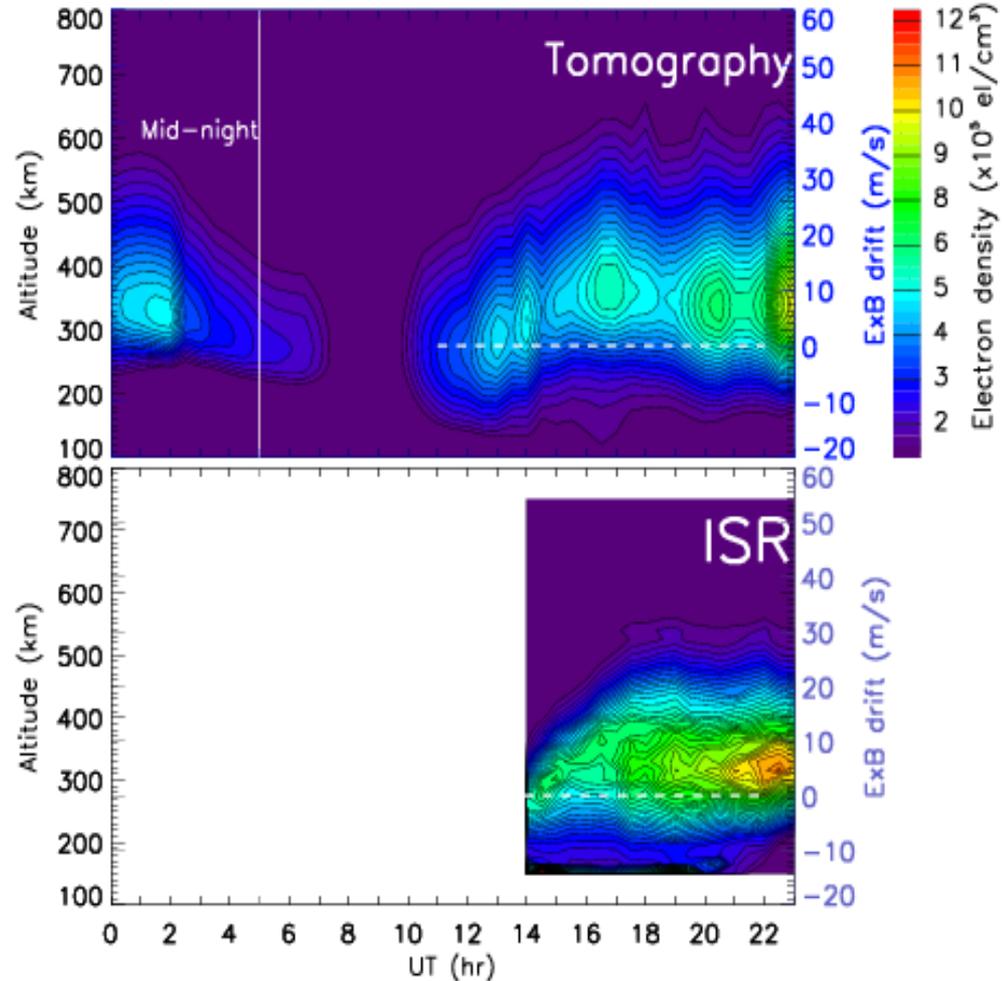


Validation of LEO Occultation Profiles with ground-based tomography results

Reconstructed Density on October 29, 2008
at Lat = -12.0°N and Lon = 290°E

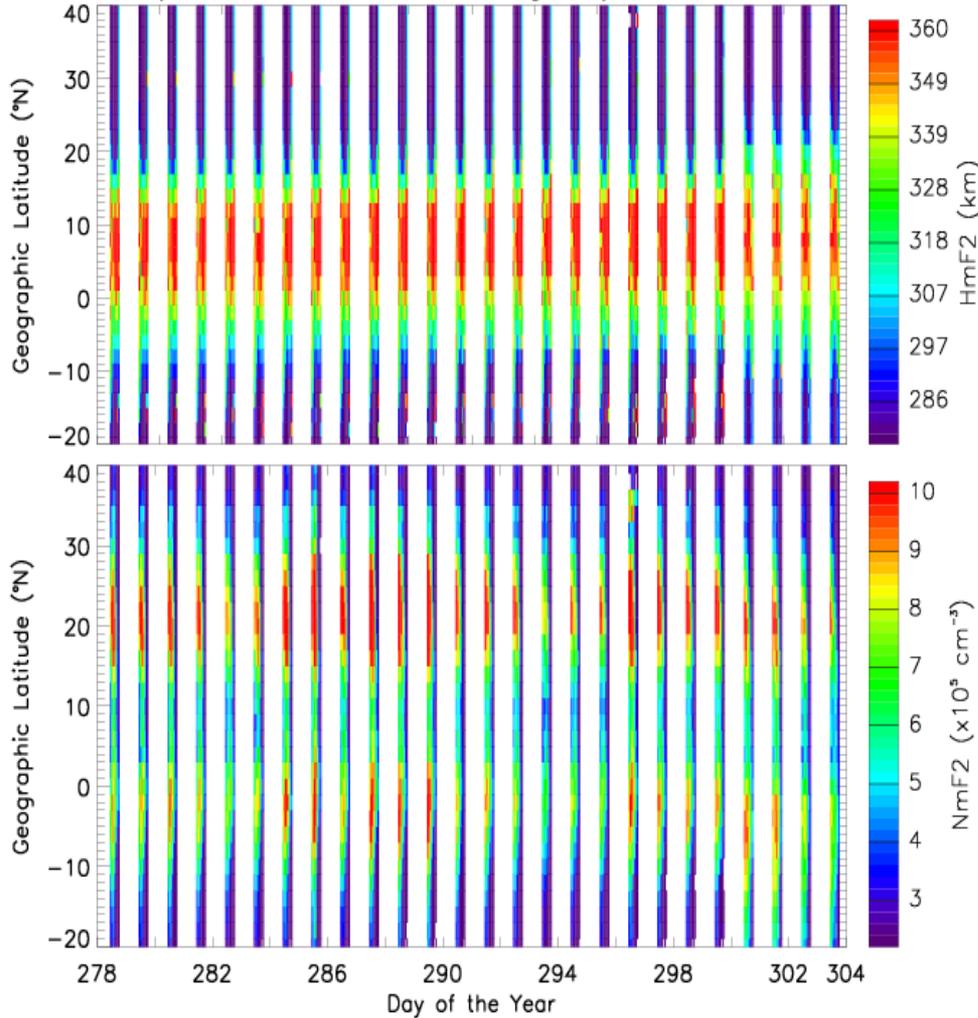


Reconstructed Density on October 28, 2008
at Lat = -12.0°N and Lon = 290°E

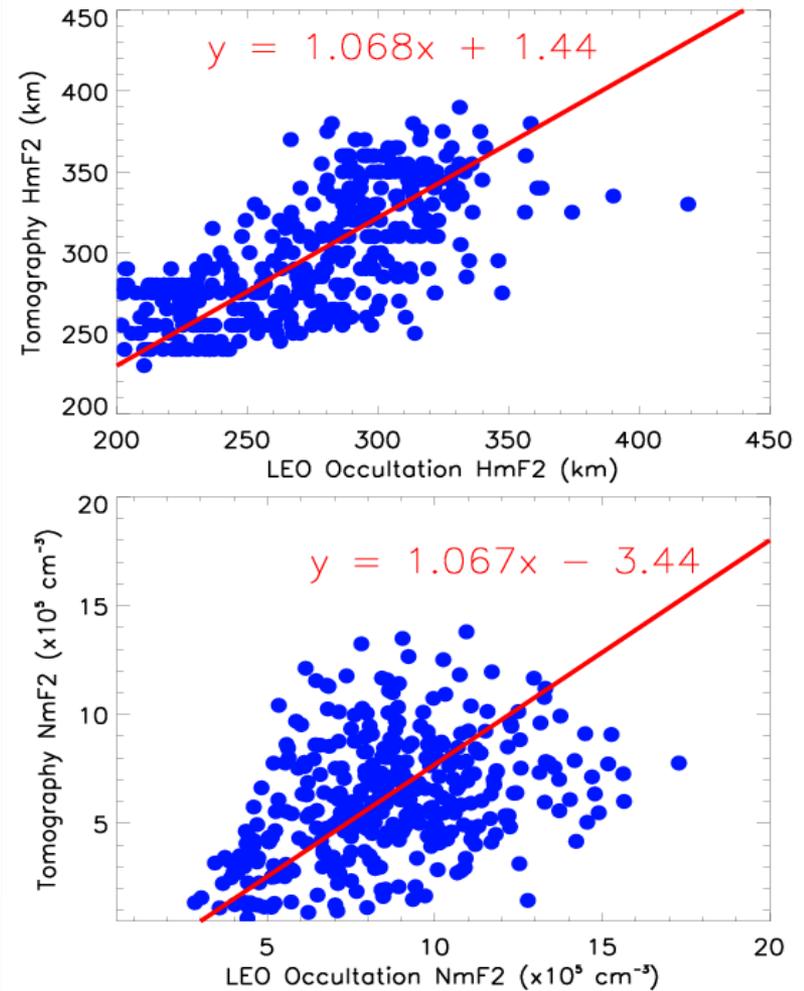


Comparison of F-layer peaks from Ground-based Tomography and LEO Occultation

F-layer peak values from Tomography out put in 2008

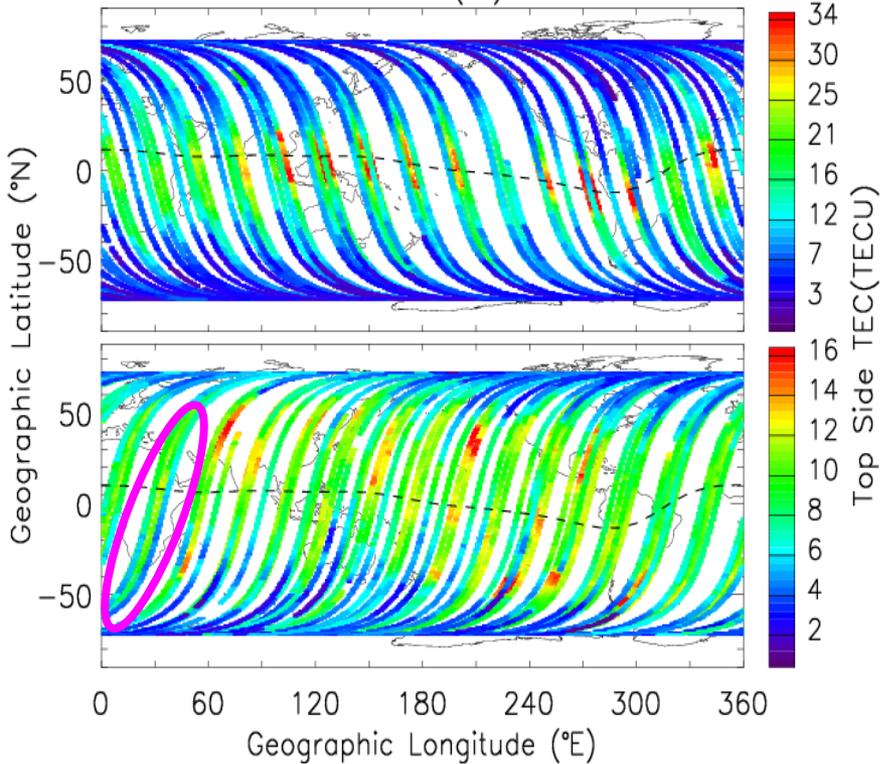
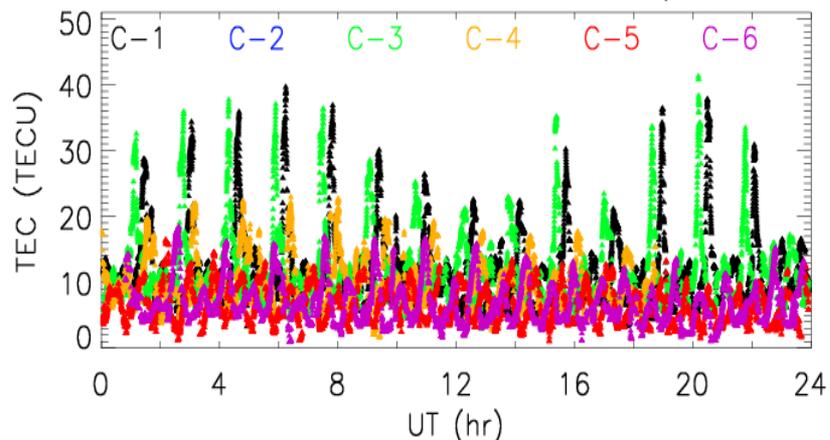


F-layer Peak values comparison in October 2008 between 30°S–30°N at 11:00–18:00LT

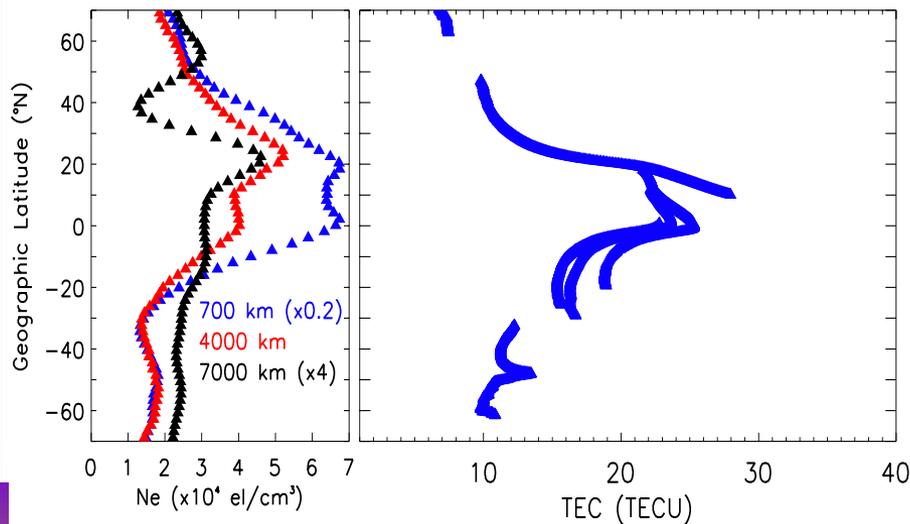
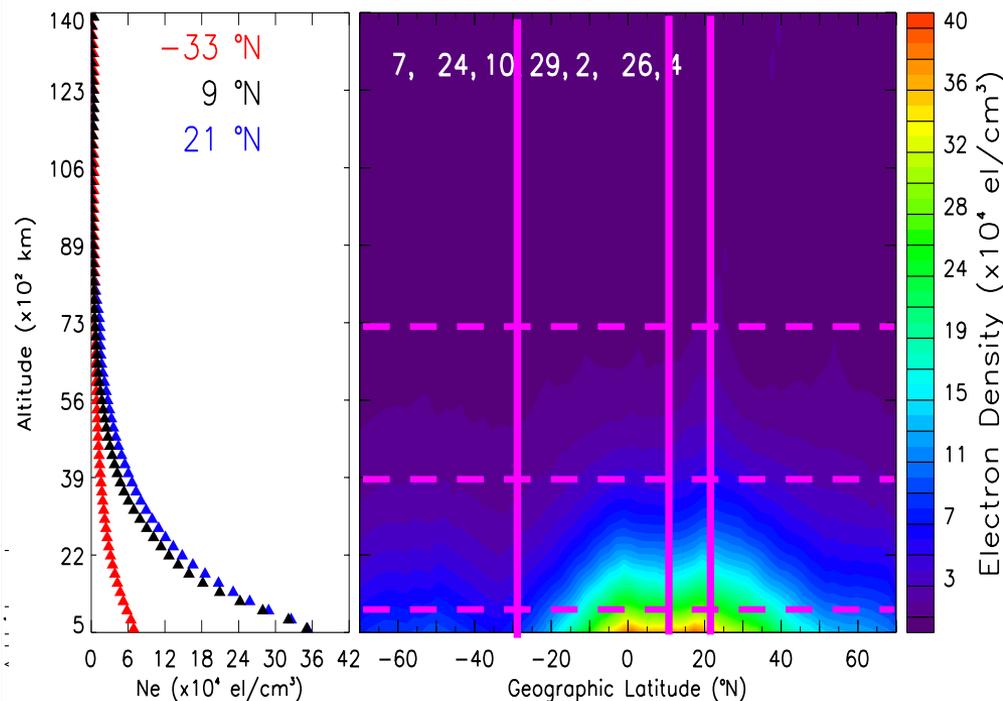


Tomographic Application on Topside LEO TEC

COSMIC TEC data on March 24, 2007

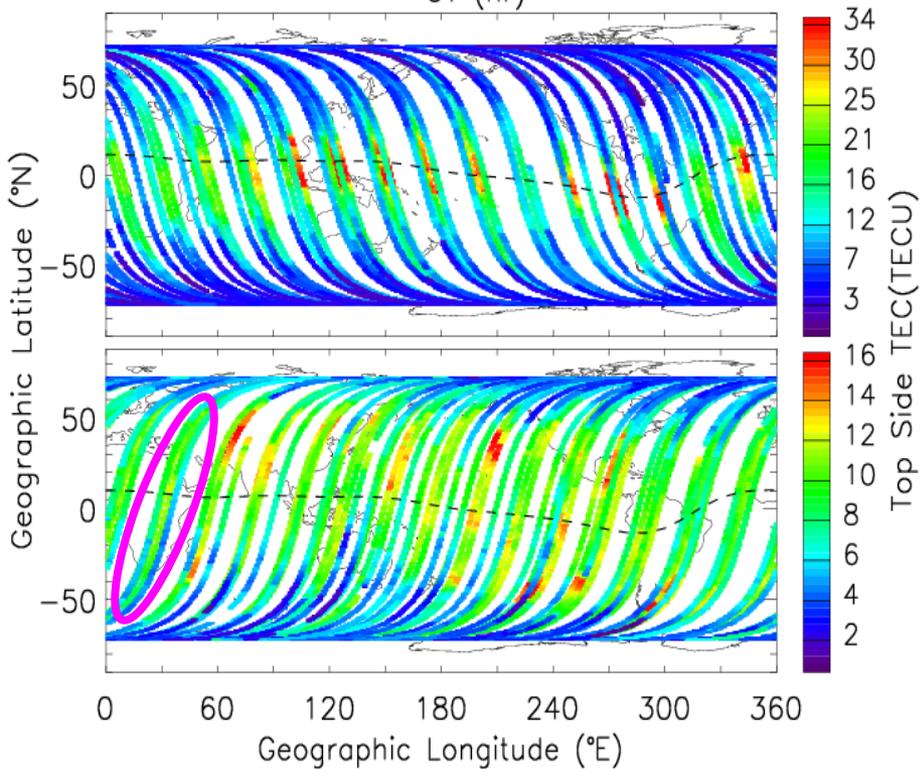
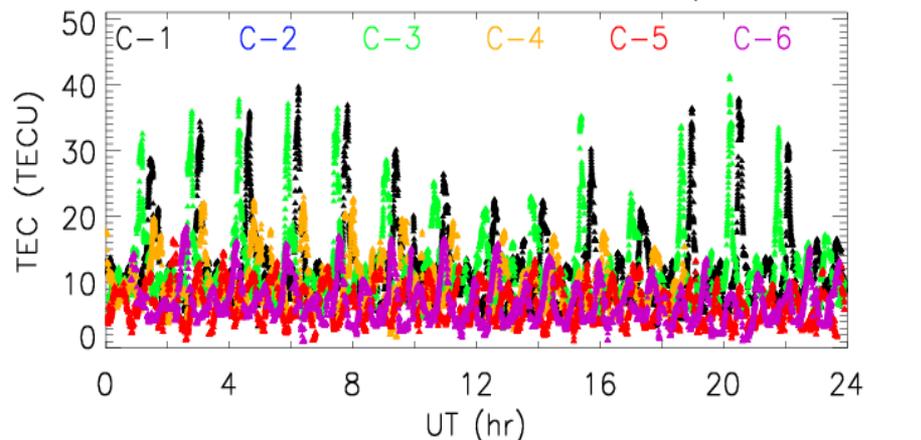


COSMIC (C3) (05:52-06:46UT on 03/24/2007)

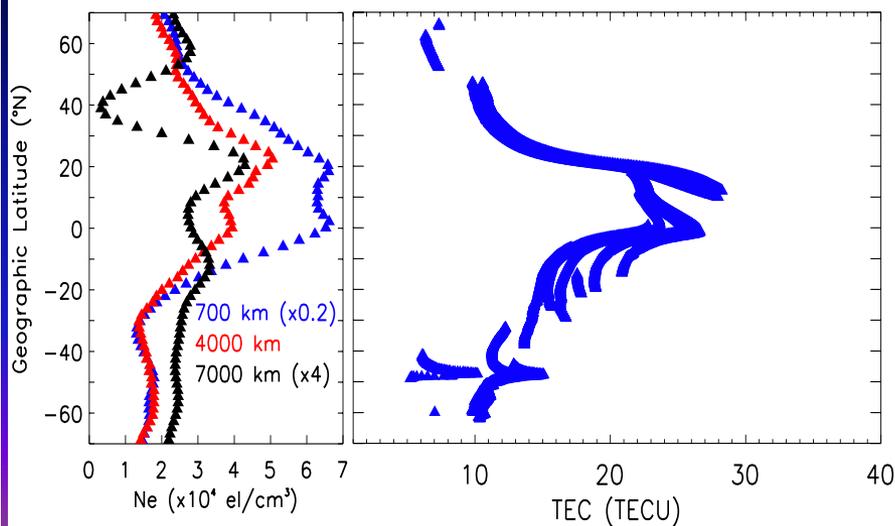
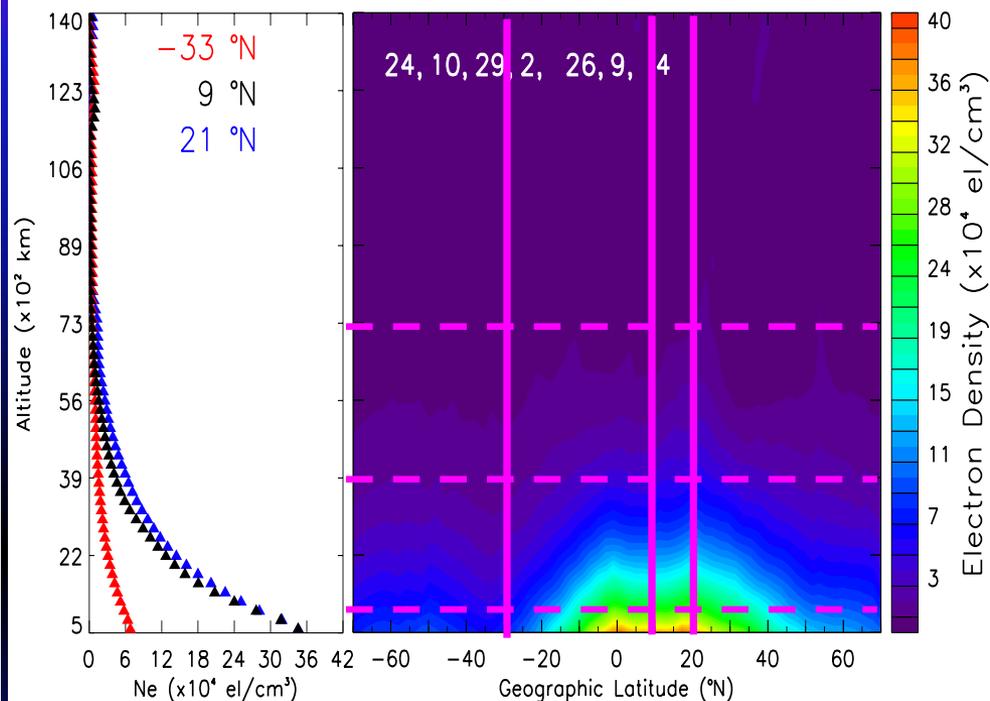


Tomographic Application on Topside LEO TEC

COSMIC TEC data on March 24, 2007

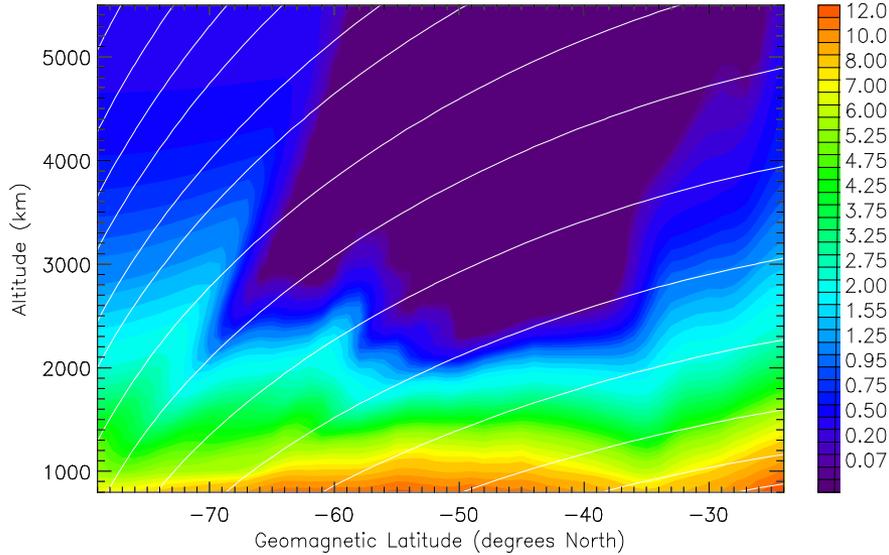


COSMIC (C1,3,4) (05:52-06:46UT on 03/24/2007)

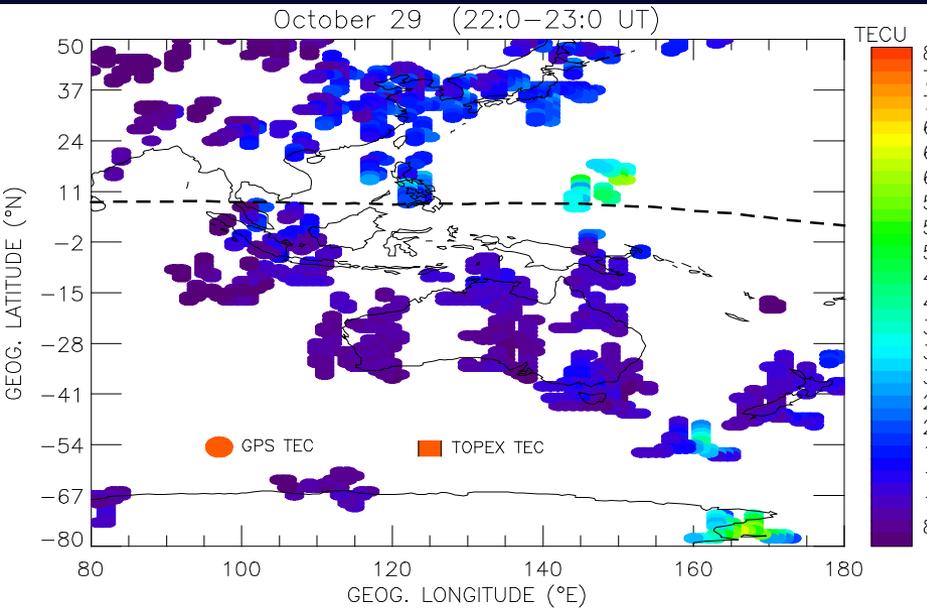
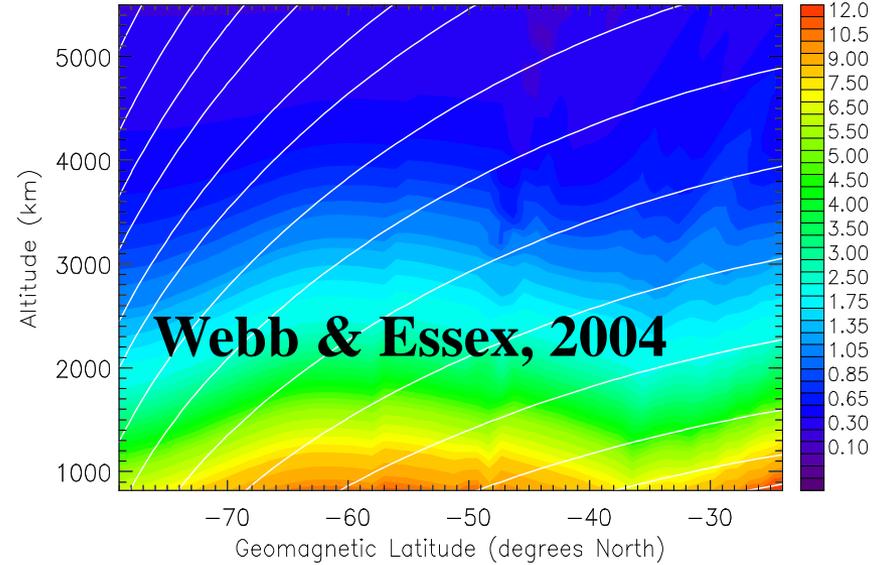


Tomographic Application on Topside LEO TEC

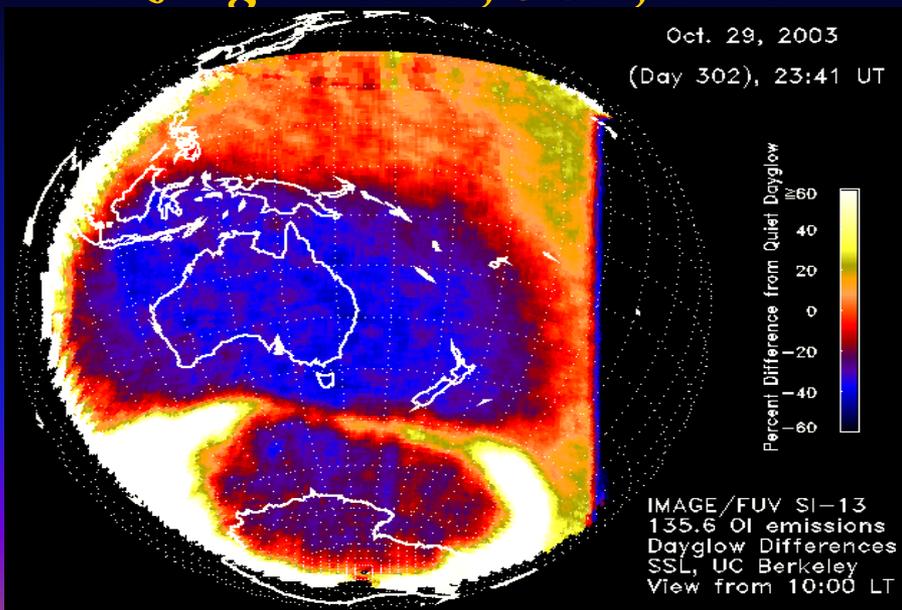
Reconstructed Electron Density ($\times 10^4$ el/cm³)
For FedSat pass at 22:20 UT on October 29, 2003



Model electron density ($\times 10^4$ el/cm³)
on 29 October 2003 at 22:20 UT

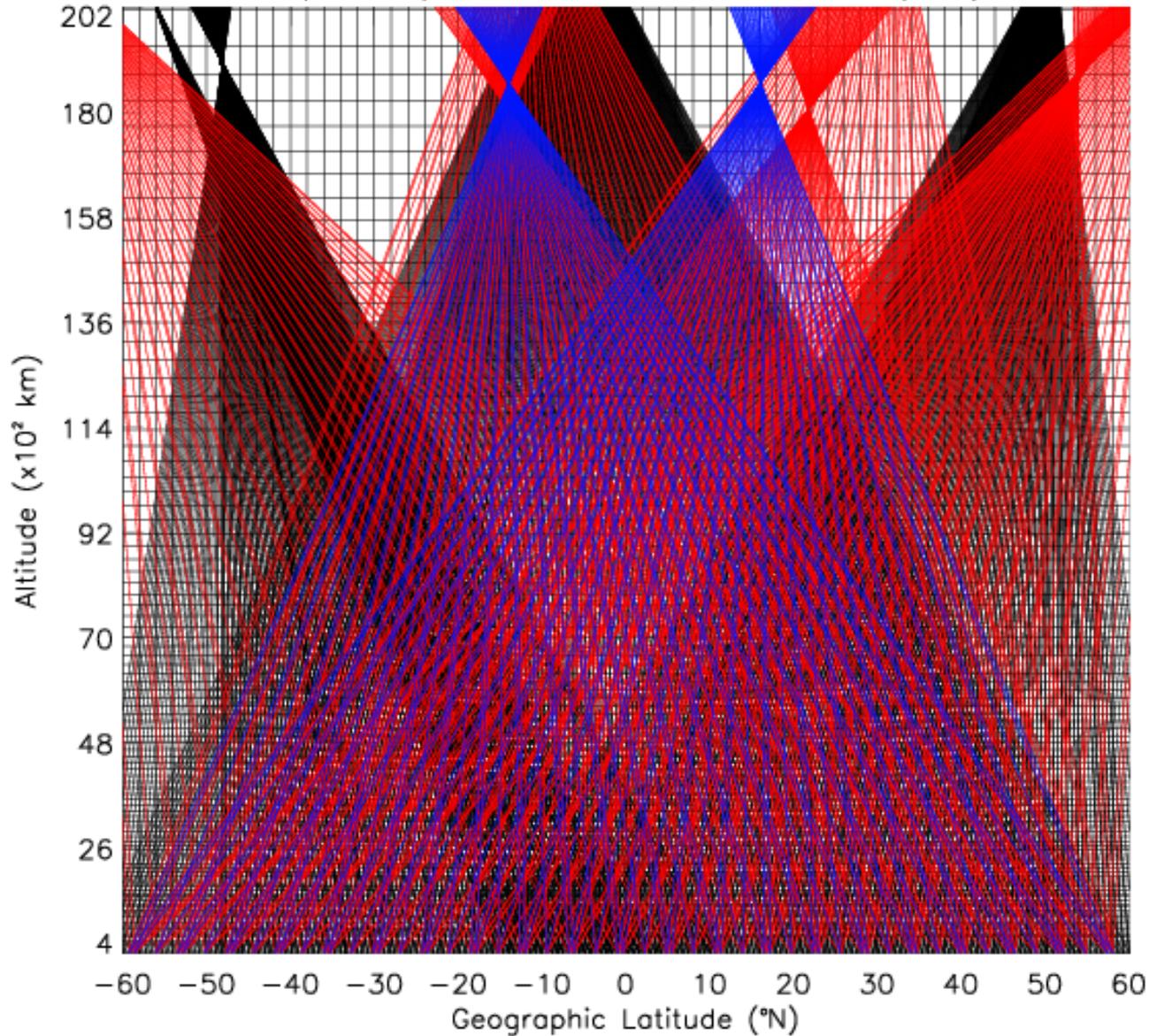


Yizengaw et al., JGR, 2005



Desired Future LEO Satellites' Data

CHAMP pass b/n 12:20–12:55 UT on 08/09/2010



GPS

GPS+GLON

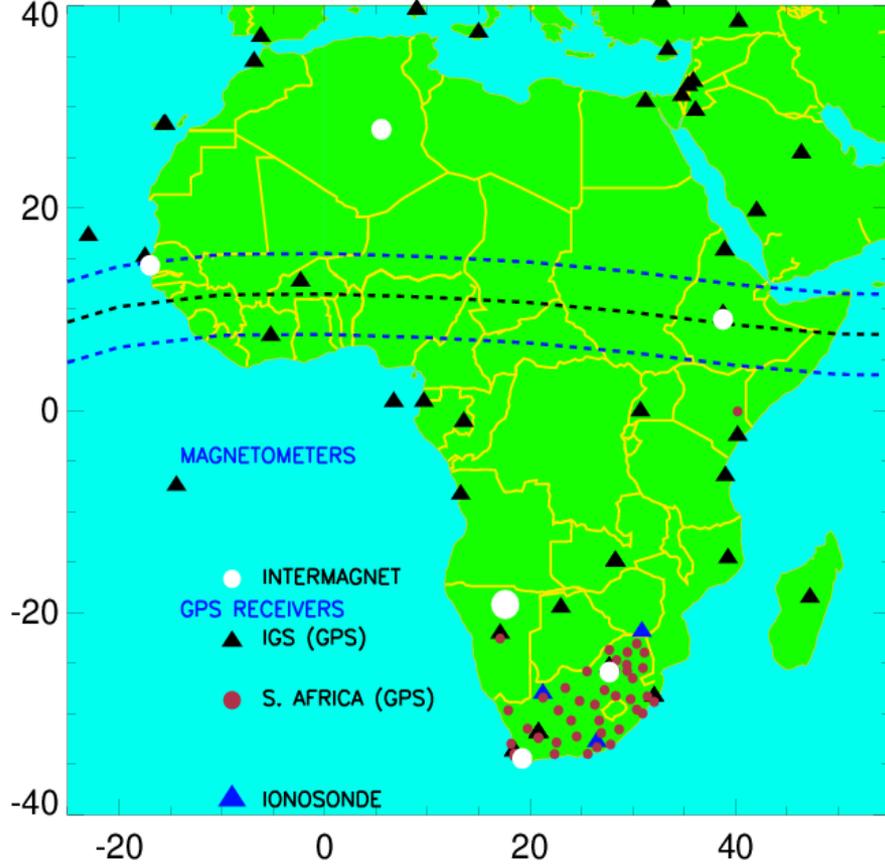
GPS+GLON+GAL

Summary and Conclusion

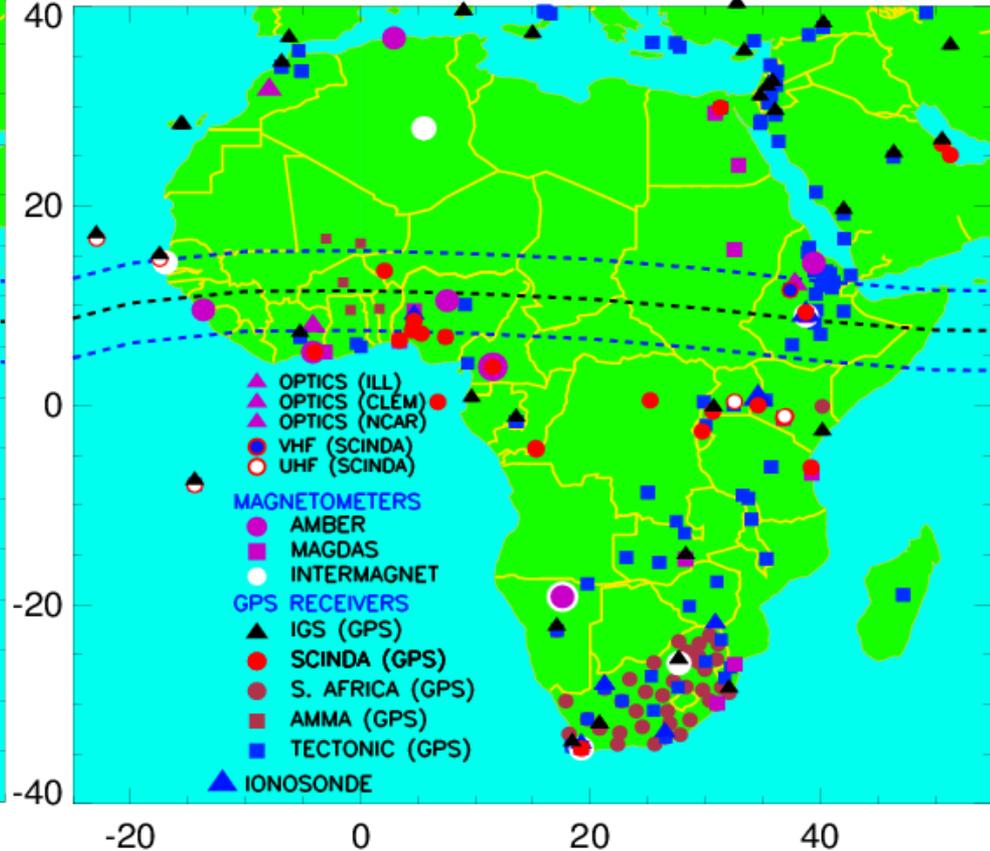
- There is no doubt that the LEO GPS data provide significant contribution to the mitigation effort of the space weather impact on communication and navigation systems.
- Topside tomographic imaging technique gives us good opportunity to view the detail structure of topside ionosphere and plasmasphere which can not be possible from the ground due to F-region density dominance.
- Having multi-channel GPS receivers onboard future LEO satellites will allow us to obtain significantly high resolution global ionospheric structure, which is very important to understand the space weather impact on our communication and navigation systems.

General Instrumentation in Africa

Space Science Instruments in Africa: 5 years ago



Space Science Instruments in Africa: Now

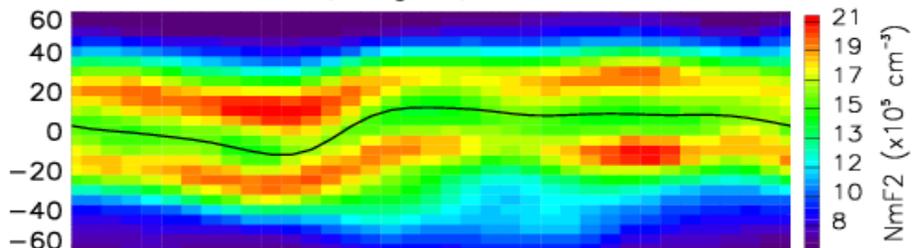


Eight Years ago

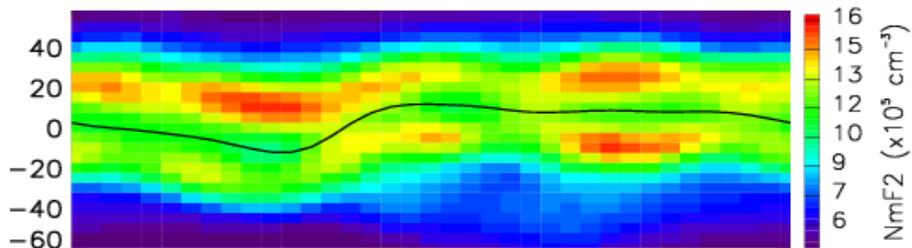
This Now!

Thank you!

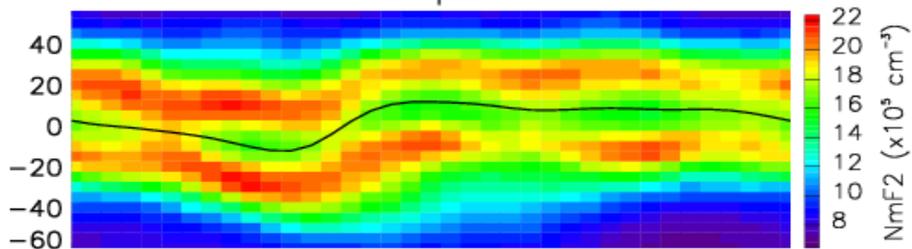
Global NmF2 at 15:00–18:00 LT in 2011–2013
Spring Equinox



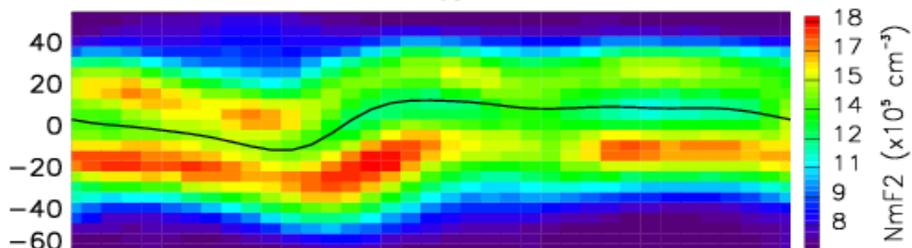
Summer



Fall Equinox

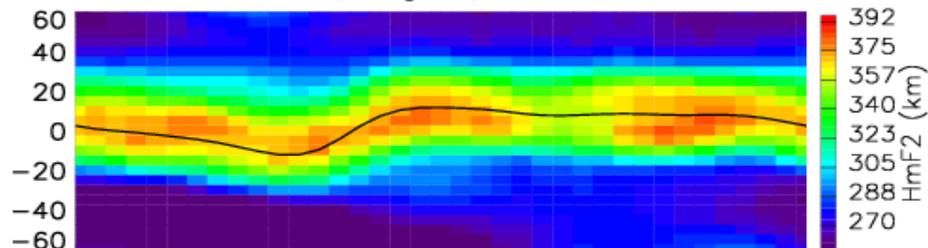


Winter

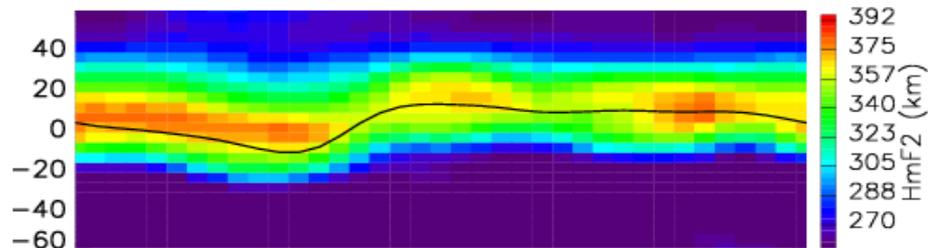


Geographic Longitude ($^{\circ}\text{E}$)

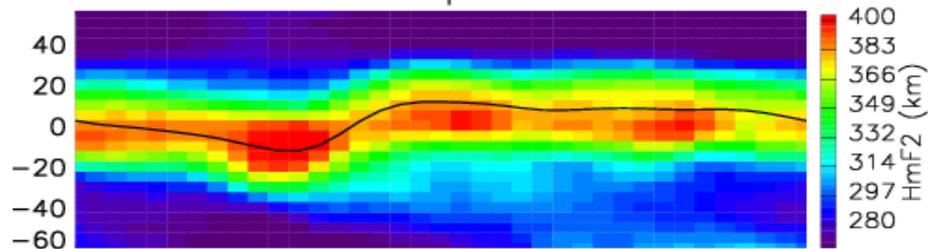
Global HmF2 at 15:00–18:00 LT in 2011–2013
Spring Equinox



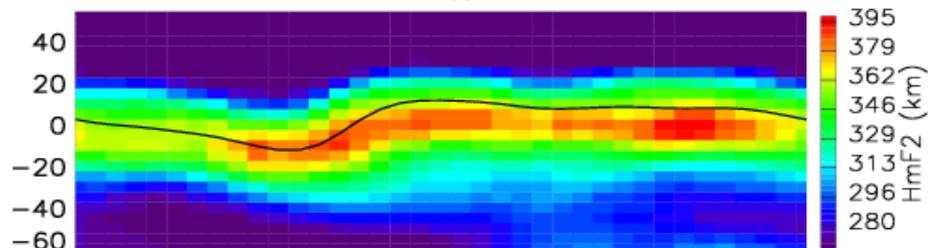
Summer



Fall Equinox



Winter

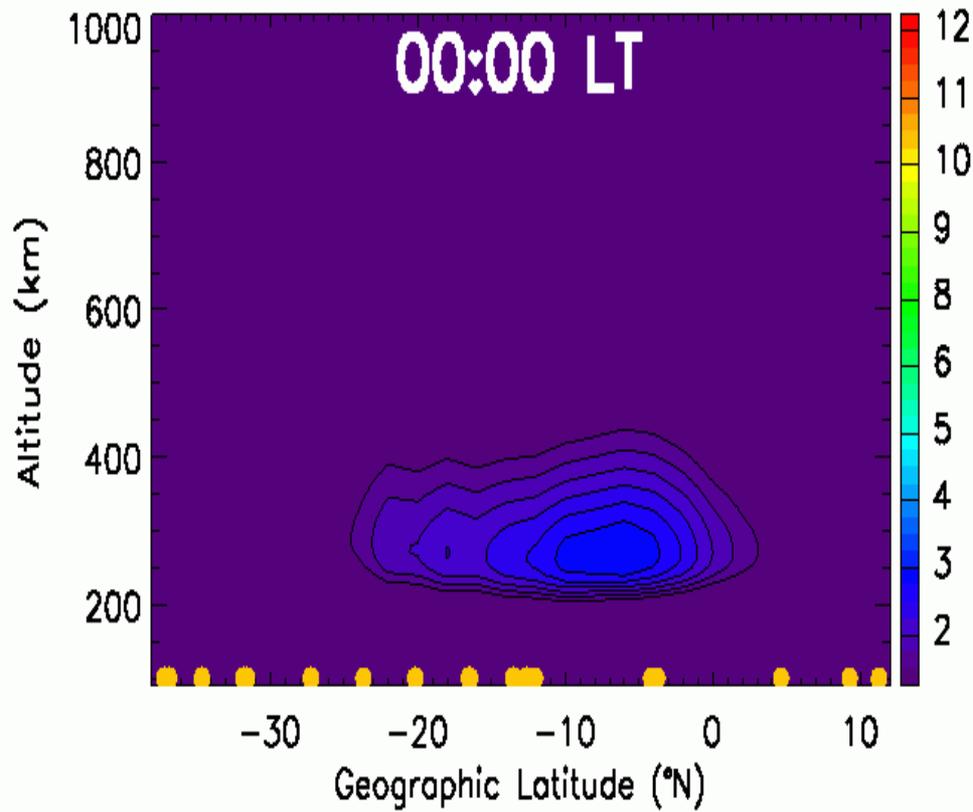


Geographic Longitude ($^{\circ}\text{E}$)

Tomographically reconstructed density profiles

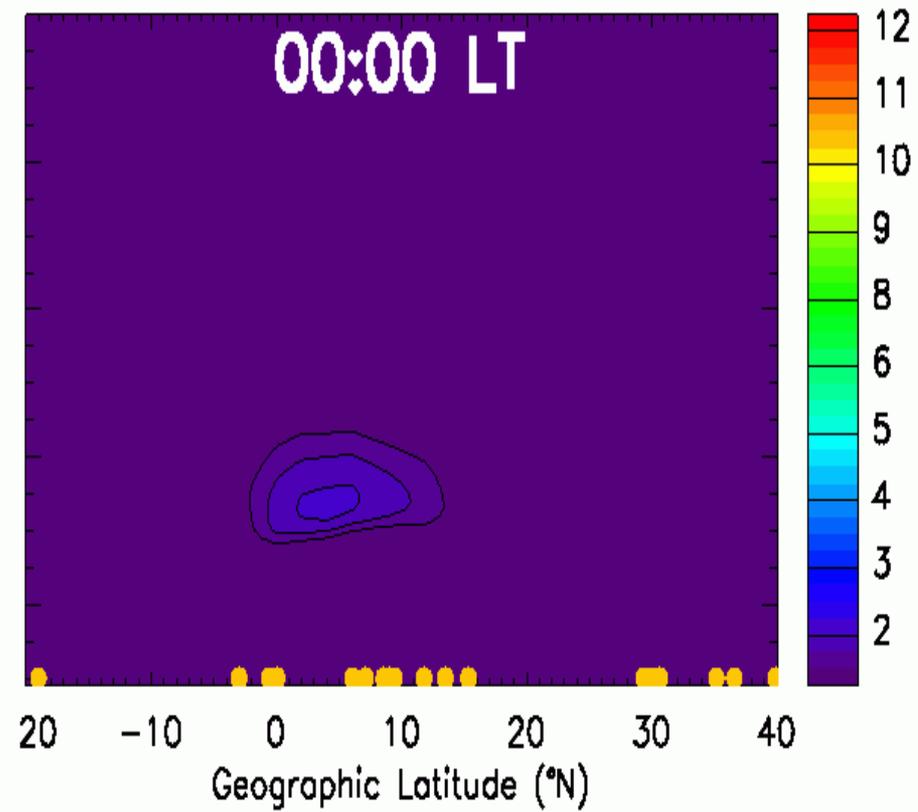
West America

Reconstructed Electron Density (10^5 el/cm^3)
at 05:00 UT on October 9, 2008

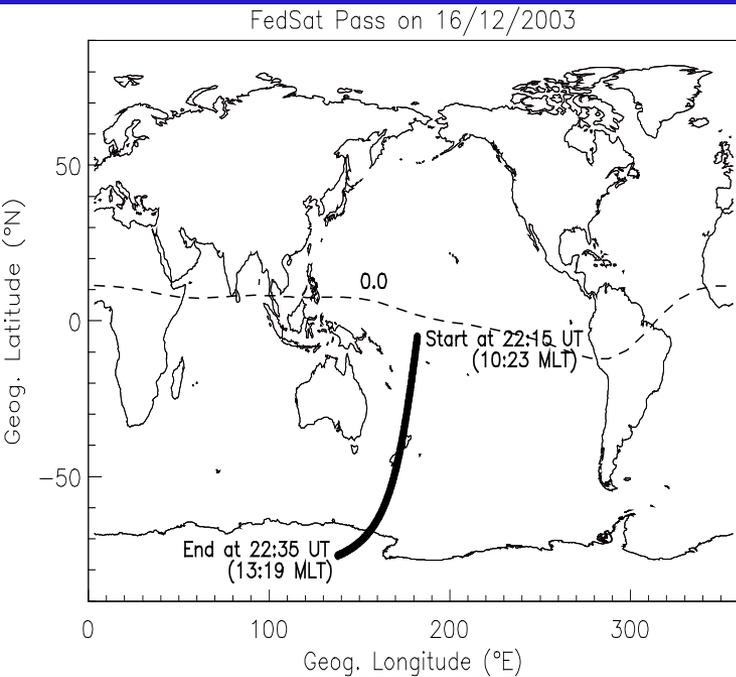


East Africa

Reconstructed Electron Density (10^5 el/cm^3)
at 21:00 UT on October 9, 2008

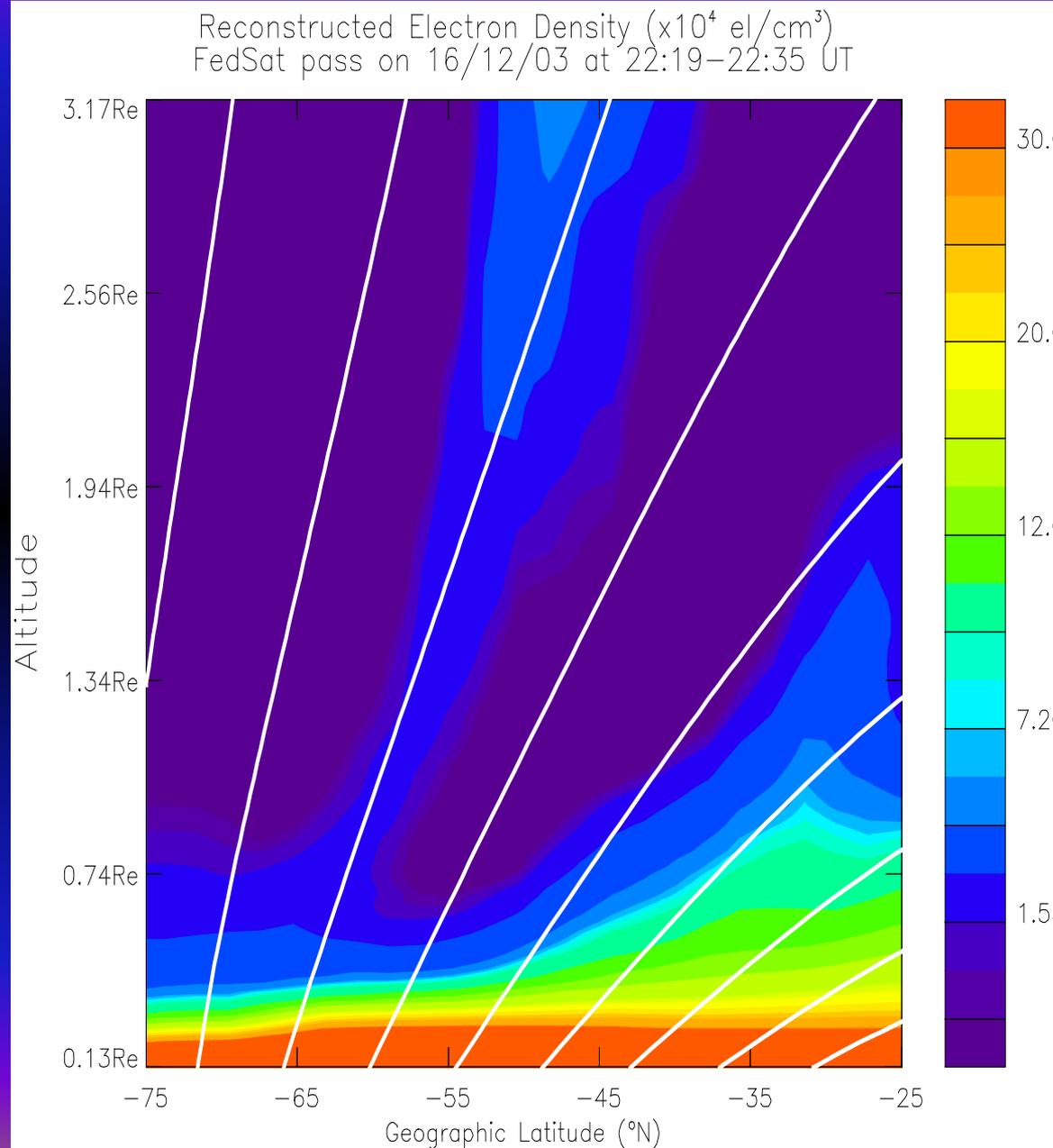


Tomographic Application on Topside LEO TEC



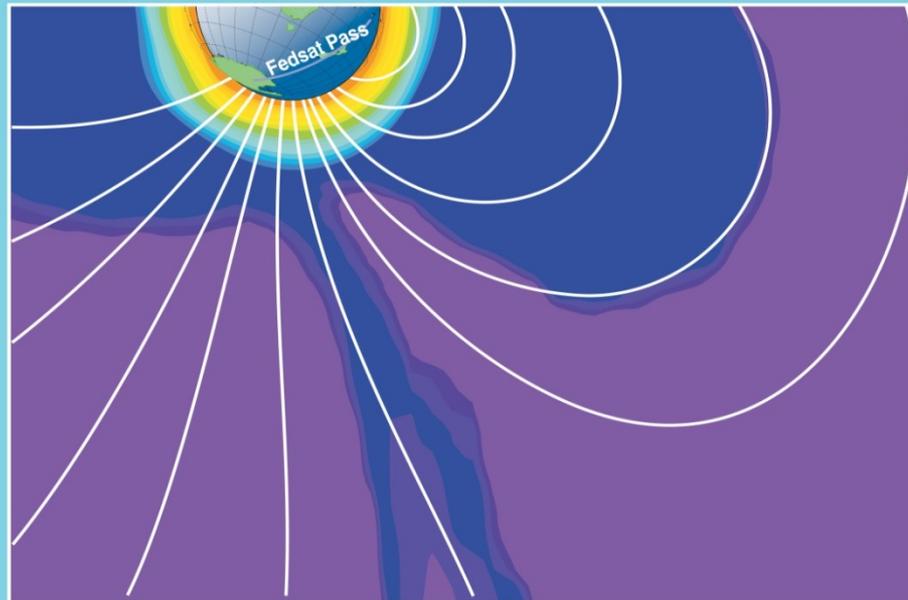
Yizengaw et al., GRL, 2006

Tomographically imaged ion outflow: from its source to its sink region.



Geophysical Research Letters

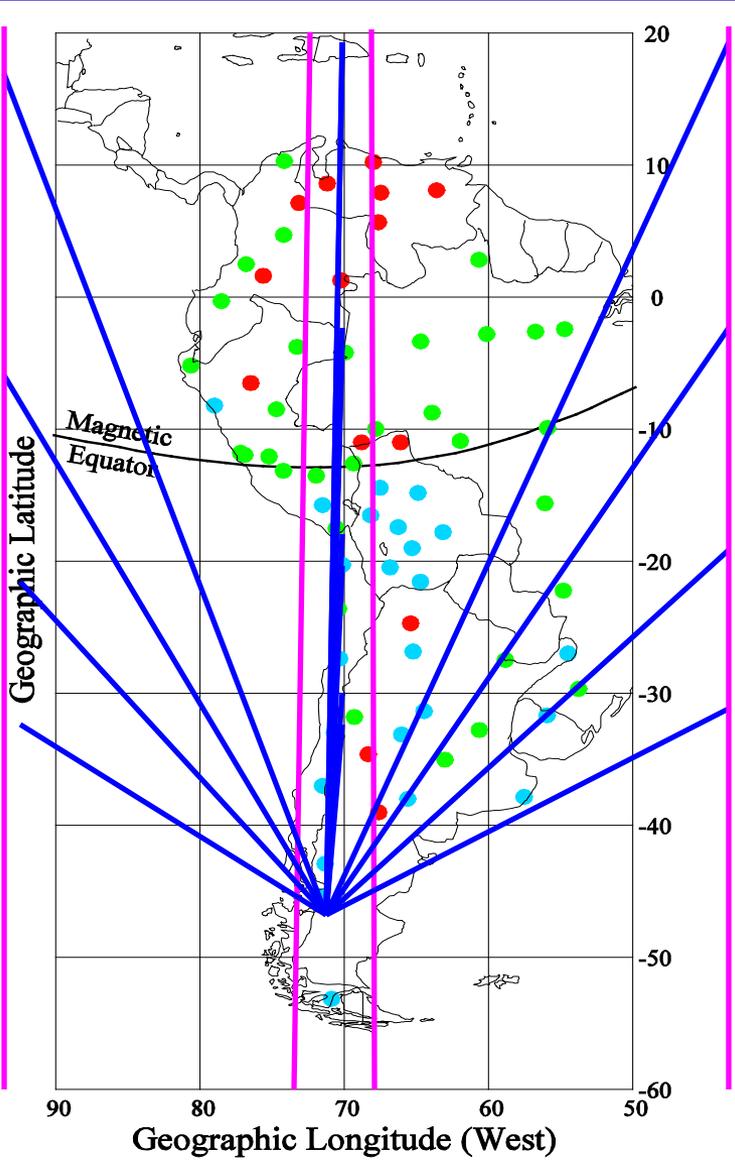
28 OCTOBER 2006
Volume 33 Number 20
American Geophysical Union



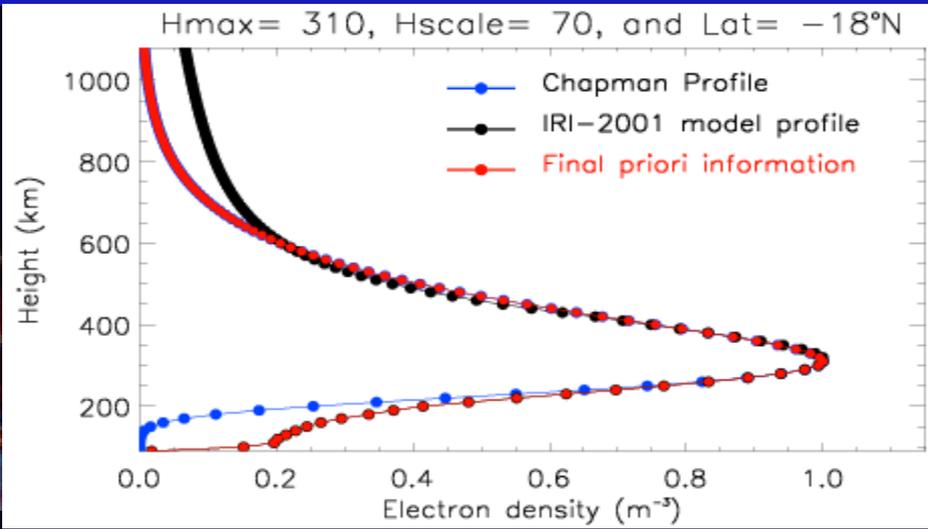
Yizengaw et al., GRL, 2006

First tomographic image of ionospheric outflows • Detailed analyses of the October 2005
Pakistan earthquake • China's surface temperatures to increase despite decrease in insolation

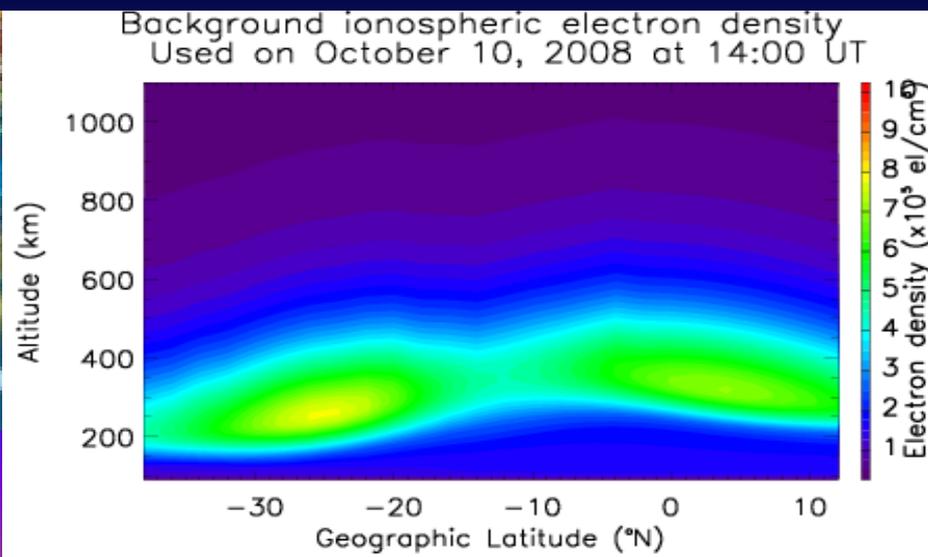
Resource for Tomography



Harmonic background profiles



Background profiles



Courtesy to Valladares

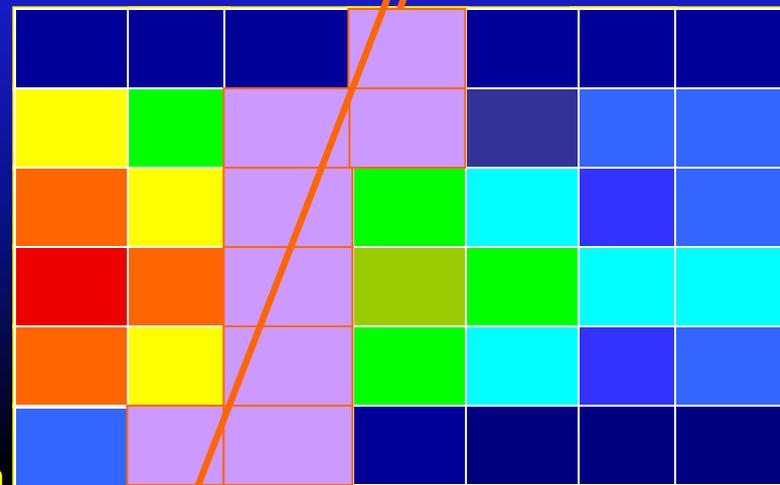
CIT Inversion technique

Q Divide the imaging region in to number of pixels P_i

$$TEC_i = \int_{P_i} N_e ds = \sum_{j=1}^N d_{ij} n_j + E$$

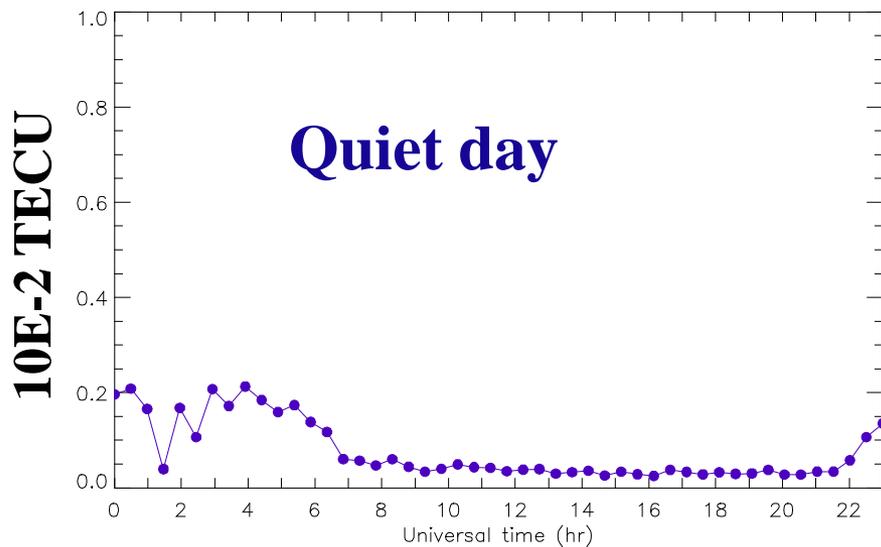
$$TEC_{guess} = \sum_{j=1}^N d_{ij} (n_{gs})_j$$

1000 km



100 km

Goodness of fit between measured and model TEC values on 18 August 2003



Goodness of fit between measured and model TEC values on 31 March 2001

