# Radio occultation diagnostics and ionosphere behaviour

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June 3, 2016

# Outline

- Radio occultation method
- Ionospheric diagnostics - The Main Ionospheric Trough

# Radio occultation method

- remote sensing technique measuring signal form the transmitter to the receiver
- the signal pass through the atmosphere and gets refracted or bent along the way
- magnitude of the refraction depends on the gradient of refractivity, which depends on the vertical density gradient
- GNSS-RO technique makes use of radio signals transmitted by the global positioning system (GPS) satellites
- vertical scanning of successive layers of the atmosphere (the GPS and LEO satellite satellite position changes)
- spherical symetry, Abel transform -> refraction index

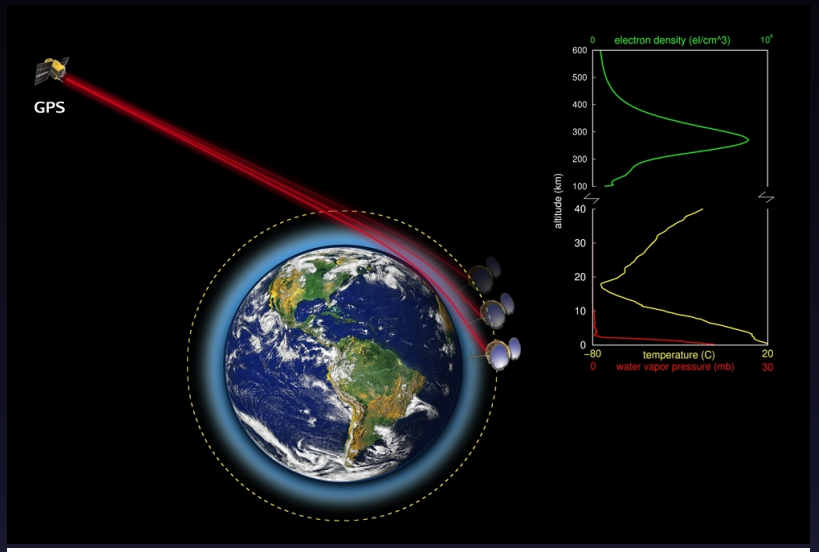
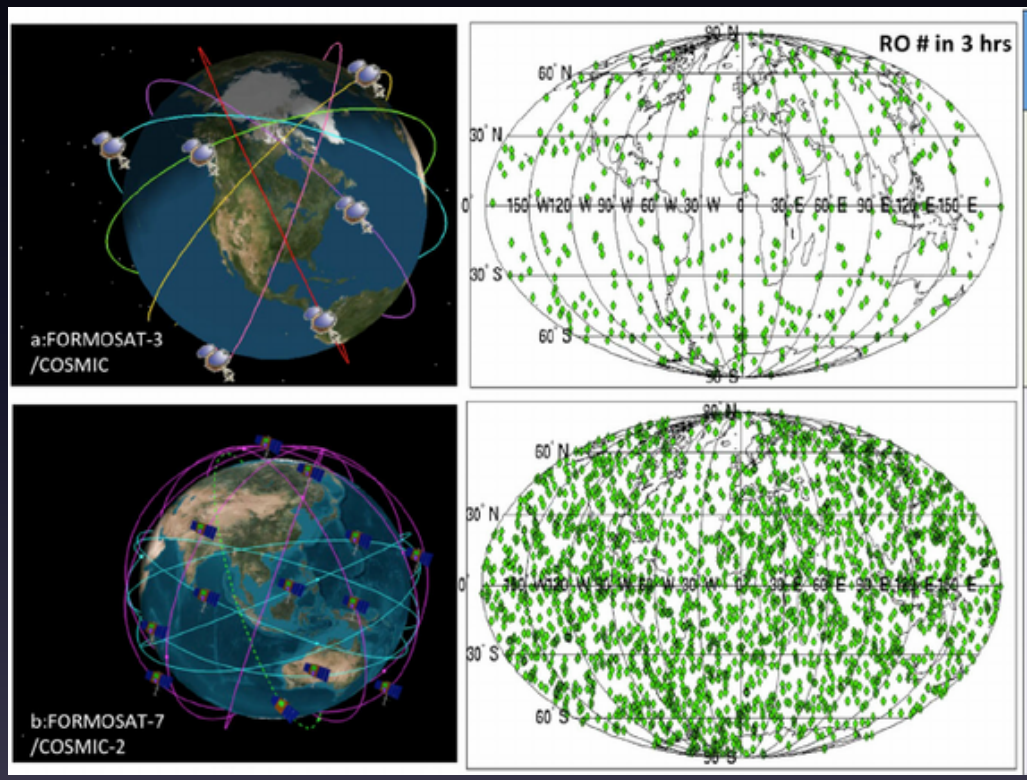



*Figure 3. RO event geometry*

Img credits: COSMIC/UCAR

# FORMOSAT-3/COSMIC

Six microsatellites using radio occultation method providing informations about meteorological conditions in the Earth's atmosphere




| RO Payload | Satellite | Space Weather Payload |
|---|---|---|
| IGOR<br>GPS<br>~2,000 per day | 6 LEO satellites<br>~72° inclination<br>~800 km altitude<br>~61 kg<br>>0.68 for 2 years<br>launched 2006 | TIP<br>TBB |
| TriG<br>GPS+<br>GLONASS<br>>8,000 tropo per day<br>>12,000 iono per day | First Launch | |
| | 6 LEO satellites<br>~24° inclination<br>~520 km altitude<br>~215 kg<br>>0.66 for 5 years<br>~launch 2016 | IVM<br>RF Beacon |
| | Second Launch | |
| | 6 LEO satellites<br>~72° inclination<br>~720 km altitude<br>~215 kg<br>>0.66 for 5 years<br>~launch 2019 | TBD |

Comparison between (a) FORMOSAT-3/COSMIC and (b) FORMOSAT-7/COSMIC-2 in (left) constellation, (middle) RO events during 3 h, and (right) key parameters. Credits Yue, X. et al.

# Analysis of Main Ionospheric Trough with COSMIC data

- depleted region of ionospheric plasma typical for the topside ionosphere
- its variability strongly affects the propagation of different natural and artificial signals
- strongly dependent on sesonal and geomagnetic conditions
- mostly night-time phenomenon
- characteristic shape, extended in longitudes but narrow in latitudes
- storm-phase dependent structure, very sensitive for geomagnetic conditions
- its location is condsidered to coincide with the plasmapause position [E. Yizengaw et al.(2005)].

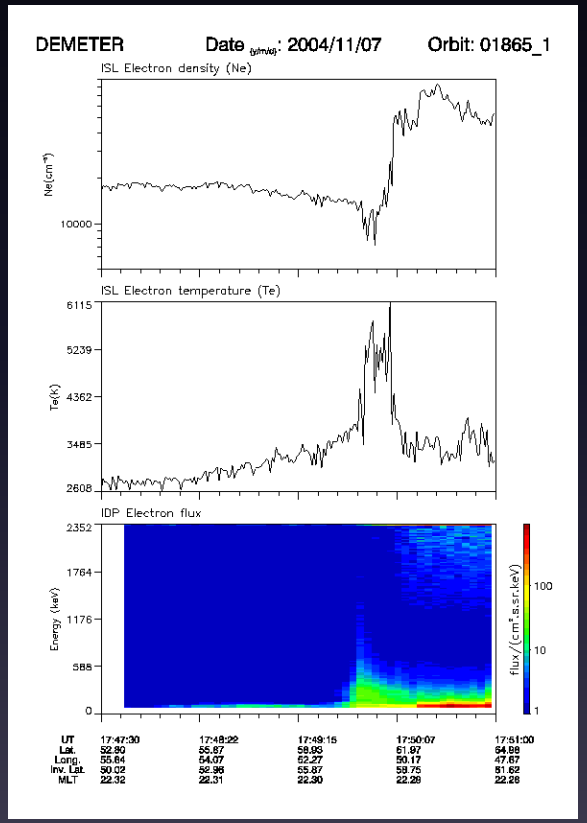



Figure: The main ionospheric trough seen from DEMETER data. Electron density: top, electron temperature-middle. Bottom figure: energy flux.

Data selection

- night-time occultation selected
- data divided in two sets: for low and high geomagnetic conditions (Kp index)
- selection of a specific altitude
- data presented in geomagnetic coordinates

# Seasonal behaviour of the main ionospheric trough

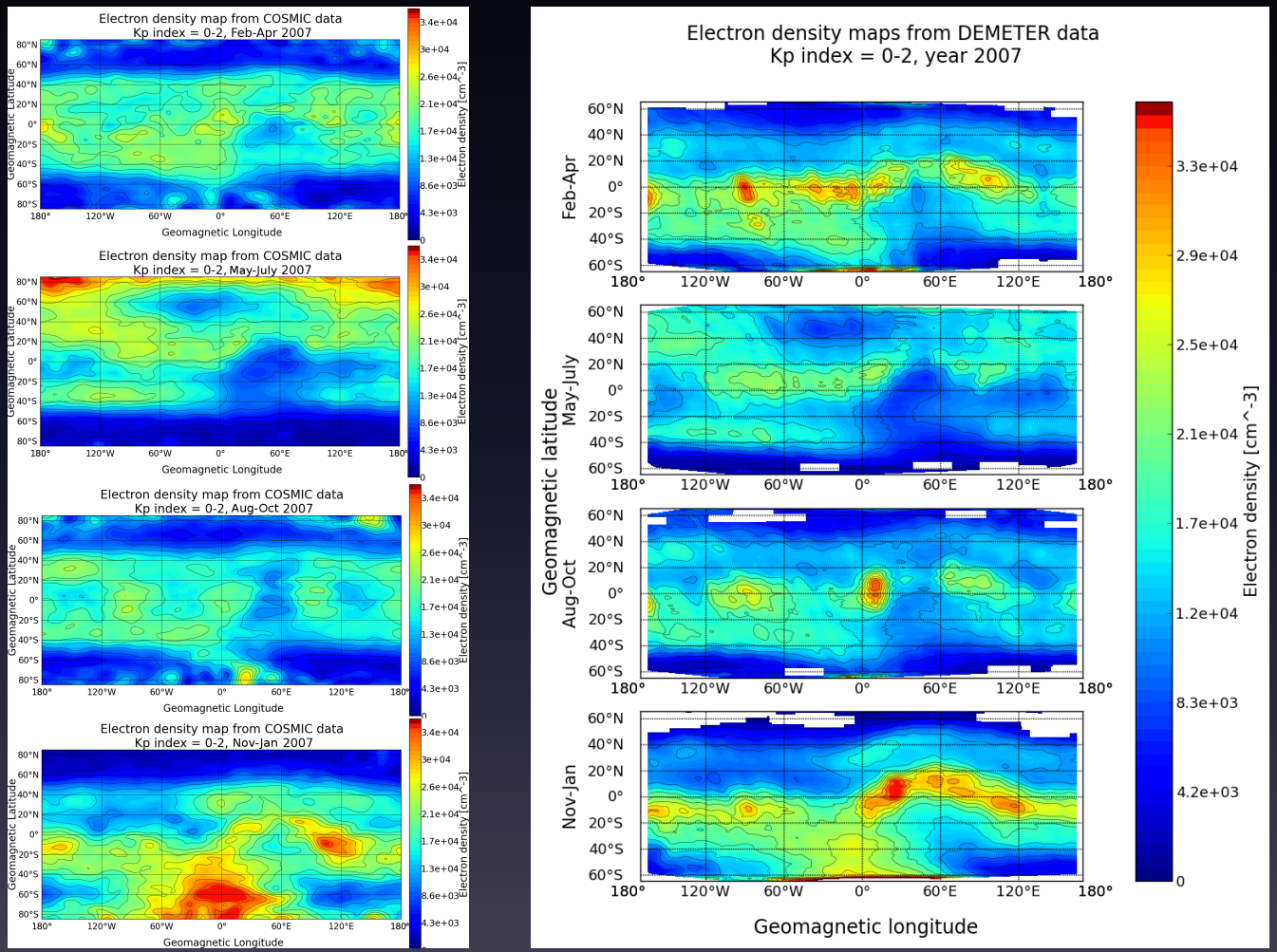
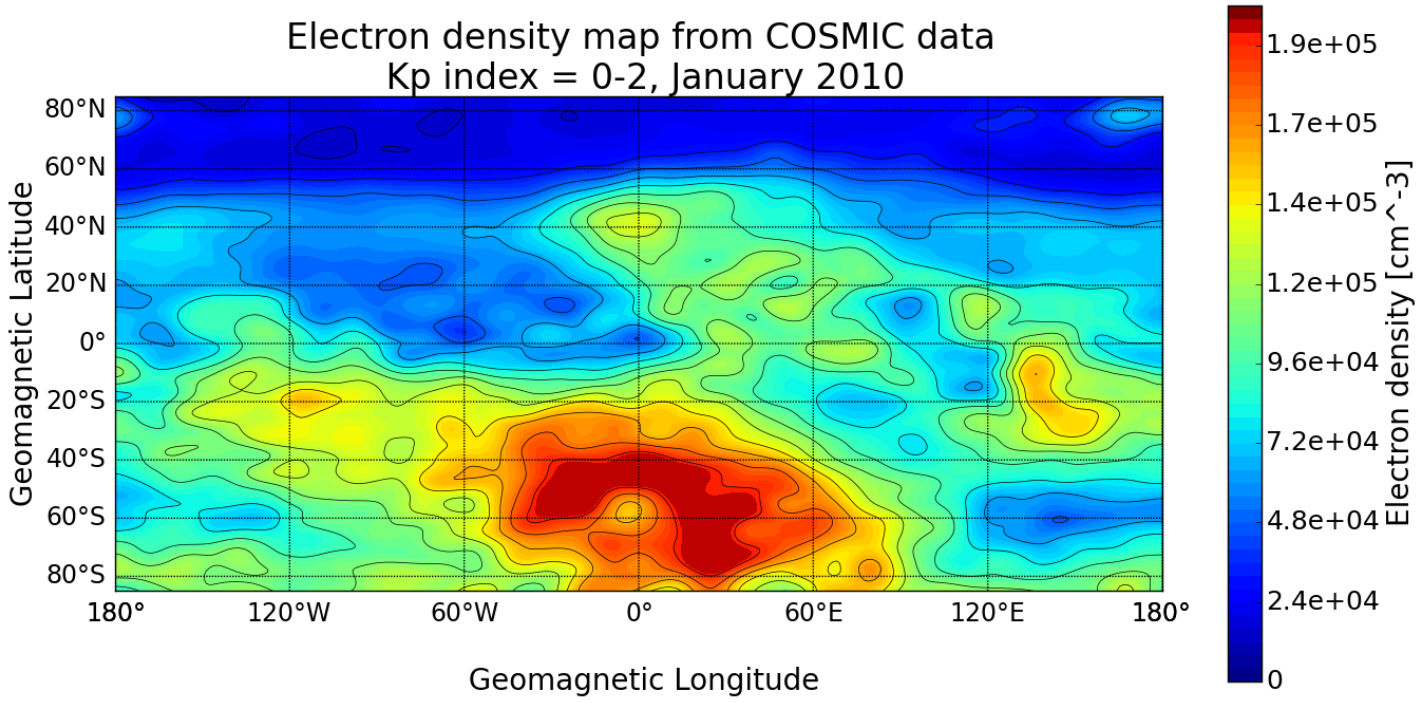



Figure: Maps of seasonal changes in electron density derived from FORMOSAT-3/COSMIC data for $K_p$ index between 0-2 range (left figures) and DEMETER data (right figures) in 2007.


Electron density map from COSMIC data
Kp index = 0-2, January 2010
Geomagnetic Latitude
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S
180°
120°W
60°W
0°
60°E
120°E
180°
Geomagnetic Longitude
1.9e+05
1.7e+05
1.4e+05
1.2e+05
9.6e+04
7.2e+04
4.8e+04
2.4e+04
0
Electron density [cm^-3]

# The trough position during night-time

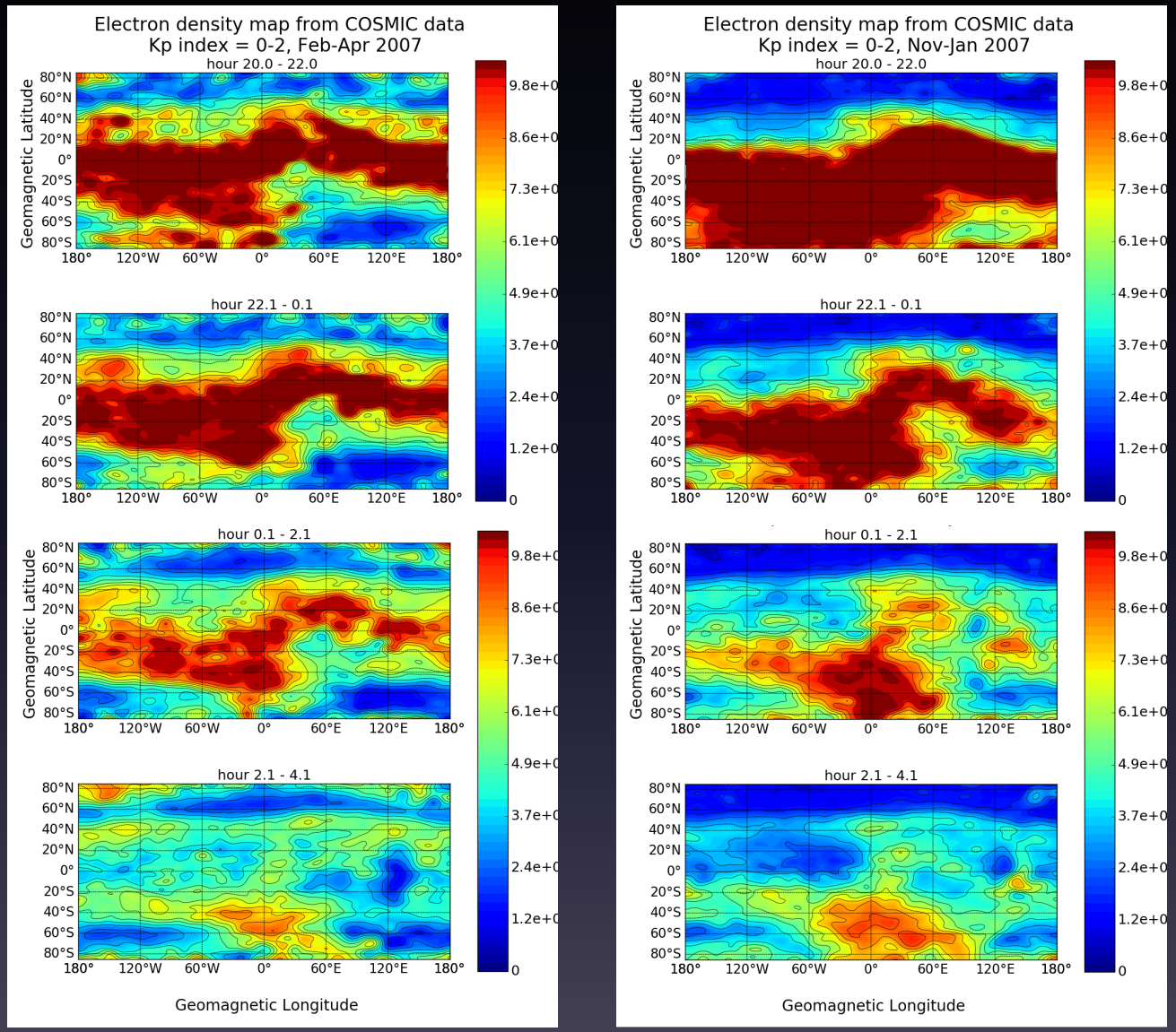
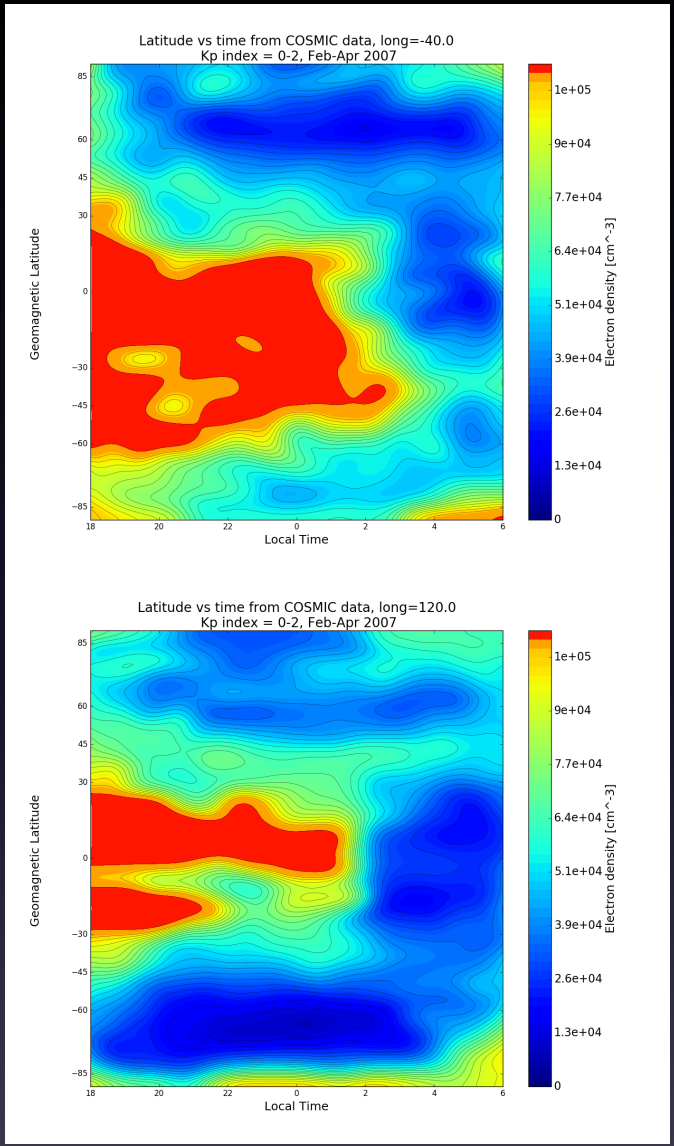



Figure: Maps of electron density for different time ranges derived from FORMOSAT-3/COSMIC data for $K_p$ index 0-2 in 2007.



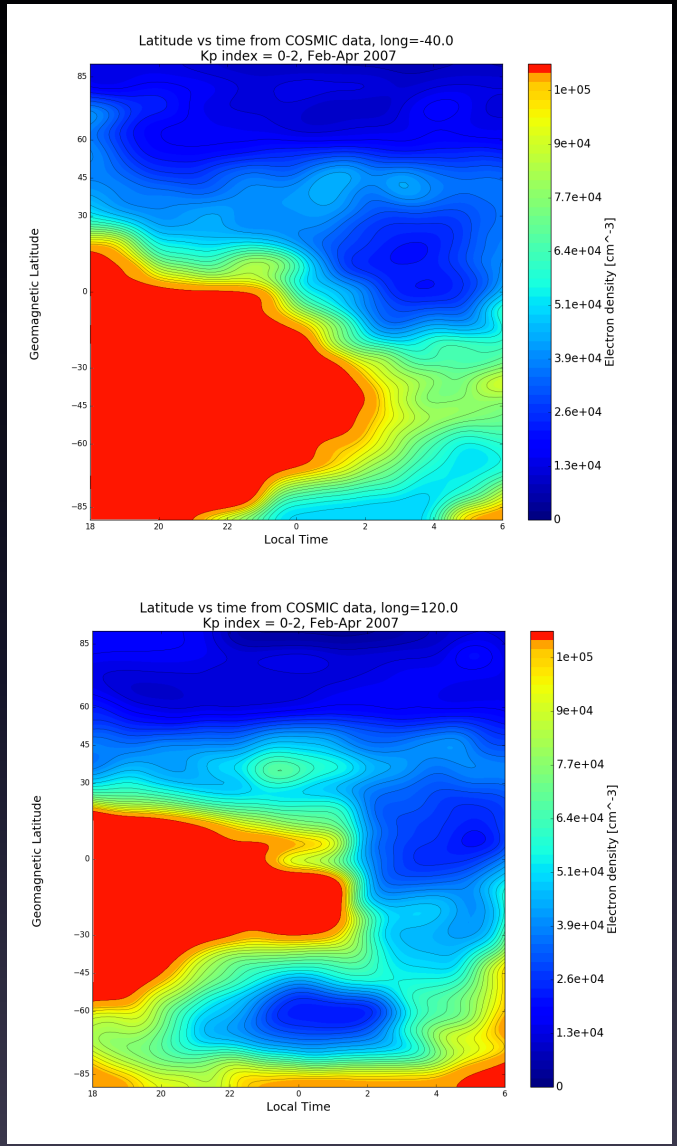




Figure: The mid latitude trough night-time occurence for different longitude ranges derived from FORMOSAT-3/COSMIC data for $K_p$ index between 0-2 range in 2007.

# Other ionospheric analysis with COSMIC data

- The earthquake precursors studies
- The equatorial scintillation model

# Conclusions

- radio occultation method is a powerful tool for atmospheric and ionospheric diagnostic (space weather diagnostics, global weather forecast models, cataclysm predictions)
- global characteristic of the ionosphere behaviour possible with RO data
- complement for other ionospheric diagnostic tools -> high coverage of RO in space and time

Thank you for your attention!