

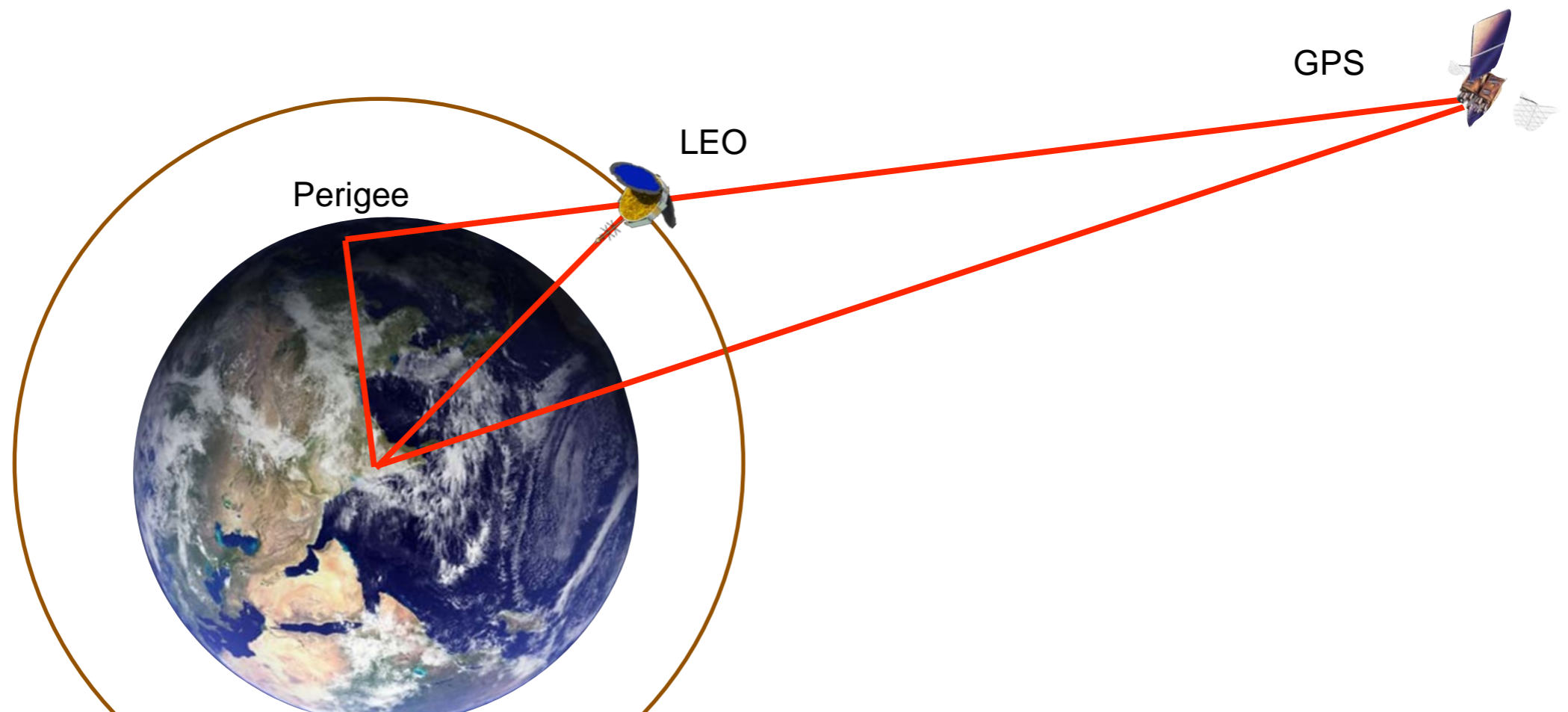
# Ionospheric gravity waves observed using radio-occultation: climatology and detection of tsunami-driven event

P. Coïsson, L.M. Rolland, E. Astafyeva



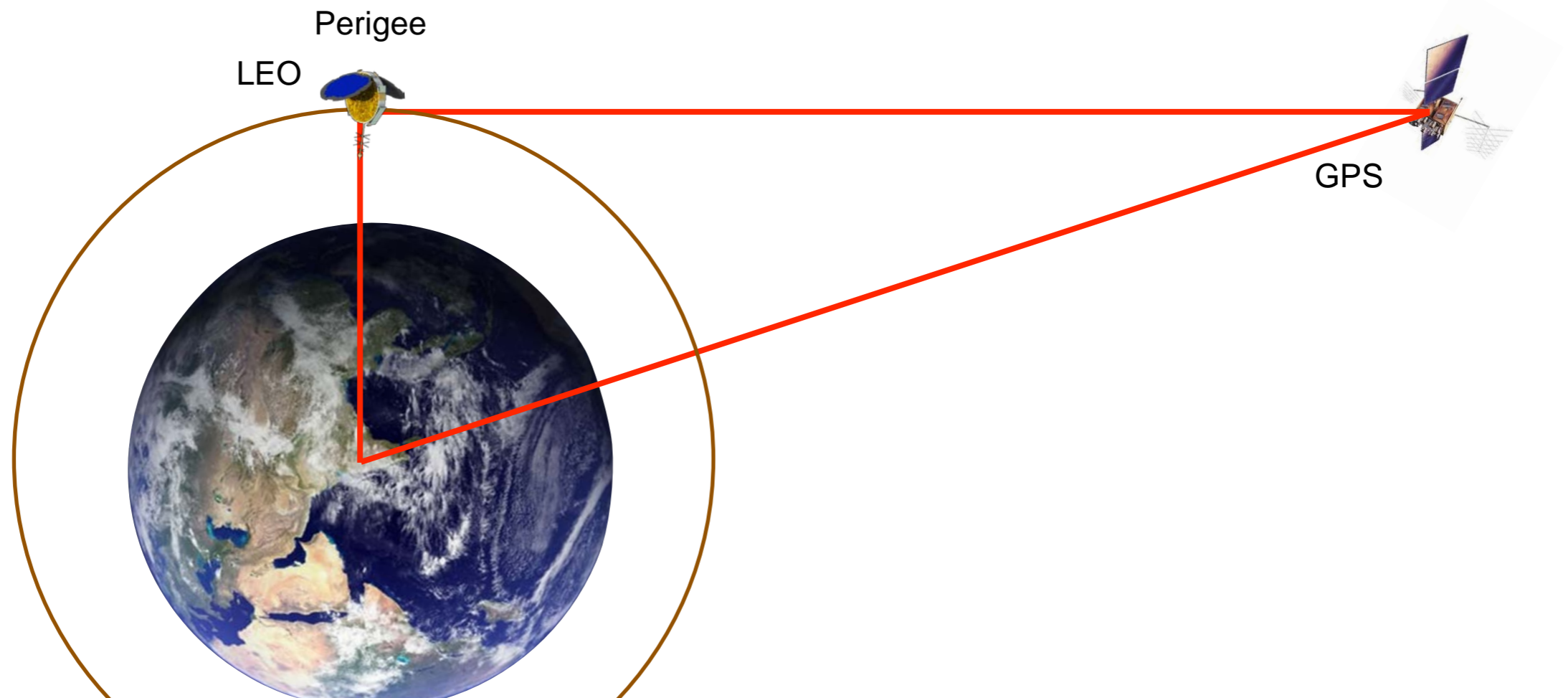
# LEO orbit and occultation

- When elevation is positive, GPS signal crosses only the topside ionosphere above satellite height



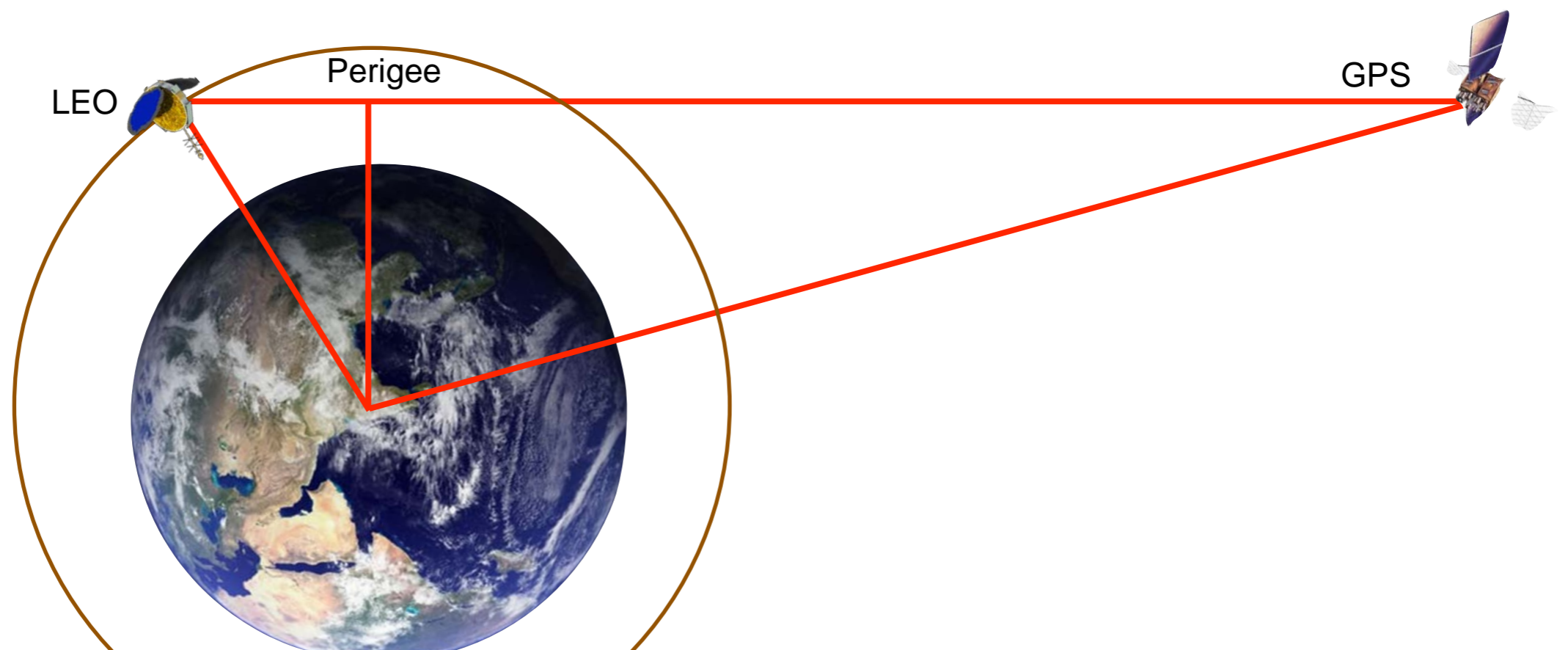
# LEO orbit and occultation

- Occultation starts when elevation of GPS=0



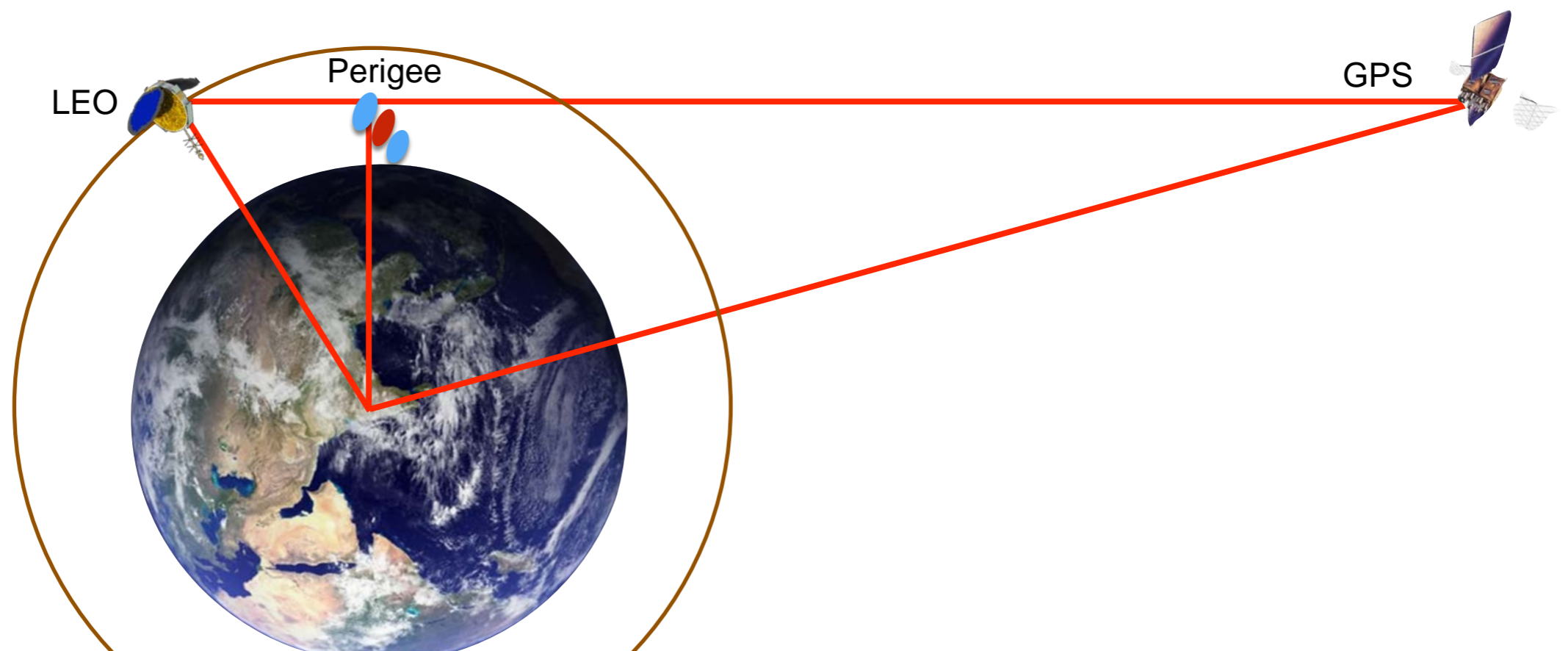
# LEO orbit and occultation

- Perigee position represents the lowest point reached by the GPS ray.



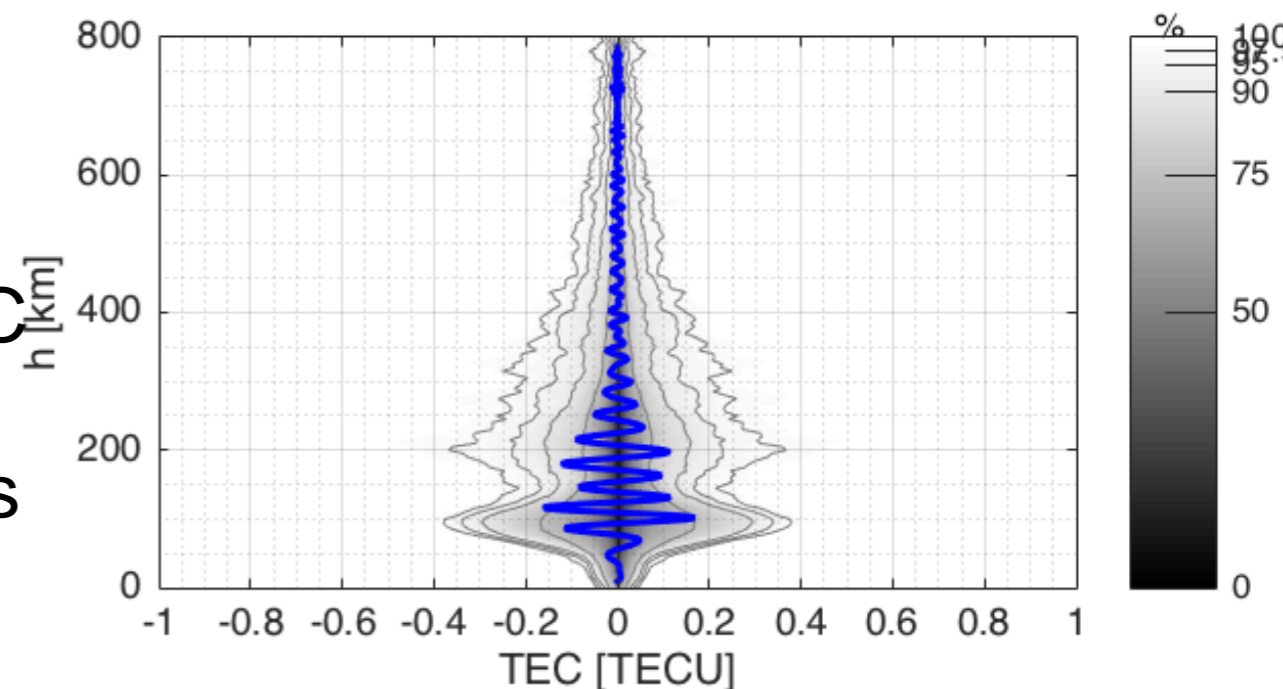
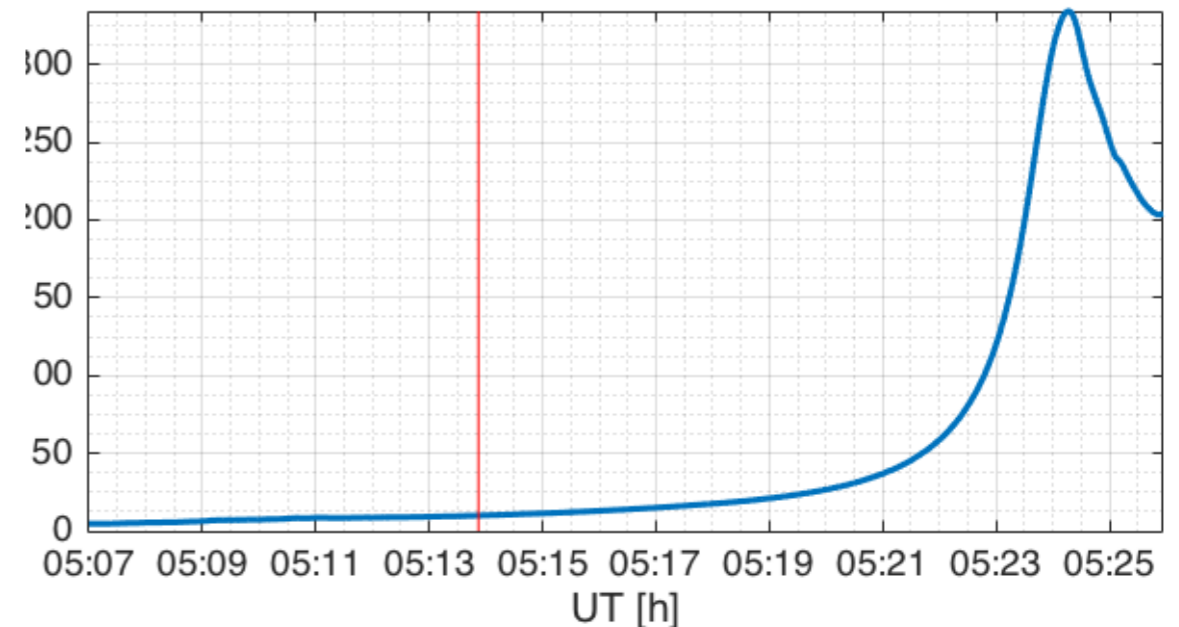
# LEO orbit and occultation

- Gravity wave can be detected if signal crosses the wave relatively near its perigee
- In general the orientation of gravity wave fronts is in a different plane than the occultation

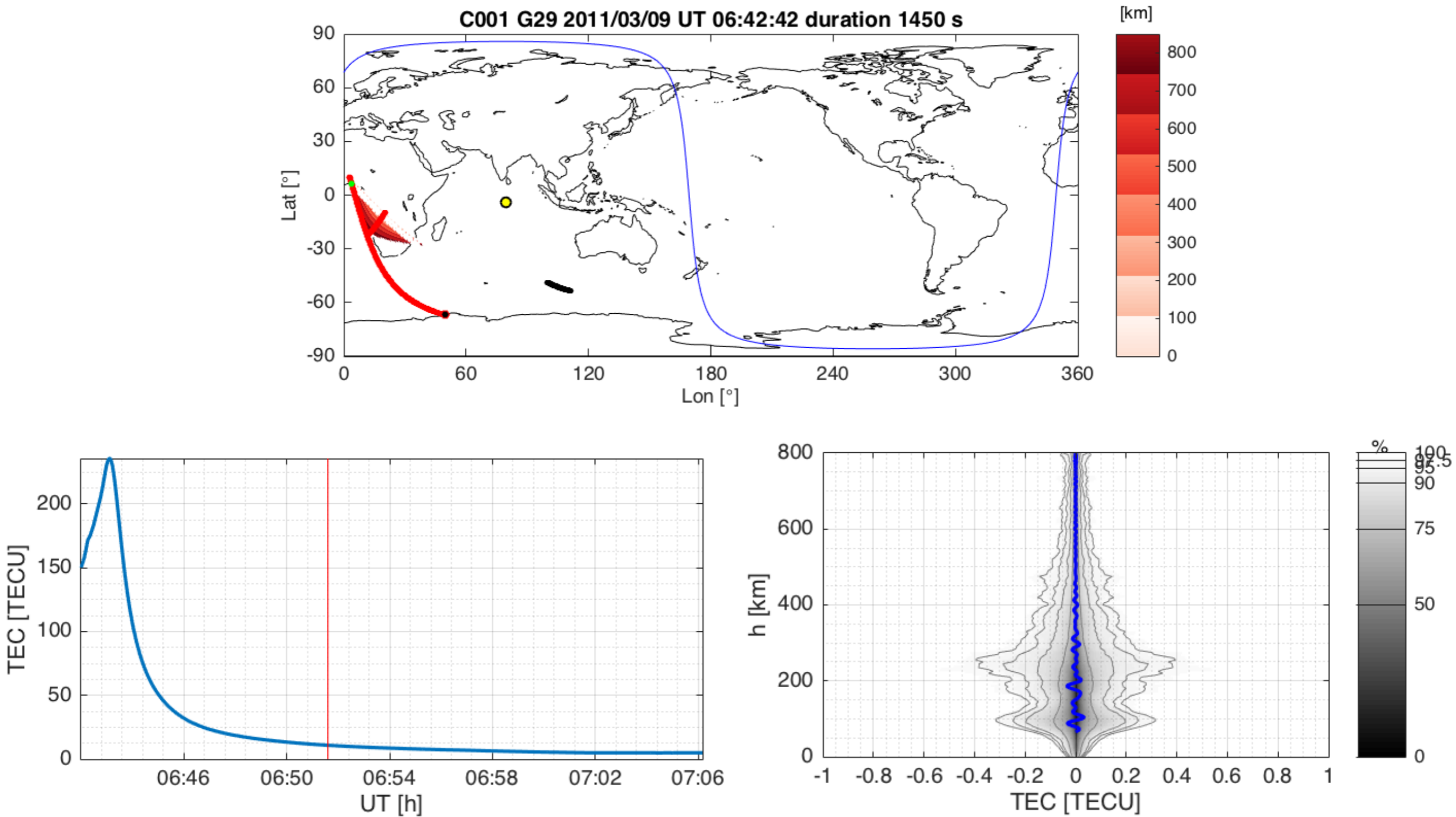


# Data processing

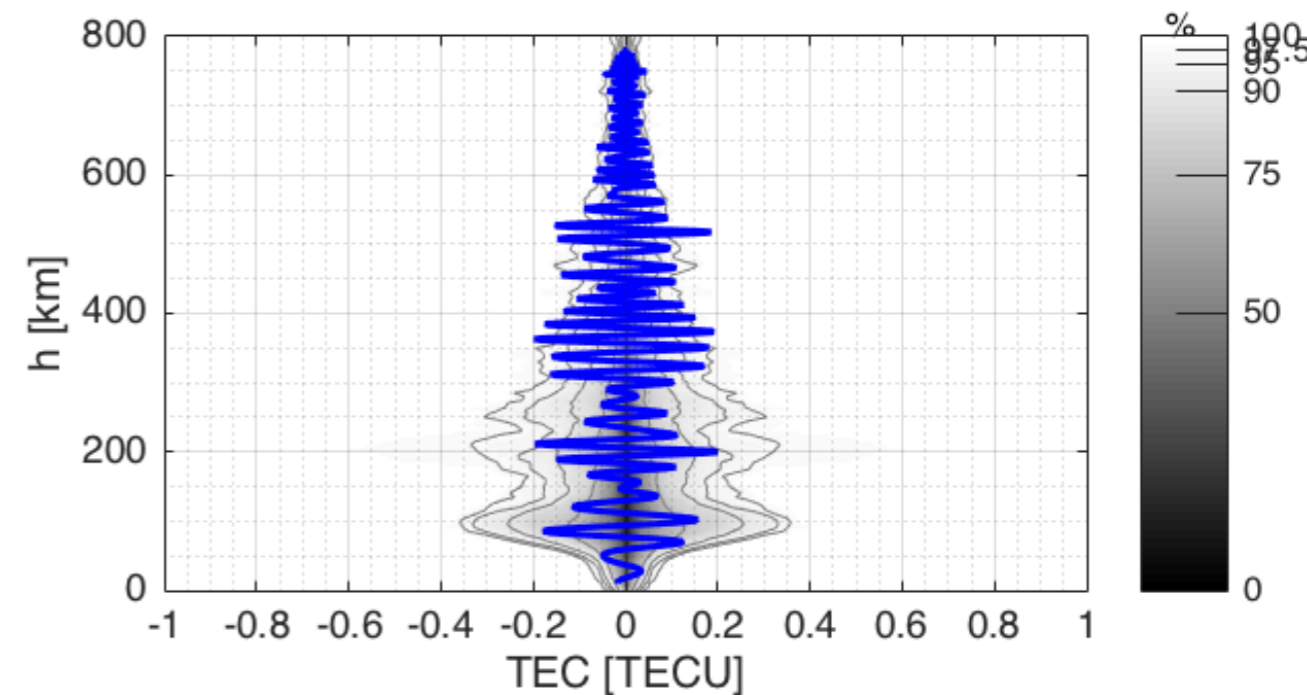
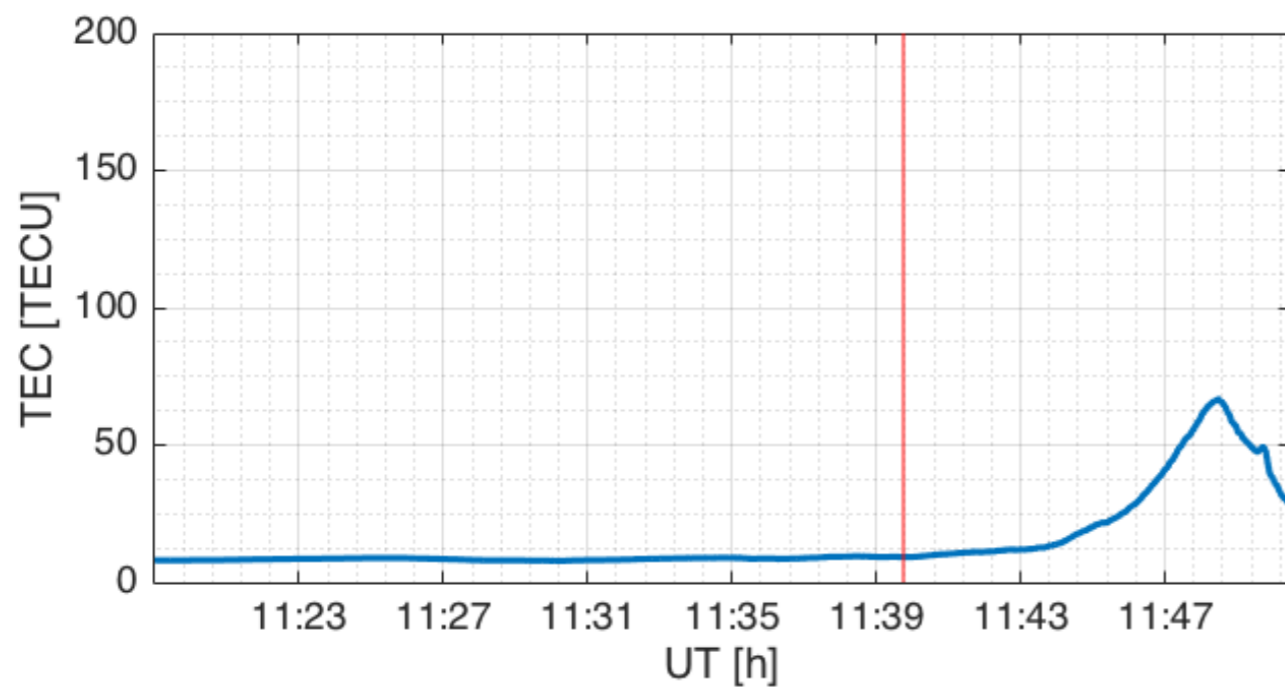
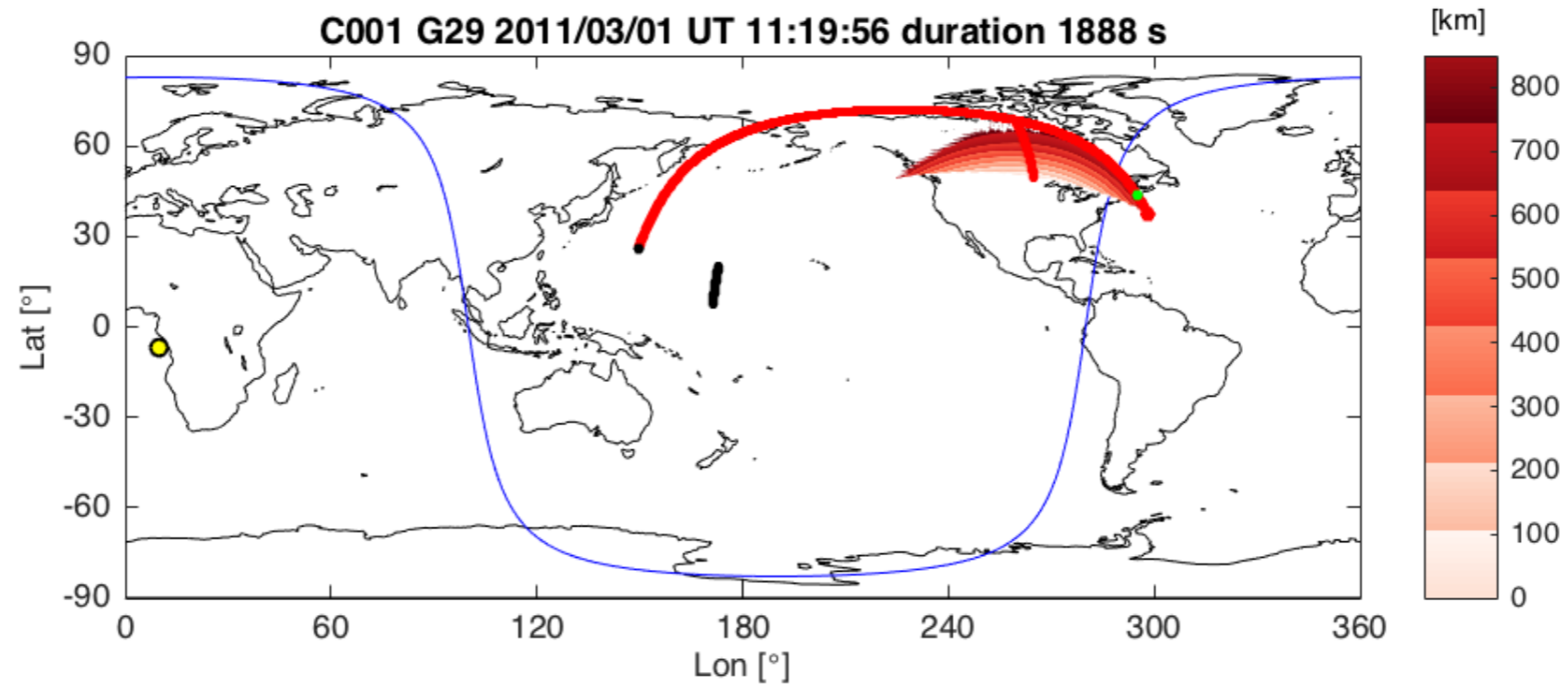
- Sampling at 1 s
- Occultation tangent point height variation is not linear
- Filtering between 50-100 mHz
- Selection of data with lowest tangent point < 200 km
- Rejection of data with jumps in TEC
- Interpolation of (few) missing points



# Example 1: quiet

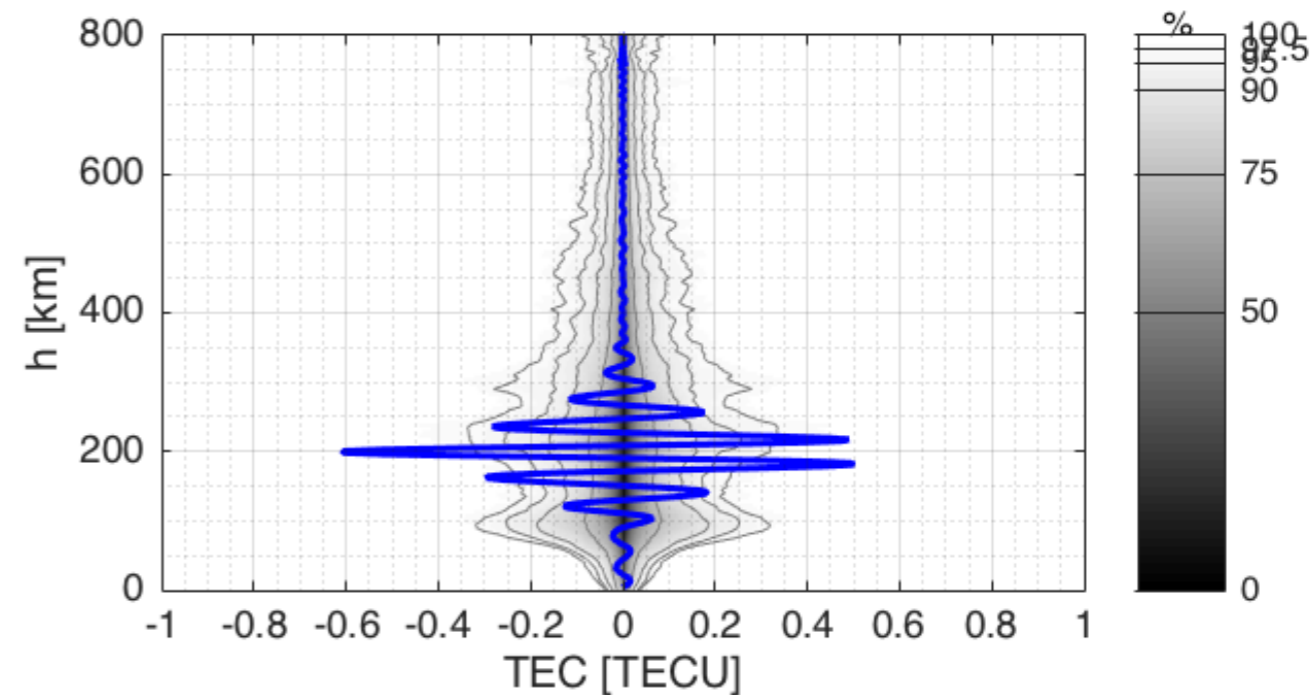
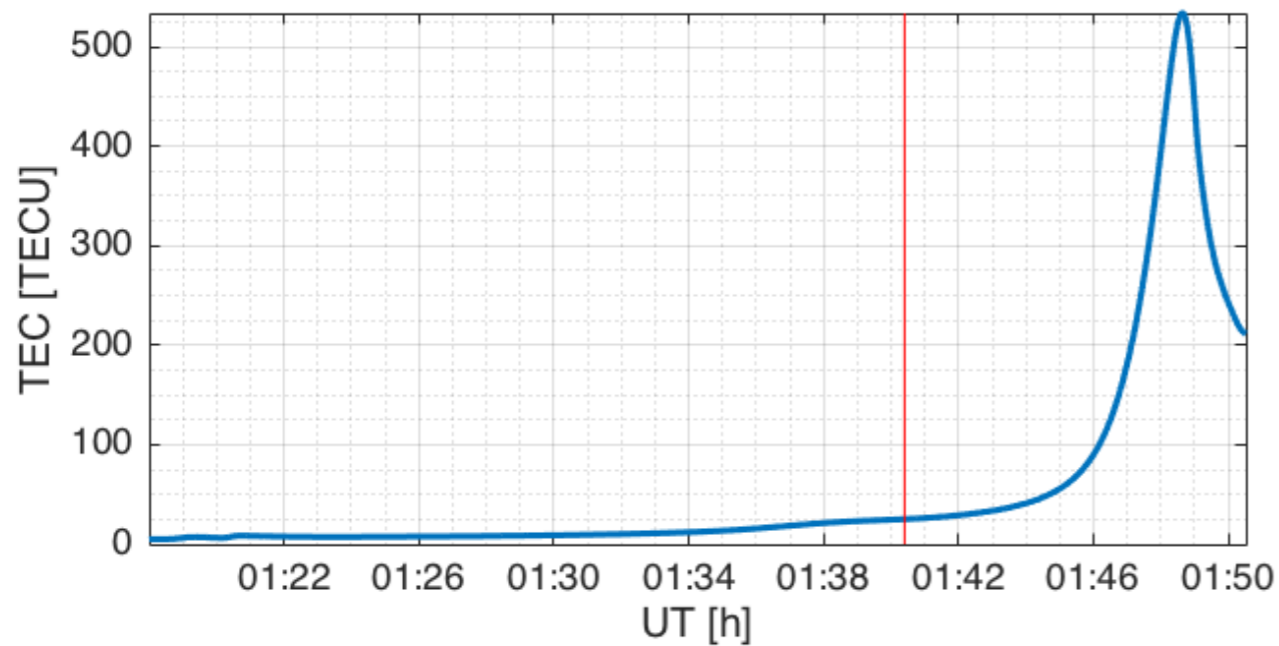
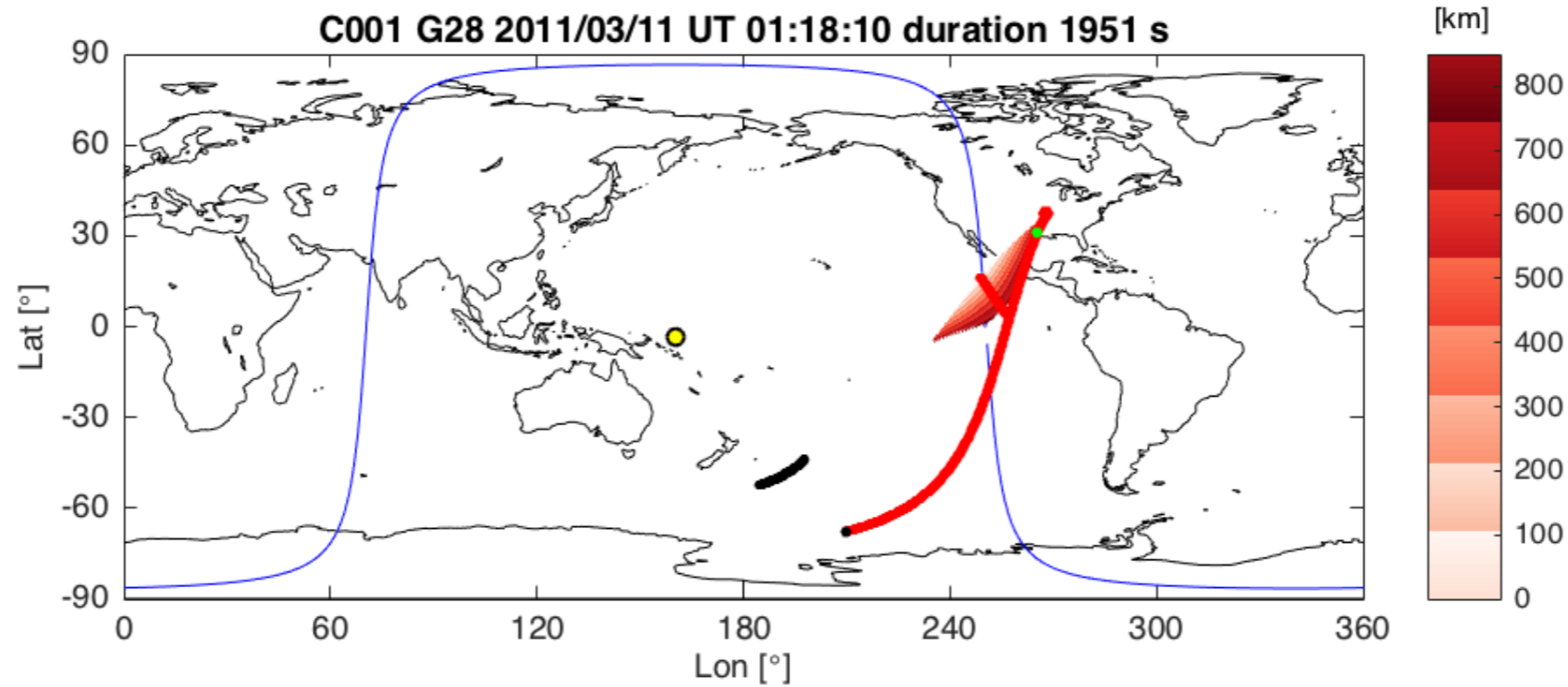


# Example 2: High latitudes



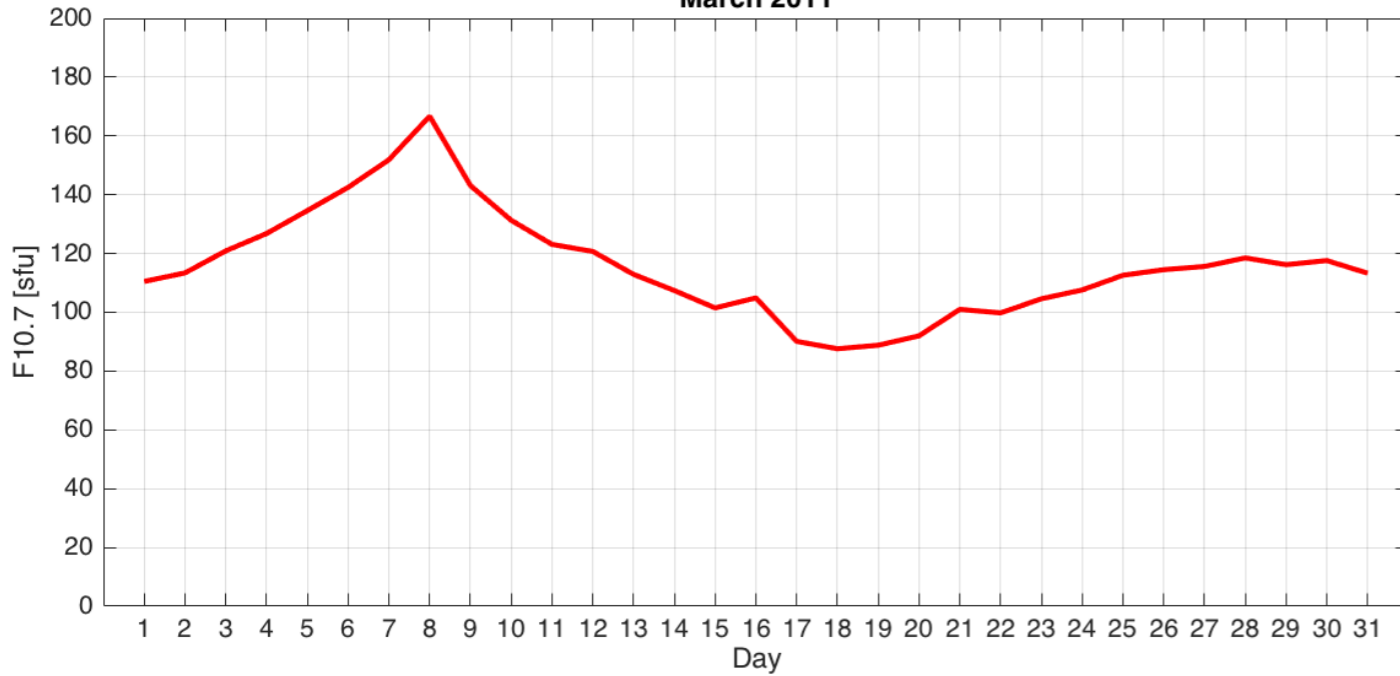


# Example 3: Gravity wave

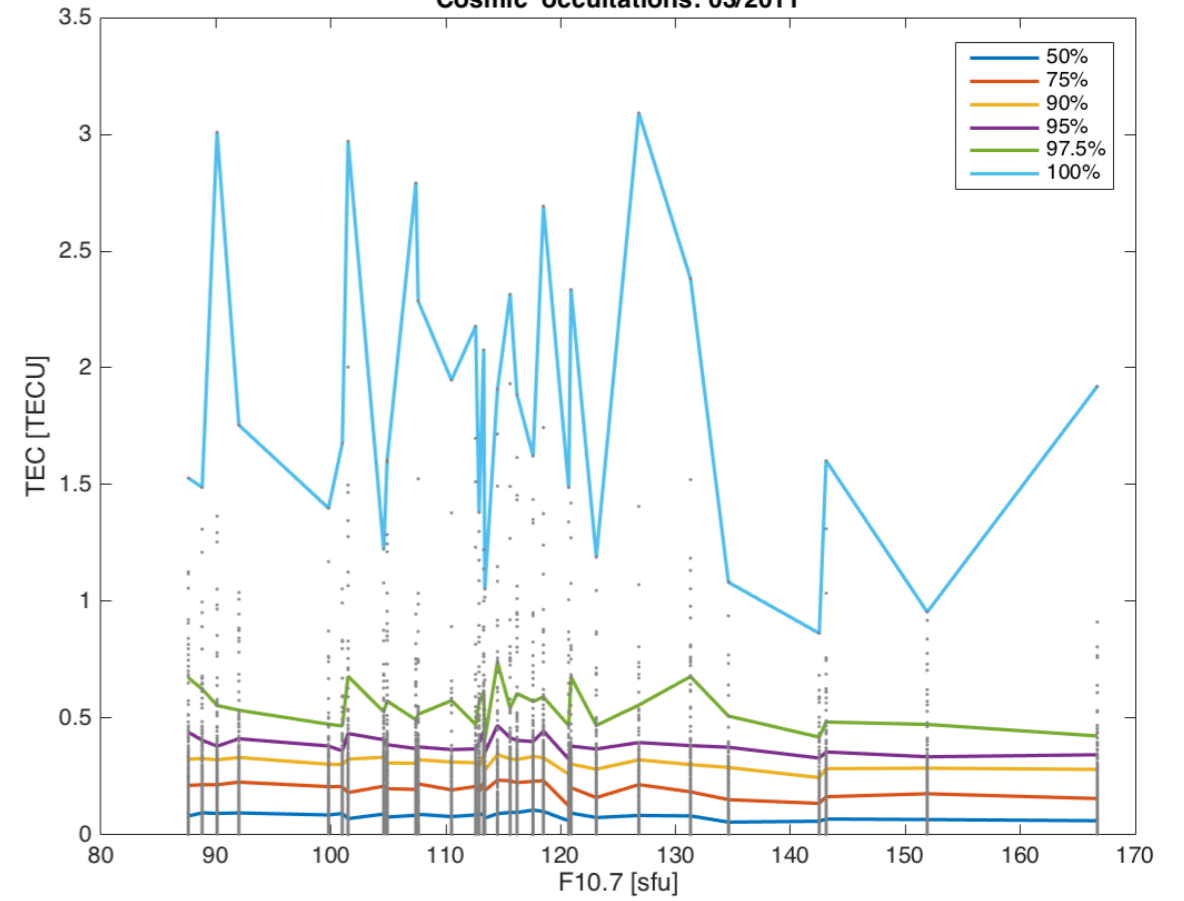


# March 2011

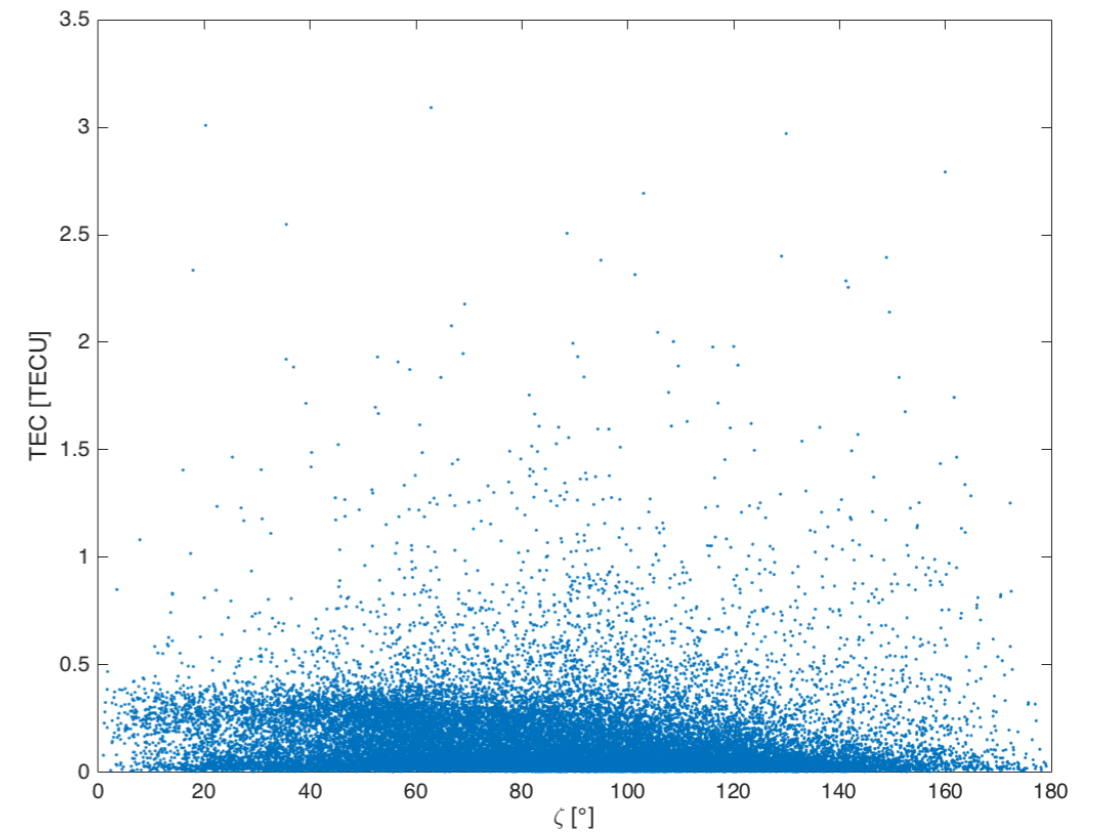
March 2011



Cosmic occultations: 03/2011



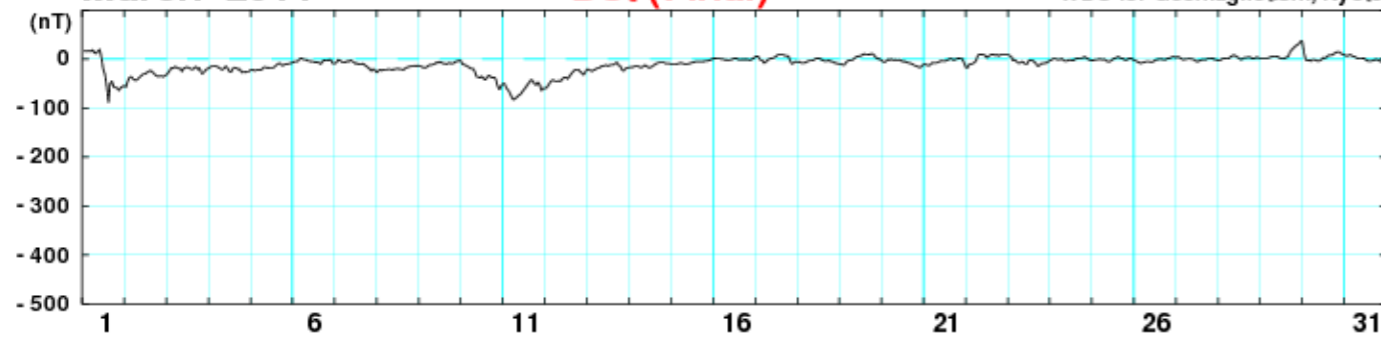
Solar zenith angle of Max(TEC)



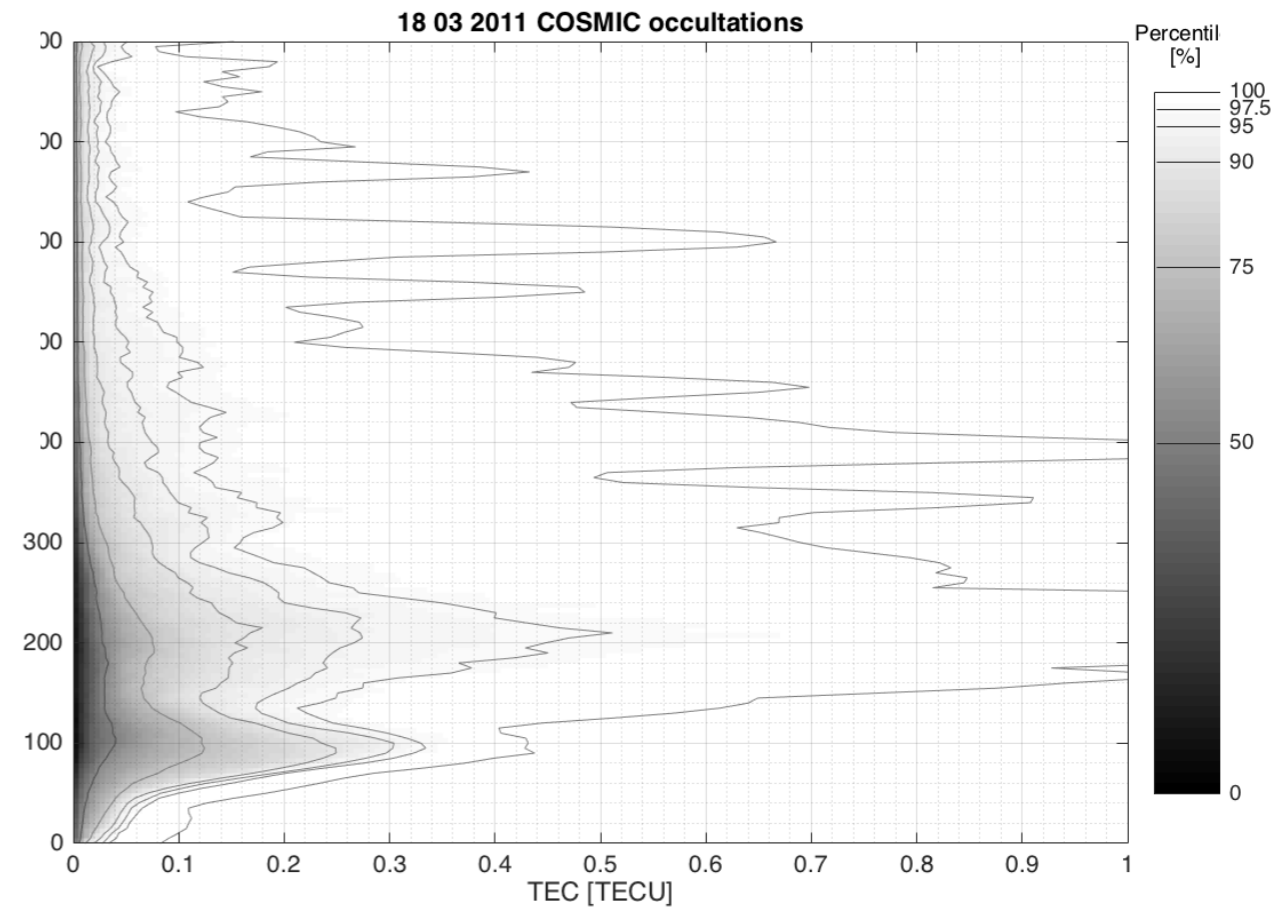
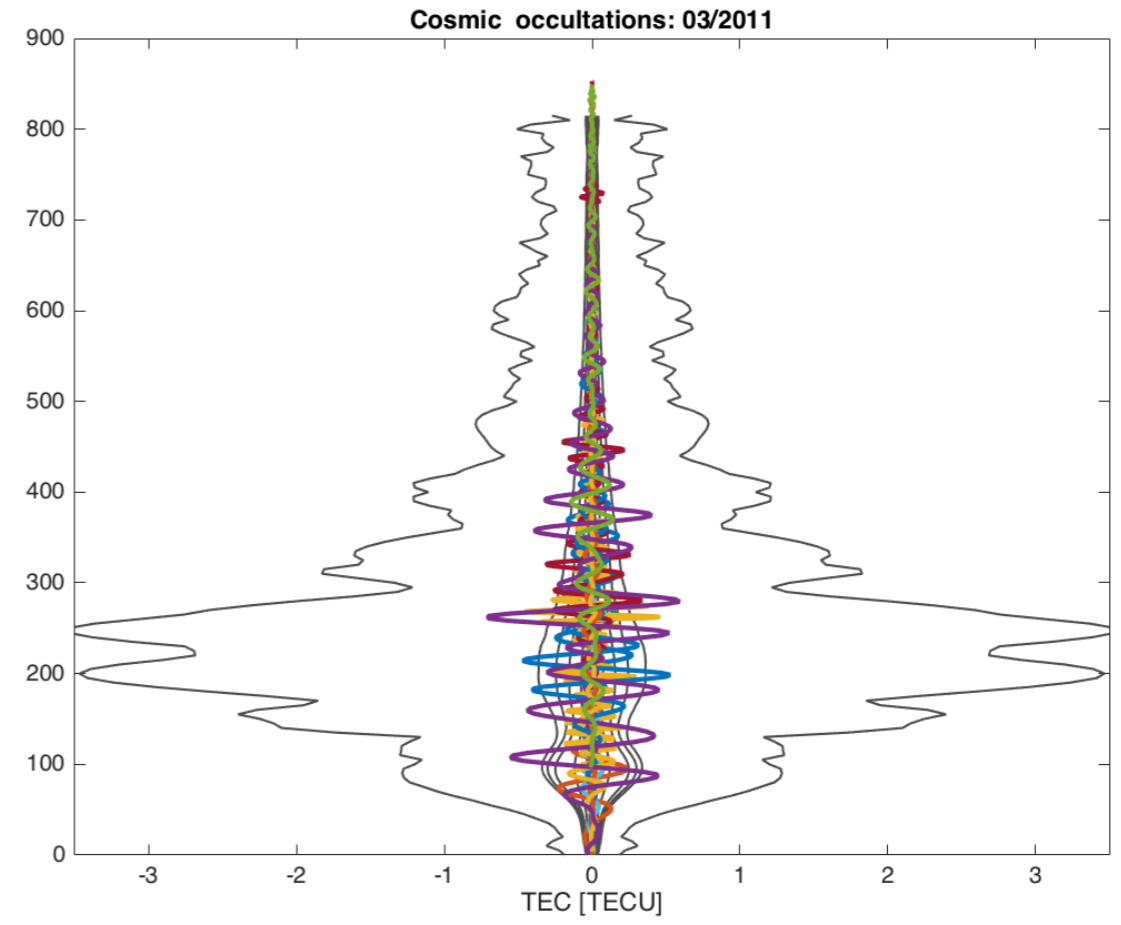
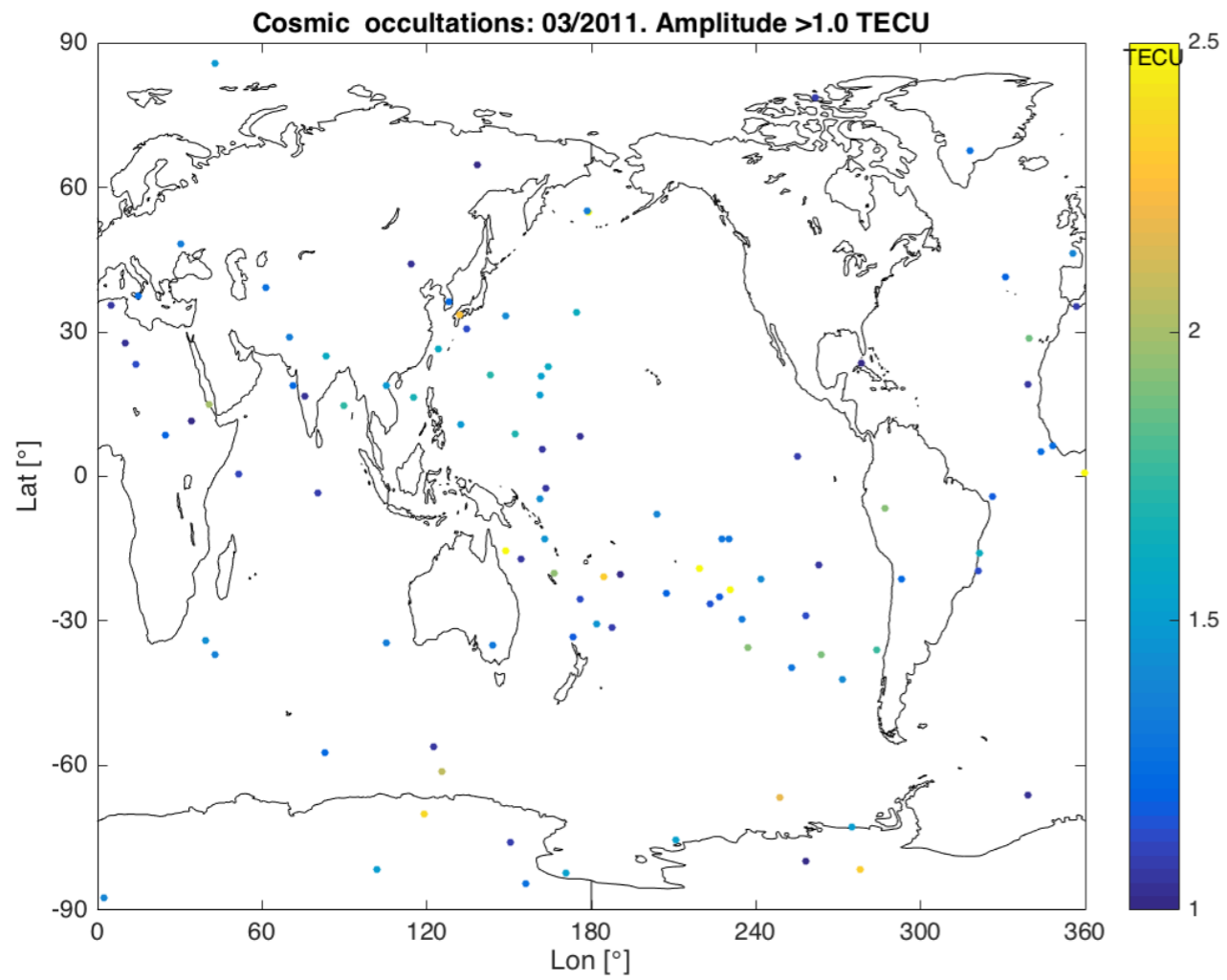
March 2011

Dst (Final)

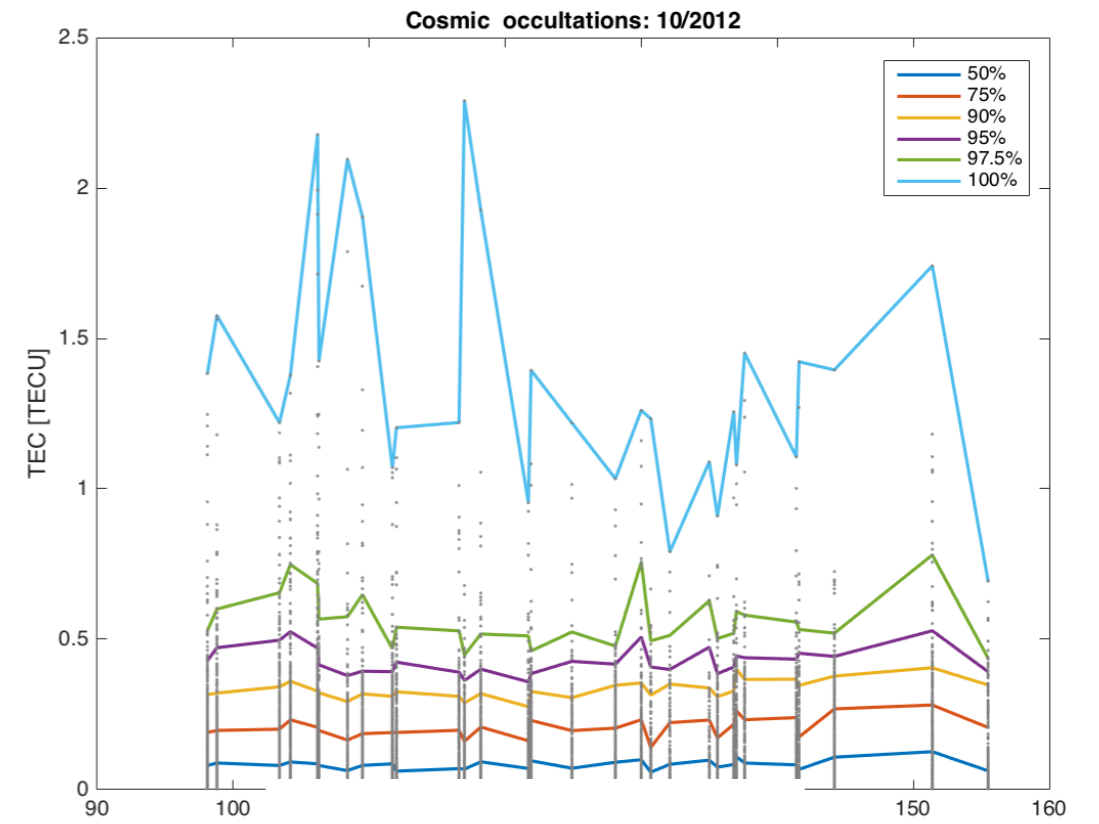
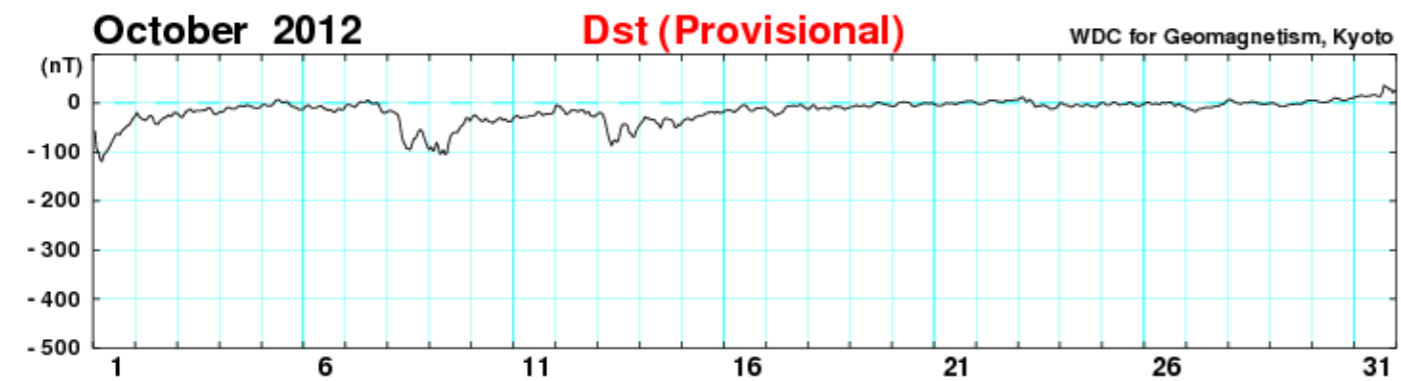
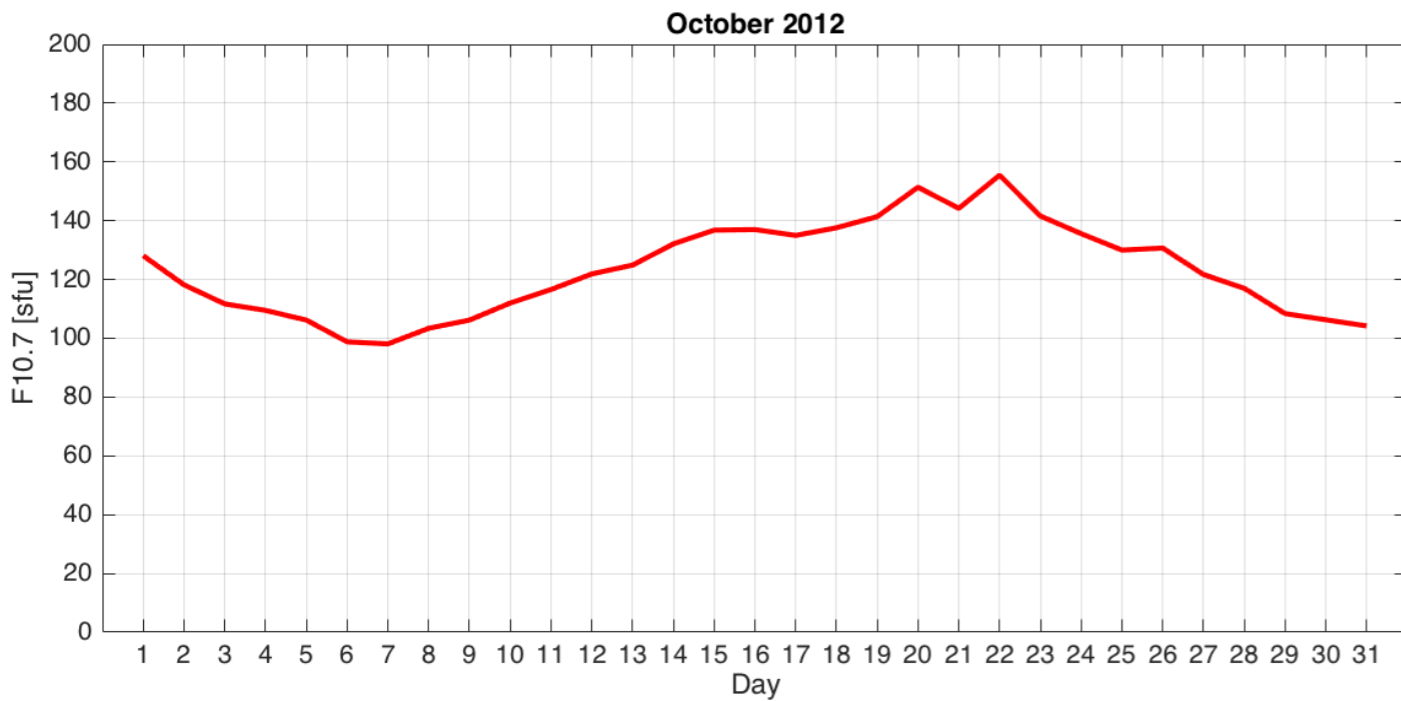
WDC for Geomagnetism, Kyoto



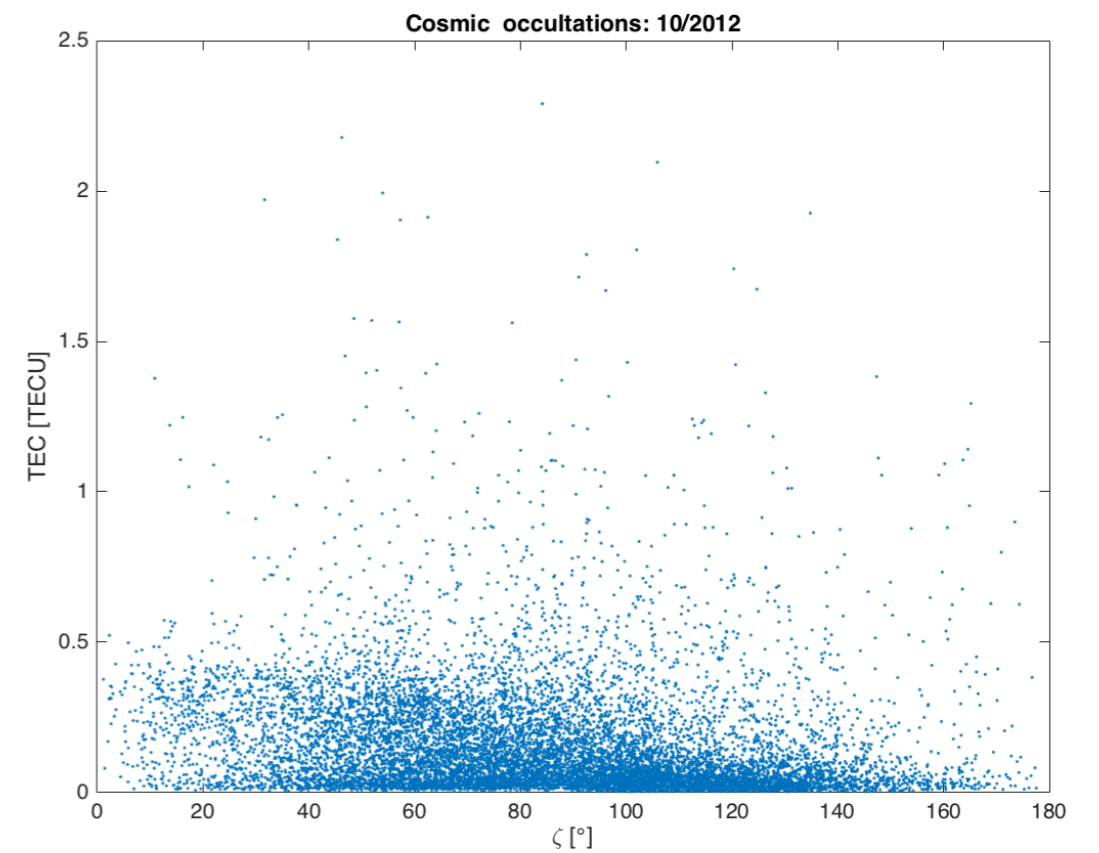
# March 2011



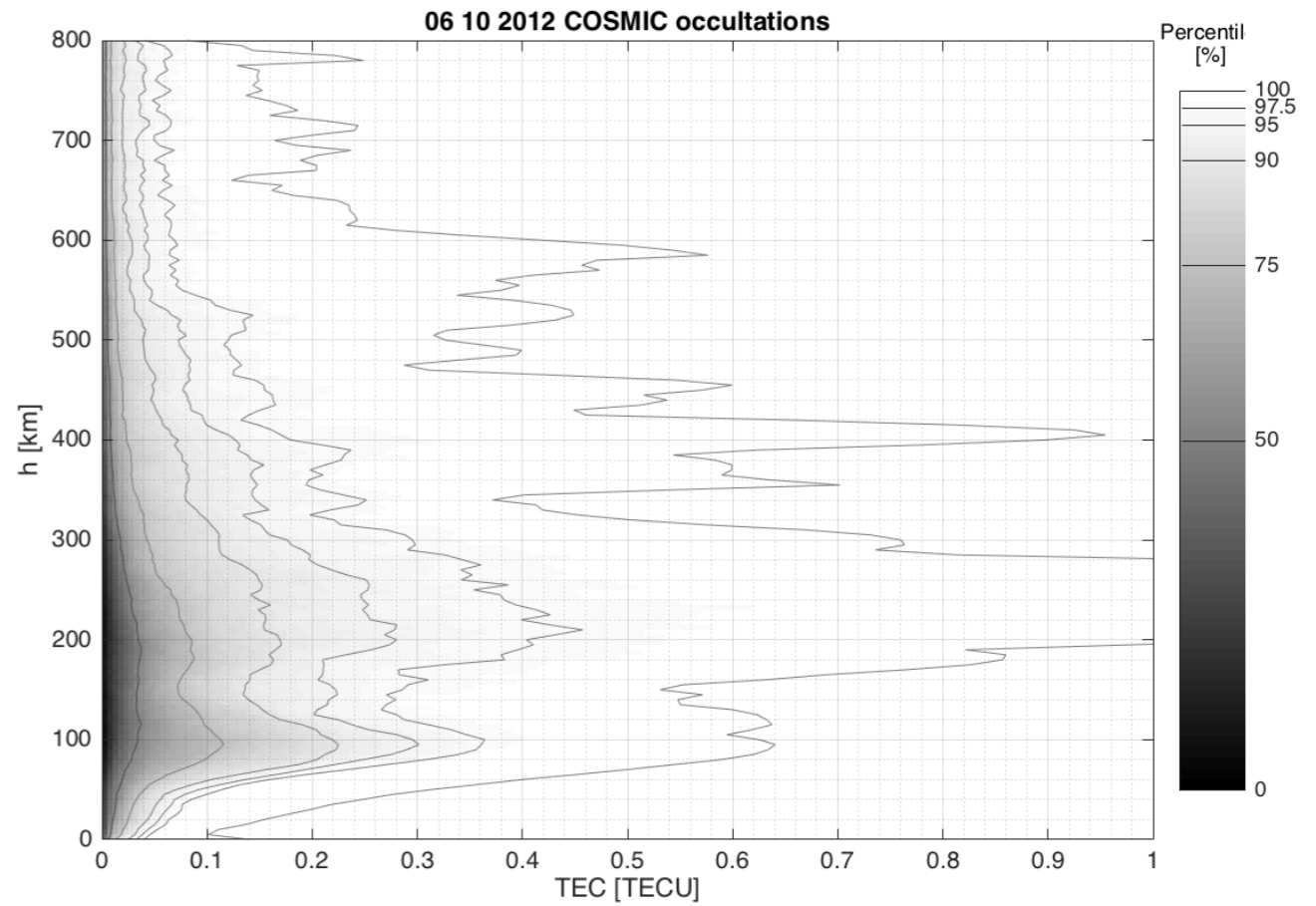
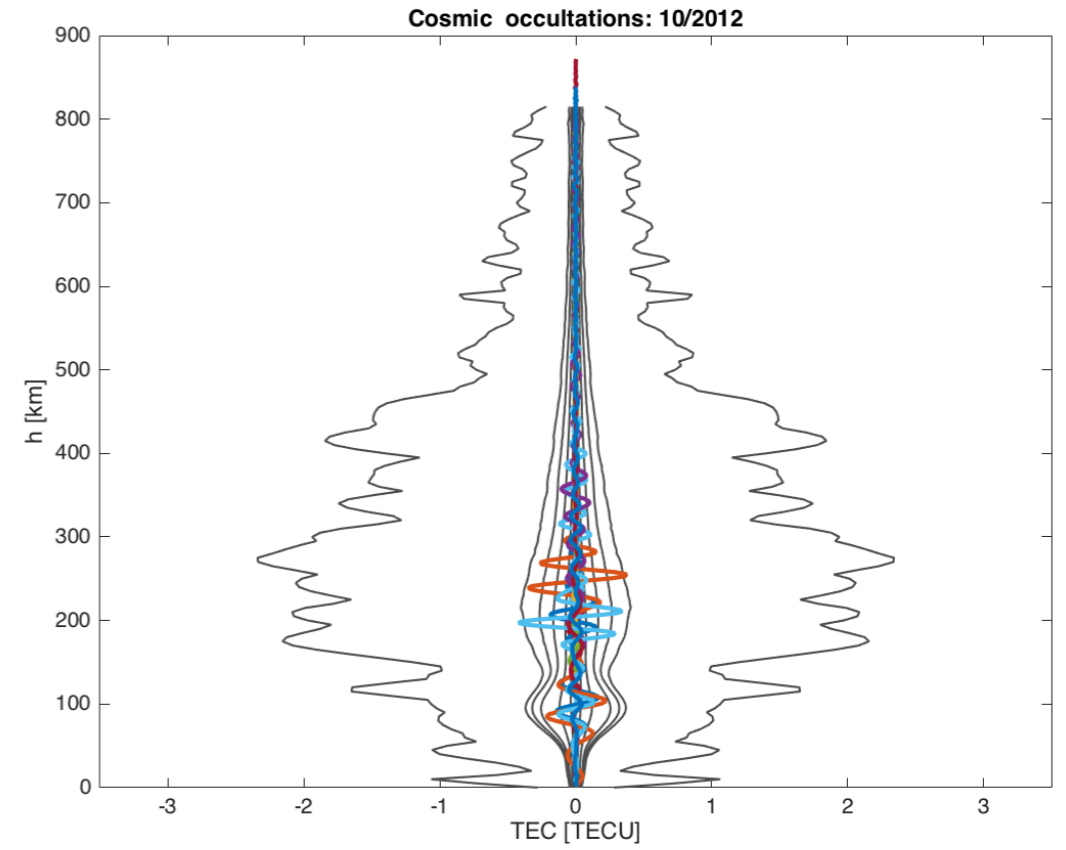
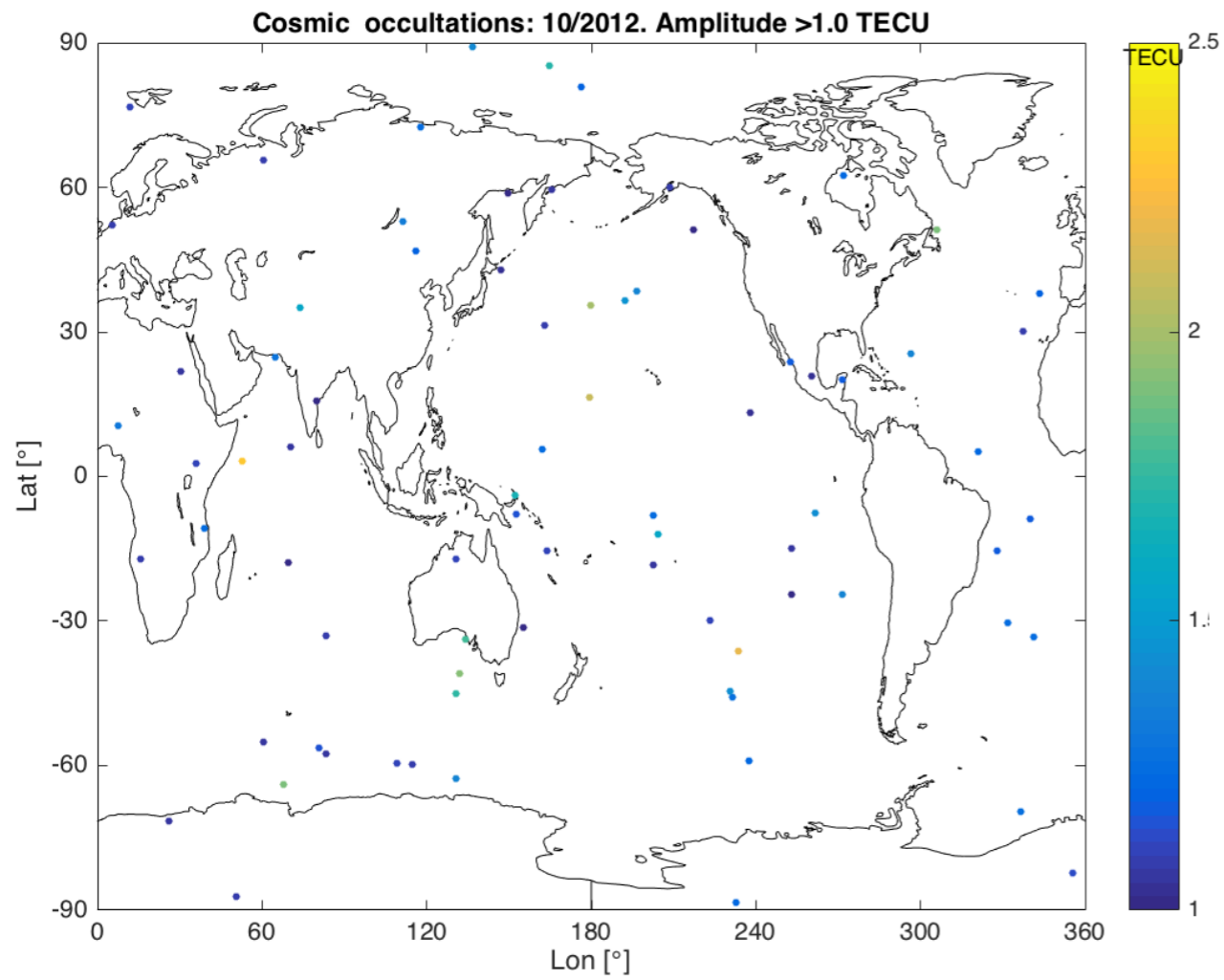
# October 2012



## Solar zenith angle of Max(TEC)

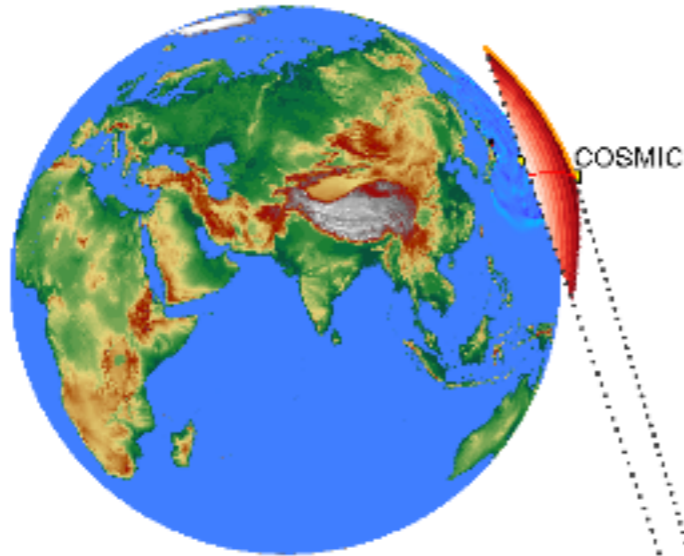


# October 2012



# COSMIC/FORMOSAT-3

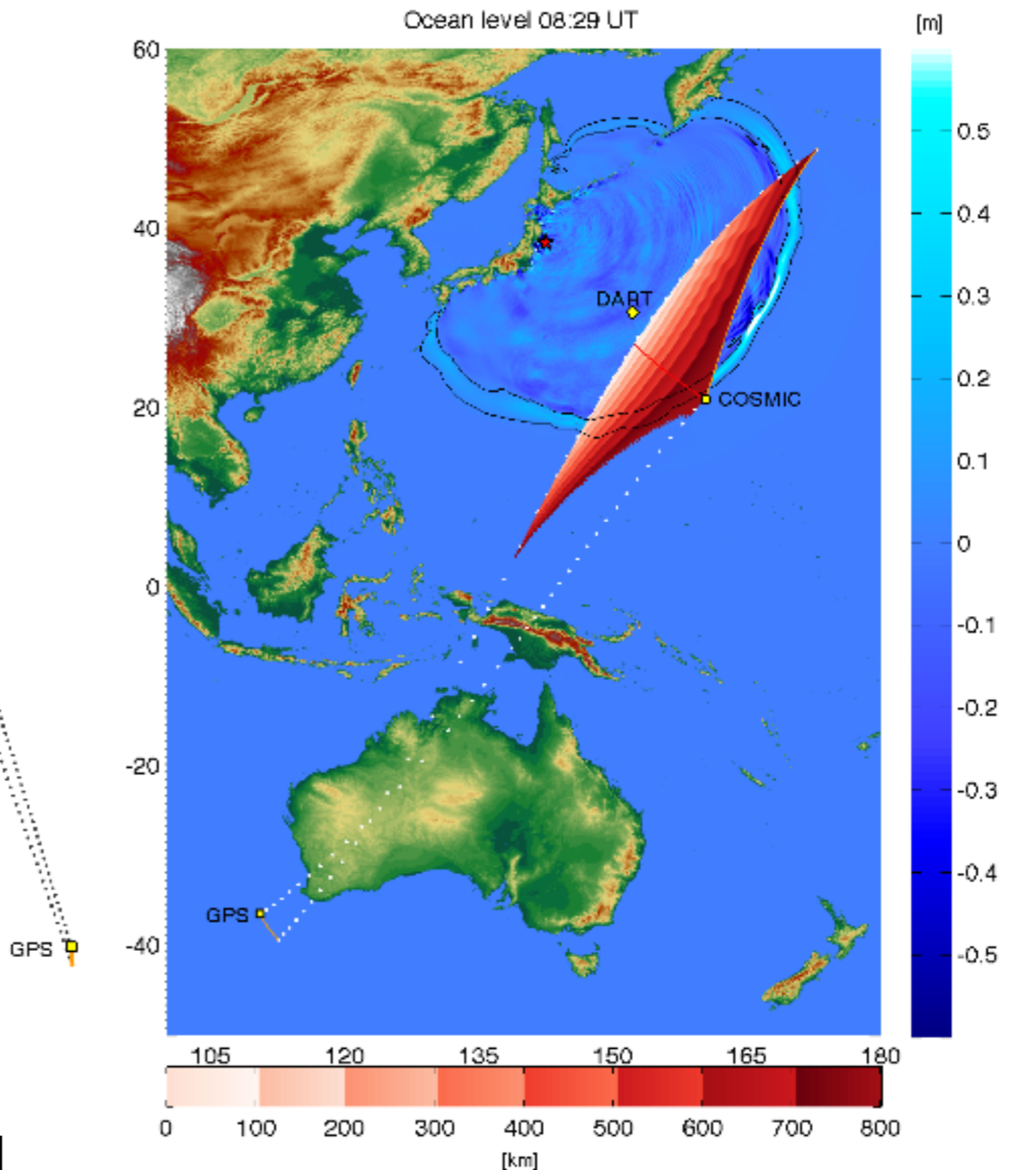
detection



Tohoku earthquake  
05:46 UT 11/03/2011  
Mw 9.0

COSMIC/FORMOSAT-3 1  
GPS 21

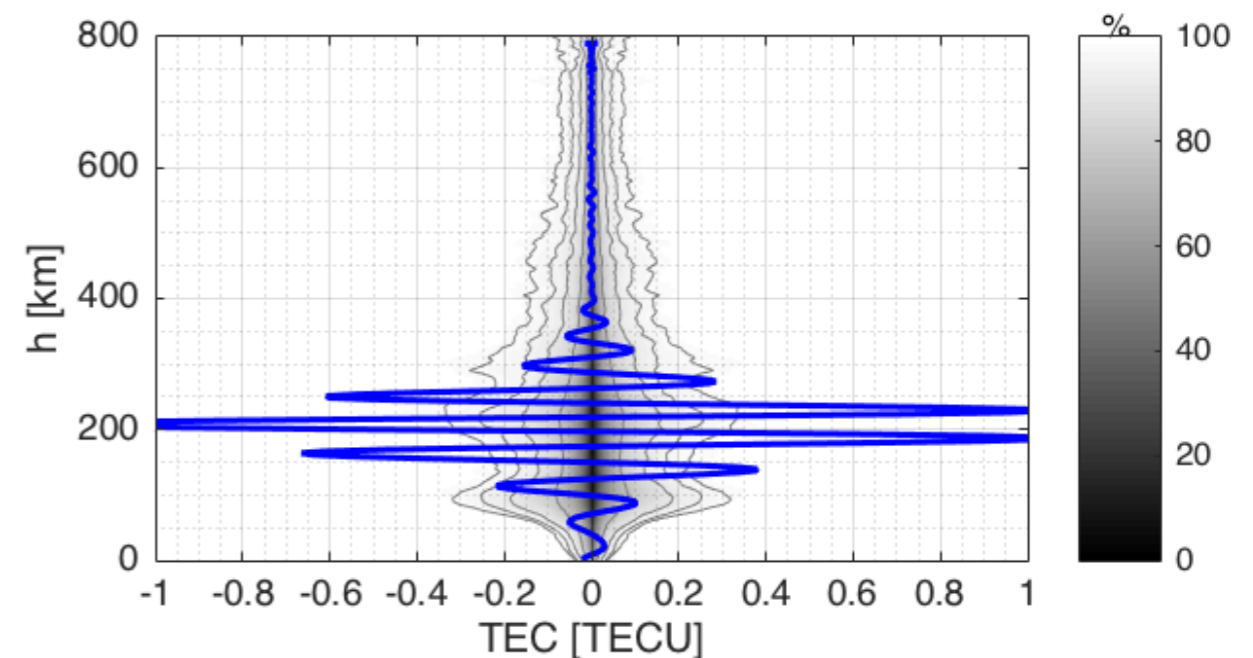
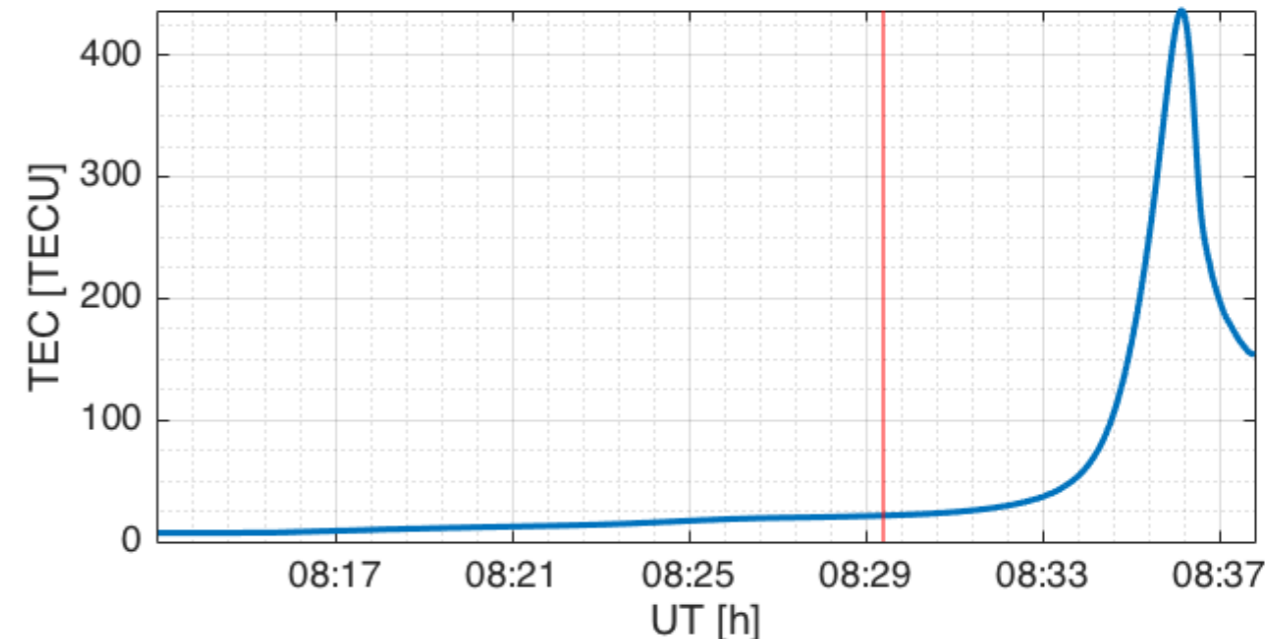
[Coisson et al. EA, 2015]



# Occultation signal

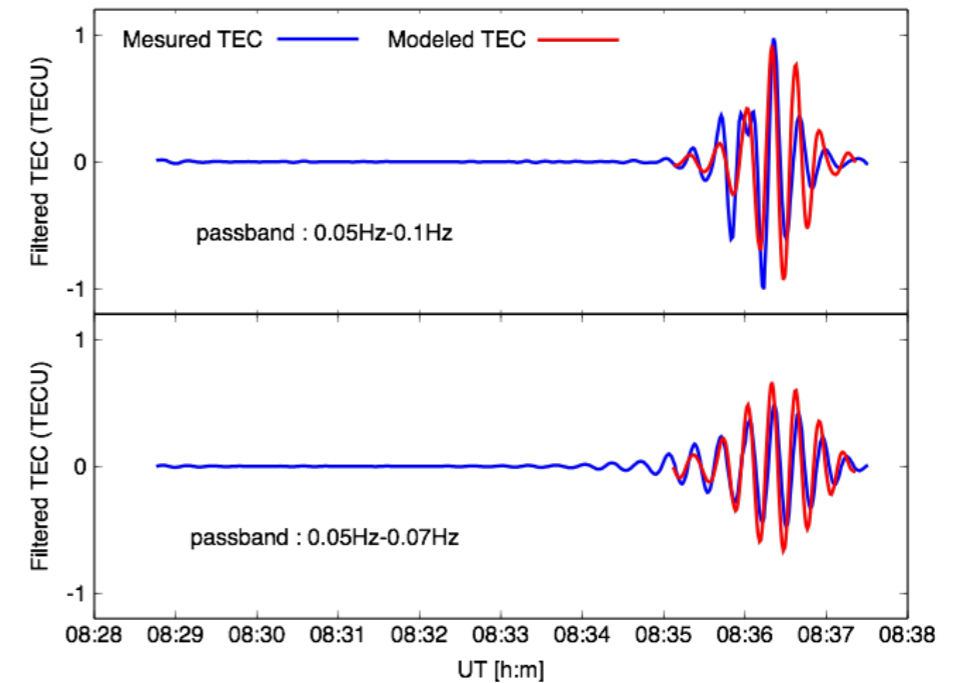
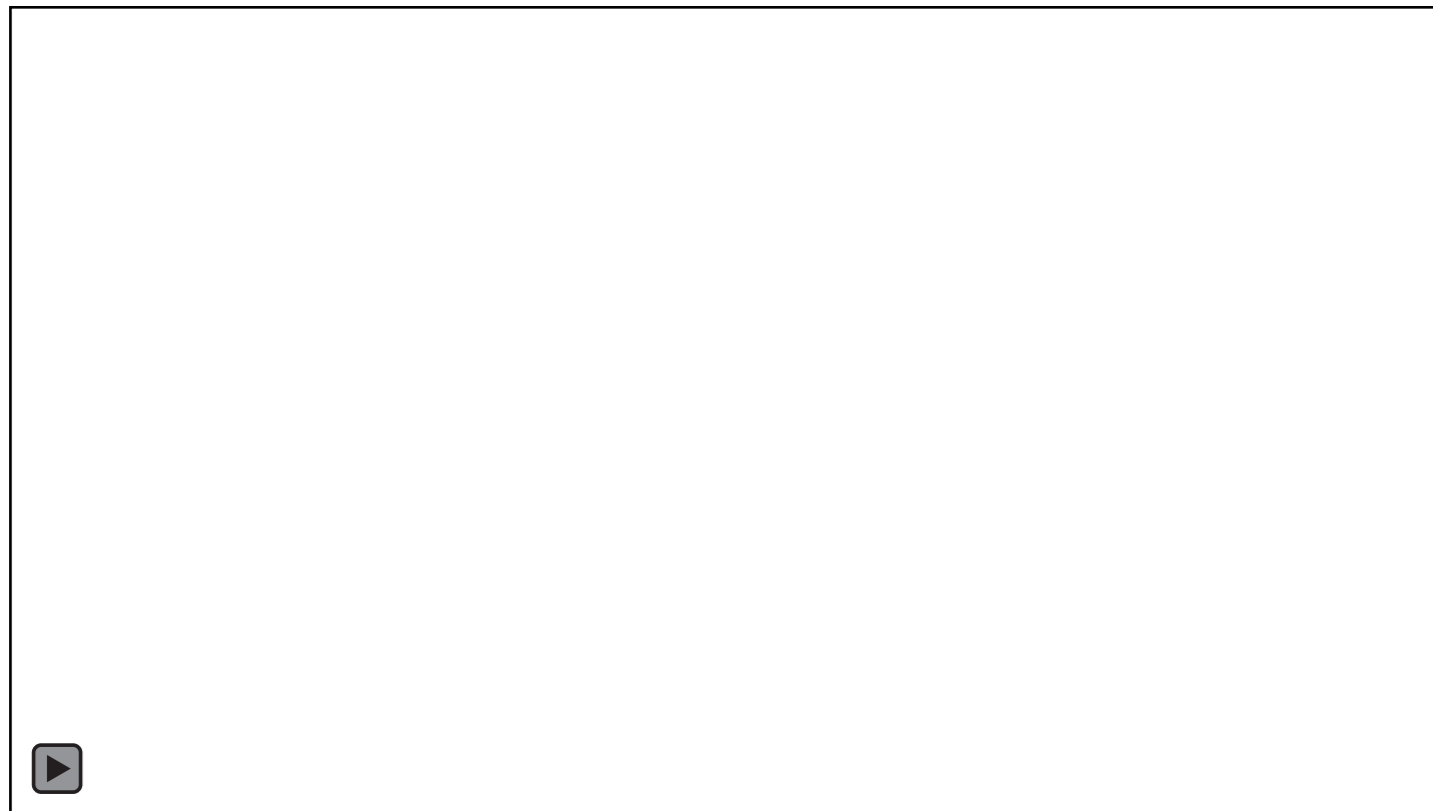
- Filtered TEC
- Comparison with the statistical TEC fluctuations of the same day
- Tsunami signal  
vertical wavelength  $\sim 50$  km,  
maximum amplitude  $\sim 200$  km

TEC between COSMIC 1 and GPS 21 satellites



[Coisson et al. EA, 2015]

# Synthetic modeling

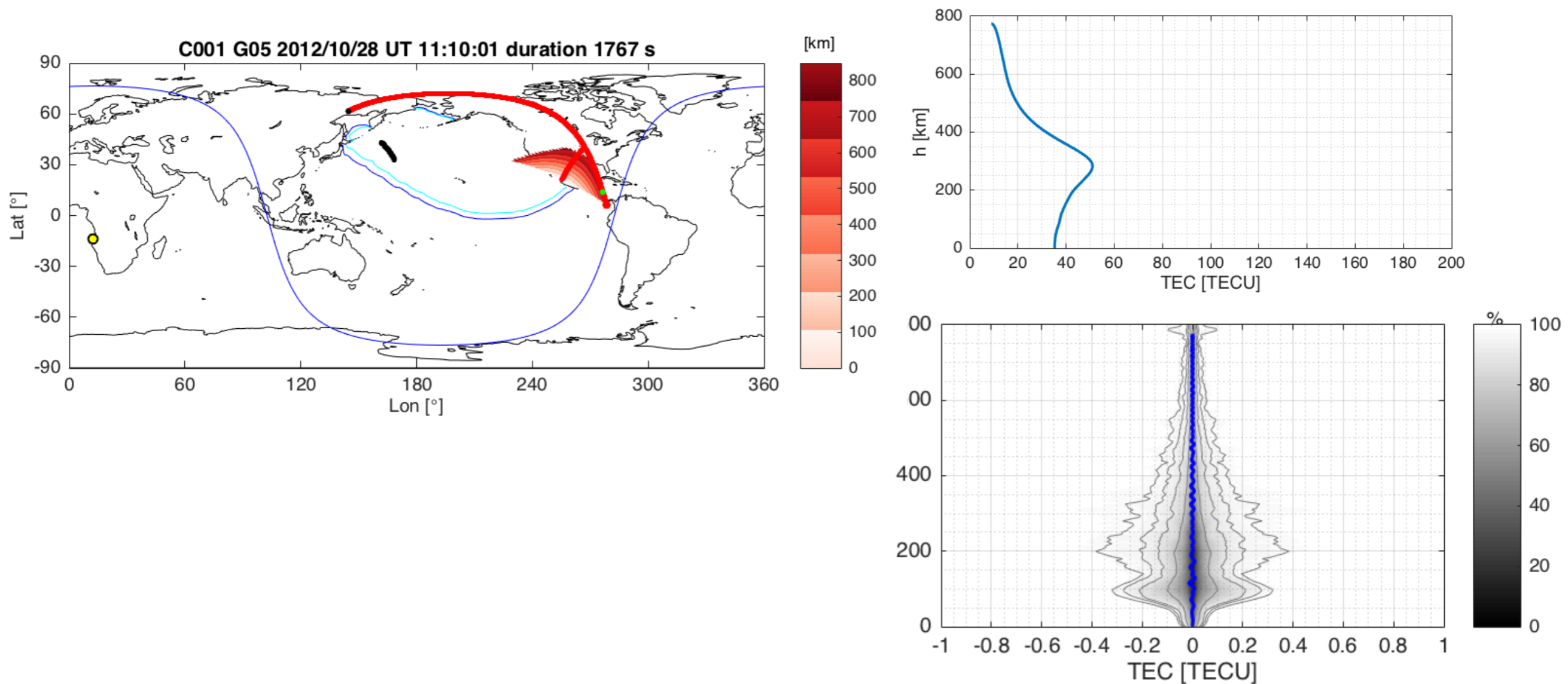


- Normal modes of 1-D Earth+Ocean+Atmosphere
- Transfer of moment from neutrals to ions:  $\mathbf{v}_i = (\mathbf{u} \cdot \mathbf{1}_b) \mathbf{1}_b$
- Electron density perturbation (background IRI), integrated along the line of sight COSMIC-GPS



# 2012 Haida Gwaii Tsunami

- No close encounter of occultation measurement with tsunami wave front



# Conclusions

- Space platforms provide data from regions not observable from the ground
- A small number of satellites makes the probability to cross the tsunami-generated gravity wave extremely small. Future missions, with receivers for multiple GNSS constellations, could provide better coverage.
- Difficulty of detection: isolated samples, no control of measurement geometry.
- Signals similar to the one observed during the 2011 Japan tsunami can occur, generated by other causes.