Long term trends of the equivalent slab thickness of the ionosphere over two solar cycles

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Outline

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- Data base
- The equivalent slab thickness τ
- Climatology of the equivalent slab thickness and other ionospheric key parameters over solar cycles 23-25
- Summary & conclusions

Investigation of long-term trends in the thermosphere and ionosphere

- Ionospheric and thermospheric temperatures depend primarily from solar energy input.
- On the other hand, changes in greenhouse gas concentration may cause long-term changes in the thermosphere and ionosphere as has shown by Roble & Dickinson (1989).
- Cooling in the upper atmosphere due to enhanced greenhouse gases is expected by Rishbeth and Roble (1992)
- Due to the complexity of ionospheric processes including coupling with the thermosphere and magnetosphere, long-term trends of ionospheric parameters such as NmF2 or hmF2 are difficult to interprete.
- To reduce the impact of natural forces such as solar activity, the analysis of the equivalent slab thickness is a promising option because it is less dependent from solar activity as NmF2 and TEC.
- Since slab thickness is closely related to the thermospheric scale height, thermospheric cooling can be studied in a direct way (Jakowski et al., 2017).

Jakowski, N., Hoque, M. M. ,Mielich, J., and Hall, C. (2017) Equivalent slab thickness of the ionosphere over Europe as an indicator of long-term temperature changes in the thermosphere, JASTP,. DOI: 10.1016/j.jastp.2017.04.008 ISSN 1364-6826

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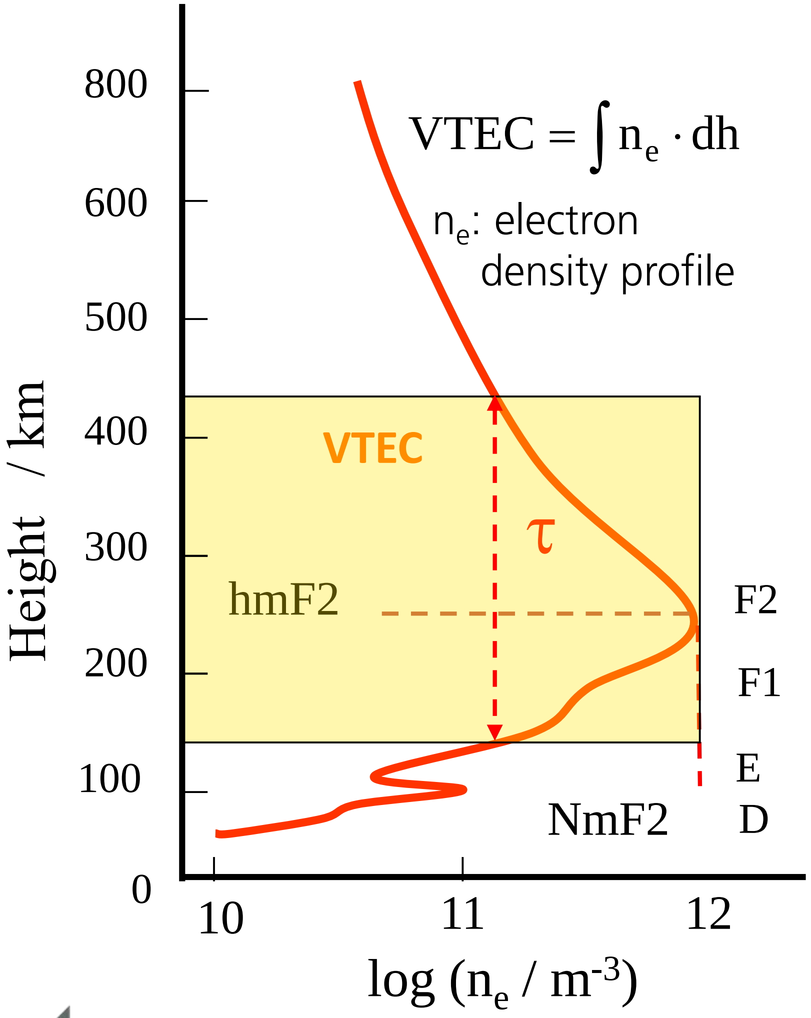
Equivalent slab thickness – physical meaning



The equivalent slab thickness τ is defined by

$$VTEC = \tau \cdot N_mF2$$

According to the Chapman theory the thermospheric scale height is given by

$$H = k \cdot T / M \cdot g$$

H is related to τ by $VTEC \approx 4.13H \cdot N_mF2 \cdot \sqrt{\cos\chi}$

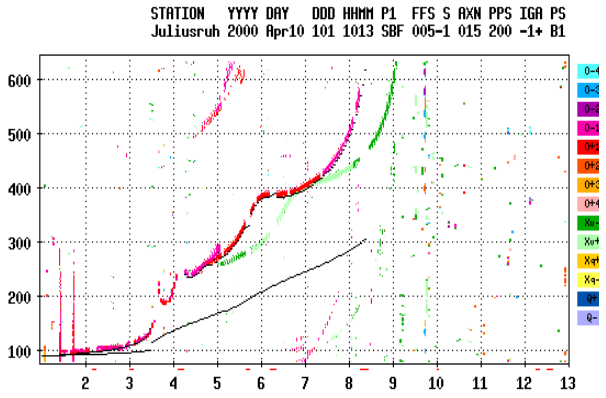
that means $\tau = \dfrac{VTEC}{N_mF2} \leq 4.13\ H$

$H \approx 50 \ldots 80$ km ⇨ $\tau \approx 200\text{-}360$ km

under diffusive equilibrium conditions (condition best fulfilled around noon).

Ionospheric data base - I

F2 layer peak density NmF2 derived from ground based ionosondes

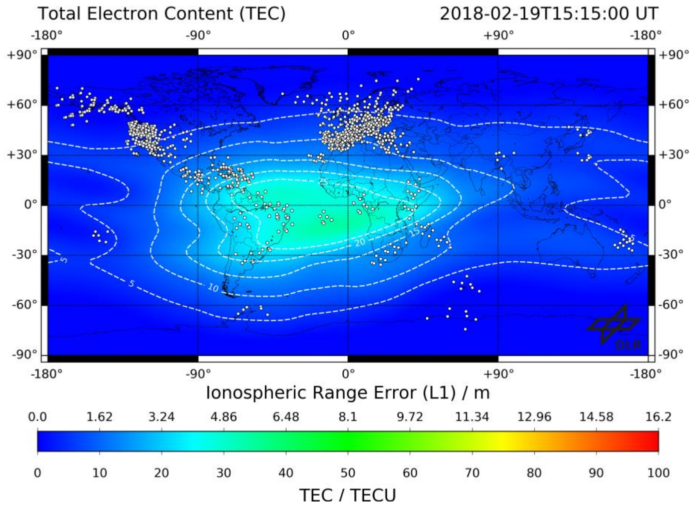


Data sources:

i) Vertical sounding data from ionosonde stations Juliusruh, Rome and Chilton

ii) ftp://ftp.ngdc.noaa.gov/ionosonde/data/

Total Electron Content (TEC) derived from ground based GNSS measurements



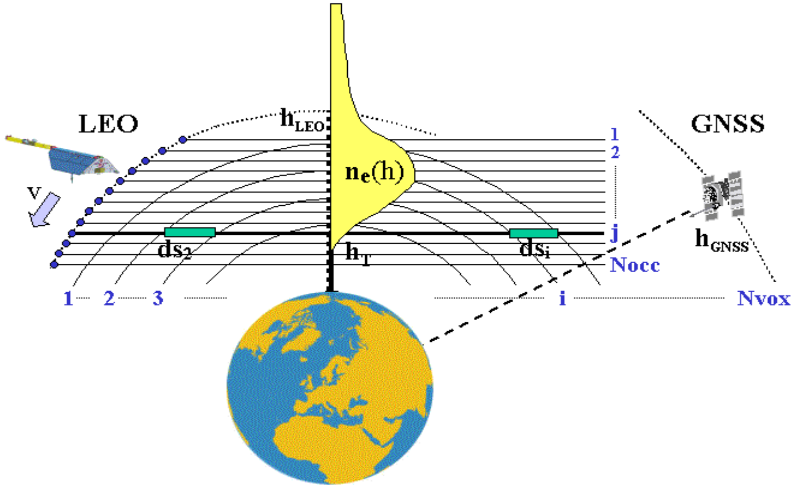
Data sources:

i) Post processed TEC maps from DLR/ SWACI

ii) Post processed TEC maps provided by the Center for Orbit Determination in Europe (CODE)

iii) ftp://cddis.gsfc.nasa.gov/pub/gps/products/ionex

F2 layer peak density NmF2 derived from radio occultation measurements



Data sources:

i) CHAMP & GRACE: SWACI/IMPC DLR

ii) COSMIC: CDAAC

iii) https://cdaac-www.cosmic.ucar.edu/cdaac/tar/rest.html

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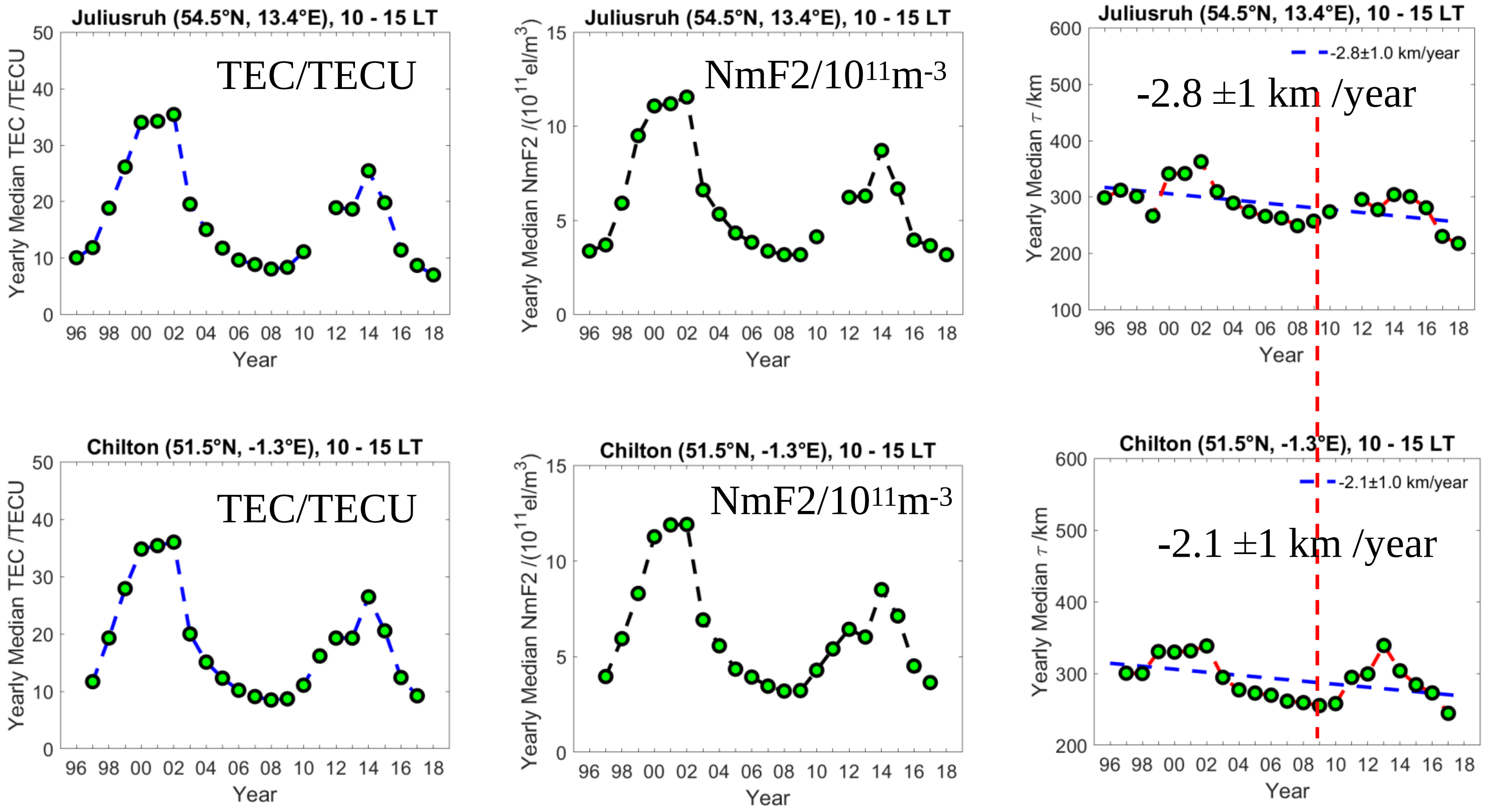
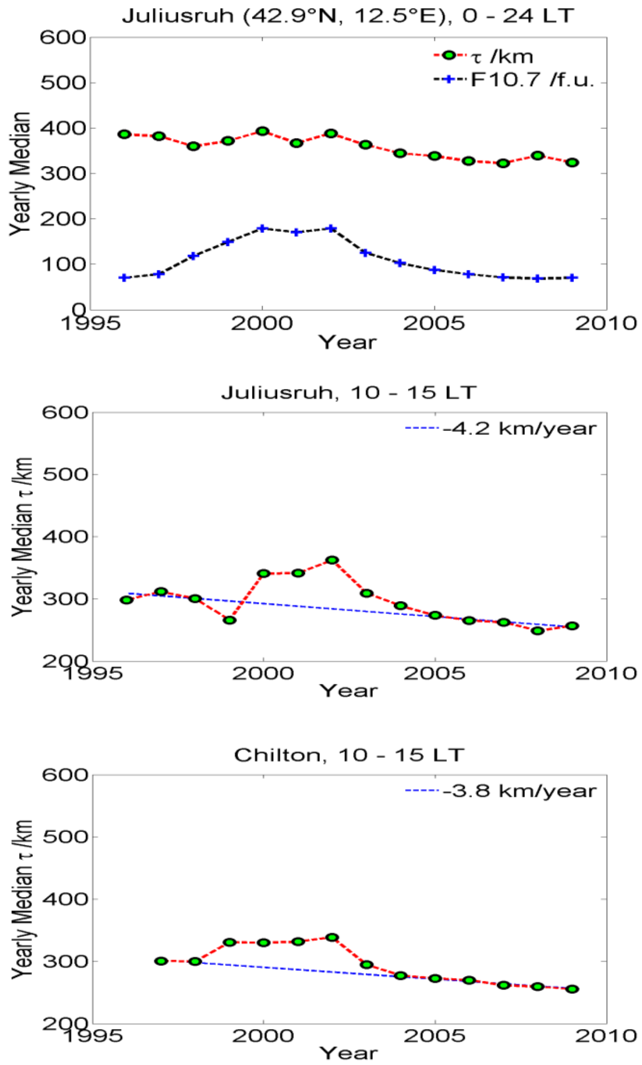
Yearly medians of NmF2, GNSS derived TEC and slab thickness over European ionosonde stations Juliusruh and Chilton





Jakowski et al. 2017, JASTP

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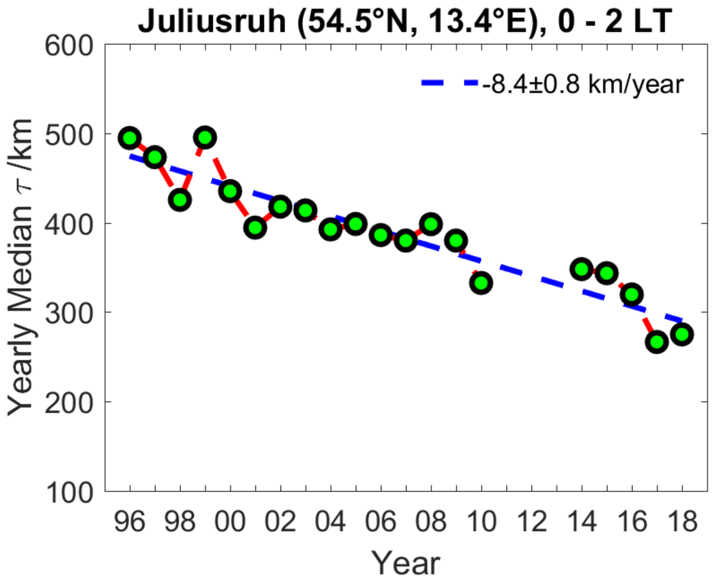
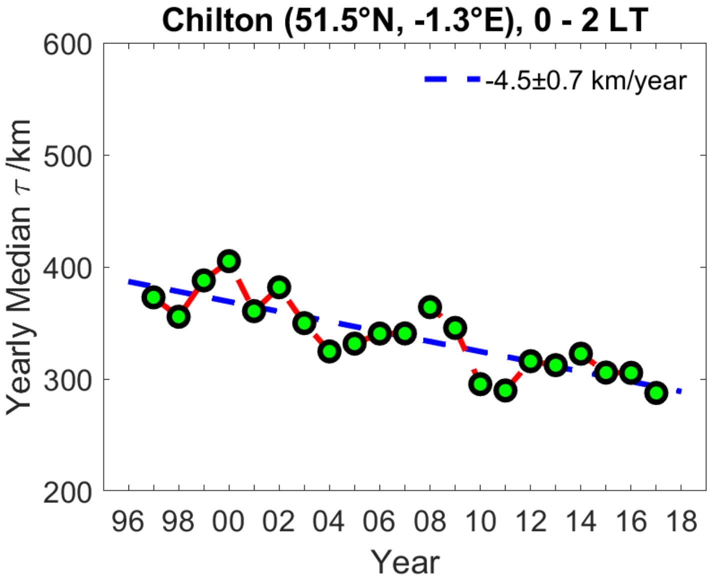
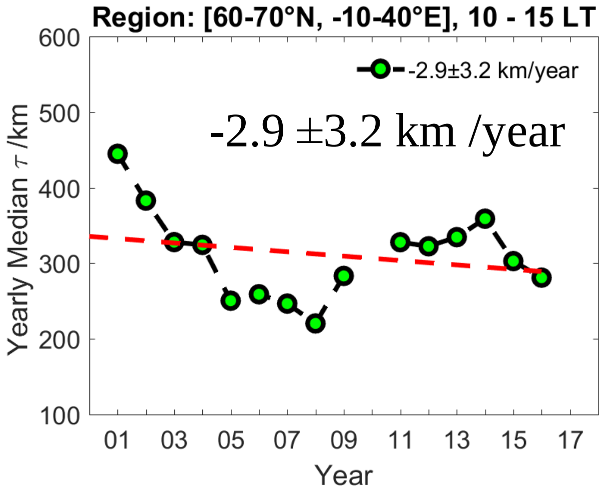
Yearly median slab thickness trend at ionosonde stations at nighttime

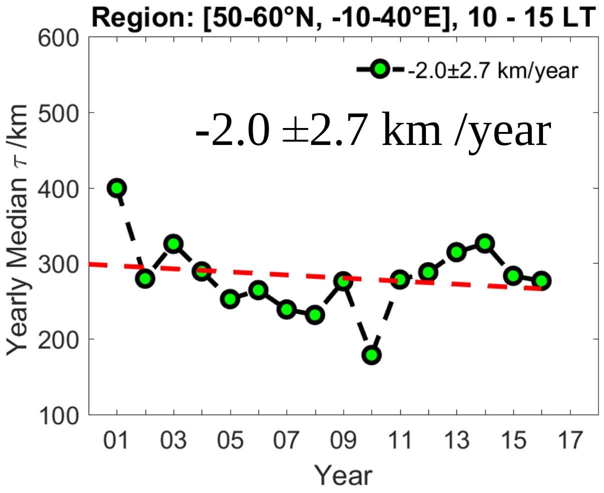


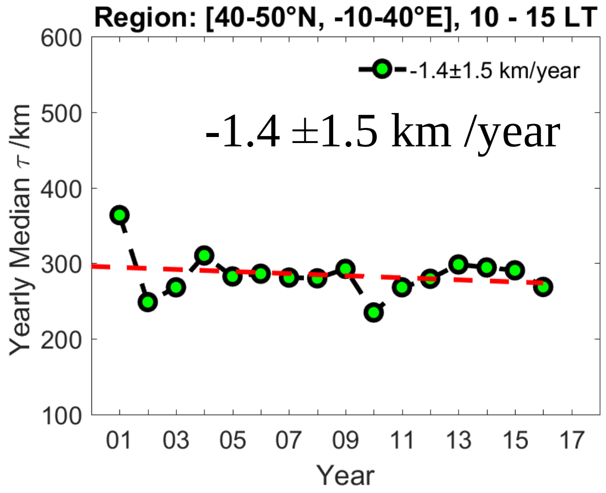


- Significant negative trends have been observed also at night (00-02LT) indicating associated cooling of the topside ionosphere. Solar activity variation not clearly visible
- Because there is a close coupling with the plasmasphere at night it is assumed that the cooling concerns altitudes up to more than 1000km.

Monthly median slab thickness over the European longitude sector derived from space based IRO and ground based TEC data

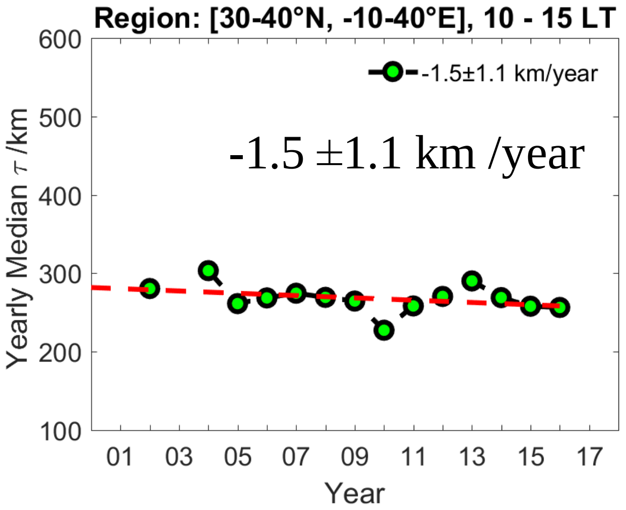






Geographic latitude dependency in the longitude sector 10°W – 40°E.

Negative trend of slab thickness decreases with latitude from about 3 to 1.4 km/year in the geographic latitude range 30-70° N.



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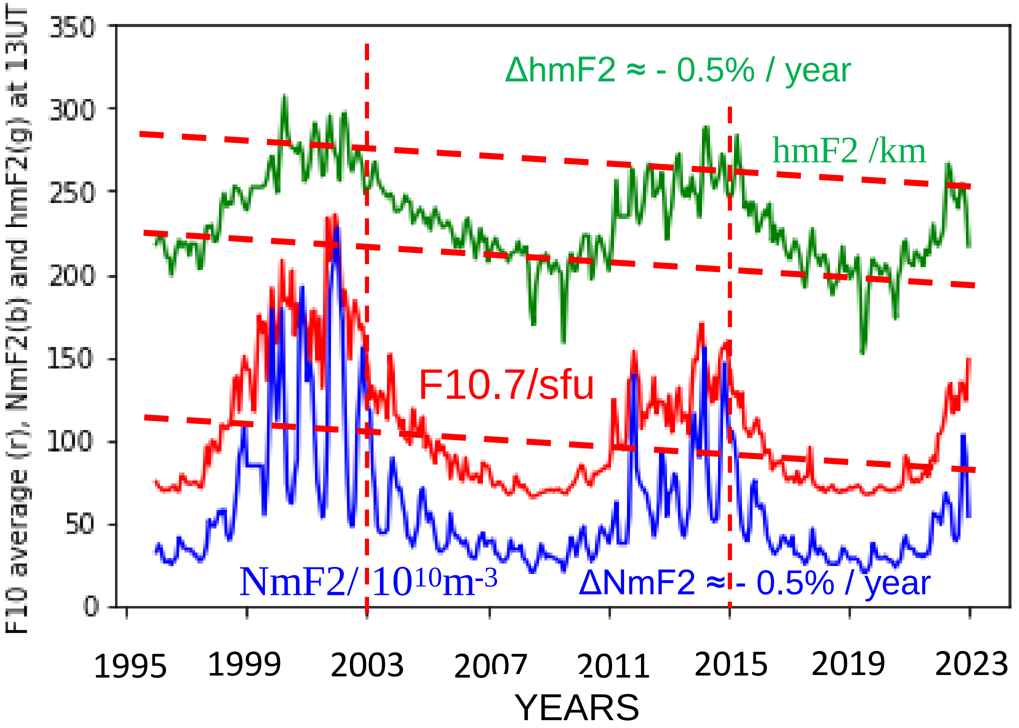
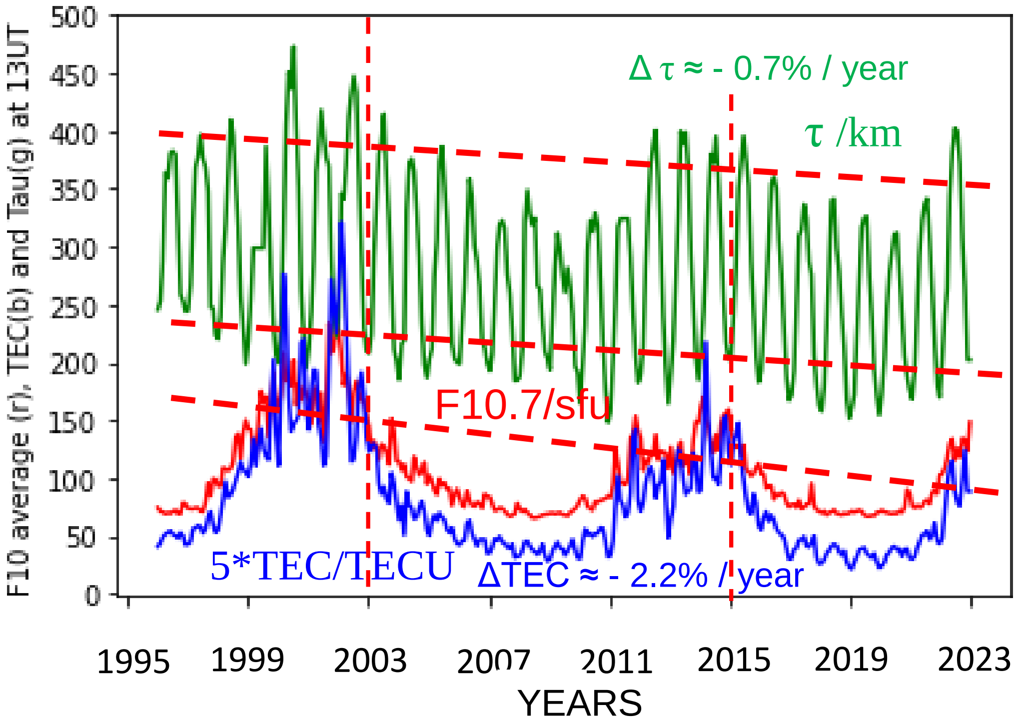
Monthly medians of NmF2/hmF2 (Juliusruh) and TEC / τ around noon (13UT)





Monthly medians of NmF2, hmF2, TEC and τ are closely related to the solar activity cycles 23-25 and follow systematic seasonal patterns:

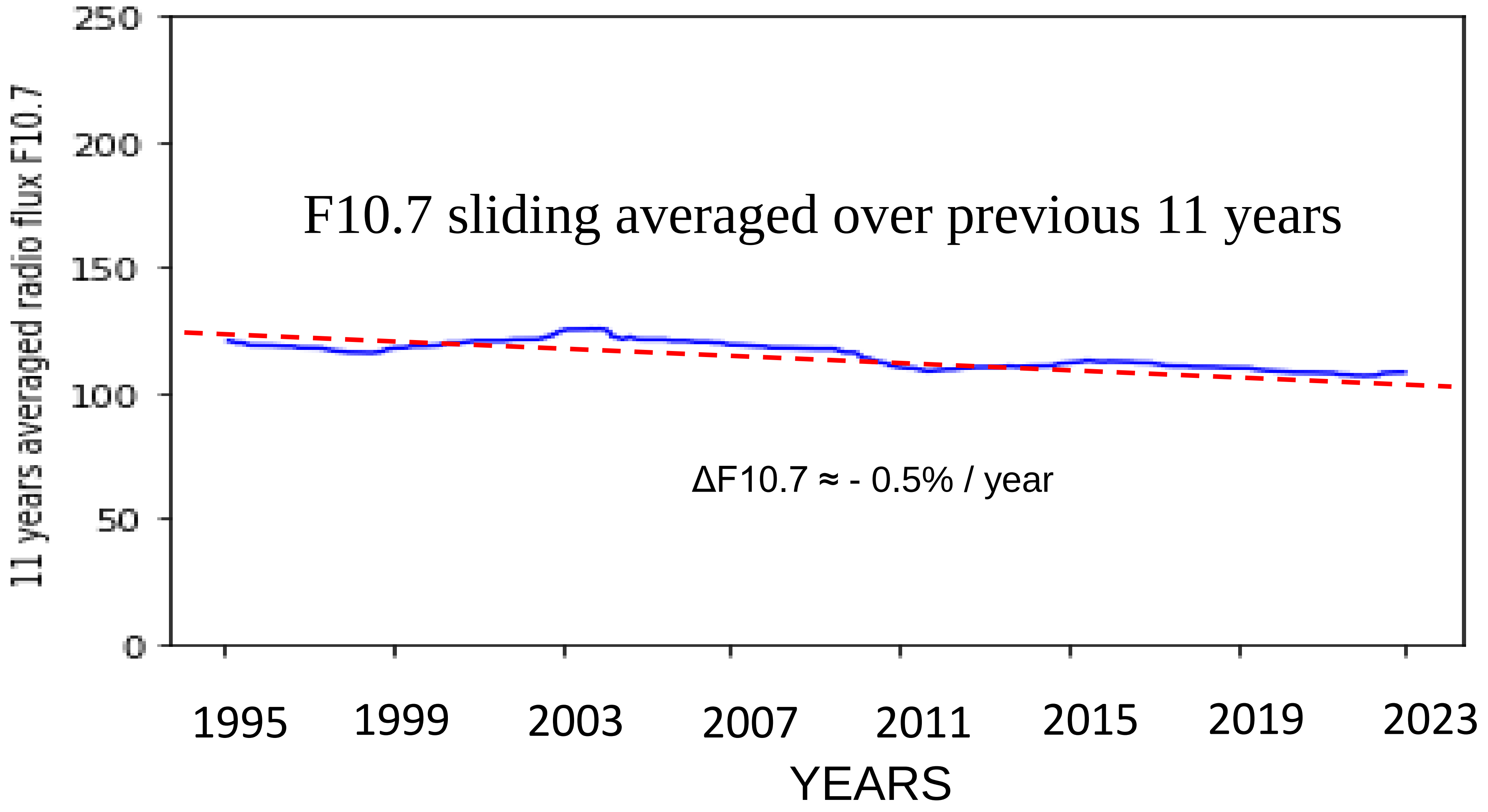
NmF2: daytime maxima in winter (annual,semiannual)

TEC: daytime maxima enhanced in winter (semiannual)

hmF2: no clear seasonal dependence

τ : clear seasonal pattern with minima in winter

Monthly medians of TEC, NmF2, hmF2 and τ since 1996

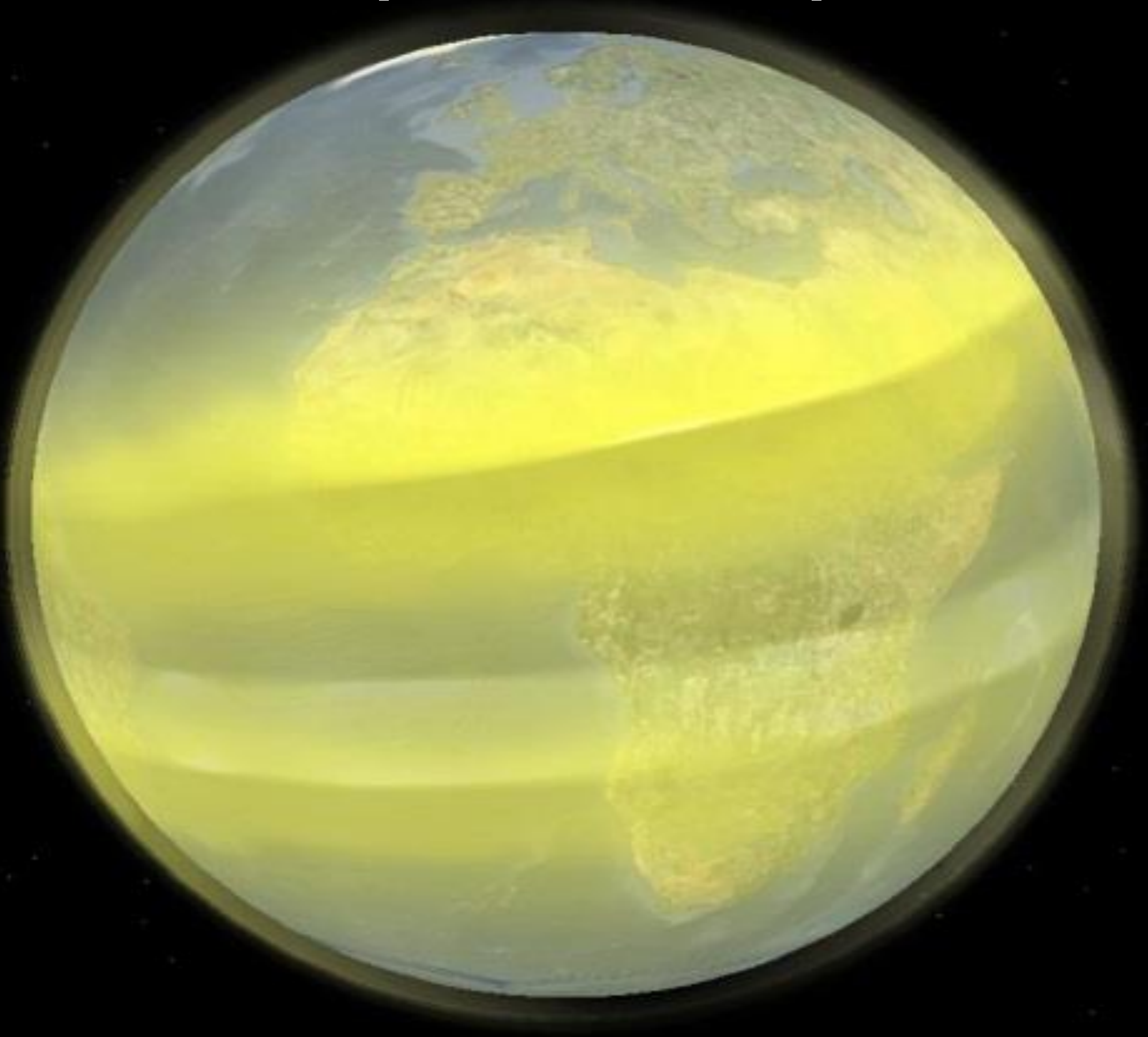


Summary and conclusions

- The equivalent slab thickness as an vertical electron density shape parameter is an ideal quantity to study long term trends of the ionosphere.
- Analyzing the equivalent slab thickness over more than two solar cycles 23-25 by vertical sounding and radio occultation techniques over Europe confirms former observations by Jakowski et al. (2017) for the period 1996-2009.
- Negative trends range from about -1.4 up to -3 km/year around noon whereas nighttime trends at ionosonde stations reach even -8 km /year.
- The observed percentage trends of ionospheric key parameters such as NmF2 and hmF2 are in the order of about -5 % /decade whereas TEC reaches about -22 % /decade; the negative trend of the equivalent slab thickness is in the order of -7%/decade.
- Since the long term trend of the solar activity during cycles 23-25 is characterized by a similar trend of about -5% /decade, it is assumed that the main driving force for the observed negative trends in ionospheric key parameters is due to the decrease of solar activity in this period.

Ionosphere from space

Electron density
July 23, 2011
14:00 UT



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Thank you for your attention!