Assessment of the NeQuick model at mid-latitudes using GPS TEC and ionosonde data

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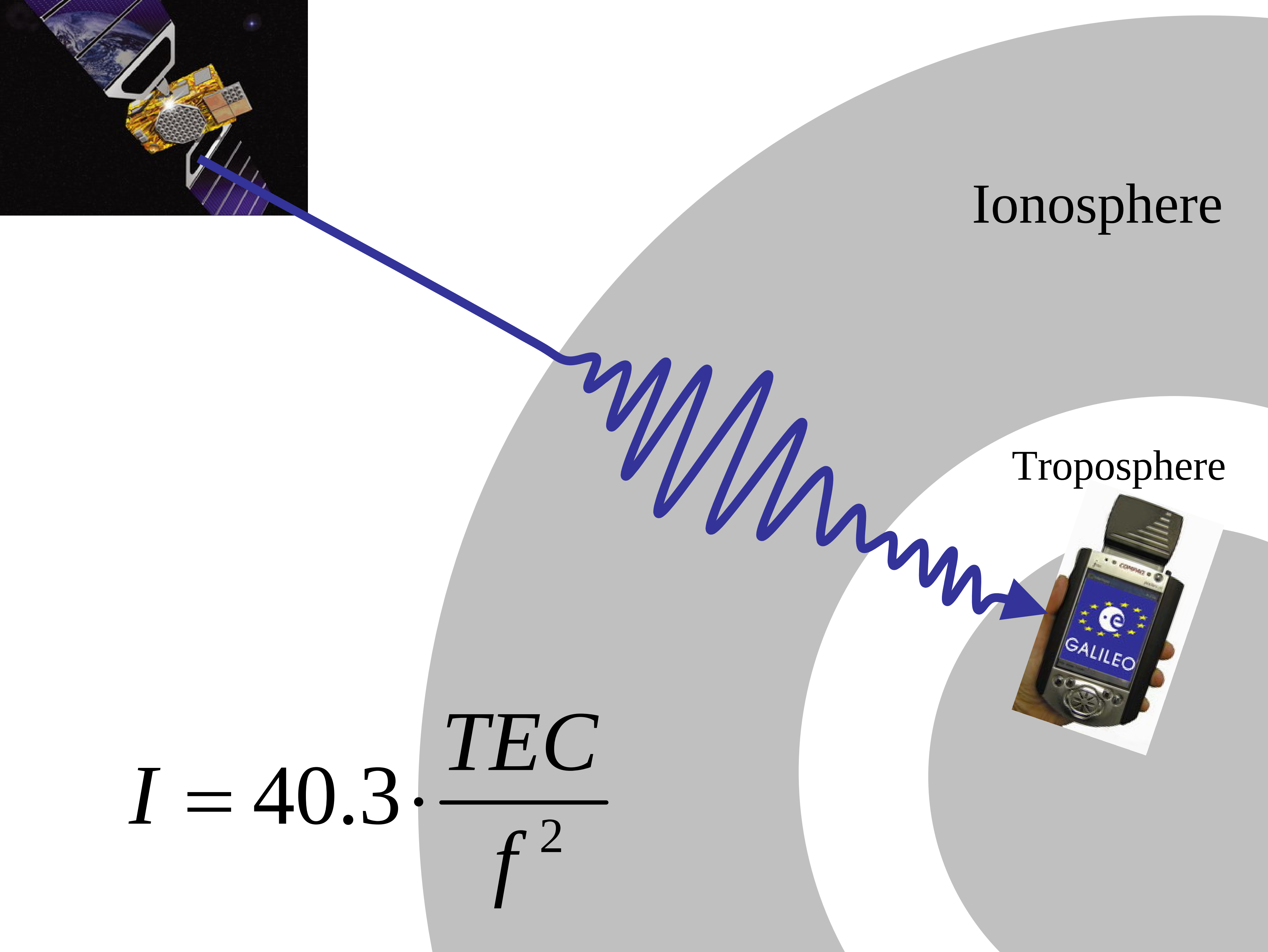
July 11th, 2007
IRI/COST 296 Workshop (Prague, Czech Republic)



$$I = 40.3 \cdot \frac{TEC}{f^2}$$

1. Tools

Modelling and measuring the ionosphere

1. Tools

Modelling and measuring the ionosphere

2. vTEC analysis

NeQuick vs GPS TEC data

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Modelling and measuring the ionosphere

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NeQuick vs GPS TEC data

3. Case days

Using GPS TEC data to identify situations for profile analysis

1. Tools

Modelling and measuring the ionosphere

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NeQuick vs GPS TEC data

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Using GPS TEC data to identify situations for profile analysis

4. Profile analysis

NeQuick vs ionosonde data

1. Tools

2. vTEC analysis

3. Case days

4. Profile analysis

NeQuick is an empirical « profiler ».

- Output = Ne → TEC with integration
- Layer peaks = anchor points
  → monthly median CCIR maps
- Input = ionospheric variations such as solar flux

1. Tools

It will be used on a daily basis for GALILEO SF users.

- Monthly flux replaced by daily parameter (Az)

Measure sTEC

→ Optimize Az →

Run NeQuick

TEC can be determined with GPS.

- Geometric free observables (code and phase)

$$P^i_{p,GF} = 40.3 \cdot TEC^i_p \left(\frac{1}{f_{L1}^2} - \frac{1}{f_{L2}^2} \right) + CG^i_{p,GF} \qquad \varphi^i_{p,GF} = -40.3 \cdot TEC^i_p \frac{f_{L1}}{c} \left(\frac{1}{f_{L2}^2} - \frac{1}{f_{L1}^2} \right) + CP^i_{p,GF}$$

- Differential code biases estimated and eliminated
- Latitude filter → vertical: $\Phi_{sta} - 1° \leq \Phi_{iono} \leq \Phi_{sta} + 1°$
- Mean over 15 minutes

1. Tools

Ne profiles can be obtained with an ionosonde.

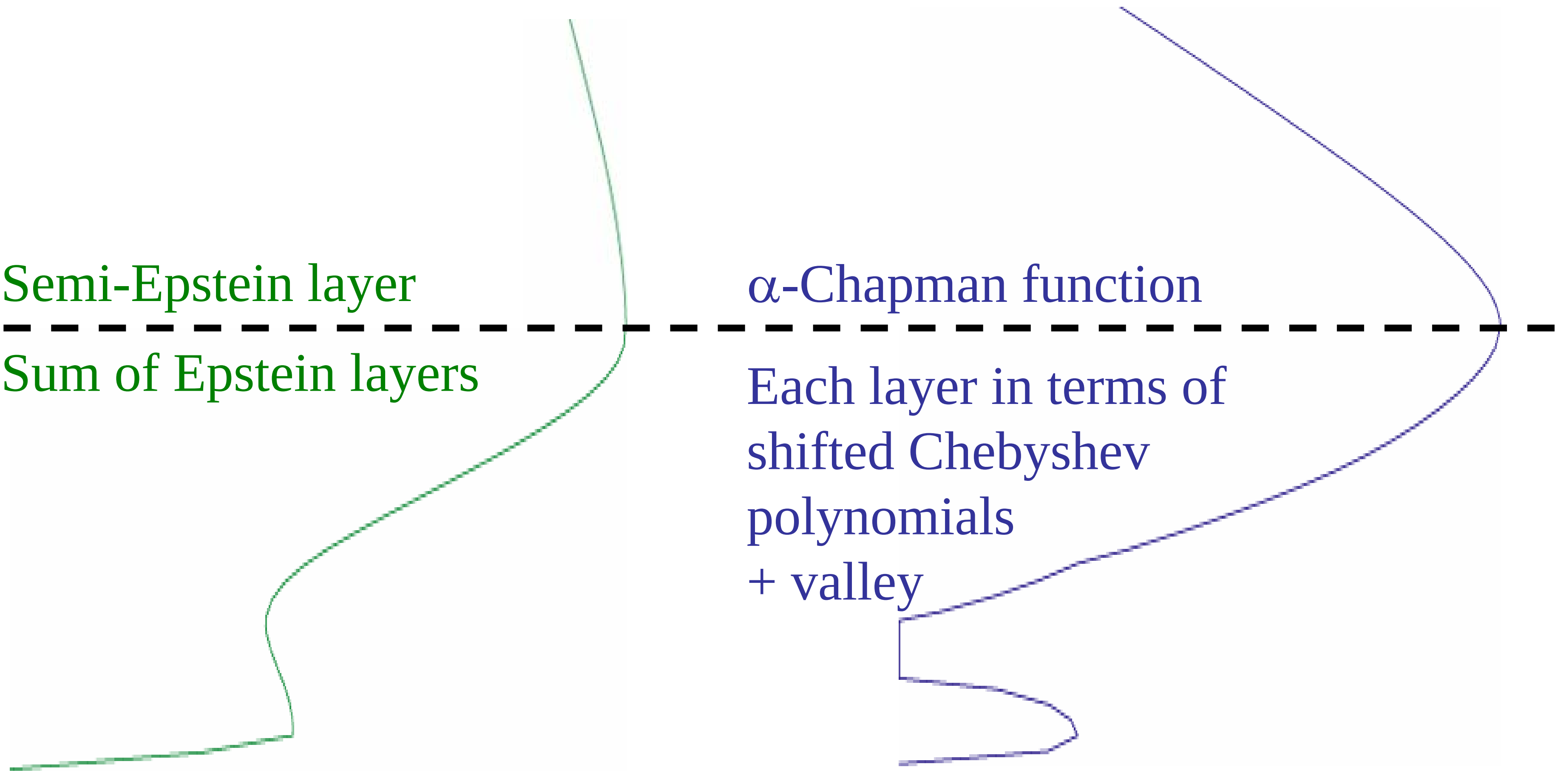
- Vertical sounding → virtual heights $h' = \frac{cT}{2}$
  and plasma frequencies $f = 8.98 \cdot \sqrt{Ne}$
- Scaling → true heights and Ne
- Digisonde from UMLCAR
  → shifted Chebyshev polynomials

1. Tools

Ne profiles have different analytical formulations.

NeQuick

Digisonde



1. Tools

We can learn a lot using collocated data.

- Dourbes (Belgium ; 50.1N 4.6E)
- GPS station: vTEC every 15 minutes
- Digisonde DGS256: profiles every hour till 2005 and every 20 minutes afterwards

→ use of collocated data for the last solar cycle

1. Tools

2. vTEC analysis

3. Case days

4. Profile analysis

2. vTEC analysis

Let's compare measured and modelled vTEC evolution with time.

- Variations: 1 solar activity (year and solar flux)

  2 season (month)

  [3 UT (expected monthly median)]

- Statistics: 1 mean (bias) [or median]

  → over/underestimation

  2 RMS → error

2. vTEC analysis

Solar activity Tools

- Data: 1998 for average solar activity,

  2000 to 2002 for high,

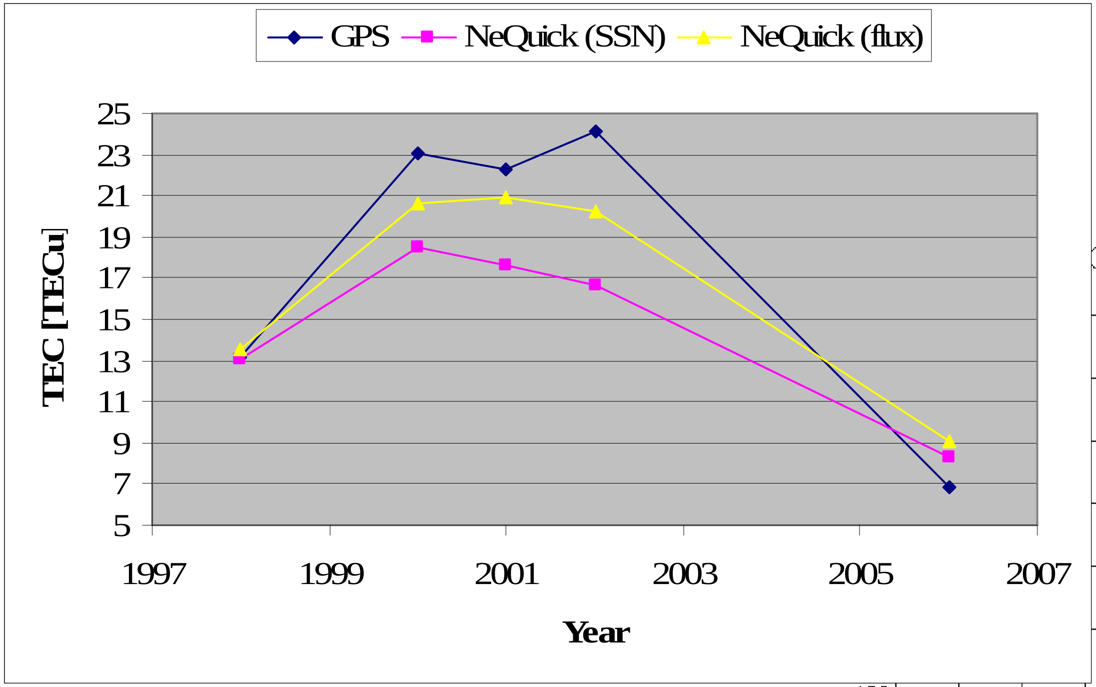
  2006 for low

- Model: ITU-R version

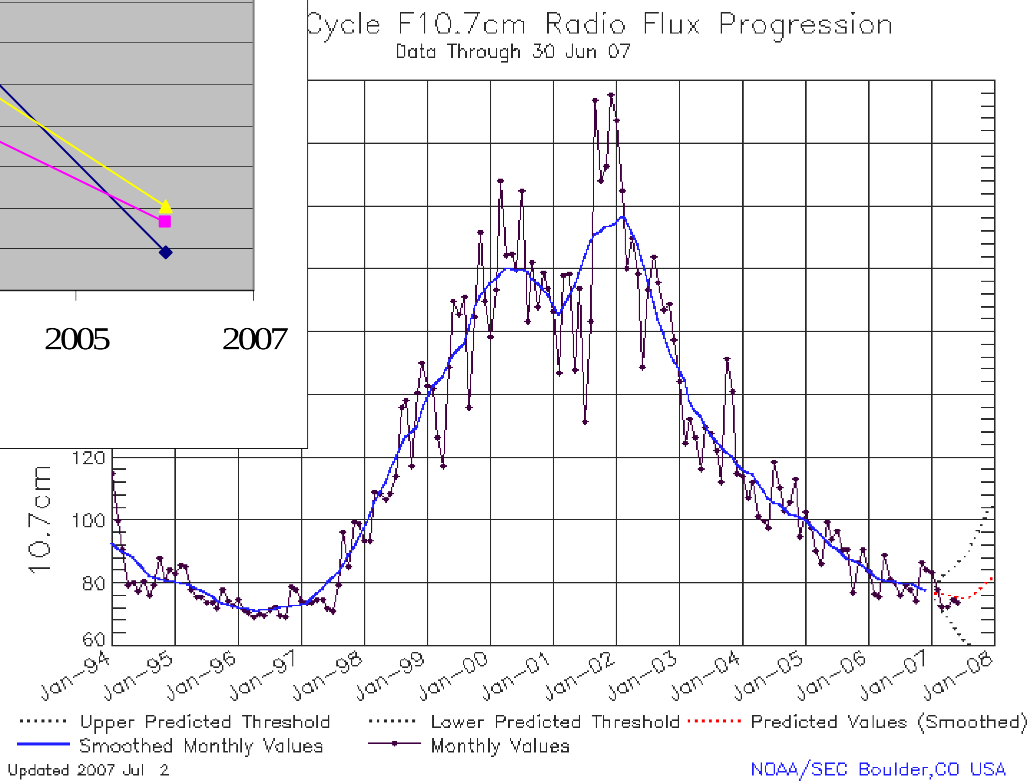
  index R_{12} (SIDC) or Φ_{12} (NOAA)

2. vTEC analysis

Solar activity TEC



Flux !

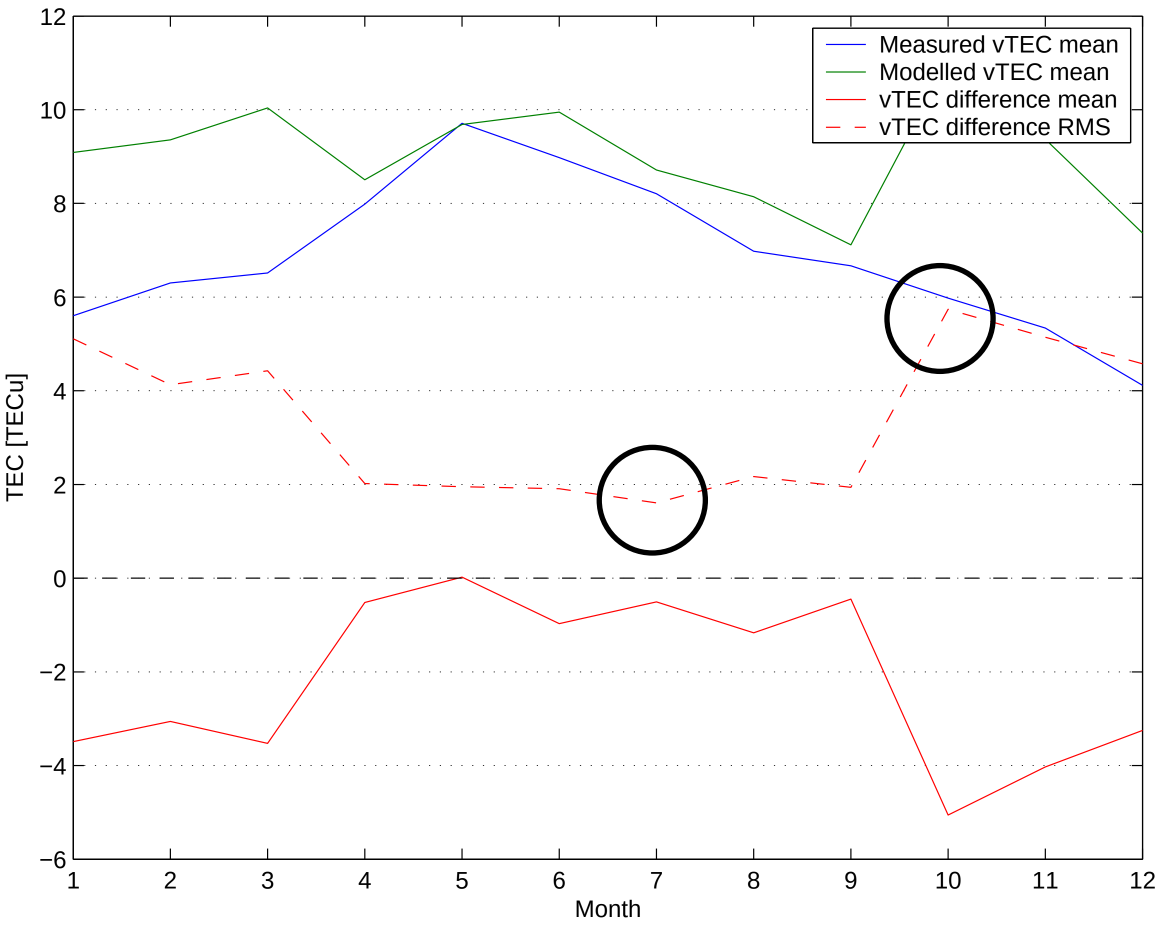


Solar activity Conclusion

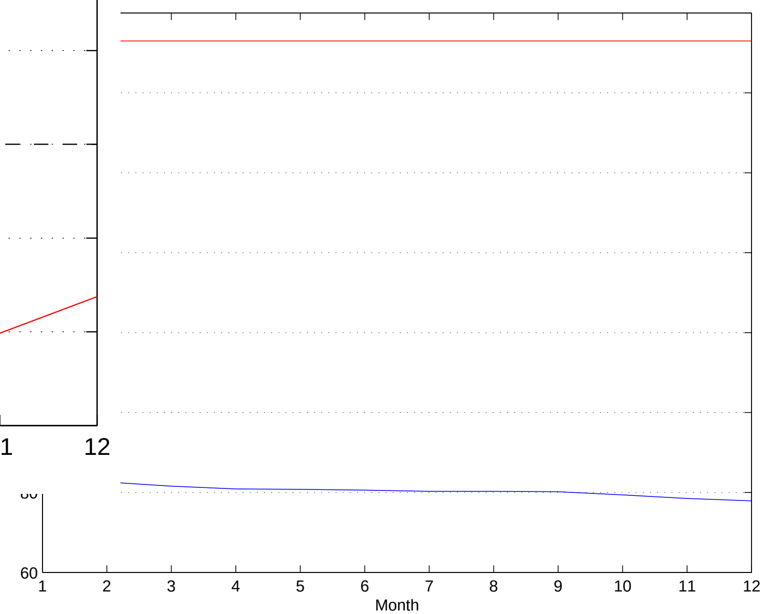
- SA index
  - Better monthly smoothed flux
  - Conversion formula to investigate
- Focus
  - Low SA level: 2006 → overestimation
  - High SA level: 2002 → underestimation

2. vTEC analysis

Season
Low solar activity level

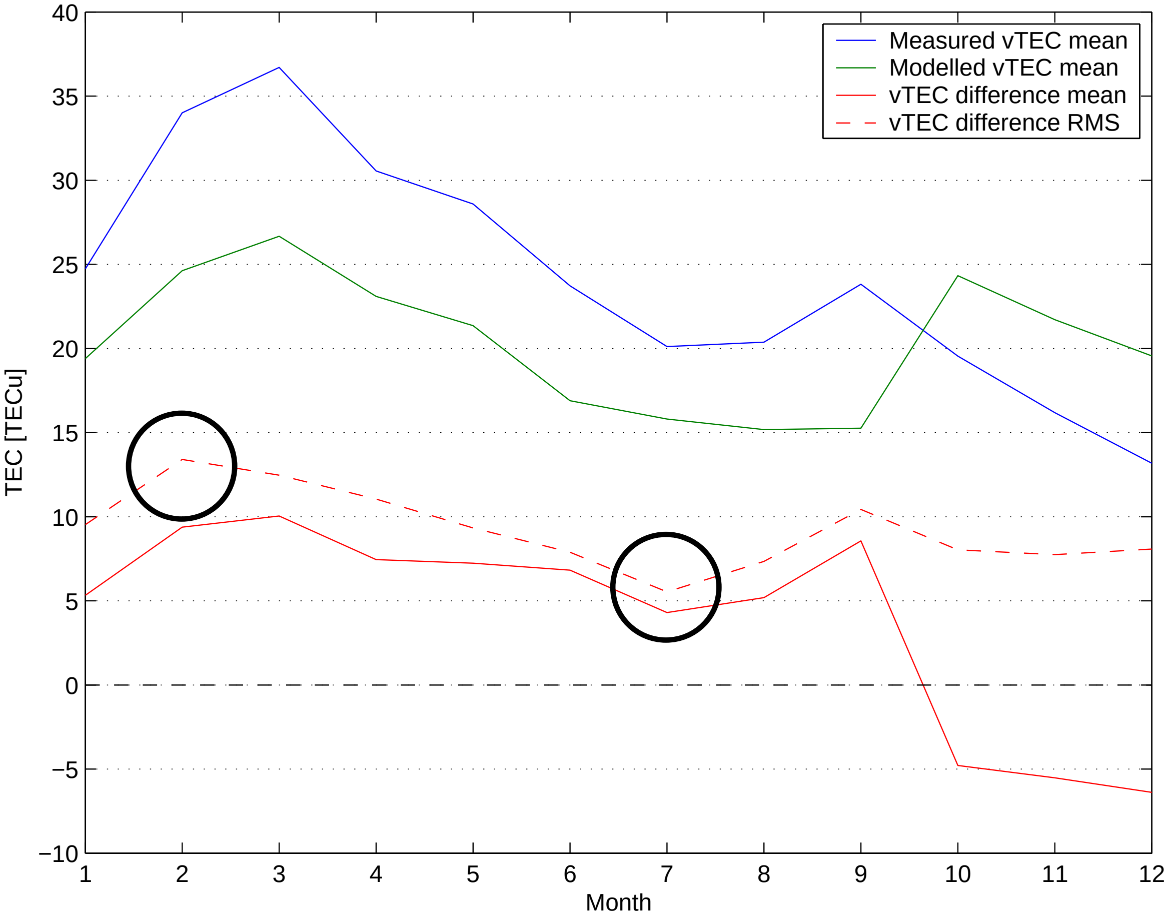


6-month fluctuations

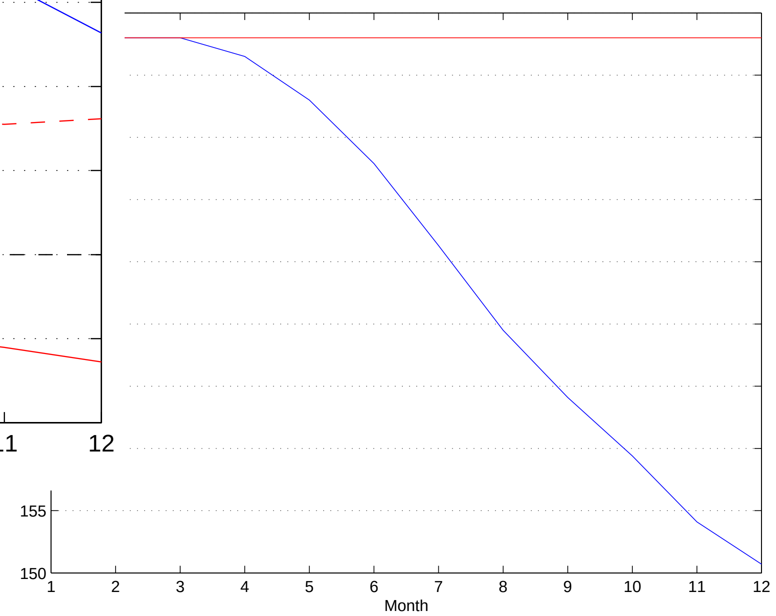


2. vTEC analysis

Season
High solar activity level



Solar flux influence



2. vTEC analysis

Season Conclusion

- Ambivalent behaviour
- Flux influence
- Focus
  - Low SA level: July 2006 → good
  - Autumn: October 2006 → bad
  - Summer: July 2002 → good
  - High SA level: February 2002 → bad

1. Tools

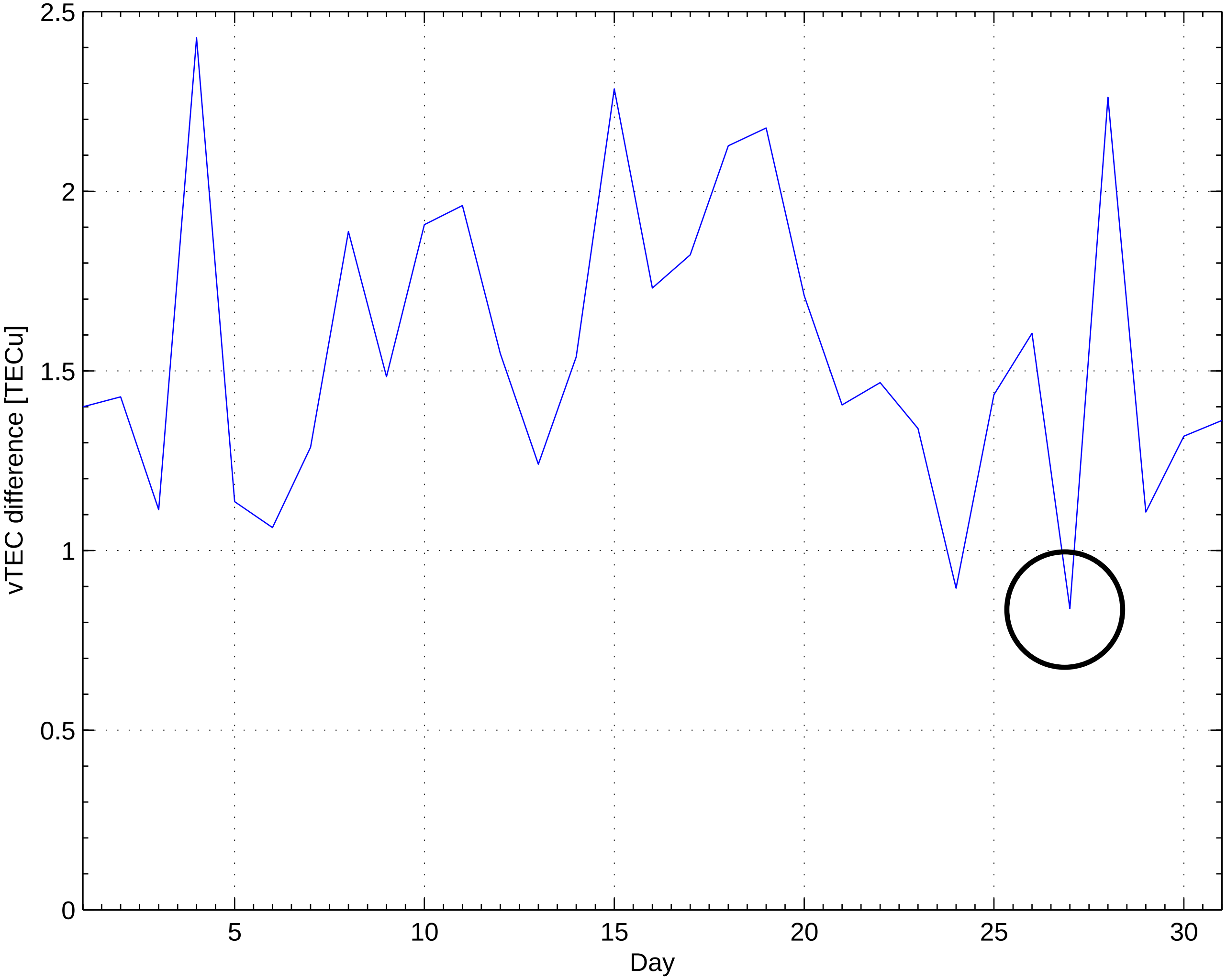
2. vTEC analysis

3. Case days

4. Profile analysis

3. Case days

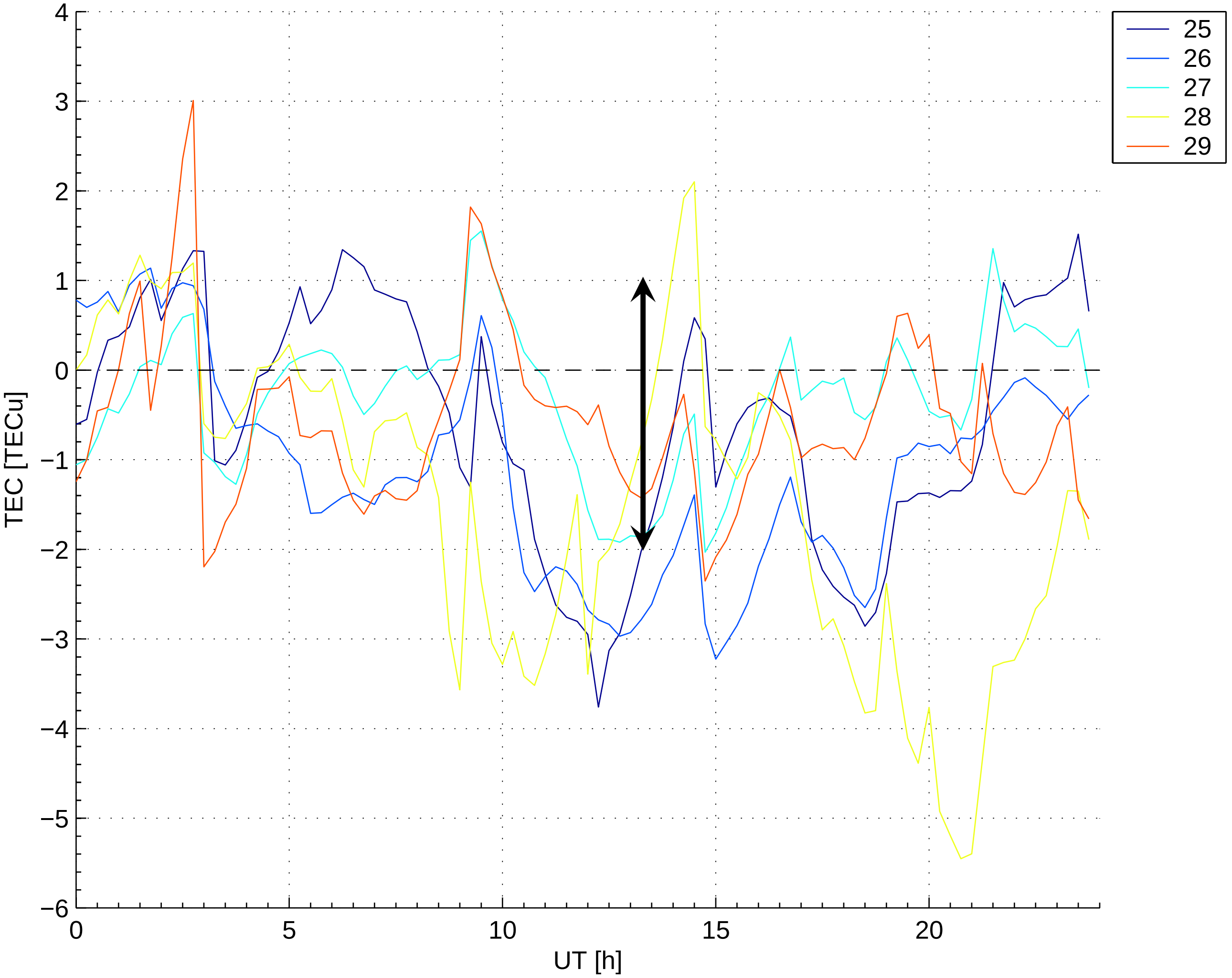
Low solar activity level



July:
best month

Lowest RMS:
27th

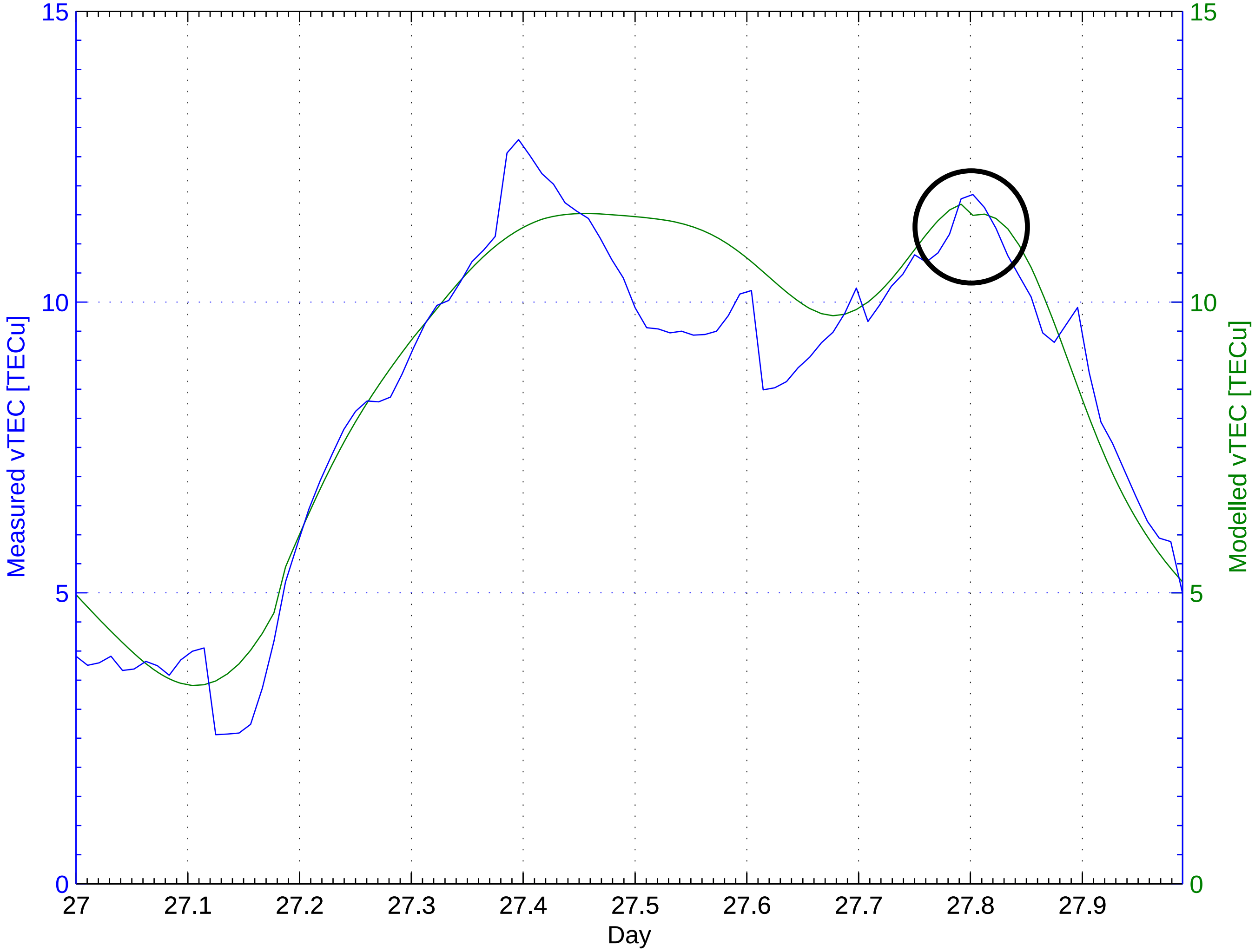
Low solar activity level



July:
best month

Lowest range
comparable with GPS
TEC uncertainty

Low solar activity level



July:
best month

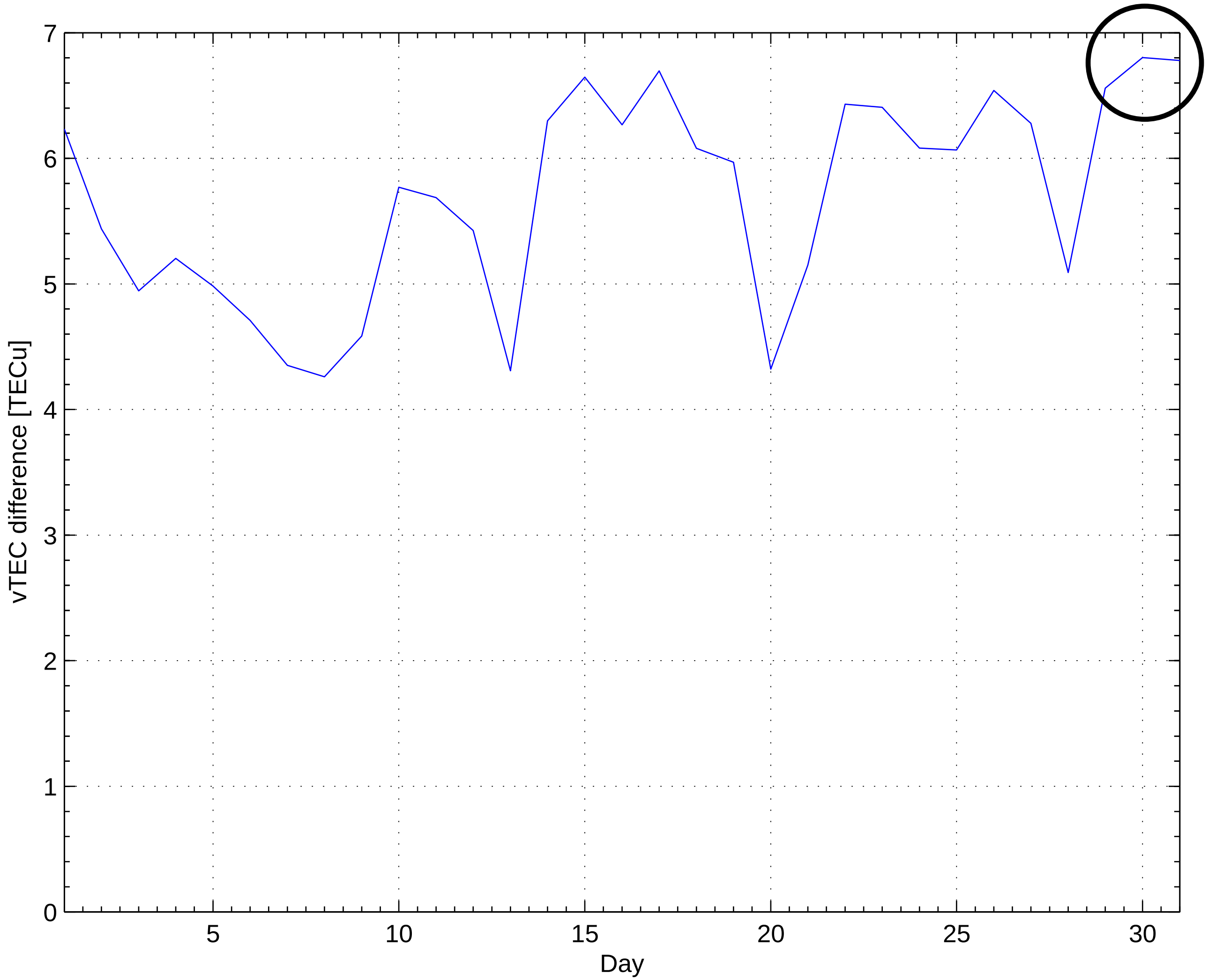
Lowest RMS:
27th

Lowest range
comparable with GPS TEC uncertainty

Maximum:
19h

3. Case days

Low solar activity level

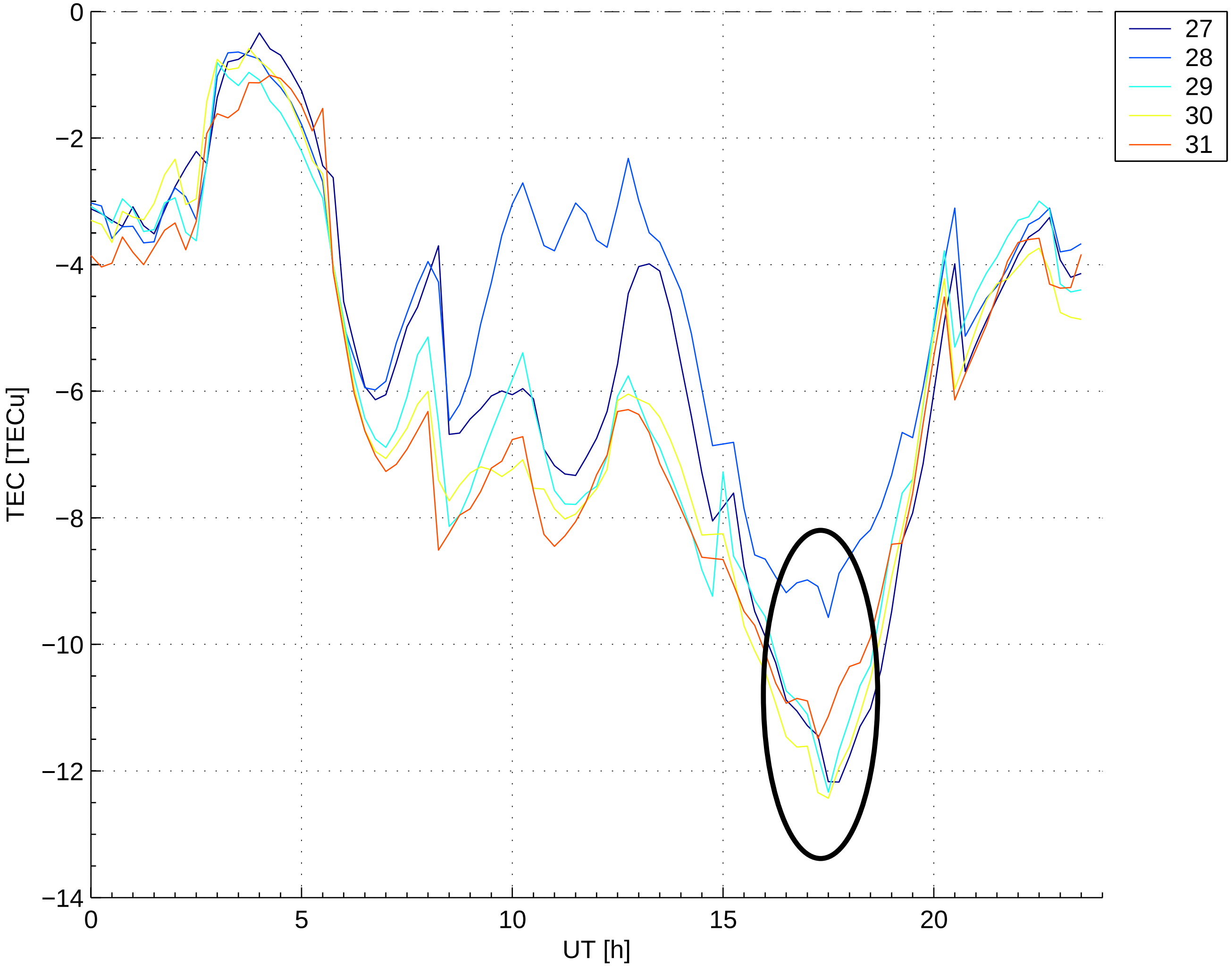


October:
worst month

Highest RMS:
30th

3. Case days

Low solar activity level

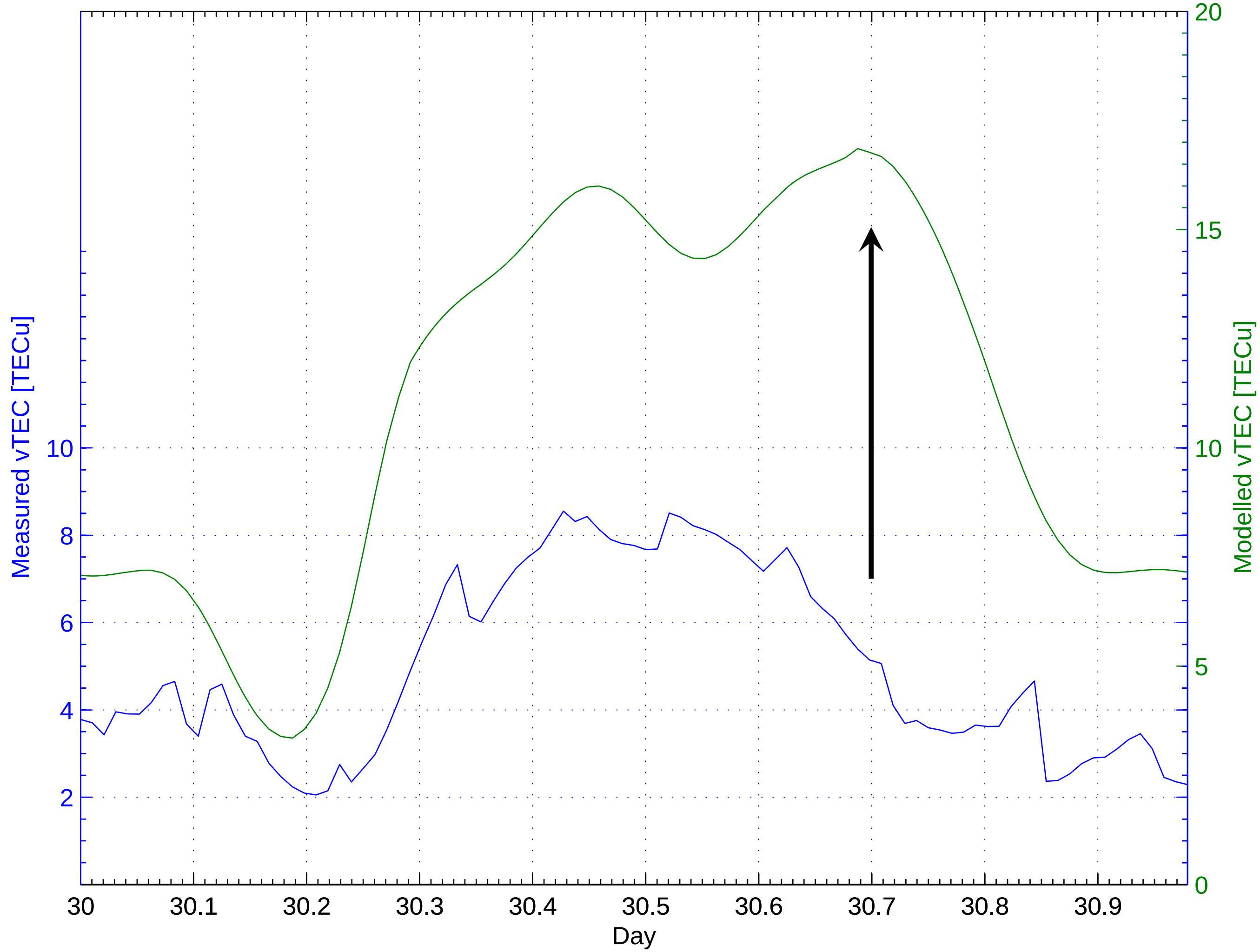


October: worst month

False maximum: 17h30

3. Case days

Low solar activity level



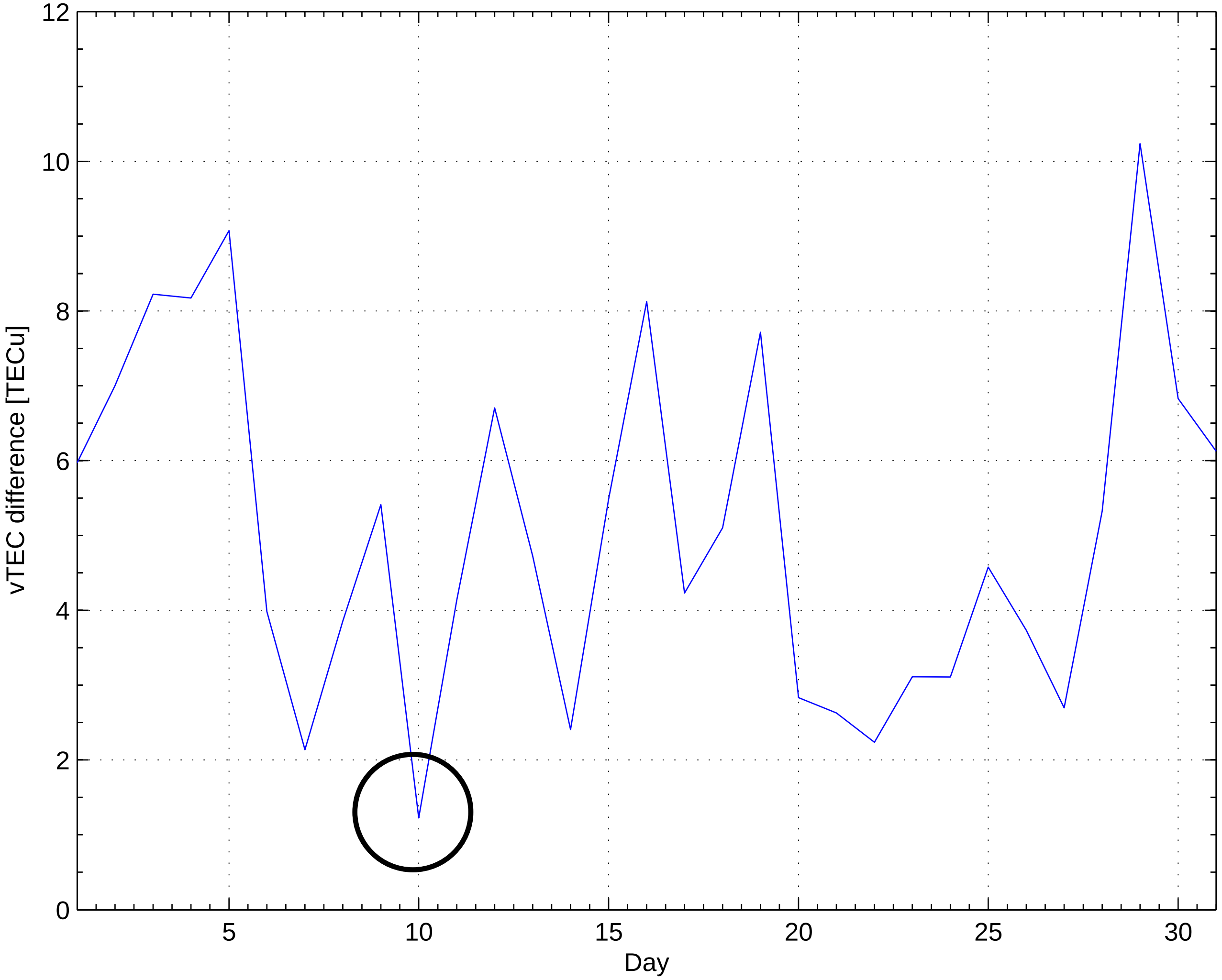
October: worst month

Highest RMS: 30th

False maximum: 17h30

3. Case days

High solar activity level

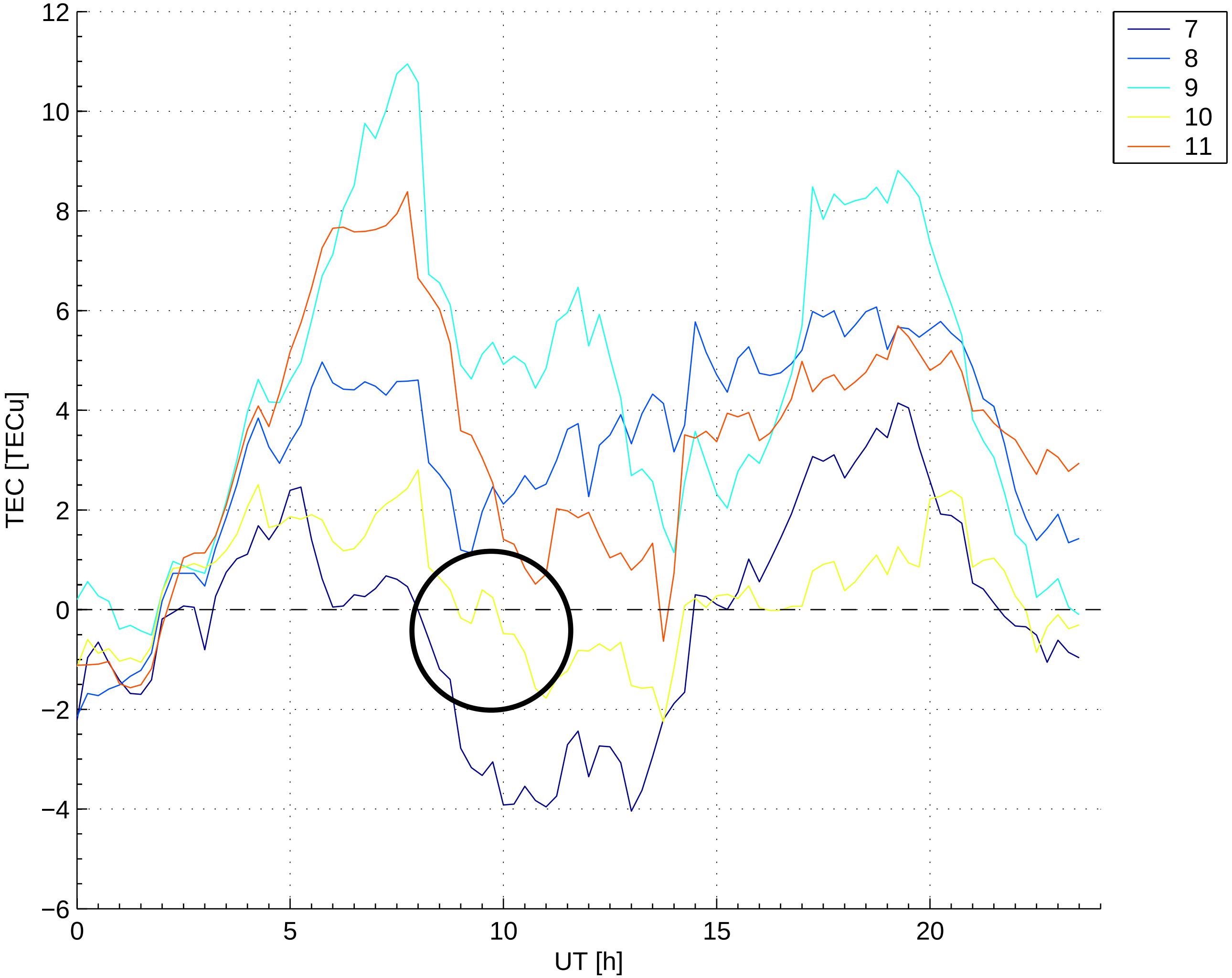


July:
best month

Lowest RMS:
10th

3. Case days

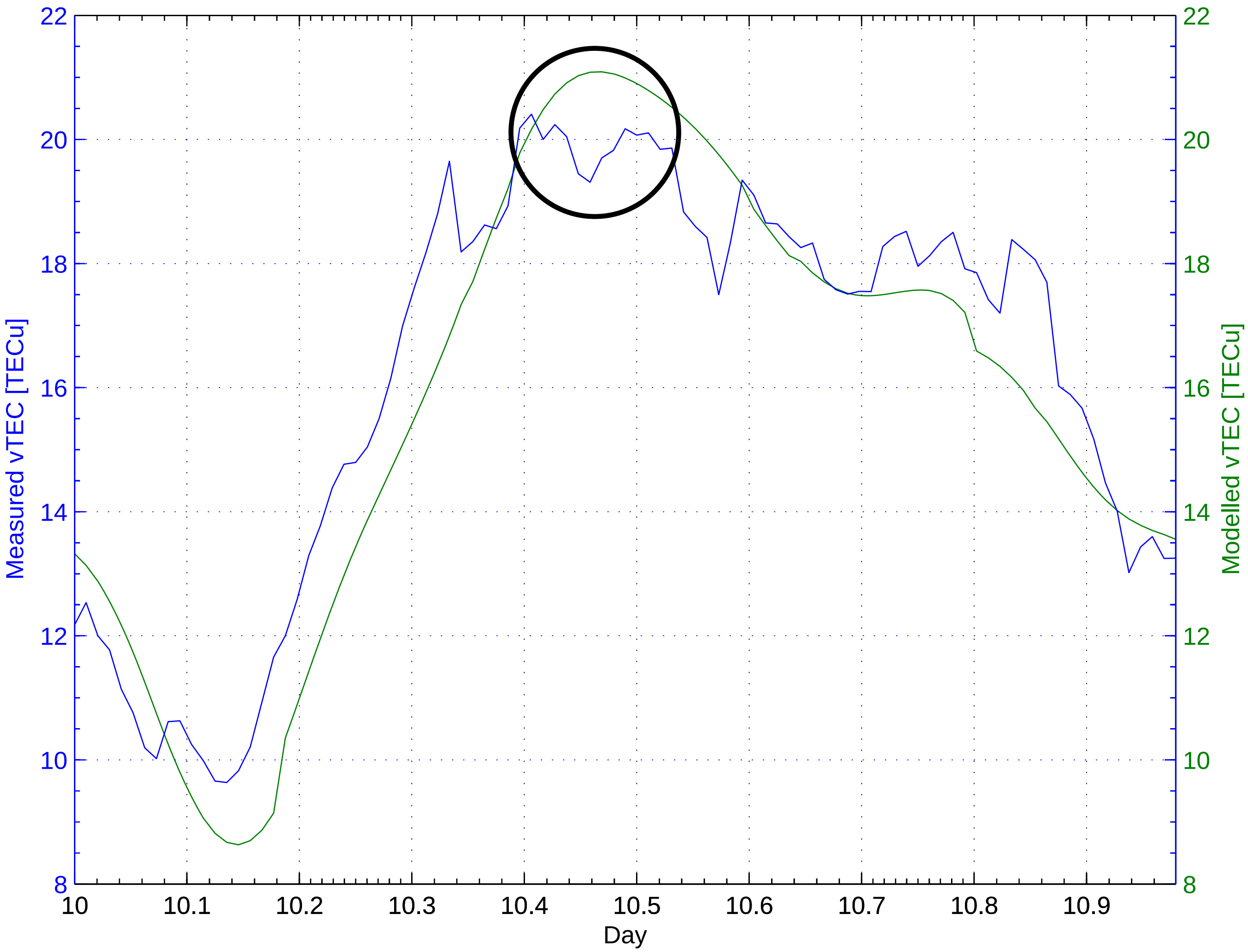
High solar activity level



July:
best month

Small bias:
9h45

High solar activity level



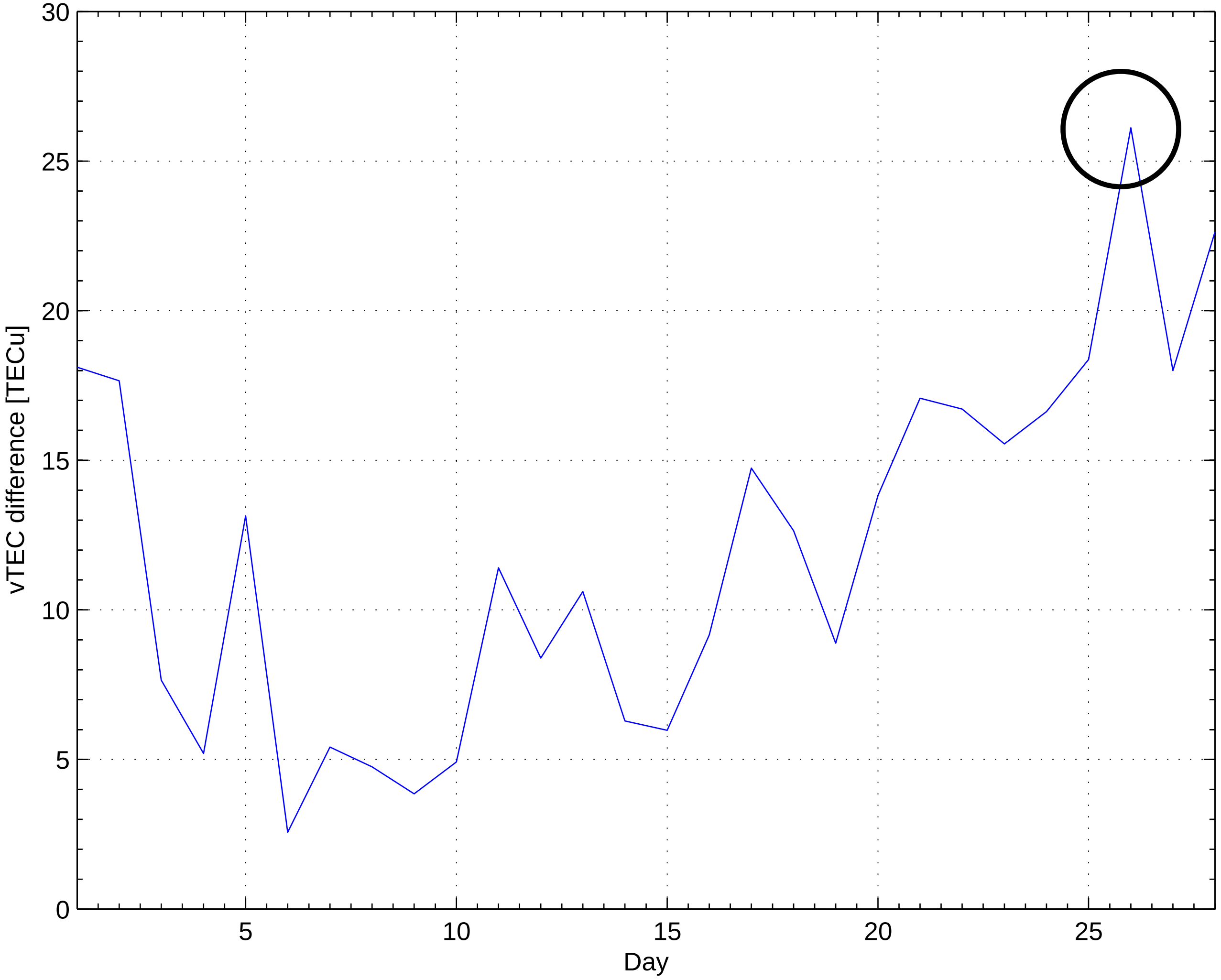
July:
best month

Lowest RMS:
10th

Small bias:
9h45

3. Case days

High solar activity level

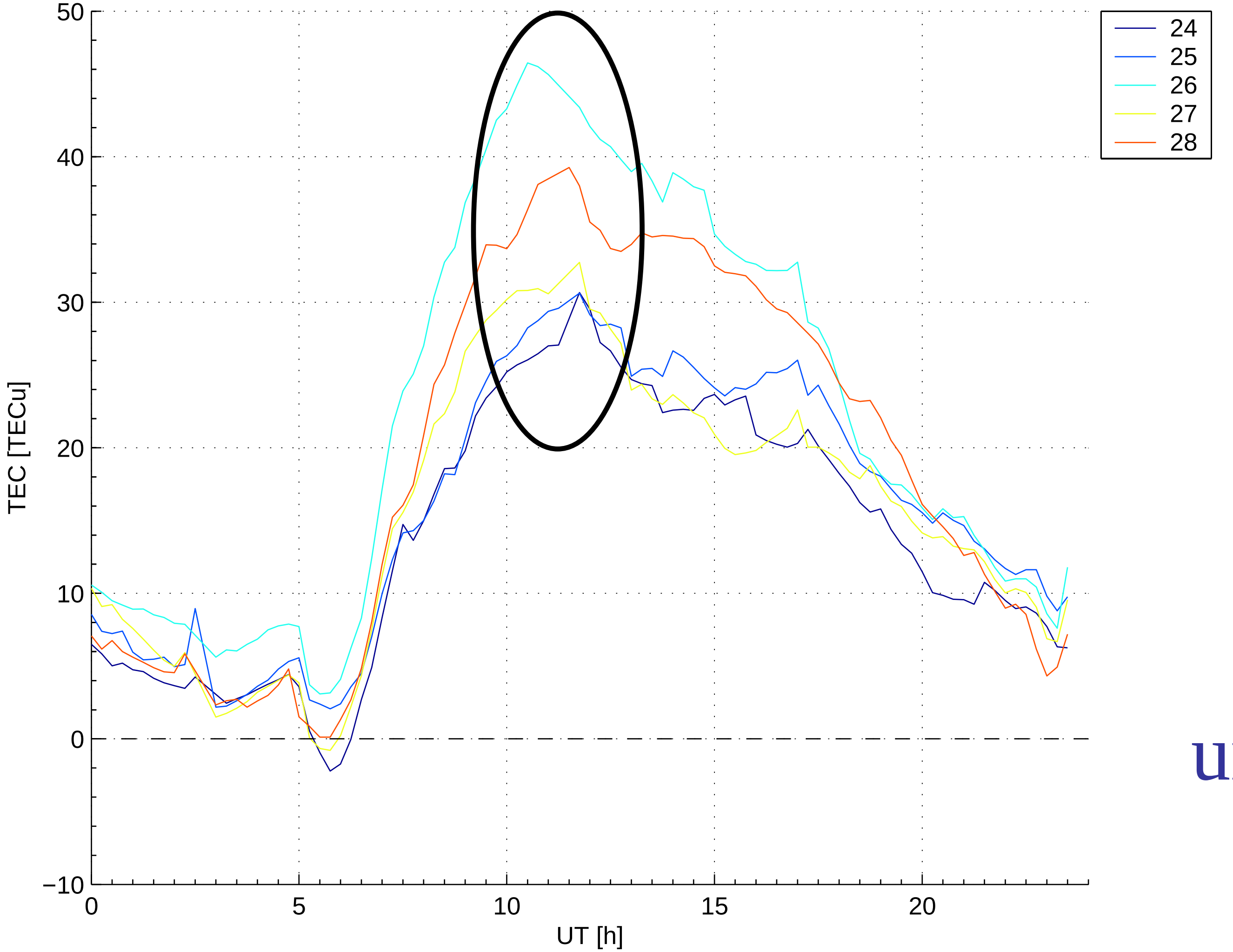


February:
worst month

Highest RMS:
26th

3. Case days

High solar activity level

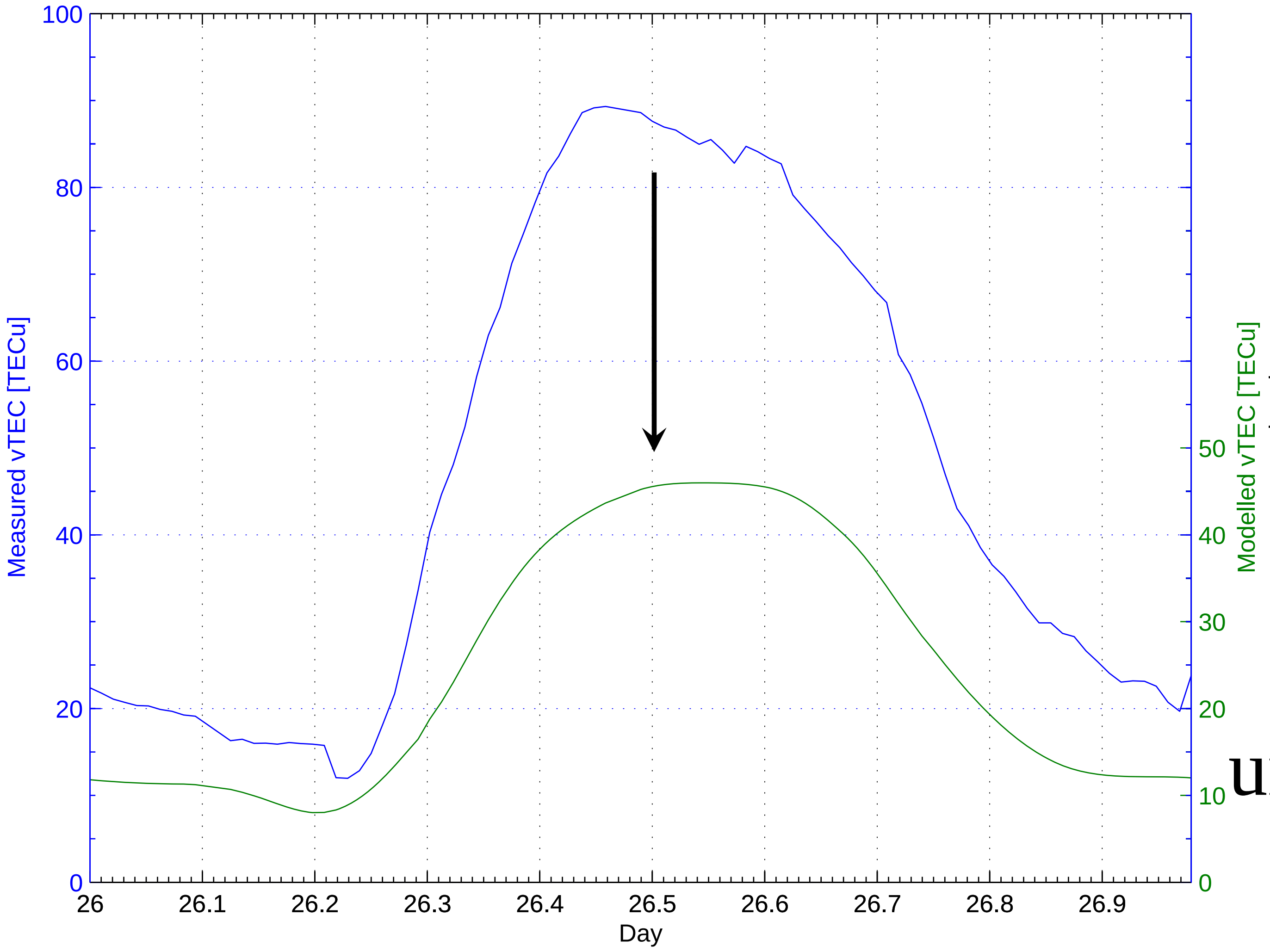


February: worst month

Maximum underestimation: 10h30

3. Case days

High solar activity level



February:
worst month

Highest RMS:
26th

Maximum underestimation:
10h30

Conclusion

- Afternoon maximum in summer:

  July 27th, 2006 – 19h

- False afternoon maximum in autumn:

  October 30th, 2006 – 17h40

- Morning maximum in summer:

  July 10th, 2002 – 10h

- Underestimation at high solar activity:

  February 26th, 2002 – 10h

1. Tools

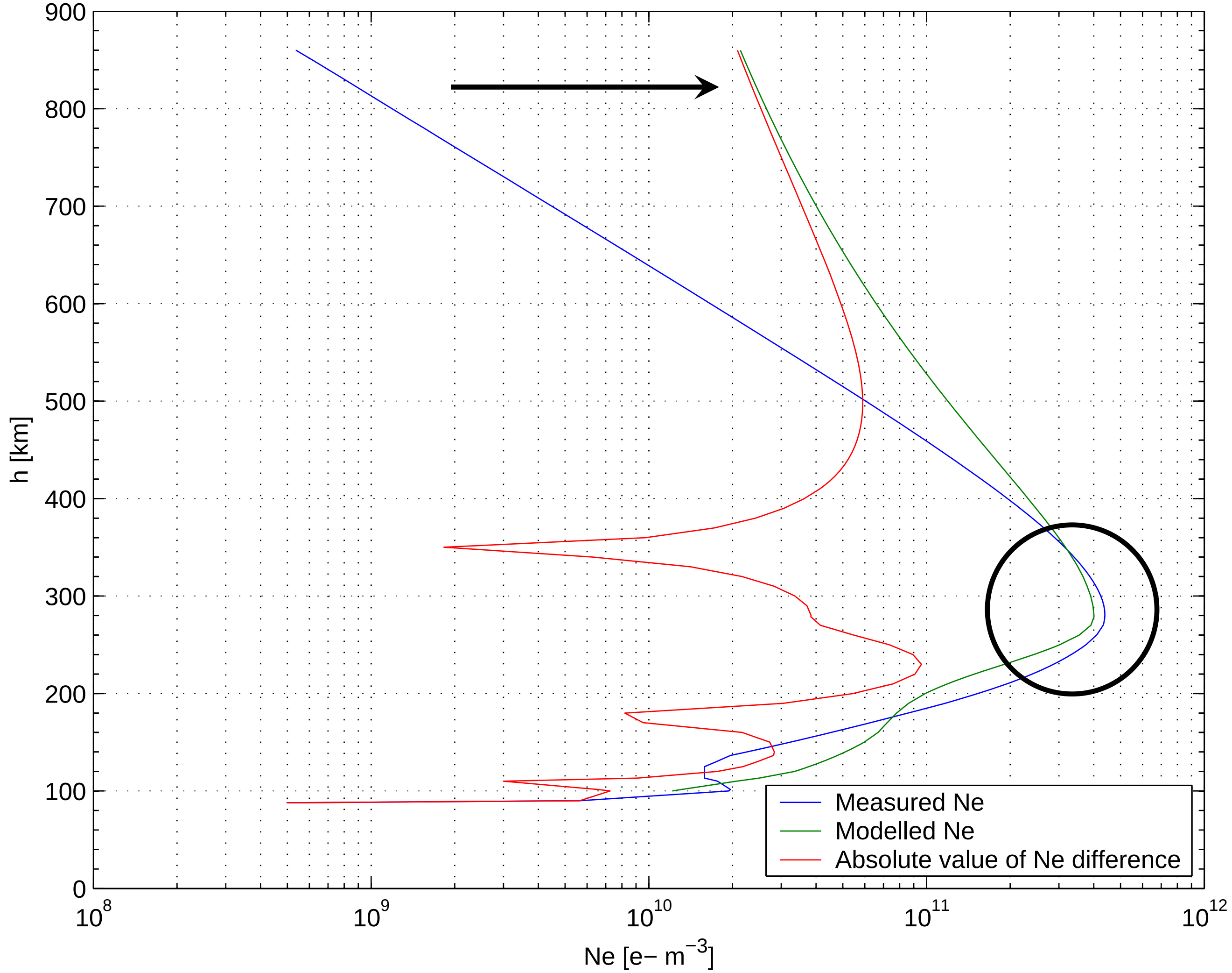
2. vTEC analysis

3. Case days

4. Profile analysis

4. Profile analysis

July 27th, 2006
19h

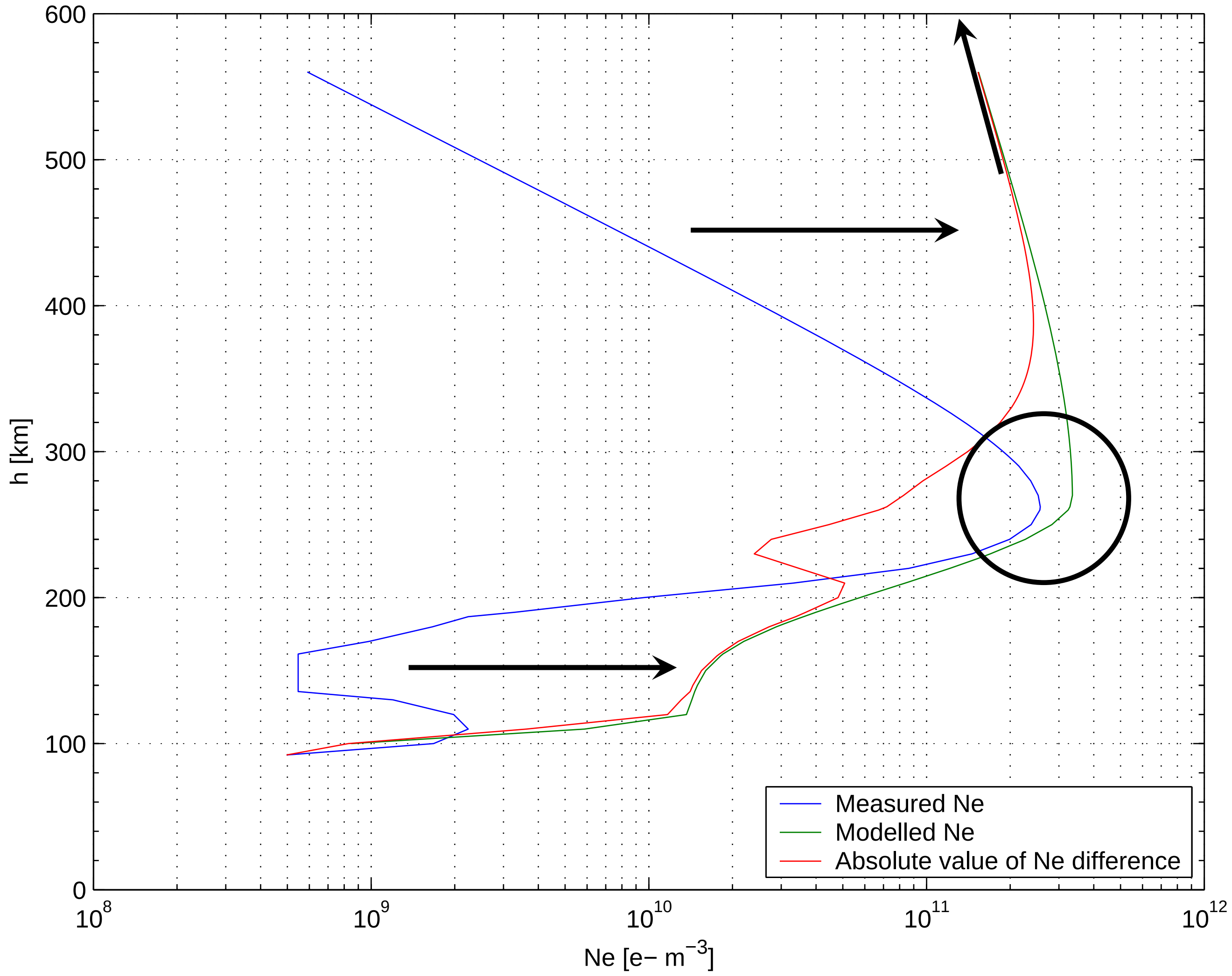


Denser
topside

Slightly less
dense
F2 peak

4. Profile analysis

October 30th, 2006
17h40



Denser topside

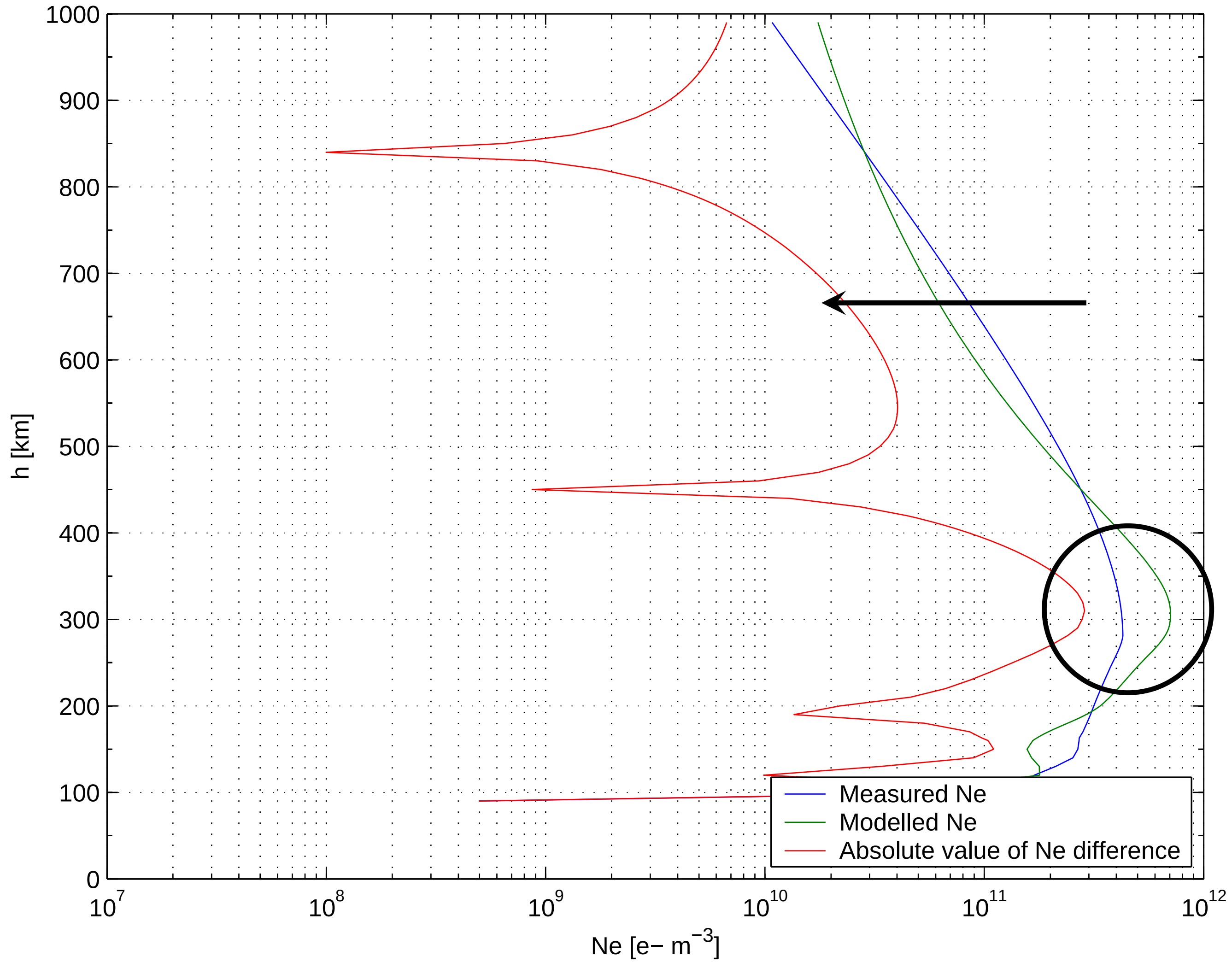
Slower decrease

Slightly denser F2 peak

Denser bottomside

4. Profile analysis

July 10th, 2002
10h

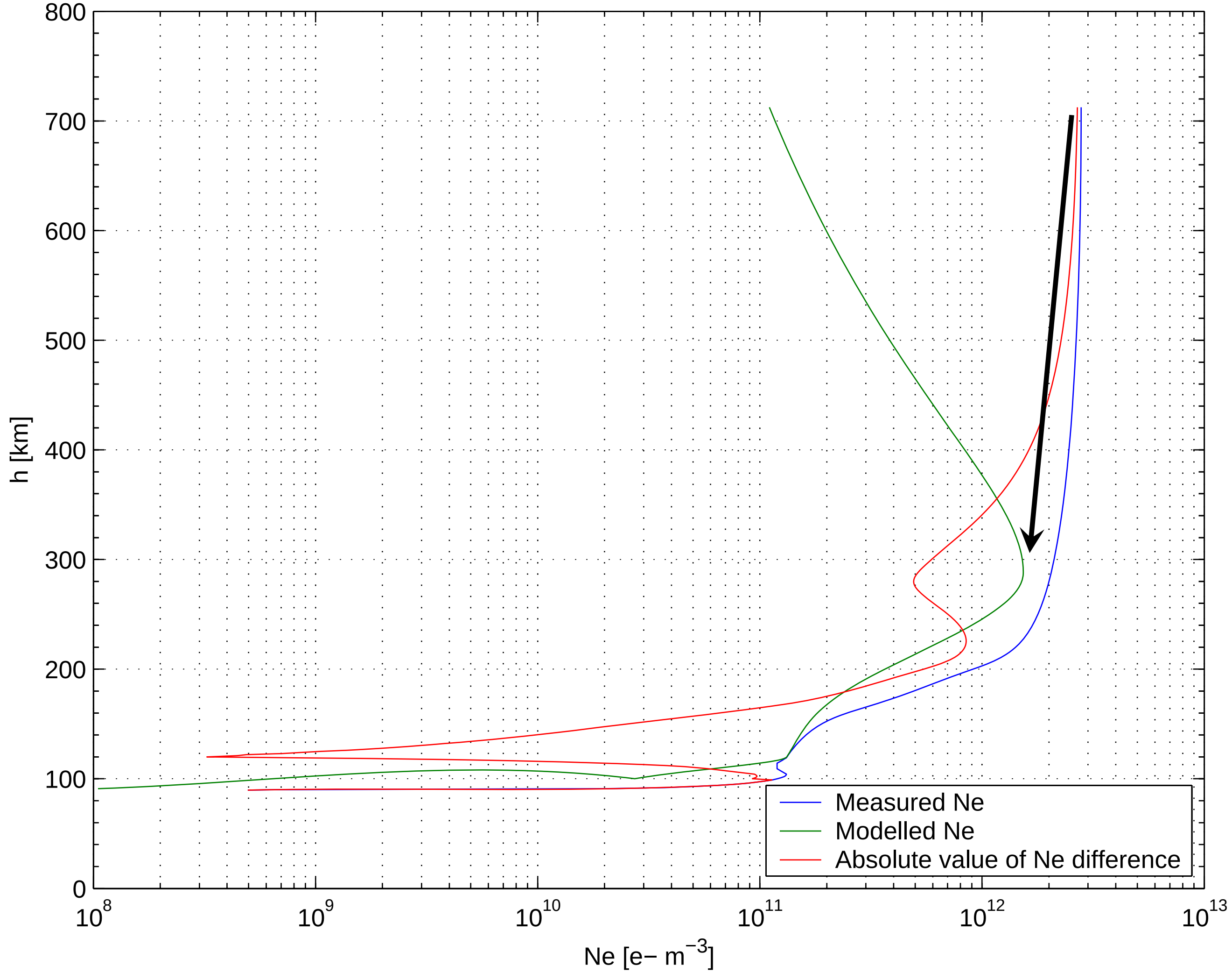


Less Dense
topside

Denser
F2 peak

4. Profile analysis

February 26th, 2002
10h



Huge difference for F2 peak

Conclusion

- Topside to be investigated
- CCIR maps to be investigated
  - SA dependence
  - Month dependence
  - UT dependence

General conclusion

- Benefit from collocated data
- NeQuick behaviour:

  varying even at mid-latitudes

- Elements to investigate:
  - solar activity parameter
  - topside formulation
  - CCIR maps

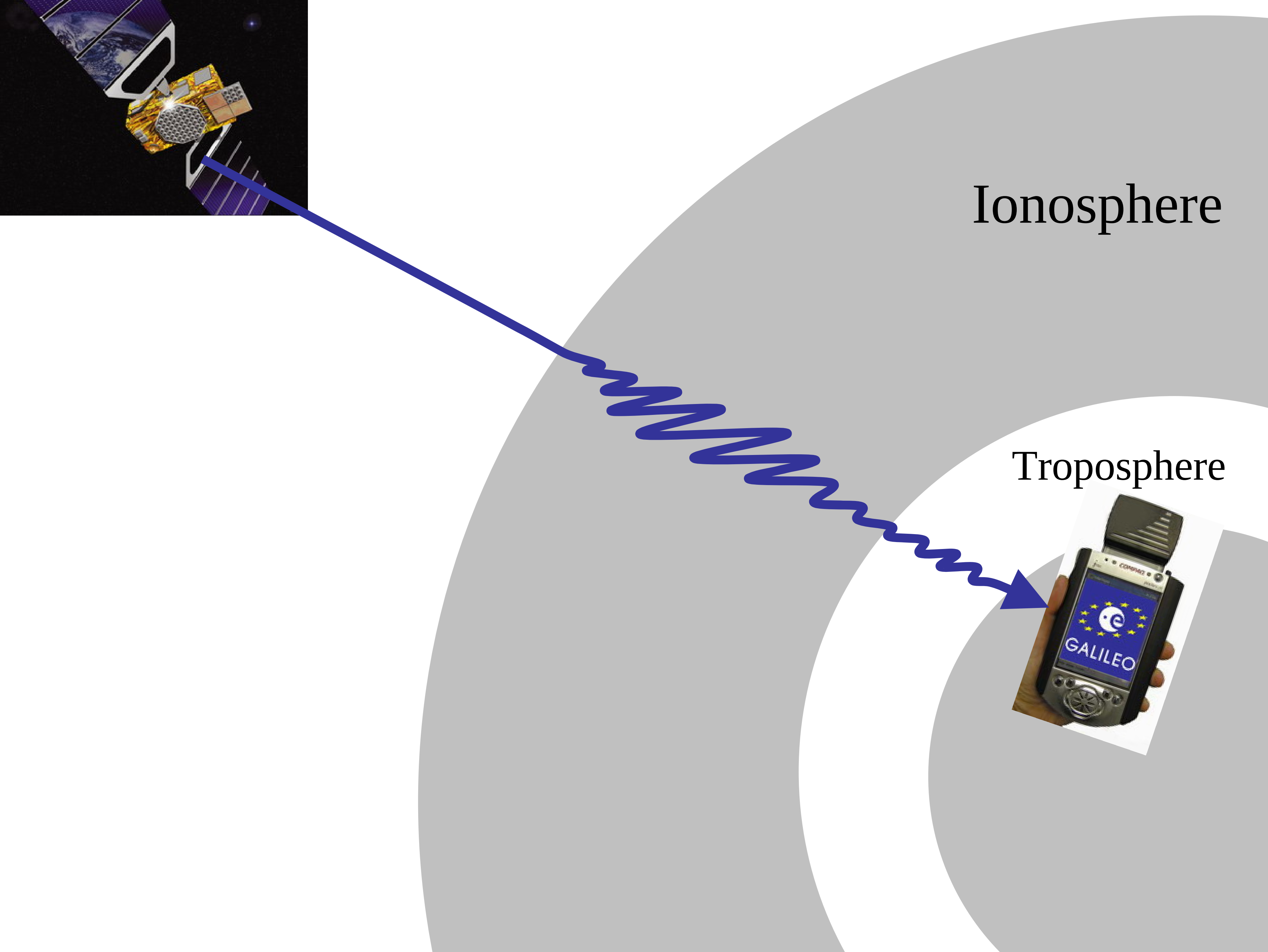
Perspectives

- Ionosonde scaled characteristics
- Evolutions of NeQuick
- Other solar activity parameters
- Generalization:

    other latitudes, sTEC, GALILEO

Framework

- PhD at University of Liège (Geomatics)
- Collaborations
  - RMI (Brussels)
  - ESA/ESTEC (TEC-EEP)
  - Others to come…


Ionosphere
Troposphere
GALILEO