Towards an Improved Single-Frequency Ionospheric Correction: Focus on Mid-Latitudes

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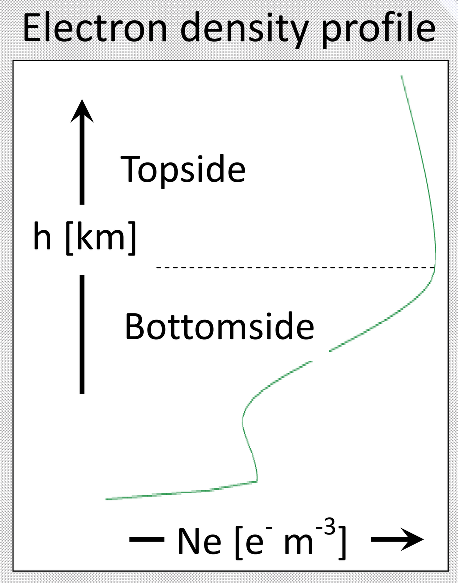
The NeQuick Ionosphere Model

- **Ionosphere affecting** radio propagation and hence **GNSS**
  - Positioning errors exceeding 100 m in extreme cases
  - **Total Electron Content** (TEC, integral of the electron density Ne) = main driver
- Importance of **TEC modelling**
  - Crucial especially for **single frequency receivers**, the most common ones constituting the mass market
  - By means of a 3D method using the **NeQuick** model **for GALILEO** (Orus et al., 2007a)
- NeQuick = **empirical model** of the electron density Ne
  - "**Profiler**" = several mathematical functions fitted on anchor points corresponding to the maxima of the layers of the ionosphere (Radicella et Leitinger, 2001)
  - Peaks and profile characteristics calculated on the basis of **monthly median measurements**
  - **New version** (NeQuick 2): main modification regarding the description of the **higher part of the ionosphere** ("topside") → two formulas for shape parameter k (each for six months of the year) replaced by a single one (Nava et al., 2008)

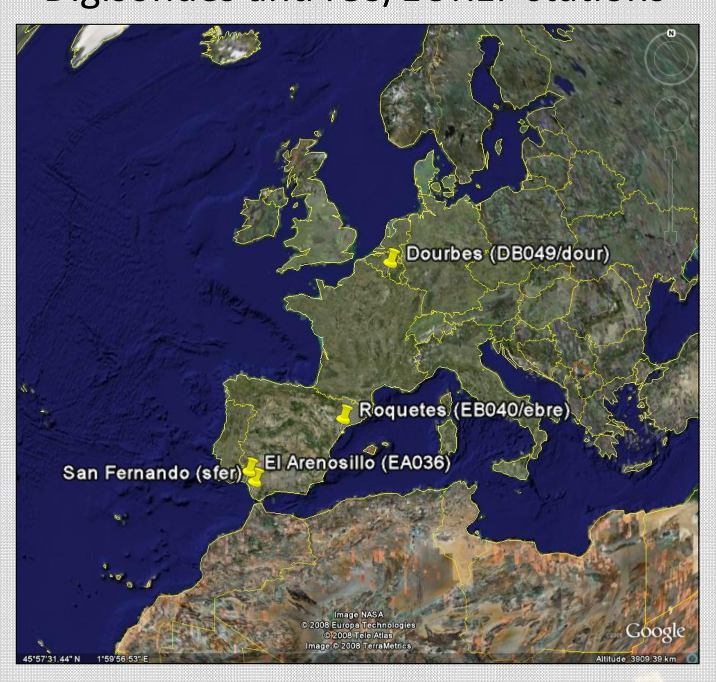
Electron density profile



Tools and Method

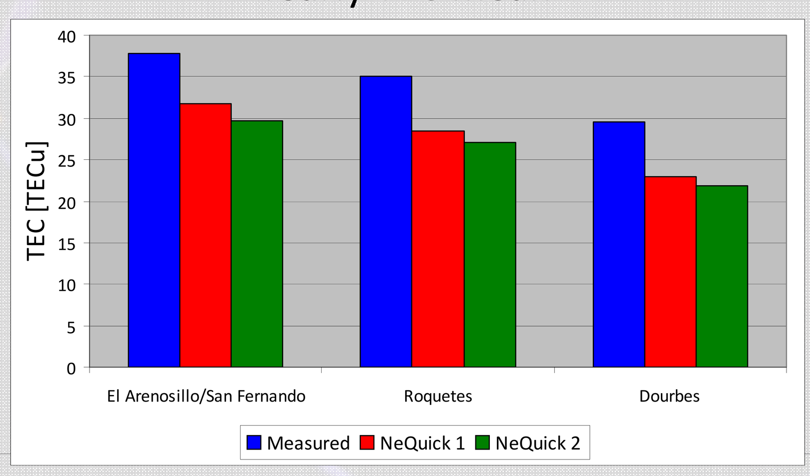
- Investigation of NeQuick **profile formulation**
  - Monthly median measurements replaced by actual ones → **model constrained by means of ionosonde data** (Bidaine et Warnant, 2007)
  - Vertical TEC compared to GPS TEC → **collocated ionosonde and GPS receiver** needed
- **Ingestion**: adapt NeQuick TEC to GPS TEC by means of effective parameters (Nava et al., 2006)
- Data types
  - **Manually validated digisonde** data
  - **Slant TEC data levelled using Global Ionospheric Maps** (Orus et al., 2007b) and mapped to vertical + elevation filter and average to obtain vertical TEC
- Tests for **mid-latitudes and high solar activity**
  - Year 2002
  - Three European locations with (nearly) collocated digisonde and IGS/EUREF station

Digisondes and IGS/EUREF stations

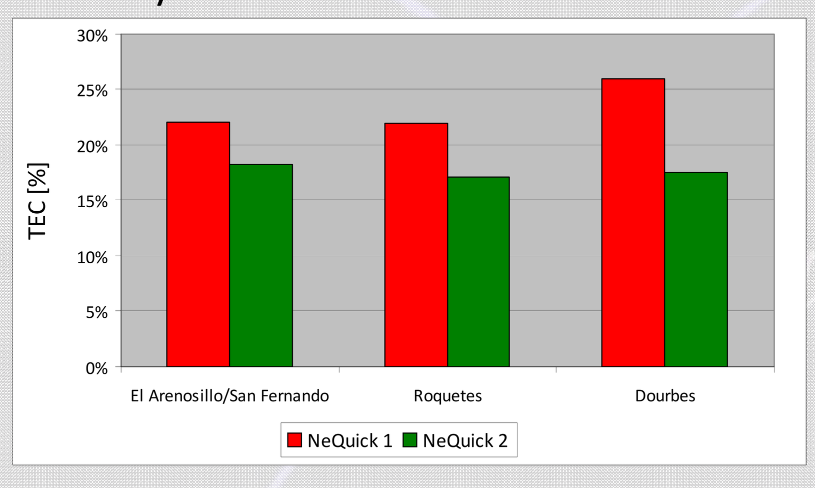


Yearly Statistics

Yearly TEC mean



Yearly relative TEC standard deviation



- Influence of **latitude**: vertical TEC mean decreasing northwards (TEC in TECu = $10^{16}\ e^{-}\ m^{-2}$)
- TEC **underestimated** on average (potential bias in GPS TEC data to take into account)
- **Bigger** (around 20%) **underestimation** with NeQuick 2
- **Lower** (around 20%) **standard deviation** for NeQuick 2 → better behaviour

$$dTEC = TEC_{mod} - TEC_{meas} \qquad Bias = \langle dTEC \rangle$$

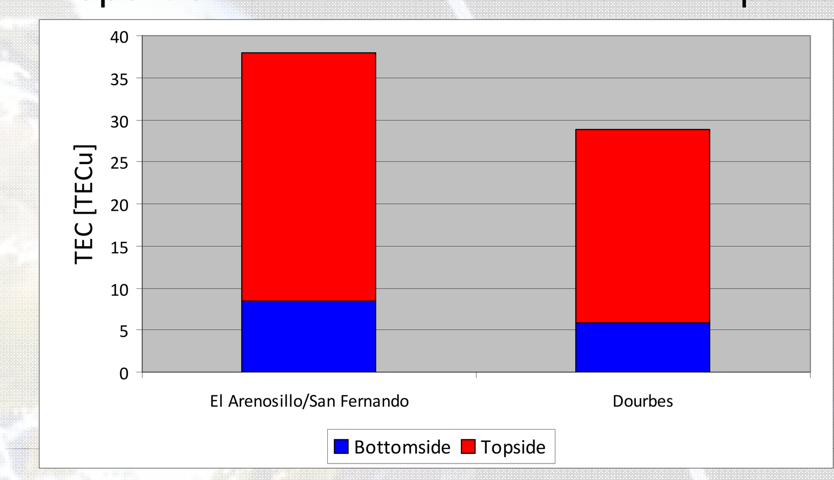
$$Standard\ deviation = \sqrt{\langle (dTEC - Bias)^2 \rangle}$$

$$Relative\ parameter = \frac{Parameter}{\langle TEC_{meas} \rangle}$$

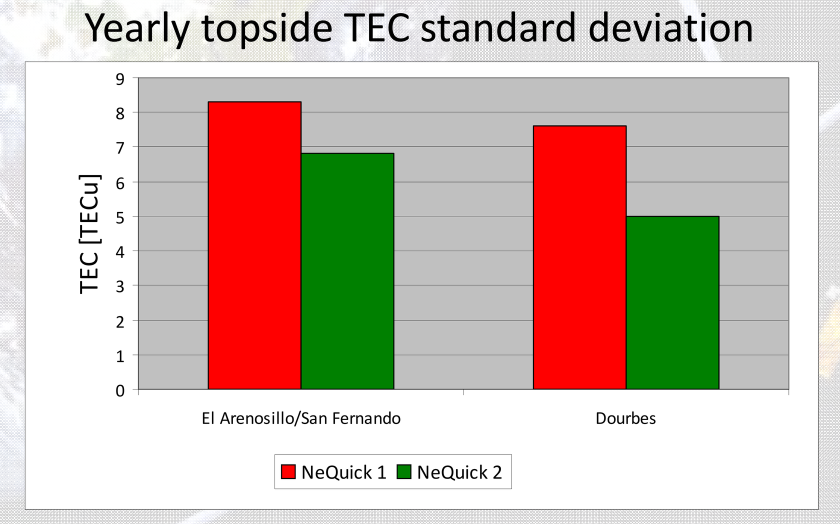
$$Evolution = \frac{Parameter_{NeQuick2} - Parameter_{NeQuick1}}{Parameter_{NeQuick1}}$$

TEC Splitting

Proportion of TEC in bottomside and topside



Yearly topside TEC standard deviation

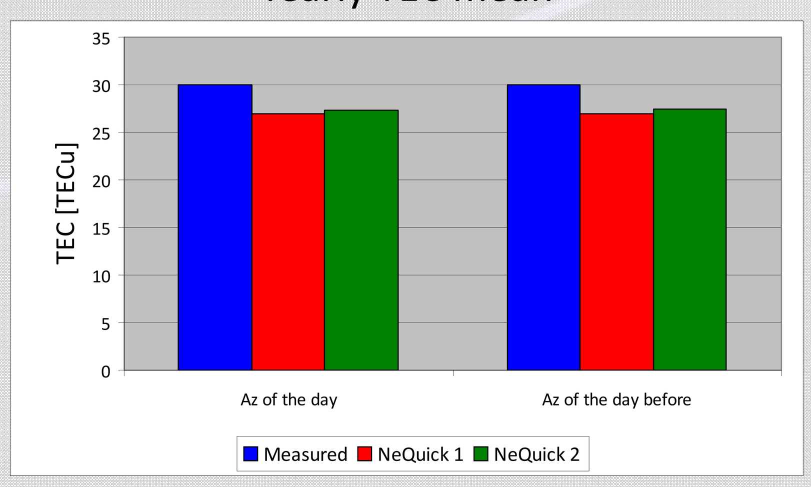


- **Integrate bottomside Ne profile** from digisonde to obtain bottomside TEC
- **Subtract** bottomside TEC **to GPS TEC** to obtain estimate of topside TEC (caution with interpretation about topside because resulting TEC value containing whole GPS TEC uncertainty)
- **Big proportion of TEC within topside** (3/4, 1/4)
- Bottomside: low bias (at least in absolute value) and relatively high standard deviation, no big evolution between NeQuick versions
- **Topside**: higher relative bias and standard deviation than bottomside, **bias/standard deviation evolution between NeQuick versions corresponding to global statistics**

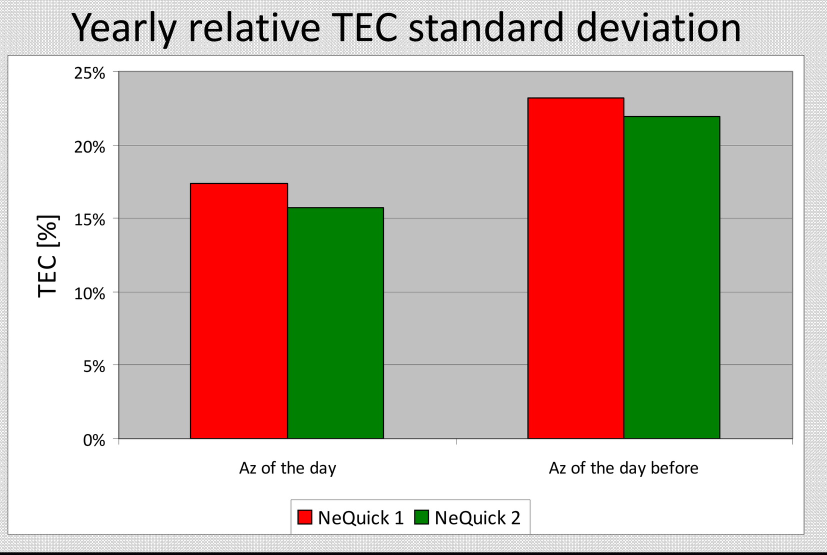
Slant TEC Ingestion

- **Effective ionization level Az:** compute solar flux value leading to the minimum daily Mean Square (MS) slant TEC difference
- Tests for **Dourbes** using Az of the day and Az of the day before (similar to GALILEO algorithm) and comparison with previous statistics
- **Az of the day**
  - Bias about three times lower thanks to ingestion
  - Standard deviation lower for NeQuick 1 and comparable for NeQuick 2
  - Improvement both in bias (15%) and standard deviation (10%) for NeQuick 2
- **Az of the day before:** standard deviation increasing by about 35%

Yearly TEC mean



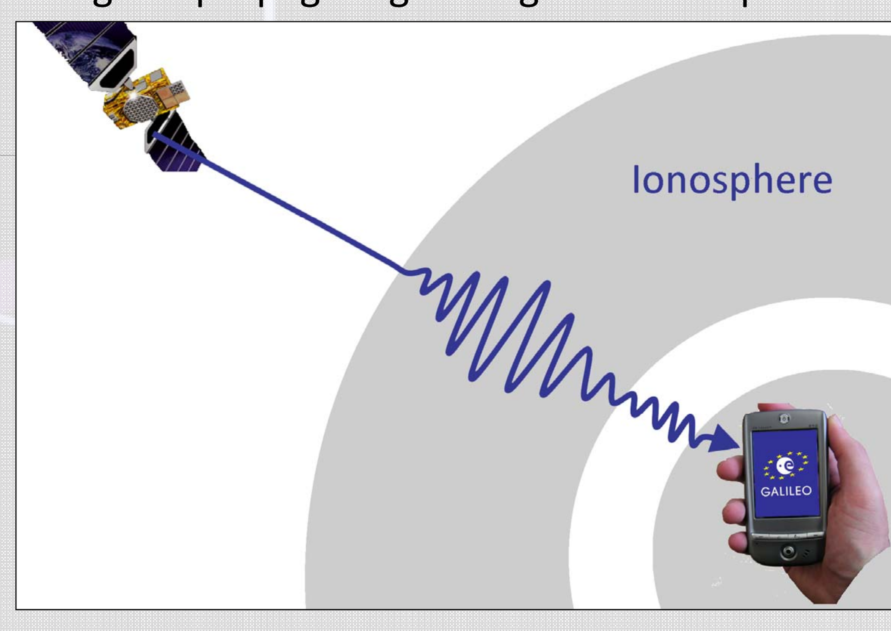
Yearly relative TEC standard deviation



Conclusion and Perspectives

- Investigation of NeQuick **profile formulation** for mid-latitudes and high solar activity
  - **Standard deviation decreasing by 20% to reach less than 20% with NeQuick 2**, bias increasing by 20% up to 25% but caution with GPS TEC data
  - Major role of the **topside**
- Slant TEC **ingestion**
  - **Improvement with NeQuick 2** (15% in bias and 10% in standard deviation)
  - Deterioration using Az of the day before
- **Further** research
  - **Ingestion** for other stations and of other parameters eg foF2
  - Investigate **GALILEO** Single Frequency Ionospheric Correction Algorithm

Signals propagating through the ionosphere



Find material about this poster on http://orbi.ulg.ac.be/handle/2268/1551

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