On the use of dual-frequency smartphones to infer the Total Electron Content (TEC)

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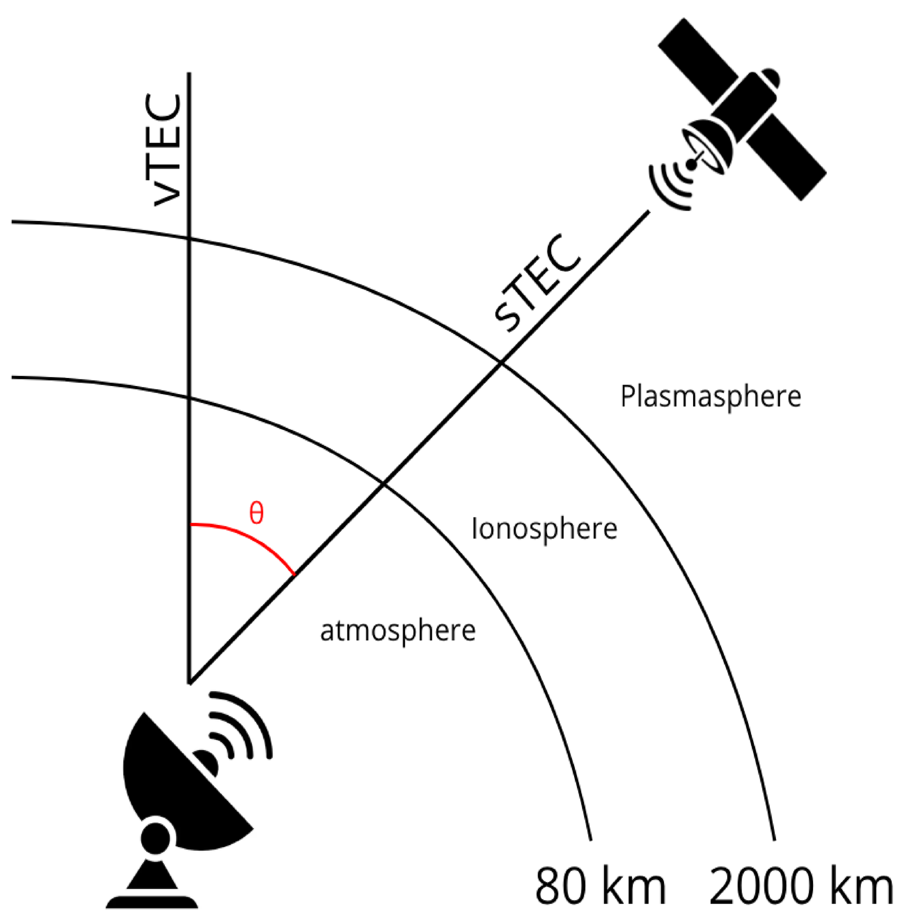
SCIENTIFIC CONTEXT

Since the beginning of the NAVSTAR (GPS) in 1994 and the deactivation of Selective Availability in 2000, people from every place in the world started to use it in order to study the atmosphere [Bonin, 2001]. In fact, the signal of approximately 1 GHz emitted by GNSS satellites is constrained by every layer of the atmosphere and principally by the ionosphere. For this reason, researchers operated on single-frequency receivers data for a long time to characterize the total electron content using Precise Point Positioning (PPP) [Hofmann-Wellenhof , 1997], then began utilising dual-frequency receivers when they became available to civilians. Nowadays, smartphones are also made with dual-frequency chipsets that can be used to better characterize the TEC. This should help us to look more closely at the variations in the TEC due to their large number.

IONOSPHERE AND PSEUDORANGE

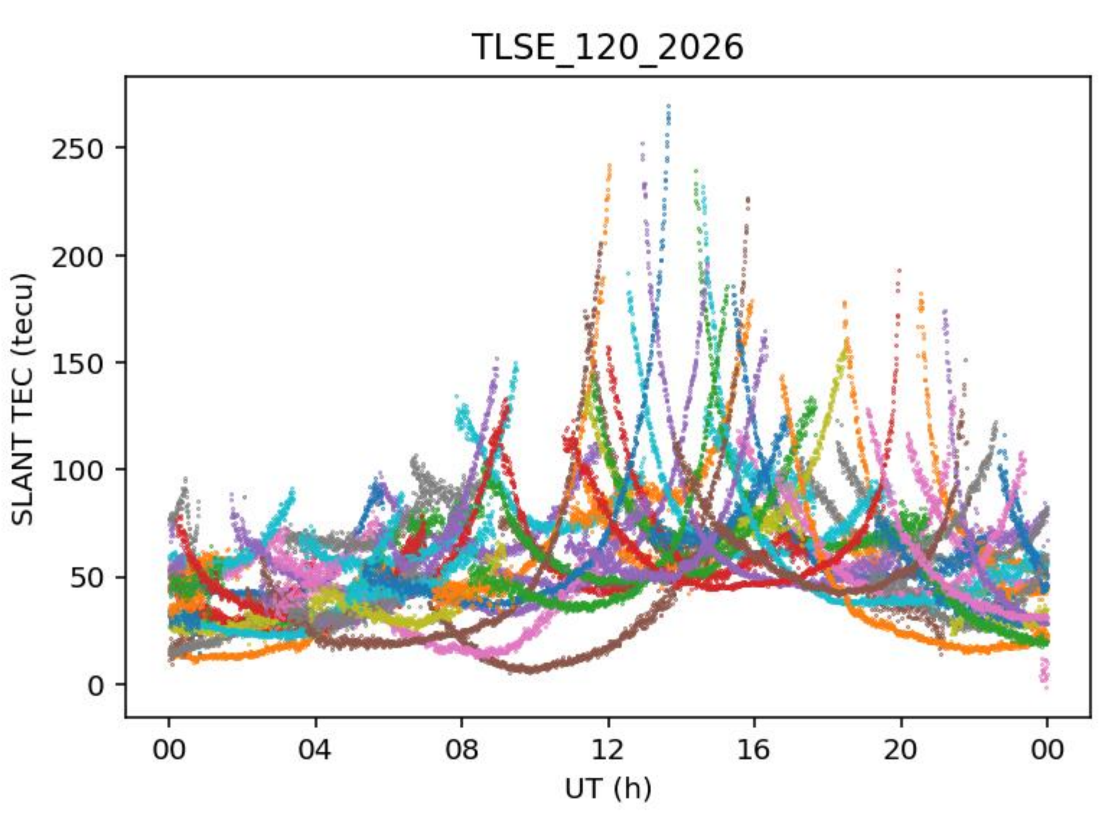


The propagation time of a wave between a satellite and a receiver allows us to determine the distance between them, this quantity is known as the pseudorange. The measurement of propagation time by a receiver can be affected by various factors. One such factor is plasma. Indeed, depending on the number of electrons it contains, the frequency of the plasma varies. This same quantity is the only variable in the atmospheric plasma layer (the ionosphere) that affects a wave transmitted by a GNSS satellite at the first order. In our work, we are therefore interested in the quantity of electrons contained in the ionosphere, the total electron content (TEC). Various methods exist for this purpose. We have decided to use measurements taken by receivers at two different frequencies in order to retain only those terms that affect the wave according to its frequency along its path. The difference between two pseudoranges then allows us to obtain the following formula:

$$P_4 = P_1 - P_2 = (\mu_1 - \mu_2).\, I_s^r + (b_{r,1} - b_{r,2}) - (b_{s,1} - b_{s,2})$$

Here, the terms I_s^r, b_r , b_r and μ refer respectively to the total electron content along the line of sight, the receiver bias, the satellite bias and the ionospheric delay conversion coefficient at different frequencies. It is then possible to obtain the TEC whilst accounting for the receiver and satellite biases.

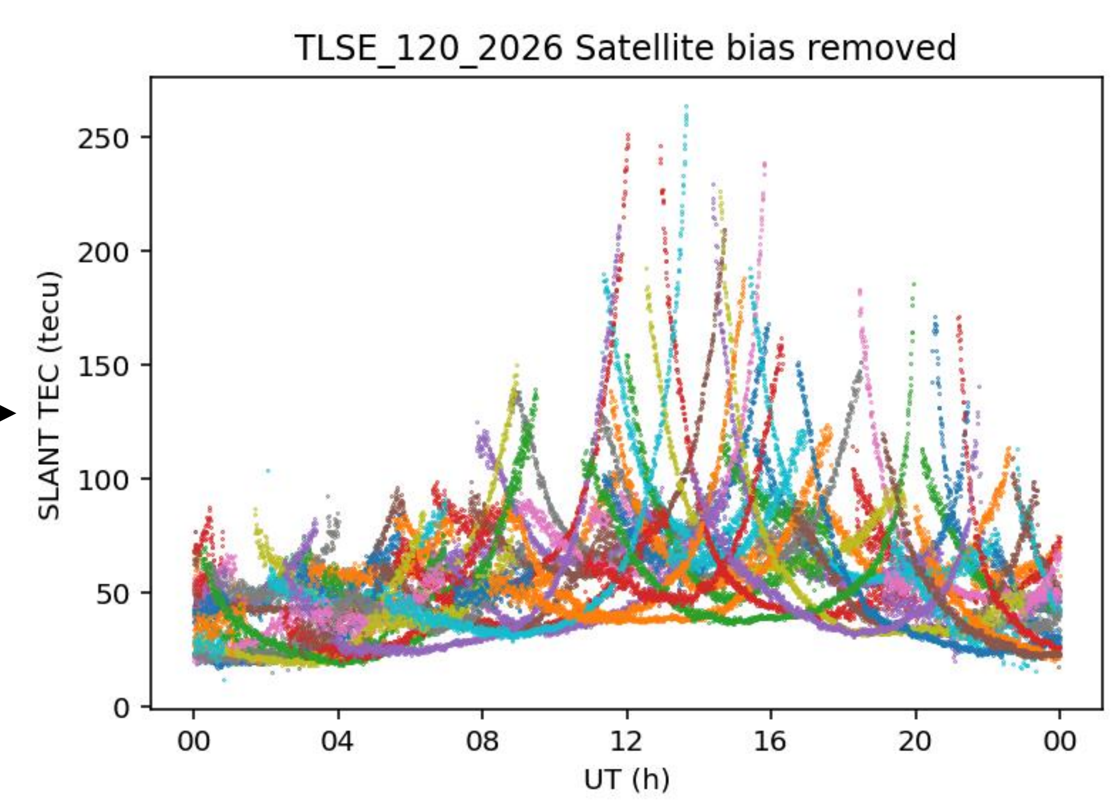
THE SLANT TOTAL ELECTRON CONTENT



The common data format of GNSS raw measurements is called RINEX.
We developed a Python program capable of treating RINEX 3 and 4 data to infer the TEC using GPS and Galileo GNSS constellations.

Fig 1. slant TEC (sTEC) obtained from data collected by the TLSE IGS receiver. Here we show the sTEC of each satellite (GPS+Galileo) in the field of view. Minimum elevation = 30°.

Fig 2. For this figure, we used the satellite bias files available on the CDDIS-NASA website to correct errors from the transmitter.



CURRENT STATE OF THE PROJECT

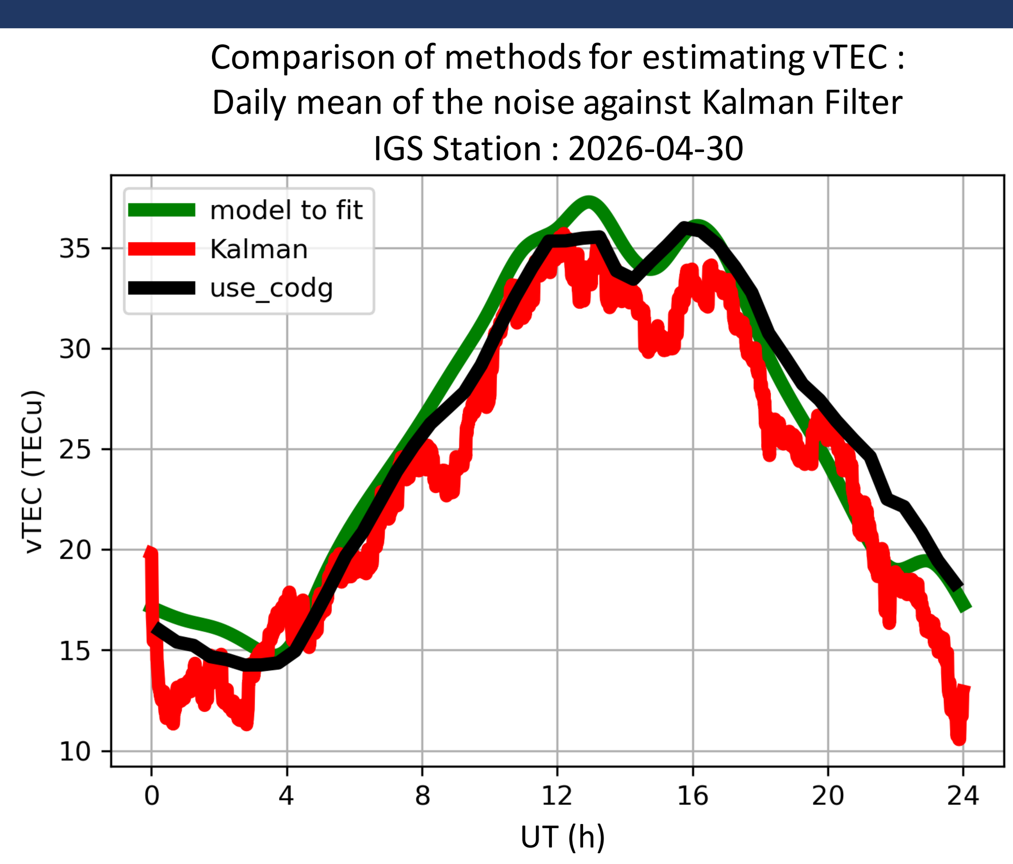
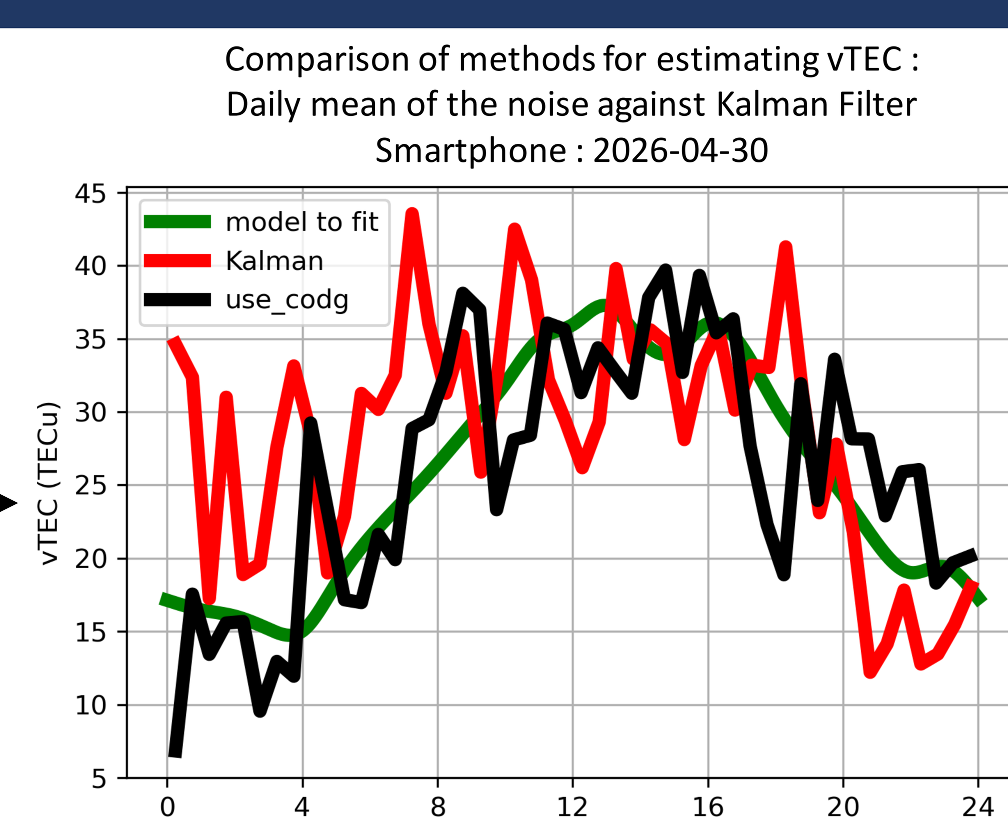


Fig 3. VTEC obtained from data collected by the TLSE IGS receiver and treated firstly with a Kalman filter (red), secondly with a model mean difference (black). The curve in blue is the CODG model (empirical TEC model) that we want to approach. Minimum elevation = 30°.

Fig 4. VTEC obtained from data collected by a smartphone using the GNSSLogger app. The data is treated under the same conditions as the IGS antenna ones

Even if the method using the CODG model seems the best one on those figures, one must remind that these maps are supplied within 5 days.



CONCLUSION AND PERSPECTIVES

To conclude, we developed our own Python tool to infer the TEC using RINEX 3 and 4 files. We show that we can put different methods in our algorithm and compare one to the other quite easily. Beside that, we also show that using pseudorange measurements from alone bi-frequency phones can be done but is far from being as precise as a high quality professional receiver (HQPR).

For that reason, we would like to find a way to compare the TEC assessment performance of smartphone clusters against HQPR. A small number of smartphones collecting data within a clearly defined area could help to better identify high DCB values in smartphones and analyse their performance depending on their number.

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GNSS Logger APP available at : [GnssLogger App - Apps on Google Play]
CODG Gims maps available at : [Index of /CODE/]