# Ionosphere vertical TEC calculated from GNSS receiver data in Lisbon: comparison with observations

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**Abstract**

We present the results of the analysis of the reliability of ionosphere TEC values produced by the GNSS receiver installed at the Lisbon airport (Portugal), since 2015. The installed equipment is a NovAtel EURO4 with a JAVAD Choke-Ring antenna. The installed firmware (SCINDA) is specific for scintillation detection. We did a comparison of the SCINDA line-of-sight TEC values with the observed vertical TEC data collected (using ionosonde) by the Ebro Observatory in Spain, and with the vertical TEC values produced using the software developed in the Royal Observatory of Belgium. The differences between the ionosonde-based and GNSS-based TEC and sources of these differences are discussed. In this study special attention was paid to the epochs accompanied by significant Space Weather events strongly affected the ionosphere and the quality of the GNSS positioning.

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## Introduction:

This work is aimed to study the relation of the ionosphere TEC data provided by the SCINDA receiver (installed in the Lisbon airport) to the similar data provided by other GNSS receivers (Lisbon and Ebro) and ionosonde (Ebro). The data are compared between each other. Special attention is paid to their sensibility to Space Weather conditions, done via the analysis of the geomagnetic storms seen in each of considered datasets.

## Chosen Space Weather active dates :

Here we present results only for 2015.
The geomagnetically active days in 2015 are:
March 17 , June 22-23, September 8-9, October 7, December 14&20.
**Here we present graphics only for March 2015, but discuss the results for all mentioned dates.**


## Data:

- **SCINDA**: the GNSS receiver installed at the Lisbon airport (Portugal), since 2015. The installed equipment is a NovAtel EURO4 with a JAVAD Choke-Ring antenna. The installed firmware (SCINDA) is specific for scintillation detection. The analyzed TEC data are uncalibrated.
- **ROB:** Observational data from GNSS receivers' network (http://gnss.be/). Here we analyze the data at Lisbon and Ebro locations.
- **Ebro:** Observational (ionosonde) data.

## Methods:

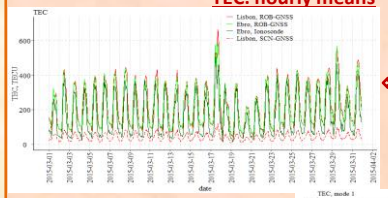
- **Principal Component Analysis (PCA)**
- **Cross-correlation analysis**

## Chosen Space Weather (SW) parameters:

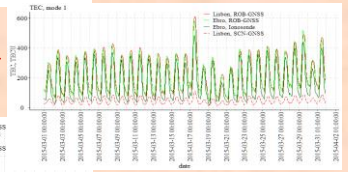
**Solar activity:**
- **F10.7** (NOAA),
- **MgII** (University of Bremen),
- **XR** (TIMED)

**Geomagnetic activity:**
- **Dst** (WDC for Geomagnetism, Kyoto),
- **Kp** (GFZ Potsdam),
- **Ki** (Coimbra Geomagnetic Obs.)

## TEC: hourly means



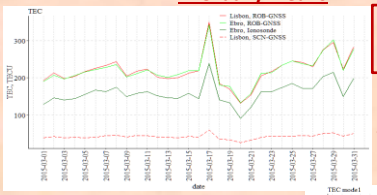

⇦ **Original data**
**Corr. coefficients: ~0.93-0.97**




**PCA: mode 1**
**Corr. coefficients: ~0.92-0.95** ⇨


⇦ **PCA: mode 2**
**Corr. coefficients: ~0.74-0.94**

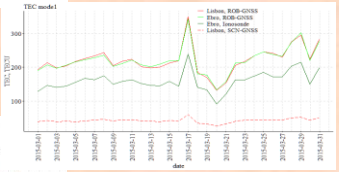
## TEC: daily means




**Corr. coefficients: in all cases are not lower than for the hourly data**

⇦ **Original data**

**PCA: mode 1** ⇨



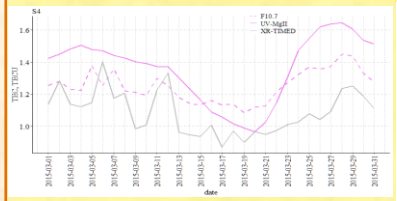


⇦ **PCA: mode 2**

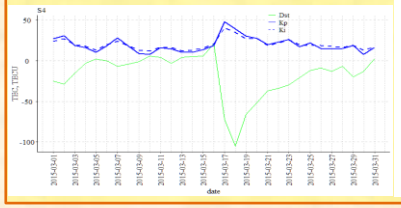
- **The highest correlation (~0.93-0.97) is seen between the SCN and ROB (Lisbon) data.**
- **The lowest correlation, but still high (r = ~0.93-0.94), is seen between the Lisbon and Ebro data.**
- **The same tendency is observed when only PCA modes 1 are compared.**
- **For the PCA mode 2 components the correlation coefficients are also high with minimal r=0.74 between the PCA mode 2 of the SCN and ionosonde series.**

## SW parameters

### Solar activity: daily means



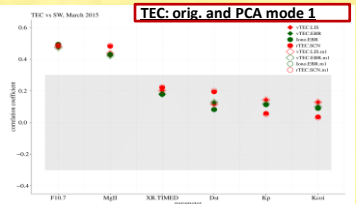

### Geomagnetic activity: daily means



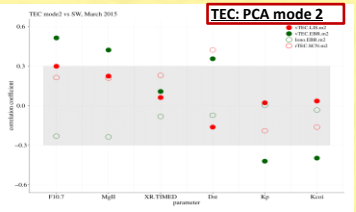

## TEC & SW

**Corr. coefficients:**

**TEC: orig. and PCA mode 1**




**TEC: PCA mode 2**




- **The highest correlation (~0.5-0.8) between TEC (orig. and PCA mode 1) and SW is seen in September.**
- **The highest correlation (~0.4-0.5) is seen between TEC (orig. and PCA modes 1, 2) and F10.7, MgII.**
- **The correlation is high (abs. values ~0.4-0.5) also with Dst for TEC (PCA mode 2) of the SCN & ROB (Ebro).**

## Conclusions:

- **The ionosphere TEC data from the SCINDA, other GNSS receivers (Lisbon and Ebro) and Ebro observatory ionosonde are well correlated between each other. The correlation coefficients are ~0.93-0.97 for the original hourly data, ~0.92-0.95 for the 1st PCA component and ~0.74-0.94 for the 2nd PCA component.**
- **The responses to the geomagnetic storms are clearly seen in the all datasets, despite that the corresponding correlation coefficients between the daily series are quiet moderate (see plots in TEC&SW).**
- **Also for all months except December there is strong dependence of the TEC variations on the solar UV & XR flux.**
- **The ionosphere TEC data provided by SCINDA receiver can be used for an analysis of the ionosphere TEC response to the Space Weather disturbances, as well as for the Space Weather alert service that is under development in the framework of thee SWAIR project.**

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