Total Electron Content Seasonality in European Middle Latitudes in Respect of Local Time

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Keywords: Ionospheric seasonality, Total Electron Content, Middle latitudes, Local time

Ionosphere introduces the largest error in Global Navigation Satellite Systems (GNSS) as it increases the propagation time of the signal travelling from a satellite to a receiver, due to refraction. The amount of ionospheric delay is proportional to the Total Electron Content (TEC), the number of free electrons on the signal propagation path. GNSS performance is affected by the ionosphere, but GNSS can also be used to collect the data invaluable for analysis of the ionospheric dynamics. The TEC can be calculated using data from dual-frequency reference GNSS stations, taking into account frequency dependency of ionospheric delay. By observing the TEC data it is possible to track temporal and spatial variations in the ionosphere. The ionosphere varies with 11-year solar cycle, time of day, geomagnetic coordinates and space weather [1]. In the non-equatorial latitudes the ionosphere also contains different amount of ionized particles in different seasons, due to Earth's axial tilt relative to its orbital plane and because of different effects of ion formation and recombination. Knowledge of ionospheric behavior, including seasonality, could further improve empiric ionospheric models [2].

In this paper the TEC data derived from reference GNSS stations situated in the European middle latitudes during three years of the solar cycle 24 were used [3,4,5]. The TEC was obtained using Ciraolo calibration technique, which removes arch-dependent offsets in ionospheric delay calculation, thus removing the contribution of satellite and receiver biases, noise and multipath [6]. Vertical TEC (VTEC) data were calculated for all satellites visible from a GNSS station with elevation higher than 20°, and the average of VTECs was assigned to that station. That minimized the effects of longitudinal difference between Ionospheric Pierce Points (IPPs) of different satellites. Initially, the TEC derived from several GNSS stations with publicly available data, having similar local time and longitude, were analyzed. There were no noticeable discrepancies between data of different stations, and each station in the observed region had data gaps during the selected period. Therefore, the research was conducted using VTEC data derived from two stations (GRAZ and WTZR), which were sufficient to enable data continuity throughout the observed period. The TEC is analyzed for each full hour of the local time. To observe trends in temporal variations, the TEC values are smoothed by local regression using weighted linear least squares and a second degree polynomial model with 121 day span.

The results show that during each year the minima of the diurnal highest TEC values (observed at 13:00 local time) appear around winter and summer solstices (Figure 1). The yearly maxima of the diurnal highest TEC values appear around vernal and autumnal equinoxes. Such findings match the results available in the literature [7]. For other local times close to the middle of day, the same seasonal variation is observed.

Switching to local time between late night and early morning, as the TEC values decrease from its maximal diurnal peak, the four seasons in ionospheric yearly variation can no longer be observed. It was expected to find single maximum and single minimum in winter and summer solstices [8]. The results represented by blue and green curves on Figure 1 reveal that the maximal night-time TEC values appear during the spring, between vernal equinox and summer solstice. The lowest TEC values appear at the time of winter solstice. The semiannual variation of the night-time TEC in European middle latitudes in solar cycle 24 shows deviation from expected values, with asymmetry between the duration of rising and declining period. The period in which the night-time TEC rises from its annual minimum towards the maximum is shorter and the maximum appears before the summer solstice, during the spring.

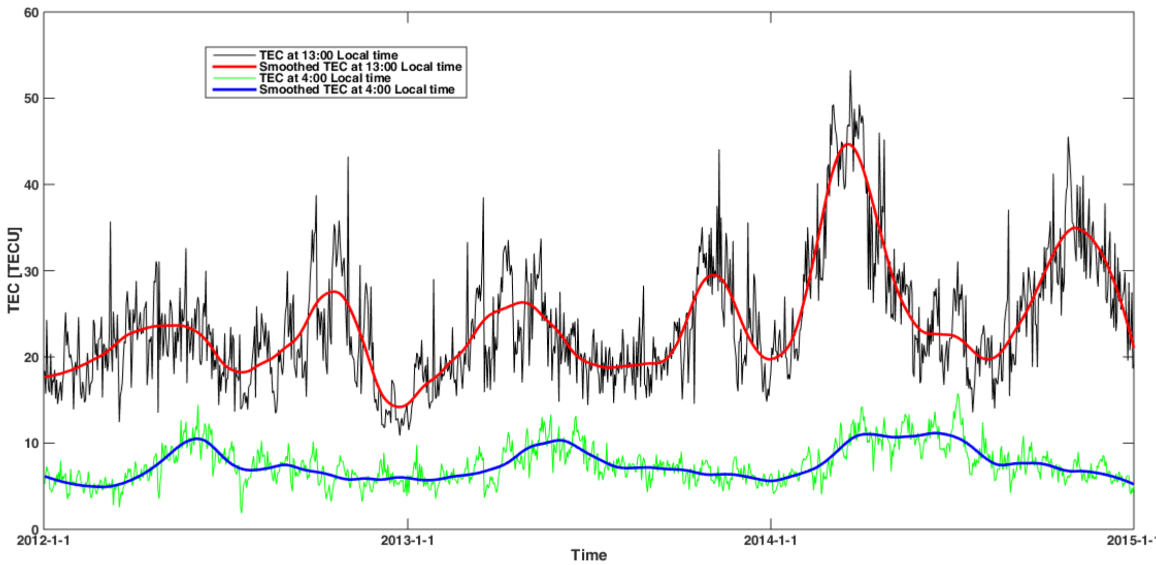

Figure 1. Actual and smoothed VTEC values at GRAZ and WTZR stations in different local time

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