A demonstration of median values applied for forecast of Total Electron Content

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Introduction and Objectives

The ionosphere is a well-known error source for many applications and services using transionospheric radiolink signals. Predictions of the ionosphere are important information for users for either mitigating threats due to ionospheric perturbations or for the purpose of mission planning. The total electron content (TEC) is a common parameter for describing the ionosphere. The uncertainties of the forecasts are a critical condition for the usability of forecasts. Here, users may have individual accuracy thresholds because different applications need to start mitigation strategies at different degrees of perturbation. Additionally, reliability and robustness of the forecast system are important parameters for users.

In this study, we are presenting the applicability of the 27 days median TEC for forecasting.

Data base

Maps of total electron content (TEC) are a common tool for presenting the ionospheric conditions. Forecasts need to consider the most current information on the state of the ionosphere and should therefore rely on near real-time (NRT) data. Therefore, our analysis uses well known NRT European TEC maps provided by DLR. These maps are generated with a cadence of 5 minutes. The map extension is 30°N to 72°N and 30°W to 50°E with a grid size of 2° by 2° in latitude and longitude.

The 27 days median at the time t is calculated as follows

$$TEC_{median27}(t) = median[TEC(t-n)]_{n=0}^{26}$$

Identification of quiet and disturbed periods

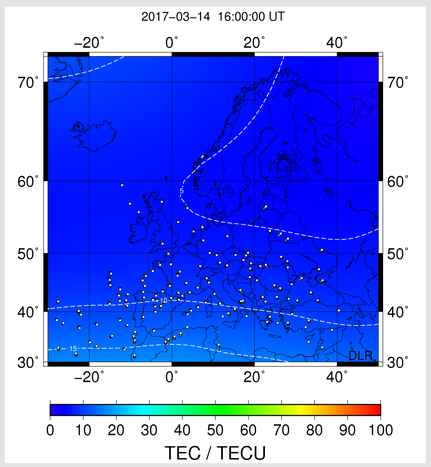
A common index characterizing geomagnetic storms is the disturbance storm time index Dst. The storm onset time is defined as the time of maximum Dst right before it starts decreasing to values below -50 nT. The storm end is considered when Dst increases to values above 50 nT (minimum 48 hours storm duration).

Test plan

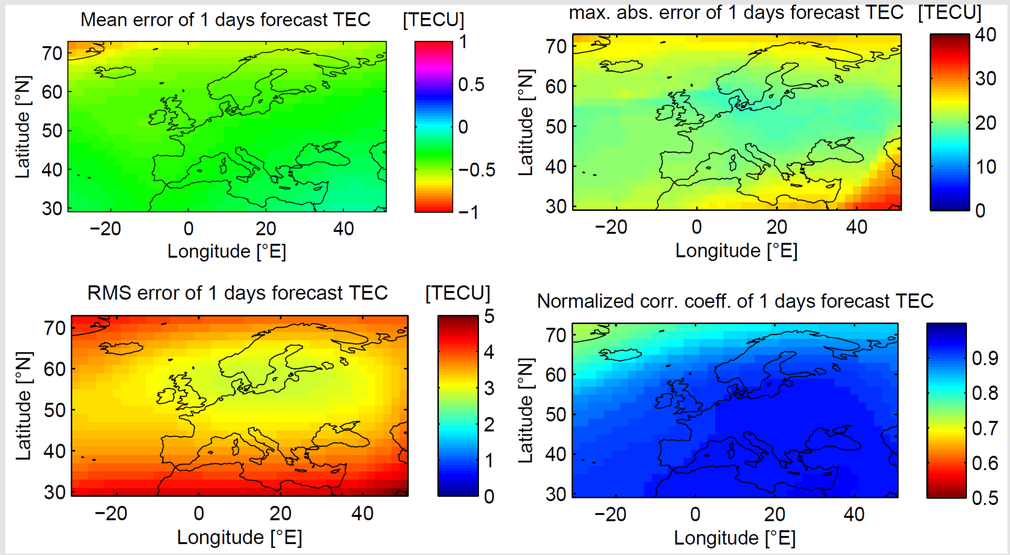
We study the error during the year 2015, which is a moderately disturbed year during solar declining phase. The error is considered to be:

$$\varepsilon_x(t) = TEC_{med27}(t-x) - TEC(t)$$

We apply regression analysis, which is a widely used tool to evaluate the performance of forecast models. Here, we present in addition to the correlation coefficient R the mean and root mean square (RMS) error.



Example NRT TEC map provided by DLR. This TEC map has been generated from ground based GNSS measurements. White dots indicate the measurement points.



Statistics on the 1 day forecast error ε_1 during geomagnetically quiet conditions in 2015. Upper left panel: mean ε_1 , upper right panel: maximum absolute ε_1 ; lower left panel: RMS of ε_1 and lower right panel: normalized correlation coefficient between *TEC(t)* and TEC_{med27}*(t-1)*.

Regular TEC perturbations

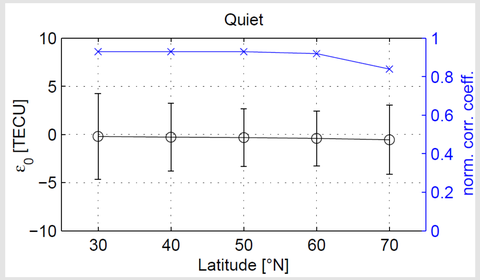
The deviation between TEC_{med27} and TEC during quiet conditions (left plot) are considered as regular TEC perturbations due to fluctuations in the atmosphere (wave, composition etc.) and EUV radiation.

24 hours forecast accuracy

The accuracy of 24 hours forecast (top panels) shows the same magnitude as quiet time perturbations. The errors are comparable with other empirical TEC forecast models (IWAF and approach of Niu et al., 2014 with ARMA model).

Accuracy of predictions up to 27 days ahead

Using TEC_{med27} to forecast 27 days ahead (not shown) has a mean error of 0.09 TECU, RMS of 4.5 TECU and R of 0.84 (50° N/16° E).



ε_0 during quiet conditions at longitude 15°E. Black lines show mean and standard deviation and blue demonstrates the normalized correlation coefficient.

Summary and conclusions

We demonstrate the performance of the 27 days median TEC for forecasting TEC. The results document that median TEC is a good approach for forecasting TEC 24 hours ahead during quiet ionosphere conditions. Even applied as 27 days forecast, it shows reasonable quality.

Reference: Niu et al.: Study of ionospheric TEC short-term forecast model based on combination method, in: 12th ICSP, doi:10.1109/ICOSP.2014.7015430, 2014.

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