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UPC VTEC FORECAST MODEL BASED ON IGS GIMS

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Abstract. This abstract provides an overview of the current UPC approach for ionospheric TEC forecasting developed in the frame of the IGS iono-WG.

1 INTRODUCTION

A short-term prediction model of ionospheric vertical Total Electron Content (VTEC) has been developed by UPC in the frame of the International GNSS Service (IGS) ionospheric Working Group. Nowadays, forecasting of TEC is of great interest to improve a wide variety of scientific and technological applications. In fact, there has been a request from ESAs water mission SMOS for using IGS TEC maps, including predicted products[5] . In this context, a preliminary 2-days ahead UPC forecast product has been developed and is being automatically distributed through cddis.gsfc.nasa.gov FTP site on a daily basis.

2 TECHNICAL DESCRIPTION

The UPC approach is currently based on using long time series of IGS vertical TEC Global Ionospheric Maps (GIMs) and applying linear regression and ridge regression[3] combined with the Discrete Cosinus Transform or DCT[1] . Appart from that, the prediction model is trained with one year of final IGS VTEC products as input data, such as UPCG files. Afterwards, the model is applied to the prediction set that includes the corresponding rapid IGS products from the last seven days. Note that rapid IGS products are available after about one day at IGS distribution server while the final ones have latencies of about 9-16 days[4] . In this way, being on day T, the last available rapid IONEX file corresponds to day $T-1$ and prediction is performed

Training	Prediction set		Pred
$T-(7+366)$	$T-7$	T	$T+1$

Table 1: Input data distribution for UPC prediction model

for day $T+1$. Moreover, the model is trained with files from $T-(7+366)$ to -8 and the prediction is applied to files from $T-7$ to $T-1$. More in detail, every single GIM in the training set and in the prediction set is transformed using the DCT by using Eq. 2 (see Fig. 1 as an example). Therefore, we express every IONEX map in local time as an expansion of cosinus functions with certain amplitudes defined by the DCT coefficients referred to as C. The use of these coefficients allows a lower dimensional representation of the map.

$$C_{p,q} = \alpha_p \alpha_q \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} x_{m,n} \cos \frac{\pi(2m+1)p}{2M} \cos \frac{\pi(2n+1)q}{2N}, \qquad (1)$$
$$0 \leq p \leq M-1, 0 \leq q \leq N-1$$

where x is the input matrix derived from each IGS GIM in consideration, p and q represent the vertical (latitude) and horizontal (longitude) spatial frequency components, p and q are normalization factors and M and N are the row and column size of x, i.e. 71 and 72 respectively considering 2.5°/5° of longitude/latitude resolution associated to the input IGS GIMs.

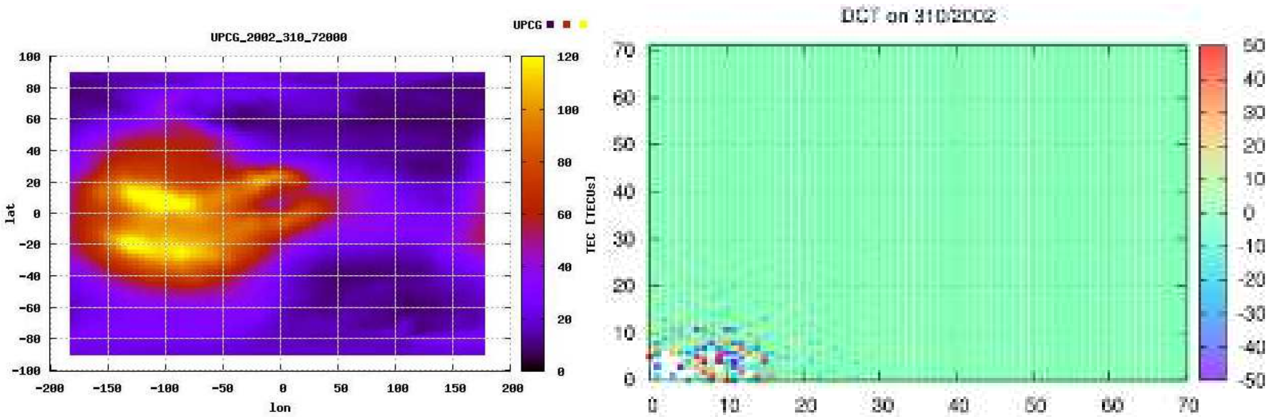

Figure 1: Example of final IGS VTEC map for UPC analysis center in longitude/latitude range (left) and its corresponding DCT transform after converting to local time for day of year 310, 2002 (right). In this case, note that values outside the color palette range appear in white color.

Then, a linear regression is applied to each of these coefficients (i.e. the prediction is done on the coefficients that are used to reconstruct the predicted map). Afterwards, the predicted value of each DCT coefficient C is obtained using Eq. 2:

$$\widehat{C_{p,q}}[t_0 + v] = \omega_0 + \sum_{u=1}^{U} \omega_u \cdot C_{p,q}[t_0 - u + 1] \tag{2}$$

where t_0 is the time index of the last available GIM map taken as input, v is the number of maps ahead (12 to 24 in case forecasting 2-days ahead), ω_0 and ω_u are the regression coefficients over time and U is the number of GIM maps backwards taken into account (85 when considering 7 days in the prediction set at 2h time resolution and after mixing 00UT maps)[2] . Finally, the obtained regression coefficients are applied to the prediction set after the DCT transform. In the current approach, the VTEC predictions are encapsulated in IONEX format for their distribution at 2.5°/5° of longitude/latitude resolution and 2h time resolution as in the case of input IGS GIMs. It is also remarkable that UPC current prediction model can be fed as well with additional physical information, such as 10.7 cm solar radio flux, Sunspot number or geomagnetic index Kp. Moreover, the ionospheric parameter Global Electron Content (GEC) can also be considered.

3 RESULTS AND CONCLUSIONS

In order to assess the performance of the model, several periods in 2002, 2004 and 2008 years have been selected including different solar/geomagnetic conditions. Also, the results are obtained considering final IGS products as reference and testing both the prediction product obtained using UPC prediction approach and without applying any prediction model, i.e. considering that ionosphere has not changed with respect to the last rapid IGS product in the input data. In the case of 2-days ahead forecast using GIMs of UPC analysis center, the forecast using UPC model is called U2PG and considering non-variant ionosphere is called UPR2 (prediction file on day $T + 1$ is considered equal to UPC rapid IGS product UPRG on day $T - 1$). Finally and for validation purposes, independent reference ionospheric TEC values have been generated from JASON altimeter GPS dual-frequency receiver. Furthermore, the Center for Orbit Determination in Europe (CODE) prediction products[6] can also be taken into account for comparison purposes when applying the UPC model. See Figure 2 for an example of performance under solar minimum conditions from day of year 020 to 040, 2010 where U2PG overall results show RMS improvements of 15.1with respect to UPR2 case (global VTEC without forecast model). Therefore, applying a prediction model shows better performance than considering non-variant ionosphere in 48 hours for this three weeks period. Moreover and for different solar/geomagnetic conditions, results seem promising enough to think on moving from a preliminar to an official UPC IGS forecast product in the near future.

4 ACKNOWLEDGEMENTS

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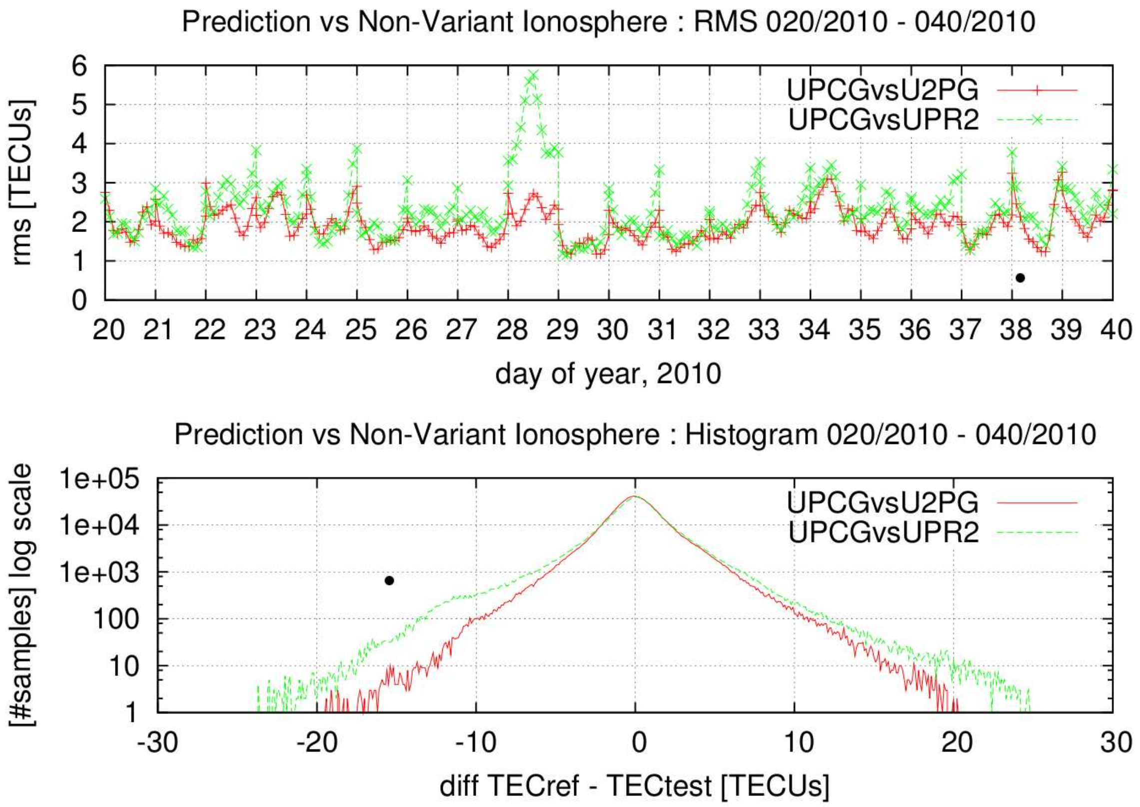

Figure 2: Test corresponding to doy 020 to 040, 2010. Plots on RMS (top) and histogram in semilogarithmic scale (bottom) of the difference between the final TEC derived from UPCG files as reference and the predicted values. U2PG corresponds to the 2-days ahead UPC forecast product and UPR2 corresponds to the non-variant ionosphere in 48 hours obtained from UPRG files.

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