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Effect of Space Weather on Ionospheric Total Electron Content Variation during the 23rd Solar Cycle.

N. Bergeot (1,2), I. Tsagouri (3), C. Bruyninx (2), J. Legrand (2), J.-M. Chevalier (1,2), P. Defraigne (2), Q. Baire (1,2), E. Pottiaux (1,2)

(1) Solar-Terrestrial Centre of Excellence, (2) Royal Observatory of Belgium, (3) National Observatory of Athens. Institute for Space Applications and Remote Sensing

One of the future challenges of the Space Weather community is to predict the Earth's ionospheric state in response to variations of the Solar activity, especially during stormy events. The beginning of the 23rd Solar cycle coincided with the start of the catalogue of global ionospheric Total Electron Content (TEC) maps based on GNSS data. Consequently, the 23rd Solar cycle (1996-2008) is the first full Solar cycle ever having both GNSS-based TEC measurements as well as observed Solar parameters. This study takes advantage of this new double dataset (1) to develop an empirical ionospheric climatological model to predict the Mean Daily Ionospheric Total Electron Content (MDITEC, i.e. the mean value of the TEC over a day at a given latitude) taking Solar parameters as input and (2) to analyze the variation of the MDITEC during identified ionospheric storm events.

In this paper, several Solar parameters (e.g. daily Sunspot Number, F10.7 flux and derived F10.7P) are tested as input and different parameterizations are considered to estimate, i.e. to model, the MDITEC for a given day and at a given latitude. The residuals between the models and the observed MDITEC are minimized by a least-squares adjustment. The best model is obtained using (1) a combination of linear, annual and semi-annual terms between the MDITEC and F10.7P; (2) a discretization w.r.t. the phases of the Solar cycle.

Our preferred ionospheric climatological model is tested in terms of yearly median absolute error (1.4 ± 0.9 TECu) and median relative error (11.5 ± 2.9 %). The relative error remains constant during the entire 23rd Solar cycle which comforts us in the robustness of our climatological model with no degradation during the different phases of the Solar activity.

Finally, differences greater than 15 TECu between the observed and modeled MDITEC are concordant with 70 intense ionospheric storm events occurred during the period 1998-2005. The onset of these events was identified from the analysis of interplanetary magnetic field (IMF) observations provided by NASA ACE spacecraft from the vantage L1 point. The storms affect significantly the MDITEC mainly in polar regions, with a loss of ionization with respect to our climatological model and a peak one day after the onset. The mean difference between the observed and modeled MDITEC (absolute error) is -3.2 ± 1.5 TECu one day after the onset and becomes negligible again 2-3 days after the onset. Concerning the relative errors, they are of the order of -19.6 ± 15.0% one day after the onset and normal values can be seen again 3-4 days after the onset. These results show a global picture of the effect of extreme Space Weather events on the Earth's upper atmosphere.