Abstract: SA51C-2713
Poster Session:
Friday, 13 December 2024; 08:30 - 12:20 EST

Model-Based Analysis of Ionospheric Reaction to Regular and Disturbed 27-day Solar EUV Profiles

Hanna Dühnen[1], Rajesh Vaishnav[2], Erik Schmölter[1], Christoph Jacobi[2]
[1]Institute for Solar-Terrestrial Physics, German Aerospace Center, Neustrelitz, Germany; [2]Institute for Meteorology, University of Leipzig, Germany

Introduction

Quiet-time ionospheric processes are primarily driven by solar extreme ultraviolet (EUV) radiation, which exhibits a periodic variation of 27 days. This periodicity is observable in ionospheric parameters such as total electron content (TEC). While photoionization caused by solar EUV is the primary driver, the ionospheric response is delayed and modulated by processes such as photodissociation, recombination, and atmospheric dynamics. The influence of solar variations on the atmospheric ionization depends on multiple factors, such as the level of solar activity and shows variability on different time scales.

Data and Methods

The ionospheric ionization is driven by solar EUV, which is represented with the F10.7 index in the available model simulations and for that reason also in the analysis of this study. For geomagnetic activity, the Kp index is used (see Figure 1).
The analysis aims to investigate ionospheric processes with Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM, Richmond et al. 1992) simulations. TIE-GCM is a high-resolution, physics-based numerical model that includes coupled dynamics, chemistry, and electrodynamics of the upper atmosphere. The data used are provided by the open time-series of the high-resolution ionosphere-thermosphere aeronomic climate simulation (OTHITACS, Kodikara, 2023).

The Pearson correlation coefficients $r(t,w)$ of the globally averaged total electron content (GTEC) with F10.7 for different time windows of width w is calculated according to

$$r(t,w) = r[F10.7(t), TEC(t)]$$
$$= \frac{\sum_{t_i=t-w/2}^{t_i=t+w/2}(F10.7(t_i) - \overline{F10.7})(TEC(t_i) - \overline{TEC})}{\sqrt{\sum_{t_i=t-w/2}^{t_i=t+w/2}(F10.7(t\_i) - \overline{F10.7})^2}\sqrt{\sum_{t_i=t-w/2}^{t_i=t+w/2}(TEC(t_i) - \overline{TEC})^2}}.$$

This method allows quantifying the ionospheric response to solar forcing for a range of temporal scales.

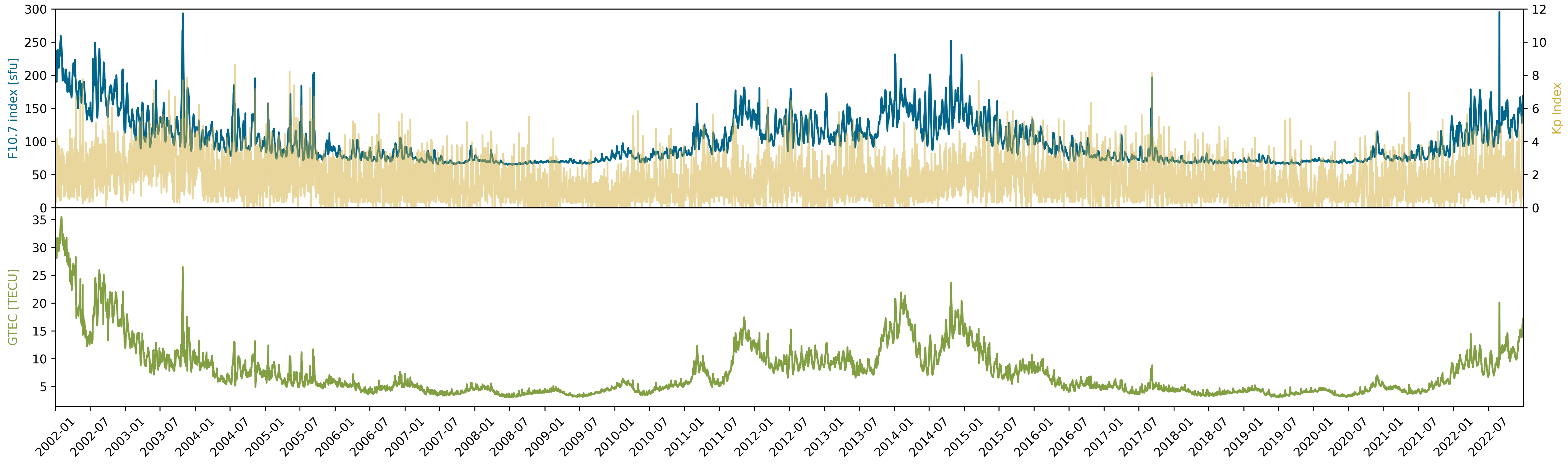

Figure 1: F10.7 index (blue), Kp index (yellow) and globally averaged GTEC (green) at 12:00 UT each day.

Results

Figure 2 shows that correlations of GTEC with F10.7 are dominated by high values for all window widths. However, during the solar minimum years (2007 to 2010 and 2017 to 2020), the Pearson correlation coefficient shows low values. In particular 2009 and 2018 show no correlation with F10.7 for both short and long correlation windows. In general, average correlations strongly increase with increased correlation width (see rightmost panel), whereas short correlation windows are strongly affected by short-term disturbances.
Additionally, the variations in correlations suggest the presence of seasonal variations in the ionospheric response.

Conclusion

Our initial result show:

1. Weak correlation of F10.7 with GTEC during low solar activity years.
2. High correlations in high solar activity years.
3. Larger correlation widths show higher correlations of F10.7 with GTEC.

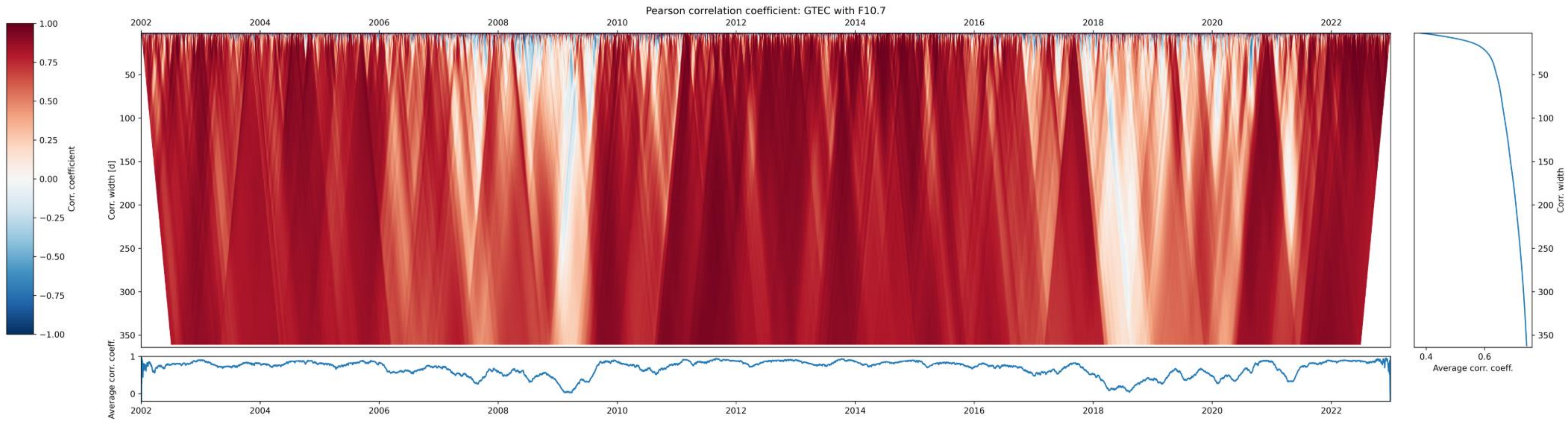

Figure 2: Daily Pearson correlation of GTEC with F10.7 at 12:00 UT with windows for the correlation ranging from 2 to 366 days. The bottom panel shows the average correlation coefficient per timestep and the rightmost panel shows the average correlation coefficient per window width.

Outlook

Future work will focus on analyzing the ionospheric delay across different solar activity periods with an emphasis on various 27-day solar activity profiles. This investigation will extend beyond total electron content (TEC) to include detailed studies of key ionospheric constituents, such as O^+ and O_2^+ , to understand the underlying processes within the ionosphere.
Additionally, comparisons between the TIE-GCM simulation results and observational datasets, including those from the International GNSS Service (IGS), will be conducted.

References:
Richmond, Ridley, Roble, 1992, ***A thermosphere/ionosphere general circulation model with coupled electrodynamics***, doi:10.1029/92gl00401.
Kodikara, Timothy (2023). ***The open time-series of the high-resolution ionosphere-thermosphere aeronomic climate simulation (OTHITACS)***. World Data Center for Climate (WDCC) at DKRZ, doi:10.26050/WDCC/OTHITACS_tiegcm.

Deutsches Zentrum für Luft- und Raumfahrt

Acknowledgments:
The DRIVAR II project is supported by Deutsche Forschungsgemeinschaft (DFG) - Nos. JA 836/48-1 and SCHM 3761/1-1.

Contact: Hanna Dühnen
DLR, Institute for Solar-Terrestrial Physics
Woldegker Chaussee 35, 17235 Neustrelitz
Email: hanna.duehnen@dlr.de