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DISPEC NEWSLETTER

Scientific exploitation of space Data for improved Ionospheric SPECification

IN THIS ISSUE

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Dear Reader,

Welcome to the first issue of the DISPEC newsletter series!

DISPEC (2024-2026) is a European Union funded project under the Horizon Europe Research and Innovation Programme.

The DISPEC project offers new high-level data products based on advanced data processing techniques that improve data quality, provides estimates of ionospheric characteristics based on the joint processing of space and ground data, provides results from post-processing of data for improved ionospheric specification, and exploits long-term time series for the study of long-term trends in the ionosphere in connection to atmospheric long-term dynamics and geophysical phenomena.

Join us to stay informed about the latest project developments.

The DISPEC Consortium

NEWS ON DISPEC FILTERS

The **DISPEC project** is working on improving how we understand and monitor the ionosphere — a layer of Earth's atmosphere that affects things like radio signals and GPS. The project creates new, advanced ways to process data, combining information from both satellites and ground-based systems to give more accurate pictures of the ionosphere.

A recent report submitted to the EC looks at early results from a new method for automatically analysing **ionograms**. This method mimics how a trained expert would analyse these charts to estimate, the maximum usable radio frequency, **foF2** and the **hmF2**. The key innovations introduced are:

- **AI-based ionogram interpretation**, improving the precision of key ionospheric measurements (e.g., foF2 and hmF2).
- **Open-source tools (e.g., POLAN)** integrated with automated workflows to ensure transparency and usability.
- **New filtering methods** that replicate expert-level analysis and reduce noise in raw data.

The early results show that POLAN performs just as well as another widely used program called **ARTIST**. However, the most important factor for getting accurate results is how precisely two values — **fmin** and **foF2** — are estimated. These two values strongly influence the overall accuracy of the ionospheric profile and the hmF2 value.

An example of the DISPEC method autoscaling performance is given in Figure 1.

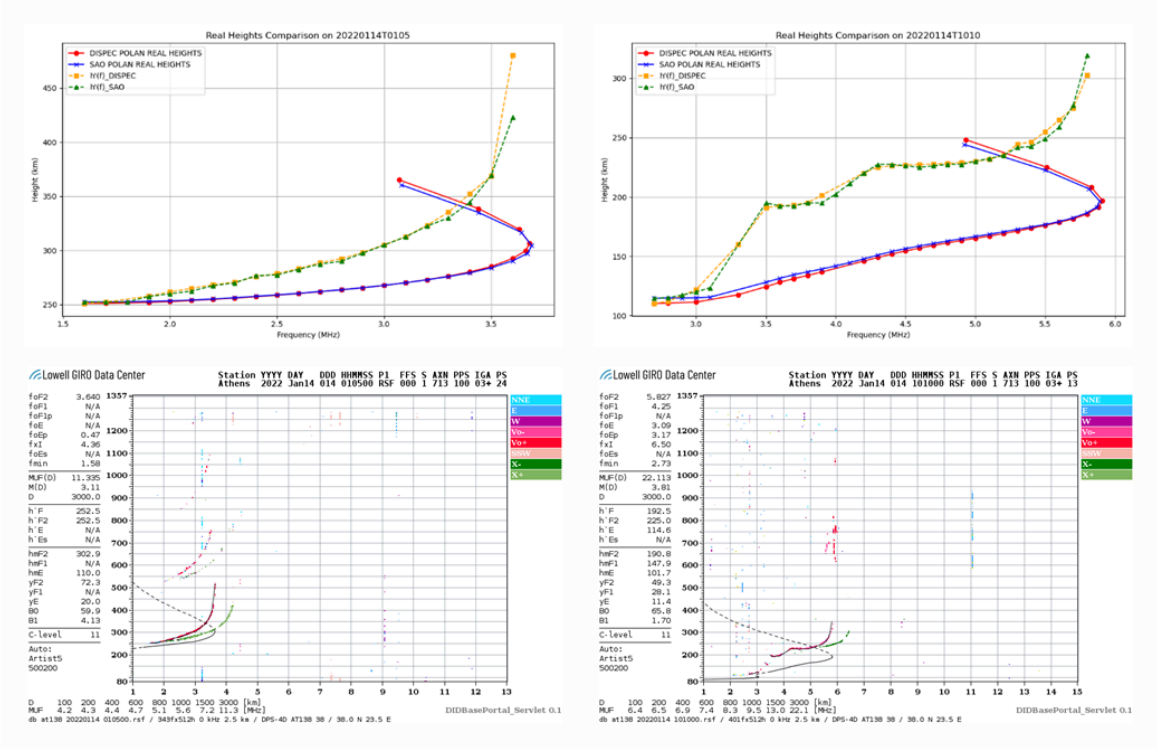

Figure 1. An example of the DISPEC method autoscaling performance applied in two ionograms recorded by Athens Digisonde, during the night (left) and the day (right).

PRELIMINARY TESTS OF SPECTRAL ANALYSIS TOOLS

There are thousands of GNSS stations worldwide collecting multi-frequency phase observations, which are one of the largest sources of ionospheric observations. The advantage of these data is their very good temporal resolution (seconds), long data records (decades), and high-rate automatic recording of multifrequency phase data. Several hundred stations continuously observe the ionosphere for two decades or longer detecting the ionospheric variations related to solar, geomagnetic, seismic and other phenomena. The vertical total electron content (VTEC) is an integral of electron density (Ne) over multiple ionospheric layers, which can be mapped in two dimensions. The time series of VTEC are composed signals, and their variations at different frequencies constitute a challenge in VTEC analysis. The Earth rotation also contributes to this complexity, and diurnal component dominates in the VTEC impeding the analysis of anomalies. The solution is the transformation of temporal variations to frequency domain, and observation of power spectral density (PSD) variations over time. The internal or external processes affecting VTEC occur in the lithosphere, Sun, ionosphere, magnetosphere and thermosphere, and some of them exhibit periodic patterns, which are confirmed in several research studies. The other shorter wave-like signals are transient variations, but they can be also correlated with external drivers. Therefore, detailed spectral analysis can be equivalently helpful in the recognition of long-term periodicities, as well as in the detection of shorter periodic signals.

The networks of stations, like e.g. public service of International GNSS Service (IGS), provide observations at different locations of the Earth, which are specific in respect of ionospheric activity. Suspectedly, the external drivers like solar wind would have a more global impact on the ionosphere, whereas Earth-fixed phenomena like seismicity can affect the ionosphere more locally. In other words, different scale of the impact can be potentially caused by the distance from the source of disturbing energy affecting typical electric circuit of Earths' ionosphere. The diurnal and sub-diurnal components dominate in the entire VTEC spectrum, but at the analysis stage, the limitation of analysed frequency bound to longer wave periods can exclude them from the spectrogram. The inter-diurnal VTEC variations have the amplitudes several times lower, but not ten or hundred times lower than diurnal/sub-diurnal components. The several-day wave periods can be even more interesting in comparison to several-hour periods, due to several-day evolution of different external phenomena.

The short-term Fourier analysis (STFT) is illustrated in Figures 2 and 3 with the spectrograms of GNSS VTEC in 2020, calculated at 12-1.4-day frequency band. The presented two IGS stations at different latitudes of northern and southern hemispheres are both located in the Pacific region. Figure 2 presents the spectrogram of VTEC from MKEA station located on Mauna Kea volcano in the Hawaii, whereas Figure 3 shows VTEC series from SOLO station located in the Solomon Islands. The shapes of increased PSD in the spectrograms are of course elongated due to the size of applied 30-day Tukey window. Therefore, in fact, the periodic signals at shorter wave periods can be shorter and last only for single days. However, this longer window is required here, as its reasonable length must be at least a bit longer than the longest analysed wave period. On the other hand, the longer window allows for a better accuracy of PSD determination in the frequency unit.

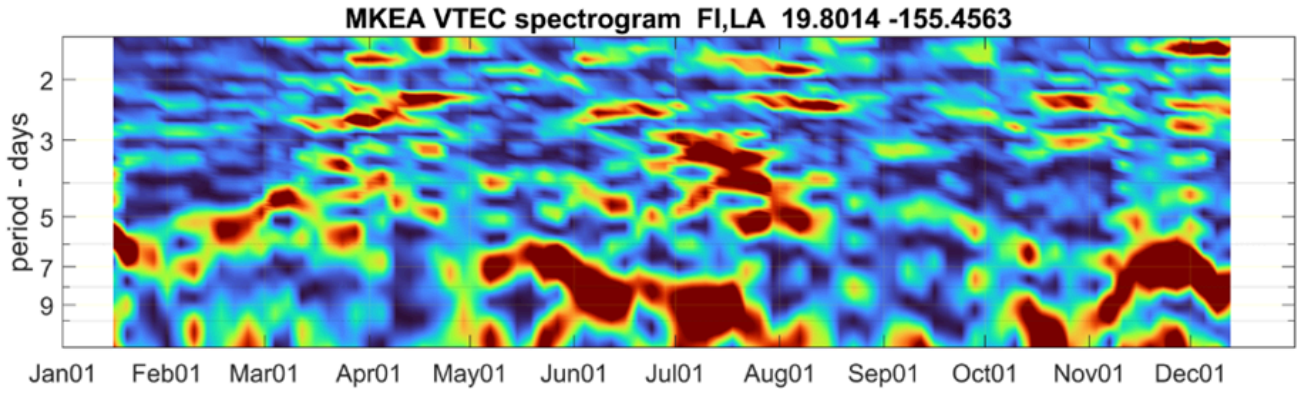

Figure 2. Spectrogram of residual yearly VTEC time series collected by MKEA IGS station for wave periods 1.4-12 days. The phase GNSS data are downloaded from IGS service (https://network.igs.org/).

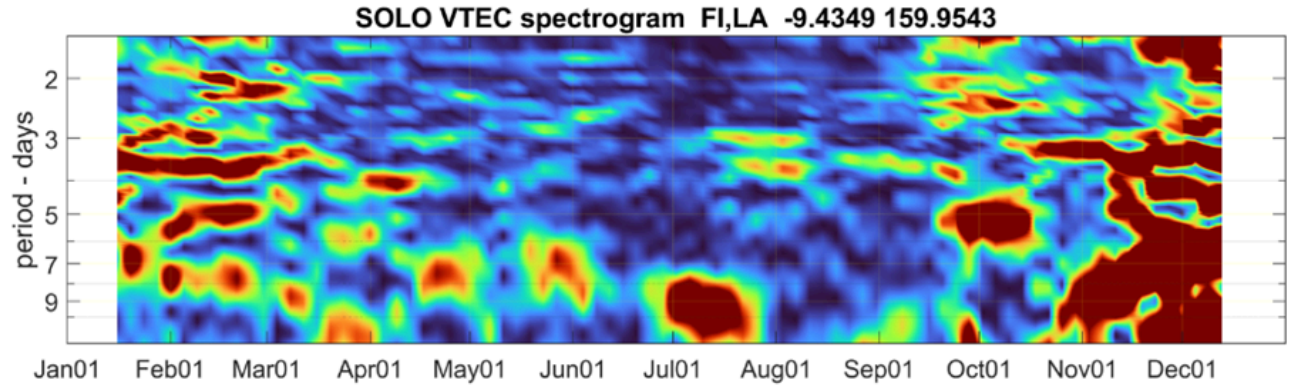

Figure 3. Spectrogram of residual yearly VTEC time series collected by SOLO IGS station for wave periods 1.4-12 days. The phase GNSS data are downloaded from IGS service (https://network.igs.org/).

The temporal variations of VTEC at MKEA and SOLO stations differ in particular within higher frequency band between 1.4-day and 5-day wave periods. However, aside from these differences even primary look at the 6-12-day band informs us about notable similarities. The anomalies in June and July 2020 located between the 6-day and 12-day wave periods in both spectrograms correspond in frequency to each other. Another evident time of similar PSD patterns, although different PSD scale, can be found in November and December 2020. Based on the previous assumption of source distance influence on the spatial scale of VTEC anomalies, it can be roughly suspected that the lower frequencies, which are more comparable between the Figures 2 and 3, correspond to more distant external drivers of ionospheric anomalies. There is a suspicion that the strong anomaly at around 10-day wave period in July 2020 can be related with the high density of protons in the solar wind at that time. Therefore, cross-spectral analyses are planned in the frame of DISPEC project. A wide set of existing parameters representing Earth magnetic field or solar wind provide a unique opportunity for cross-spectral analysis between VTEC and ancillary data, and attempts at classification of selected VTEC anomalies.

COMMUNICATION ACTIVITIES

Knowledge Hub

The DISPEC Knowledge Hub is being populated!

Space Science Comic Books about **Space Weather**, **the Aurora**, and **the Upper Atmosphere** are available through the project website. These Comic Books, along with seven more focusing on other topics, were originated by Prof. Yohsuke Kamide at the Solar-Terrestrial Environment Laboratory at Nagoya University in Japan, in collaboration with SCOSTEP's CAWSES program, and are available in various languages.

In the frame of the DISPEC project the comic books have been **translated** into **Polish by the UWM Team** and into **Greek by the NOA Team**.

RECENT PUBLICATIONS AND PRESENTATIONS

UWM has performed the following two international contributions, associated with DISPEC:

- Wojciech Jarmołowski, Paweł Wielgosz, "Several-day variation of electron density sensed by Swarm satellites over tectonic plate junctions", EMSEV 2024, Workshop on Electromagnetic Studies of Earthquakes and Volcanos, Chania, Crete, Greece, 6-9 October 2024.
- Wojciech Jarmołowski, Paweł Wielgosz, Anna Krypiak-Gregorczyk, Beata Milanowska, Jacek Paziewski, "Correlation of Swarm in-situ electron density with geomagnetic indices and solar activity parameters at different frequency bands", COSPAR 2024, 45th Scientific Assembly, Bexco, Busan, Korea, 13-21 July 2024.

A full list of publications, presentations and reports related to DISPEC can be found on the project website.

PAST EVENTS

DISPEC Networking Meetings

The final goal of the DISPEC project is to provide methodologies for improved ionospheric specification through the derivation of high-level data products, that support the enhanced and reliable use of data from ground and space-based instruments. This ambitious goal requires the engagement of potential users and stakeholders in all phases of the project development.

Two Networking Meetings were organised. Their objective was the awareness of the stakeholders about the plans of the consortium for the development of the specific high-level products, seeking input on their requirements and receiving feedback on the DISPEC planned developments.

The work carried out in the framework of the DISPEC project - focusing on data analysis methodologies for improved ionospheric specification, including the effects of Travelling Ionospheric Disturbances (TIDs) - has been presented in the **DISPEC First Networking Meeting**, which was organised as a specific topic during the T-FORS Second Innovation Day, held in Athens (Greece) on the 4th of December 2024.

The representative Scientific Data Applications (SDAs) that concern with the most important types of ionospheric disturbances were presented in the **DISPEC Second Networking Meeting**, held in Barcelona (Spain) on the 11th of February 2025.

The presentations given by our members are available on the **DISPEC YouTube Channel**.

UPCOMING EVENTS

DISPEC Third Networking Meeting

The DISPEC Third Networking Meeting will take place at ONERA premises in Toulouse (France) on Thursday, 11 December 2025. The goal of this meeting is to demonstrate the newly developed high-level products, and to receive feedback on potential exploitation.

Details on the event will be announced soon through the project website.

DISPEC PARTNERS

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Scientific exploitation of space Data for improved Ionospheric SPECification (DISPEC)

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