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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

INTRODUCTION TO THE PROJECT

The ionosphere from above and below: so, what's in there anyway?

The ionosphere is a part of the Earth's upper atmosphere, a shell around the Earth between about 80 and 600 kilometres from its surface. It consists of a weakly ionised plasma or electron-ion gas formed by ionisation of atoms and molecules by extreme ultraviolet and X-ray solar radiation. Many satellites circle the Earth in the ionosphere, which is influenced by Earth and space weather, and disturbances there can disrupt important communications signals. Terrestrial communications based on High Frequency transmissions are also greatly influenced by the state of the ionosphere.

The EU-funded DISPEC project aims at the exploitation of bottomside and topside ionospheric data, provided by space missions – such as Swarm, DORIS, GRACE, GRACE-FO, Spire, COSMIC-2– and by ground-based GNSS receivers and ionosonde sounders, to support research activities for improved ionospheric specification, through the derivation of high-level data products. The project outcomes have the potential to complement the ESA Space Science Archives and the Space Weather Network of Services, the data collections provided by the global networks of ionosondes and GNSS ground based receivers, and to enhance the capacity of European Research Infrastructures.

DISPEC KICK-OFF MEETING

On the 1st & 2nd of February 2024 the National Observatory of Athens – coordinator of DISPEC – successfully organised a two-day kick-off meeting for the project launch with the participation of the EC Project Officer, the Advisors and representatives from all project beneficiaries. The meeting, which was held as a hybrid event, was a great opportunity for fruitful discussions on the project developments and the activities to be carried out the next 10 months.

SPECTRAL ANALYSIS METHODOLOGY AND DATA REQUIREMENTS

The idea of high-level product generation from ionospheric data is stimulated by the fact of complexity of data time series and data time-space series. The composed spectrum makes data complicated in the analyses of physical processes, especially if unwanted, e.g., diurnal or seasonal signals have high amplitude. The concept of high-level product is based on the application of spectral analysis and band-pass filtering preserving narrower signal bands, which are better prepared for use in the applications, like modelling, process analysis or correlation analysis. The physical domain of spectral data analysis is frequency domain, which is sampled from time domain in case of station-based data and data series generated from developed models, or from time-space domain typical for satellite moving platforms. The idea of spectral processing includes five primary steps, which are: high-pass filtering for data detrending, but also denoising, time-space-frequency or time-frequency analysis by Fourier-based techniques, cross-spectral analysis, coherence analysis, and generation of high-level datasets by band-pass filtering.

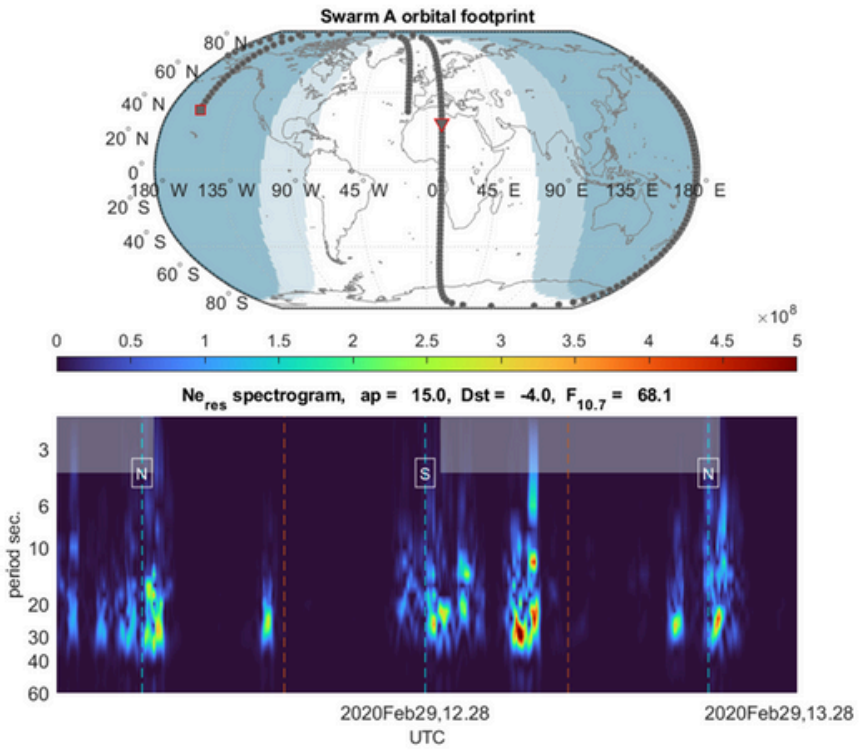


Figure 1. Swarm Alpha orbital footprint with night/day terminators at the start/end of the selected orbital track (upper). Swarm residual Ne spectrogram with indicated equator (red dashed) and pole (blue dashed) passes (bottom).

The low-Earth orbit (LEO) satellite signals are time-space data collected during fast run of the satellites along the orbit. An example LEO speed for Swarm satellite is around 7.6 km/s, which makes 1D in-situ electron density (Ne) signal really transient measurements of ionospheric variations during very short time spans. The scale of ionospheric variations over such short time intervals is not large, so LEO satellite detects mainly spatial characteristics of ionospheric variations. However, different variations can have different spatiotemporal scales, which can be recognized better with spectral analysis (*Figure 1*).

The complexity of along-track satellite data suggests that high-level products from spectral analysis can better represent different variations of ionospheric parameters triggered by different sources, e.g. processes generated by the Sun, magnetosphere and other coupled environments. There is an opportunity for cross-spectral analysis of along-track LEO data, due to multiple payload carried by the spacecrafts, which measures separate physical quantities, e.g. magnetic field components.

The ground-based stations developed for different type of ionospheric observations (GNSS, Digisondes, etc.) collect time series of data at fixed geolocations. The advantage comes from the networks of such stations, as they provide the observations at different locations on the Earth, which are specific in respect of ionospheric activity. The ionospheric conditions over such stations vary over time, as it is influenced by different internal (Earth-fixed) and external processes. These processes occur in the lithosphere, ionosphere, magnetosphere, thermosphere or on the Sun. Several processes are periodic at some already well-known wave periods, which is confirmed in several research studies. The other shorter wave-like signals can be transient variations, but can be also important and correlated with external drivers. Thus, long-term time series of high-rate ionospheric data compose a really rich spectrum of ionospheric signals, e.g. station-based GNSS data (*Figure 2*). The high-level products based on band-pass filtering are a chance for representation of selected ionospheric variations, which are characteristic for selected processes. The other important issue is an elimination of unwanted masking signals like diurnal or seasonal periodicity (*Figure 2*). The cross-correlation for ionospheric time series can be calculated with respect to various time series of potentially coupled ancillary data like geomagnetic indices or solar activity parameters.

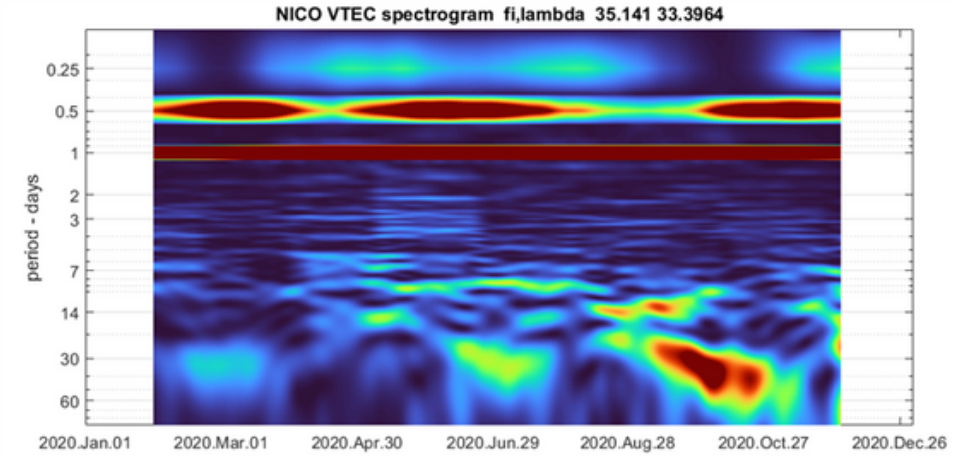


Figure 2. Spectrogram of residual yearly VTEC time series collected by IGS NICO station after subtraction of 60-month trend.

The satellite along-track data are referred to time-space-frequency domain in spectral analysis, whereas ground-based series are analysed in time-frequency domain. Different domains, different spatial reference of data collection, and different measurement techniques slightly differentiate data requirements for different data types, but most of general requirements are similar. The first requirement of spectral analysis is a homogeneous data spacing over time. The data processing level should be as close to observational as possible, i.e. including only processes necessary for creation of data time-space series. Any denoising, filtering, averaging or smoothing processes can destroy data spectrum. Also, one of the most desired data properties in respect of spectral analysis, is possibly highest continuity and the lowest number of data gaps. The frequency of data sampling approximately determines the highest frequency of analysis. The length of continuous data span determines the lowest frequency of spectral analysis. In case of time-space-frequency analysis, recalculation of frequency to wave period, and to wavelength can be done. The wavelength can represent the spatial scales of analyzed ionospheric structures. In case of time-frequency analysis, recalculation of frequency to wave period is only applicable. The wave period will correspond to the period of variation. For all data types, the optimal numerical resolution of the data should correspond to their spectral content, i.e. consecutive data values preserve required spectral signal details at Nyquist frequency. Fortunately, station-based GNSS data and Digisondes have nowadays high sampling rates, and long time series collected.

The concept of high-level products generated from spectral analysis is based on band-pass filtering of the data and division of complex signals. The band-pass filtered signals from different frequency bands can be sensitive to separate physical processes. The band-pass filtered data supported by correlation analyses presenting their potential of applicability will fill the database of new high-level data products.

COMMUNICATION ACTIVITIES

Knowledge Hub

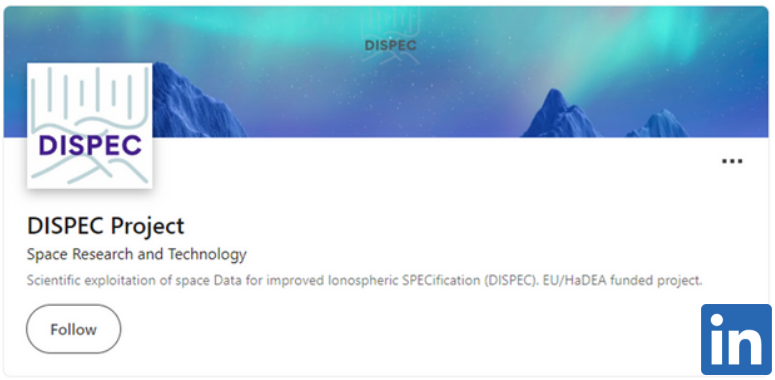
DISPEC established a Knowledge Hub addressed to different audiences: school children and students, the general audience and targeted groups (radio enthusiasts), as well as stakeholders, providing materials to attract interest in space and upper atmosphere sciences and to increase users' awareness.

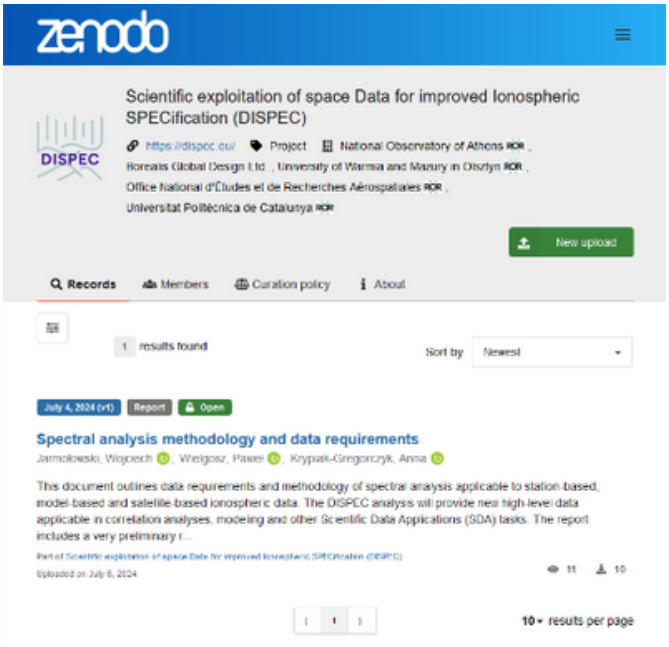
The Knowledge Hub, accessible via the public website at https://dispec.eu/dispec-users/knowledge-hub, will be enhanced with educational videos, webinars, articles and brochures throughout the project implementation.

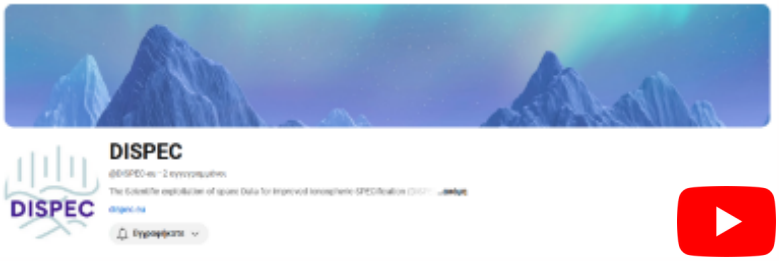
Social Networks

DISPEC developed dissemination and communication activities through social networks:

- LinkedIn account: https://www.linkedin.com/company/dispec/
- YouTube account: https://www.youtube.com/@DISPEC-eu
- Zendo account: https://zenodo.org/communities/dispec/







Different materials, reports and video presentations are being shared via the social networks to increase the users' awareness.

OUTREACH ACTIVITIES

UPC GIMSs @ PITHIA-NRF e-Science Centre

UPC-IonSAT has been doing intensive processing during the first year of DISPEC project in order to generate new products for the historical database of ionospheric electron content computed since 1996. Namely, vertical gradients of the electron density have been computed from the tomographic solutions, and VTEC gradient global maps have been obtained from rapid UPC Global Ionospheric Maps (with 15 mins time resolution, and pixels of size 5° x 2.5° in longitude and latitude, respectively). The historical dataset of UPC GIMs is available at the PITHIA-NRF e-Science Centre. This new database will be one main input for the UPC-IonSAT contribution to SDA4 "Proxies for geophysical phenomena and long terms trends" and will also be made available at the PITHIA-NRF e-Science Centre.

NOA 29th Summer School of Astrophysics

The National Observatory of Athens (NOA) team contributed to the 29th Summer School of Astrophysics organised by NOA's Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS) on 2-4 September 2024.

The school was attended by fifty high school students attending the first two years of high school (16-17 years old). The students attended general lectures on astrophysics/space physics/ionosphere. They were then divided into groups, and one of them worked on the laboratory topic on "Broadcasting radio waves into space", under Dr. A. Belehaki's supervision.

Finally, they presented the results of their project (vertical and lateral emission of radio waves – Marconi's experiment) to all students and parents.

European Researchers' Night 2024

The National Observatory of Athens (NOA) contributed to the "European Researchers' Night 2024" on 27 September 2024 by organising parallel events at its premises in Athens (Thissio and Penteli) and Korinthos (Stefanion Observatory). Over 1500 people participated in NOA events in total.

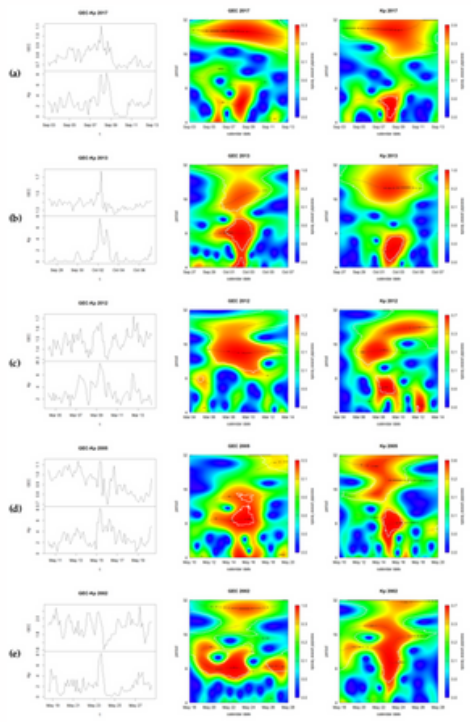
The Ionospheric Group of the Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS) of NOA participated in the event at Thissio. The event attracted approximately 700 visitors of all ages, and we received particularly favourable feedback from them.

Our team shared its work through presentations, videos, e-comic books and demonstrations. We talked with school and university students about the observations of the Athens Digisonde, the Ionosphere, the Solar Storms, and the Aurora, and demonstrated Athens Digisonde operations in real-time.

RECENT PUBLICATIONS AND PRESENTATIONS

UPC-IonSAT has performed the following two international contributions, associated with DISPEC, and acknowledging it:

- Manuel Hernández-Pajares, Cristina Álvarez San Martín, Victoria Campillo-Rueda, David Roma-Dollase, Miquel Garcia-Fernàndez, Raul Orús-Pérez, Alberto García-Rigo, Jiaojiao Zhao, Zishen Li, Liang Wang & Hong Yuan (2024) Some experiences in Low Cost GNSS Ionosphere, talk at 4th URSI AT-RASC, Gran Canaria, 19-24 May 2024.
- Aroca-Farrerons, J.M., Hernández-Pajares, M., Lyu, H., Roma-Dollase, D., Orus-Perez, R., García-Rigo, A., Graffigna, V., Olivares-Pulido, G., Monte-Moreno, E., Yang, H. and Liu, Q., 2024. The Spectrum of Global Electron Content: A New Potential Indicator of Space Weather Activity. Sensors, 24(2), p.393.



Representative examples of GEC and Kp time evolution (top and bottom, respectively of left-hand plots), GEC spectrograms (central plots) and Kp spectrograms (right plots), vs. time (horizontal axis, in days) and period (vertical axis, in multiples of three hours), with extremely high similarity (day 2017-09-08, row a), high similarity (day 2013-10-02, row b), mid similarity (day 2012-03-09, row c), low similarity (day 2005 05-15, row d) and extremely low similarity (2002-05-24, row e) - reproduced from Aroca-Farrerons et al., (2024).

NOA delivered the following presentations at the 4th URSI-RASC, Gran Canaris, 19-24 May 2024:

- Belehaki, A., Exploiting Digisonde observations for nowcasting and forecasting ionospheric weather, Invited Talk in Session G07.
- Belehaki, A., An overview of the DISPEC project objectives and activities, INAG Session

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

UPCOMING EVENTS

DISPEC First Networking Meeting

The DISPEC First Networking Meeting will be organised as a specific topic during the T-FORS Second Innovation Day. The event will take place in Athens on the 4th of December 2024. Details about the event are being announced through the T-FORS website; you can secure your place and interact with stakeholders here.

Upcoming scientific conferences

Members of the project consortium will be presenting their scientific research at the AGU24 Annual meeting, “What’s Next for Science”, Washington D.C. - USA, 9-13 December 2024:

- DISPEC presentation in Session - SA003 - Advances in Radio Frequency Propagation Modeling and Applications: “Improved automatic scaling of vertical incidence ionograms”, by K. Koutroumbas and A. Belehaki

DISPEC PARTNERS

ABOUT

Title
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Topic
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