

ISSUE 3 | FEBRUARY 2026

# DISPEC NEWSLETTER

Scientific exploitation of space Data for improved  
Ionospheric SPECification

## IN THIS ISSUE

HISTORICAL DATASETS FROM  
TOMOGRAPHY MODEL

SVD ANALYSIS AND MODELLING

COMMUNICATION ACTIVITIES

OUTREACH ACTIVITIES

RECENT PUBLICATIONS AND  
PRESENTATIONS

PAST EVENTS

UPCOMING EVENTS

BODO W. REINISCH OBITUARY (1936 -  
2025)

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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

# HISTORICAL DATASETS FROM TOMOGRAPHY MODEL

The following historical datasets (since 1997) have been generated in DISPEC after one year of continuous parallel computations on UPC-IonSAT linux servers:

- Ne and Ne (v) gradient datasets
- Vertical Total Electron Content (VTEC) global maps
- VTEC gradient global maps
- Global maps of Ionospheric Storm Scale Index
- Global Electron Content (GEC) time series
- Differential Code Biases (DCB)

The ionospheric electron density is the output of the TOMION software package developed and maintained by the UPC-IonSAT team. TOMION computes the Ne across voxels (pixels in 3D) in two thick layers (each centred around 450 km and 1,130 km height), alongside with the ambiguity of the GNSS carrier phase measurements from hundreds of GNSS ground receivers (from the IGS network) distributed worldwide.

The Ne vertical gradients are computed directly from the tomographic output and global maps of the horizontal and temporal components of the VTEC gradient and global maps of the Ionospheric Storm Scale Index (kind of a local Kp index) are computed directly from the global maps of VTEC (UQRG). Their computational methods have been previously published in Liu et al. (2022) and Liu et al. (2021), respectively.

The estimation of GNSS carrier phase ambiguities then leads to the calibration of carrier-phase-based Slant Total Electron Content (STEC) measurements. The STEC is then projected vertically to obtain the VTEC value for each pixel. Finally, all the geographical gaps (i.e. in regions with no GNSS measurements) are filled by kriging interpolation in the computation of global VTEC maps.

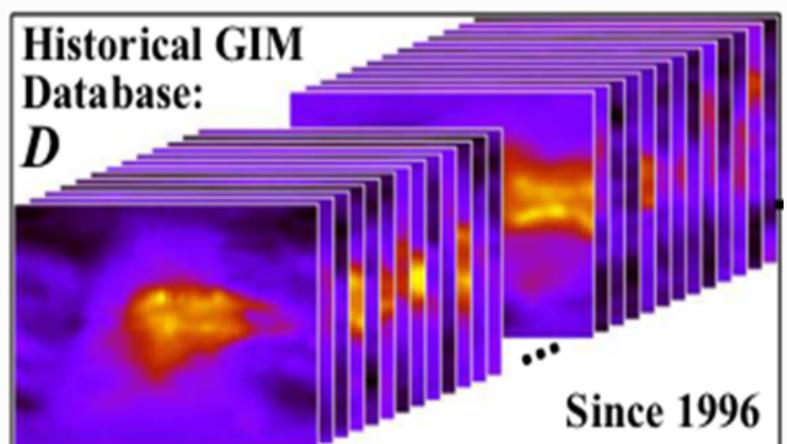


Figure 1. Generation of data sets with TOMION software & GNSS data

Figure 1 shows a sample of the VTEC global maps since 1996. From this VTEC dataset, other datasets have been computed, namely, VTEC gradients maps, the Ionospheric Storm Scale Index, and the time series of GEC. The GEC is computed by 2D integration of the VTEC for each map.

Finally, since DCBs and the STEC come out right away from the difference of the codes in two frequencies (a.k.a. the ionospheric combination), the former are computed by subtracting the calibrated STEC from such an ionospheric combination.

#### References:

- Liu Q, Hernández-Pajares M, Lyu H, Nishioka M, Yang H, Monte-Moreno E, Gulyaeva T, Béniguel Y, Wilken V, Olivares-Pulido G, Orús-Pérez R. Ionospheric storm scale index based on high time resolution UPC-IonSAT global ionospheric maps (IsUG). *Space Weather*. 2021 Nov;19(11):e2021SW002853.
- Liu Q, Hernández-Pajares M, Yang H, Monte-Moreno E, García-Rigo A, Lyu H, Olivares-Pulido G, Orús-Pérez R. A New Way of Estimating the Spatial and Temporal Components of the Vertical Total Electron Content Gradient Based on UPC-IonSAT Global Ionosphere Maps. *Space Weather*. 2022 Feb;20(2):e2021SW002926.

## SVD ANALYSIS AND MODELLING

Some of the historical datasets have been analysed using an approach similar to Singular Value Decomposition (SVD). In particular, VTEC, VTEC gradients and the Ionospheric Storm Scale Index historical datasets are considered as third order tensors, or, alternatively, 3D matrices.

The analysis of spatiotemporal patterns in such data sets consists in factorising their tensors. The factorisation method used is called High Order SVD, which has been also used by other researchers and it is broadly used in image processing, e.g. see Oumane et al. (2017) and references therein.

The following table summarizes the principal periods detected by the HOSVD method in all three time series and their potential sources. As expected, solar dynamics is the main driving force, with the period of about 11 years manifesting as one of the highest peaks in the spectral analysis of the HOSVD factorisation. The relative distance between the Sun and the Earth (and the Earth axis inclination), is also important in the temporal modulation of the ionospheric system. However, other non-solar sources also seem to be part of the global modulation of the ionospheric temporal patterns. For example, periods of 14 days have been detected in the spectrum of the ionospheric time series, which brings the Lunar tide modulation as a potential source.

A second non-solar source is the biannual period detected in the ionospheric spectrum obtained with the HOSVD method. A potential source may be the Quasi-Biennial Oscillation (QBO). The QBO is related to the dynamics of the equatorial zonal wind. Thus, the detection of this oscillation could be an indication of interactions between lower and bottom atmospheric layers.

Period	GIM	Potential Source
4000 days (about 11 years)	VTEC, VTEC gradients, Iscale	Solar Cycle
Biannual - 700 days	VTEC, VTEC gradients	(potentially) Quasi-Biennial Oscillation (QBO)
Annula - 365 days	VTEC, VTEC gradients, Iscale	Earth translation around the Sun
Semiannual - 187 days	VTEC, VTEC gradients, Iscale	Earth translation – Earth Axis inclination
Seasonal - 90 days	VTEC, VTEC gradients, Iscale	Earth translation – Seasons
Semimonthly - 14 days	VTEC, VTEC gradients, Iscale	Lunar Tide modulation

We have found that the results obtained with the HOSVD method are in good agreement with the spectral analysis of the GEC timeseries. There is, however, a difference between both methods. Since the GEC is the integration of the VTEC over a closed surface (at 450 km effective height) it cannot provide information about local spatial patterns, thus it is more difficult to detect periods related to spatial structures in the ionosphere. One of such structures, for example, is the spatial modulation induced by the Lunar tides in the atmosphere. Another one, the QBO (if finally confirmed).

As expected, the GEC (Figure 2, top) is modulated by several periods. For example, among others, the interannual and subannual modulations are clearly visible in Figure 2 (left). The FFT analysis (Figure 2, right) provides further details. According to the FFT analysis, the most important source is the 11-years Solar Cycle. Other peaks are also visible, such as the annual, semiannual and the 27-days (related to the Sun rotation) periods. In conclusion, the spectrum reveals that the ionosphere is a system characterised with several time-scales. However, the non-zero slope of the spectrum also indicates that such time-scales are correlated. Therefore, such correlation among time-scales could potentially be exploited for the benefit of forecasting models.

Further details on the spectral analysis of the GEC can be found in Aroca-Farrerons et al. (2024).

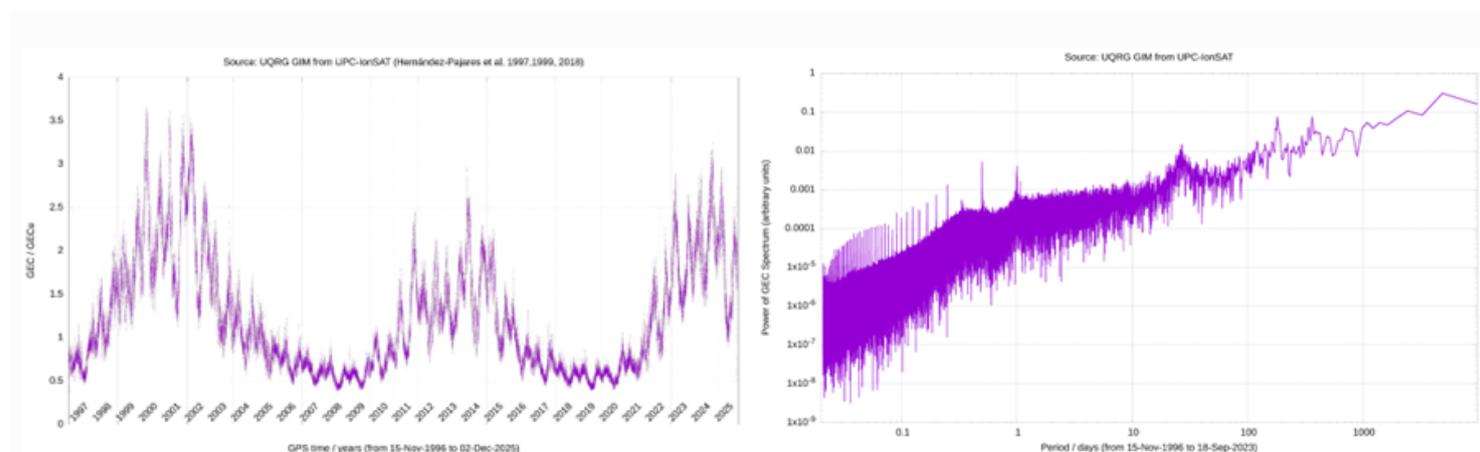


Figure 2. **Left:** GEC, expressed in GECU, vs. time, in years, from the end of 1996 to September 2023. **Right:** Logarithmic plot of the FFT spectrum of the GEC time series.

Another potential application of the ionospheric historical datasets is the analysis of the Ne and Ne-vertical-gradient datasets during natural-hazards events that may interact with the ionosphere. Indeed, Travelling Ionospheric Disturbances (TIDs) can be triggered by tsunamigenic gravity-waves. Figure 3 (from Alfonsi et al. (2023)) shows an example of the increase in the vertical Ne gradient generated by gravity waves. The increase in the top figure occurs after an earthquake near Samos island followed by a tsunami. The green square marks the moment of the earthquake, which happened about 45 minutes before the increase in the vertical Ne gradient. As opposed to such an increase, the vertical Ne gradient in the same area is displayed at the bottom of Figure 3. The scale of the vertical Ne gradient is almost 20 times shorter than the day of the event.

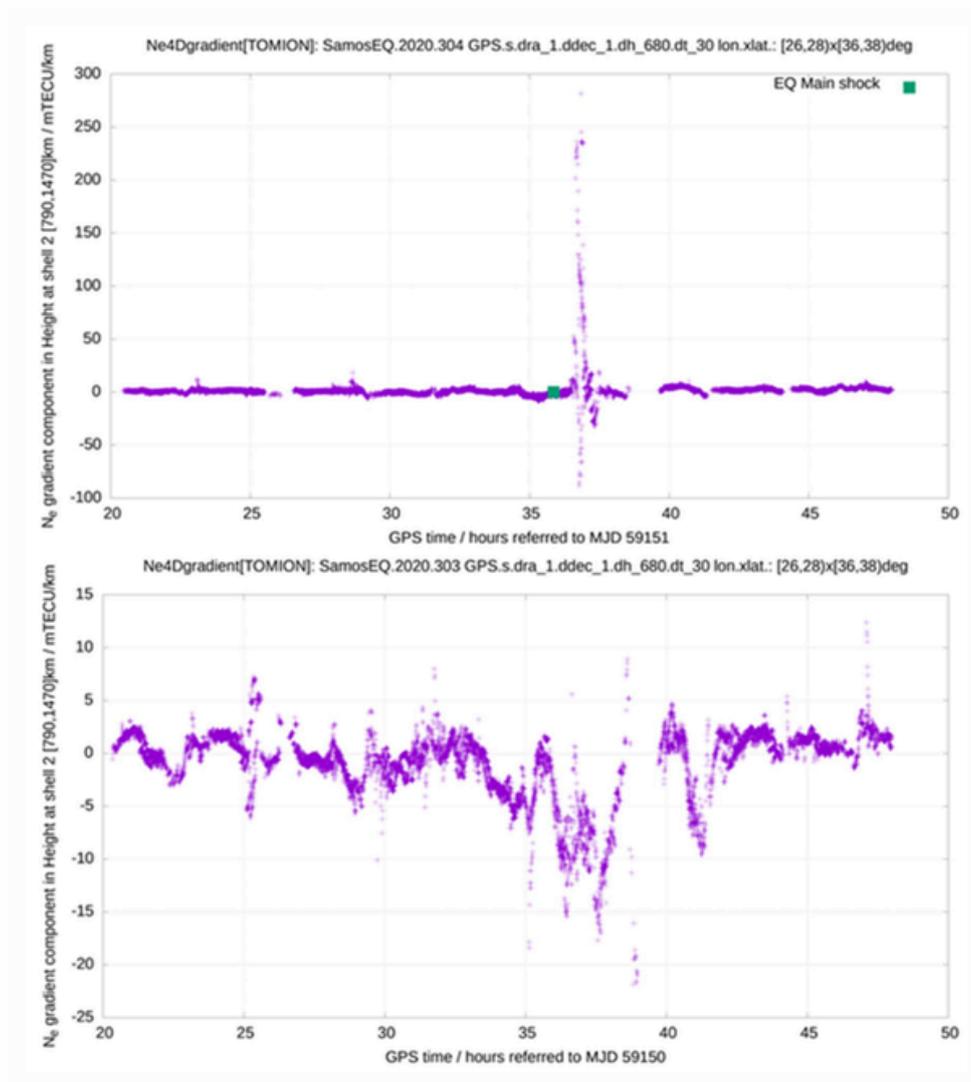


Figure 3. Example of vertical component if the Ne gradient estimated from TOMION among the two-layers, with central heights at 450 km and 1,130 km during the earthquake day (**top**) and during the previous day (**bottom**) in the bin 26-28N, 36-38E

Gravity waves generated by typhoons also seem to be potentially detectable by tomographic Ne and vertical Ne gradient timeseries. This is currently the topic of a PhD thesis in development by a PhD student in the UPC-IonSAT team. His work uses the Ne and vertical gradient Ne data sets computed in this project.

#### References:

- Alfonsi L, Cesaroni C, Hernandez-Pajares M, Astafyeva E, Bufféral S, Elias P, Belehaki A, Ioanna T, Yang H, Guerra M. Ionospheric response to the 2020 Samos earthquake and tsunami. *Earth, Planets and Space*. 2024 Jan 19;76(1):13.
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# COMMUNICATION ACTIVITIES

## Knowledge Hub

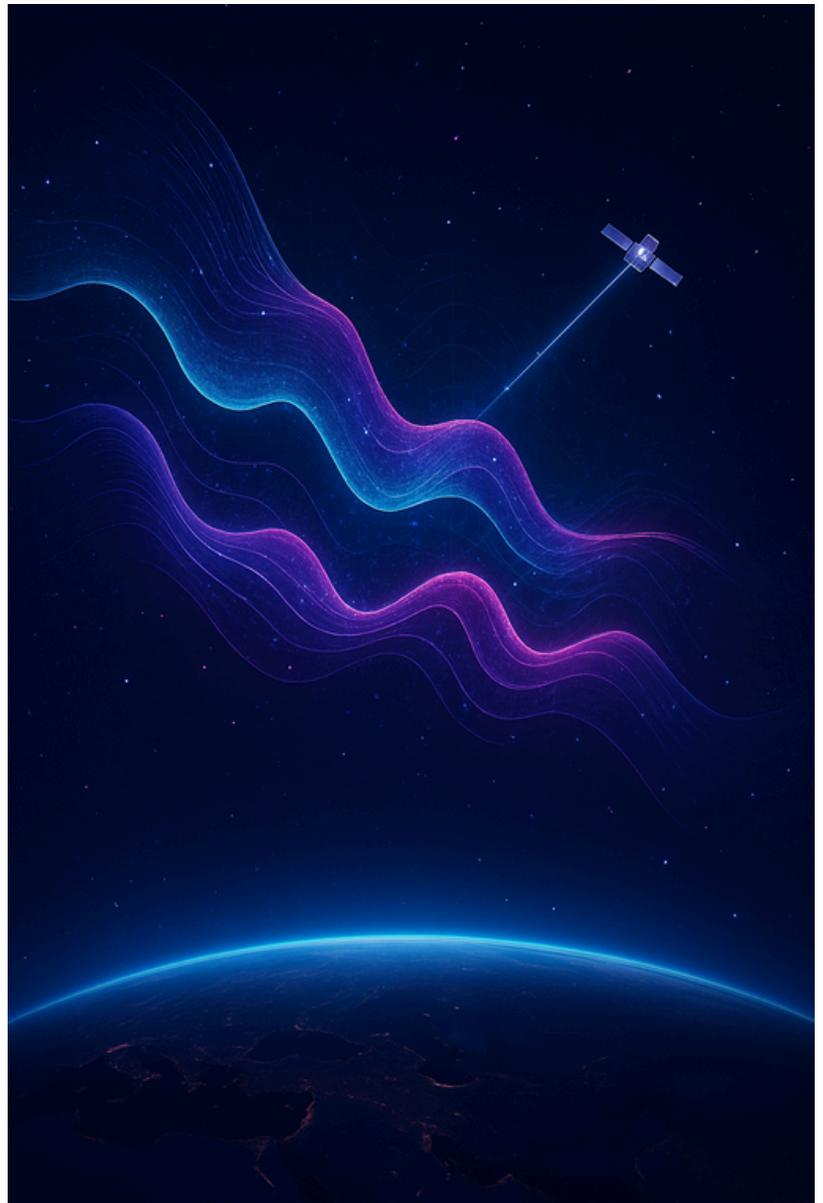
The DISPEC Knowledge Hub is being populated!

On the **Webinars** you can:

- **Learn** about the **representative Scientific Data Applications (SDAs)** that concern with the **most important types of ionospheric disturbances**.
- **Learn** about the **methodologies** that lead to the **high-level data products derivation** (including accuracy and uncertainty).

On the **Library** you can:

- **Learn** how the **DISPEC project merges science, AI, and open data for operational resilience and scientific excellence**.
- **Learn** how the **DISPEC project addresses Space Anomalies**, which affect the Earth's Ionosphere, by developing **software tools** capable of curating data from various observational platforms in Space and on the ground, and by demonstrating the **efficiency of the resulting high-level data products in enhancing the performance of ionospheric prediction models**.



# OUTREACH ACTIVITIES

## NOA 30th Summer School of Astrophysics

The National Observatory of Athens (NOA) team contributed to the 30th Summer School of Astrophysics organised by NOA's Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS) on 2-4 September 2025.

The school was attended by 72 high school students (48 on-site and 24 online) in their first two years of high school (16-17 years old). The students participated in nighttime/solar observations and attended general lectures on astrophysics, space physics, and the ionosphere.

Dr Anna Belehaki delivered a lecture titled "Understanding the Ionosphere: from Earth to Space" and supervised a group of students working on the laboratory topic on "Broadcasting radio waves into space".



## European Researchers' Night 2025

The National Observatory of Athens (NOA) contributed to the “European Researchers’ Night 2025” on 26 September 2025 by organising parallel events at its premises in Athens (Thissio and Penteli) and Korinthos (Stefanion Observatory).

Two unique talks for the general public were delivered! Professor Nikolaos Michalopoulos, Research Director at NOA, gave the keynote speech on the topic "How well do we know the air we breathe?". Maria Kaselimi, Researcher at IAASARS/NOA, gave a talk on the topic "Understanding the Earth through Artificial Intelligence".

Our team participated in the event at Thissio and 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. We attracted visitors of all ages, and we received very positive feedback from them.



# RECENT PUBLICATIONS AND PRESENTATIONS

The following paper is under revision:

- Jarmolowski, W., Belehaki, A., Wielgosz, P., Krypiak-Gregorczyk, A. “Spatio-temporal characteristics of total electron content anomalies above the Eurasian-African tectonic plate boundary”, *Journal of Space Weather and Space Climate*, 2026.

The following presentations have been delivered or submitted:

- Wojciech Jarmolowski, Anna Belehaki, Pawel Wielgosz, Anna Krypiak-Gregorczyk, Beata Milanowska, Manuel Hernandez-Pajares, German Olivares-Pulido, Ivan Galkin, Vincent Fabbro, Xavier Baumann. “Different frequency-time characteristics of total electron content anomalies over different tectonic plate boundaries”, *URSI 2026*, Krakow, Poland, 15-22 August 2026.
- German Olivares-Pulido, Manuel Hernandez-Pajares, Alberto Garcia-Rigo. “DISPEC-UPC-IonSAT contributions as new potential developments”, *ESA Space Weather Service Network Workshop 2026*, European Space Operations Centre (ESOC), Darmstadt, Germany, 3-5 February 2026.
- Anna Belehaki, Kostas Koutroumbas, Themistocles Herekakis, Angeliki Thanasou. “DISPEC high-level data-products for clean ionospheric characteristics”, *ESA Space Weather Service Network Workshop 2026*, European Space Operations Centre (ESOC), Darmstadt, Germany, 3-5 February 2026.
- Xavier Baumann, Vincent Fabbro, Ivan Galkin. “Sky wave propagation modelling in HF band”, *IEEE CAMA - Conference on Antenna Measurements and Applications*, Antibes, France, November 2025.

The following technical reports have been published:

- Anna Belehaki, George Stamatakis, Themistocles Herekakis, Angeliki Thanasou. “Validation and operational application of the hybrid NeQuick-TaD 3D ionospheric electron density reconstruction model”, *Zenodo*, August 2025.
- Kostas Koutroumbas, Anna Belehaki, George Stamatakis. “Ionospheric Data Filters: A new method for ionograms scaling”, *Zenodo*, July 2025.

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

# PAST EVENTS

## DISPEC Third Networking Meeting

The **DISPEC Third Networking Meeting** was held on Thursday, 11 December 2025, at ONERA premises in Toulouse (France). 35 participants - DISPEC members, scientists and stakeholders - attended the meeting, which was hybrid.

The goal of the DISPEC Third Networking Meeting was to demonstrate the newly developed high-level products, the specific capabilities and receive feedback on potential exploitation. The meeting addressed technical, policy, organisational and sustainability issues.

DISPEC jointly processes space- and ground-based observations to deliver high-quality data products and explore long-term ionospheric trends linked to atmospheric dynamics and geophysical phenomena. The resulting open-access methodologies and data products invite active involvement from users, innovators, and stakeholders to ensure practical impact and scientific excellence.

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



During the Third Networking meeting, the **DISPEC Demonstrator** was launched. It offers access to DISPEC raw data and high-level data products and workflows. Its content and functionalities are specified based on the Scientific Data Applications (SDAs) implemented in the course of the project and further adjusted to meet the requirements of the stakeholders.

The pre-selected SDAs correspond to data-driven models that provide critical characteristics required for reliable ionospheric specification, such as the electron density profile, the mapping of ionospheric irregularities and the radio signal propagation under irregularities, but also in-long term with the definition of proxies for the specification of abrupt high energy geophysical phenomena in long-term time series.

In the final phase of the project, the DISPEC data collections and software tools will be hosted in the PITHIA e-Science Centre for open use by the scientific community.

## ESA Space Weather Network Workshop

UPC and NOAA, members of the Ionospheric Weather Expert Service Centre (I-ESC) of the ESA Space Weather Network (ESA/SWESNET), participated in the Network workshop, which took place on 3-5 February 2026 at the European Space Operations Centre (ESOC) premises in Darmstadt (Germany).

During the “Ionospheric Weather Expert Service Centre Product Developments and Future Improvements” session, Anna Belehaki (NOA) and Alberto Garcia-Rigo (UPC) presented the results of the DISPEC developments, emphasising the opportunity to enhance product quality, operational relevance, and scientific robustness of the current I-ESC products.



# UPCOMING EVENTS

## DISPEC Training School

The Training School of the "Scientific exploitation of space Data for improved Ionospheric SPECification (DISPEC)" project will be held **on 21-25 September 2026 at the Conference Centre of CIHEAM-MAICh in Chania, Crete, Greece.**



The DISPEC Training School is an advanced, interdisciplinary programme designed to equip early-career researchers with a solid theoretical background and practical skills in the observation, modelling, and interpretation of ionospheric variability and disturbances.

The school focuses on the physics and dynamics of the ionosphere across multiple spatial and temporal scales, with particular emphasis on ionospheric irregularities and space-weather-driven processes that are often under-represented in standard models. Through a combination of lectures, discussion-oriented sessions and hackathons, participants will be introduced to both established and emerging methodologies used in contemporary ionospheric research.

The school is primarily aimed at MSc students, PhD candidates, and early postdoctoral researchers in space physics, atmospheric science, geophysics, and related fields. Participants are expected to have a basic background in space or atmospheric science, but no prior specialized expertise in ionospheric modelling is required.

By the end of the Training School, participants will be better equipped to assess and apply different observational and modelling tools in their own research and to engage with international research networks and with the Space Safety European Programme.

Details on the event will be announced soon through the project [\*\*website\*\*](#).

# **BODO W. REINISCH OBITUARY (1936 - 2025)**

Bodo W. Reinisch, Professor Emeritus at the University of Massachusetts Lowell, passed away on December 16, 2025, at the age of 89.

Dr. Reinisch was an influential figure in both ionospheric physics and radio science and made a number of seminal contributions. Perhaps best known is the development of a network of radio sounder systems which constantly monitor global ionospheric conditions. Over 200 units have been built in Lowell, Massachusetts for installation in 32 countries, and these have become an integral part of ionospheric scientific research. Dr. Reinisch was also the principal force behind the development of the International Reference Ionosphere (IRI) climatology model and, its real-time extension, the IRI-based Real-Time Assimilative Model (IRTAM). The latter provides real-time global nowcasts of ionospheric weather for science, national security, and business operations. Subsequently, Dr. Reinisch drew on his knowledge of ground-based radio sounding technologies to lead the team which successfully designed and launched the Radio Plasma Imager on NASA's IMAGE satellite. He also led the development of the high-power, high-voltage VLF transmitter for the U.S. Air Force DSX mission which was eventually successfully launched 2019.

In recognition of his outstanding scientific contributions, Dr. Reinisch received numerous honors, including the International Union of Radio Science (URSI) Appleton Prize (2011), with the citation "For revolutionizing radio sounding from ground and space"; the Officer's Cross of Merit First Class of the Federal Republic of Germany (2012); and the Kristian Birkeland Medal for Space Weather and Space Climate (2014).

Dr. Reinisch's life was strongly influenced by his childhood experiences in Germany during WW2 and he worked tirelessly to develop international communities which could both address important scientific questions and also learn that all peoples benefit by working together – not against each other. In so doing he touched the lives of many of us, inspiring as he did generations of researchers whose careers would not have been so successful without him.

Dr. Reinisch profoundly shaped the field of radio remote sensing of space plasmas and model development, and his passing is a major loss to the entire ionospheric science and radio science community. We have lost a giant in our field – but more particularly we have lost an inspirational friend.

- Anna Belehaki, Dieter Bilitza, Paul Cannon, Phil Erickson, Ivan Galkin, James Green, and Paul Song

# DISPEC PARTNERS



## ABOUT

### Title

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

### Topic

HORIZON-CL4-2023-SPACE-01-71

### Coordinator

Dr Anna Belehaki  
IAASARS, National Observatory of Athens

### Dissemination, Exploitation & Communication Leader

Dr Anna Belehaki  
IAASARS, National Observatory of Athens

### Duration

1 January 2024 - 31 December 2026

### Grant

1,492,875.00 Euros

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