ISSUE 5 | SEPTEMBER 2024

T-FORS NEWSLETTER

TRAVELLING IONOSPHERIC DISTURBANCES FORECASTING SYSTEM

IN THIS ISSUE

Contributors to this issue
V. Ventriglia (INGV), K. Themelis (NOA), A. Thanasou (NOA), V. Barta (FI)

Editor
V. Barta (FI)

Editor Assistant
A. Thanasou (NOA)

Final responsible
V. Barta (FI)

T-FORS AT A GLANCE

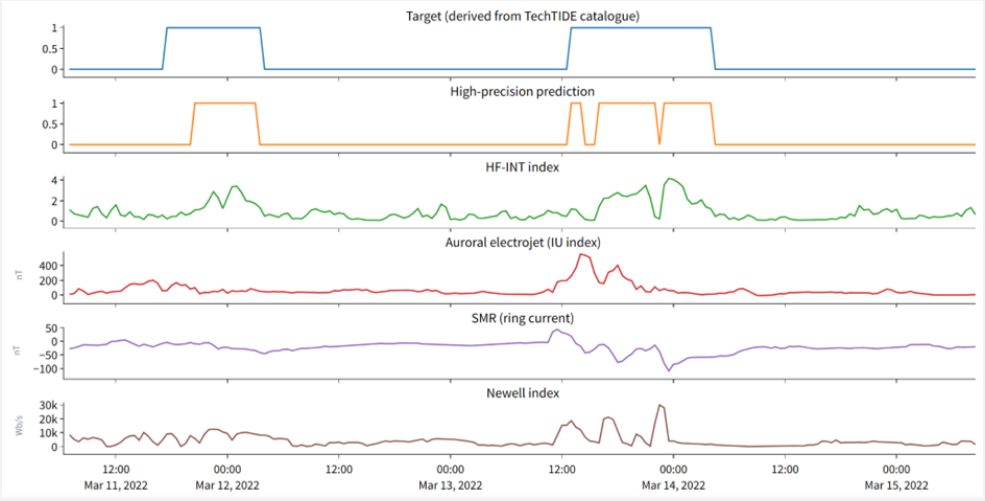
Travelling Ionospheric Disturbances (TIDs) constitute a specific type of space weather disturbance affecting the performance of critical space and ground infrastructure by disrupting operations and communications in multiple sectors. T-FORS aims at providing new models able to interpret a broad range of observations of the solar corona, the interplanetary medium, the magnetosphere, the ionosphere and the atmosphere, and to issue forecasts and warnings for TIDs several hours ahead. Machine Learning techniques are used to train the models based on existing databases developed in the frames of past Horizon 2020 projects, to estimate the occurrence probability of medium scale TIDs and to forecast the occurrence and propagation of large scale TIDs. Prototype services are developed based on specifications from the users' community and following harmonized standards and quality control similar to the best practices of meteorological services. On ground demonstration tests are organised, by aerospace and civil protection agencies, to validate the performance of the T-FORS prototype services. A comprehensive architectural concept is proposed, including the densification of ground instrument networks, and new space missions, and possible future adjustments in order to develop a real-time operational service fully compliant and complementary to the ESA Space Weather services.

LSTID VALIDATION RADVANCEMENTS IN LSTID FORECASTING & VALIDATION

We are excited to share the latest developments on the forecasting of Large-Scale Travelling Ionospheric Disturbances (LSTIDs). Our primary objective remains unchanged: predicting the occurrence and propagation characteristics of LSTIDs across various atmospheric regions by leveraging cutting-edge Machine Learning (ML) techniques. In August, we released the final version of the models that, following a thorough validation process, proved capable of predicting the occurrence of LSTIDs with a time horizon of 1 to 3 hours. The LSTID forecasting models are accessible via the T-FORS repository.

Here is a peek at our developments and methodologies.

For the Catalogue-based Forecasting Model, we leveraged a refined version of the TechTIDE catalogue, which is based on the European ionosonde network and covers a 9-years period (2014-22). We designed a multivariate time-series binary classifier to forecast the occurrence of LSTIDs within 3 hours. The model stems from an efficient, fast and scalable gradient-boosting framework on decision trees (CatBoost). Notably, an explanatory framework (SHAP) aids us in deciphering feature influences, enhancing model interpretability and explainability. To explore the final version of the code, you can visit our GitHub repository. You can also play around with the web application we developed to display, debug and validate the model results (see figure below).

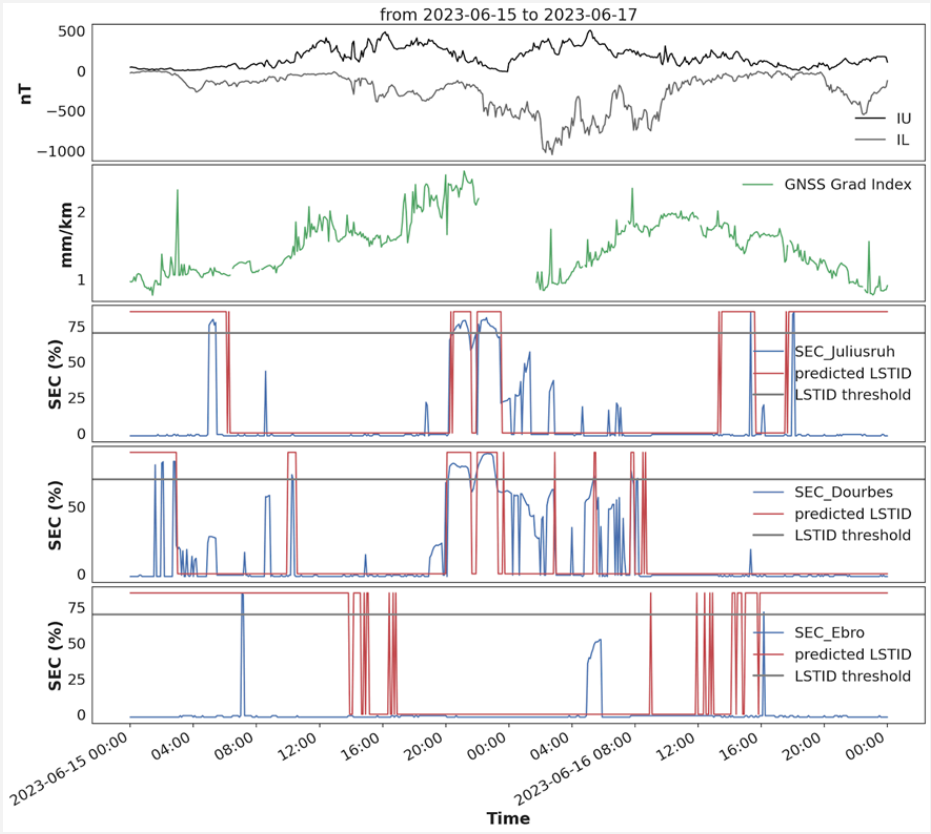


Web app of Catalogue-based Forecasting Model, showing some features and target variable vs. model outputs

In addition to model development, we conducted a thorough validation which was provided to the community.

Validation of a ML model is a governance procedure to ensure it produces adequate results, in accordance with both quantitative and qualitative goals. This step includes testing of the model's soundness and fit for the scientific purpose, including identification of potential risks and limitations. The validation framework we used began with a global evaluation and interpretation phase, which also allowed us to identify those drivers that the model deems to be the best precursors of an LSTID. Then we evaluated some appropriate metrics meant to assess the model's ability to predict LSTID events based on the available physical drivers, having learned an association with the labels derived from the catalogue. This statistical evaluation was performed on fresh, unseen data and, depending on the operating mode, we reported a performance improvement of +72% to +93% compared to a rule-based benchmark. Finally, to compensate for the lack of an always robust ground truth, the model's performance has also been scrutinised by considering 15 case events for which we meticulously compared the model outputs with independent LSTID detection methods.

Our efforts also led to the development of a second LSTID forecasting model, which utilizes the Spectral Energy Contribution (SEC) values and targets Digisonde locations. The proposed model is based upon a Temporal Fusion Transformer (TFT), a type of neural network that excels at processing sequential data. Based on time series data like the Auroral electrojet indicators or the Gradient GNSS TEC Activity Index, the model can provide precise SEC forecasts for each Digisonde station. The system also furnishes us with explanatory tools that enable a comparative analysis of our input time series data and the model's prognostications. Our neural network has been trained with data collected over a three-year period, from 2022 to 2024. The model is available through the Zenodo platform. It can successfully detect LSTIDs as demonstrated also below, in the accompanying figure.



Model forecast for two-day events in Juliusruh, Dourbes, and Ebro. Model predictions are indicated by the solid red line.

OUTREACH ACTIVITIES

PyData Rome

On 23 September, the catalogue-based LSTID forecasting model was presented at PyData in Rome. PyData is an educational program of NumFOCUS, a non-profit charity which helps organise Python conferences focused on Data Science methods and Machine Learning models. The talk, given in Italian by Vincenzo Ventriglia (INGV), was entitled “GPS doesn't work! Can a model warn us before it happens?”.

An introduction to the T-FORS project was given, together with an overview on the need for this type of research, applying Explainable Artificial Intelligence (XAI) methods to ensure interpretability and reliability of the model. The presentation attracted a lot of attention from the local community, which showed a vivid interest in the topic of Machine Learning applied to Space Weather.

Vincenzo Ventriglia presenting for INGV

PyData Rome, 23 September 2024

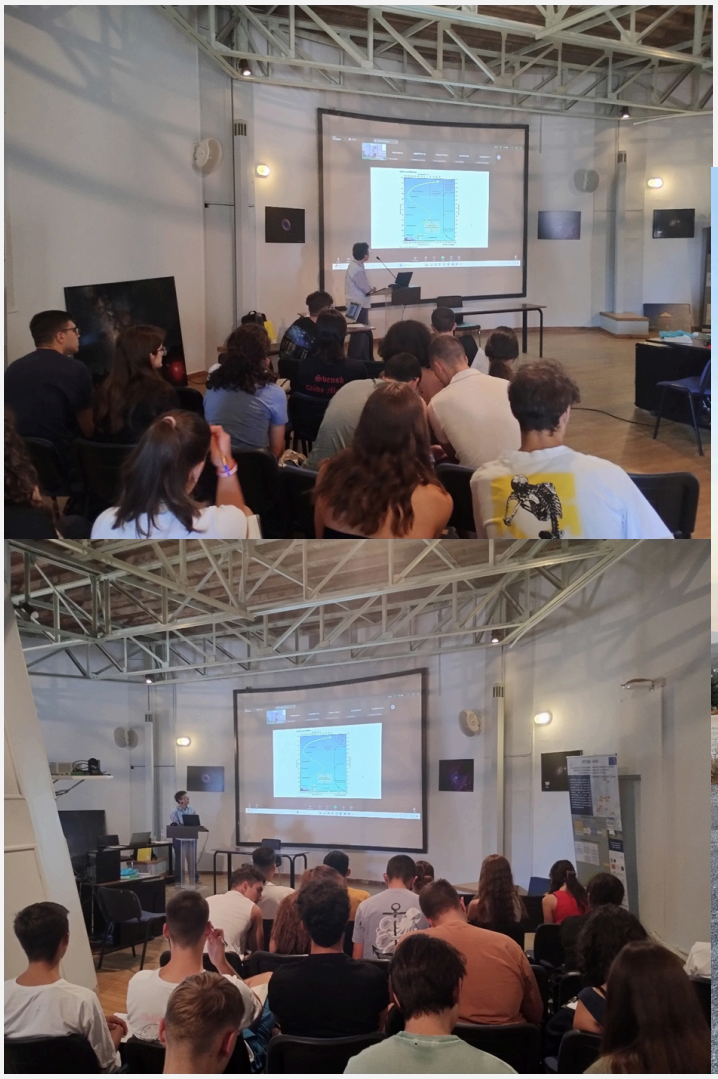
NOA 29th Summer School of Astrophysics

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.



NOA 29th Summer School of Astrophysics, 2-4 September 2024

European Researchers' Night 2024 at NOA

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.

European Researchers' Night 2024 at NOA, 27 September 2024

European Researchers' Night 2024 at the HUN-REN EPSS

HUN-REN Institute of Earth Physics and Space Science (Sopron, Hungary) held an open day in the European Researchers' Night on 27 September 2024. The researchers gave talk about geodynamic activity of Europe with a special focus of the Carpathien Region, and about the methods to detect the movements by ground-based and satellite data.

Furthermore, they had presentations about the red sprites and the Aurora Borealis, as the spectacular manifestation of the Sun-Earth connection. The visitors could also look through an exhibition about Lorand Eötvös, the famous Hungarian geophysicist, and some outreach movies, e.g. about the T-FORS project.

European Researchers' Night 2024 at the HUN-REN EPSS, 27 September 2024

UPCOMING EVENTS

T-FORS Second Innovation Day

The T-FORS Second Innovation Day is scheduled for **December 4, 2024, in Athens, Greece**. This event marks a significant milestone in the T-FORS project, providing a forum to showcase its achievements and engage with stakeholders.

The event aims to present the major achievements resulting from the T-FORS project and to discuss with stakeholders their needs and priorities in Travelling Ionospheric Disturbances (TID) forecasting services. Attendees can look forward to a comprehensive program that includes presentations, discussions, and demonstrations focusing on the latest developments in TID forecasting services. Details are available on the project website.

Scan to Register

Final Project Meetings

The T-FORS project is coming to a close in December 2024. The Final General Assembly meeting will be held on December 3, and the Second Innovation Day on December 4 in Athens, Greece. Watch the project website for further information regarding these events.

T-FORS PARTNERS

ABOUT

Title
Travelling Ionospheric Disturbances Forecasting System (T-FORS)

Topic
HORIZON-CL4-2022-SPACE-01-62

Coordinator
Dr Anna Belehaki
IAASARS, National Observatory of Athens

Dissemination, Communication & Exploitation Leader
Dr David Altadill
Observatorio del Ebro Fundación

Duration
1 January 2023 - 31 December 2024

Grant
999,750.00 Euros

VISIT OUR WEBSITE

https://t-fors.eu/

FOLLOW US

CONTACT US

info@t-fors.eu

Funded by the European Union

The T-FORS project is funded by the European Union (GA-101081835). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Health and Digital Executive Agency (HaDEA). Neither the European Union nor the granting authority can be held responsible for them.