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T-FORS NEWSLETTER

TRAVELLING IONOSPHERIC DISTURBANCES FORECASTING SYSTEM

IN THIS ISSUE

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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 RESULTS, FORECASTING ACCURACY AND EARLY INDICATORS

The performance of the Large-Scale Travelling Ionospheric Disturbances (LSTID) forecasting and warning Machine Learning (ML) models developed under T-FORS WP2 has been evaluated. In addition, an inventory of LSTIDs indicators has been provided. Indicators of solar activity, magnetosphere-solar wind coupling, geomagnetic field and ionosphere have been analysed to build an inventory of possible early precursors of LSTID activity. The models attempt to cope with the complexity of the physical processes leading to the generation and propagation of LSTIDs through the solar wind, the magnetosphere and the auroral oval and the high-latitude ionosphere.

The preliminary versions of the models followed two different approaches, the LSTID Catalogue Based Forecasting Model (CB-FM) and the LSTID Spectral Energy Contribution (SEC) Based Forecasting Model (SECB-FM), and as a result, the output of the models is related to the forecasting of LSTIDs occurrences with different time horizons (up to 3 hours in advance). The models are able to improve forecast accuracy at the expense of decreasing the forecast time horizon from several hours in advance to a few minutes.

The validation of the ML models considers the confusion matrix as a metric for the detection of LSTIDs (True positives, True negatives, False positives, and False negatives). Moreover, three additional metrics (statistical error) for evaluation purposes in classification methods have been used: Accuracy which is defined as the percentage of correct predictions for the test dada, precision which is defined as the fraction of relevant examples (True positives) among all of the examples which were predicted to belong in a certain class, and Self-consistency validation in real-time which provides a retro-validation of the instantaneous performance (error) of the model, that differs from the statistical performance evaluation (statistical error).

The performance of the LSTID forecasting models, CB-FB and SECB-FM, has been analysed and cross-compared for events over a wide time interval spanning the years 2021 to 2023 (not used to build and train the models). The results of the performances of CB-FM and SECB-FM forecasting the LSTID activity compare reasonably well, and the forecasting of LSTID activity results in a good agreement with observed activity.

Finally, the goodness of the early indicators in light of the feature importance for both forecasting models of LSTID, CB-FM and SECB-FM, has been evaluated. The CB-FM has the High Frequency-Interferometry (HF-INT) index and its 2-hour moving average (details for the used catalogue is below), the Solar zenith angle, the IU-IE indices and its moving averages (12h and 3h), the solar activity index F10.7, and the HP-30 geomagnetic activity as the most impactful variables on the model's decisions. The CB-FM has the values at certain times before the prediction of the IE, IL, and IU activity indices as the most useful for forecasting the Spectral Energy Contribution SEC (LSTID activity) over Digisonde sensors.

The Catalogue of LSTIDs

This dataset is a Catalogue of Large-Scale Travelling Ionospheric Disturbances (LSTID) events detected using the HF-Interferometry (HF-INT) method and revised by visual inspection by an expert. HF-INT identifies LSTIDs from the monostatic measurements of a given network of HF sensors (Ionosondes). The method looks for coherent oscillation activity at different measuring sites within the network and sets bounds for the time intervals for which such activity occurs in a given region. HF-INT detects Travelling Ionospheric Disturbances (TID) activity and provides TID Period, Amplitude, Velocity and Direction of propagation, and contribution of the TID to the total variability for a given time series. HF-INT can only identify LSTIDs due to the geographical distribution of Digisonde sites within Europe, whose activity is mainly associated with auroral and geomagnetic activity, which are directly related to Space Weather.

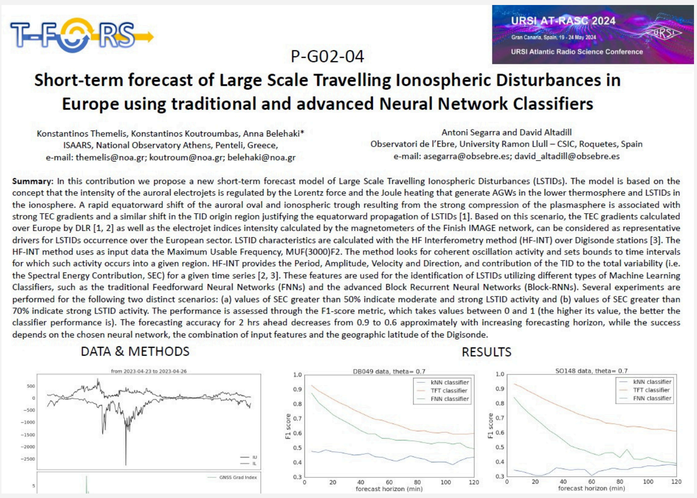
The HF-INT method uses the Maximum Usable Frequency (MUF) for a distance of 3000 km obtained from 10 European Digisondes (Athens, Dourbes, Sopron, Fairford, Chilton, Pruhonice, Juliusruh, Rome, San Vito and Roquetes). It uses near real-time data from the Global Ionospheric Radio Observatory (GIRO) Digital Ionogram Data Base (DIDBase) Fast Chars (http://giro.uml.edu/didbase/scaled.php). Once an event is detected, an average of the main characteristics is calculated out for all stations and for the entire duration of the event. The files contain the following information distributed in columns: - Year - Month - Day - Starting time - Duration (hours) - Period of the LSTID (minutes) - Amplitude (MHz) - Spectral Energy Contribution (%) - Velocity (m/s) - Azimuth (Degrees), measured clockwise from the true North - Quality Indicator based on the data availability of the network (0 to 1). The files cover the period from 2014 to the present.

Reference: Segarra, A.; Altadill, D.; de Paula, V.; Navas-Portella, V., 2024, "Catalogue LSTID", https://doi.org/10.34810/data1383, CORA. Repositori de Dades de Recerca, V1.

URSI AT-RASC 2024 MEETING

T-FORS members actively contributed to organizing a conference session at the Union Radio Scientifique Internationale (URSI) meeting, URSI AT-RASC 2024 (https://www.atrasc.com/home.php). The conference took place in Maspalomas, Gran Canaria, Spain, from May 19 to 24.

The G02 session of URSI AT-RASC 2024, chaired by Dr. Geoff Crowley and co-convened by Dr. Anna Belehaki, Dr. David Altadill Felip, and Dr. Sivakandan Mani, focused on nowcasting and forecasting Travelling Ionospheric Disturbances (TIDs) for ionospheric weather and mitigation services. The session featured 11 contributions on TIDs identification and tracking experiments and methodologies, models for nowcasting and forecasting TIDs and corresponding ionospheric weather services, descriptions of operational issues caused by TIDs, and possible mitigation technologies to prevent the degradation of affected applications.



URSI AT-RASC 2024
Gran Canaria, Spain, 19 - 24 May 2024
URSI Atlantic Radio Science Conference

P-G02-04

Short-term forecast of Large Scale Travelling Ionospheric Disturbances in Europe using traditional and advanced Neural Network Classifiers

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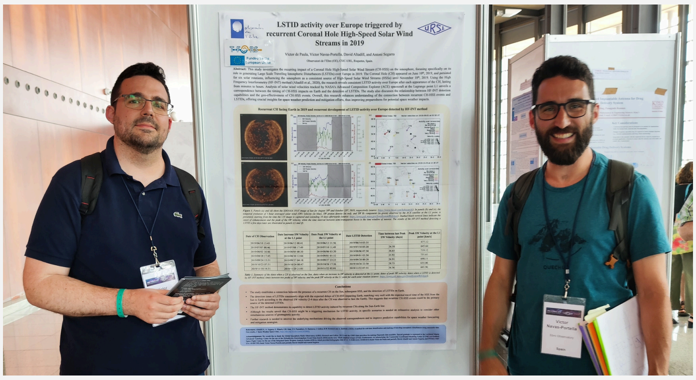
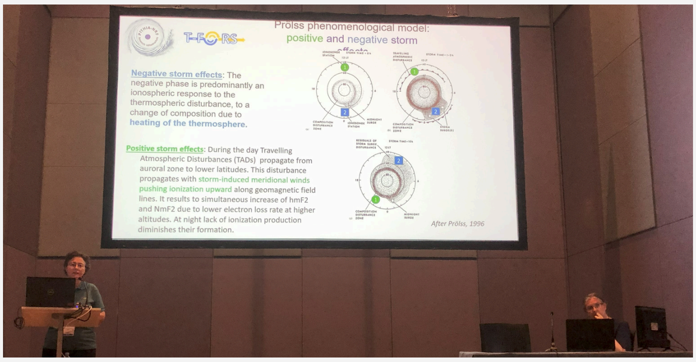
Summary: In this contribution we propose a new short-term forecast model of Large Scale Travelling Ionospheric Disturbances (LSTIDs). The model is based on the concept that the intensity of the auroral electrojets is regulated by the Lorentz force and the Joule heating that generate AGWs in the lower thermosphere and LSTIDs in the ionosphere. A rapid equatorward shift of the auroral oval and ionospheric trough resulting from the strong compression of the plasmasphere is associated with strong TEC gradients and a similar shift in the TID origin region justifying the equatorward propagation of LSTIDs [1]. Based on this scenario, the TEC gradients calculated over Europe by DLR [1, 2] as well as the electrojet indices intensity calculated by the magnetometers of the Finish IMAGE network, can be considered as representative drivers for LSTIDs occurrence over the European sector. LSTID characteristics are calculated with the HF Interferometry method (HF-INT) over Digisonde stations [3]. The HF-INT method uses as input data the Maximum Usable Frequency, MUF(3000)F2. The method looks for coherent oscillation activity and sets bounds to time intervals for which such activity occurs into a given region. HF-INT provides the Period, Amplitude, Velocity and Direction, and contribution of the TID to the total variability (i.e. the Spectral Energy Contribution, SEC) for a given time series [2, 3]. These features are used for the identification of LSTIDs utilizing different types of Machine Learning Classifiers, such as the traditional Feedforward Neural Networks (FNNs) and the advanced Block Recurrent Neural Networks (Block-RNNs). Several experiments are performed for the following two distinct scenarios: (a) values of SEC greater than 50% indicate moderate and strong LSTID activity and (b) values of SEC greater than 70% indicate strong LSTID activity. The performance is assessed through the F1-score metric, which takes values between 0 and 1 (the higher its value, the better the classifier performance is). The forecasting accuracy for 2 hrs ahead decreases from 0.9 to 0.6 approximately with increasing forecasting horizon, while the success depends on the chosen neural network, the combination of input features and the geographic latitude of the Digisonde.

DATA & METHODS

RESULTS

Besides the G02 session, T-FORS project members also participated in the URSI AT-RASC 2024 poster session G with 7 contributions. Additionally, a full-day tutorial on ionograms interpretation and scaling was conducted during the conference. The project was further promoted to conference attendees through the distribution of leaflets, which included general information about the project as well as details about the upcoming T-FORS Innovation Day.





The following contributions presented at the URSI-AT-RASC 2024 were related to the T-FORS activities.

Oral presentations:

- Exploiting Digisonde observations for nowcasting and forecasting ionospheric weather, Belehaki Anna, National Observatory of Athens, Greece
- Multi-Instrument detection of the ionospheric response to the 6 February 2023 Turkey Earthquake, Guerra Marco, La Sapienza, Università di Roma, Italy
- Climatology of the Travelling Ionospheric Disturbances over Europe, Mani Sivakandan, Leibniz Institute of Atmospheric Physics at the University of Rostock, Germany (Presenting Author)
- Assessing Ionogram Processing Techniques: A Comparative Analysis of Autoscaling and Manual Evaluation During Disturbed Conditions, Kouba Daniel, Institute of Atmospheric Physics, Czech Academy of Sciences, Czech Republic
- Estimating the drift velocity of Equatorial Plasma Bubbles with GNSS and digisonde data, Víctor Navas-Portella, Ebro Observatory, Spain

Posters:

- P-G02-01 - Travelling Ionospheric Disturbances detection: a statistical study on detrending techniques, induced period error and near real-time observables. Guerra Marco, La Sapienza, Università di Roma, Italy.
- P-G02-02 - Multi-instrument analysis of MSTIDs generated by extreme tropospheric events in Europe. Barta Veronika, Institute of Earth Physics and Space Science, Hungary.
- P-G02-03 - A feasibility study of TID events forecasting with a machine learning model. Vincenzo Ventriglia, Istituto Nazionale di Geofisica e Vulcanologia (INGV), Italy.
- P-G02-04 - Short-term forecast of Large Scale Travelling Ionospheric Disturbances in Europe using traditional and advanced Neural Network Classifiers. Belehaki Anna, National Observatory of Athens, Greece.
- P-G02-05 - LSTID activity over Europe triggered by recurrent Coronal Hole High-Speed Solar Wind Streams in 2019. De Paula Víctor, Ebro Observatory, Spain.
- P-G05-03 - Quantifying the socioeconomic impacts of Space Weather in Europe: How costly is the effect of Medium Scale Travelling Ionospheric Disturbances on GNSS positioning? Mainella Sara, Istituto Nazionale di Geofisica e Vulcanologia (INGV), Italy.
- P-G07-02 - Digisonde and Ionogram Techniques in Comparative Vertical Ionospheric Drift Analysis. Kouba Daniel, Institute of Atmospheric Physics, Czech Academy of Sciences, Czech Republic.

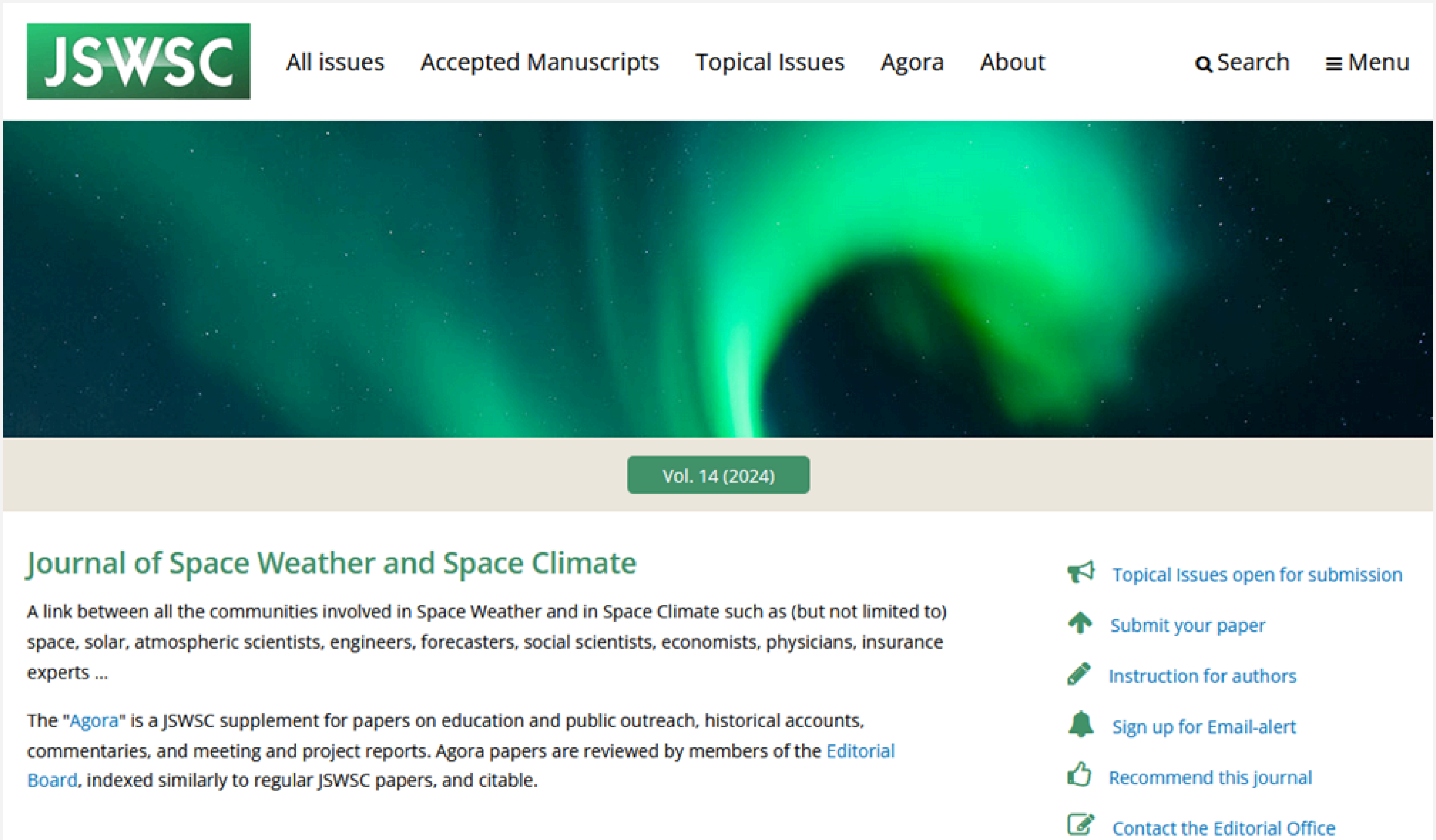
TOPICAL ISSUE OF JSWSC

T-FORS project proposed to edit a Topical Issue (TI) "Observing, modelling and forecasting TIDs and mitigating their impact on technology", which have been accepted by the *The Journal of Space Weather and Space Climate* (https://www.swsc-journal.org/topical-issues-open-for-submission).

The TI has Dr. Anna Belehaki as Editor-in-Chief, and Dr. Dalia Buresova, and Dr. Claudio Cesaroni assisting as Topical Editors.

The TI is open for submissions of manuscripts which address TID identification and tracking, TID nowcasting and forecasting, as well as feeding the obtained results into ionospheric weather services. Manuscripts on methods and technologies capable of mitigating adverse effects of TIDs on the performance of critical space and ground-based infrastructure are also welcome.

Dead-line for submissions is 30th September of 2024.



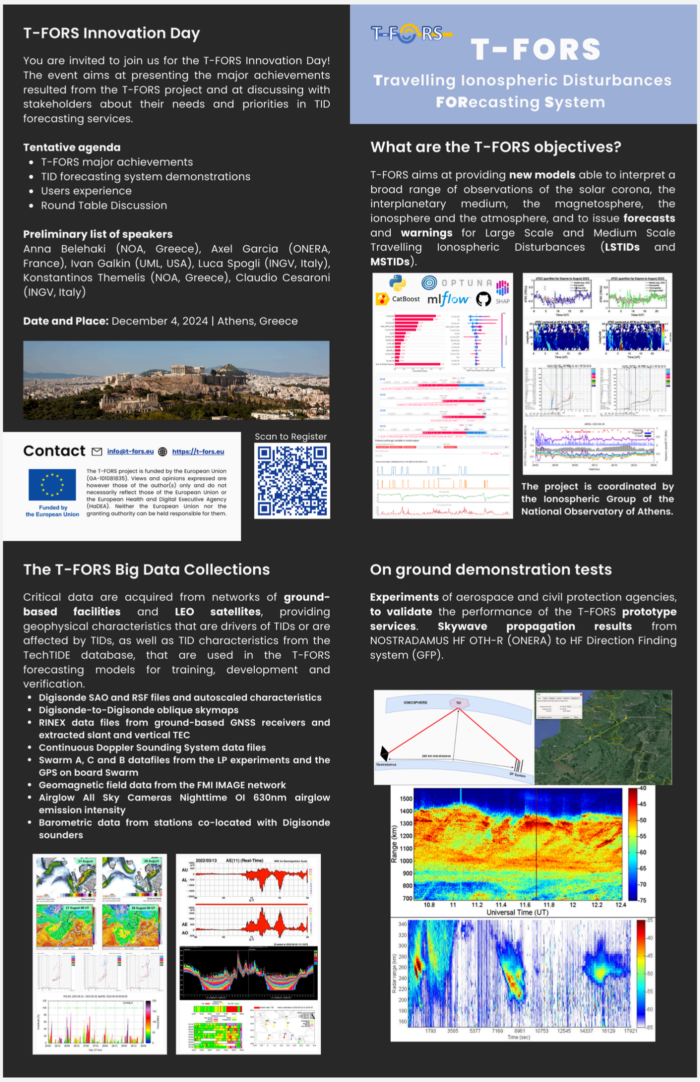
T-FORS SECOND INNOVATION DAY

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.

The Innovation Day represents an opportunity for collaboration and knowledge exchange among researchers, industry professionals, and end-users. It aims to foster dialogue and collaboration to address the evolving needs and challenges in TID forecasting and space weather mitigation.

A leaflet promoting the T-FORS Second Innovation Day has been prepared and distributed to the community through different means (e-mail distribution lists, linked-in, hands-on in science meetings, etc.).



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ABOUT

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

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Observatorio del Ebro Fundación

Duration
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