C. Cesaroni on behalf of the WP 2 team

Innovation Day

4 December 2024

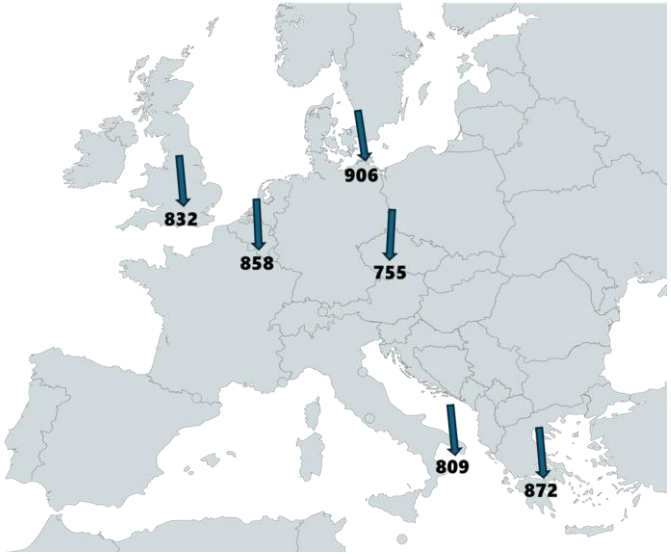
What do we have at hand?

Real-time monitoring and prediction of TIDs are very complex and a model that could form the basis for an alert system is of considerable scientific and technological interest for mitigating TID effects

Catalogue-based model

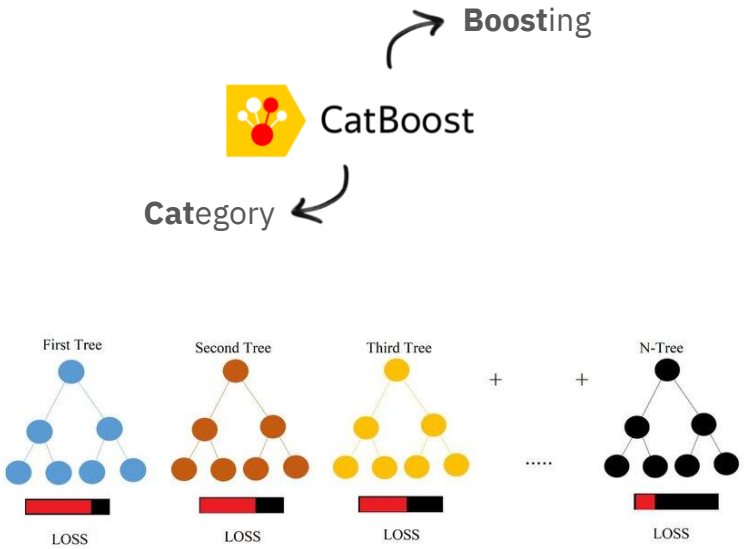
Forecasting horizon: 3hrs

European-wide forecasting



Estimated velocities (m/s) during an intense geomagnetic storm
(derived from **TechTIDE catalogue**)

Machine learning methodology – CatBoost & Optuna



Gradient boosting algorithm on decision trees

Categorical variables and **missing values** (NaN) are natively and efficiently supported

The **symmetric-trees** architecture:

- ensures efficient implementation on CPU/GPU
- reduces inference times
- naturally prevents overfitting (regularisation)

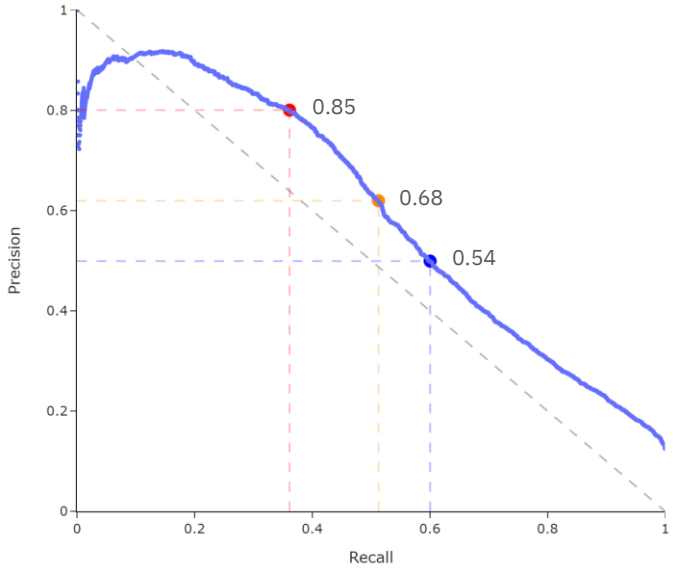
Integrates **SHAP** as a method of eXplainable Artificial Intelligence (**XAI**)

Easy to integrate with Optuna, a framework for **automatic hyperparameter optimisation**, which uses a Bayesian sampling method aborting unpromising trials

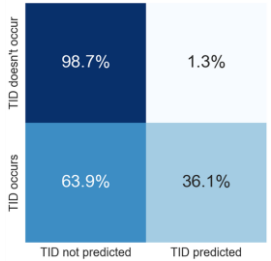
OPTUNA

Machine learning methodology – operating modes

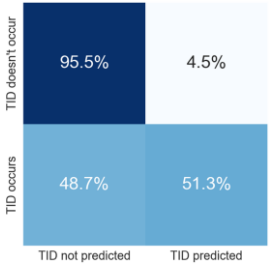
The **trade-off between precision and recall** is generally a **function of the user**, since the cost of a false positive is generally (very) different from that of a false negative



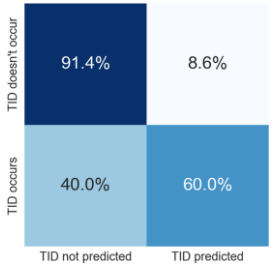
High precision
(high cost for FP)



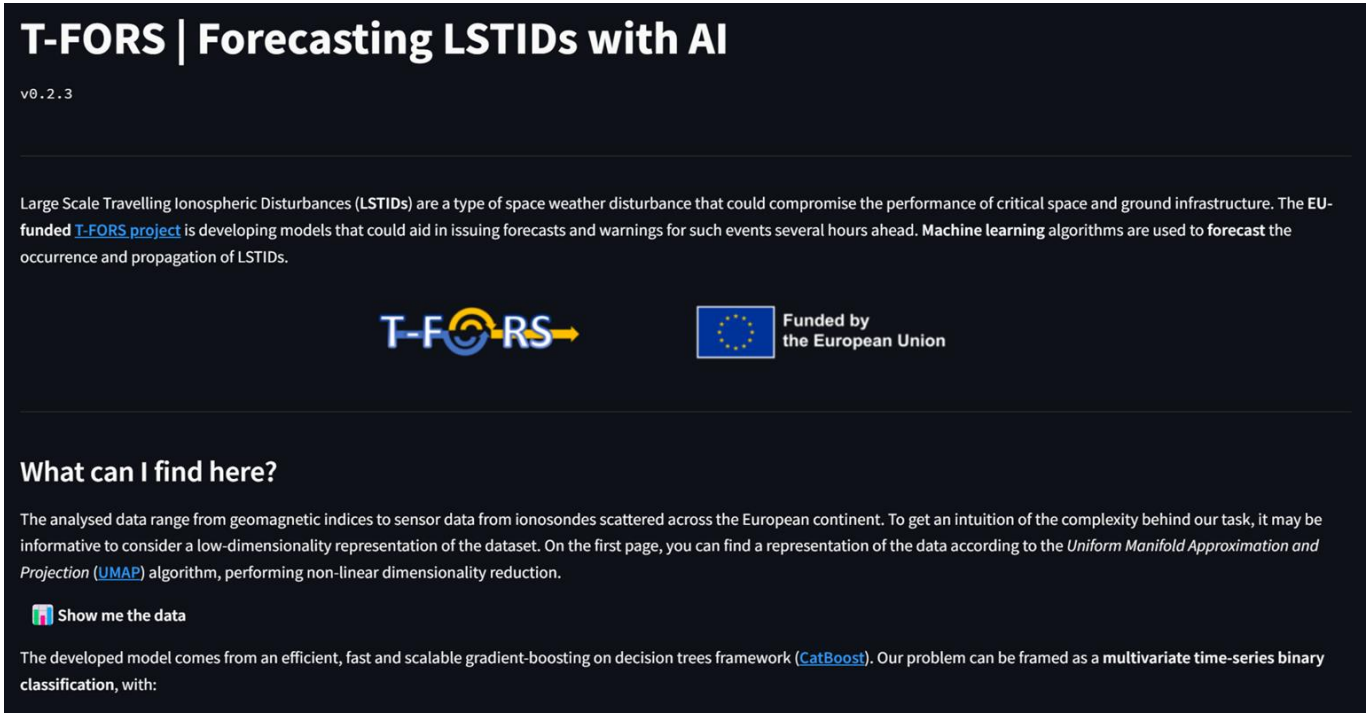
Balanced



High sensitivity
(high cost for FN)



Web application



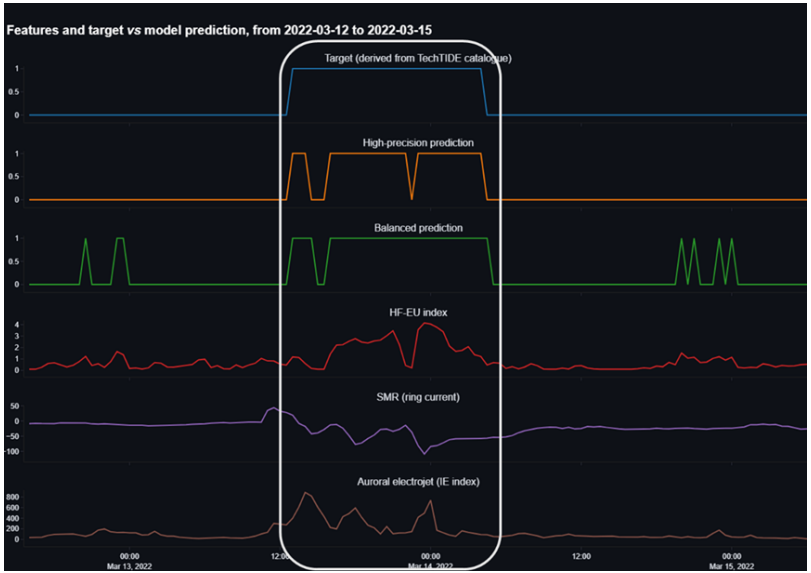
https://t-fors-ai.streamlit.app/

Selected events from validation phase

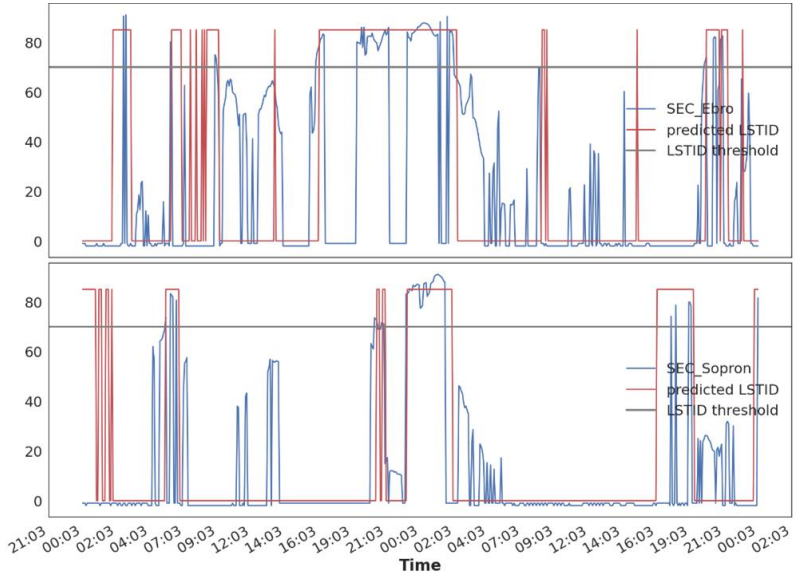
Event	**Catalogue**	**Start** (approx.)	**End** (approx.)	**Drivers**	**Forecast** (CB | SB)
1	Yes	2022/03/13 16:05 2022/03/13 23:00	2022/03/13 21:40 2022/03/14 04:30	Yes Yes	Yes | Yes Yes | Yes
2	Yes	2022/07/01 23:10	2022/07/02 02:30	Yes	Yes | Yes
3	No	2022/02/03 16:30	2022/02/04 00:00	Yes	Yes | Yes
4	Yes	2022/07/27 03:00	2022/07/27 04:35	No	No | Yes

Event 1 – catalogue- and SEC-based models

Event	**Catalogue**	**Start** (approx.)	**End** (approx.)	**Drivers**	**Forecast** (CB | SB)
1	Yes	2022/03/13 16:05 2022/03/13 23:00	2022/03/13 21:40 2022/03/14 04:30	Yes Yes	Yes | Yes Yes | Yes



Catalogue-based



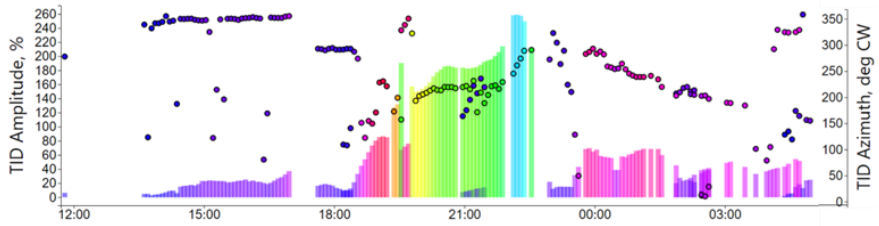
Ebro

Sopron

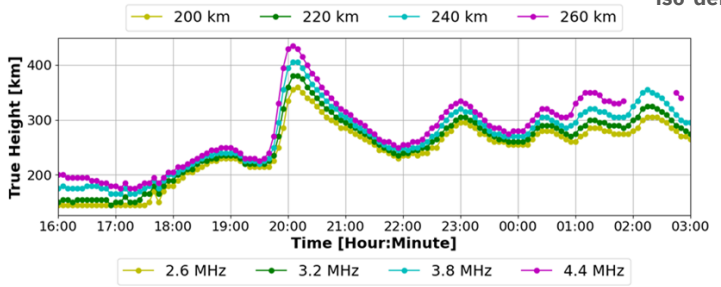
SEC-based

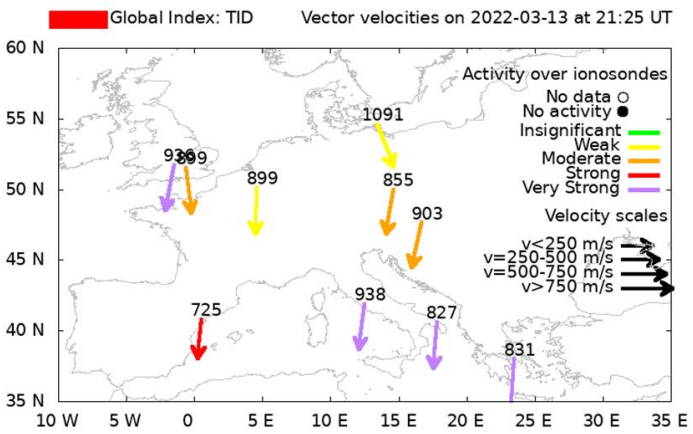
Event 1 – HF-INT, HF-TID, iso-density and detrended TEC

HF-TID Pruhonice-Juliusruh

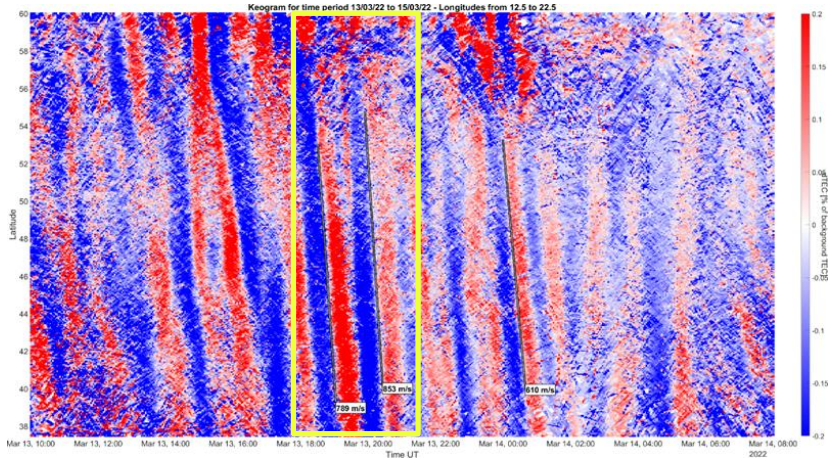


iso-density





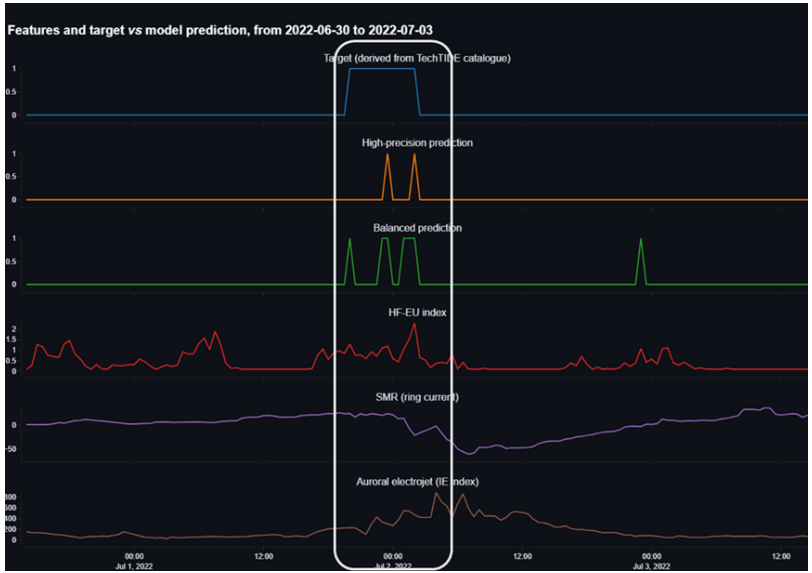
HF-INT



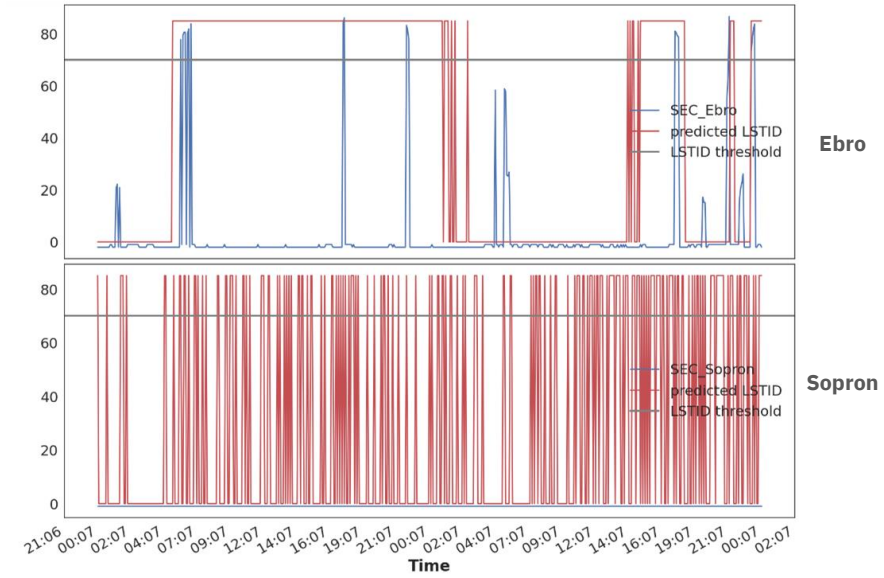
dTEC

Event 2 – catalogue- and SEC-based models

Event	**Catalogue**	**Start** (approx.)	**End** (approx.)	**Drivers**	**Forecast** (CB | SB)
2	Yes	2022/07/01 23:10	2022/07/02 02:30	Yes	Yes | Yes

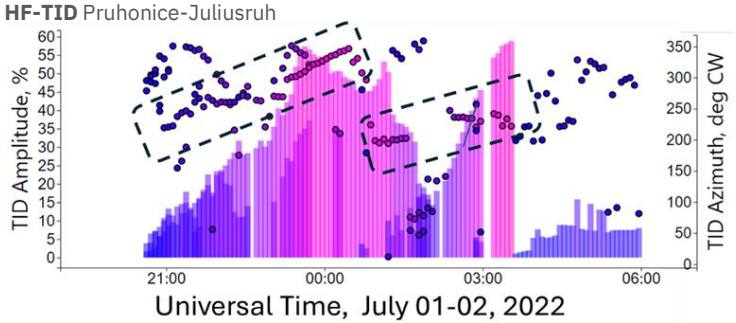


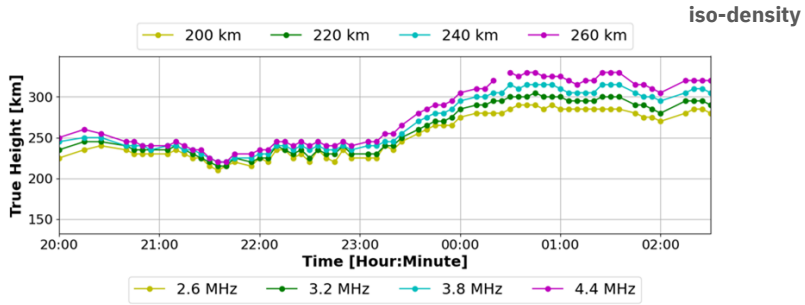
Catalogue-based

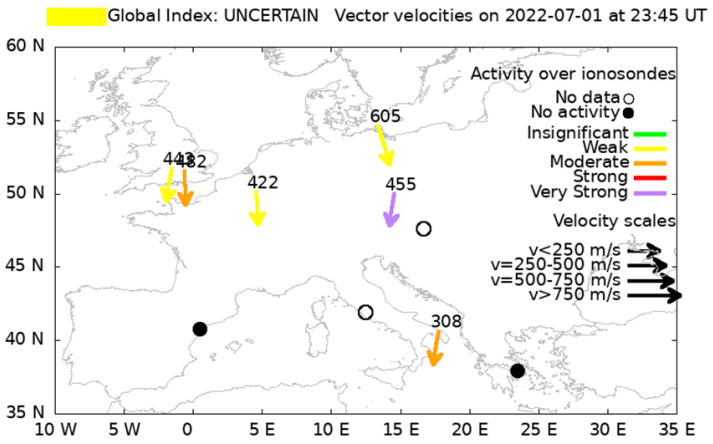


SEC-based

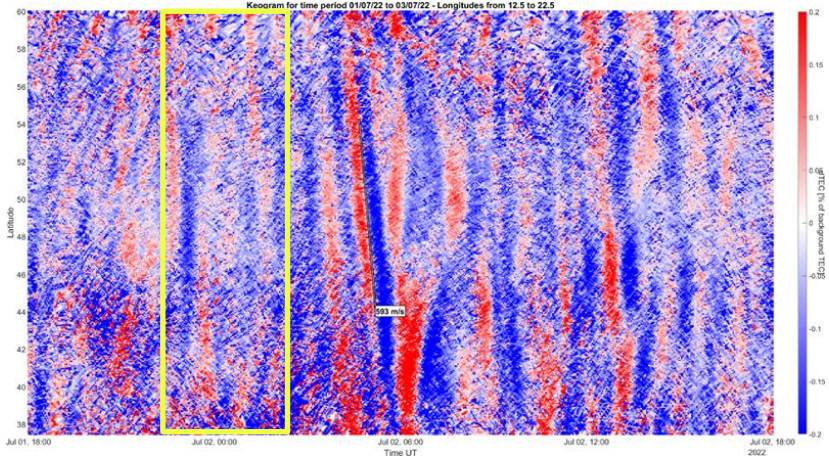
Event 2 – HF-INT, HF-TID, iso-density and detrended TEC







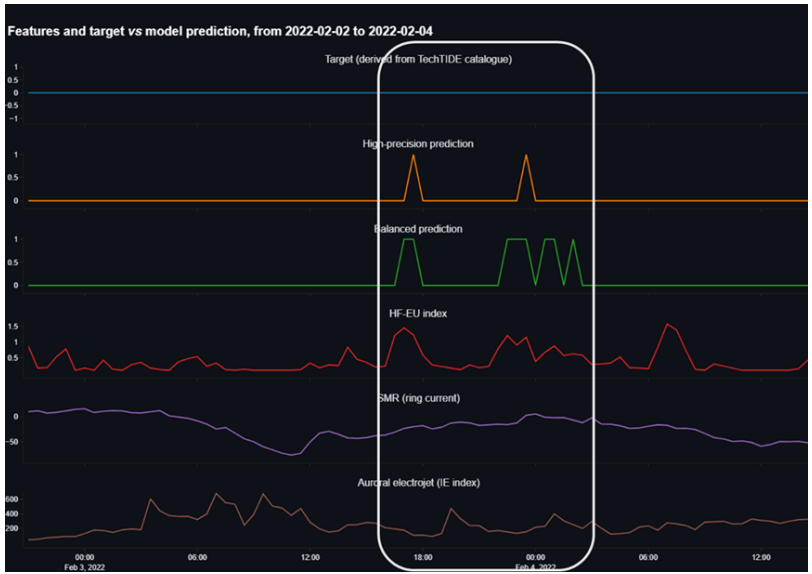
HF-INT



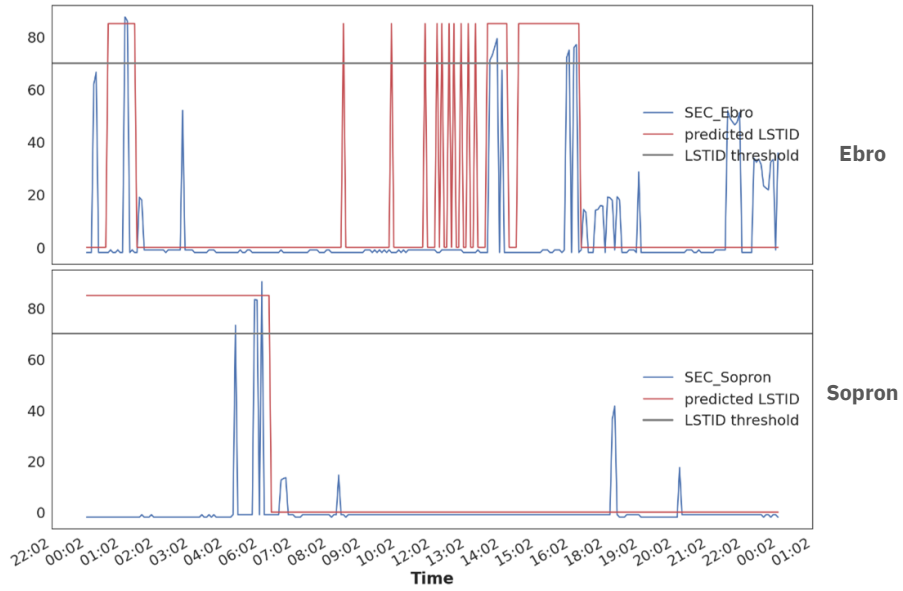
dTEC

Event 3 – catalogue- and SEC-based models

Event	**Catalogue**	**Start** (approx.)	**End** (approx.)	**Drivers**	**Forecast** (CB | SB)
3	No	2022/02/03 16:30	2022/02/04 00:00	Yes	Yes | Yes



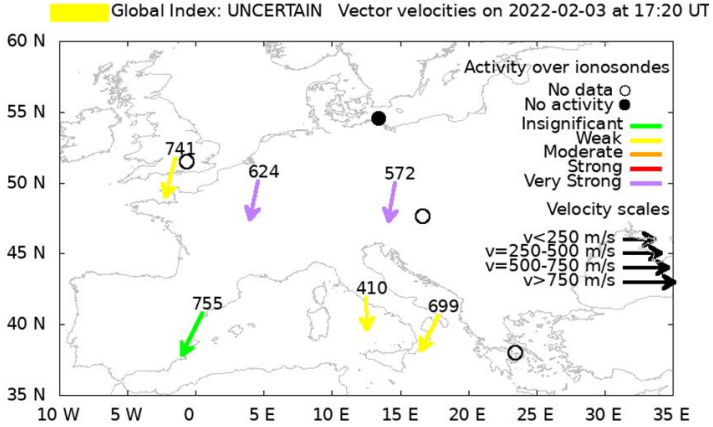
Catalogue-based



SEC-based

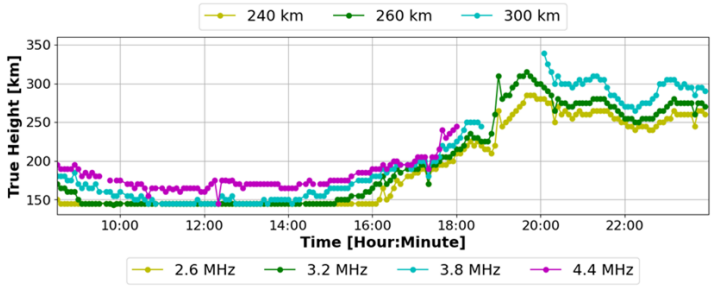
Event 3 – HF-INT, HF-TID, iso-density and detrended TEC

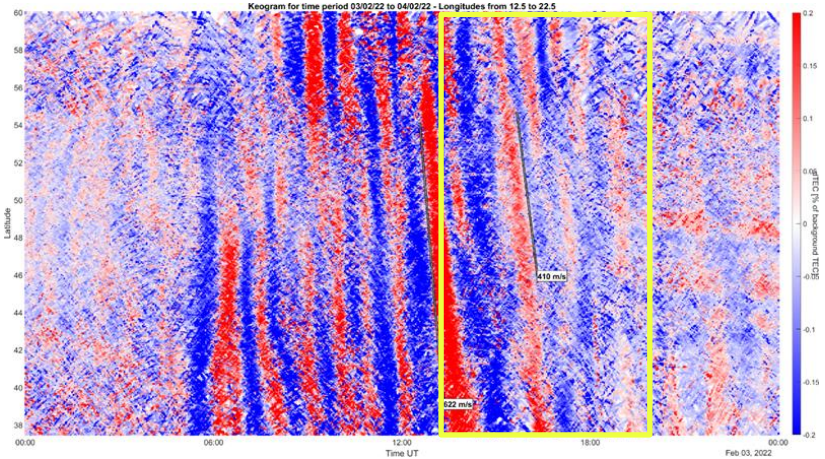
The HF-TID method reports unknown LSTID activity because no relevant data was found due to the unavailability of the Pruhonice-Juliusruh radio link



HF-INT

iso-density

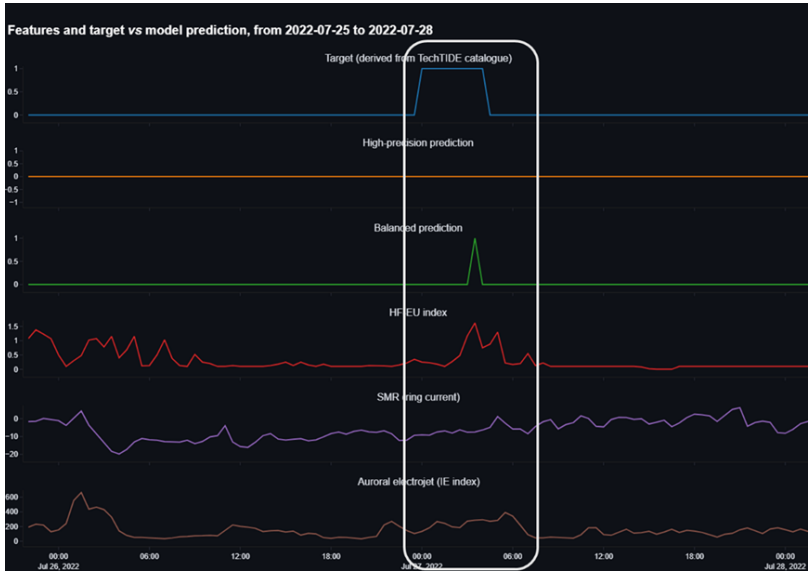




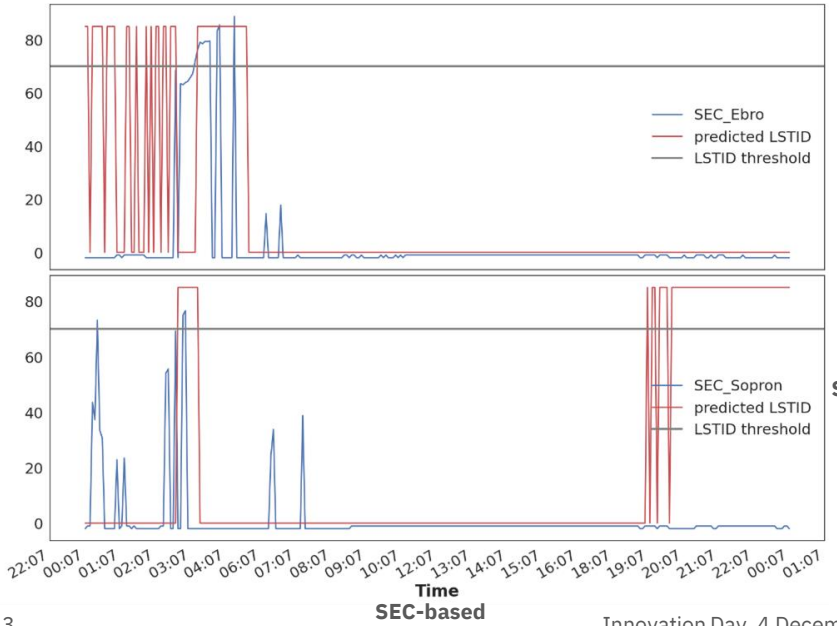
dTEC

Event 4 – catalogue- and SEC-based models

Event	**Catalogue**	**Start** (approx.)	**End** (approx.)	**Drivers**	**Forecast** (CB | SB)
4	Yes	2022/07/27 03:00	2022/07/27 04:35	No	No | Yes



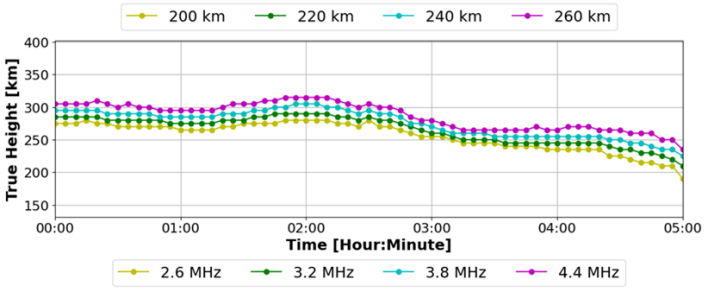
Catalogue-based



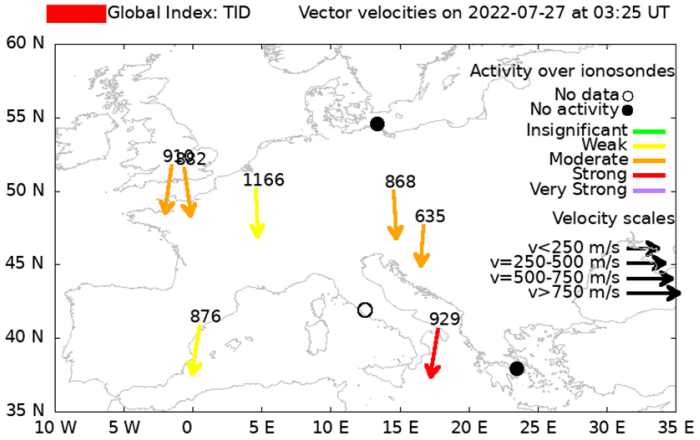
SEC-based

Event 4 – HF-INT, HF-TID, iso-density and detrended TEC

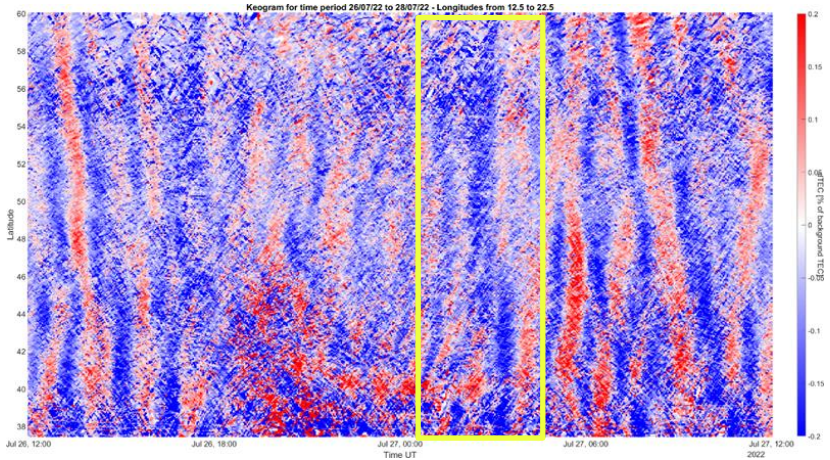
The HF-TID method reports unclear LSTID activity because no relevant data was found due to the unavailability of the Pruhonice-Juliusruh radio link due to weak/missing reception of the D2D, with a complicated mode structure due to the presence of a blanketing Es layer



iso-density



HF-INT



dTEC

Summary and future steps (beyond T-FORS lifetime)

- 2 different AI-based models are available in T-FORS for LSTID forecasting (CB model, SB model)
- Catalague based model gives a forecasting at European level 3 hours in advance
- SEC based model gives a forecasting at ionosonde level up to 2 hours in advance
- A first version of the demonstrator is available
- Validation of the models have been performed on a statistical and case event level (report under evaluation)