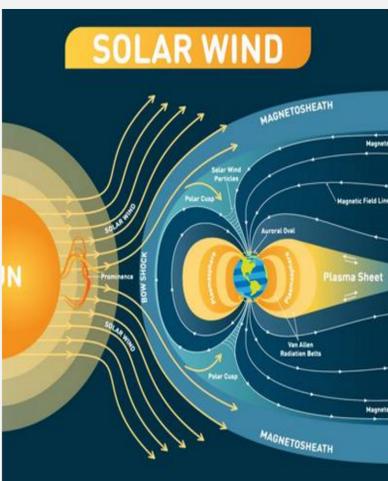


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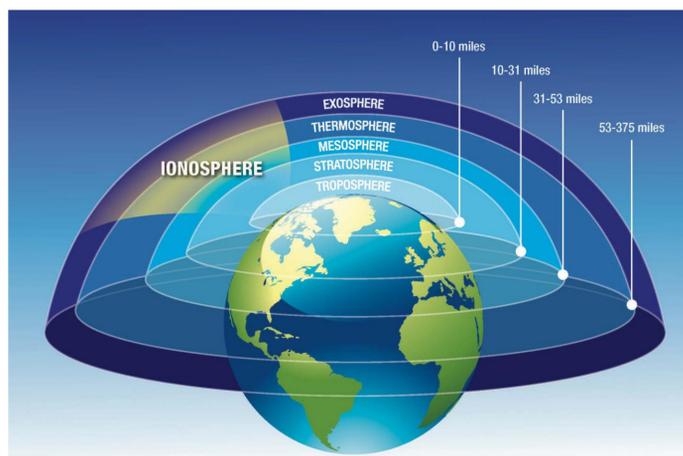


INTRODUCTION

GNSS positioning accuracy is strongly affected by ionospheric and tropospheric delays. Solar activity induces dynamic ionospheric conditions, leading to irregular VTEC variations. VTEC (Vertical Total Electron Content) is a key parameter for ionospheric error mitigation in Network RTK (N-RTK). This study uses GNSS data from Exagone's Teria network combined with IGS products. Traditional interpolation-based correction models show limitations under disturbed ionospheric conditions.

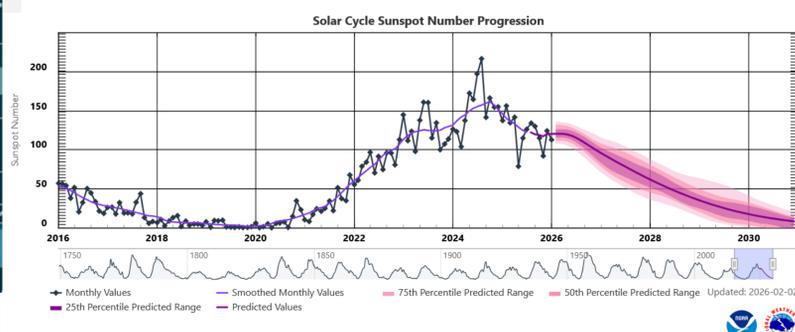


These limitations motivate the development of more advanced, domain-specific methodologies. ML models can learn complex relationships governing ionospheric variability. This enables a more effective representation of the spatio-temporal evolution of ionospheric effects.



OBJECTIVE

The first objective is to forecast the VTEC values over France using data from Exagone's Teria GNSS network for training and validation of Machine Learning models.



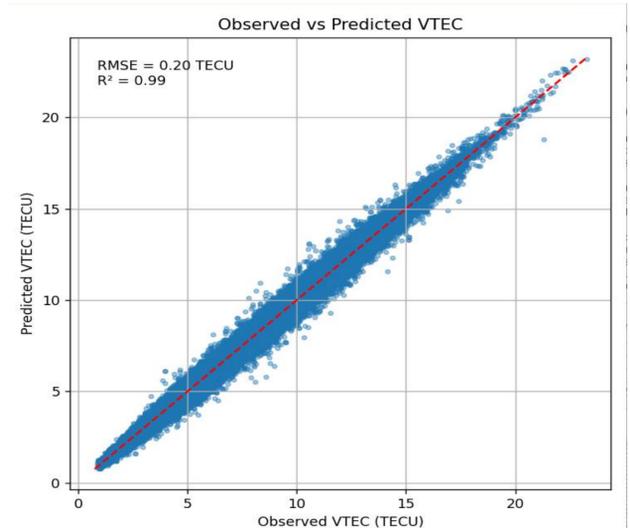
METHODOLOGY

- GNSS observation data were extracted from Exagone's Teria network and complemented with Precise GNSS products (SP3 files) from the international GNSS service (IGS).
- A dataset was generated using Python scripts to extract and preprocess the relevant parameters.
- The dataset was structured with VTEC values defined as the target variable.
- The XGBoost Machine Learning algorithm was selected for VTEC prediction.
- The dataset was divided into training (80%) and validation (20%) subsets.
- Model performance was evaluated using statistical metrics to assess its ability to capture VTEC temporal variability.

DATASET FEATURES

- Epoch_utc:** Data and time of GNSS measurements recorded at stations in France.
- Cartesian coordinate:** 3D Earth-centered coordinates of GNSS stations.
- Geographic Location:** Latitude and Longitude of the receiver.
- VTEC:** Target variable derived from GNSS observations.
- Additional features:** Auxiliary parameters related to ionospheric and temporal variability.

PRELIMINARY RESULTS



- The scatter plot compares observed and predicted VTEC values.
- The red diagonal line represents perfect prediction.
- Most points lie close to the line, showing high accuracy.
- Model metrics: $RMSE \approx 0,20$ TECU, $R^2 \approx 0,99$, indicating the model explains almost all variability.
- Some outliers appear, representing rare or extreme conditions, but overall predictions are strong.

ONGOING AND FUTURE WORKS

- This study is a first step toward a generalized ML-based atmospheric model.
- Improve model generalization using larger and more diverse datasets.
- Extend the approach to tropospheric delay estimation.