Machine learning based modelling of tropospheric parameters with GNSS enhanced by meteorological data

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1. INTRODUCTION

Global Navigation Satellite System (GNSS) is mostly known for autonomous global positioning, navigation, and timing services. However, it is also a key tool for many areas of science such as quantification of global-scale geodynamical phenomena or studies on the atmosphere.

Over the past years, modern smartphones facilitate the collection of raw GNSS measurements. These affordable smart devices are utilized by billions of people making crowdsourcing of GNSS observations possible. This forms a great opportunity for investigating the usage of smartphone-based GNSS data for different subjects such as weather forecasting or atmosphere studies at large. By combining the observations acquired by high-quality GNSS stations with a dynamic network of GNSS-capable Internet-of-Things (IoT) devices, the sample of observations can be significantly increased and an unprecedented spatio-temporal resolution can be achieved.

2. PROJECT OVERVIEW

Appli**ca**tion of **Ma**chine **L**earning Technology for GNSS **IoT** data fusion (CAMALIOT) is an ongoing project funded by the European Space Agency (ESA) that aims to collect large amounts of GNSS observations by developing an Android application and conducting a dedicated crowdsourcing campaign.
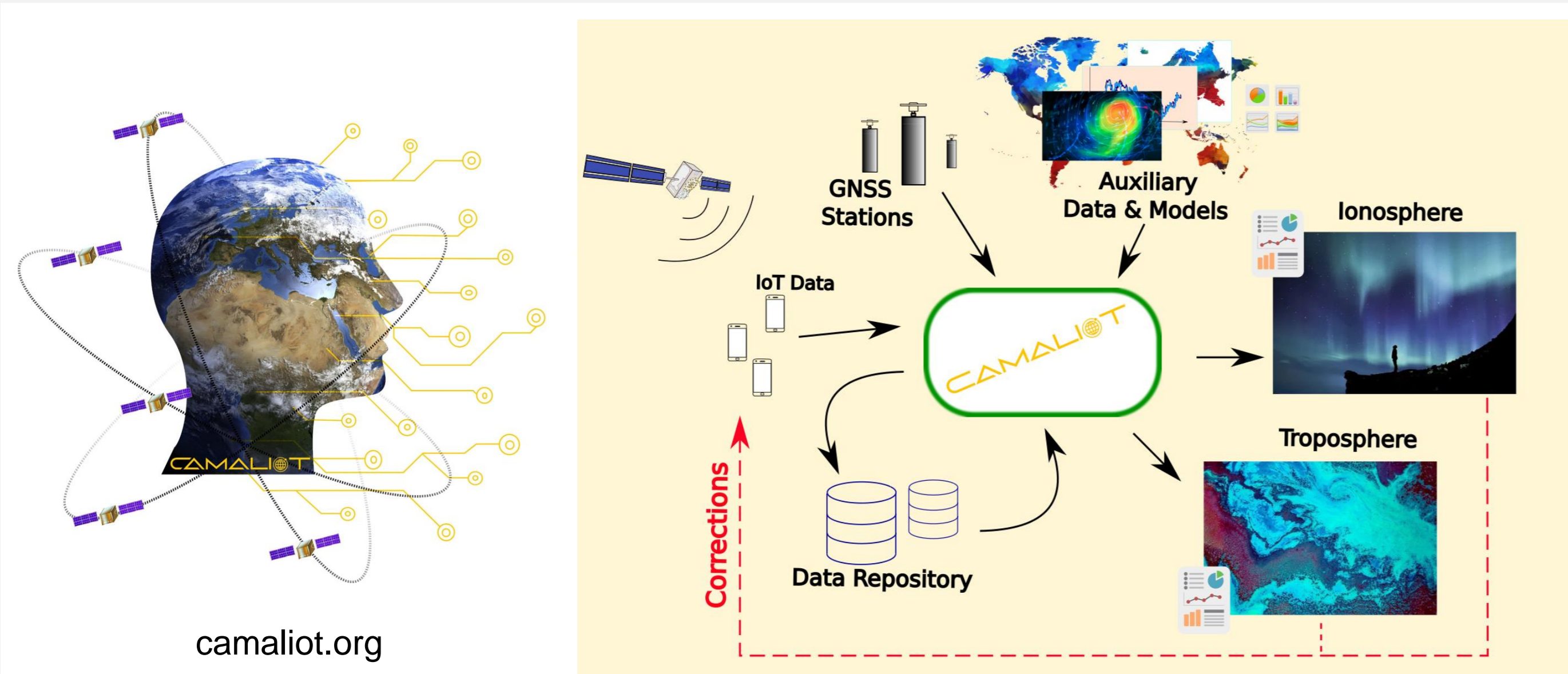

Fig. 1: A high-level overview of the concept exploited within the CAMALIOT project

3. CROWDSOURCING CAMPAIGN

Campaign to collect data from satellites for scientific research

- Started on 17th March 2022
- Android app with 35k+ installations
- 10k registered users
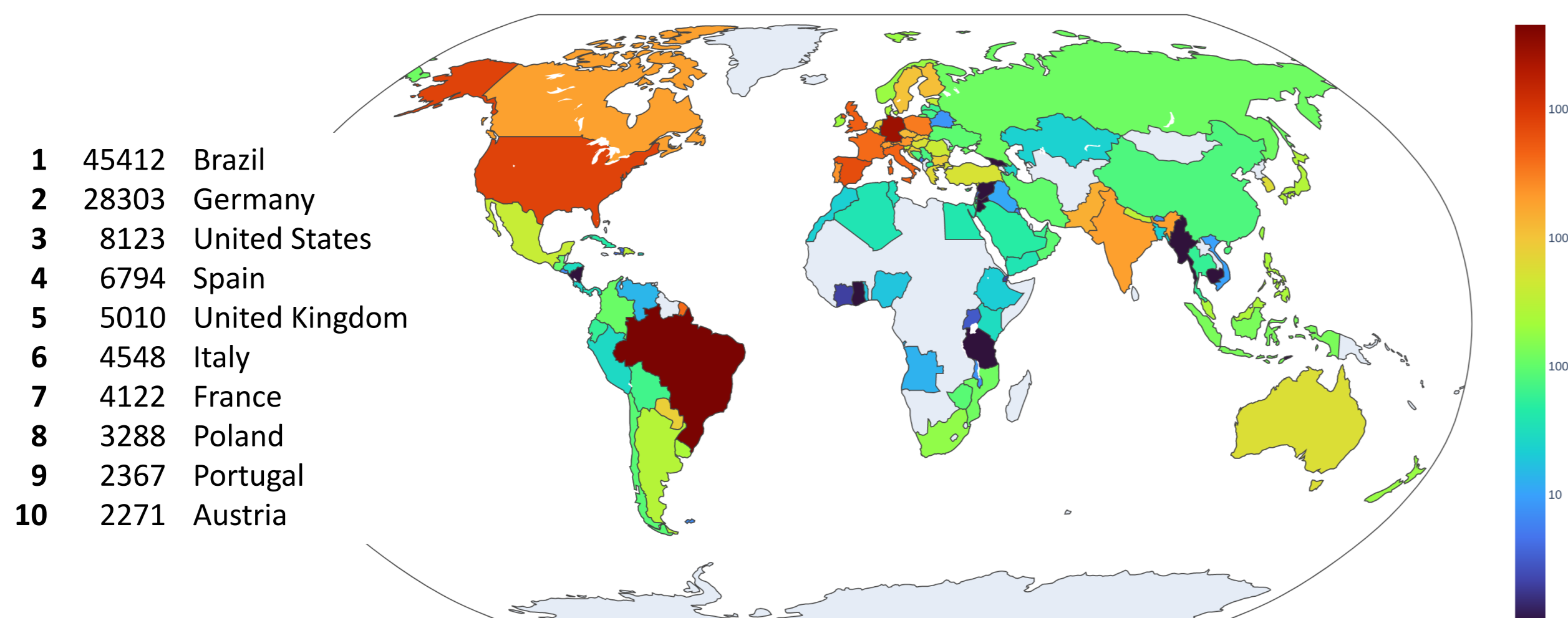- 10 billion GPS observations collected

1	45412	Brazil
2	28303	Germany
3	8123	United States
4	6794	Spain
5	5010	United Kingdom
6	4548	Italy
7	4122	France
8	3288	Poland
9	2367	Portugal
10	2271	Austria

Fig. 2: Map showing the number of files uploaded from different countries (until 29th April 2022)

4. SCIENCE USE CASE

ML-based forecasting of tropospheric parameters

One science use case is to utilize the IoT GNSS data to investigate its feasibility for augmenting modelling and prediction of tropospheric parameters such as Zenith Wet Delay (ZWD). ZWD is strongly related to the water vapour content in the atmosphere, which in turn drives weather systems and climate change to a great extent.

The aim is to derive a global ML-based model enhanced by Earth Observation data that can predict ZWD in space and time.
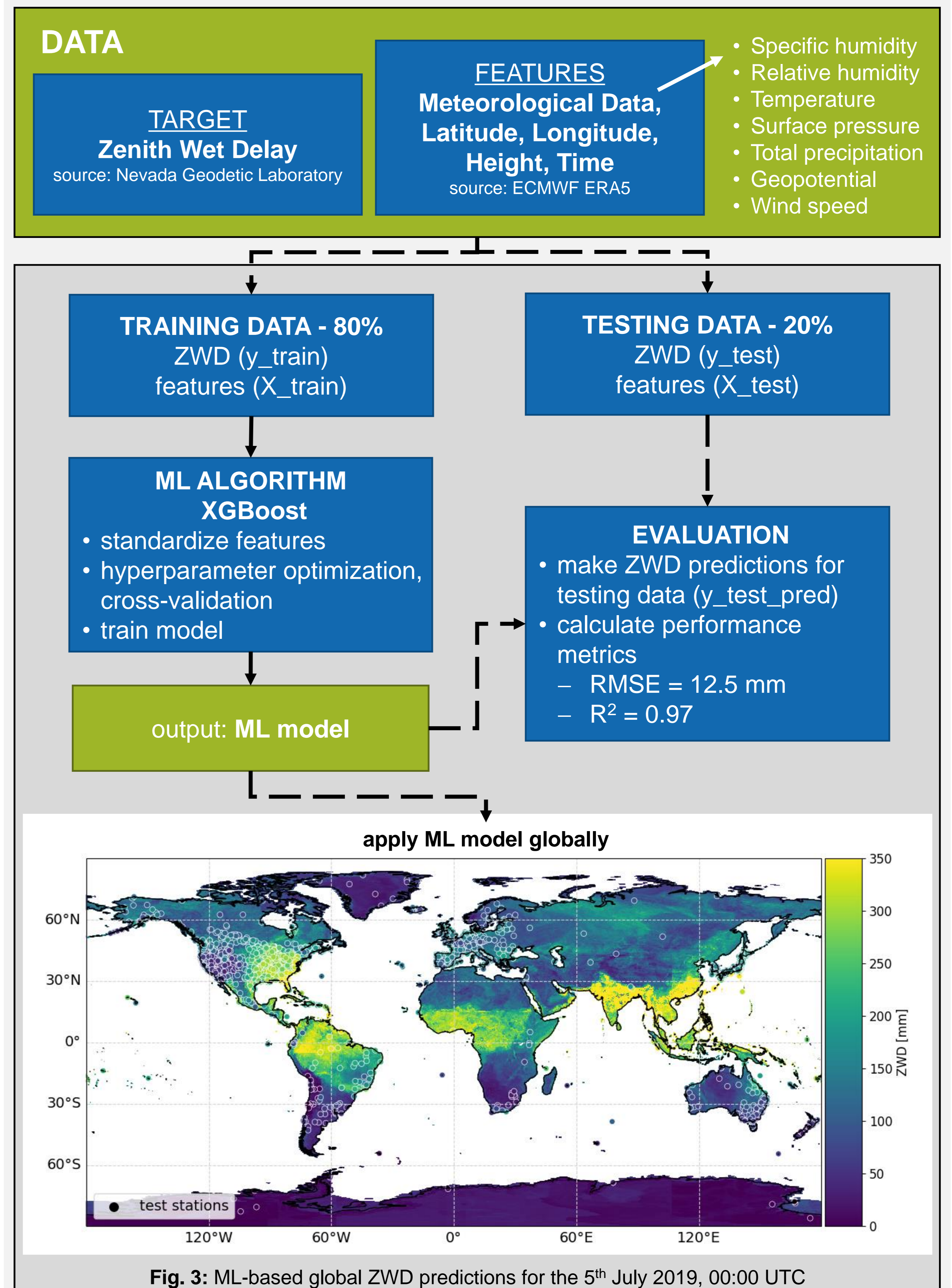

DATA

TARGET
Zenith Wet Delay
source: Nevada Geodetic Laboratory

FEATURES
Meteorological Data, Latitude, Longitude, Height, Time
source: ECMWF ERA5

- Specific humidity
- Relative humidity
- Temperature
- Surface pressure
- Total precipitation
- Geopotential
- Wind speed

TRAINING DATA - 80%
ZWD (y_train)
features (X_train)

TESTING DATA - 20%
ZWD (y_test)
features (X_test)

**ML ALGORITHM
XGBoost**
- standardize features
- hyperparameter optimization, cross-validation
- train model

output: **ML model**

EVALUATION
- make ZWD predictions for testing data (y_test_pred)
- calculate performance metrics
  - RMSE = 12.5 mm
  - R^2 = 0.97

Fig. 3: ML-based global ZWD predictions for the 5th July 2019, 00:00 UTC

5. SUMMARY

- CAMALIOT will advance current knowledge and experience concerning GNSS observations as collected from smartphones and applied for scientific purposes
- Global ML-based ZWD model can make predictions for every point on Earth (assuming meteorological data is available) and achieves an average RMSE of 12.5 mm

Reference:
Navarro, V., Grieco, R., Soja, B., Nugnes, M., Klopotek, G., Tagliaferro, G., See, L., Falzarano, R., Weinacker, R., Ventura Traveset, J., "Data Fusion and Machine Learning for Innovative GNSS Science Use Cases," *Proceedings of the 34th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2021)*, St. Louis, Missouri, September 2021, pp. 2656-2669. https://doi.org/10.33012/2021.18115