ETH zürich | SPACE GEODESY | IIASA International Institute for Applied Systems Analysis

GSSC Webinar CAMALIOT:

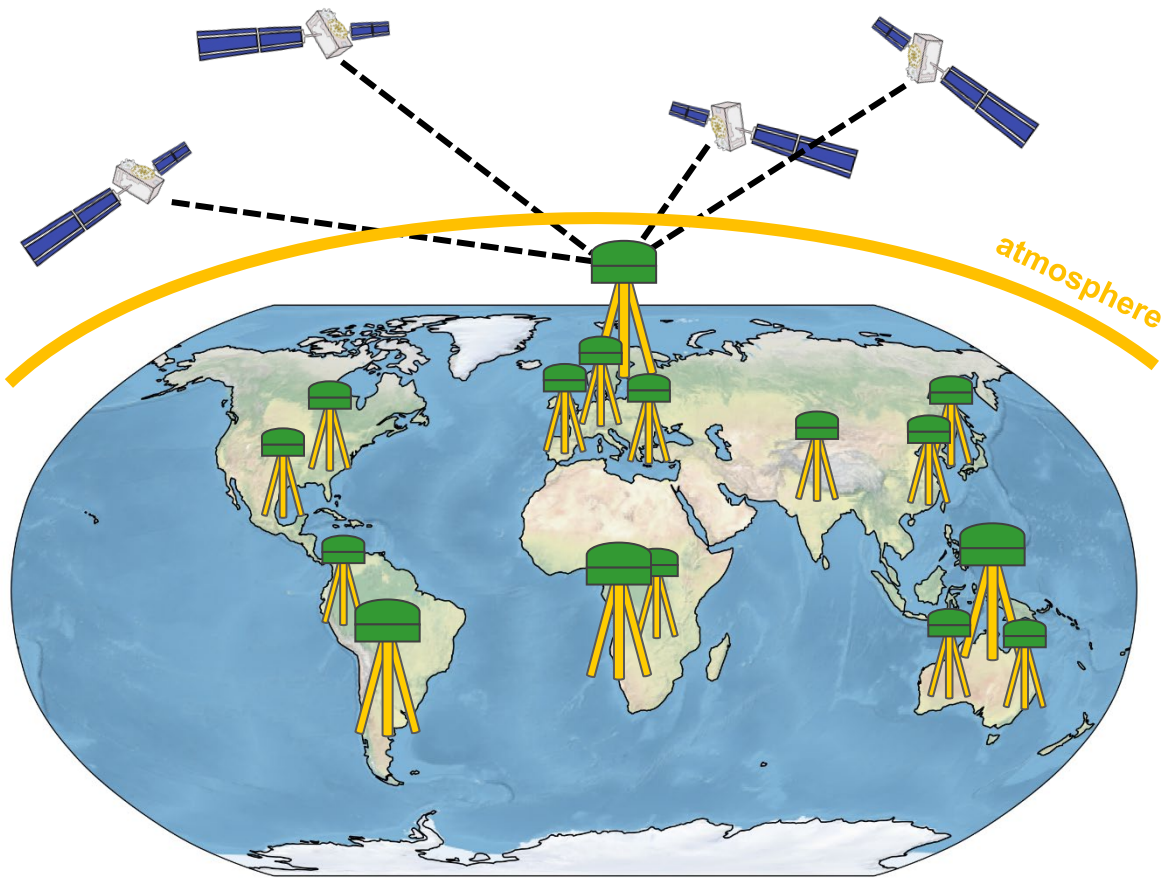
Application of machine learning technology for GNSS IoT data fusion

NAVISP EL1-38.2

Benedikt Soja

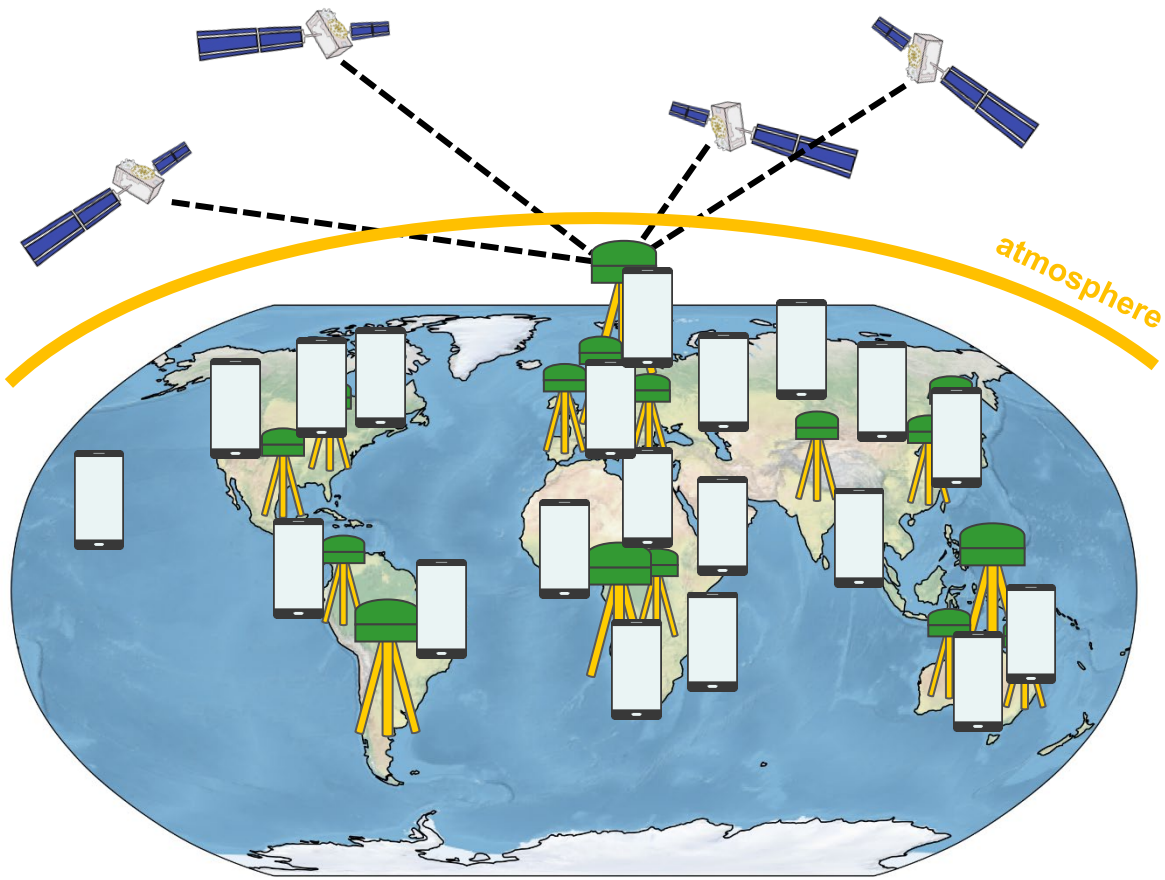
November 29th, 2023

GNSS for atmospheric monitoring



- GNSS signals traverse the atmosphere
- Atmospheric path delays
  - Positioning errors
  - Measurements of atmospheric properties
- GNSS sensitive to atmospheric water vapor
  - Assimilation into numerical weather models for better weather forecasts
- GNSS sensitive to free electrons
  - Contribution to space weather monitoring

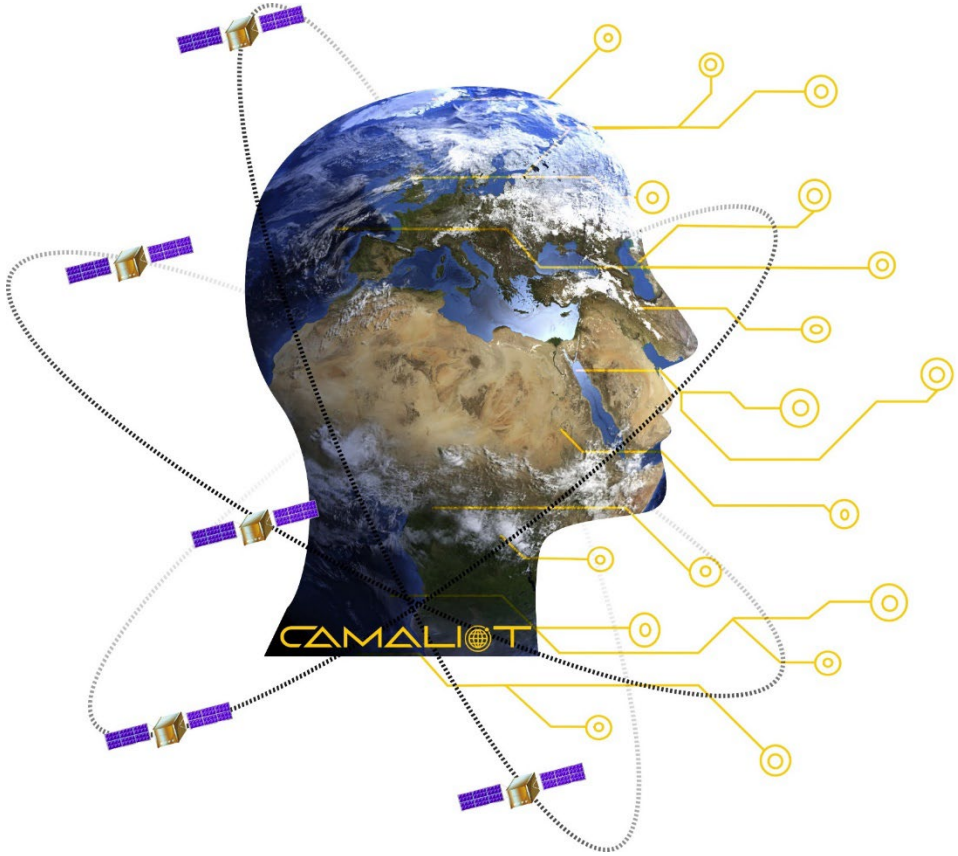
GNSS for atmospheric monitoring



- Local weather variations → spatial coverage essential for atmospheric monitoring
- Geodetic GNSS stations very expensive
- Exploration of new data sources → low-cost IoT devices and smartphones

CAMALIOT

Appli**ca**tion of **ma**chine **l**earning technology for GNSS **IoT** data fusion



https://camaliot.org

Consortium

ETH zürich

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Shuyin Mao

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IIASA

Linda See

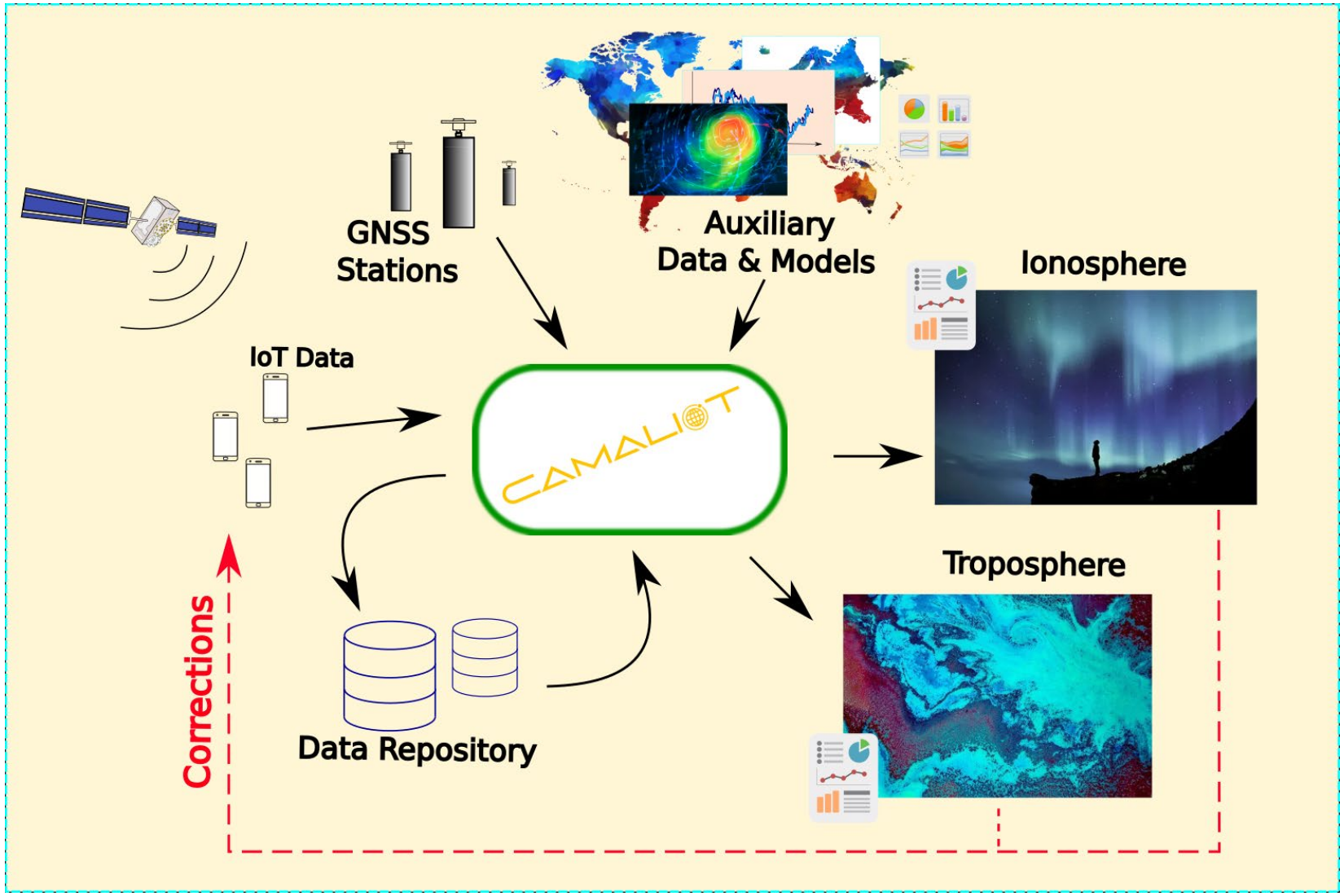
Tobias Sturn

Rudi Weinacker

Ian McCullum

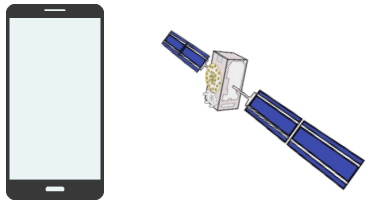
Fritz Steffen

High-level overview

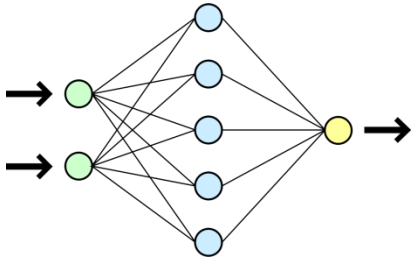


Objectives

1. GNSS IoT data
   - Investigate alternative sources of GNSS IoT data
   - Crowdsourcing GNSS data



2. GNSS big data processing
   - Develop framework for automated and robust GNSS processing
   - Machine learning for anomaly detection and data selection



3. Science use cases
   - Troposphere – Earth weather
   - Ionosphere – space weather

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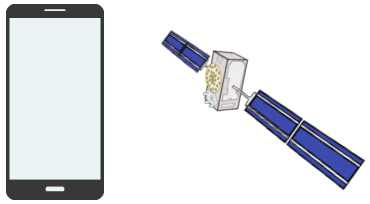

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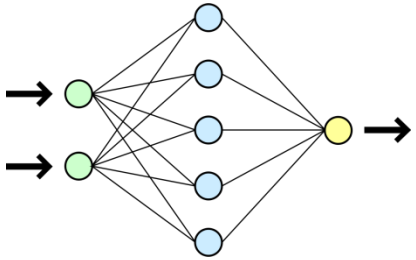

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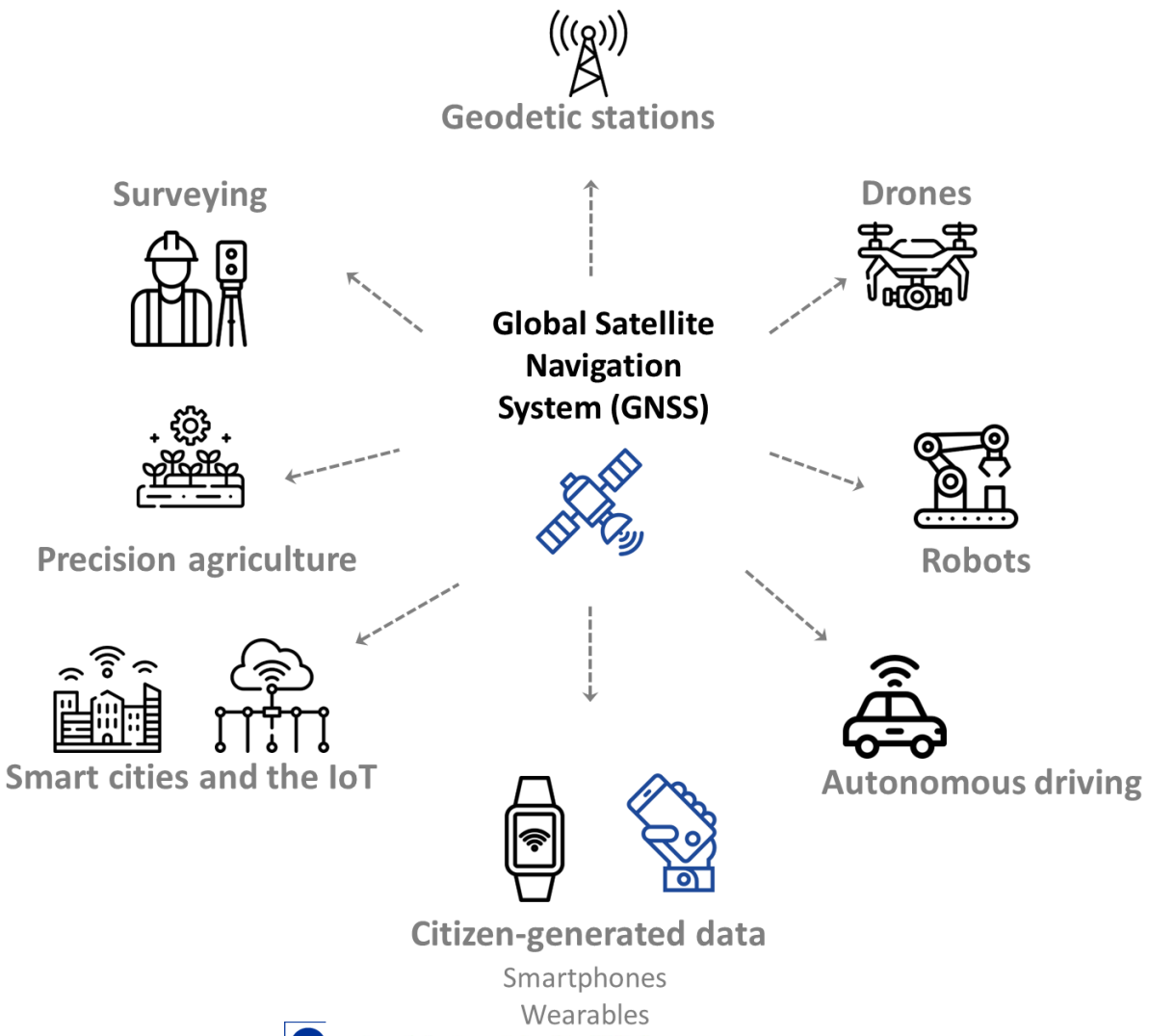
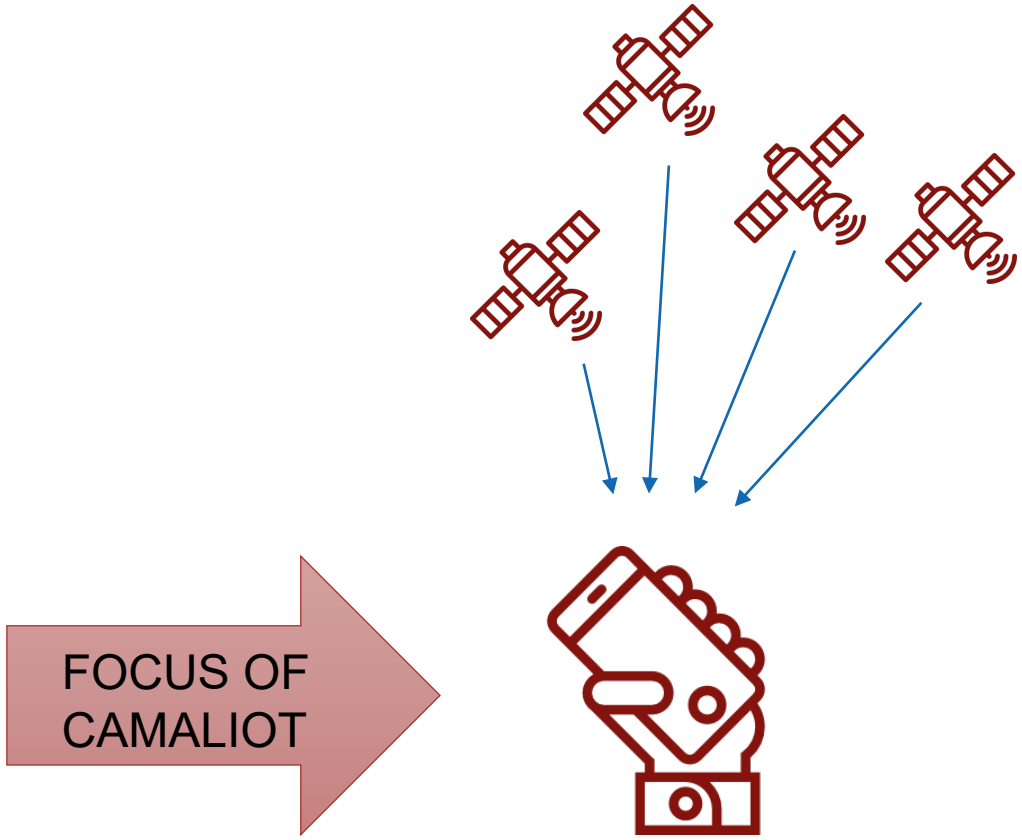
Sources of GNSS data





Collecting GNSS data using Android smartphones

- Access to the data from Android 7.0
- Dual frequency capabilities

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Android API for raw GNSS measurements

developers | Platform | Android Studio | Google Play | Jetpack | Kotlin | Docs | Games

DOCUMENTATION

Overview | Guides | Reference | Samples | Design & Quality

Filter

- android.content
- android.content.pm
- android.content.pm.verify.domain
- android.content.res
- android.content.res.loader
- android.database
- android.database.sqlite
- android.drm
- android.gesture
- android.graphics
- android.graphics.drawable

Android Developers > Docs > Reference

GnssMeasurement

```
public final class GnssMeasurement
extends Object implements Parcelable
```

java.lang.Object
↳ android.location.GnssMeasurement

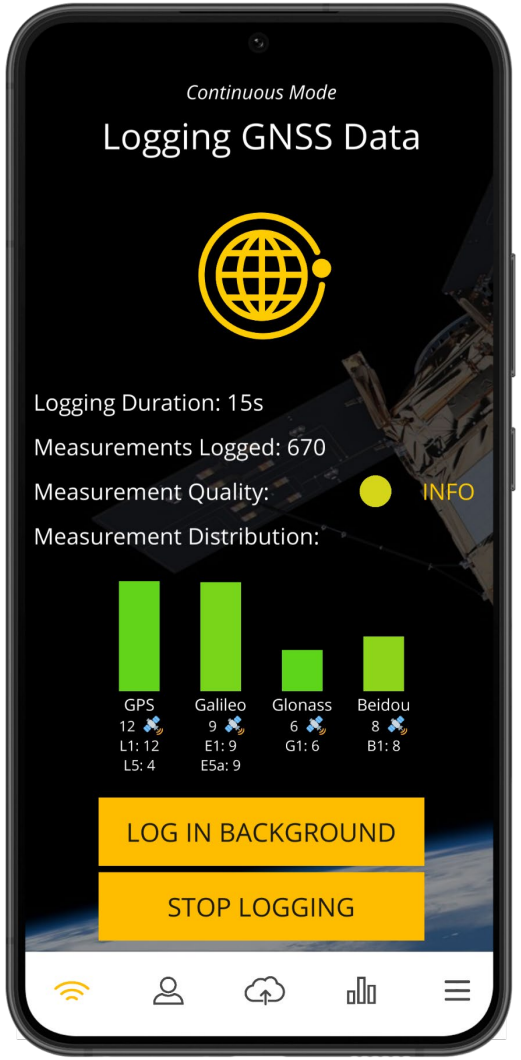
Android 7.0

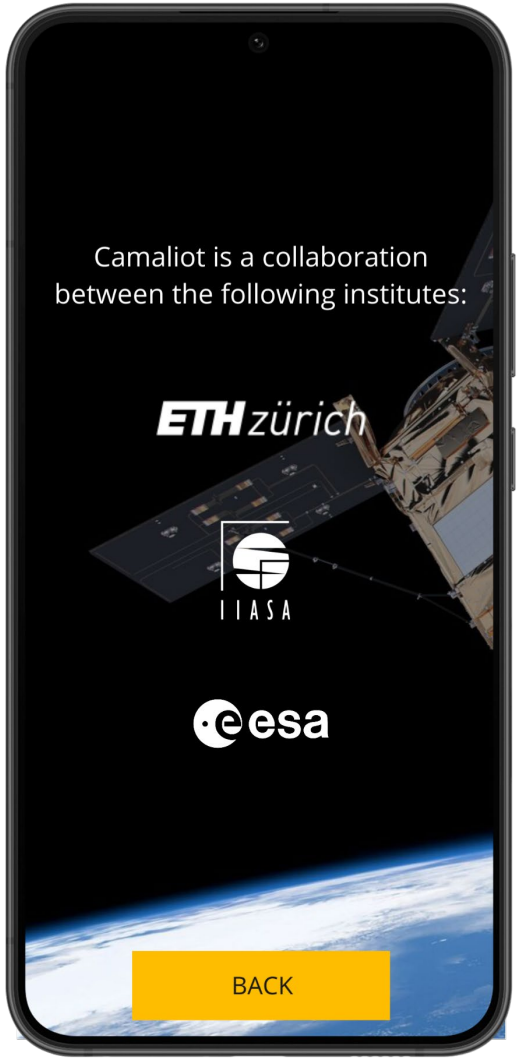
https://developer.android.com/reference/android/location/GnssMeasurement

CAMALIOT mobile app

GET IT ON Google play

SCAN ME





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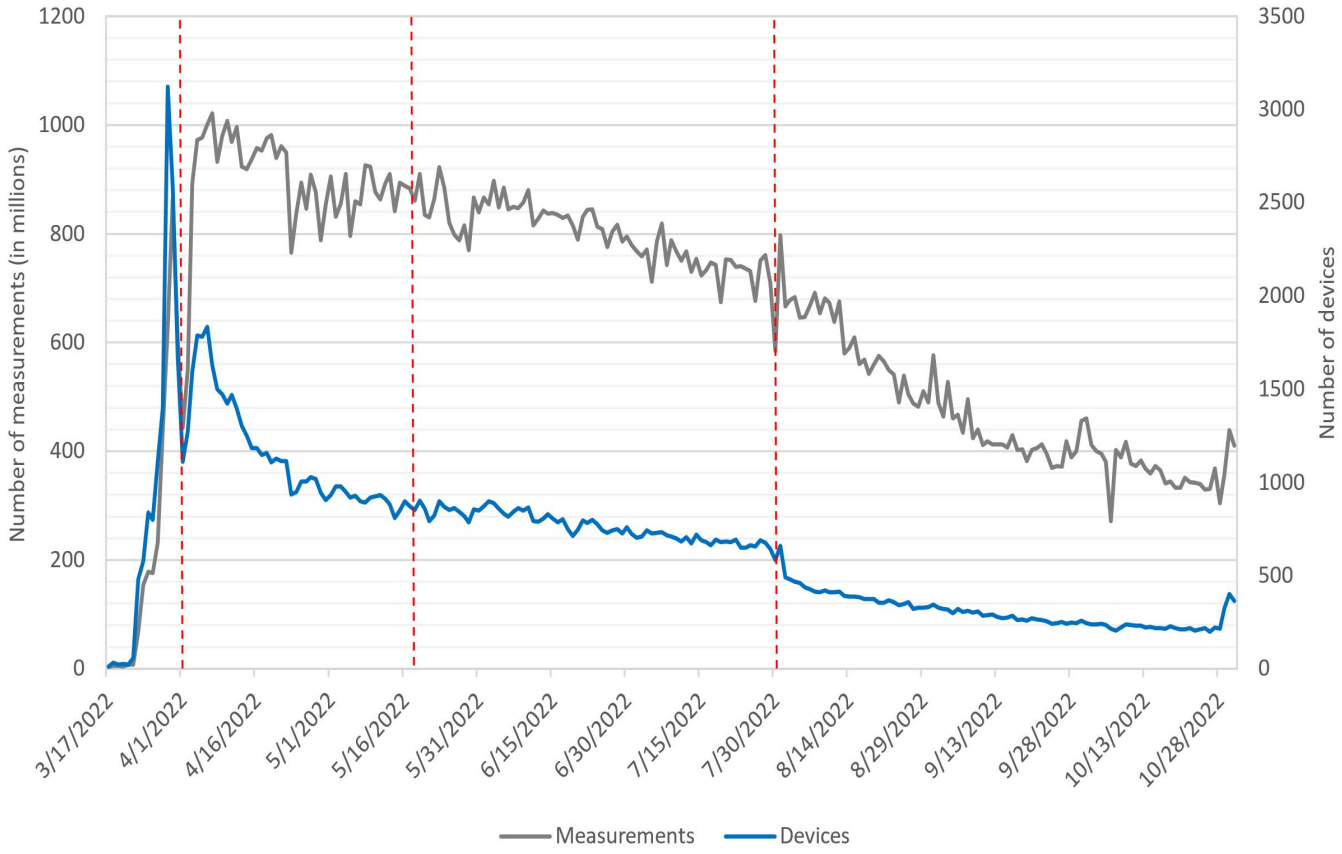
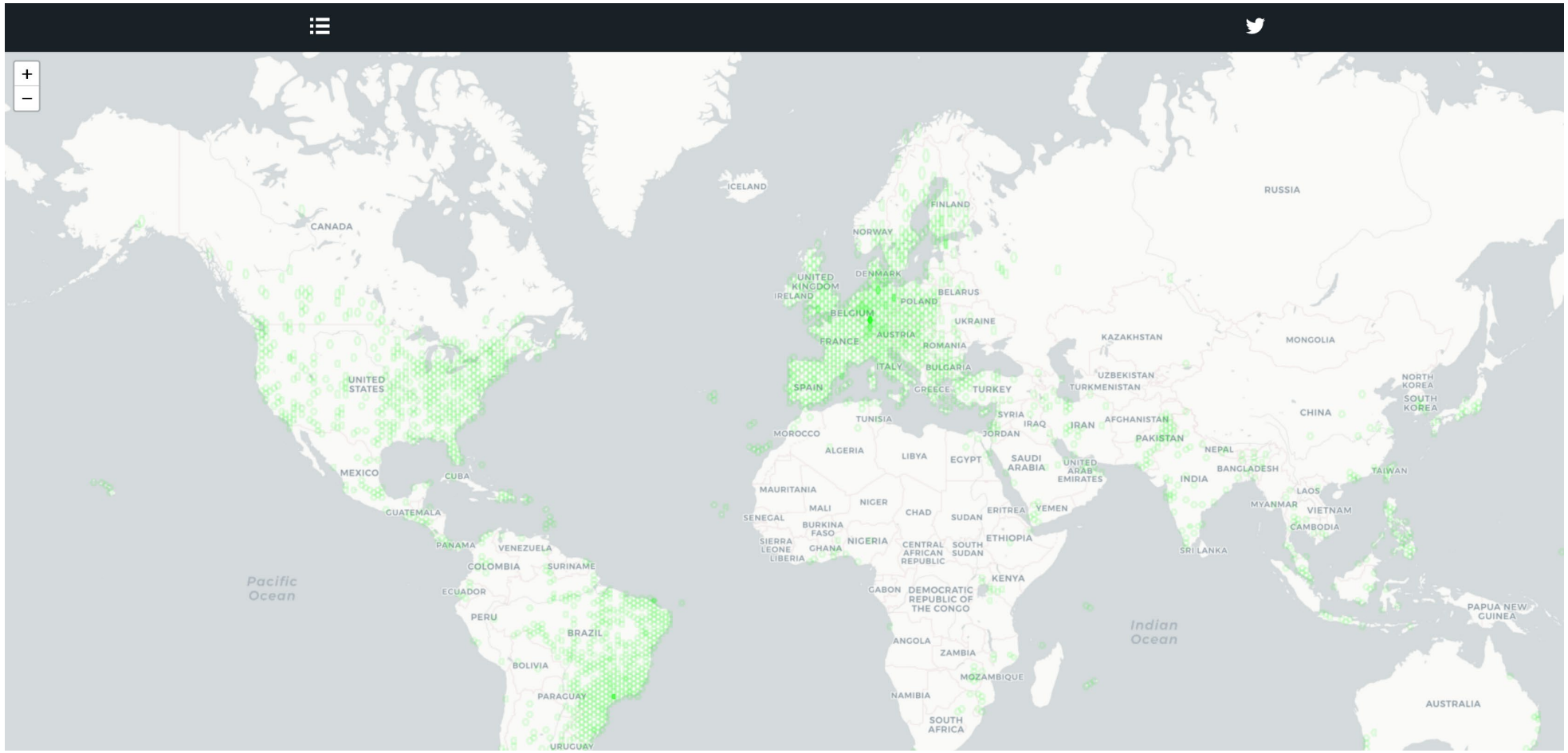
GNSS data collection success

- First campaign
  - March 17th – July 31st, 2022
  - 12k users
  - 116 billion GNSS measurements
- Autumn campaign
  - August 1st – November 30th, 2022
  - 1.2k+ users
  - 40+ billion GNSS measurements
- Regular data collection ongoing



Global distribution of crowdsourcing data

Live updates at
https://camaliot.org



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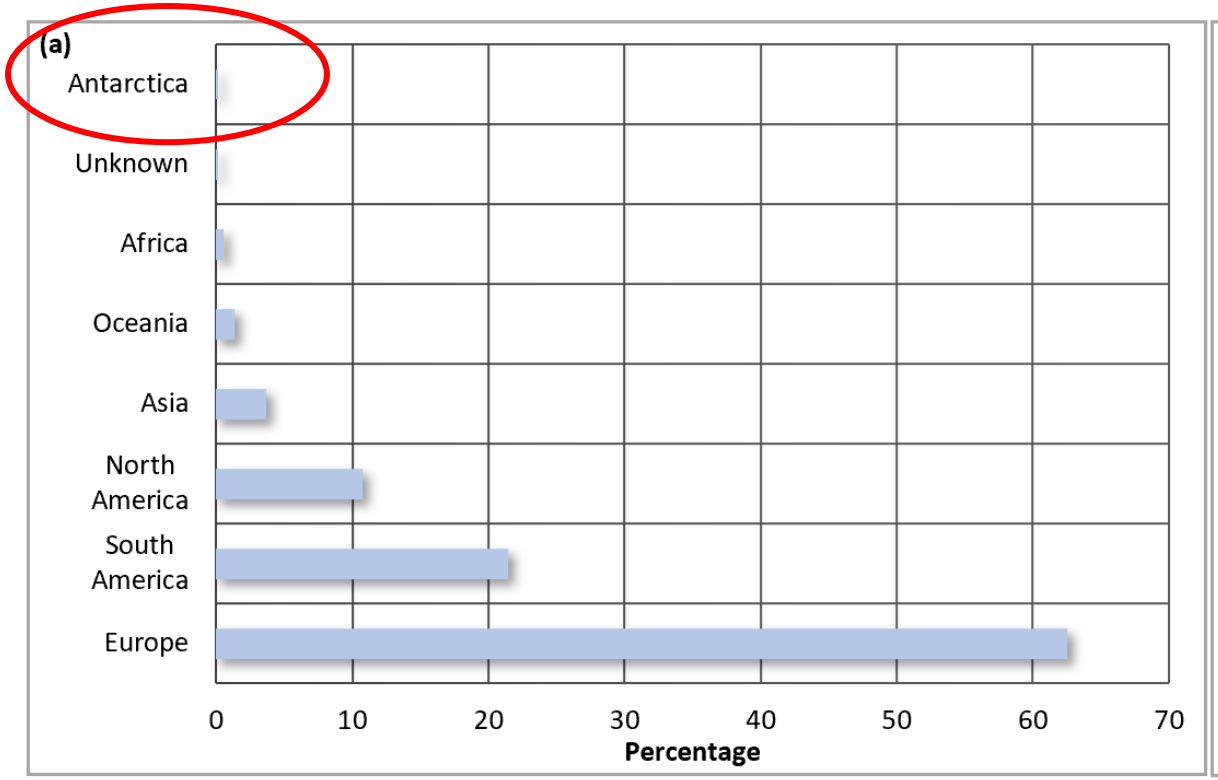
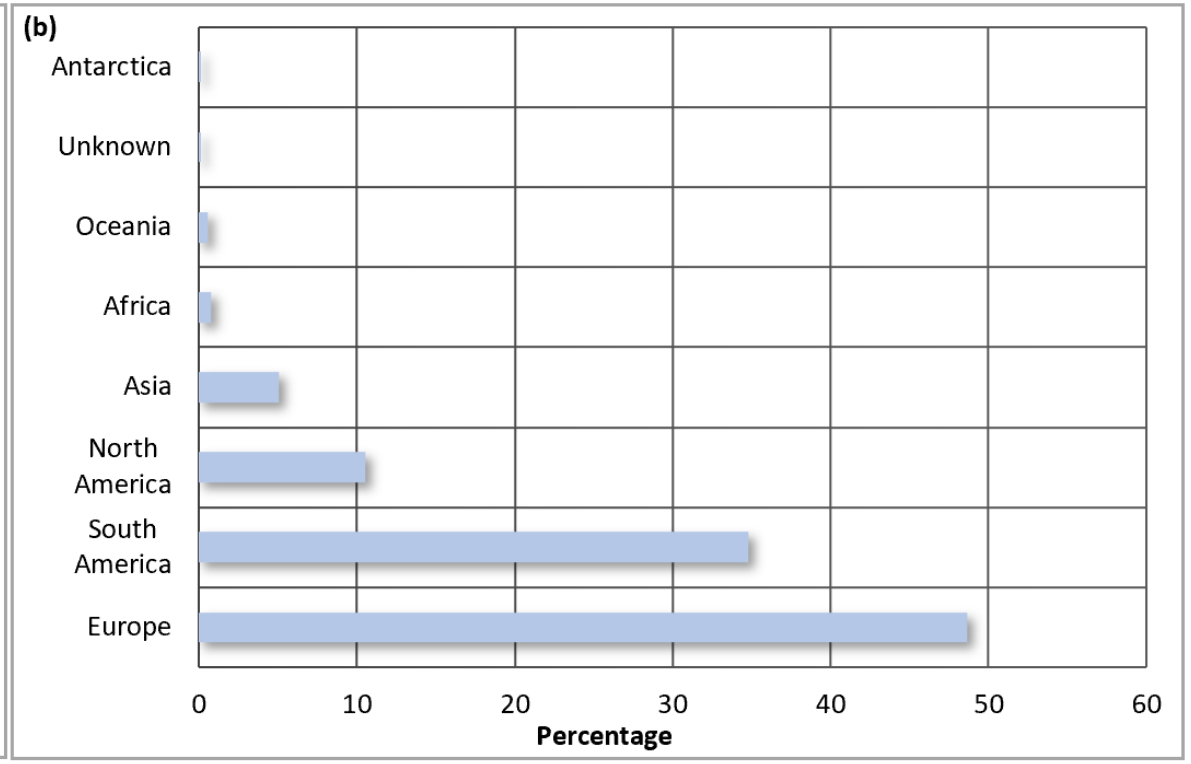
Distribution of contributions by continent

1 device in Antarctica!



Percentage by number of devices



Percentage by number of measurements

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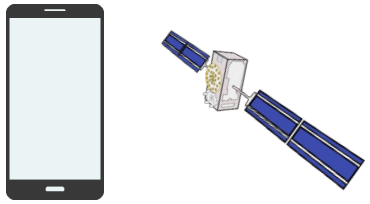

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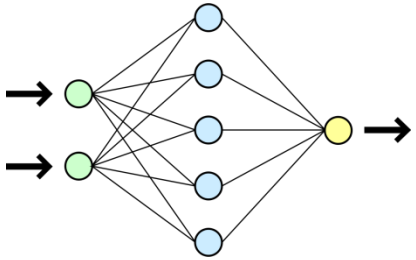
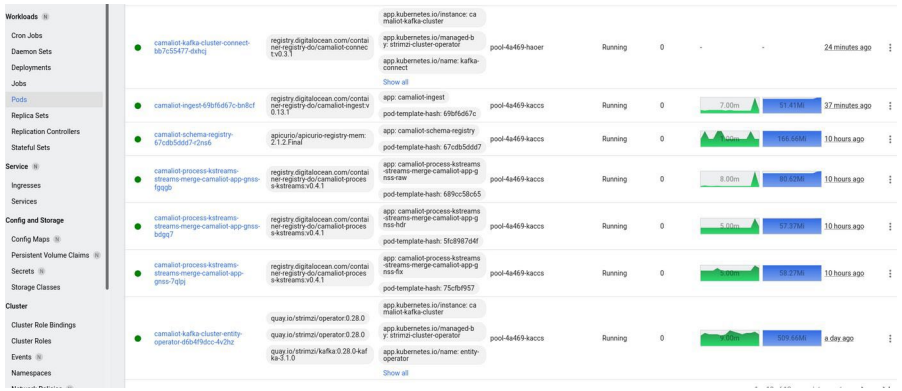
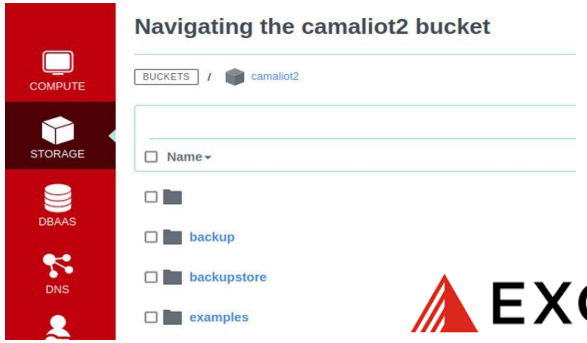


3. Science use cases
   - Troposphere – Earth weather
   - Ionosphere – space weather

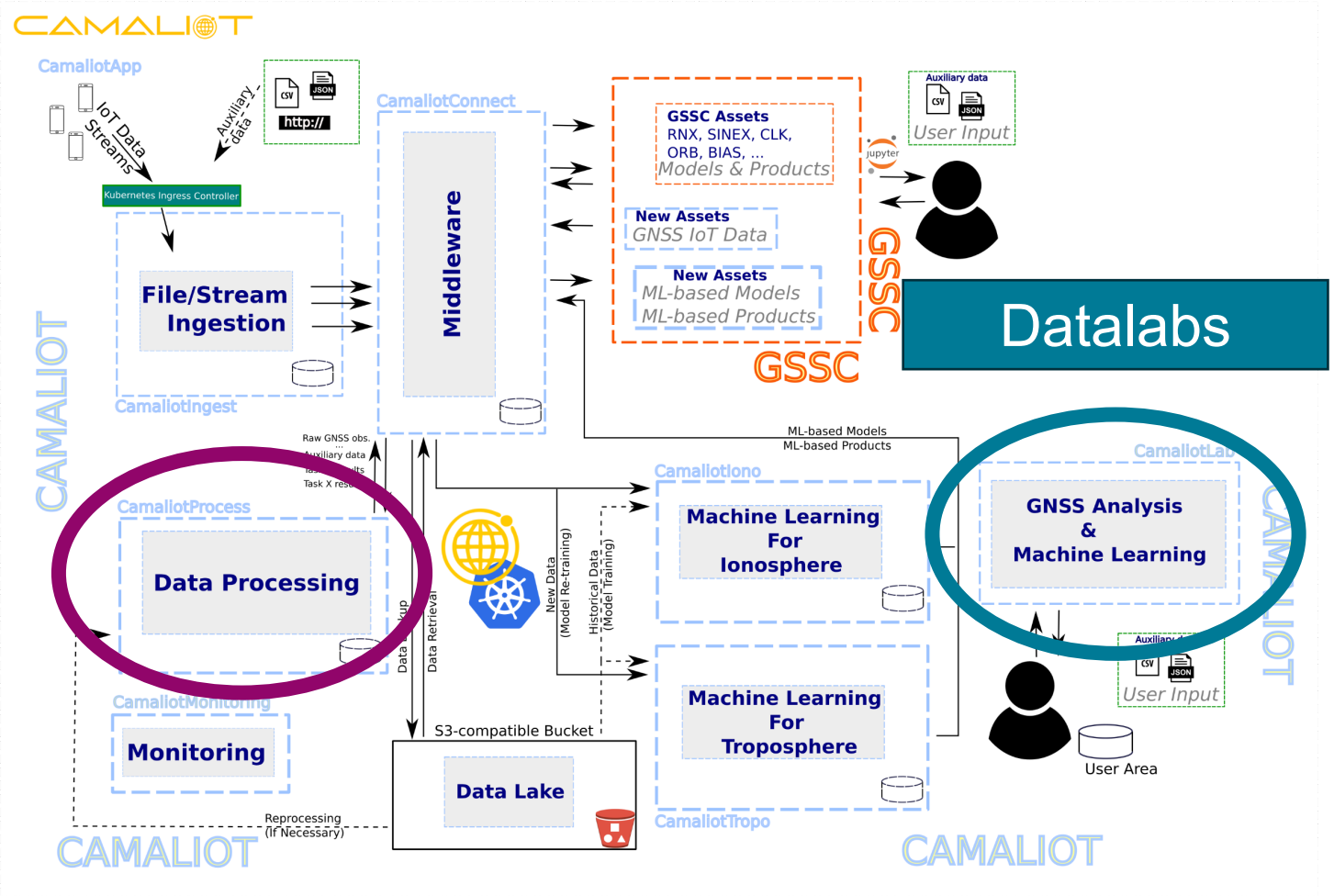
CAMALIOT software architecture

Kubernetes cluster





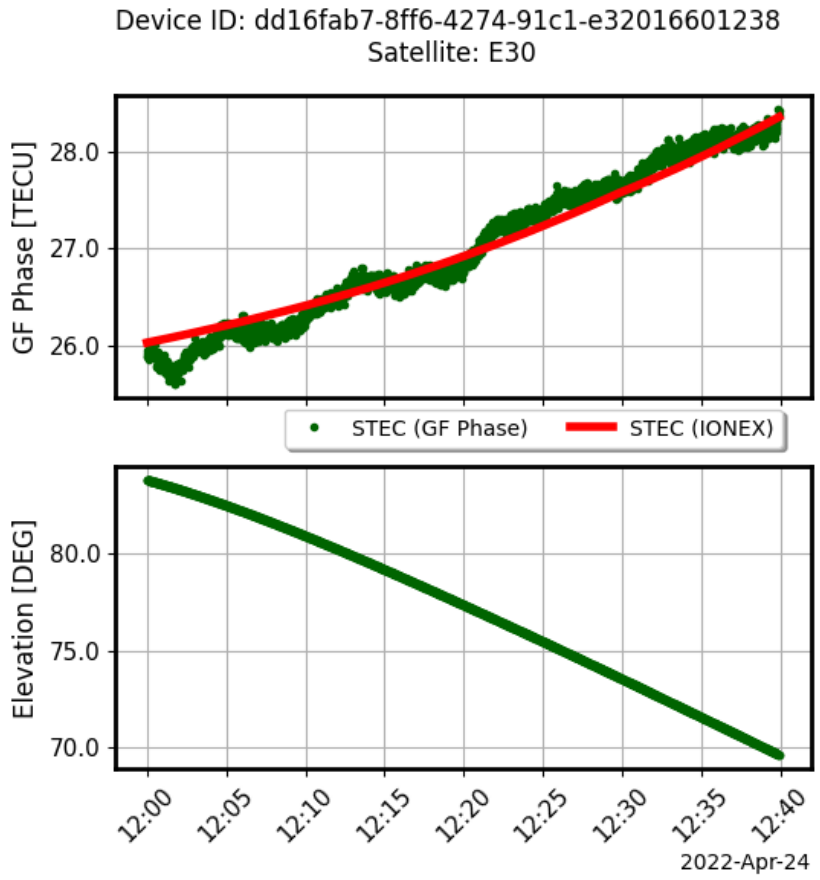
EXOSCALE



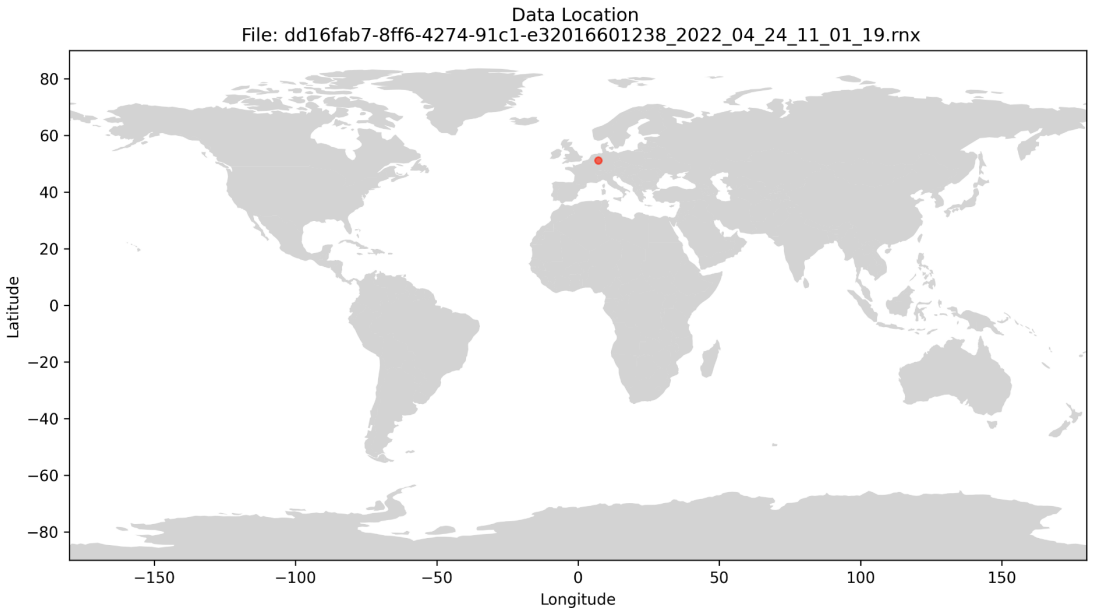
GNSS data processing

Ionosphere parameter estimation with campaign data

Method: geometry-free (GF) combination (L1+L5)



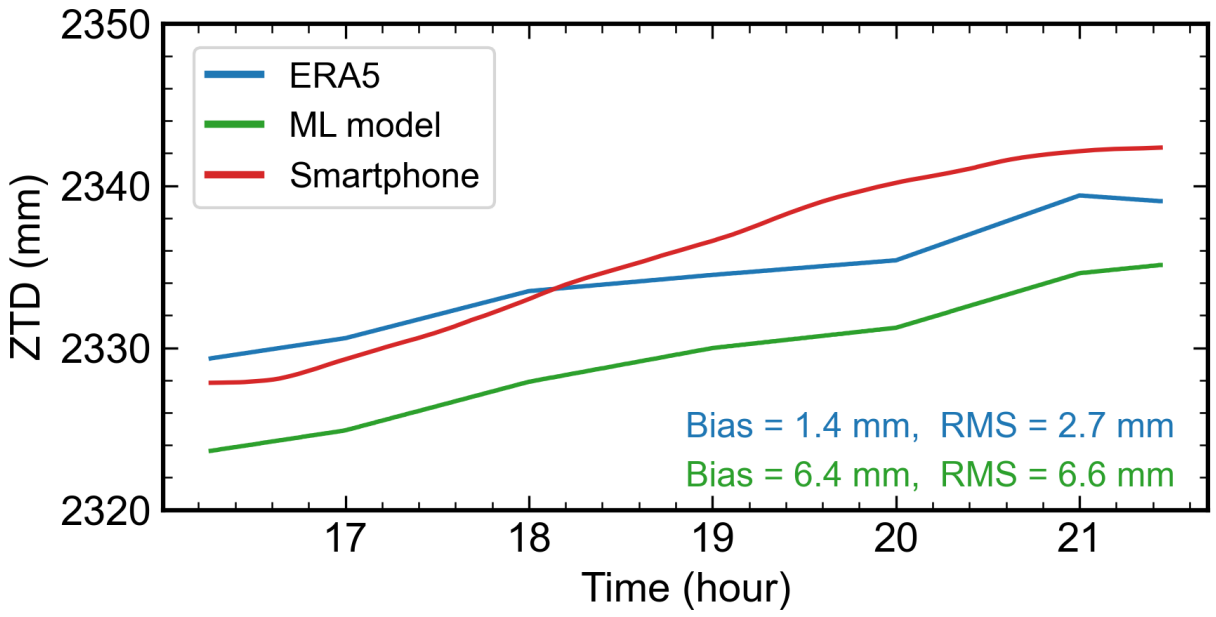
Location: Germany

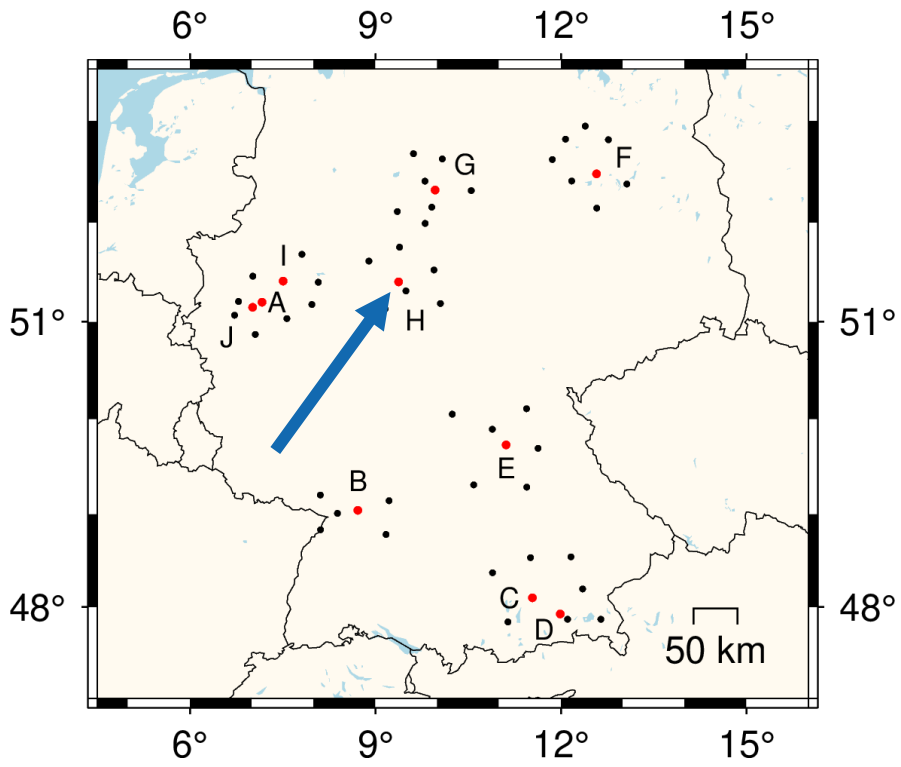


Reference: IGS global ionospheric map

Troposphere parameter estimation with campaign data

Method: PPP with external ionospheric correction





Reference 1: Vertical integration of ERA5
Reference 2: Machine learning model based on GNSS data and ERA5

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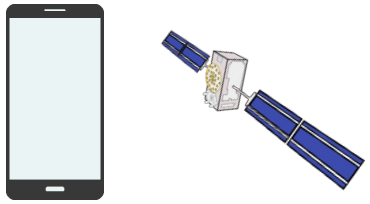

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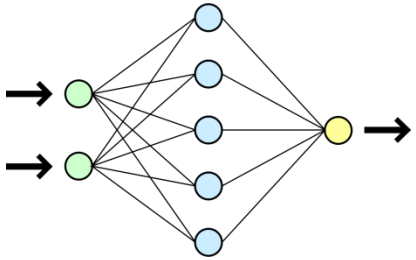


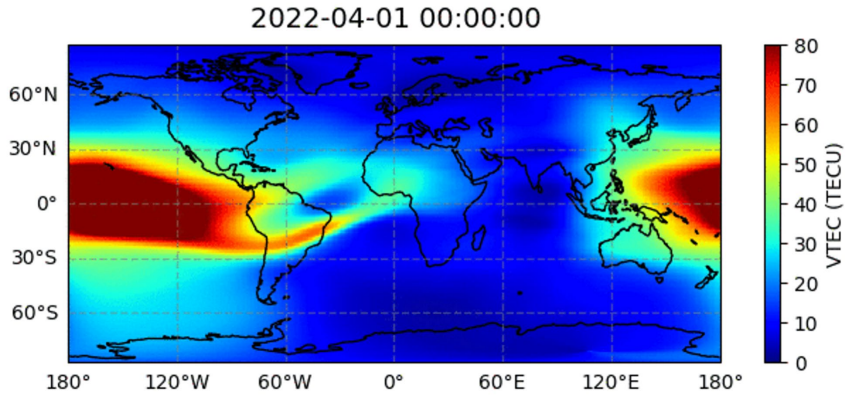
3. Science use cases
   - Troposphere – Earth weather
   - Ionosphere – space weather

Modeling and predicting atmospheric parameters with machine learning

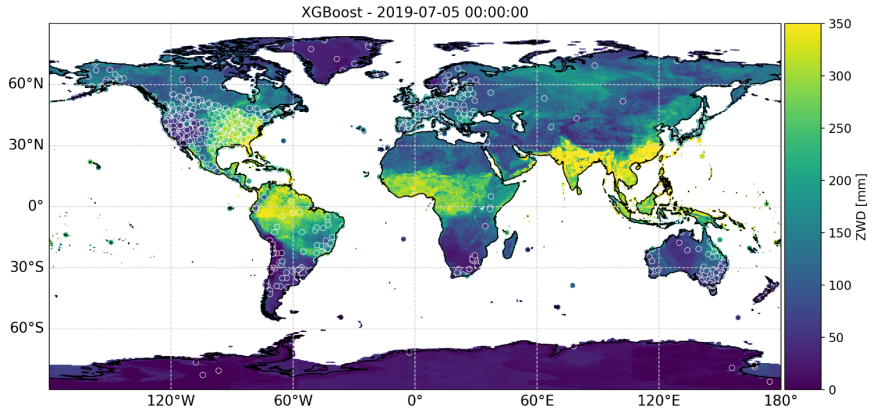
- Goal: data fusion with machine learning
  - Smartphone GNSS data
  - Geodetic GNSS data
  - Environmental data, models, indices
- Tasks:
  - Temporal prediction
  - Spatial modeling
- Domains:
  - Ionosphere
  - Troposphere

4 Science Use Cases total, here:
- Spatial modeling of the troposphere

Ionospheric total electron content



Tropospheric zenith wet delay



Spatial prediction of tropospheric parameters

TARGET: Zenith Wet Delay (ZWD)

FEATURES: lat, lon, height, time, specific humidity on six pressure levels

ECMWF

DATA

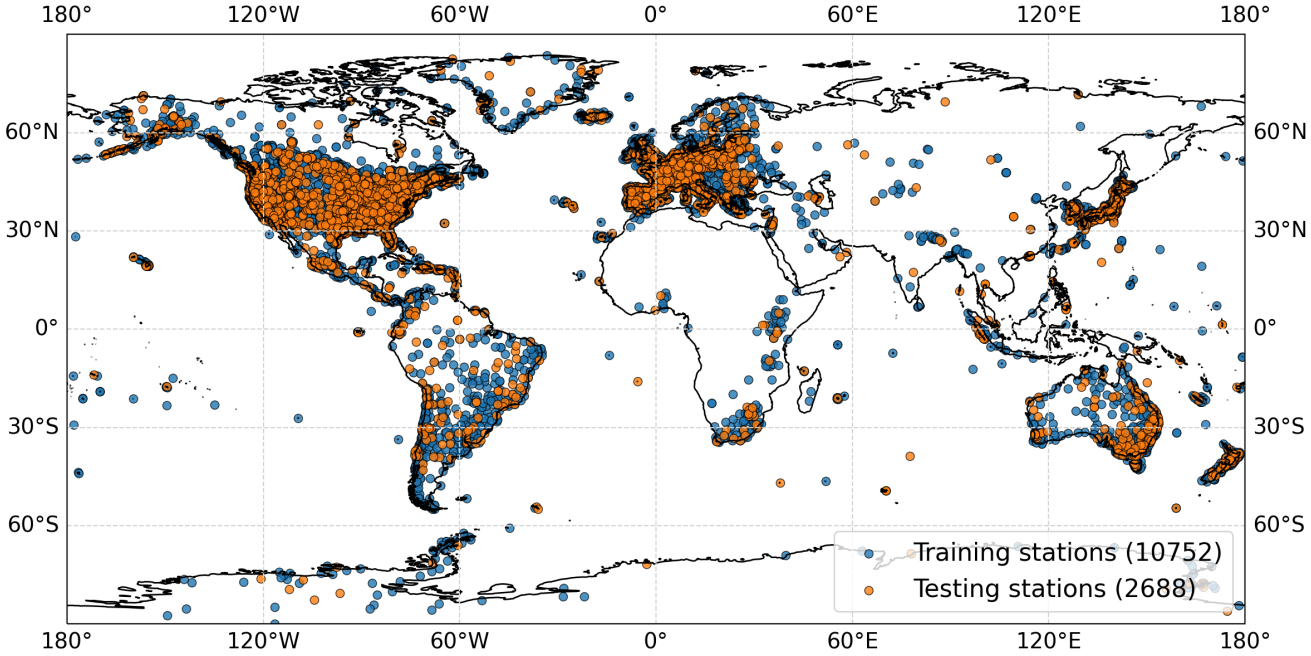
TRAINING STATIONS - 80%

TESTING STATIONS - 20%

ML ALGORITHM
- standardize features
- hyperparameter tuning
- cross-validation
- train model

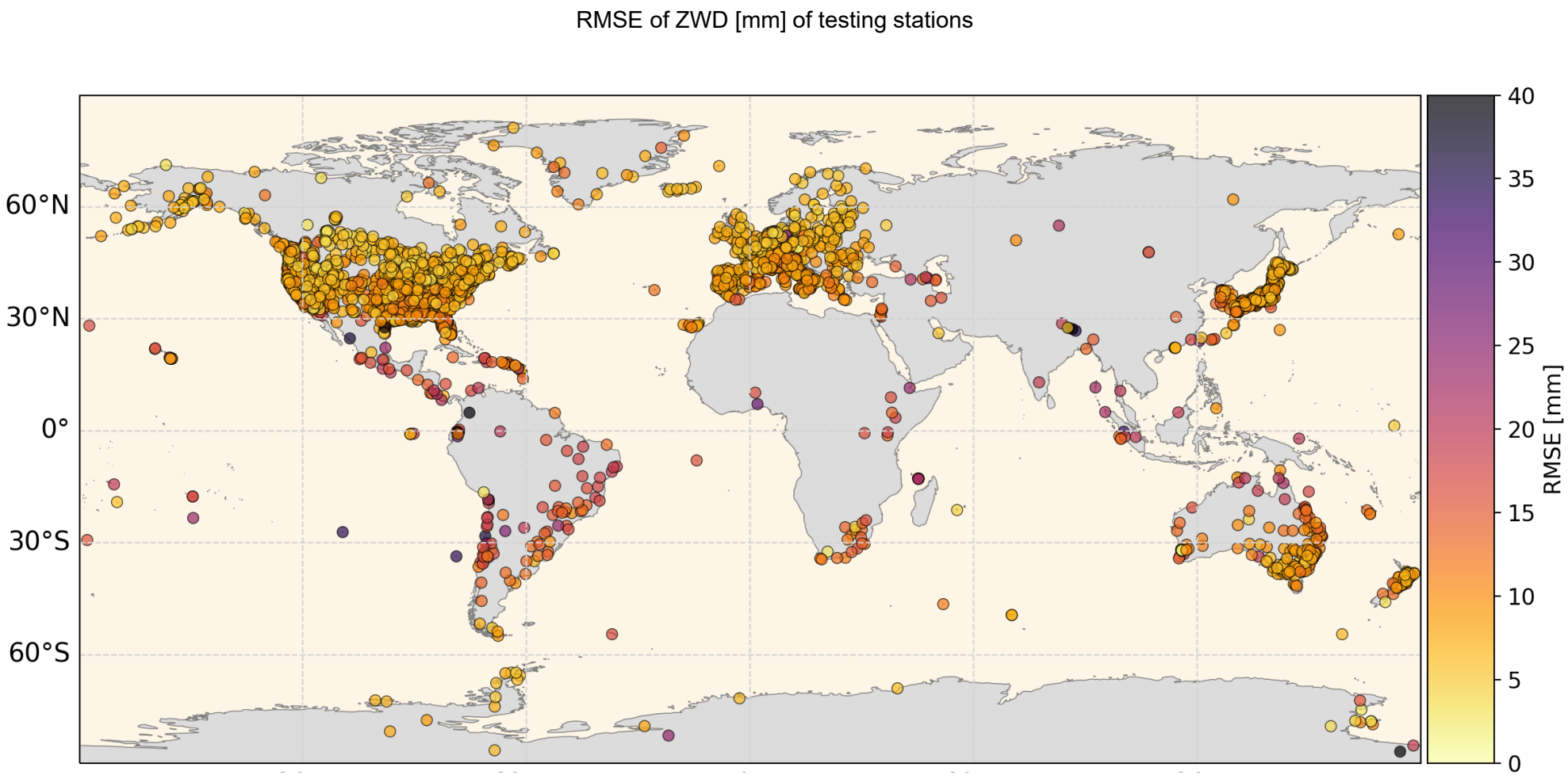
output: **ML model**

EVALUATION
- make ZWD predictions for testing data (y_test_pred)
- calculate performance metrics

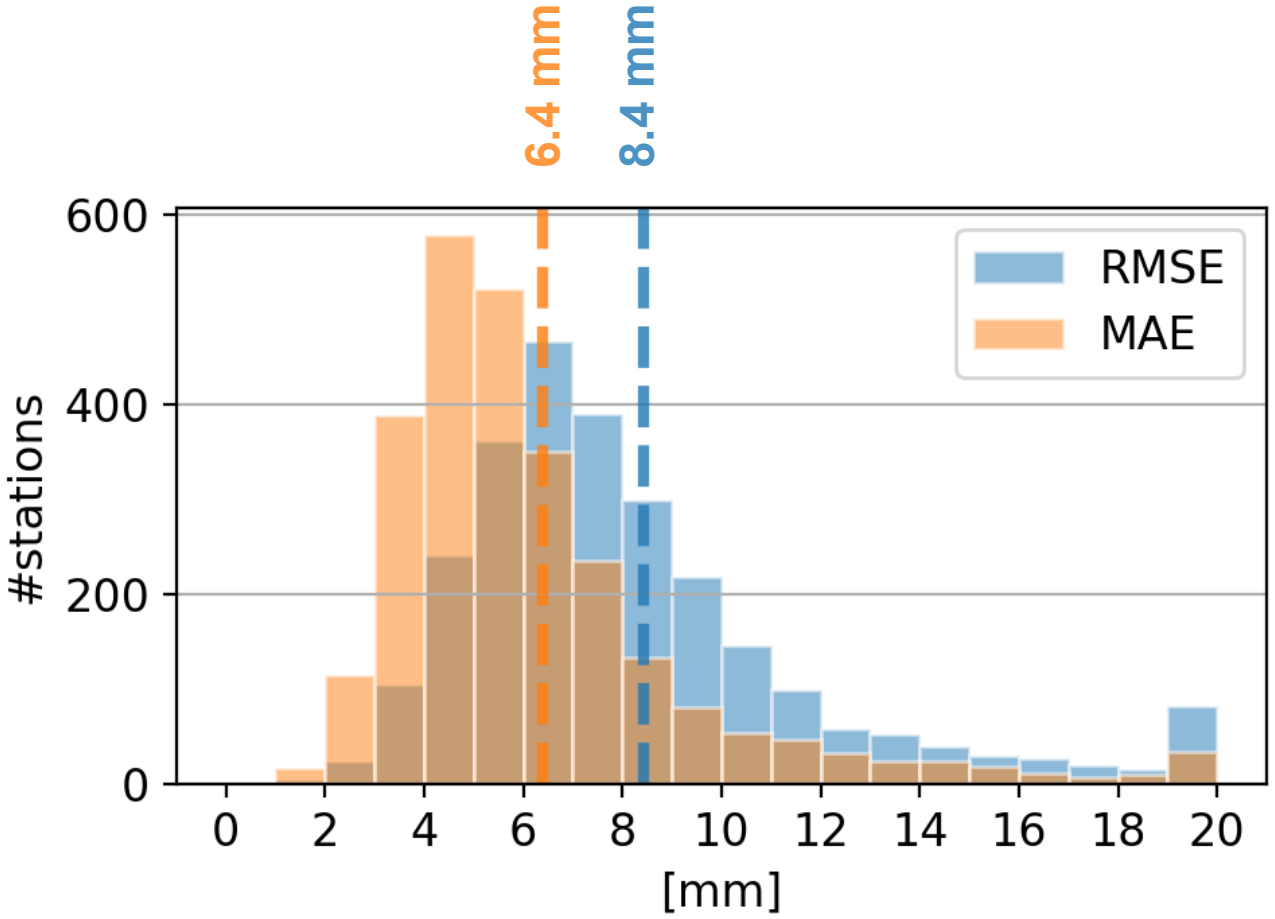


ML algorithms: **XGBoost**, Random Forest, MLP

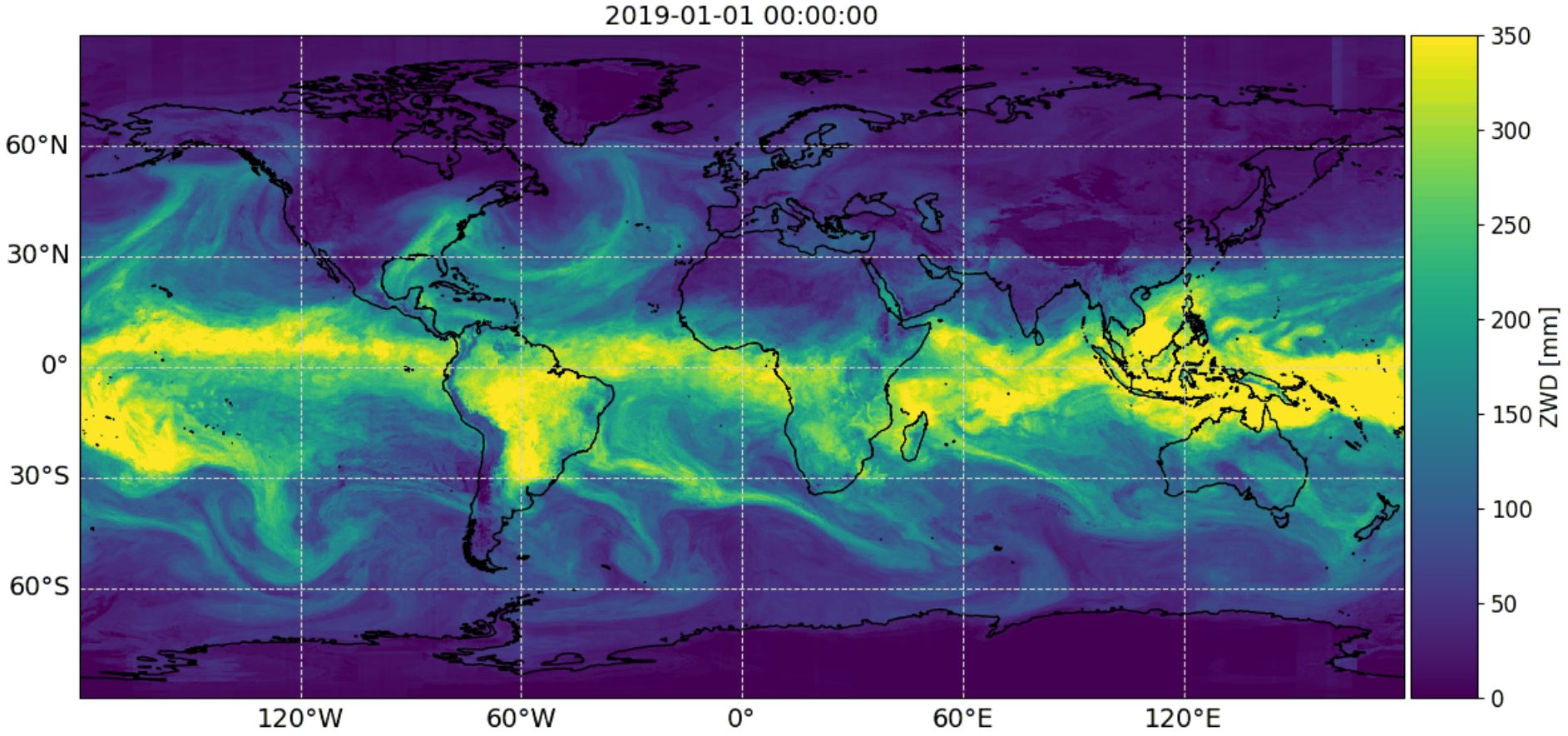
Performance of individual test stations



Performance of all test stations

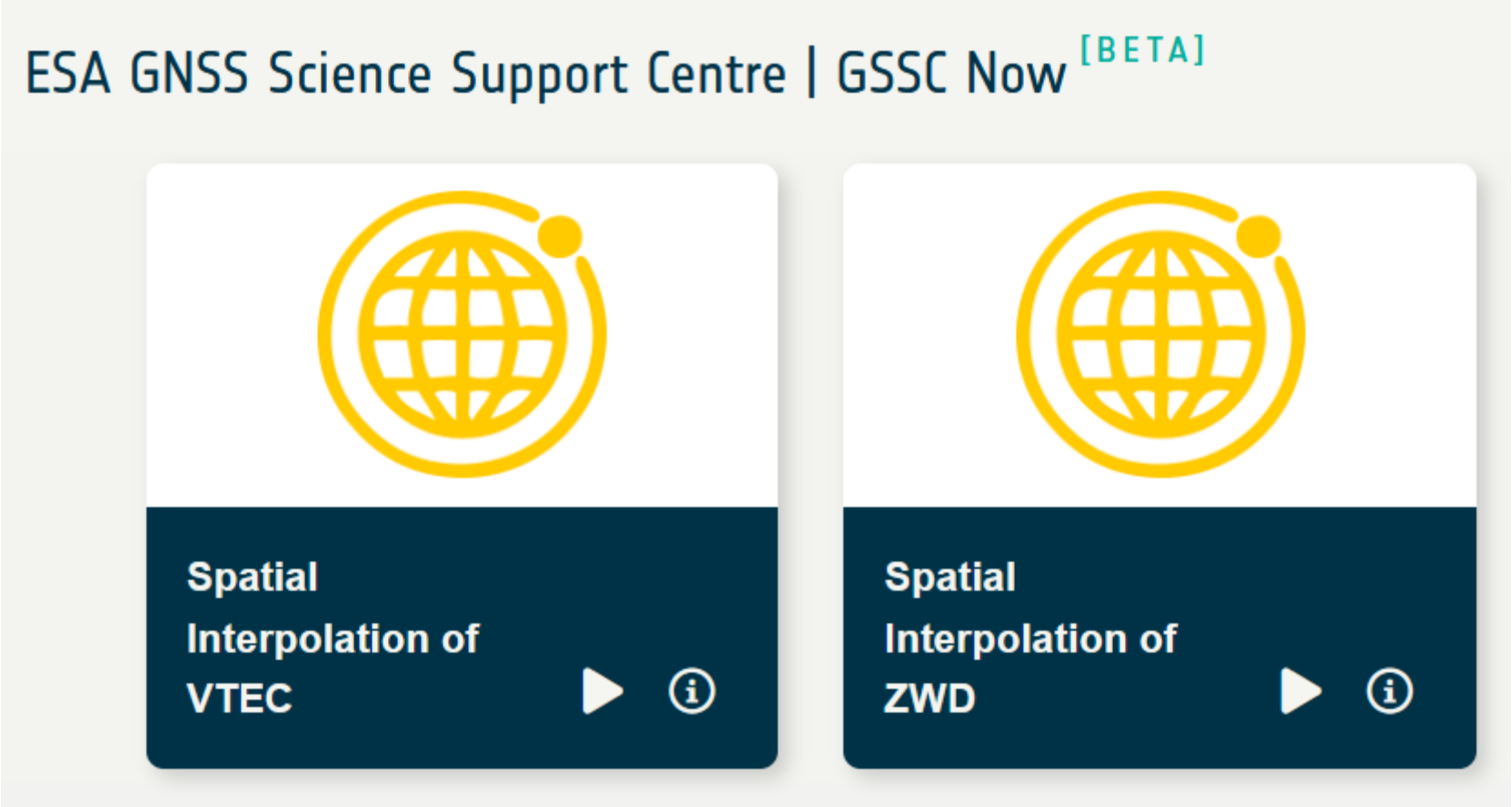


Global ZWD predictions



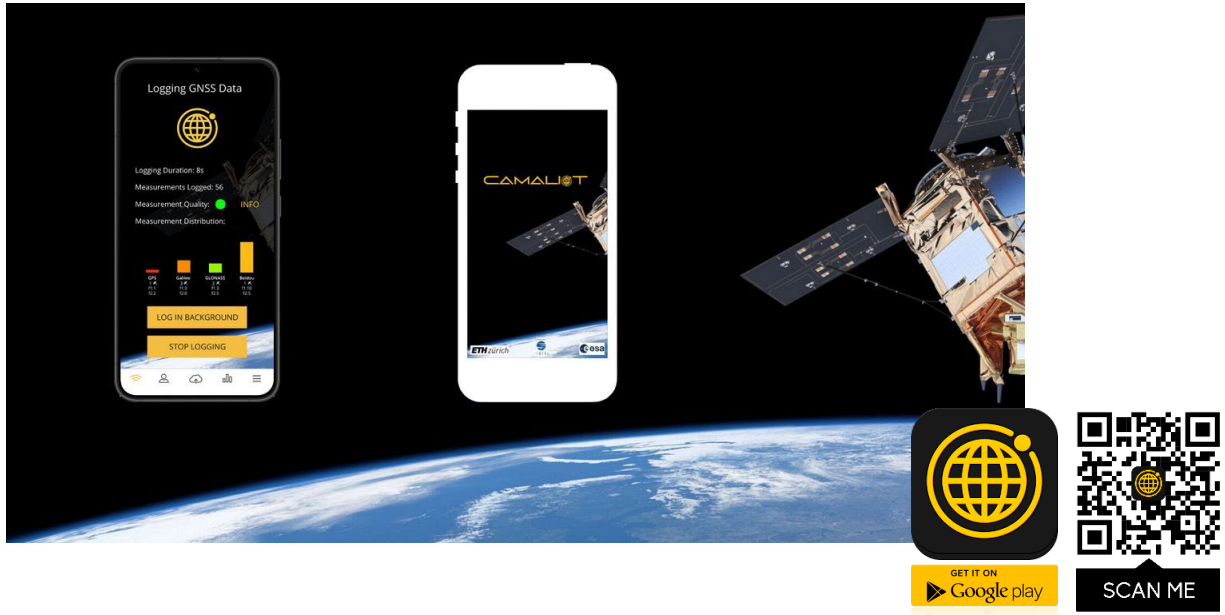
CAMALIOT Datalabs on ESA GSSC

https://gssc.esa.int



Summary

- **Crowdsourcing** campaign for collection of GNSS community data – **still ongoing**!
- **GNSS big data** processing framework
- Determination of **atmospheric parameters** from smartphones
- **Fusion of GNSS data** and models related to the atmosphere with machine learning
- **Potential of smartphone data clearly demonstrated** → exploring follow-up activities



https://camaliot.org

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Thanks for your attention!

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Institute of Geodesy and Photogrammetry

Chair of Space Geodesy

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