HIGH-SPATIAL-RESOLUTION GROSS PRIMARY PRODUCTION ESTIMATION USING SENTINEL-2 AND HYBRID GAUSSIAN PROCESSES MODELING

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HIGHLIGHTS

- Developing **hybrid GPR models** for **high-spatial-resolution (20m)** Gross Primary Productivity (**GPP**) from **Sentinel-2** (S2) reflectance.
- Optimizing **Gaussian processes regression** (GPR) models with **Active Learning** (AL) for **10 Plant Functional Types** (PFTs)-specific models.
- Validation against **67 eddy-covariance** (EC) flux towers accros Europe (2017-2024 ICOS data).
- Intercomparison with **MODIS GPP.**
- Scalable workflow in **Google Earth Engine** (GEE) for accessible local GPP/carbon monitoring..

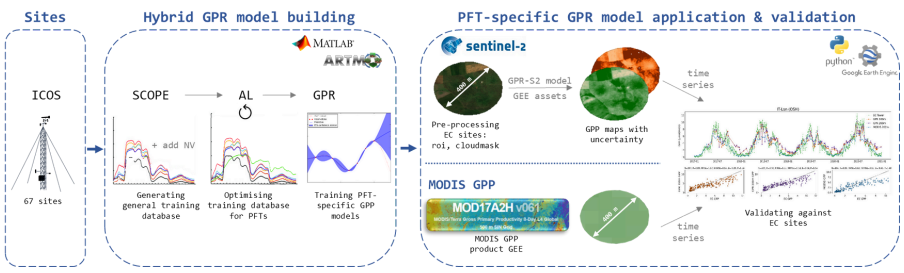
1 INTRODUCTION

Problem: Accurate, high-resolution GPP is crucial for local carbon monitoring, especially in heterogeneous landscapes where global products lack spatial detail.

Challenge: Developing scalable, fine-resolution GPP models that capture ecosystem-specific dynamics is complex.

Objective: To develop and validate novel, PFT-specific high-sptial-resolution GPP models from Sentinel-2 (S2) data using a hybrid Gaussian Process Regression (GPR) approach for cloud deployment.

2 MATERIALS AND METHODS

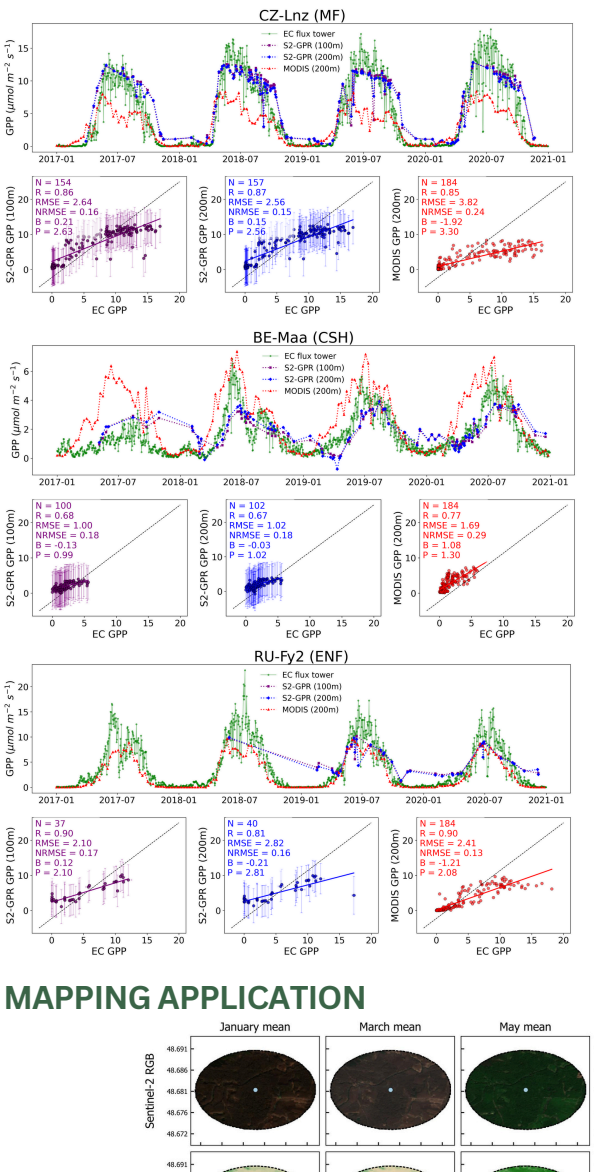


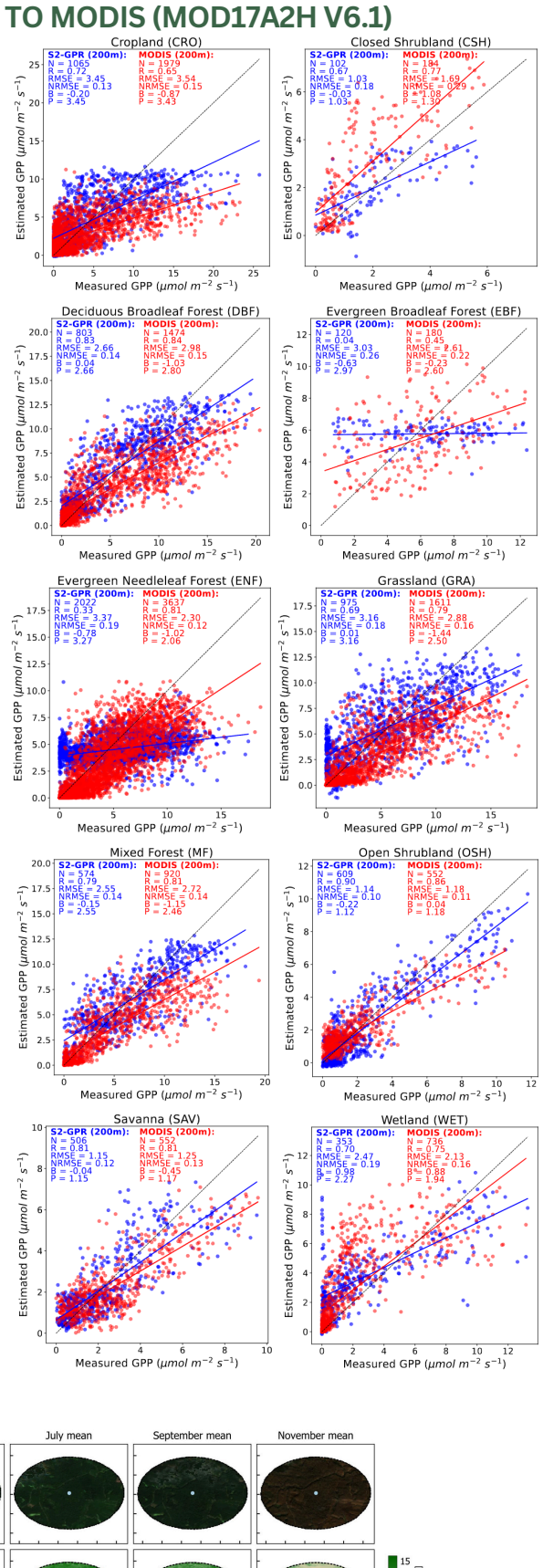
- **Data**
  - **Sentinel-2** surface reflectance: high-spatial resolution optical imagery.
  - **EC fluxtower data**: ground data from 67 EC sites across Europe (2017-2020 for tuning AL and testing; 2021-2024 for independent validation).
  - **SCOPE Radiative Transfer Model**: to generate a general simulated training dataset (5000 samples).
- **Hybrid GPR approach**
  - **PFT-specific models**: AL-optimized SCOPE database resulting in 10 distinct PFT-specific training data.
  - **Gaussian Process Regression** (GPR): Bayesian machine learning for robust GPP estimation with uncertainty.
- **Application**
  - Implementation of S2-GPR models in GEE and pyEOGPR package for **cloud-computing.**
  - Created **timeseries** to test/validate the models against ICOS EC data and MODIS GPP data.
  - Showcasing high-spatial-resolution **mapping** examples.

3 RESULTS AND DISCUSSION

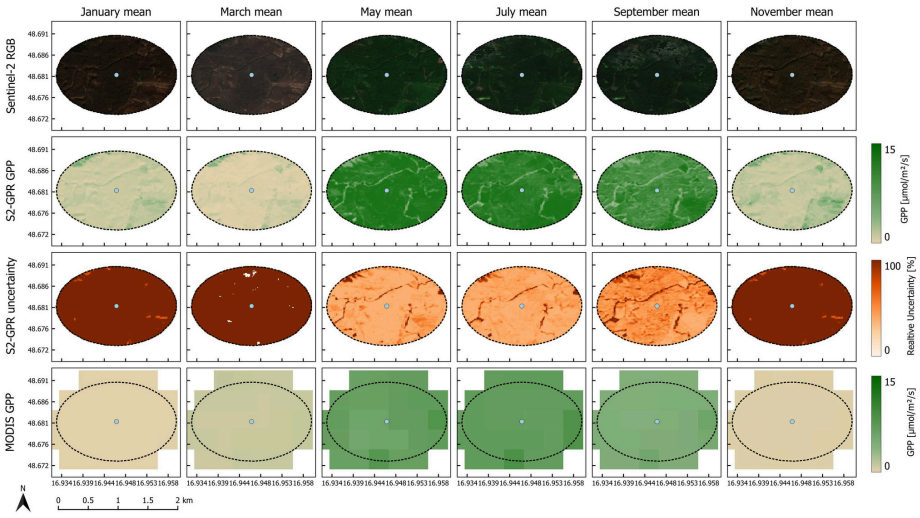
MODEL PERFORMACE & COMPARISON TO MODIS (MOD17A2H V6.1)

- Strong agreement
  - Deciduous Broadleaf Forests
  - Savannas
  - Croplands
  - Open Shrublands
  - Mixed Forests
- Intermediate accuracy
  - Closed Shrublands
  - Grasslands
  - Wetlands
- Lower performance
  - Evergreen Needleleaf Forests
  - Evergreen Broadleaf Forests





MAPPING APPLICATION



4 CONCLUSIONS

- Our S2-GPR models provide robust, high-spatial-resolution, PFT-specific GPP estimates, effectively complementing coarser global products and enabling detailed local carbon monitoring.
  - Hybrid approach (SCOPE + AL+GPR) is effective for PFT-specific GPP.
  - GEE deployment enables flexible, scalable local GPP mapping.
- Future directions: investigate purely data-driven models, ptentially with data synergy e.g. SIF, SAR, meteorological data...
  - Specifically for evergreen forests, other modeling strategies are required.

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