Implementation of Python Software for Estimating Vegetation Properties From Hyperspectral Satellite Data in the Prospect of CHIME

Viktor Ixion Mészáros[1,2*], Louis Trinkle[1,3], Dávid D.Kovács[1], José Luis García-Soria[1], Pablo Reyes-Muñoz[1], Ana Belén Pascual-Venteo[1] and Dr. Jochem Verrelst[1]

1. Image Processing Laboratory (IPL), Universitat de València, C/Catedrático José Beltrán, 2, 46980 Paterna, Spain
2. Department of Space, Earth and Environment (SEE), Chalmers University of Technology, Hörsalsvägen 9, 41258 Gothenburg, Sweden
3. Institute for Earth System Science and Remote Sensing, University of Leipzig, Talstraße 35, 04103 Leipzig, Germany

*Contact: viktor.meszaros@uv.es

Digital version

Materials and Methods

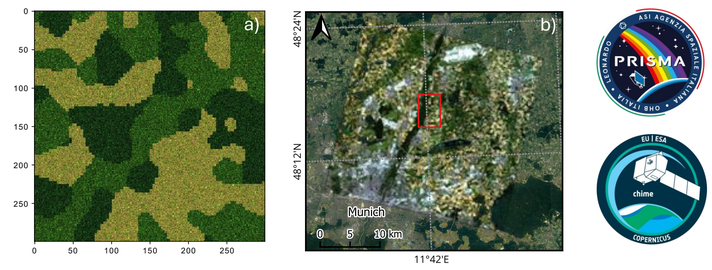

Figure 1. BOA reflectance data from: a) simulated CHIME (L2A), provided by CHEES b) PRISMA scene (L2D), taken in 2020 August

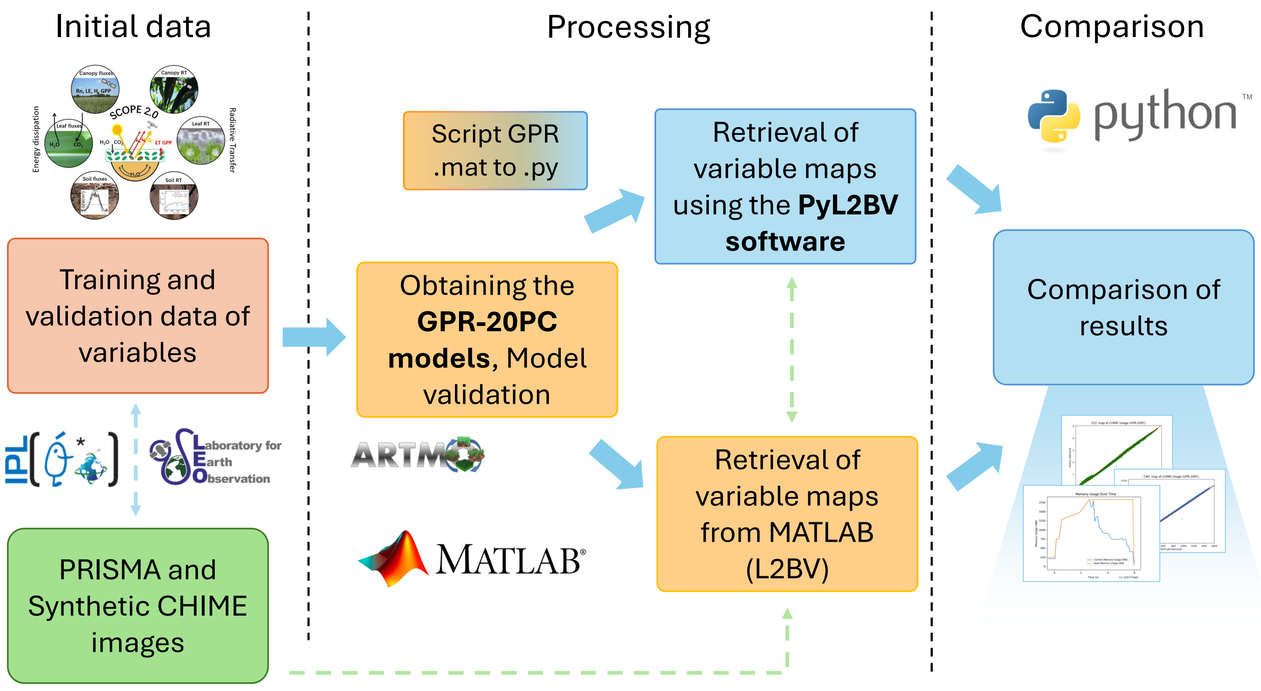

Figure 2. Overview of the complete processing workflow used in the study

GPR models were trained using **hybrid approaches** with simulated datasets from **radiative transfer models (RTM)** by the **Soil Canopy Observation Photochemistry and Energy fluxes (SCOPE)** model. Datasets were further optimized with active learning, and **principal component analysis (PCA)** was used for dimensionality reduction. [4]

Models were obtained for **canopy vegetation traits**: Leaf Area Index (LAI), Canopy Chlorophyll Content (CCC), Canopy Water Content (CWC), the Fraction of Absorbed Photosynthetic Active Radiation (FAPAR), and Fractional Vegetation Cover (FVC). [5]

All **models were trained and validated in ARTMO**, using in-situ data collected from Grosseto (Italy) and Munich North Isar (MNI) field campaigns for LAI, CCC, CWC, and theoretical cross validation for FAPAR and FVC due to lack of available data.

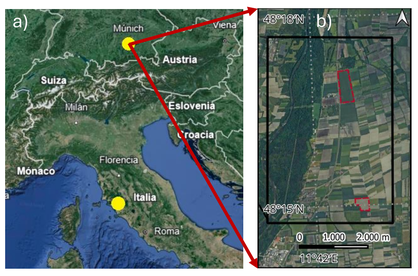

Figure 2. a) Location of field campaigns and b) the MNI site

PyL2BV

`pip install pyl2bv`

PyL2BV (Python Level-2B Vegetation) is a **Python software package** for processing **ARTMO-based models on satellite images**.

Key Features:

- Command-Line Interface (**CLI**) and Graphical User Interface (**GUI**)
- Supported **input image** formats: **ENVI Standard**, CHIME netCDF
- **Performing PCA** for **hyperspectral images**
- **GPR retrieval** for vegetation parameters
- Customizable **chunk-based parallel** retrieval
- Supports **large-scale** image **processing**
- **Automated** ENVI and NetCDF **exports**

https://github.com/mv-xion/PyL2BV

Figure 4. GUI with input parameters

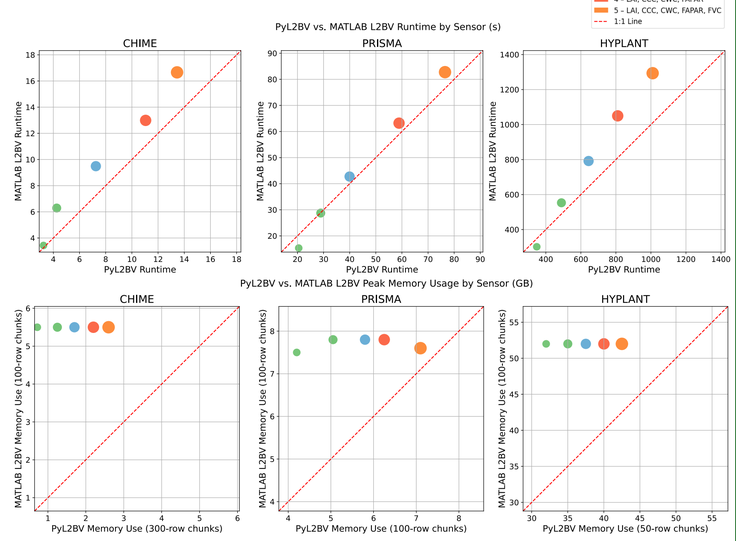

Figure 5. General steps to obtain the models and use the PyL2BV software for the retrievals

Figure 6. a) Runtime and b) Memory use comparison of PyL2BV and MATLAB L2BV for 3 different image sizes

Introduction

- The **CHIME** mission will deliver **routine hyperspectral data** to support sustainable agriculture, climate change mitigation [1]
- At the University of Valencia's Image Processing Laboratory (IPL), the **Level-2B Vegetation (L2BV) module** for CHIME is being implemented to retrieve vegetation-related biophysical variables **in MATLAB**, a commercial software [2]
- ESA **prefers open-source solutions**, prompting a shift away from MATLAB for operational processors
- To meet this requirement, the **PyL2BV software package** has been developed in Python, providing an open-source alternative
- PyL2BV uses models from the ARTMO Toolbox, and a **Python-based** Gaussian Process Regression (**GPR**) retrieval method [3]
- The aim is to **evaluate the accuracy and efficiency** of the PyL2BV software, with a focus on its GPR retrieval capabilities

Results

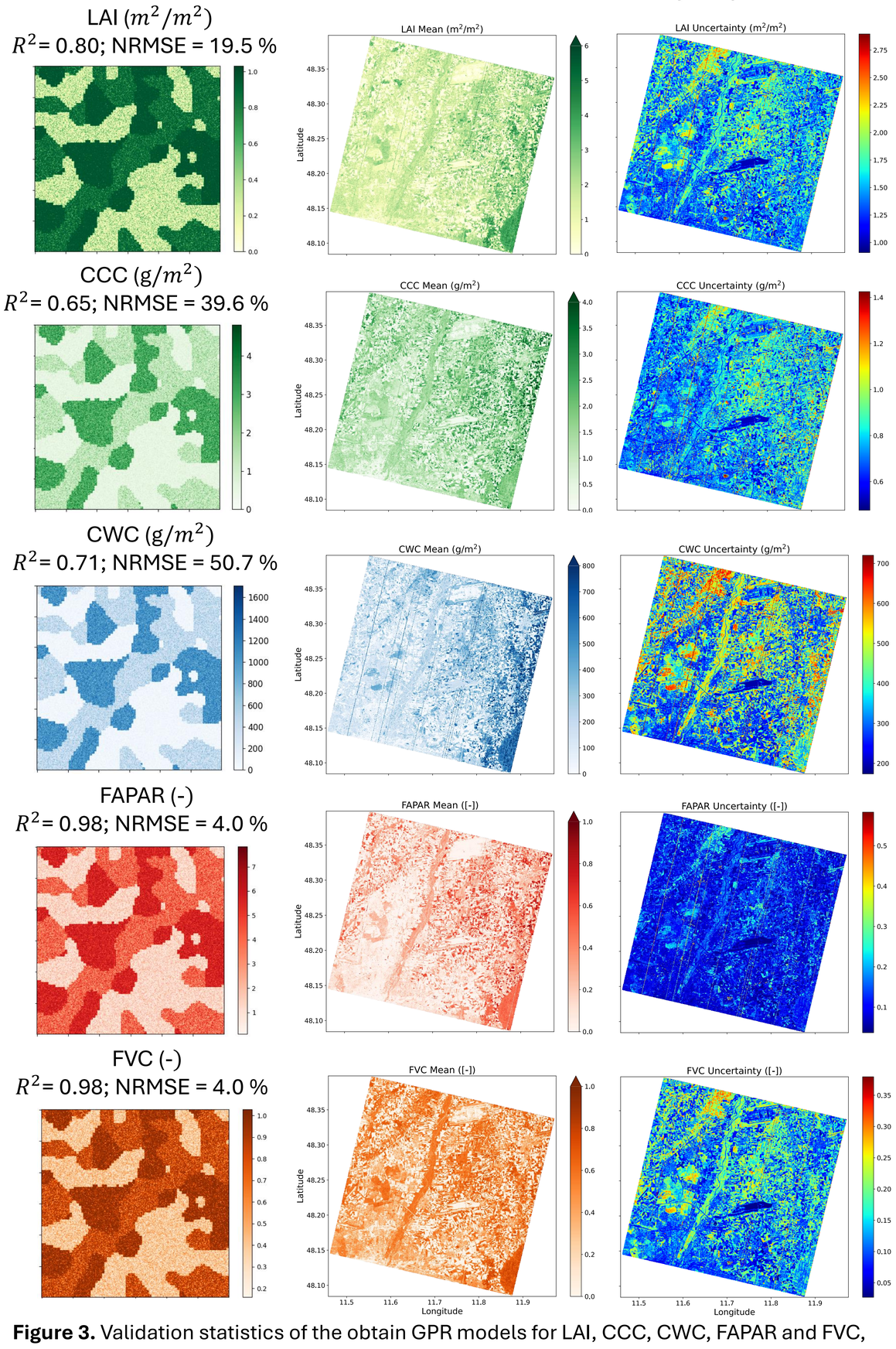

Figure 3. Validation statistics of the obtain GPR models for LAI, CCC, CWC, FAPAR and FVC, result after applied to hyperspectral images of simulated CHIME (left) and PRISMA (right) scenes. For the PRISMA scene both Mean and Uncertainty estimates are shown

Conclusions

- **PyL2BV was successfully developed** for the retrieval of biophysical variables using ARTMO-trained models **for hyperspectral images**
- **Strong model performance** allowed for accurate retrievals and **fair comparison**
- While producing the **same results**, PyL2BV demonstrated **notable computational advantages** over MATLAB L2BV for the GPR retrievals, both **in runtime and memory usage**, due to its **configurable chunk size and parallel processing**

Limitations and Opportunities of PyL2BV:

- Only works with GPR, **more MLRAs** need to be **implemented**
- **No corrupted pixel correction** was incorporated at this stage
- Heavy images need to be **stored locally**
- Could be a **base for** future **operational processors** like CHIME

References and Acknowledgements

[1] Celesti, M., Rast, M., Adams, J., Boccia, V., Gascon, F., Isola, C., & Nieke, J. (2022). The Copernicus Hyperspectral Imaging Mission for the Environment (CHIME): Status and planning. In 2022 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) (pp. 5011–5014). IEEE. https://doi.org/10.1109/IGARSS46834.2022.9883592

[2] Verrelst, J., De Grave, C., Amin, E., Reyes, P., Morata, M., Portales, E., Belda, S., Tagliabue, G., Panigada, C., Boschetti, M., Candiani, G., Segl, K., Guillasso, S., Berger, K., Wocher, M., Hank, T., Rascher, U., & Isola, C. (2021). Prototyping vegetation traits models in the context of the hyperspectral CHIME mission preparation. In 2021 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) (pp. 7678–7681). IEEE. https://doi.org/10.1109/IGARSS47720.2021.9554407

[3] Pipia, L., Muñoz-Marí, J., Amin, E., Belda, S., Camps-Valls, G., & Verrelst, J. (2019). Fusing optical and SAR time series for LAI gap filling with multioutput Gaussian processes. Remote Sensing of Environment, 235, 111452. https://doi.org/10.1016/j.rse.2019.111452

[4] Verrelst, J., Malenovský, Z., Van der Tol, C., Camps-Valls, G., Gastellu-Etchegorry, J. P., Lewis, P. E., North, P. R. J., & Moreno, J. (2019). Quantifying vegetation biophysical variables from imaging spectroscopy data: A review on retrieval methods. Surveys in Geophysics, 40, 589–629. https://doi.org/10.1007/s10712-018-9478-y

[5] Pascual-Venteo, A. B., Garcia, J. L., Berger, K., Estévez, J., Vicent, J., Pérez-Suay, A., Van Wittenberghe, S., & Verrelst, J. (2024). Gaussian process regression hybrid models for the top-of-atmosphere retrieval of vegetation traits applied to PRISMA and EnMAP imagery. Remote Sensing, 16(7), 1211. https://doi.org/10.3390/rs16071211

Thanks to:
PANGEOS - Conference grants for young researchers and innovators

Supported by the European Union (European Research Council, FLEXINEL, 101086622) project.