Crop trait retrieval from EnMAP hyperspectral data using radiative transfer modeling and machine learning

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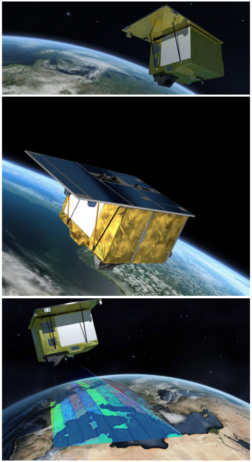
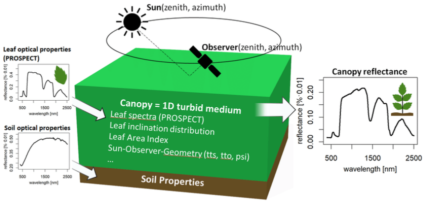
Introduction

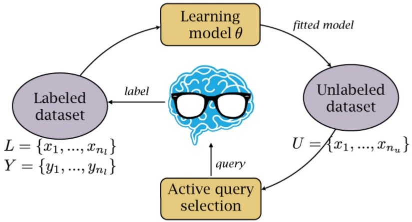
- EnMAP is exceptionally high spectral data availability in the visible and near-infrared (VNIR) domain (420-1000 nm) and (SWIR) domain (900-2450nm) allows preparing efficient and accurate models for retrieval of different vegetation traits.
- In our study we will focus on leaf area index (LAI), canopy water content (CWC), fraction of absorbed photosynthetically active radiation (FAPAR), fraction of vegetation cover (FVC), canopy chlorophyll (CCC)
- This study leverages the EnMAP mission to develop hybrid models based on Gaussian Process Regression (GPR), trained on data simulated by SCOPE, both at Bottom of Atmosphere (BOA) and Top of Atmosphere (TOA).



RTM PROSAIL-PRO and Active Learning

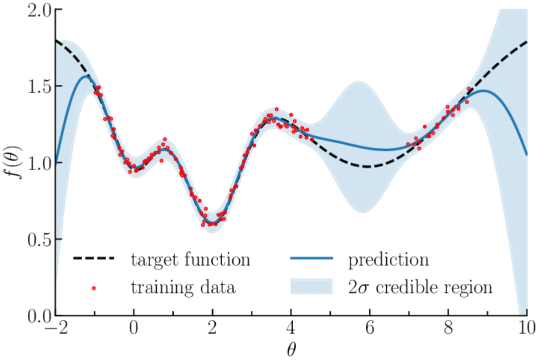


RTM PROSAIL-PRO Scheme of PROSAIL, coupling the leaf RTM PROSPECT-PRO and the bidirectional canopy reflectance model 4SAIL



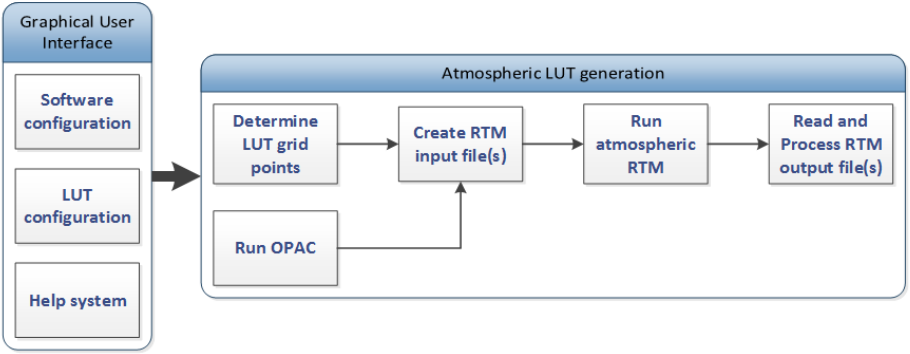
Active Learning (AL) goal: Improve results by reducing and optimizing labeled data for model training.

Gaussian Processes



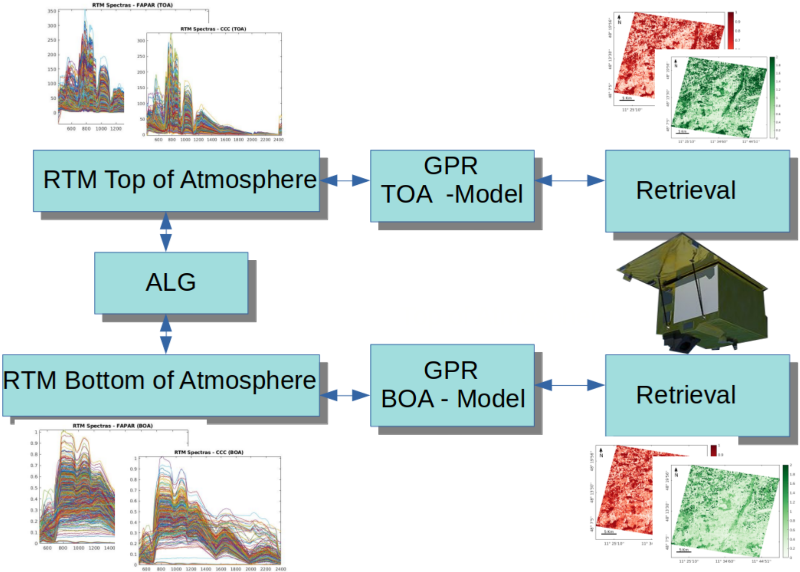
- AL strategy was Euclidean distance-based diversity
- Learning model was Gaussian Process Regression
- Both AL and GPs have been done through ARTMO toolbox! https://artmotoolbox.com/

Atmospheric Look-up table Generator (ALG)



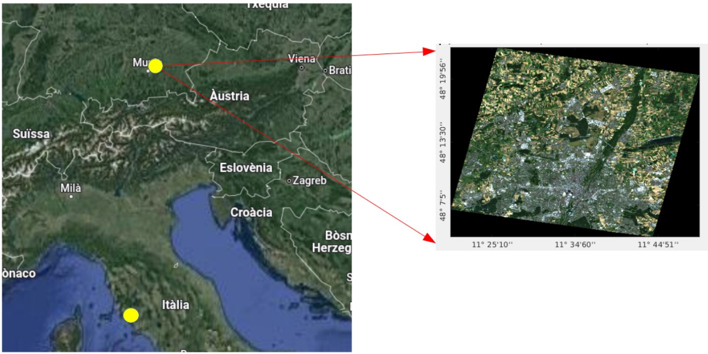
- ALG generate & analyse LUTs based on a suite of atmospheric RTMs
- ALG is developed for automated running of atmospheric RTMs: **libRadtran**
- ALG express the RTM LUT in the top-of-atmosphere through the corresponding atmospheric transfer functions

Workflow



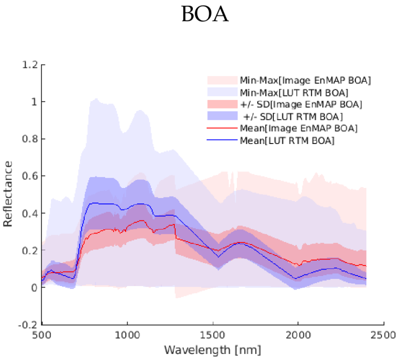
RTM Spectras - FAPAR (TOA)
RTM Spectras - CCC (TOA)
RTM Top of Atmosphere
GPR
TOA -Model
Retrieval
ALG
RTM Bottom of Atmosphere
GPR
BOA - Model
Retrieval
RTM Spectras - FAPAR (BOA)
RTM Spectras - CCC (BOA)

Data set and Experiments

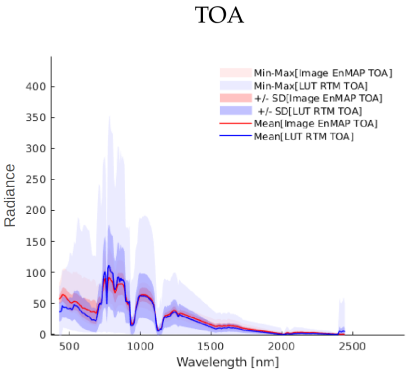


- EnMAP scene at North of Munich, Germany (12/11/2022). The Grosseto and MNI test sites are also indicated as yellow dots(validation with in situ data using earlier scene).
- *LUT* was generated with SCOPE, $N = 2000$ samples
- After AL we obtained an optimal set of $n = 400$ samples
- PROSAIL-PRO simulated reflectance was resampled to match with CHIME resolution

Spectra descriptive statistics



Spectral contrast in BOA between EnMAP image and RTM



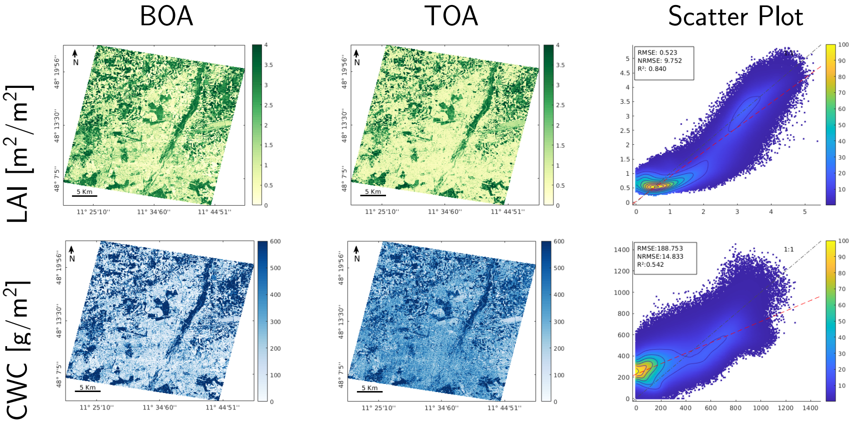
Spectral contrast in TOA between EnMAP image and RTM

BOA Validation results

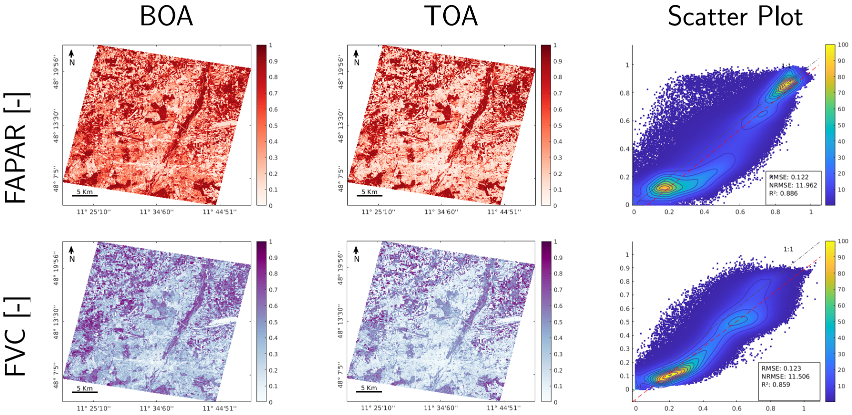
Variable	Samples	RMSE	RRMSE	NRMSE	R^2
LAI	526	0.975	46.310	16.255	0.855
CWC	526	194.419	30.781	9.149	0.823
FAPAR	1036	0.035	4.546	3.644	0.980
FVC	1036	0.038	5.083	3.890	0.981
CCC	409	0.490	28.709	8.150	0.864

Goodness-of-fit statistics in Grosseto and MNI in situ data sets (and theoretical results for FVC and FAPAR) achieved with methodology GPR-20PCA

EnMAP retrieval results: LAI and CWC



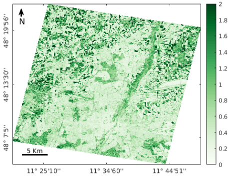
EnMAP retrieval results: FAPAR and FVC



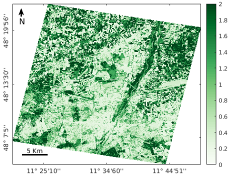
EnMAP retrieval results: CCC

CCC $[g/m^2]$

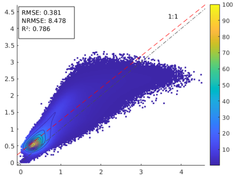
BOA



TOA



Scatter Plot



Variable	RMSE	NRMSE	R^2
LAI	0.52	9.75	0.84
CWC	188.75	14.83	0.54
FAPAR	0.12	11.96	0.88
FVC	0.12	11.50	0.86
CCC	0.38	8.47	0.79

Numerical results of BOA and TOA scatter plots

Conclusions & Future work

- We presented a valid methodology to retrieve five vegetation variables: LAI, CWC, FAPAR, FVC, CCC, both in BOA and TOA
- Results in BOA were validated with in-situ data achieving good performance
- TOA models were checked against validated BOA models reporting good coefficient of determination values: $0.54 \leq R^2 \leq 0.87$
- Overall, the consistency between BOA and TOA results confirms the feasibility of directly estimating vegetation characteristics from TOA radiance data.
- Building models directly from TOA radiance circumvent critical atmospheric corrections could simplify the work and avoid error propagation in subsequent retrieval processes.
- Future work: enrich the set of studied variables along with the use of time series EnMAP imagery
- # Thank you for your attention!!

  questions to ana.b.pascual@uv.es

References I