EVALUATING SENTINEL-3 VIABILITY FOR VEGETATION CANOPY MONITORING AND FUEL MOISTURE CONTENT ESTIMATION

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Abstract

The main objectives of the Sentinel-3 mission are to support ocean forecasting systems, environmental monitoring and climate monitoring. However, the coverage of the visible, near-infrared and short-wave infrared portion of the electromagnetic spectrum with a 300 meter resolution and a revisit period of less than 2 days make it very appealing also for vegetation monitoring. In this paper we explore the possibility of using the Sentinel-3 Synergy surface directional reflectances and the PROSAIL model to reliably estimate biophysical variables in general and live fuel moisture content in particular. The latter is a fundamental variable in fire behaviour models and in fire danger assessment, and consequently of high interest in fire management activities. We performed a Global Sensitivity Analysis to identify the most significant PROSAIL parameters in each Synergy channel, and tested the results by implementing a simple Look-Up Table based retrieval algorithm. The results show the potential of biophysical parameter estimation based on this Sentinel-3 product.

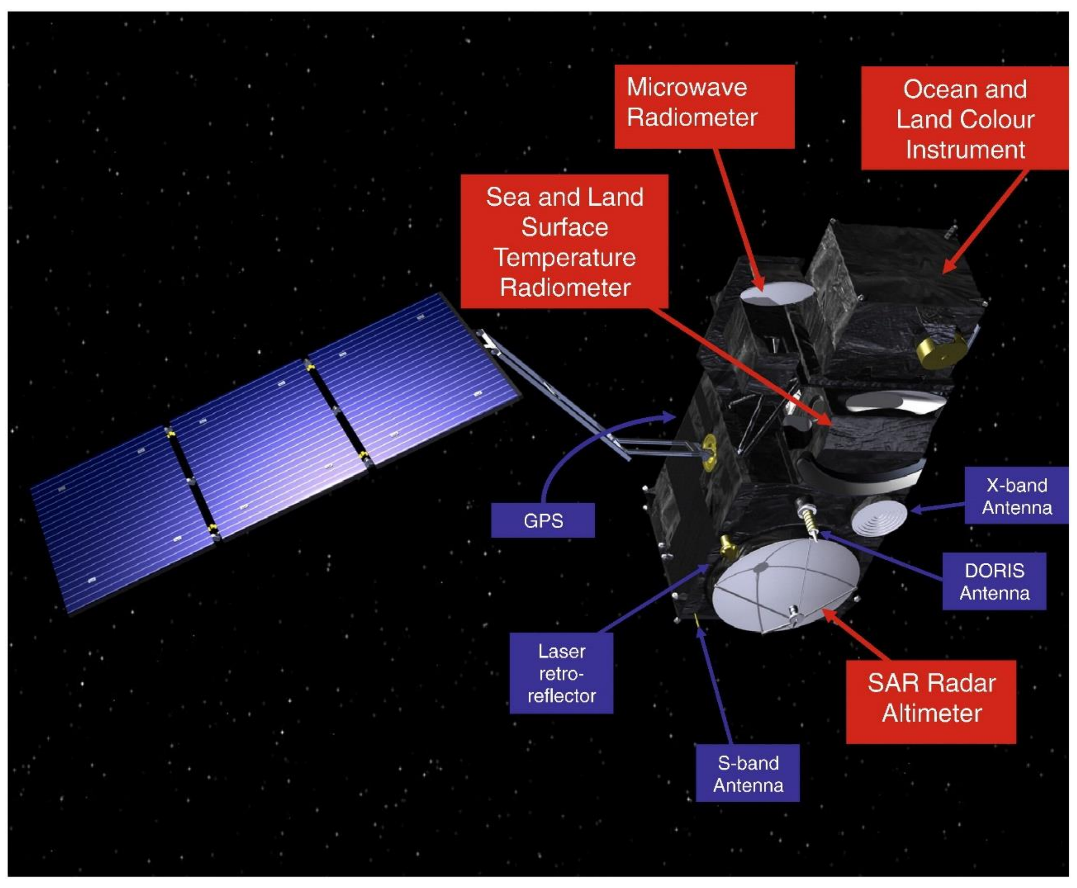
The Sentinel-3 Platform...

- **Ocean and Land Color Instrument (OLCI)** → 21 spectral bands in the VNIR between 400 and 1020 nm
- **Sea and Land Surface Temperature Radiometer (SLSTR)** → 9 spectral bands in the VNIR/SWIR/TIR between 0.55 and 10.85 µm
- 300 meter spatial resolution
- Less than 2 days revisit time

...and the SYNERGY Products

- All OLCI channels except Oa13-15, 19, 20
- SLSTR Nadir S1-S3, S5-S6
- SLSTR Oblique S1-S3, S5-S6

Attractive platform for vegetation monitoring



Live Fuel Moisture Content

- Staple variable in fire behaviour models and fire danger indices

$$LFMC_{\%} = 100 \cdot \frac{Fresh\ Weight - Dry\ Weight}{Dry\ Weight}$$

- Can be calculated on-field with gravimetric techniques (costly and time-consuming)

Strong interest in remotely sensed estimates

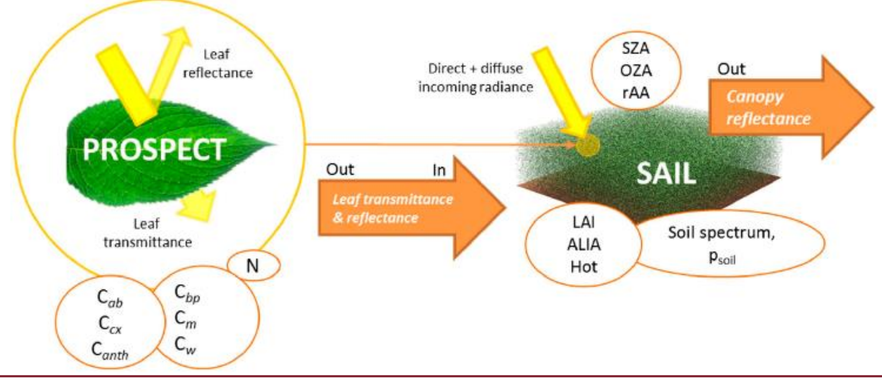
The Prospect + SAIL (PROSAIL) Model

PROSAIL is the result of the combination of:

- The **PROSPECT** leaf reflectance model
- The **Scattering by Arbitrarily Inclined Leaf (SAIL)** canopy bidirectional reflectance model

PROSPECT describes the leaf in terms of its **biochemical properties** and outputs leaf reflectance and transmittance.

These can be fed directly as inputs to the SAIL model, which describes the directional properties of plant canopy reflectance in terms of **canopy architecture**, soil characteristics and illumination conditions.



Estimating LFMC

Live Fuel Moisture Content can be calculated as the ratio of two PROSPECT input parameters: the water thickness C_w and the dry matter content C_{dm}:

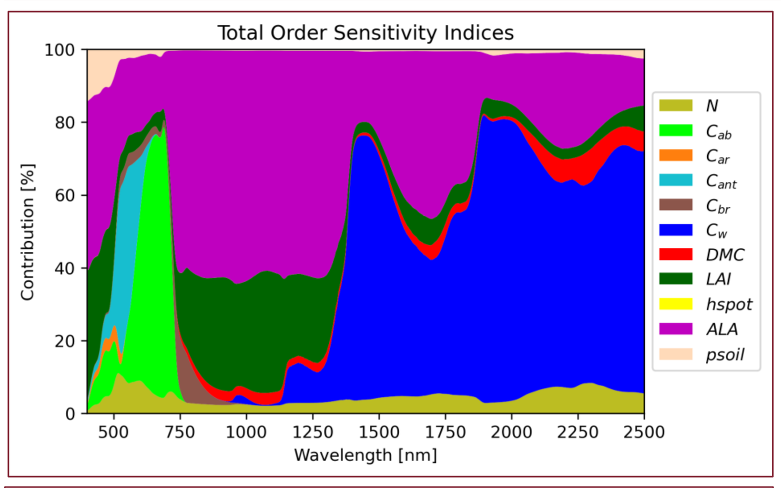
$$EWT = C_w \cdot \rho_w = \frac{Fresh\ Weight - Dry\ Weight}{Leaf\ Surface\ Area} = \frac{FW - DW}{A};\ C_{dm} = \frac{DW}{A}$$

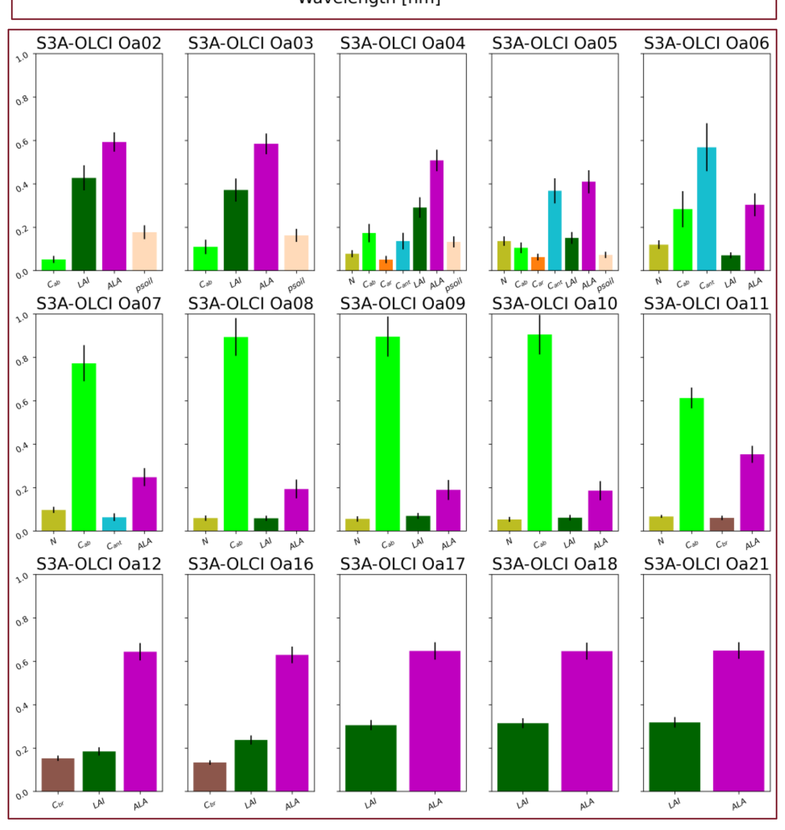
$$LFMC_{\%} = 100 \cdot \frac{EWT}{C_{dm}} = 100 \cdot \frac{\frac{FW - DW}{A}}{\frac{A}{DW}} = \frac{FW - DW}{DW}$$

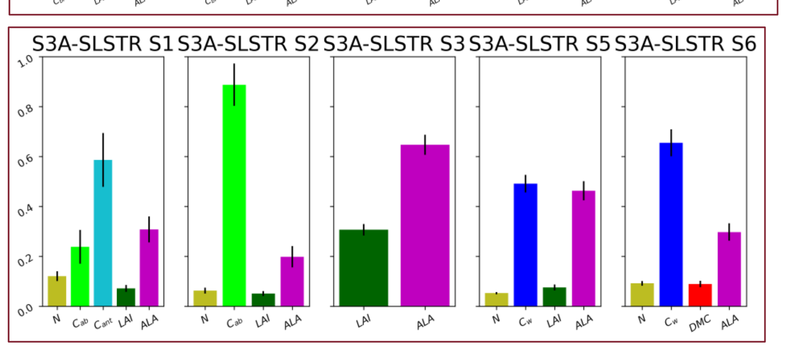
LFMC can be estimated from Top Of Canopy reflectances by inversion of the PROSAIL model

Global Sensitivity Analysis

Global Sensitivity Analysis (GSA) methods are a family of mathematical procedures that allow to discriminate the contribution of each individual parameter of a model into the resulting output, while at the same time accounting for interactions between parameters and non-linear effects. In the case of vegetation Radiative Transfer Models, GSAs have often been performed to determine which model parameters can be reliably estimated from remotely sensed data in general and for a specific sensor in particular. Using realistic input parameter boundaries for a grassland land cover, we performed a GSA and obtained total order sensitivity indices, which account for both the first-order effects and all the higher-order interactions. The results for the whole PROSAIL spectrum are shown in the stacked plot, while the bar plots contain the relevant total sensitivity indices for each of the SYNERGY channels.

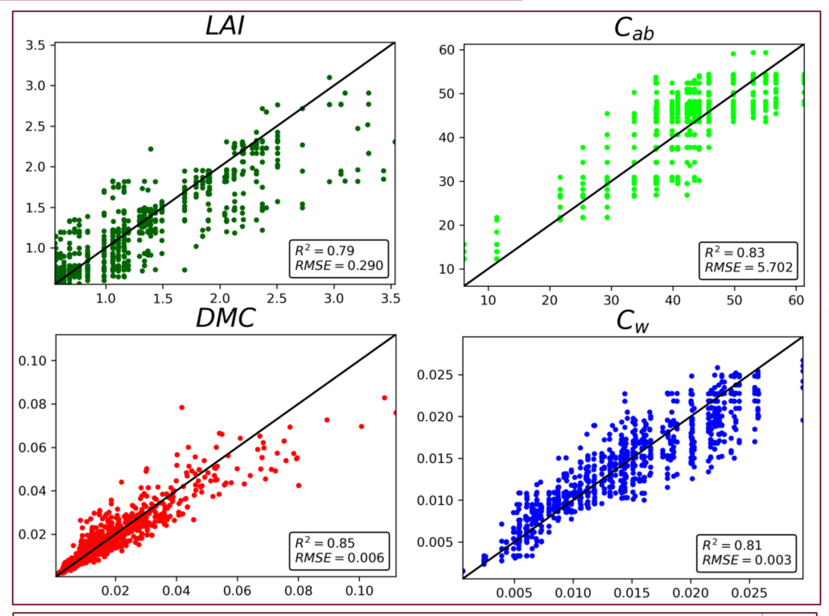


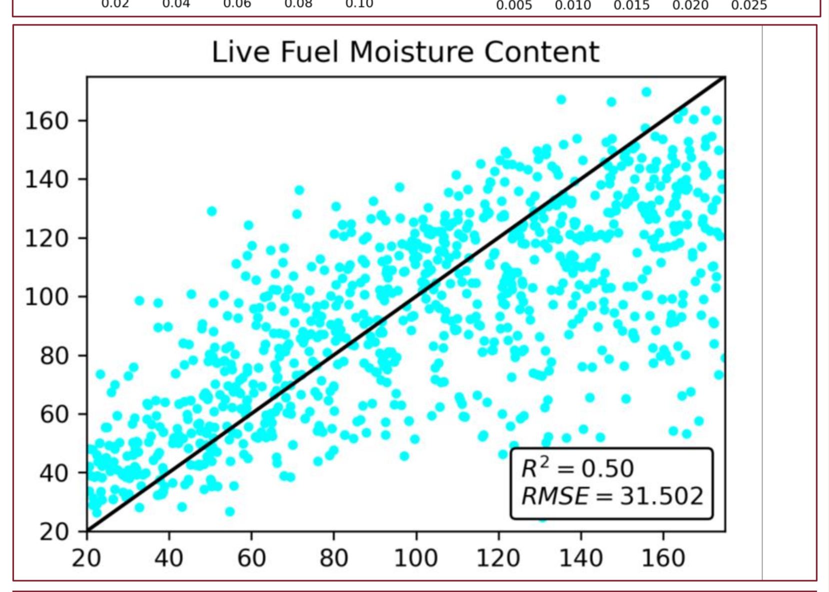




A Retrieval Exercise Using LUTs

A popular parameter inversion method is based on **Look-Up Tables** (LUT): a large amount of spectra are pre-computed for different combinations of the model parameters and compared with the observations. The closest matching spectra are then selected based on a cost function, and the input parameters used to generate them are processed to provide a realistic estimate of the biophysical parameters that generated the observed spectra. Therefore, by integrating PROSAIL TOC reflectances with the OLCI and SLSTR mean spectral response functions, we generated 50'000 Sentinel-3 Synergy S3A grassland observations and stored them in a LUT. Subsequently, we performed a retrieval on 1000 simulated observations using all the Synergy OLCI bands and all the Synergy SLSTR nadir bands. To select the best matches among the pre-computed spectra, we used a simple minimum squared distance cost function and selected the median of the best 20 performers. The y-axes represent the retrieved parameter values and the x-axes the original ones used to simulate the synthetic spectra.





Conclusions

- Sentinel-3 is a viable platform for vegetation monitoring
- The SYNERGY product can be used to estimate LAI, chlorophyll content, and LFMC
- As expected, SWIR channels are the most relevant for fuel moisture content estimation
- Proper LUT parametrization is necessary to estimate LFMC with state of the art reliability

Acknowledgements

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