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Gaussian Processes regression for biophysical parameter retrieval from Sentinel-2 and Sentinel-3 data

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The Global Monitoring for Environment and Security (GMES) Sentinel satellite missions are designed to provide globally-available information on an operational basis for services and applications related to land, ocean and atmosphere. Particularly Sentinel-2 and -3 are intended for land monitoring applications. Building upon experience from earlier missions, these two optical satellites are configured with improved spectral capabilities (e.g. with specific bands dedicated to better atmospheric correction and cloud screening, bands in red edge, etc.). At the same time, there is also a demand for improved and robust algorithms for biophysical parameter retrieval. Here, we present a novel non-parametric method that is not only able to retrieve useful biophysical parameters from these new Sentinel data streams, but also provides information about the quality of these retrievals.
Recently a new statistical method has been proposed within the family of Bayesian statistics, being Gaussian Processing (GP) regression, which is simpler and more robust than their family members. For instance, GP requires a much smaller training data set than neural networks, and unlike support vector machines GP can adopt very flexible kernels including several free parameters since their optimization can be efficiently done through maximum likelihood estimation. At the same time, GP maintains very good numerical performance and stability. Further, of particular interest is that GP not only provides pixelwise estimations of a (biophysical) parameter, but also confidence intervals for the estimation.
We evaluated the use of Gaussian processes (GP) for biophysical parameter retrieval from Sentinel-2 and Sentinel-3 (Ocean and Land Colour Instrument: OLCI) data. Special emphasis was put on the retrieval of Chl, LAI and fractional vegetation cover (FVC) parameters, but note that in practice any other canopy parameters can be retrieved when having in situ measurements available for model parameterization. The data used came from several ESA-led field campaigns that were dedicated to the study of canopy parameters retrievals: SPARC, AgriSAR and SEN3EXP. These campaigns took place over agricultural sites in Barrax, Spain and Demmin, Germany. Apart from the collection of extensive field data sets, the sites have been overflown by various airborne and spaceborne hyperspectral instruments: AHS, CASI, CHRIS.
These images were spatially and spectrally resampled to the Sentinel-2 and -3 configurations and were subsequently used for analyzing the efficacy of parameter retrieval in conjunction with GP regression. An interesting feature of GP is that it provides insights in the relevance of all bands. As such, the performance of conventional vegetation indices and the individual bands of both sensors were evaluated. It was found that nonlinear GP regression through all available bands led to best results. Besides, the related confidence intervals delivered information on the quality of the retrievals. For most of the tested land cover types (various crop types, bare soil, semi-natural areas) robust retrievals were achieved. Nevertheless, because GP is a statistical approach it relies on a representative training data set. When applying GP to images across the globe, therefore, it is crucial that measurements of all dominant land cover types are included in the parameterization of the model. In conclusion, the use of GP led to several interesting results: i) robust retrievals of chl, LAI and FVC, ii) insight in relevant bands, iii) additional confidence maps. Finally, as GP is easy to compute it could be effortlessly implemented into operational monitoring activities.