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Sensitivity in forward modeled hyperspectral reflectance due to phytoplankton groups

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Phytoplankton is an integral part of the ecosystem, affecting trophic dynamics, nutrient cycling, habitat condition, and fisheries resources. The types of phytoplankton and their concentrations are used to describe the status of water and the processes inside of this.
This study investigates bio-optical modeling of phytoplankton functional types (PFT) in terms of pigment composition demonstrating the capability of remote sensing to recognize freshwater phytoplankton. In particular, a sensitivity analysis of simulated hyperspectral water reflectance (with band setting of HICO, APEX, EnMAP, PRISMA and Sentinel-3) of productive eutrophic waters of Mantua lakes (Italy) environment is presented.
The bio-optical model adopted for simulating the hyperspectral water reflectance takes into account the reflectance dependency on geometric conditions of light field, on inherent optical properties (backscattering and absorption coefficients) and on concentrations of water quality parameters (WQPs). The model works in the 400-750nm wavelength range, while the model parametrization is based on a comprehensive dataset of WQP concentrations and specific inherent optical properties of the study area, collected in field surveys carried out from May to September of 2011 and 2014.
The following phytoplankton groups, with their specific absorption coefficients, a*Φi(λ), were used during the simulation: Chlorophyta, Cyanobacteria with phycocyanin, Cyanobacteria and Cryptophytes with phycoerythrin, Diatoms with carotenoids and mixed phytoplankton.
The phytoplankton absorption coefficient aΦ(λ) is modelled by multiplying the weighted sum of the PFTs, Σpia*Φi(λ), with the chlorophyll-a concentration (Chl-a).
To highlight the variability of water reflectance due to variation of phytoplankton pigments, the sensitivity analysis was performed by keeping constant the WQPs (i.e. Chl-a=80mg/l, total suspended matter=12.58g/l and yellow substances=0.27m-1).
The sensitivity analysis was based on the decomposition of the output reflectance variance in partial variances of the output due to each functional group. This approach considers the sensitivity analysis of the model to each variable on its own and the corresponding interaction with the other variables, allowing identifying the single variability as well as the spectral interaction index.
The analysis recognized three spectral ranges with specific level of interactions between the inputs. The first part of the spectrum up to 500 nm had average level of 10% of interaction; the second up to 600nm showed values of 5% with a peak around 580nm; the third showed an increasing interaction level until 15% near 715nm.
The results presented in this study provide information relating the sensitivity of hyperspectral water reflectance as observable with band setting of the latest generation space- and air-borne sensors depending on different phytoplankton groups. In particular PRISMA was the best in the spectral sensitivity definition in the first part of the spectrum, while APEX in the second and third domain. The Sentinel 3 showed lower performances although in the third domain it was able to identify some spectral features. Results showed the Chlorophyta had high main effect at 440 nm and 480nm; sensitivity indices of phycoerythrin showed peaks at 550-580nm the range and near 680nm; phycocyanin showed high influence at 620-640nm. The research activity is part of the EU FP7 INFORM (Grant No. 606865, http://www.copernicus-inform.eu/).