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Marine fluorescence from high spectrally resolved satellite measurements

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When chlorophyll molecules absorb light, most of this energy is transformed into chemical energy in a process of photosynthesis. However, a fraction of the energy absorbed is reemitted as fluorescence. As a result of its relationship to photosynthetic e?ciency, information about chlorophyll fluorescence can be used to assess the physiological state of phytoplankton (Falkowski and Kolber,1995). In-situ measurements of chlorophyll fluorescence are widespread in physiological and ecophysiological studies. When retrieved from space, chlorophyll fluorescence can improve our knowledge of global biogeochemical cycles and phytoplankton productivity (Behrenfeld et al., 2009; Huot et al., 2013) by providing high coverage and periodicity.

So far, the only satellite retrieval of sun-induced marine fluorescence, Fluorescence Line Height (FLH), was designed for MODIS (Abbott and Letelier, 1999), and later also applied to the similar sensor MERIS (Gower et al., 2004). However, it could so far not be evaluated on global scale.

Here, we present a different approach to observe marine chlorophyll fluorescence, based on the Differential Optical Absorption Spectroscopy (DOAS) technique (Perner and Platt, 1979) applied to the hyperspectral data from Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) and Global Ozone Monitoring Experiment-2 (GOME-2). Since fluorescence, as a trans-spectral process, leads to the shift of the wavelength of the radiation, it can be observed in the filling-in of Fraunhofer lines. In our retrieval, we evaluate the filling-in of the Zeeman triplet Fraunhofer line Fe_I at 684.3 nm, which is located very close to the emission peak of marine fluorescence ($\sim$685 nm). In order to conduct the chlorophyll fluorescence retrieval with the DOAS method, we calculated the reference spectra for chlorophyll fluorescence, based on simulations performed with the coupled ocean-atmosphere radiative transfer model SCIATRAN (Rozanov et al., 2014). Based on the simulated data, we also calculated corrections the influence of for water vapor, Raman scattering and solar zenith angle on the retrieved fluorescence emissions.

Our fluorescence results from SCIAMACHY and GOME-2 show similar spatial patterns when compared to the MODIS FLH. The fluorescence is generally stronger in areas of high chlorophyll concentration. The observed differences between SCIAMACHY and GOME-2 DOAS FLH and MODIS FLH arise from differences among instruments, retrieval methods, spatial and temporal sampling and overpass time. Our hyperspectral retrieval shows noisier results than MODIS FLH, but is not susceptible to certain problems as the multispectral FLH, which arise from backscattered light by particulate matter or phycocyanin fluorescence (Abbott and Letelier, 1999). For our fluorescence retrieval, we acquired better quality for the SCIAMACHY data than for GOME-2, due to the higher spectral resolution and the smaller size of the footprint.

Our results demonstrate that it is feasible to detect the weak fluorescence signal from the oceans within hyperspectral data from satellite measurements. The method presented is generic and can be applied to other instruments in the future.