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UAV-based cm-scale mapping of biofilms and Chl-a patterns in glacial forefields using visible band ratios

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Biofilms have received great attention in the last few decades including their potential contribution to carbon fluxes and ecosystem engineering in aquatic ecosystems. Quantifying the spatial distribution of biofilms and their dynamics through time is a critical challenge. Satellite imagery is one solution, and can provide multi- and hyper-spectral data but not necessarily the spatial resolution that such studies need. Multi- and hyper-spectral data sets may be of particular value for not simply detecting the presense/absence of biofilms but also indicators of primary productivity such as chlorophyll-a concentrations. Spatial resolution is sensor quality dependent, but also controlled by sensor elevation above the ground. Hence, higher resolutions can be achieved either by using a very expensive sensor or by decreasing the distance between the target area and the sensor itself. To date, sensor technology has advanced to a point where multi- or even hyper-spectral cameras can be easily transported by UAVs, potentially yielding wide-range spectral information at unprecedented spatial resolutions. That said, such set ups have often exorbitant costs (several 1000s of US$) that few research institutions can afford or, due to the high probability of sensor lost, are risky to use. This is particularly true for glacier forefields where low air temperatures, dust and sudden wind gusts can easily damage both UAV and sensor components.

In this paper we test the performance of visible band ratios for mapping both biofilms and chlorophyll-a concentrations in an alpine glacier forefield characterized by a well-developed and heterogeneous (kryal, krenal and rhithral) stream system. The paper shows that low-cost and consumer grade UAVs can be easily deployed in such extreme environments, delivering high temporal resolution datasets and with sufficient quality RGB images for photogrammetric (SfM-MVS) processing and post-processing image analysis (i.e., band ratios). This paper shows also that visible band ratios correlates with chlorophyll-a concentrations yielding reliable chlorophyll-a information of the forefield and at the centimetric scale. This in turn allows for precise identification of the environmental conditions that lead to both biofilm development and removal through perturbation.