Spectrofluorescence and reflectance properties of Arctic benthic algae as future LiDAR targets

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Context
Due to overall ice coverage decrease caused by warmer air and ocean temperatures, a regime shift (Fig 1a) in Arctic macroalgal communities has since been observed, where brown and red macroalgae (Fig 1c) are seen covering or replacing encrusting algae and sessile organisms (Fig 1b) (Svalbard). Increased light availability to the benthic environment is also believed to contribute to this change.

Objectives
Remote detection of photosynthetic organisms (i.e., phytoplankton) via light stimulated fluorescence is well understood, where fluorescence signal intensity can be linked to in water chlorophyll a (chl-a) concentration. Macroalgae, however, are different in their 3-D morphology (e.g., blade, filament), surface characteristics (e.g., flat, rough) and packaging of chl-a, factors possibly affecting fluorescence and absorption return signals when observed by remote methods.

Following the AUV LiDAR approach (Fig 4), macroalgae must be studied whole. Hence, we initially attempt to characterize their fluorescence properties as encountered by our LiDAR. Our initial approach is to investigate fluorescence response via spectrofluorometry analyses on macroalgal samples.

We describe the response to multiple wavelengths of light to guide LiDAR component selection (e.g., laser source λ = 473nm, λ = 532nm), as well as better understand how target structure may influence fluorescence detection.

Theory
I. Fluorescence

II. Nature - pigment assemblage

Fluorescent response at typical chl-a peak emission wavelength (i.e., 685 nm) to excitation wavelength (530 - 650 nm) in brown, red and green macroalgal groups.

Here the normalized spectra of three typical species are shown for better visualization, while fluorescence is shown corrected to Raman units (true intensity, ) in figure inset.

Color groups are characterized by their differences in photosynthetic assemblages and absorption properties.

Hypotheses
Manipulative experiments
I. Layer / thickness effect
Increasing macroalgal layering in optical path will increase detected fluorescence signal intensity (H1):

II. Structure complexity effect
Increasing macroalgal structure complexity in optical path will affect detected fluorescence emission peak (H1):

Results
I. Layer effect
Adding layers / thickness increases fluorescence but maintains 685 nm peak

II. Structure complexity effect
Increasing complexity changes fluorescence intensity and peak wavelength

Conclusions: In brown kelp Alaria esculenta, observed fluorescence increases with the addition of flat layers, while emission peak remains at 685 nm regardless of changes in thickness. In more complex surfaced Agarum cribosum (and altered A. esculenta), effects of water reabsorption near 685 nm (possibly related to an increased optical path in water surrounding the sample), and possible reabsorption by chl-a at 675 nm (see chl-a - Theory) of initially emitted fluorescence + reemission at 705-730 nm are thought to be observed. This latter phenomenon appears to result in a visible shift + widening of the fluorescence emission band, and reduces total fluorescence energy.

Upcoming
- Fluorescence
- Reflectance + BRDF
- Polarization – retroreflection

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