Remote Sensing Antarctic Snow Algae

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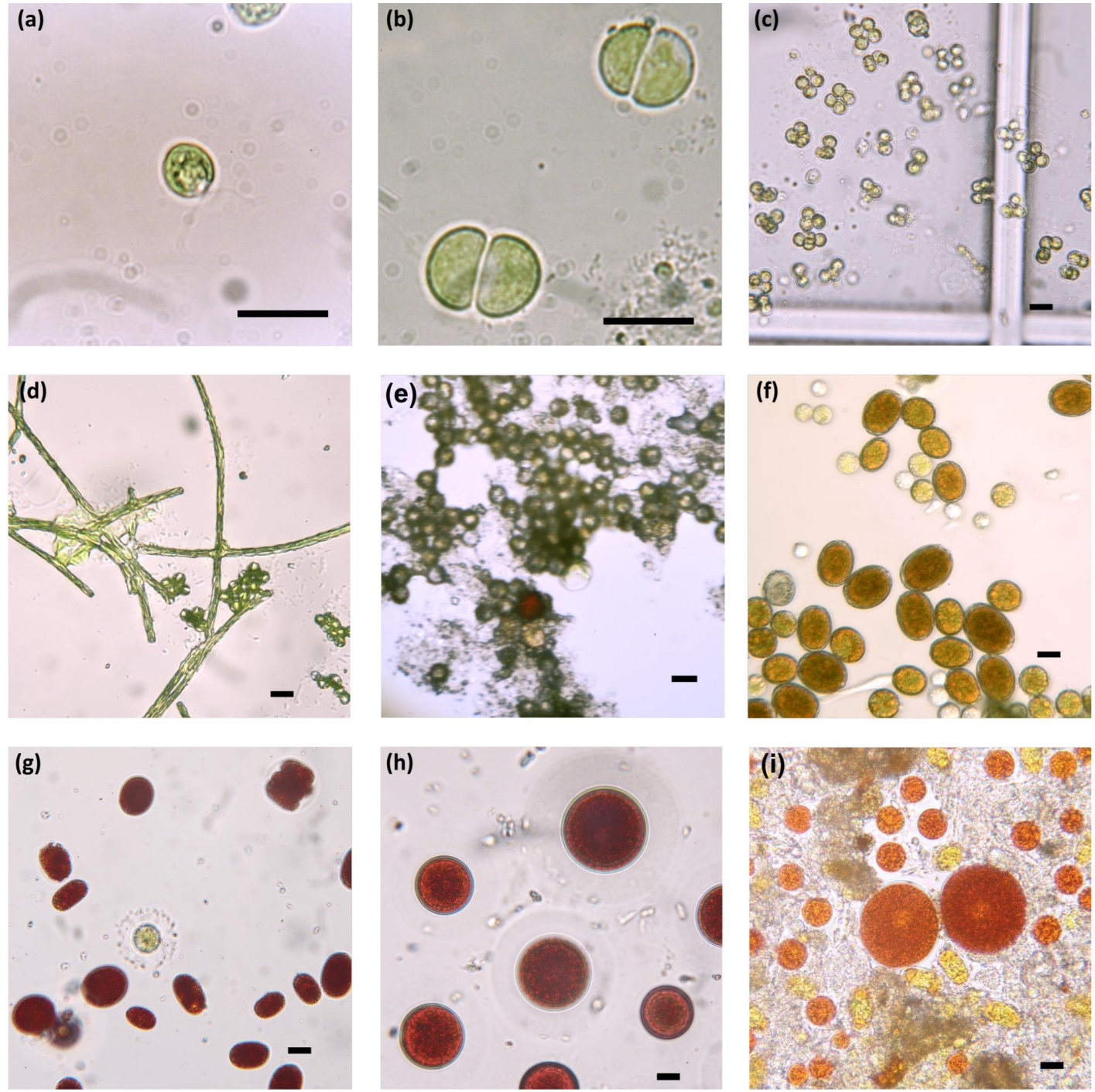
Introduction

- Snow algae inhabits the summer, coastal snowpacks of the Antarctic
- As an ecosystem, little is known about its abundance, distribution, controls on its life cycle, its ability to adapt to a warming Antarctic or its role within Antarctica's biosphere or carbon cycle,
- We aim to address some of this uncertainty using well studied patches of snow algae to build and validate models to detect snow algae in satellite imagery across Antarctica.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WHY REMOTE SENSING?

- The coastline of the Antarctic Peninsula is a potentially huge habitable area for snow algae. This is mostly inaccessible.
- Optical satellites can (in theory) image the entire Peninsula several times a day, every day, at 30 cm resolution (if you can afford it).
- This gives you **Data**, e.g. area coverage, biomass estimates and seasonal development of green/red stages of life cycle.
- It also lets you relate these factors to things like: snow temperature, aspect, latitude, elevation etc.

- But… it is important to have data on the ground, to ensure you know what your are looking at in satellite imagery.

How do we detect snow algae?

Spatial resolution:

On the ground,
snow algal blooms can be anything from a 10cm wide strip of green to something hundreds of meters squared.

We need to know the sensitivity of our satellite images for detecting small blooms otherwise we risk overlooking them.

Spatial resolution: The Premium Option

World View 3
Ground Resolution: 1.24m

$50 per km^2

Approximate cost to collect data across Antarctic Peninsula, once: $64.5million

Spatial resolution: Copernicus Mission

European Space Agency's Sentinel 2

Ground Resolution: 10 m

Cost: Free

Spatial resolution: The Free Option

European Space Agency's Sentinel 2

Ground Resolution: 10 m

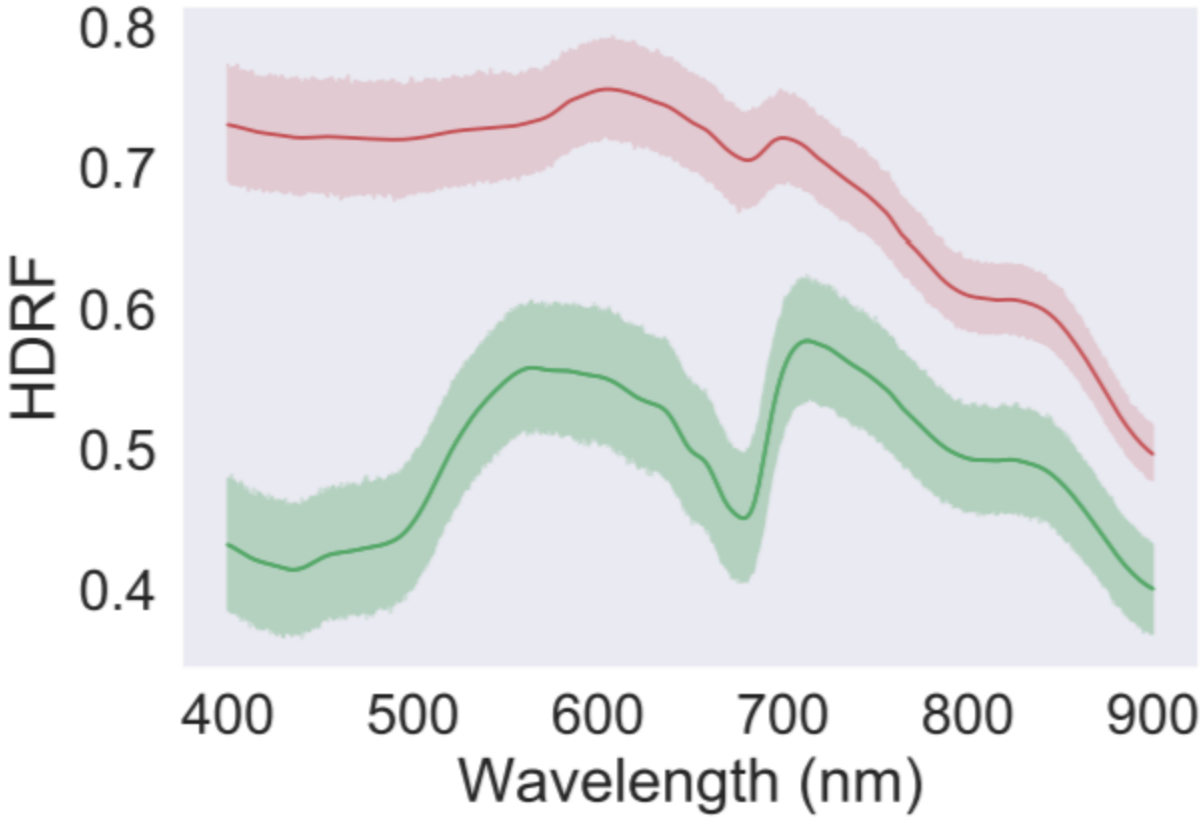
Cost: Free

Green algae blooms are still visible, but how much information do we lose?

How to build detection models?

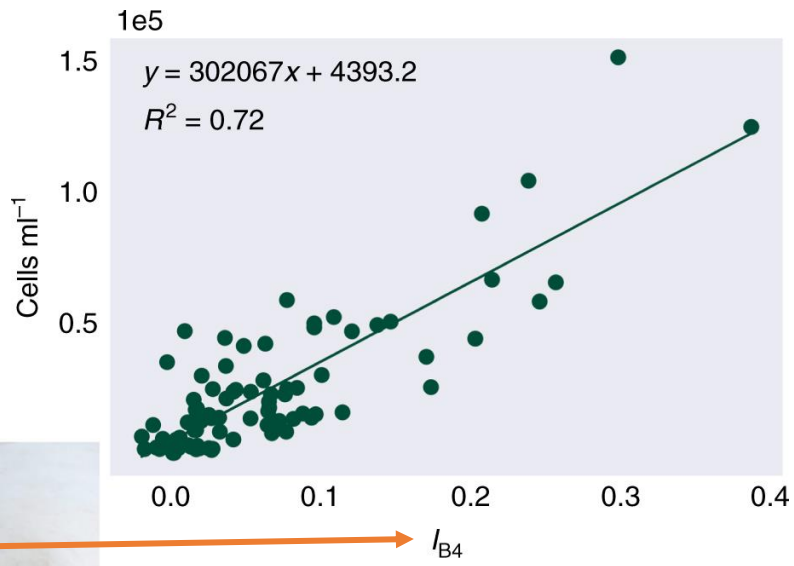
- Field spectrometers measure the spectral reflectance of light off of a surface: same information as a satellite's pixel.
- Measuring the spectral reflectance of each land surface type lets us build a library to query when classifying an image.
- Measuring the spectral reflectance snow algae alongside biological sampling lets us relate it to: biomass, species, life cycle stage etc.

Snow Algal Reflectance

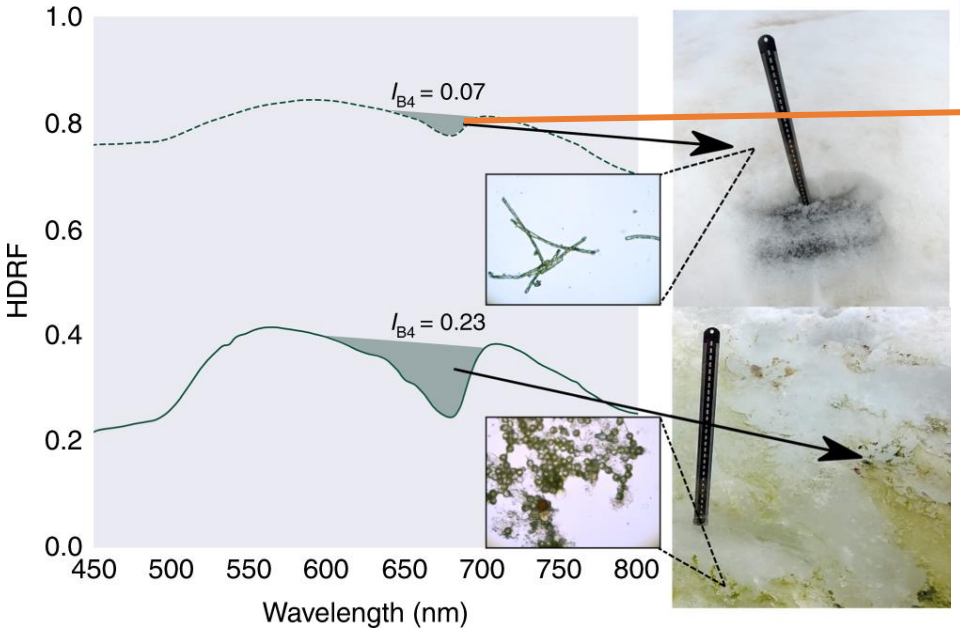


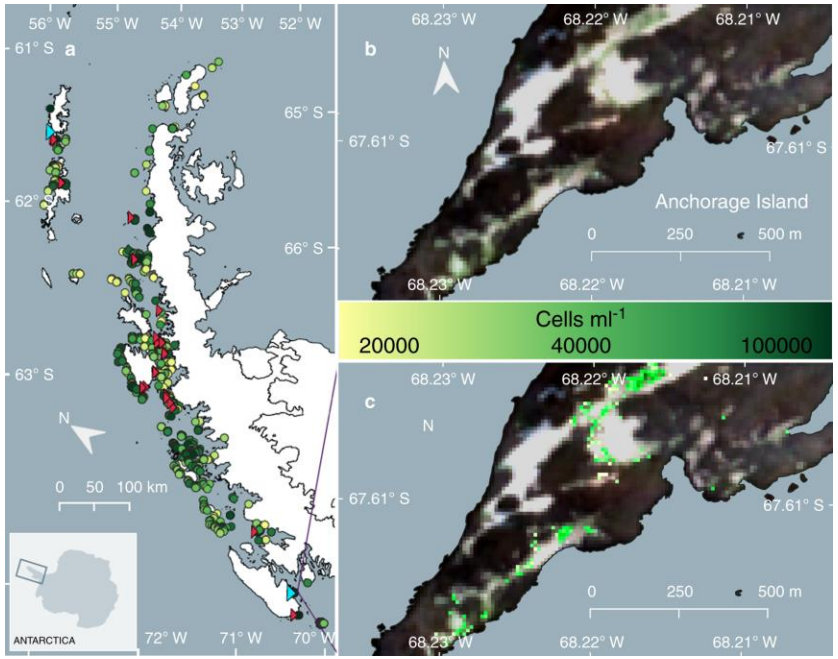
Developing Indices to Detect Snow Algae Biomass

Empirical model of band ratio vs physical variable.



Field Spectroscopy: Object-based reflectance





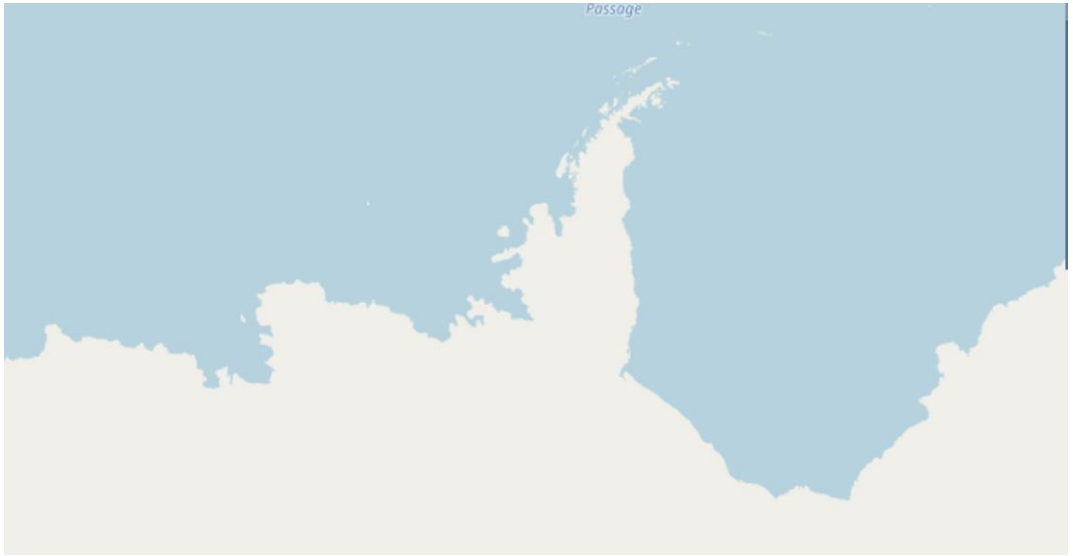
Convert to Sentinel 2 Band Indices:

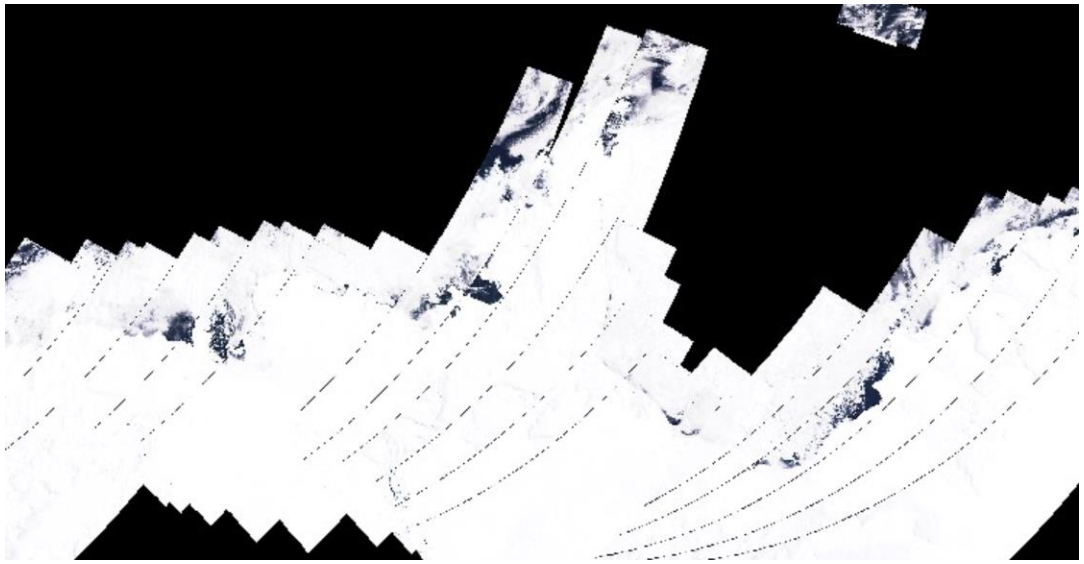
(((B3*(705-665)+ B5*(665-566))/(705-566))-B4)/((B3*(705-665)+ B5*(665-566))/(705-566))

Map Biomass Distribution of Algae in Snow across Antarctica

Problems with Sentinel 2

- ESA Stopped collecting Antarctic data during our 2018 field season!
- Cloud!
  - Solution: aggregate cloud free images over 3 summer seasons
- Mixed pixels
  - Solution: filter out mixed pixels from analysis. Future work involves spectral unmixing analysis to include sub-pixel blooms
- Missing red snow algae!
  - Sentinel 2 bands don’t allow the integration of chlorophyll absorbance in red snow algae due to carotenoid absorbance.
  - Solution: Worldview imagery, hyperspectral satellite imagery….





Some interesting outcomes:

- Sentinel 2 identified about 2km^2 of snow algae. Or 1600 individual blooms. Sounds like not a lot, but there is only about between 2 and 46km^2 of vegetation in total. And we are missing out a huge amount of snow area because of Sentinel's 10m resolution.
- This snow algae photosynthesises about 500 tonnes of CO_2 in a growth season.
- About 60% of blooms were less than 1km from a bird or seal colony.
- They are larger the further north you go, i.e. the warmer it gets.

Gray, A., Krolikowski, M., Fretwell, P. *et al.* Remote sensing reveals Antarctic green snow algae as important terrestrial carbon sink. *Nat Commun* **11,** 2527 (2020). https://doi.org/10.1038/s41467-020-16018-w