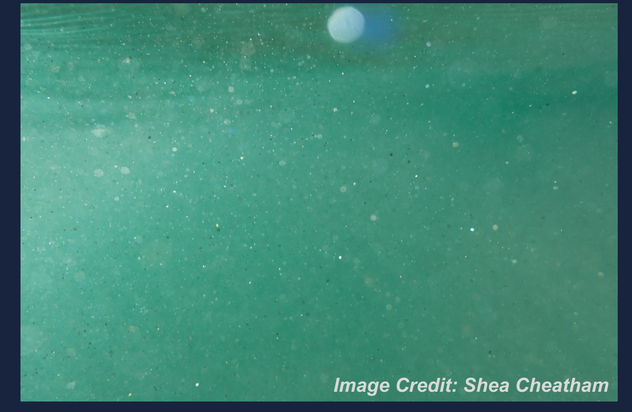
Robots, lasers, and the future of ocean observing

Improving the capabilities of autonomous platforms in marine science with optical sensors

SEAS Annual Meeting, 15–17 November, 2023



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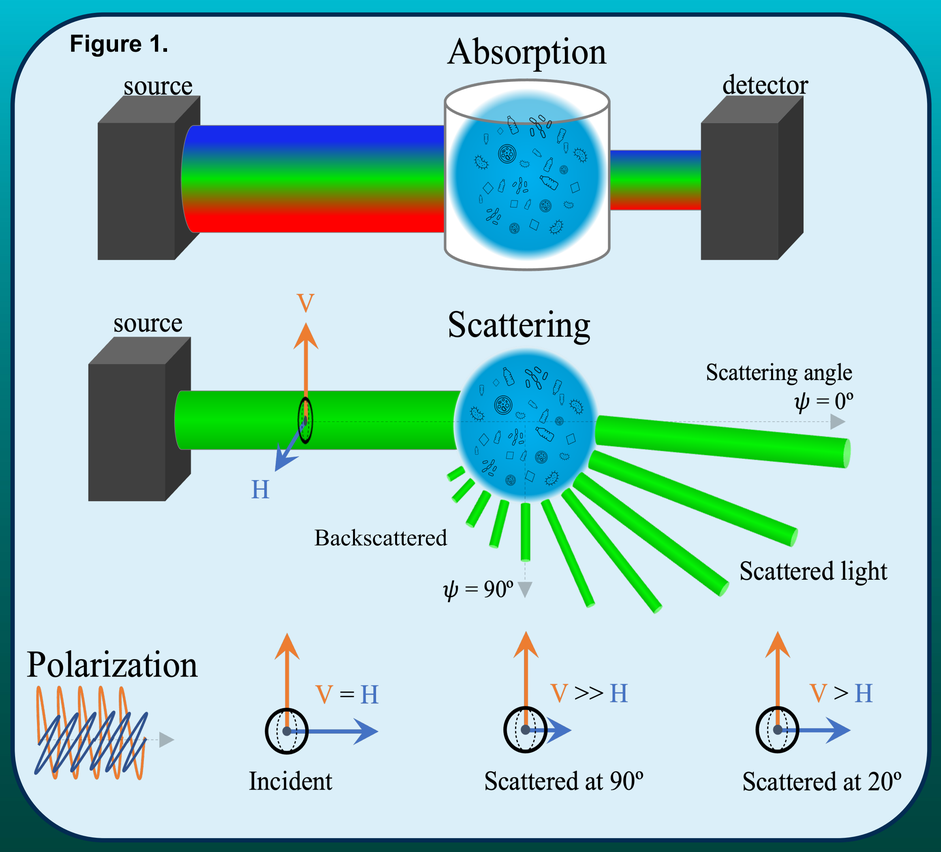
Background and Motivation

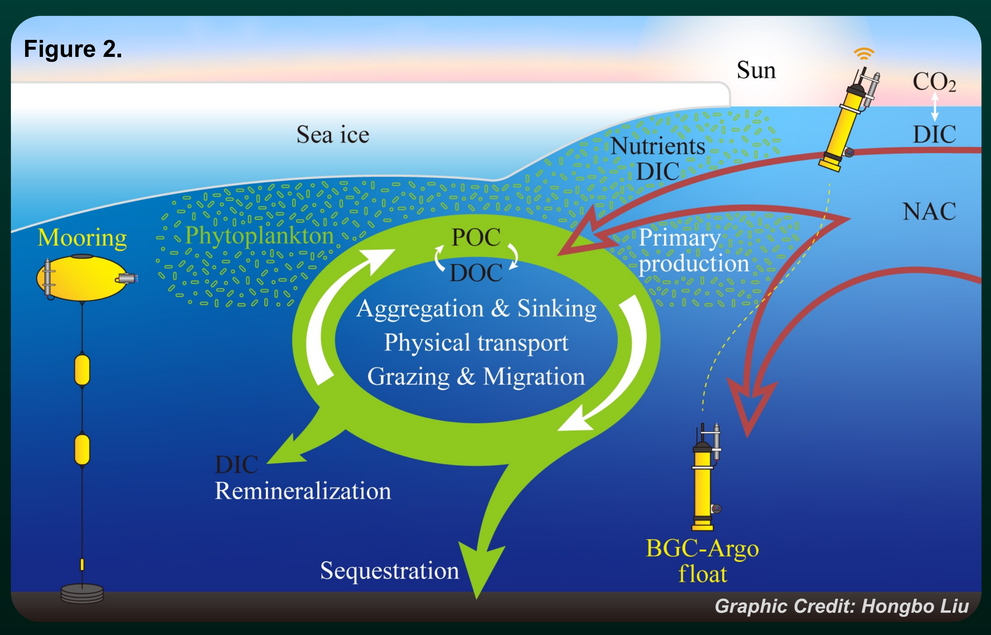
I have a PhD in Oceanography and my doctoral work focused on understanding and interpreting optical measurements of seawater. Like many soups, the ocean is a salty mixture of dissolved and suspended materials. All of the ingredients impact the appearance and, just like soups, we can learn a lot about what the ingredients are just by looking at it. However, it can be difficult to know *exactly* what is in a soup by looking at it, so we make comprehensive measurements of absorption (loss) and scattering (redirection) of visible light (Figure 1). Some of the key ingredients in the ocean are living and non-living particles associated with phytoplankton, tiny microscopic plants which produce over half of the oxygen we breath on earth.

The goal of my research is to develop robust inversion techniques to enable the inference of important information about the ocean's content from simple optical measurements.



Introduction

- The ocean plays a vital role in the global carbon cycle, regulating our climate and sustaining life on Earth through exchanges and transformations of atmospheric CO_2. The fate of carbon in the ocean is driven by several interconnected processes. The biological carbon pump refers to the biogeochemical processes which transfer dissolved and particulate organic carbon from the surface ocean to the deep ocean (Figure 2). Without this biological carbon pump, it is estimated that atmospheric CO_2 levels would be ~50% higher than they are today.
- **Particulate organic carbon** (POC) in the ocean forms the base of marine food webs and refers to the amount of organic carbon in all phytoplankton, heterotrophic organisms, and non-living organic detrital material. A major limiting factor on the development of a better quantitative understanding of the biological carbon pump is the limited number of observations of the spatial and temporal distribution of POC.



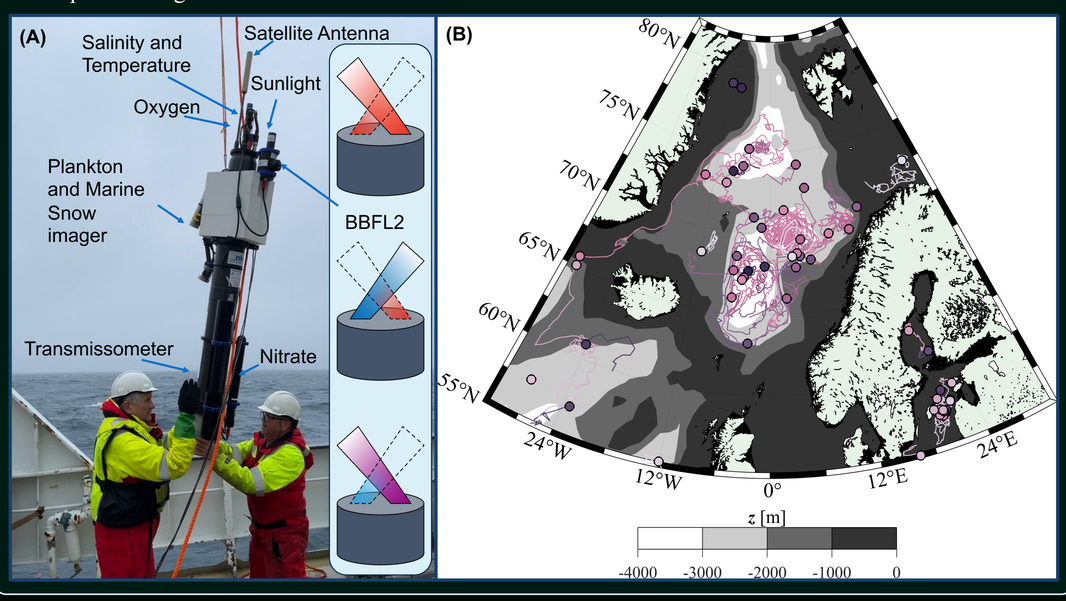
Project Objectives

1. Develop advanced approaches to estimate POC from available optical measurements
2. Apply approaches to autonomous platforms in the Nordic Seas to examine sinking POC supporting the drawdown of atmospheric CO_2.

Biogeochemical (BGC) Argo floats in the Nordic Seas

(A) Description of sensors available on a BGC-Argo float deployed in the Norwegian Sea on a research cruise with the Institute of Marine Research in May 2023. These floats contain many sensors to measure Essential Ocean Variables like oxygen and chlorophyll-a, the main photosyntheic pigment of phytoplankton. The BBFL2 also measues optical backscattering which is used to estimate POC.

(B) Locations and trajectories of the 54 BGC-Argo floats surveying the Nordic Seas since 2018. My project will involve data processing and analysis of over 5500 vertical profiles containing optical and other important biogeochemical measurements.



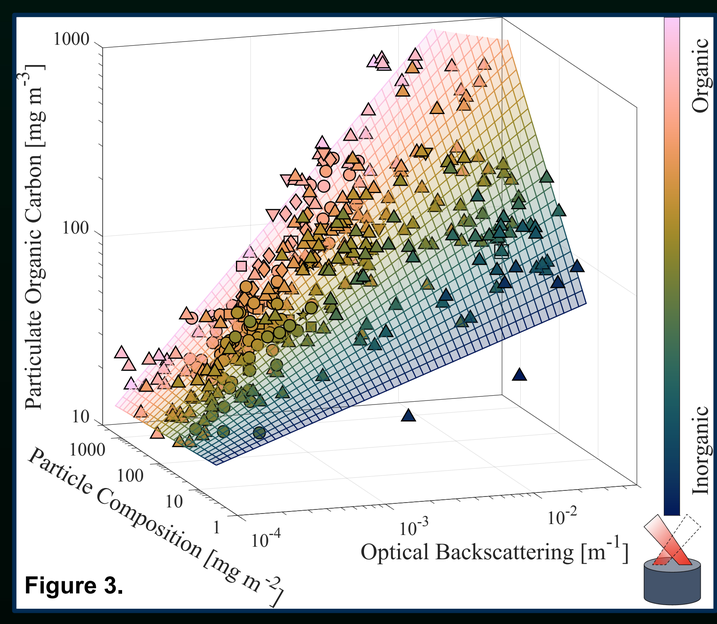
Relevance to Marine Sustainability

Marine sustainability refers to the long-term preservation of marine resources with environmental, social, and economic value. Paramount to the achievement of marine sustainability is the development of efficient observational techniques to monitor important aspects of marine environments. When considering the task of monitoring marine resources, autonomous platforms—such as floats, moorings, and gliders—present an economically and environmentally sustainable approach, as they are both more cost effective and energy efficient than traditional ship-based observations. These platforms rely greatly on optical measurements.

My project will advance optical approaches for estimating POC. This may prove essential to sustainable fisheries management and the characterization of oceanic carbon sequestration.

Key Results and Activities

- A novel method to optically-estimate POC (*Under Revision* at Frontiers in Marine Science; Figure 3)
- Optical measurements of microplastics (*Under Revision* at Limnology and Oceanography Letters)
- Three coauthored peer-reviewed publications in 2023
- Presentation of results at four international conferences
- Participation in three BGC-Argo float data quality and science workshops
- Three research cruises: Svalbard (August 2022), Nordic Seas (May 2023), and with OceanX (November 2023)
- Counting and Sizing of Marine Snow using Remotely Operated Vehicles (Master's Student Supervision w/ OceanX)
- NASA proposal review panelist (2023)
- Proposal writing, submitting a Research Council of Norway FRIPRO proposal by end of 2023.



Supervisory Team and Collaborators

- Camilla Sætre (Supervisor, IFT)
- Børge Hamre (Co-supervisor, IFT)
- Kjell Arne Mork (IMR)
- Henrik Søiland (IMR)
- Veli Çağlar Yumruktepe (NERSC)
- Hongbo Liu (Postdoc, IFT)
- Håkon Sandven (SEAS, IFT)
- Shea Cheatham (PhD student, IFT)
- Mauro Passarella (SEAS, GEO)
- Gillian Mary Damerell (SEAS, GFI)

Other Outreach Activites

- **Meditations on the Deep Sea**, an ongoing audio-visual project dedicated to the creation of immersive intimate experiences, connecting us with this unique environment through the narrative power of music. In collaboration with M. Passarella et al., and OceanX.
- **Journey into the Ocean's Colour!** Potential installation at Science Is Wonderful 2024 in Brussels with H. Liu. The background gradient of this poster simulates the vertical distribution of light and color from a BGC-Argo float in the Atlantic Ocean.
- **Why do some Norwegian fjords turn green?** Popular Science article at sciencenorway.no