An Optical Sensor for Autonomous Detection of Particulate Inorganic Carbon (PIC) Concentration in Seawater

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(Source: Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC)

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MarSens MARINE OPTICS & REMOTE SENSING

SEQUOIA Tools and Research for Particle Intelligence

LCP

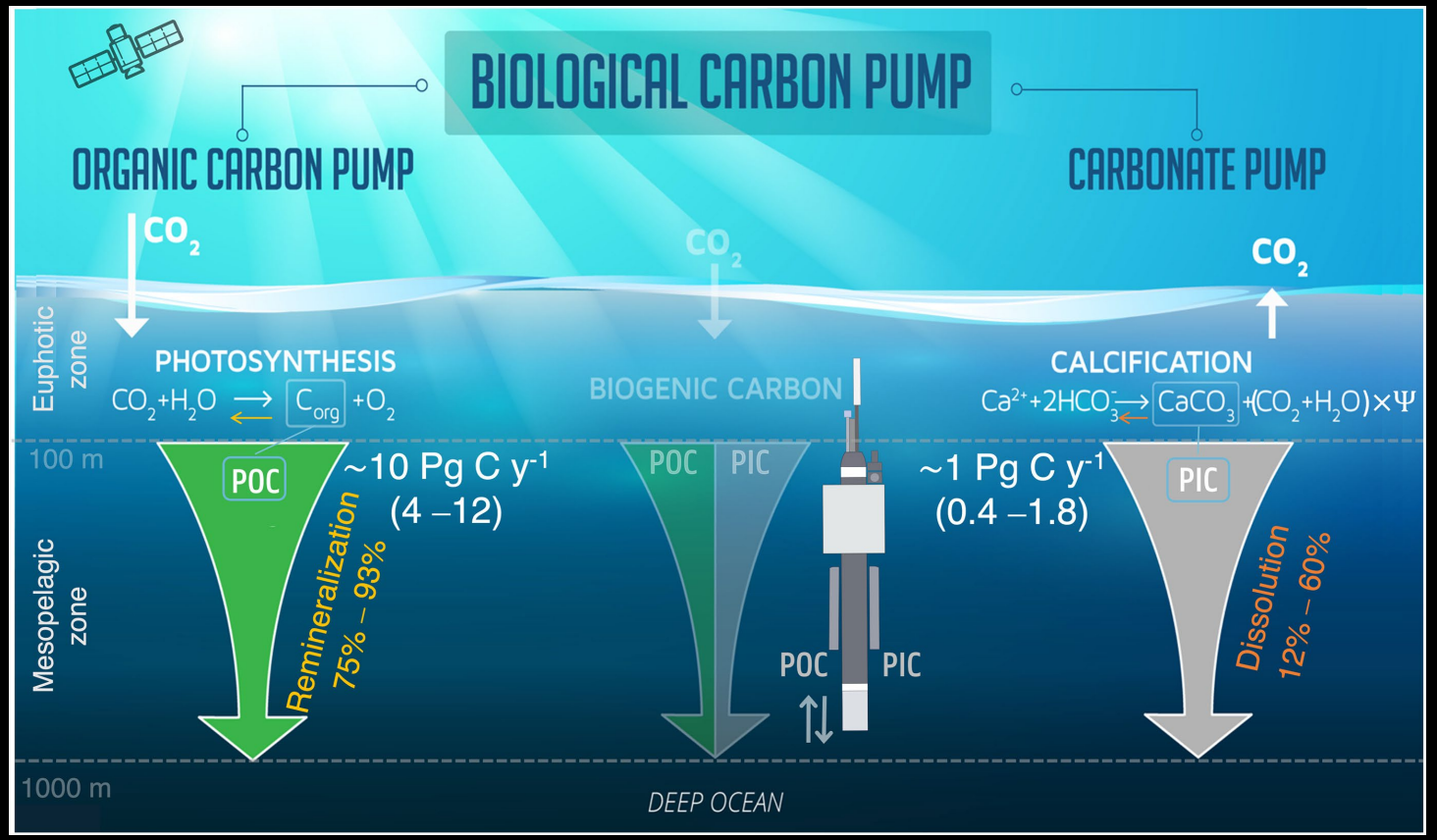
erc CarbOcean

PROTISTOLOGY AQUATIC ECOLOGY

Defence Research and Development Canada

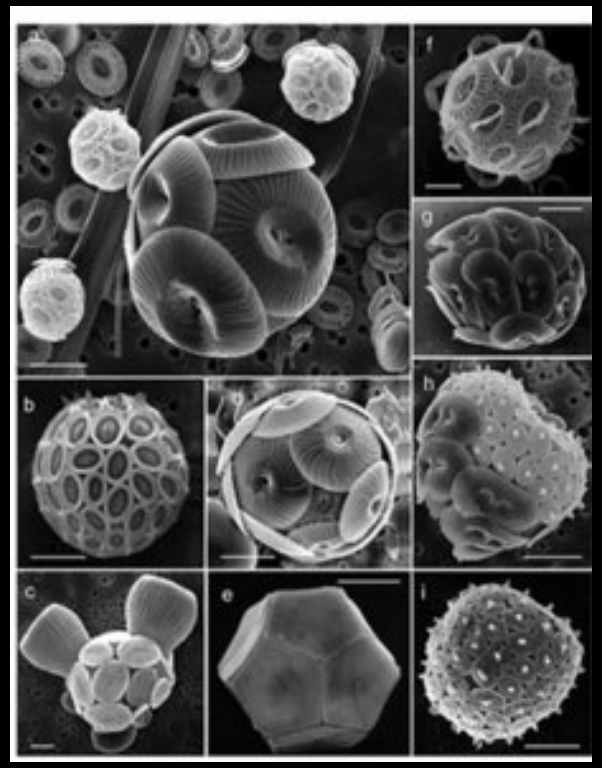
Biological Carbon Pump

- Organic carbon pump - fueled by photosynthesis, generates POC
- Carbonate pump - fueled by calcification, generates PIC
- Opposing effects on the surface ocean CO_2
- PIC ballast effect - dense PIC may enhance the downward flux of organic carbon



(Source: Neukermans et al., 2023)

Calcifying Plankton

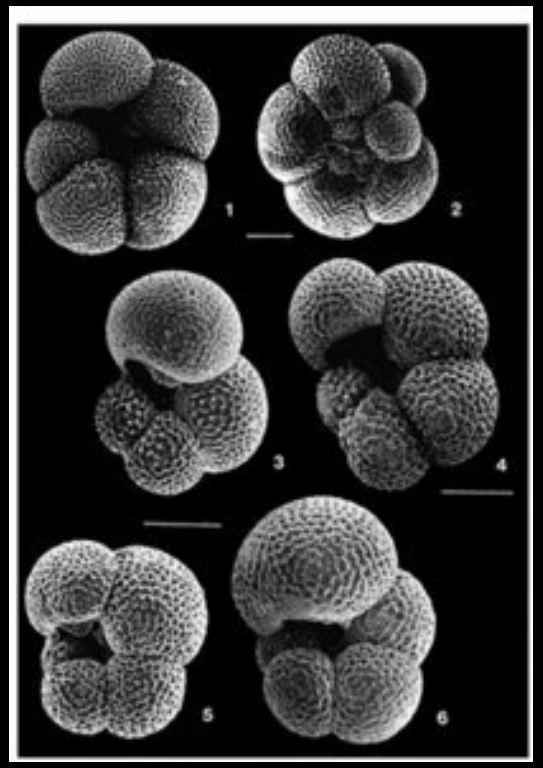


Coccolithophore

Calcifying phytoplankton

Calcite

D:5-50µm

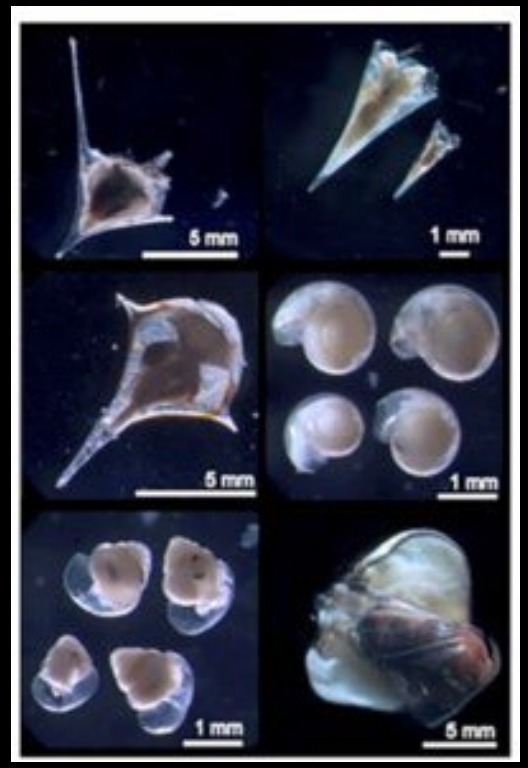


Foraminifera

amoeboid protists

Calcite

D:50µm-1mm



Pteropods

sea snails

aragonite

D:1-3mm

With estimated relative contributions to global meso- and bathypelagic $CaCO_3$ flux

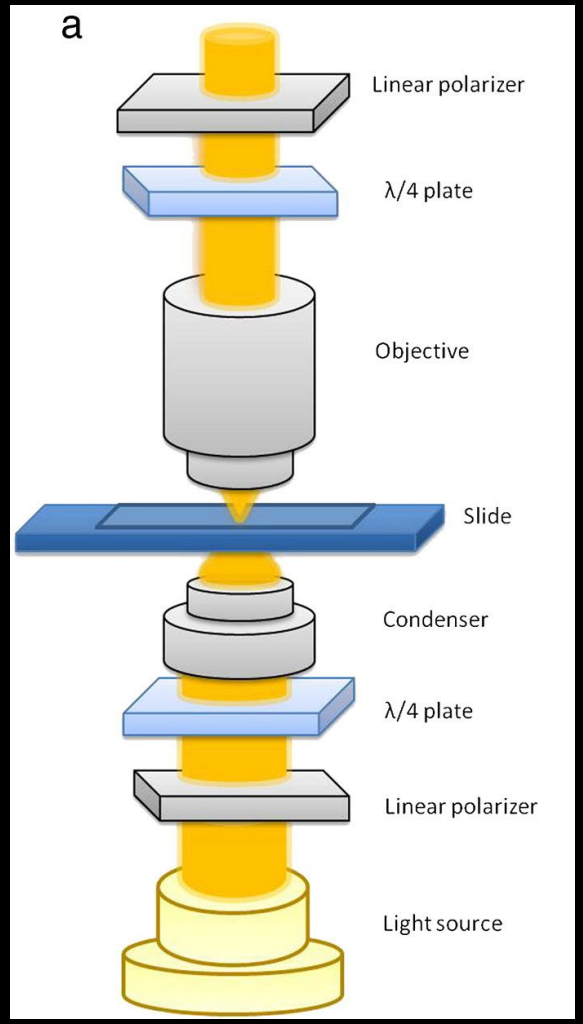
40-45%

40-45%

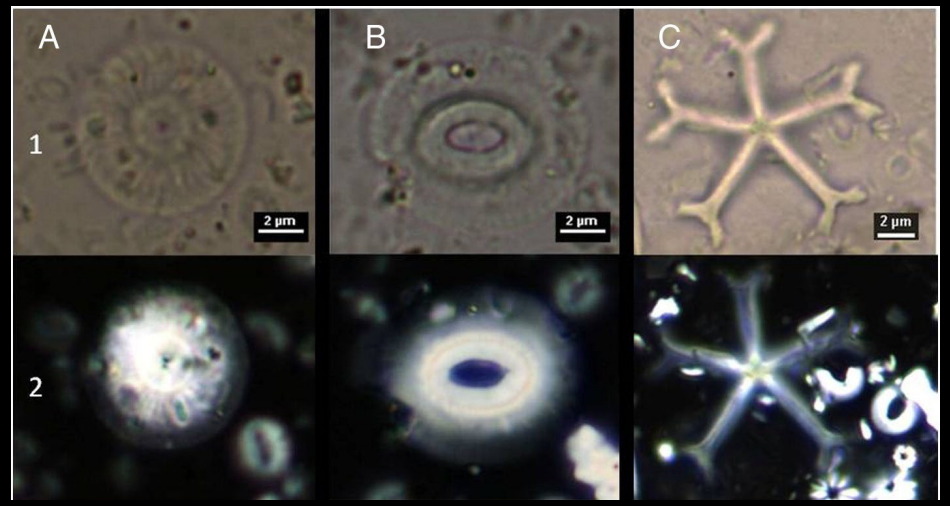
10-20%

Neukermans et al. (2023)

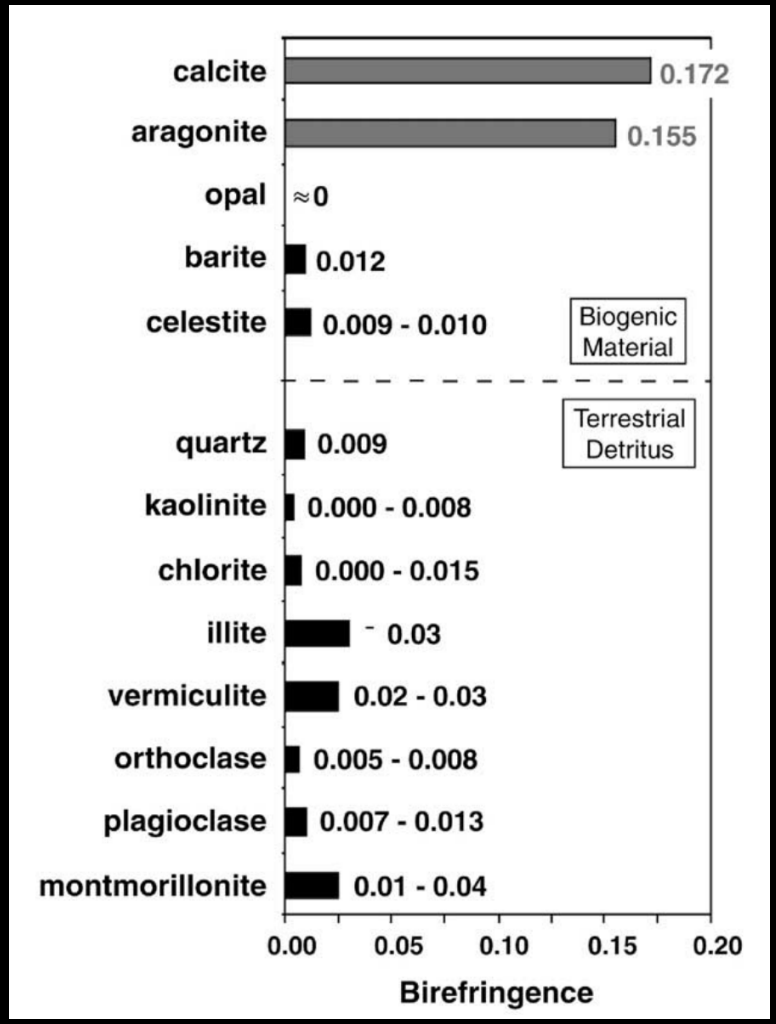
PIC Sensing: The Optical Basis



Fuertes et al. (2014)

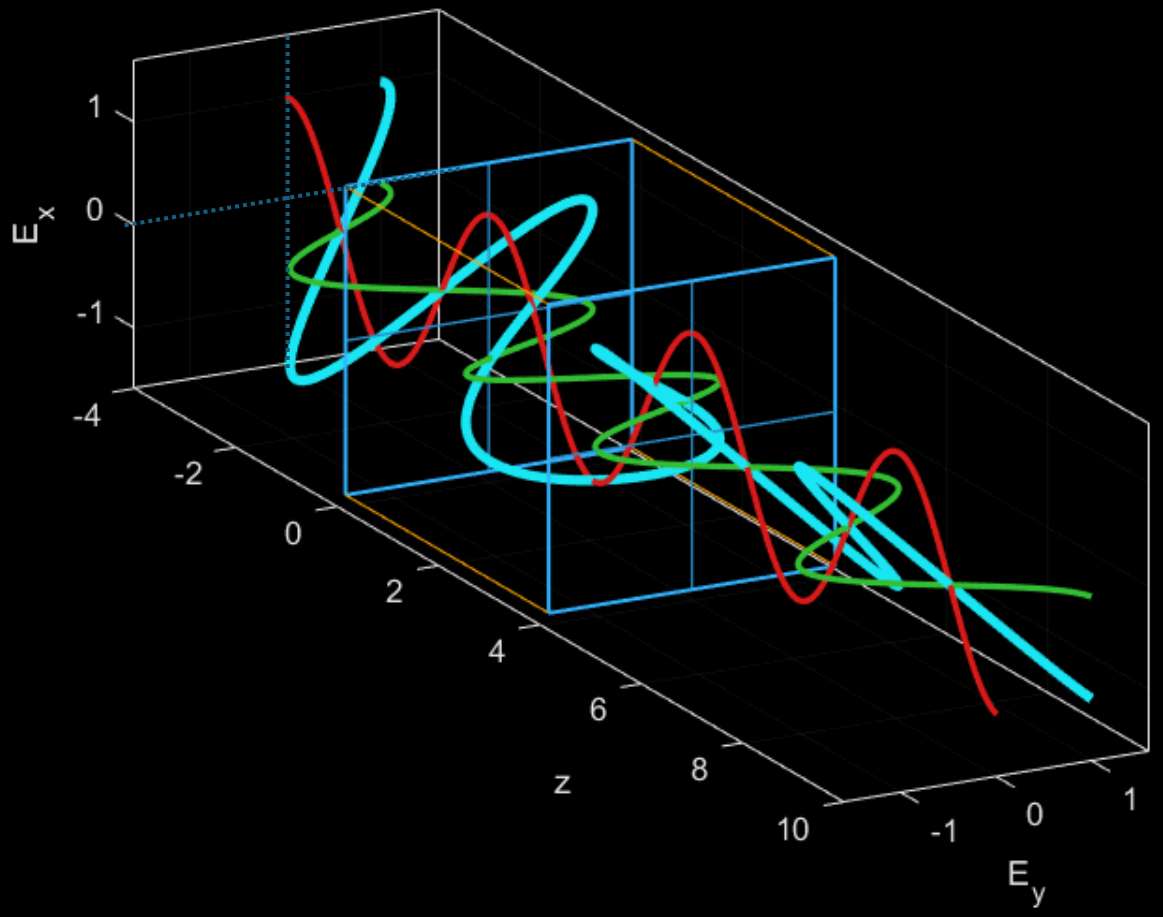


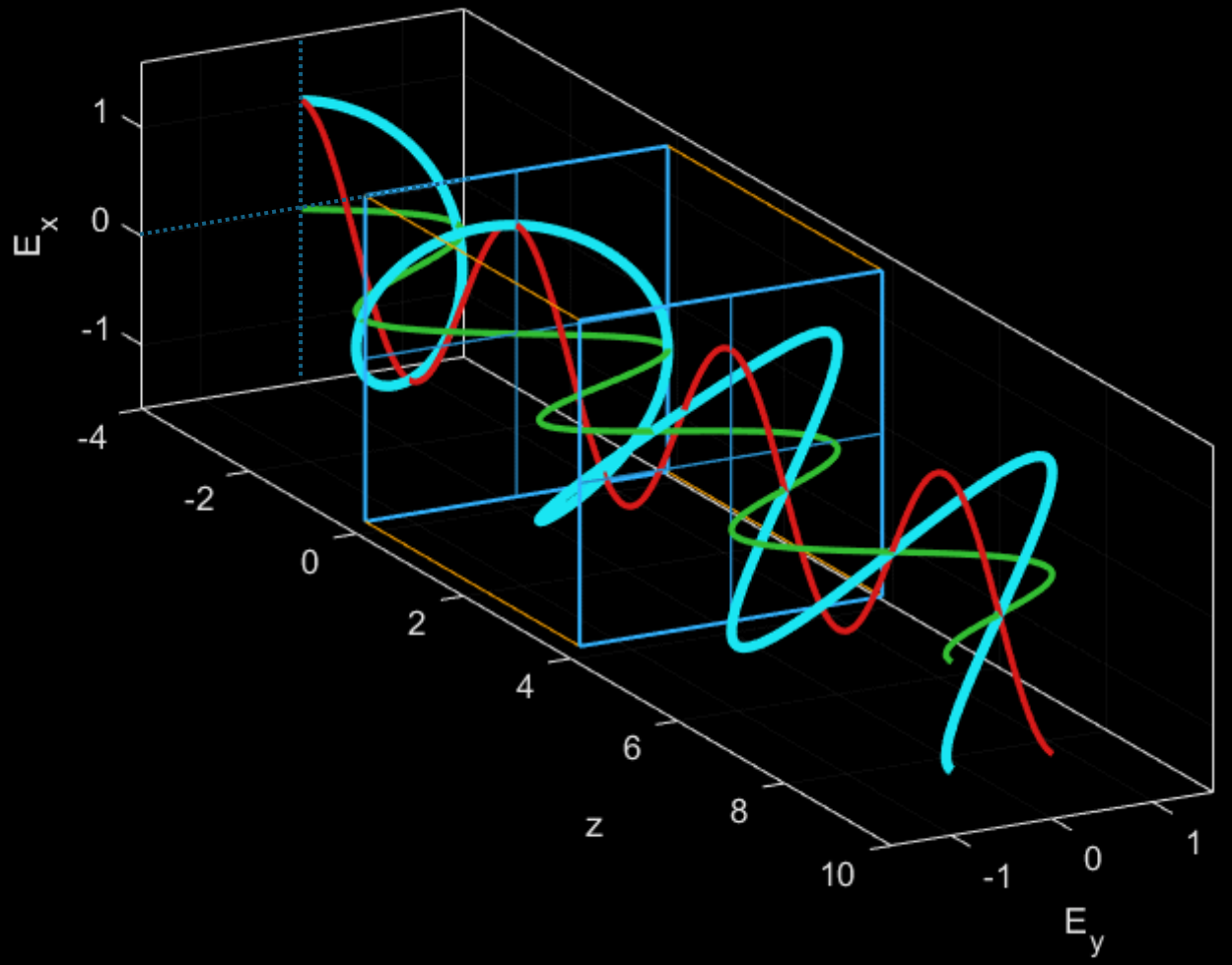
Fuertes et al. (2014)



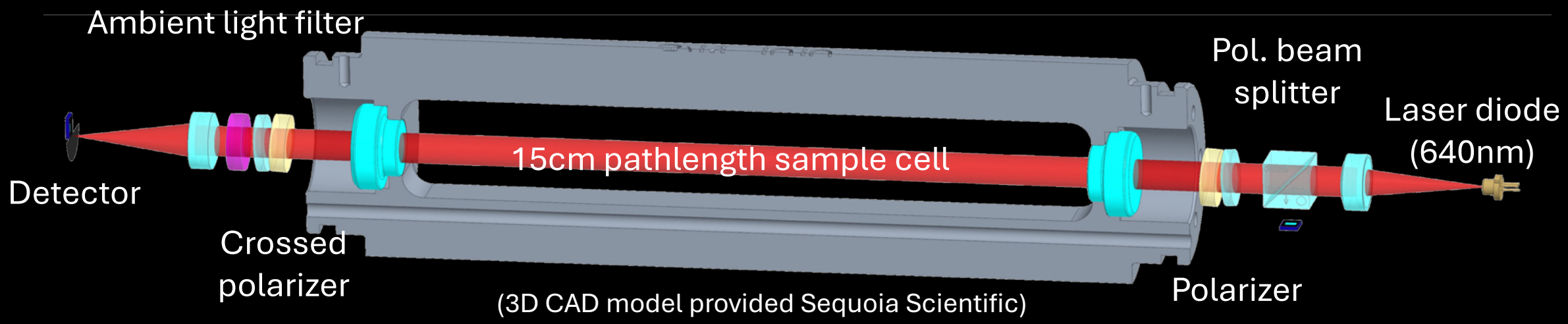
Guay and Bishop (2002)

PIC Sensing: The Optical Basis



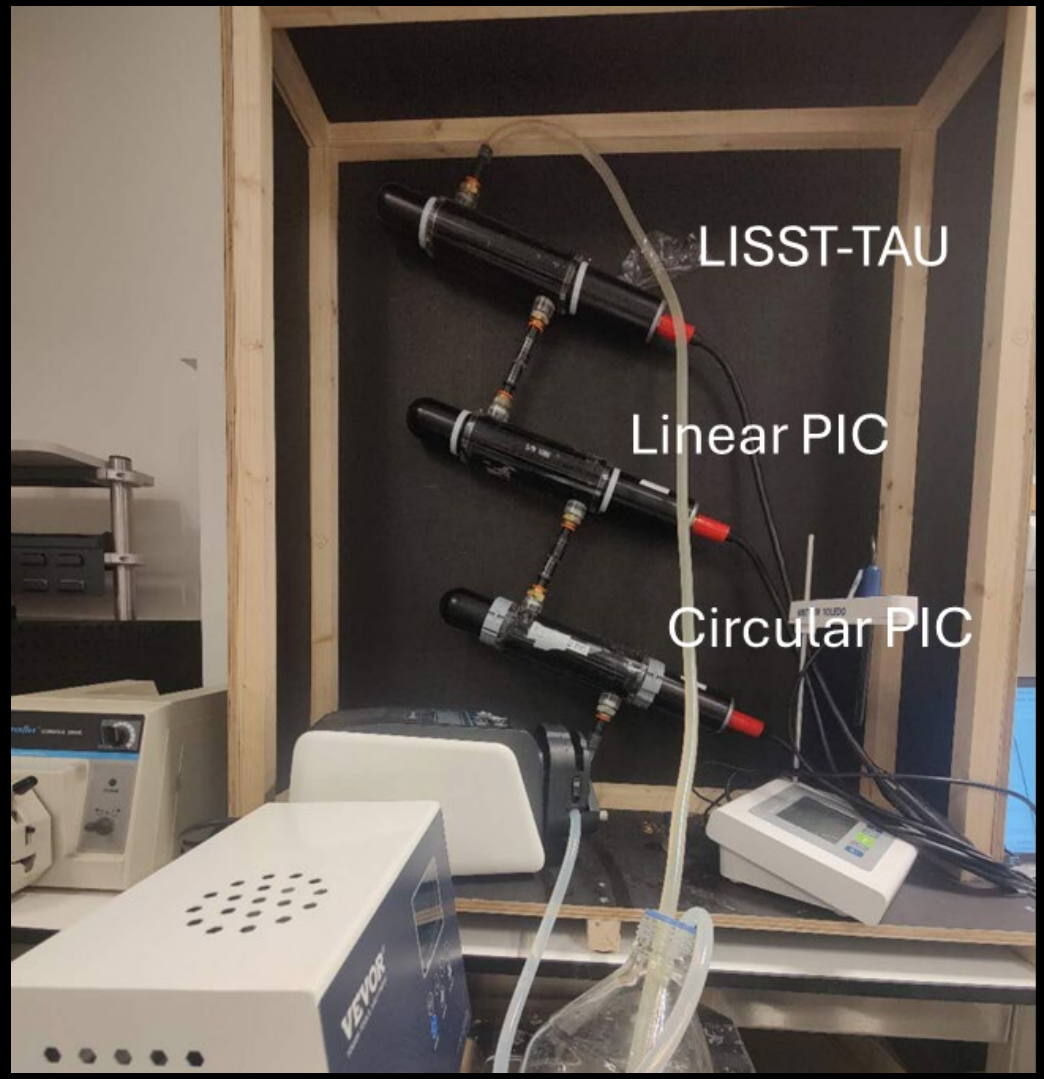


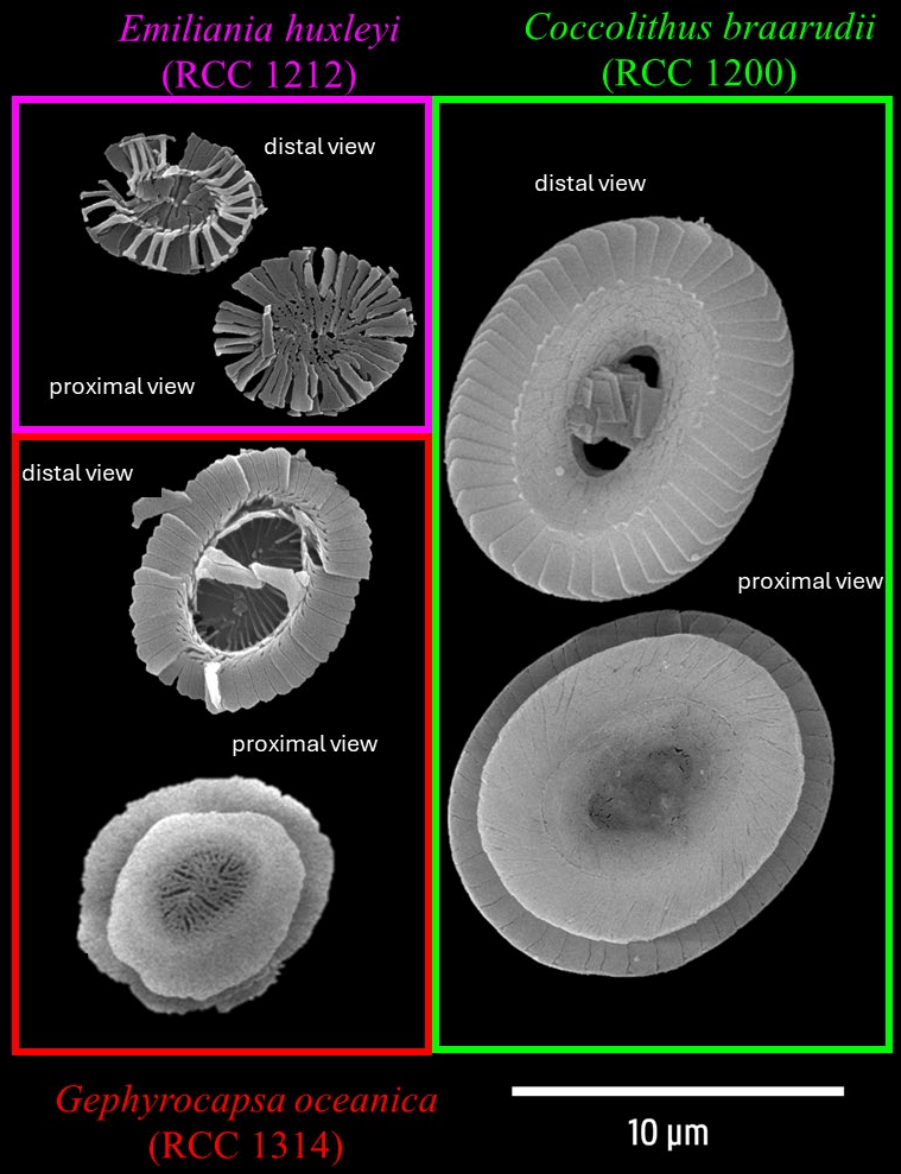
PIC Sensing: Design



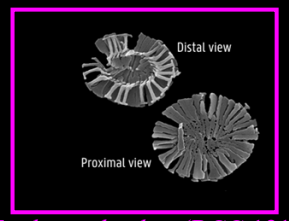
(3D CAD model provided Sequoia Scientific)

PIC Sensing: Lab Calibration

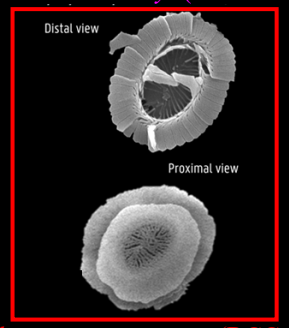




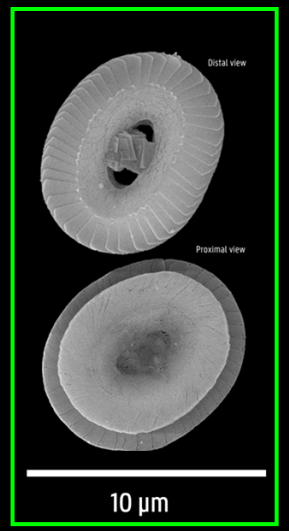
PIC Sensing: Lab Calibration



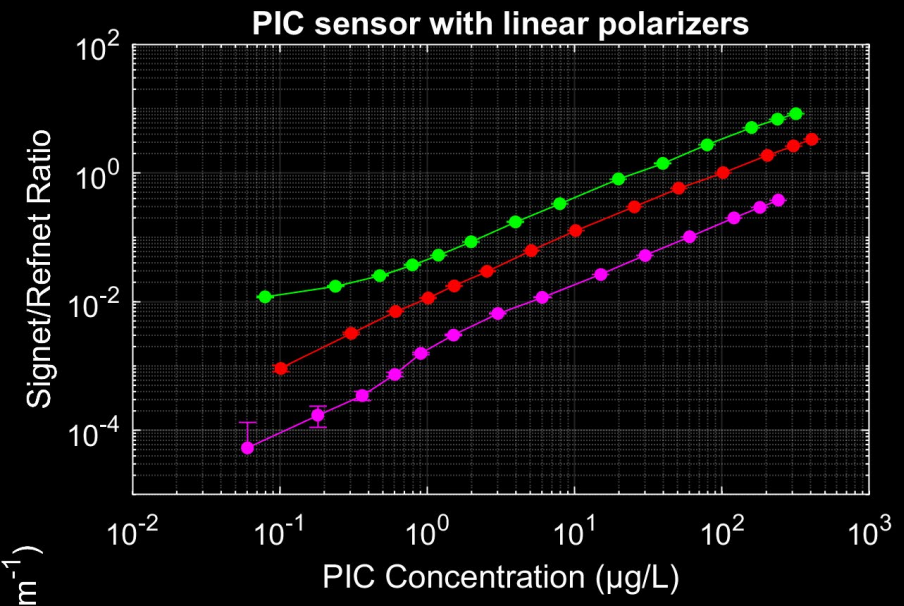
Emiliania huxleyi (RCC 1212)

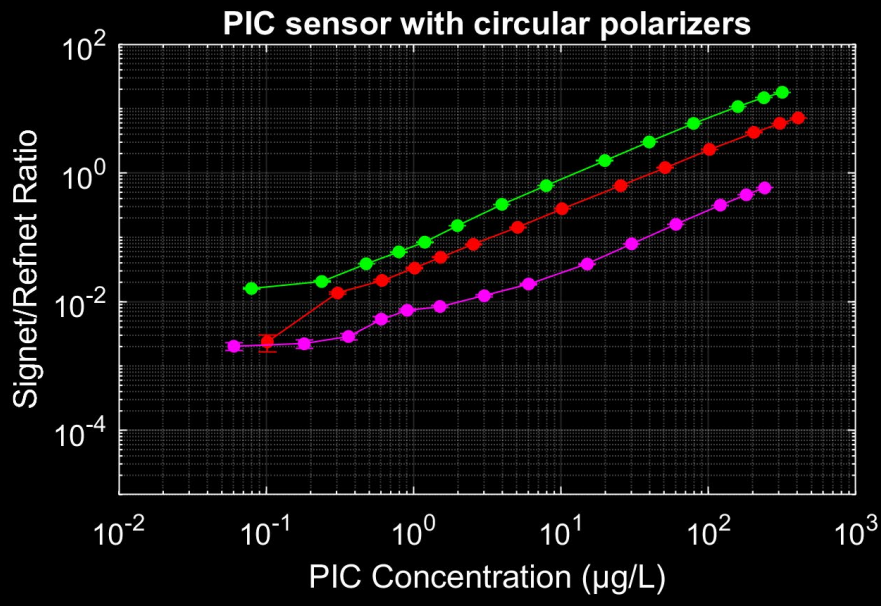


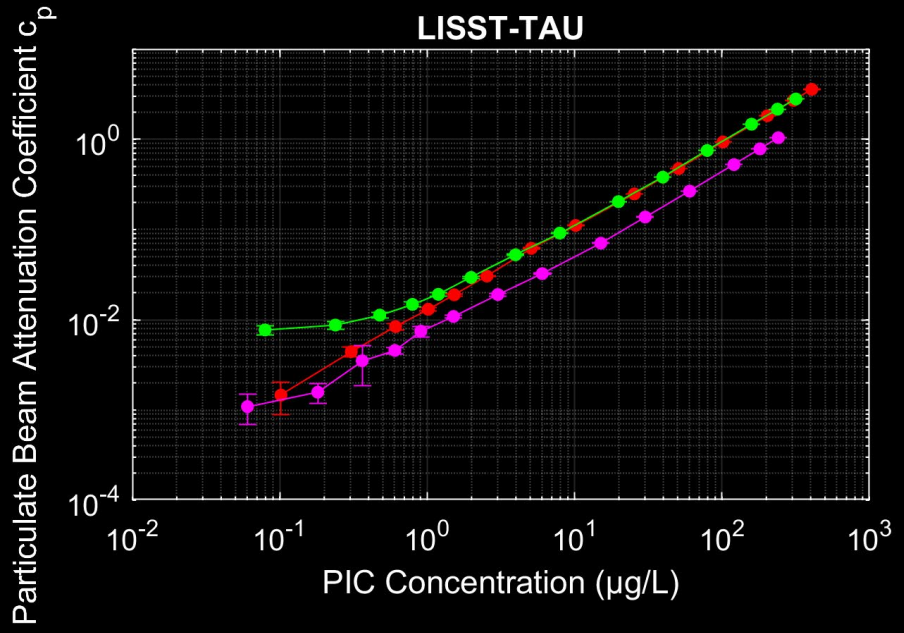
Gephyrocapsa oceanica (RCC 1314)



Coccolithus braarudii (RCC 1200)







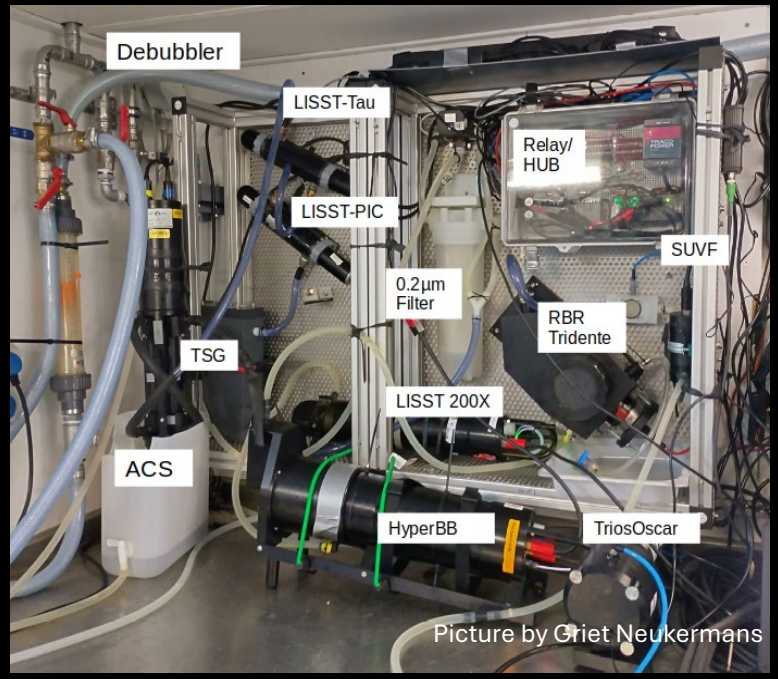
- Detection range: 4 orders of magnitude
- Signal linearly related to concentration
- Factor-of-2 difference between the circular and linear prototypes
- Signal variance related to coccolith size/thickness

Field Test

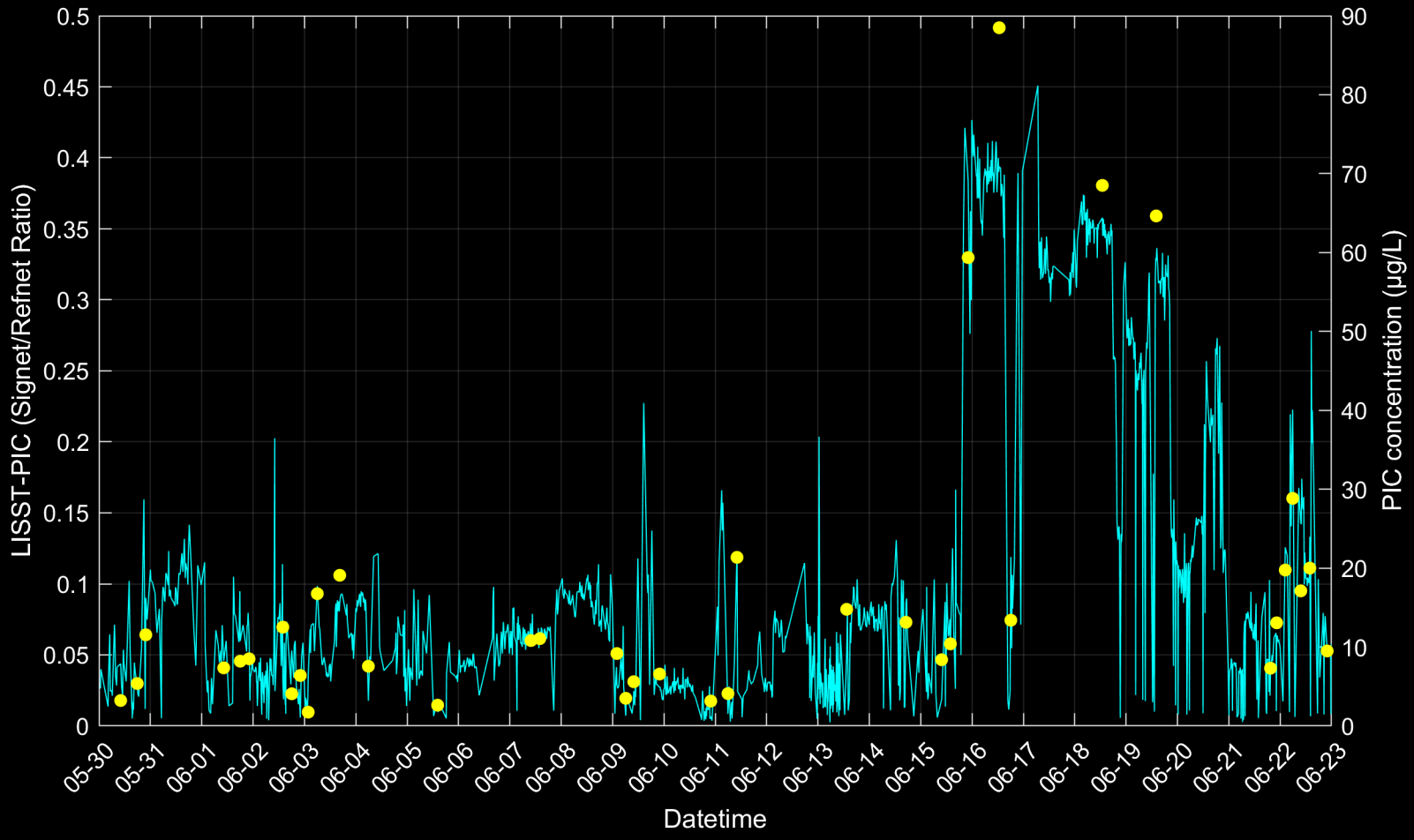
LISST-PIC was integrated into an underway bio-optical system operating on pumped surface seawater (with an acidification cycle every 20 minutes) for one month on the RRS Discovery in the Icelandic Basin (2024).

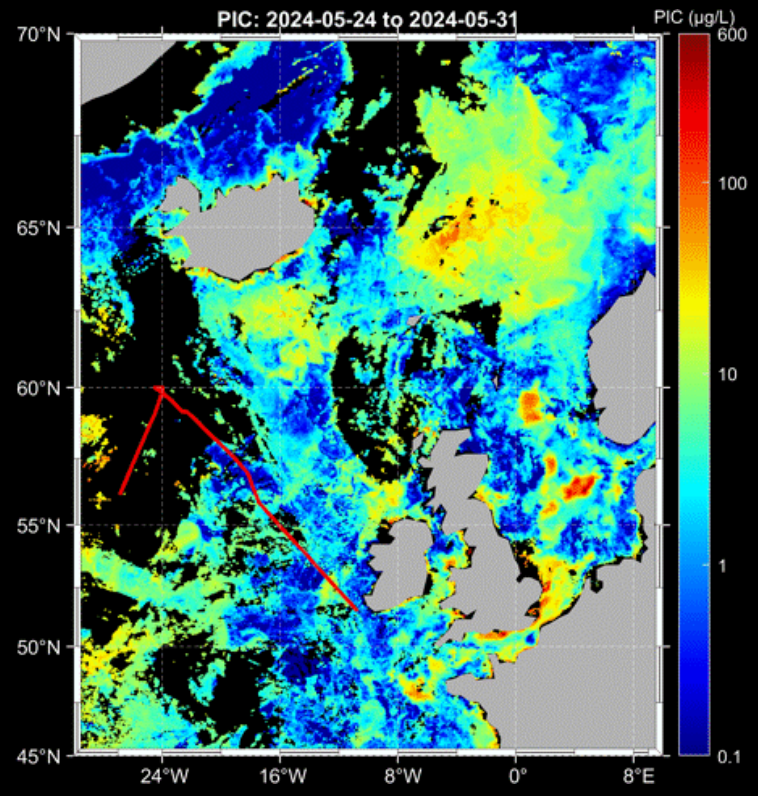
LISST-PIC was integrated in an underway bio-optical system on RV Simon Stevin in the North Sea.

5:35 pm – 5:50 pm
Neukermans et al.: Integrated Autonomous Monitoring of Carbonate Chemistry, Marine Reflectance, and Bio-Optics During Ship Transit



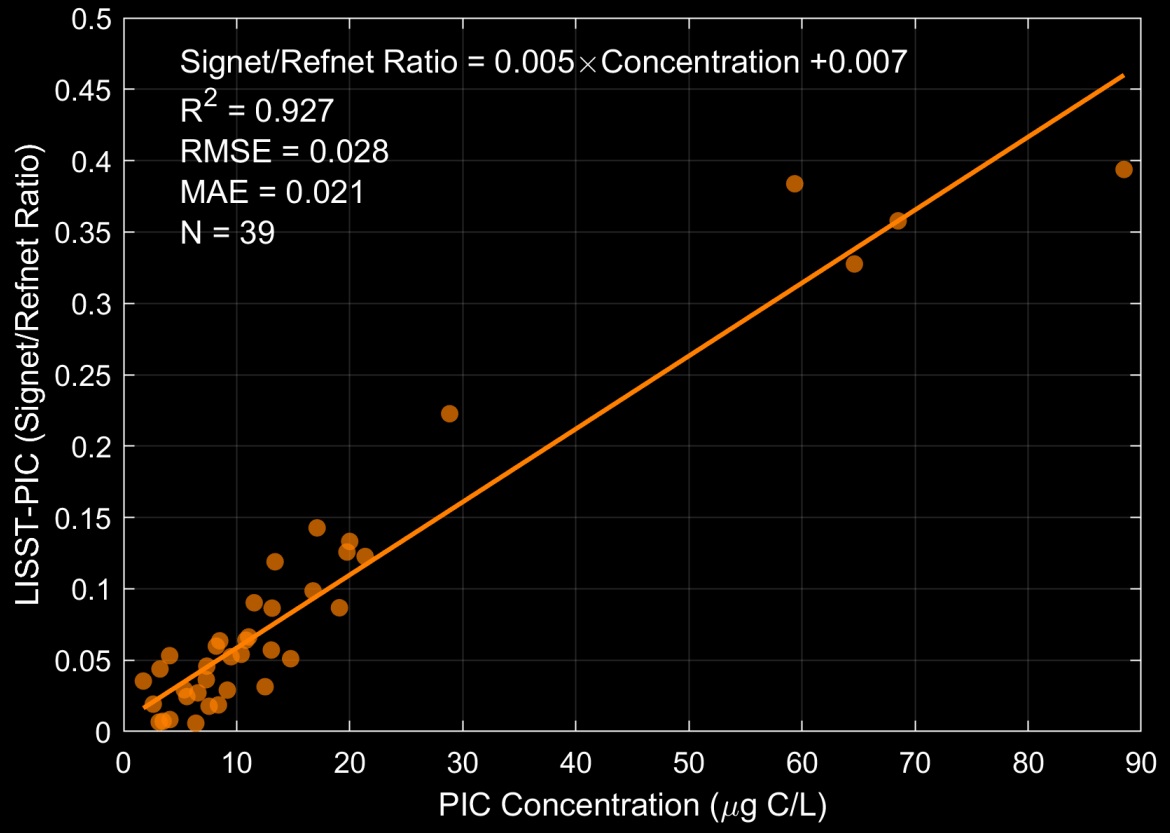
Field Test in the Icelandic Basin



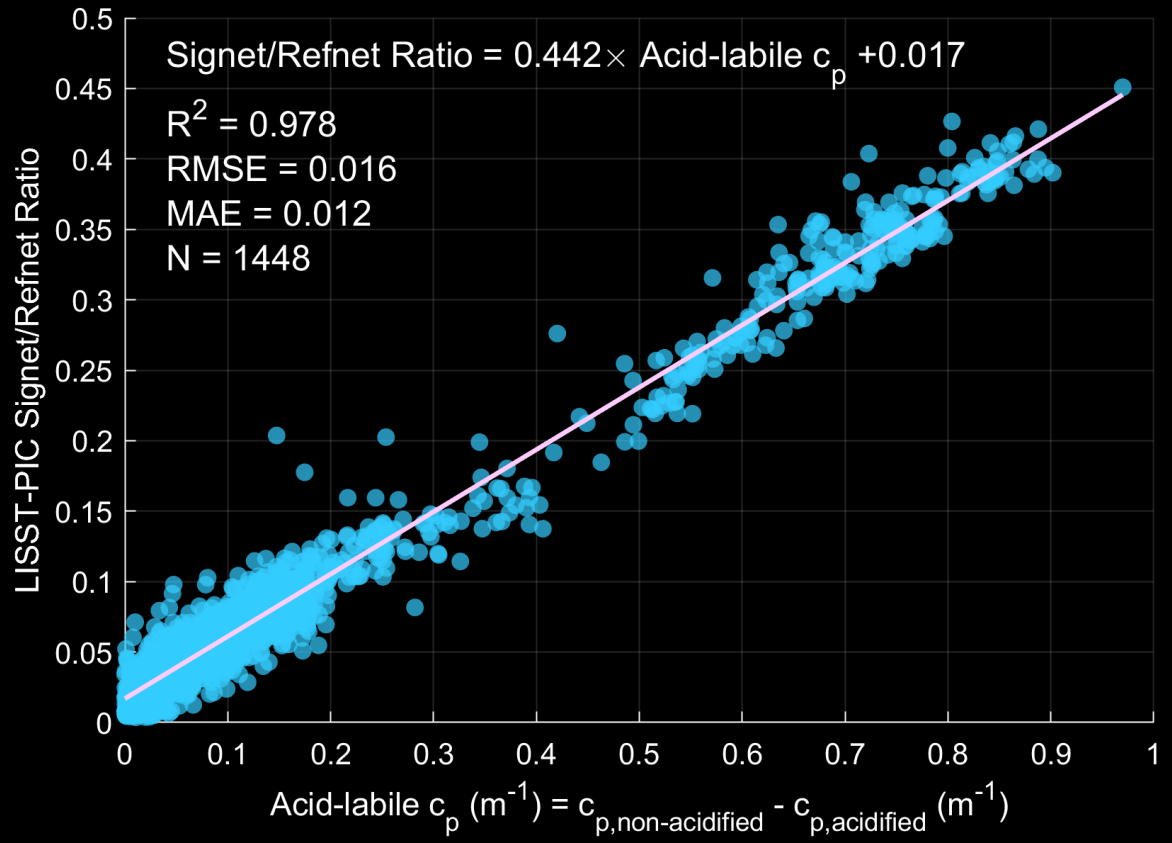


Field Test in the Icelandic Basin

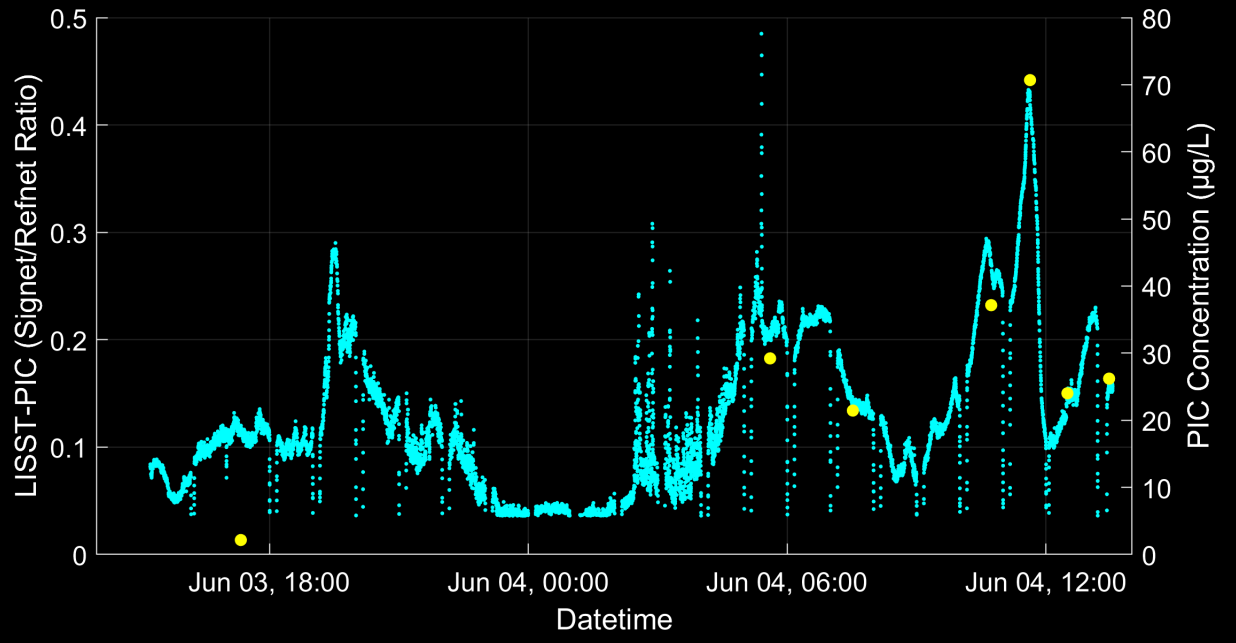
Validated against discrete sample (ICP-OES)

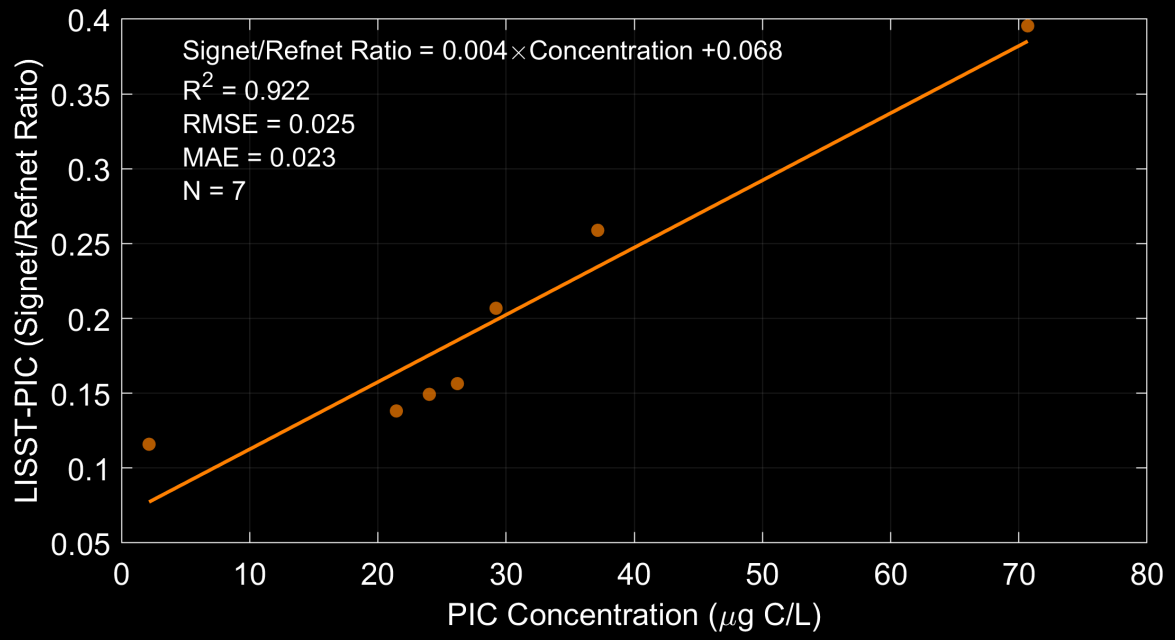


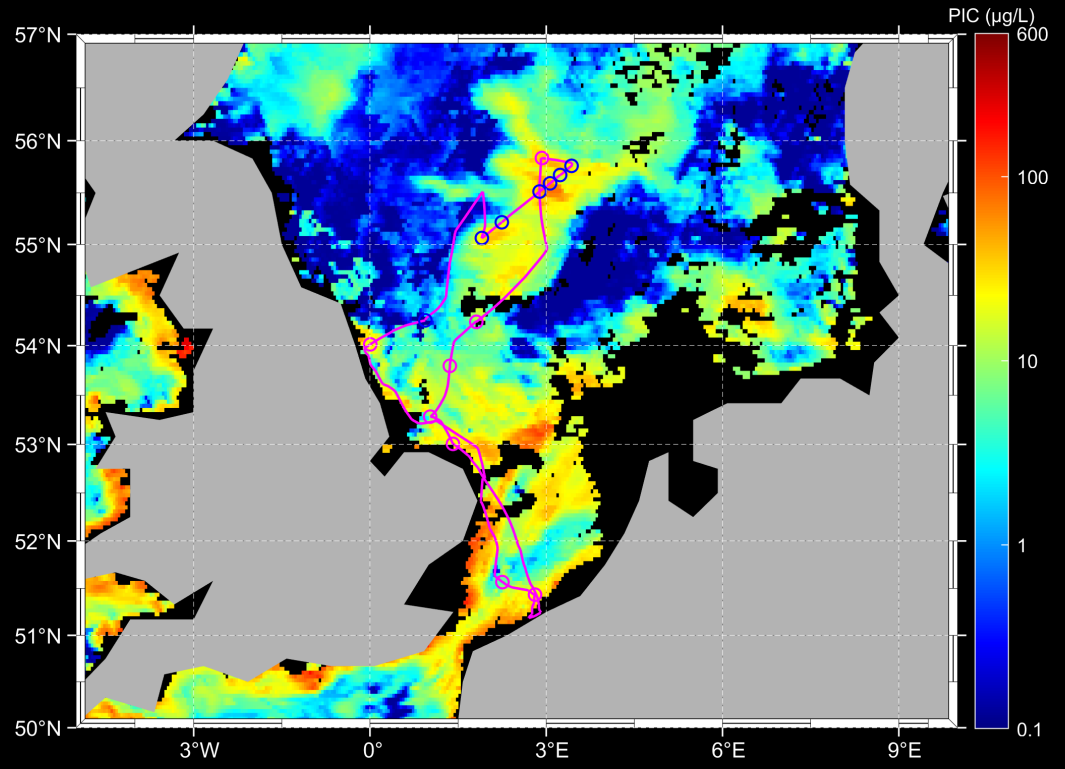
Validated against Acid-labile c_p



Field Test in the North Sea







Knowledge Gaps and Priorities

Next year

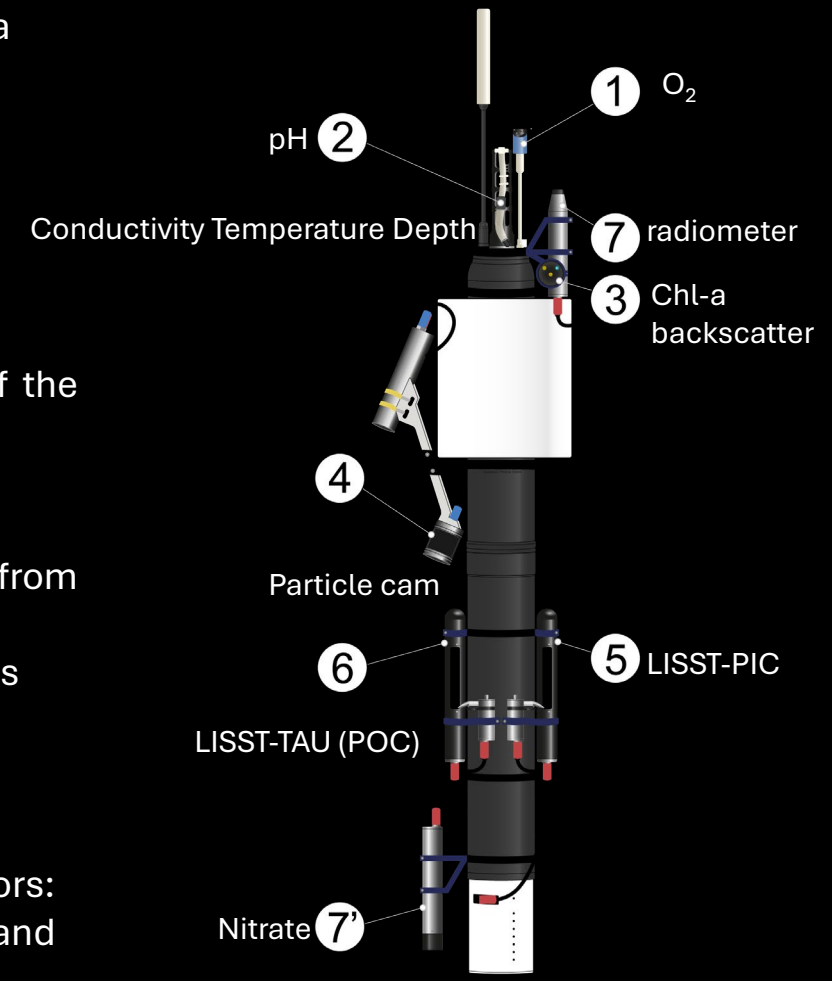
- Further deployments of LISST-PIC and LISST-Tau in ship-based flow-through mode in North Sea
- Laboratory testing of LISST-PIC signals for widely diverse PIC particles
- Pressure testing of LISST-PIC in tank (*ongoing*)
- Vertical profiling of LISST-PIC with LISST-Tau and FChla/bbp on ship CTD Rosette

Next 5 years

- Integrate LISST-Tau and LISST-PIC onto enhanced BGC-Argo floats (*initiated*)
- Deploy enhanced floats in the North Atlantic: new sensors enter the *experimental phase* of the Argo global ocean observation system (*planned for 2026-2027*)
- Set up sensor calibration and validation protocols for LISST-PIC.
- Set up Argo data management and quality control procedures for LISST-Tau and LISST-PIC.
- Deliver a proof-of-concept for quantifying PIC concentration, stocks, and fluxes in the ocean from BGC-Argo floats.
- Set up new optical remote sensing algorithms for PIC retrieval in open ocean and coastal waters

Next 10 years

- Enter and complete the pilot phase of the Argo global ocean observation system for new sensors: develop and assess real-time and delayed mode quality control procedures for LISST-Tau and LISST-PIC.
- Develop improved quantitative and process-based understanding of the carbonate pump (counter and ballast effects) based on novel observations from BGC-Argo and remote sensing



Schematic by Thomas Jessin (SU-LOV)