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New Tools for Optical Measurements in Sea Ice

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Light measurements in ice

- Currently there is only very limited data on light measurements within sea ice
- In ice light measurements are crucial for the correct determination of the inherent optical properties (IOP)
- The solid nature of sea ice makes non-destructive measurements challenging

To help adress these problems we present the following novel tools with low impact on the sampled ice

- IMB style multispectral autonomous light sensor chain
- A new in-ice profiler similar to previously used ones, but based on the field proven RAMSES-ARC sensor
- First prototypes of optical sensors for an endoscopic probe allowing in-situ investigations with minimal disturbance of the medium

In-ice profiler with angular resolution

To investigate the vertical decay of light and its changing angular distribution within a 2" hole in sea-ice, we designed and deployed different fore-optics for the TriOS RAMSES-ARC hyperspectral radiance sensor.

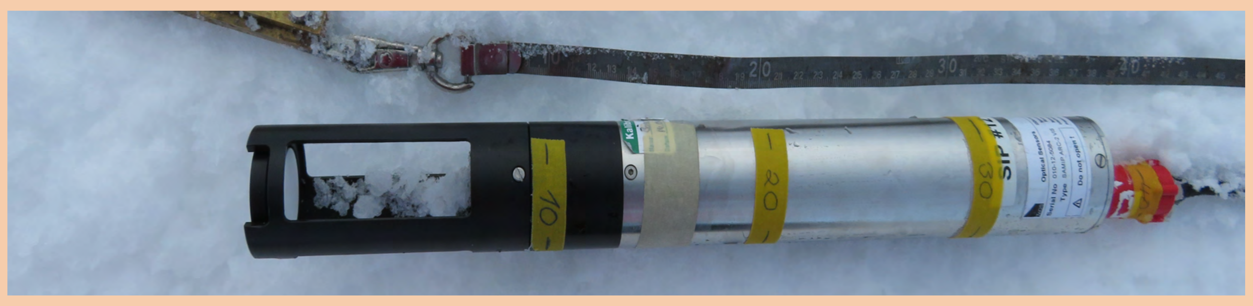


Figure 1: Picture of the „irradiance" foreoptic similar to previously deployed in-ice profilers

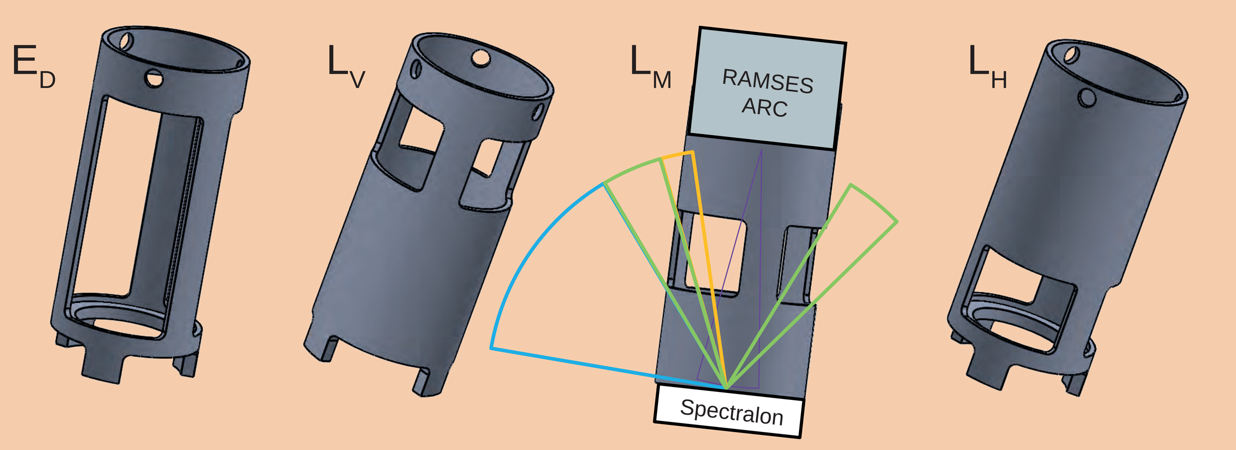


Figure 2: Different foreoptics holding a spectralon reflectance target in front of the radiance sensor enable the separate measurement of different parts of the radiance disrtibution within sea ice.

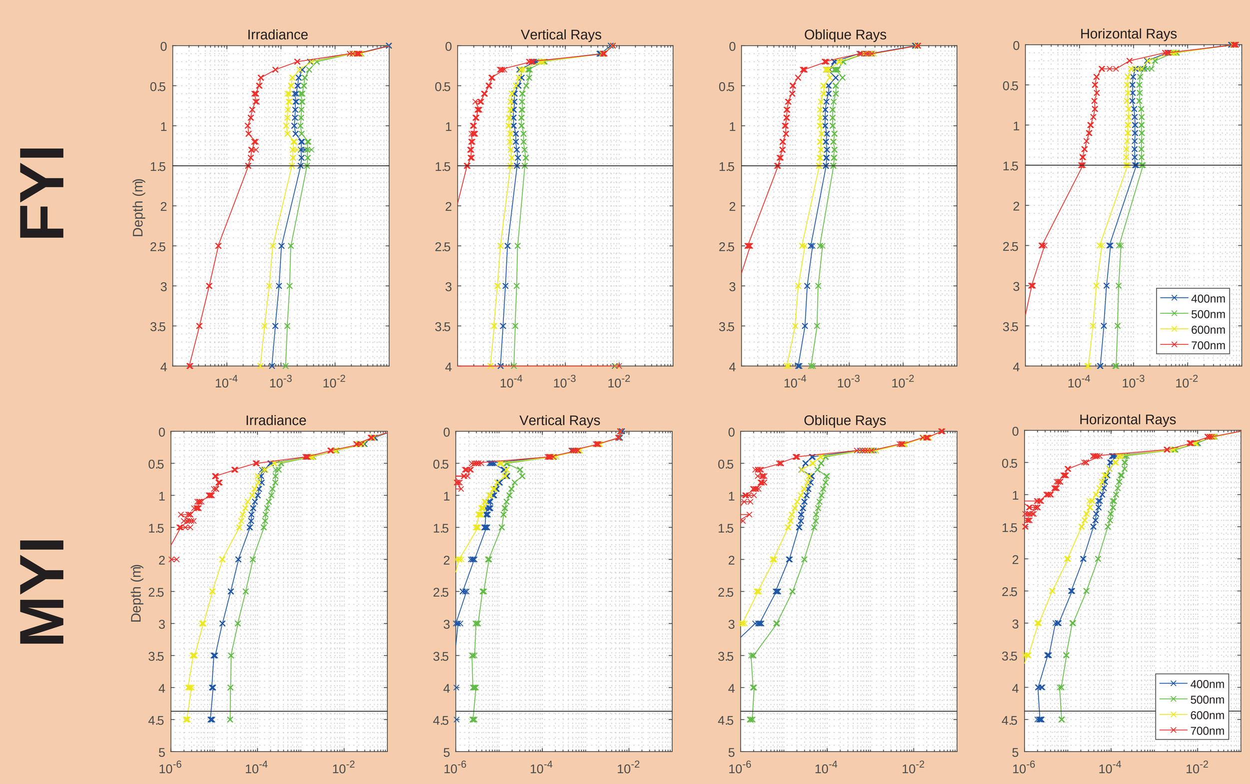


Figure 3: Plot of the vertical decay of different components (irradiance E_D, vertical rays L_V, oblique rays L_M, horizontal rays L_H) of the radiance distribution in first-year (top row) and multi-year (bottom row) sea ice as measured in May 2018 on landfast ice off CFB Alert in the Lincoln sea. Measurements are normalized to the surface reference sensor. The solid black line depicts the sea ice bottom. Light extinction in interior first-year ice (z_i=154cm, z_s=17cm) is surprisingly low, while measurements in interior multi-year ice (z_i=393cm, z_s=44cm) show strong light attenuation.

Sea ice endoscope

A multimodal endoscopic approach for characterizing sea ice optics, physics, biology and biogeochemistry at small scale - Marcel Babin, Session 10, Tuesday morning

Posters:

Development of a reflectance probe to measure sea ice inherent optical properties - Christope Perron

Measurement of in-ice angular radiance distributions
Raphael Larouche

On the design of an optical sensor to measure nitrate in sea ice - Yasmine Alikacem

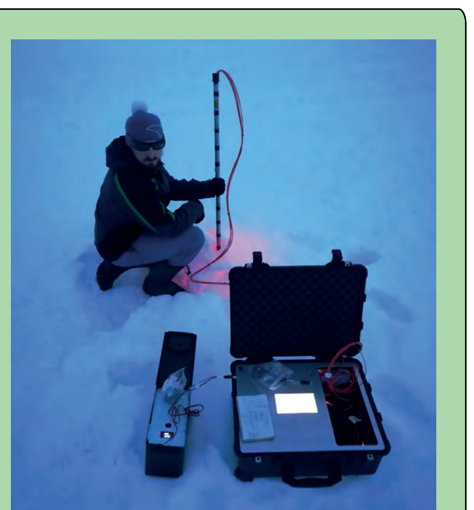


Figure 4: Field test of the new IOP senor on land-fast ice in Qiqiktarjuak (Baffin Island)

Light sensor chain

For long term monitoring of the in-ice light field, we developed a 2m long chain with 48 multispectral (RGB+PAR) sideward looking irradiance sensors. A prototype was deployed in August 2018 at the geographic North Pole and several units of an improved version will be used during MOSAiC.

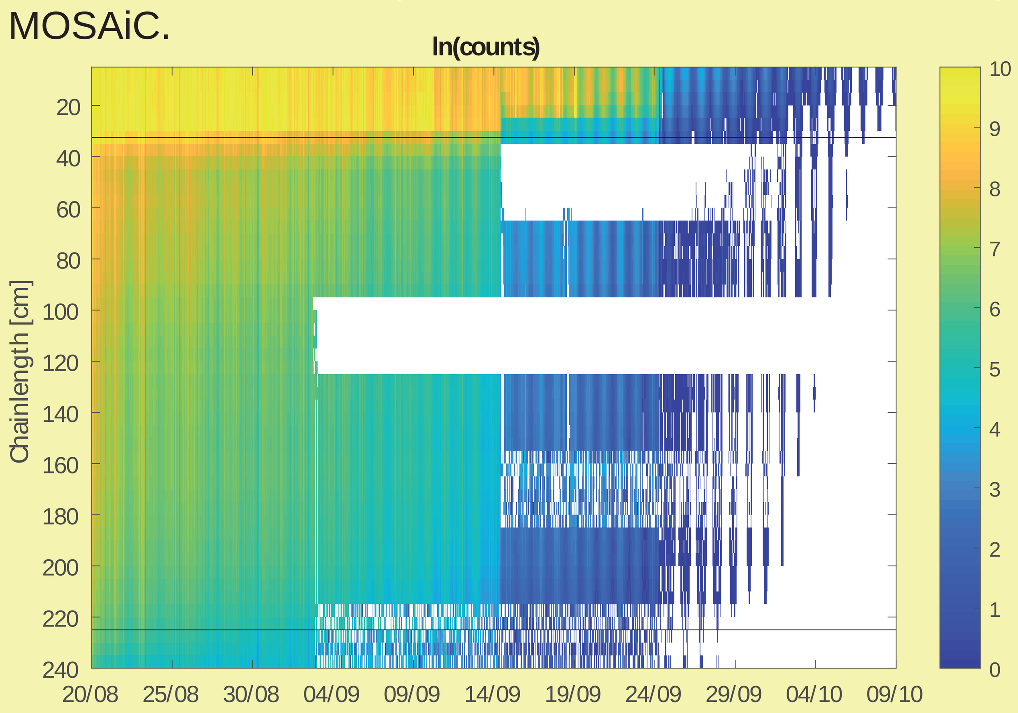


Figure 5: Raw data of light chain measurements during the deployment in autumn 2018. Four chain segments failed on 3 September and 15 September.

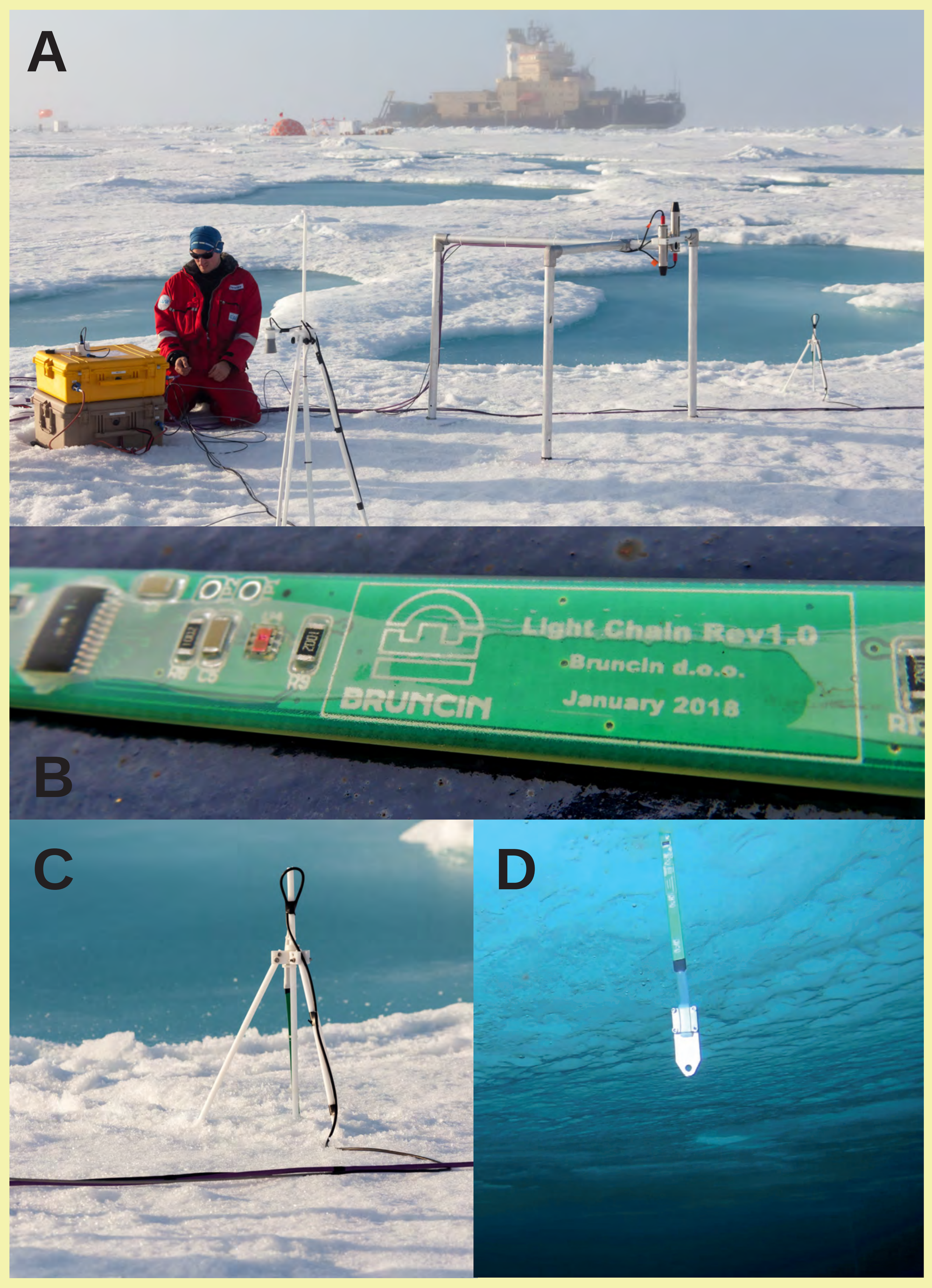


Figure 6: Deployment of the light chain prototype as part of a hyperspectral radiation station during the AO18 expedition of icebreaker Oden in the vicinity of the North Pole, August 2018: A) Overview of station setup B) Close up of light sensor chain C) Surface and D) bottom view of deployed light chain.

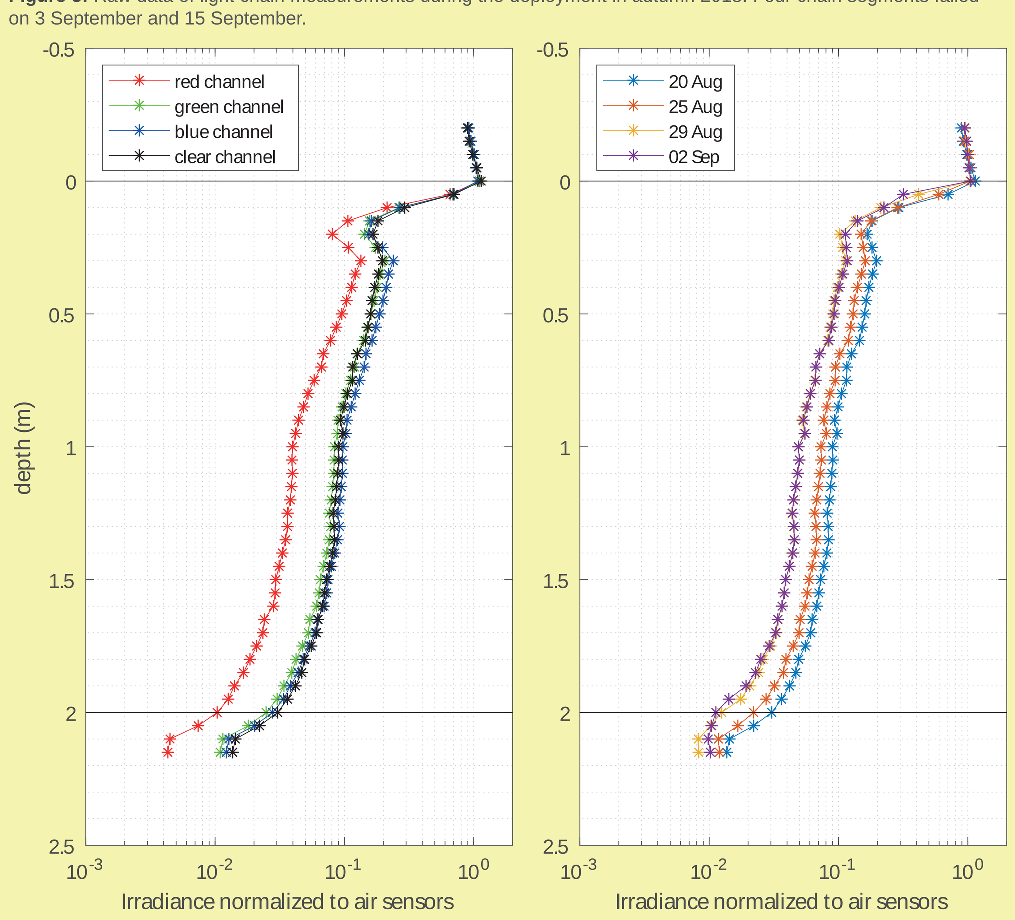


Figure 7: Vertical profiles of sideward irradiance measured in different bands (left) and for different days (right)

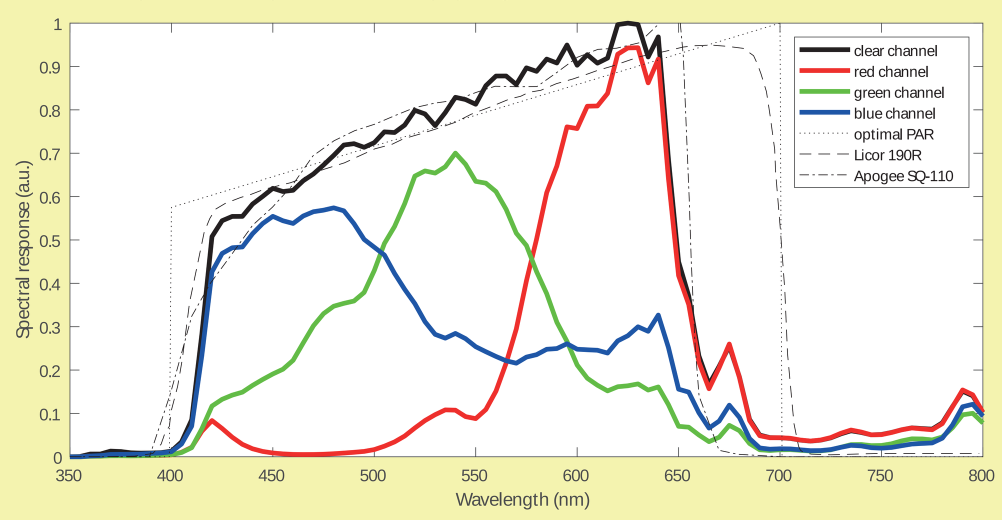


Figure 8: Spectral sensitivity of the four channels used on the light chain sensor (TCS3472), as well as reference sensitivities of different PAR sensors (thin black curves)

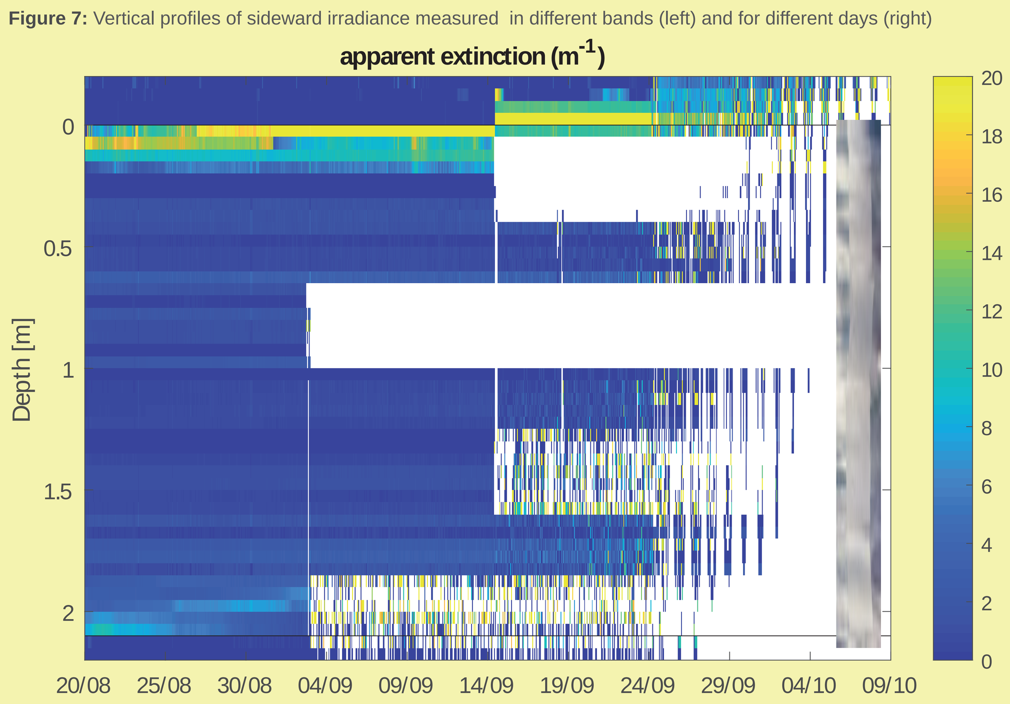


Figure 9: Coefficient of apparent extinction of sideward irradiance derived from light chain measurements.

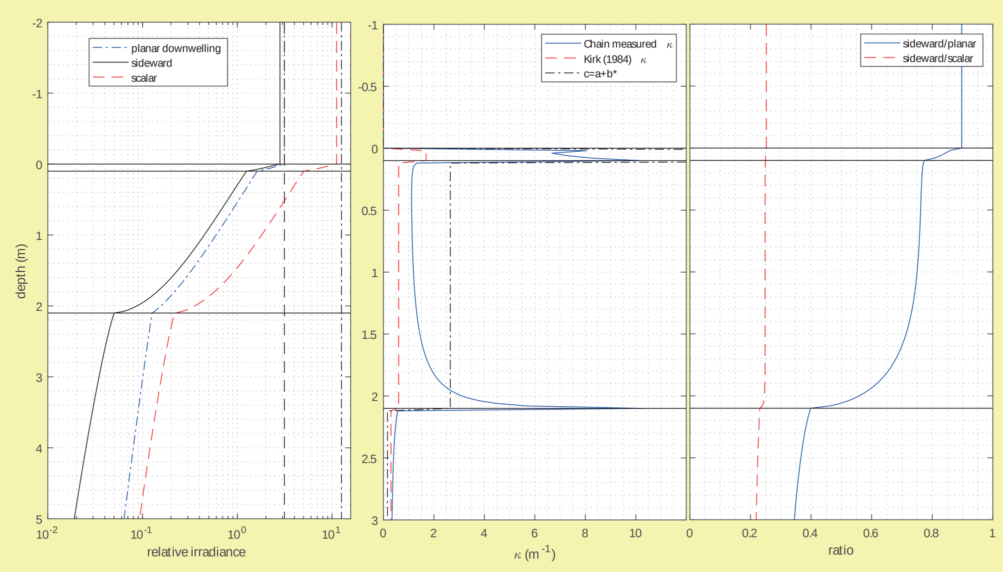


Figure 10: DORT2002 modeled irradiance curves through an icepack similar to the one determined during deployment (left). Modeled chain retrieved extinction coefficents in comparison to beam c and Kd (middle). Irradiance ratios (right)

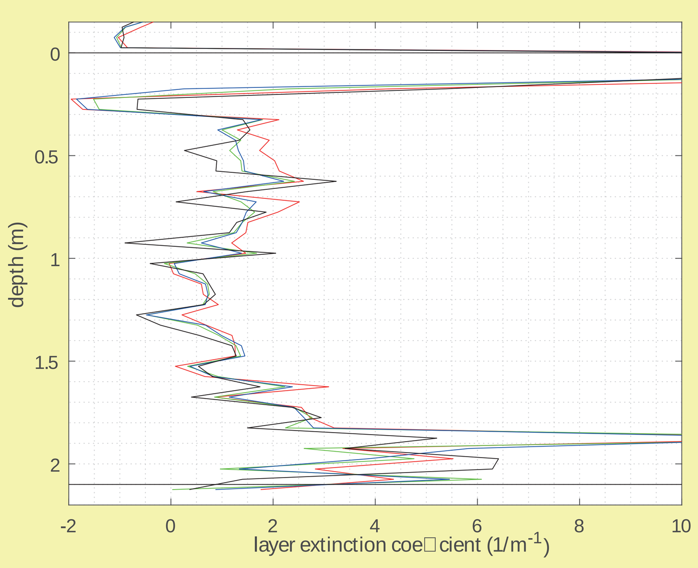


Figure 11 (left): Vertical profile of measured extinction coefficients

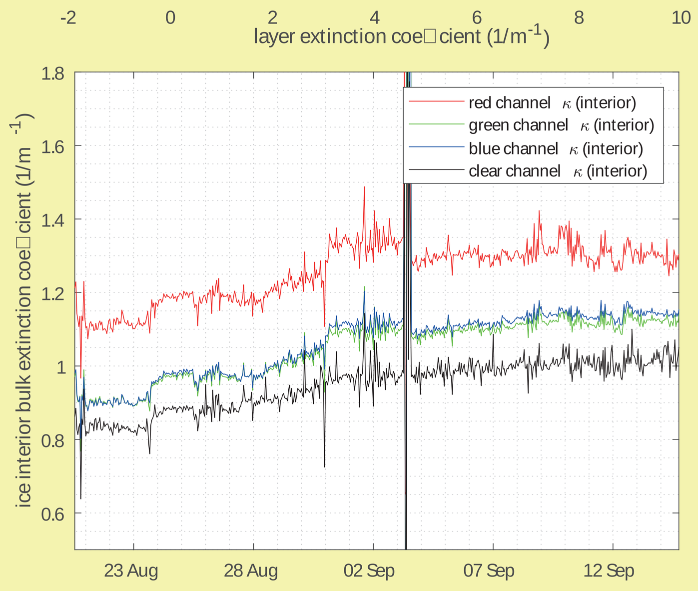
Figure 12 (bottom left): Timeseries of the measured average ice interior (35-180cm) sideward irradiance extinction coefficient.

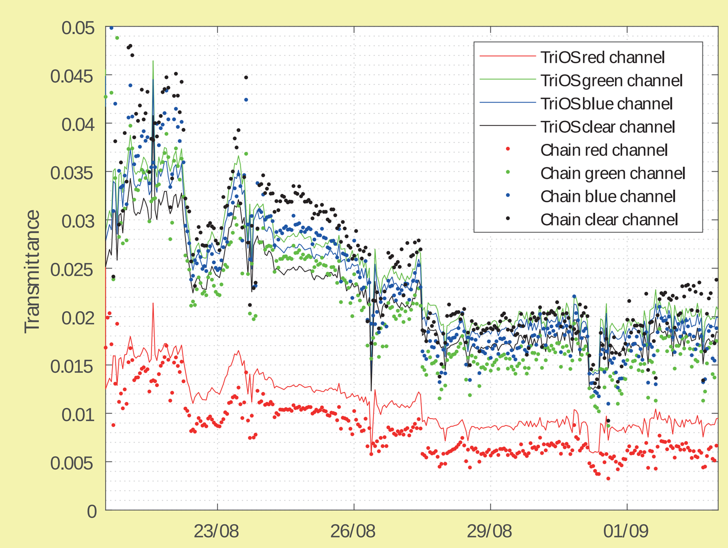
Figure 13 (bottom middle): Comparison of light-chain derived light transmittance and light transmittance as measured with a TrIOs hyperspectral setup at the same location. TriOS measurements are folded with the respective spectral sensitivities of the channels.

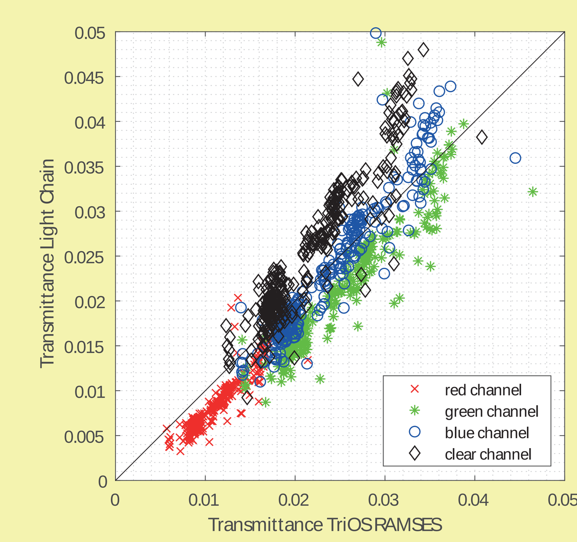
Figure 14 (bottom right): Scatterplot comparing TriOS and light-chain derived transmittance measurements.

Light chain highlights

- easy deployment similar to IMB
- sideward irradiance ~= Scalar irradiance
- vertically resolved extinction profile
- measured transmittance and noise level comparable with TriOS sensors.
- multispectral sensors (PAR+RGB)
- low system cost







Acknowledgements
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