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ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

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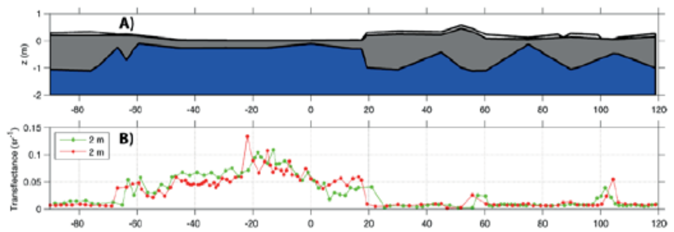
Remotely Operated Vehicles under sea ice – Experiences and results from five years of polar operations

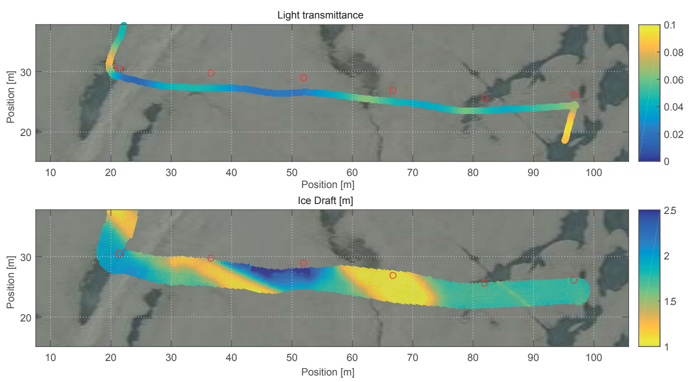
ROV Method

Operating ROVs under sea ice changes various paradigms of ROV operations as compared to bluewater operations. Heavy tether and vehicle trim as well as specialized navigation solutions are necessary for a smooth scientific investigation of the bottom side of sea-ice. In spite of the challenges, ROVs provide a great tool for interdisciplinary sea ice science.

📖 Nicolaus & Katlein, Mapping radiation transfer through sea ice using a remotely operated vehicle (ROV), The Cryosphere, 2013



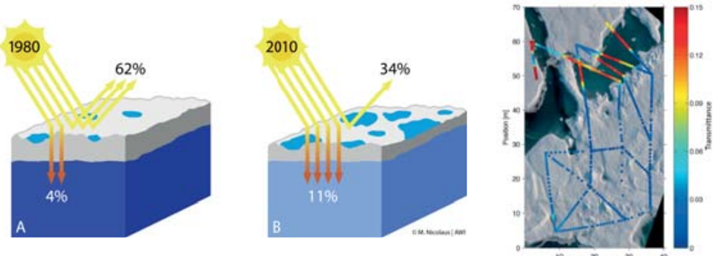
Influence of ice thickness and surface properties



A coordinated survey with the new NUI H-ROV revealed different length scales of variability and enabled a statistic description of light transmittance based on the physical properties.

📖 Katlein et al., Influence of ice thickness and surface properties on light transmission through Arctic sea ice, JGR, 2015

Increasing Light transmittance



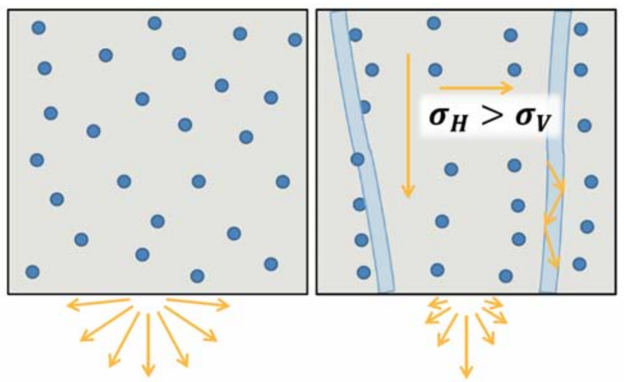
The first ROV data showed, that recent changes in the physical properties of the Arctic ice pack lead to a significant increase in light transmission.

📖 Nicolaus et al., Changes in Arctic sea ice result in increasing light transmittance and absorption, JGR, 2012

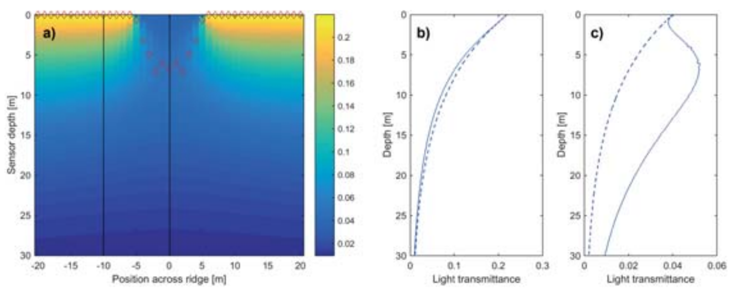
Anisotropic scattering coefficient

ROV data and laboratory experiments proved together with numerical modeling, that the light scattering coefficient in sea-ice is anisotropic.

📖 Katlein et al., The anisotropic scattering coefficient of sea ice, JGR, 2016



Geometric effects



Numerical studies showed the significant impact of geometric effects on light measurements aqcuired using underwater vehicles.

📖 Katlein et al., Geometric Effects of an Inhomogeneous Sea Ice Cover on the under Ice Light Field, Frontiers in Earth Science, 2016

Conclusions

Operations under sea ice require adjusted procedures (vehicle/tether trim, contingency plans, navigation solutions)

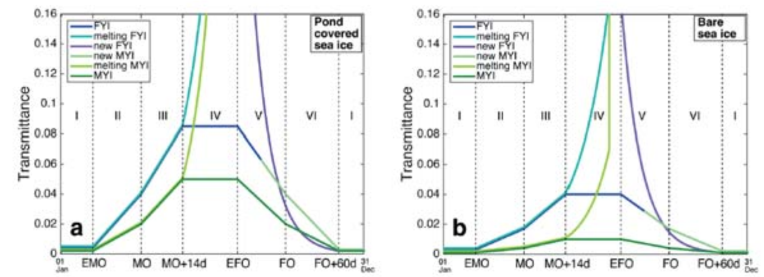
ROV based observations provided insights into:

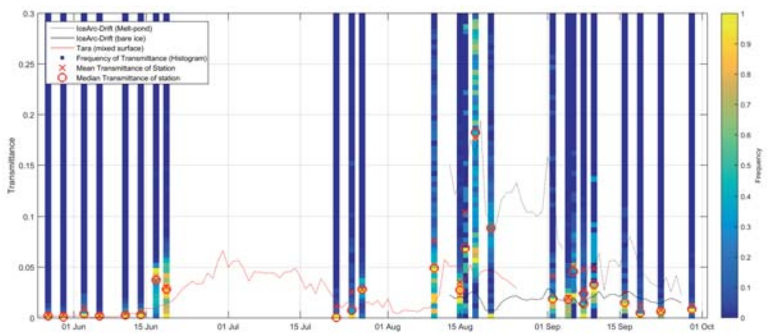
- spatial variability of energy fluxes
- sea ice radiative transfer
- seasonal evolution of light transmission
- distribution of ice algae

Perspectives: new ROV

In the Helmholtz infrastructure program FRAM, we plan to commission a new observation class ROV. The vehicle benefits from the past experiences and will comprise an extended sensor suite including various sonars, video and still cameras, spectroradiometers as well as bio-optical and oceanographic sensors. A multibeam sonar will enable complete three-dimensional mapping of the ice underside.

Seasonal Evolution

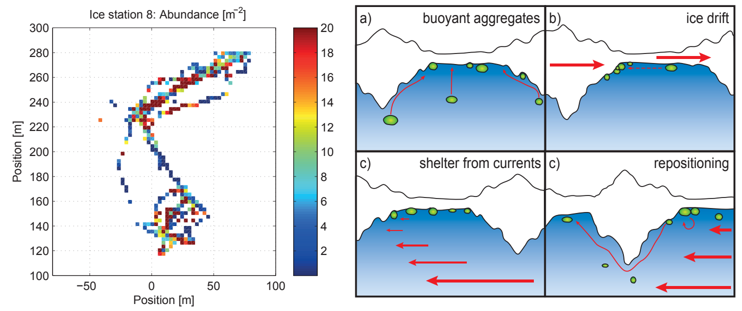




A parameterisation of the seasonal evolution of light transmittance was derived from the ROV data. It was used to upscale energy fluxes to the entire Arctic and reveals the spring-melt transition as the key factor influencing the energy budget.

📖 Arndt et al., Seasonal cycle and long-term trend of solar energy fluxes through Arctic sea ice, The Cryosphere, 2014
📖 Katlein et al., Seasonal evolution of light transmission through Arctic summer sea ice, in prep.

Algal Aggregates

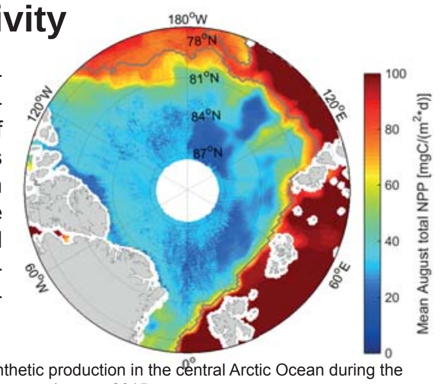


Spatial distribution and biomass of under-ice algal aggregates were analyzed from upward-looking imagery. Aggregate distribution was found to be tightly linked to ice topography and rapid aggregate sinking was found to be a provider of strong cryo-benthic coupling.

📖 Katlein et al., Distribution of algal aggregates under summer sea ice in the Central Arctic, Polar Biology, 2014
📖 Assmy et al., Floating Ice-Algal Aggregates below Melting Arctic Sea Ice, PLOS One, 2013
📖 Boetius et al., Export of Algal Biomass from the Melting Arctic Sea Ice, Science, 2013

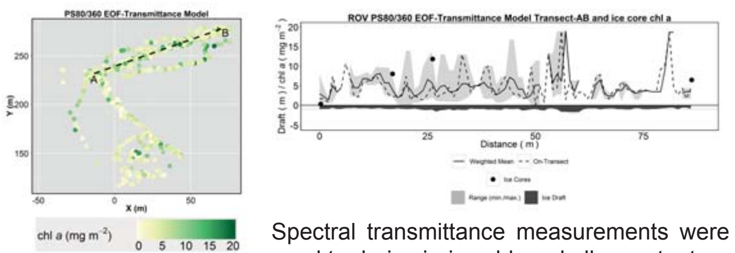
Primary Productivity

The seasonal parameterization was combined with biological measurements of photosynthetic parameters for an Arctic-wide estimation of primary productivity. The algorithm performed well compared to productivity retrievals from satellite observations.



📖 Fernández-Méndez et al., Photosynthetic production in the central Arctic Ocean during the record sea-ice minimum in 2012, Biogeosciences, 2015
📖 Lee et al., An assessment of phytoplankton primary productivity in the Arctic Ocean from satellite ocean color/in situ chlorophyll-a-based models, JGR 2015

Hyperspectral retrieval of Chlorophyll$_a$



Spectral transmittance measurements were used to derive in-ice chlorophyll a content

📖 Lange et al., Spectrally-derived ice-algal chlorophyll a concentrations using under-ice remotely operated vehicle, in prep.

Acknowledgements
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