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

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The availability of advanced robotic technologies to the Earth Science community has largely increased in the last decade. Remotely operated vehicles (ROV) enable spatially extensive scientific investigations underneath the sea ice of the polar oceans, covering a larger range and longer diving times than divers with significantly lower risks.
Here we present our experiences and scientific results acquired from ROV operations during the last five years in the Arctic and Antarctic sea ice region. Working under the sea ice means to have all obstacles and investigated objects above the vehicle, and thus changes several paradigms of ROV operations as compared to blue water applications. Observations of downwelling spectral irradiance and radiance allow a characterization of the optical properties of sea ice and the spatial variability of the energy partitioning across the atmosphere-ice-ocean boundary. Our results show that the decreasing thickness and age of the sea ice have led to a significant increase in light transmission during summer over the last three decades. Spatially extensive measurements from ROV surveys generally provide more information on the light field variability than single spot measurements. The large number of sampled ice conditions during five cruises with the German research icebreaker RV Polarstern allows for the investigations of the seasonal evolution of light transmittance.
Both, measurements of hyperspectral light transmittance through sea ice, as well as classification of upward-looking camera images were used to investigate the spatial distribution of ice-algal biomass. Buoyant ice-algal aggregates were found to be positioned in the stretches of level ice, rather than pressure ridges due to a physical interaction of aggregate-buoyancy and under-ice currents. Synchronous measurements of sea ice thickness by upward looking sonar provides crucial additional information to put light-transmittance and biological observations into context. Observations of under-ice topography by upward-looking multibeam sonar combined with aerial images provide a unique three dimensional picture of the complexity of the non-uniform sea ice layer. ROV surveys cover the scale of an entire ice floe and are an excellent tool to bridge the scale gap between isolated point measurements and larger scale surveys, such as specifically designed under-ice nets with sensor arrays or surveys by autonomous underwater vehicles (AUV).
In the framework of the infrastructure project FRAM (Frontiers in Arctic Marine Monitoring), the Alfred Wegener Institute is in the process of commissioning a new lightweight mobile ROV system for interdisciplinary research underneath sea ice. This new system profits from the acquired experiences and will receive a significantly upgraded suite of scientific sensors, maintaining the rugged and reliable characteristics of the past systems. The interdisciplinary sensor suite will be extended towards the measurement of more oceanographic and biological parameters with a CTD, different fluorometers, and biogeochemical sensors. While basic intervention capabilities are already available, the system can be extended with advanced manipulation and sampling capabilities in the future.