Influence of surface properties and sea ice thickness on light transmission

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Nereid Under-Ice, a new polar ROV

Increased light transmission leads to increased deposition of solar energy in the upper ocean and thus plays a crucial role in the amount and timing of sea-ice melt and under-ice primary production. Recent developments in underwater technology provide new opportunities to undertake challenging research at the largely inaccessible underside of sea ice.

We measured spectral under-ice radiance and irradiance onboard the new Nereid Under-Ice (NUI) underwater robotic vehicle, during a cruise of the RV Polarstern to 83°N 6°W in the Arctic Ocean in July 2014. NUI is a next generation hybrid remotely operated vehicle (H-ROV) designed for both remotely-piloted and autonomous surveys underneath land-fast and moving sea ice. Here we present results from one of the first comprehensive scientific dives of NUI employing its interdisciplinary sensor suite. We combine underwater optical measurements with three-dimensional under-ice topography and aerial images of the surface conditions.

Conclusions

- 72% of light variability can be explained by ice draft and surface albedo
- Averages over larger footprints better describe the variability
- Light field variability is governed by melt ponds on small scales (~100m) and by ice thickness/type on larger scales
- Spatially extensive datasets allow statistical treatment on the basis of histograms
- Histograms of under-ice light conditions can be inferred from distribution functions of albedo and ice thickness
- Geometric effects have to be considered in data interpretation underneath a heterogeneous ice cover

Geometric effects under a heterogeneous sea ice cover

Arctic summer sea ice exhibits strong heterogeneity of optical properties on relatively short spatial scales. As the footprints of different radiometers are rather large, this heterogeneity causes geometric effects that need to be taken into account in the analysis of measured data.

This affects small scale lateral investigations, as well as vertical measurements where sensors are lowered through a hole in the ice. Derivation of inherent optical properties of the seawater can thus be erroneous in ice covered waters, if contamination by geometric effects is not avoided effectively.

Length scales of variability

<table>
<thead>
<tr>
<th></th>
<th>Pole survey (100m)</th>
<th>All data (~2km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ice-draft</td>
<td>11.8m</td>
<td>15.1m</td>
</tr>
<tr>
<td>albedo</td>
<td>8.4m</td>
<td>10.6m</td>
</tr>
<tr>
<td>light transmission</td>
<td>8.4m</td>
<td>16.6m</td>
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</tbody>
</table>

Estimation of light histograms

Variability length scales were derived from different subsets of the dataset by analysis of spatial variograms:

Figure 2: Mosaic of aerial images of the investigated ice floe taken during a low altitude helicopter survey and used for albedo calculations.

Figure 3: Radiometric measurements taken from the ROV during the investigated dive series. a) Light transmittance through the ice-water system. Point estimates of light transmittance were calculated for each 5-m depth slice from the image. Black dots indicate spot data, while blue squares show averaged over circles with different diameters. b) Ice draft derived from the difference between the seafloor and the center beam of the multibeam sonar. The length of Polarstern is 120m for reference. Inlay map shows the cruise track (red line) and the ice station position (black cross) offshore of the ice edge (H-ROV). Geometric effects are clearly visible in transition zone (red line).

Figure 4: For estimation of light histograms an example from the dataset is presented. a) Light transmittance calculated with the correction method described in this study (gray bar) and with the method by Jago et al. (red line) applied to the full transect. The light transmittance is the ratio between the in situ light transmittance (gray line) and the transmittance corresponding to the climatological data (red line) for this specific site. b) Light transmittance histograms generated with the correction method described in this study and the method by Jago et al. The light transmittance histograms are derived from the light transmittance data with different binning. A) Light transmittance histogram of the ice-water system for the top 2 m. Light transmittance for the top 2 m was derived from the ice thickness measured at the transect location by the DVL and the seawater transmittance measured in the corresponding depth of the sunlit region (red line). The histogram is calculated for a binning of 0.1.