Seasonality of Spectral Albedo and Transmission of Sea Ice in the Transpolar Drift, Arctic Ocean

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Introduction

The physical and optical properties of snow and sea ice in the Polar Regions control the amount of solar short-wave radiation, reflected at the surface, scattered and absorbed within snow and ice, and transmitted into the ocean beneath.

Albedo and transmissivity of snow and sea ice strongly influence heat fluxes within the coupled atmosphere-ice-ocean system, and by that the evolution of the sea ice.

Both were measured continuously at high spectral and temporal resolution during the transpolar drift of the schooner *Tara* through the Arctic Basin between April and September 2007. In addition, a nearby ice mass-balance buoy (IMB) was used for data analysis.

Simultaneous in-situ measurements of snow and sea ice properties and meteorological observations complement the autonomous datasets [Gascard *et al.* 2008].

Results

Results show significant seasonal changes and highlight key events during the transitions from spring to summer and summer to autumn.

Melt season began on 11 Jun and lasted 65 days until 15 Aug, including formation, evolution, and freeze up of melt ponds.

Net short-wave (330-920 nm) flux was 29 W/m^2 at the surface and 2.6 W/m^2 under the ice. Resulting potential melt of sea ice was 1 m.

Spectral composition of transmitted light changes significantly during summer, showing increased absorption between 400 and 600 nm. 92% of transmitted light were in the PAR range (400-700 nm).

Primary production of organisms and increased mass of Dissolved Organic Matter caused most likely a mid-summer decrease of transmitted light. Algae growth on the under-ice sensor, and later grazing might have affected the result, too.

Sea-ice mass balance was dominated by surface ablation and bottom ablation was of minor importance.

Surface properties of snow and sea ice represent typical summer conditions: ablation of the entire snowpack, deteriorated sea-ice surface, and isothermal surface temperatures of 0°C.

Textural analyses show that the measurements were performed over and under multi-year sea ice with 88% columnar ice.

Conclusions

We have gathered a unique data set of continuous and high temporal-resolution spectral albedo and transmission measurements on Arctic sea ice.

Results show how coordinated scientific programs during private expeditions can contribute to extensive data sets of snow and sea ice properties.

Our observations have a large potential to be used for upcoming model and remote sensing applications. Especially because they were made prior to the Arctic sea ice extent minimum in autumn 2007.

Absolute values and timing of energy transfer through snow and sea ice into the ocean are now available for biological process studies. Light data are of special interest, since light is usually the limiting factor for primary production.

Spectral radiation results show that this method might also be used for other studies on (semi-) autonomous platforms.

The drift of *Tara* (2006 to 2008)

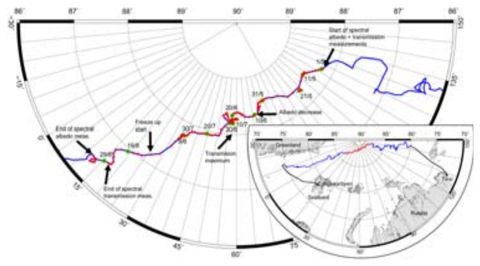


Figure 1: Map of Tara drift during spectral radiation measurements (main figure) and map of the entire voyage of Tara from Tiksi, Russia, to Longyearbyen, Svalbard (inlay). The blue line shows the drift track and red dots give daily positions of Tara at the time of highest sun elevation, green dots and text labels mark every 10th day for better orientation. Additionally, significant events are labeled.

The *Tara* expedition was initiated as a non-scientific transpolar drift, emulating Nansen's *Fram* expedition from 1893 to 1896.

Intensive field work was carried out as part of the DAMOCLES project during the drift, most intensively during summer 2007, just before the minimum of Arctic sea-ice extent.

Snow and sea-ice properties were measured in-situ weekly.

Optical measurements

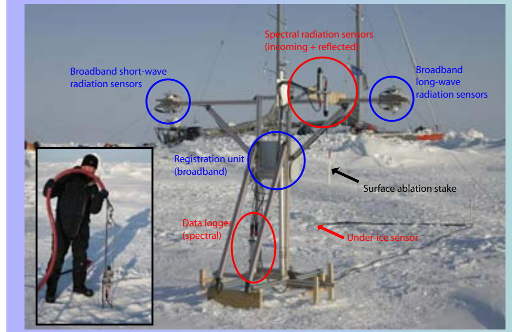


Figure 2: Photograph of the station set-up (28 Apr 2007) showing both, spectral and broadband radiation sensors (photo: M. Nicolaus). The under-ice sensor is lowered at the end of the black cable behind the station and cannot be seen from the surface. The schooner Tara and the field camp are shown in the background. The small inset-picture shows the deployment of the under-ice sensor in its rack (photo: F. Latreille). Initial sea-ice and snow thickness was 2.0 and 0.1 m, respectively.

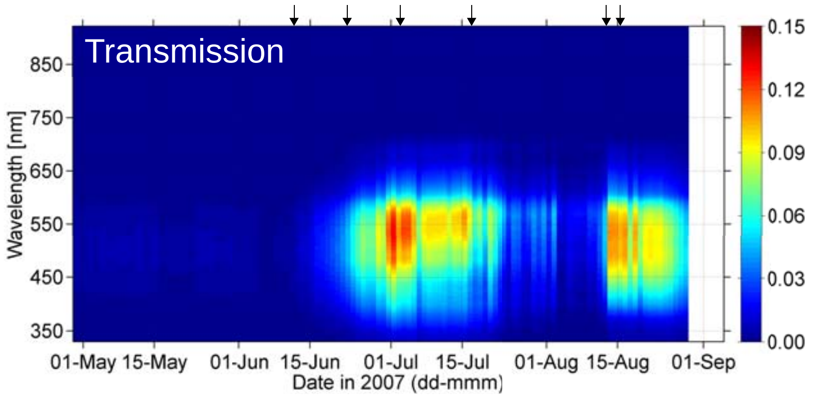
Spectral radiation was measured with 3 Trios Ramses radiometers (320-950 nm, 3.3-nm resolution).

Two sensors were installed above the surface and one was hanging under the sea ice. Broadband radiation was measured at the same rack (Fig. 2).

Spectral radiation was measured in 30-min intervals from 28 Apr to 28 Aug (transmission) and 05 Sep (albedo) 2007.

The station was maintained daily, but the spectral sensors did not need to be cleaned at all during the entire observation period.

Spectral radiation measurements



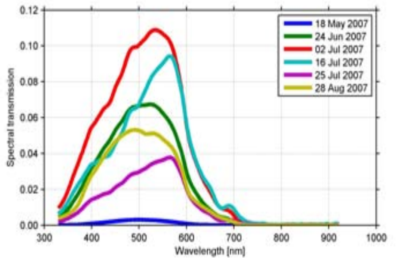


Figure 4: Spectral transmission at times of highest sun elevation during the drift (Fig. 1). Left: Daily spectra, above: Selected dates of different surface conditions (Fig. 3). No transmission data are available after 28 Aug 2007, because the under-ice sensor had to be retrieved for security reasons.

Characteristic events (see also arrows)

11 Jun:	Melt onset (drop of IR albedo, increase of transm.)
21 Jun:	First melt ponds observed
02 Jul:	Water standing on surface, BB-albedo minimum
16 Jul:	Drop of transmission, no change in albedo
12 Aug:	Re-increase of transmission, no change in albedo
15 Aug:	Begin of freeze-up (first new snow, albedo increase)

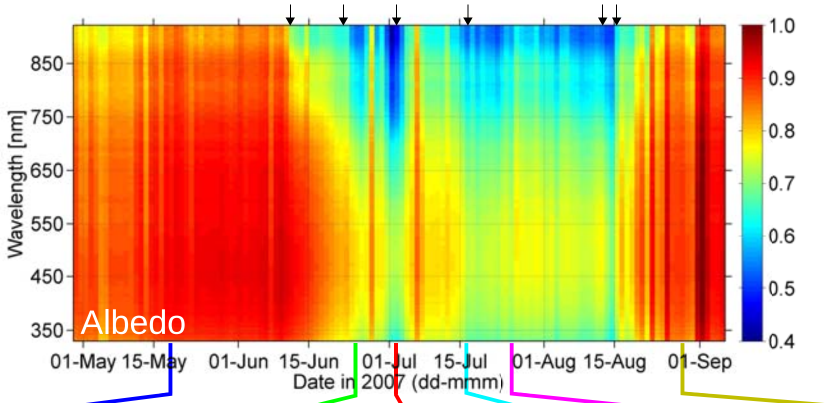
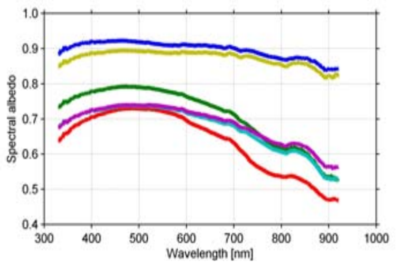
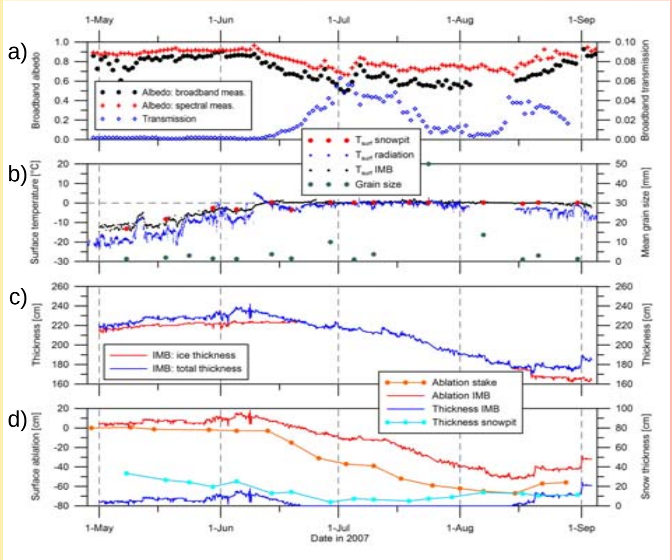


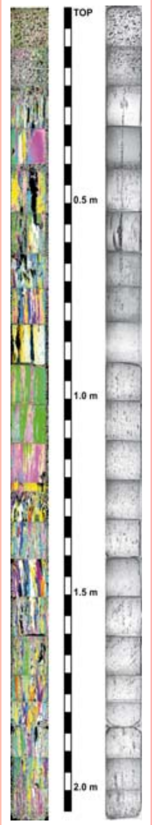
Figure 5: Spectral albedo at times of highest sun elevation during the drift (Fig. 1). Left: Daily spectra, below: Selected dates of different surface conditions (Fig. 3).



Snow and sea-ice conditions

Figure 6: Time series of (a) broadband albedo and transmission, albedo time series compare direct broadband measurements [Vihma et al., 2008] and integration from spectral measurements (Fig. 2), (b) surface temperature (from snow pits, IMB, and radiation measurements) and snow grain size, (c) sea-ice and total (snow+ice) thickness measured with IMB 2007C, installed close to the radiation station, and (d) snow ablation and thickness. Snow properties were measured weekly in snow pits and along stakes, both within 50 m from the radiation station.





Broadband albedo from spectral measurements was on average 0.12 higher than from broadband measurements, as expected because of the limited spectral coverage, but both are consistent in relative changes.

Sea-ice thickness decreased by 0.6 m, with 0.5 m of the loss due to surface ablation. Snow thickness varied between 0 (from 21 Jun to 14 Aug) and 21 cm (2 Sep).

Surface temperature are consistent from snow pits and radiation measurements, mostly 0°C during summer.

Figure 7: Thinsection-photo mosaic from an ice core, retrieved at the under-ice sensor site (25 Apr 07). Thin sections were photographed under transmitted light with crossed polarizers (left) and without (right). Scale is in 0.05 m sections, total core length was 2.06 m.

Figure 3: Seasonal changes of surface conditions around the radiation station. Photographs show late winter conditions (18 May), early melt pond formation (24 Jun), further melt pond evolution (02, 16, and 30 Jul), and autumn freeze up (28 Aug). Note that the photo from 18 May was taken from the opposite side. Most pictures were taken by T. Palo (all photos © Tara expeditions). Spectra of each surface condition (day) are given in Figure 5, plotted in the same color.

Acknowledgement

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References

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Vihma et al. (2008), Meteorological conditions in the Arctic Ocean in spring and summer 2007 as recorded on the drifting ice station Tara, GRL, 35(L18706), doi:10.1029/2008GL034681.