A Modern Concept for Autonomous and Continuous Measurements of Spectral Albedo and Transmittance of Sea Ice

Marcel Nicolaus[1], Stephen R. Hudson[1], Sebastian Gerland[1], Sara de la Rosa[2], and Anders Sirevaag[2]

[1] Norwegian Polar Institute, Tromsø, Norway [2] Geophysical Institute, University of Bergen, Norway

UNIVERSITY OF BERGEN

Abstract

Time series data of spectral irradiance with high temporal and spectral resolution on sea ice are needed for advancing studies of atmosphere-ice-ocean interaction during different seasons. Synchronous measurements of albedo and transmittance enable increasing knowledge about physical, biological, and geochemical processes in sea-ice regions. In particular, more observations of under-ice irradiance are needed to quantify fluxes through snow and sea ice and their seasonality.

Here we present a modern setup for synchronous, autonomous, continuous, and high temporal-resolution measurements of spectral irradiance over and under sea ice. Spectral albedo and transmittance are derived from the three measured irradiances. The setup is based on three spectral radiometers (RAMSES ACC) and one data logger (all instruments: Trios GmbH, Germany). Sensors, data logger, and their setup all worked well during different applications. More detailed information may be found in Nicolaus *et al.* (subm.) and Nicolaus *et al.* (in prep.).

Data sets

Data set name	Time and Duration	Region and Description	Number of albedo / transmittance spectra and Meas. interval	Additional observations
Vagabond06	30 Mar – 03 May 2006 35 days	Storfjorden, Svalbard Fast ice	812 / 812 60 min	Ice thickness, CTD*, AWS*, Broadband radiation*
Tara07	28 Apr – 02 Sep 2007 129 days	Central Arctic Drift station	6213 / 5838 30 min	Snow pits, Ice cores, Ice mass balance*, AWS*, Broadband radiation*
Oden08	15 Aug – 01 Sep 2008 17 days	Central Arctic Drift station	2410 / 2325 10 min	Snow pits, Ocean heat flux*, AWS*, Broadband radiation*
Barrow09	23 Feb – 12 Jun 2009 109 days	Chukchi Sea, near Barrow, Alaska Fast ice	*No data recorded (battery failure)*	
Vagabond09	15 Apr – 08 Jul 2009 84 days	Storfjorden, Svalbard Fast ice	7490 / 4603 10 min	Ice thickness, Snow surface, CTD*, AWS*, Broadband radiation*

Table 1: Summary of data sets, collected with the presented setup, comprising continuous measurements for more than 24 hours. In addition, available data sets of highest relevance for optical measurements are listed. Some of these observations were performed by project partners (marked with *).
Abbreviation: AWS: Automatic Weather Station

Instruments

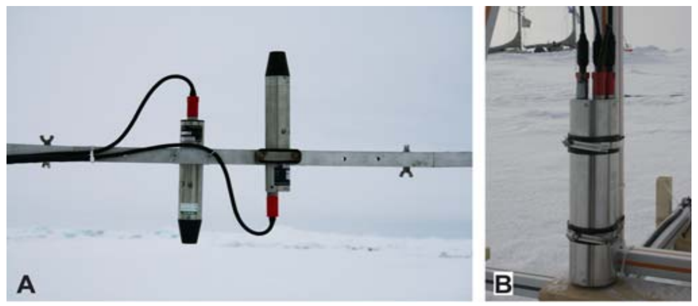

Figure 1: Close-up of (a) 2 RAMSES ACC sensors for albedo measurements over sea ice and (b) data logger with three connected sensors, mounted on an aluminum rack (see also Figure 3b).

Concept & Setup

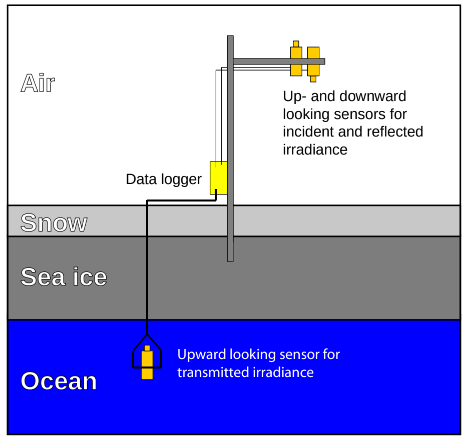

Figure 2: Schematic of setup for three sensors and a data logger. Two sensors are installed above the surface and one is hanging in a frame under the ice.

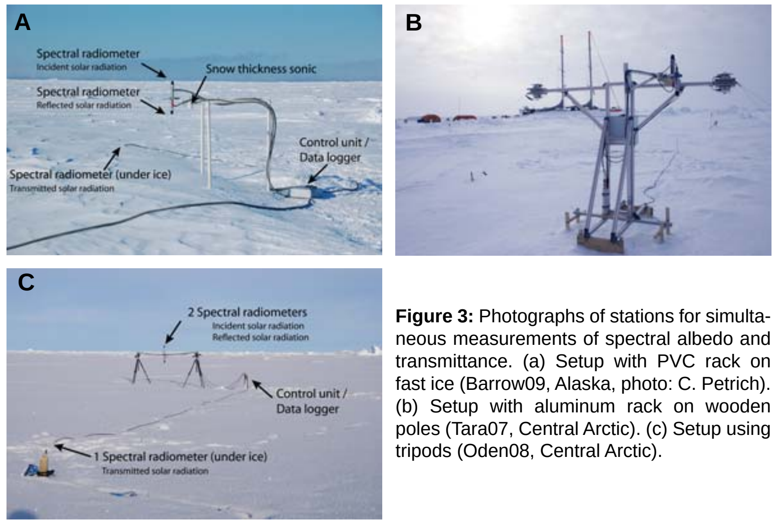

Figure 3: Photographs of stations for simultaneous measurements of spectral albedo and transmittance. (a) Setup with PVC rack on fast ice (Barrow09, Alaska, photo: C. Petrich). (b) Setup with aluminum rack on wooden poles (Tara07, Central Arctic). (c) Setup using tripods (Oden08, Central Arctic).

Sensor facts:

- Sensor type: RAMSES Advanced Cosine Collector
- Spectral range: 320 to 950 nm (3.3 nm resolution)
- Integration times: 4 to 8192 ms (automatic)
- 256 chan. photodiode array (incl. dark current)
- Pressure and inclination module optionally included
- Ultra-low power consumption
- Waterproof (to 300 m) stainless steel casing

Data-logger facts:

- Measurement intervals: 1 min to 24 hours
- Typical intervals: 10 to 30 min
- Records up to 105,500 spectra
- Includes sensor control unit
- Includes power supply (Li-ion batteries)
- Designed for year-round measurements
- Stainless steel casing

Data examples

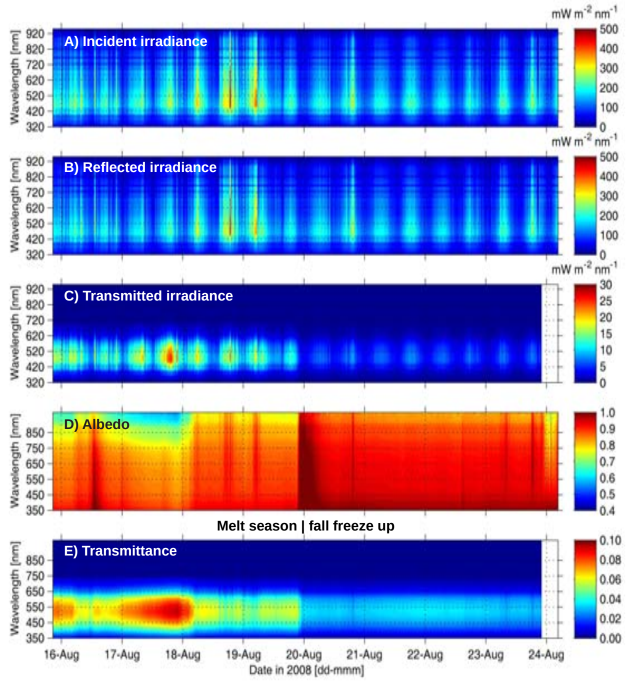

Figure 4: Time series (1-hour resolution) of (a) incoming, (b) reflected, and (c) transmitted spectral irradiance, (d) spectral albedo, and (e) spectral transmittance measured during Oden08. Albedo and transmittance data are restricted to 350 to 920 nm and albedo are linearly interpolated between 748 to 773 nm, due to poorer data quality in these wavelength ranges (Figure 5).

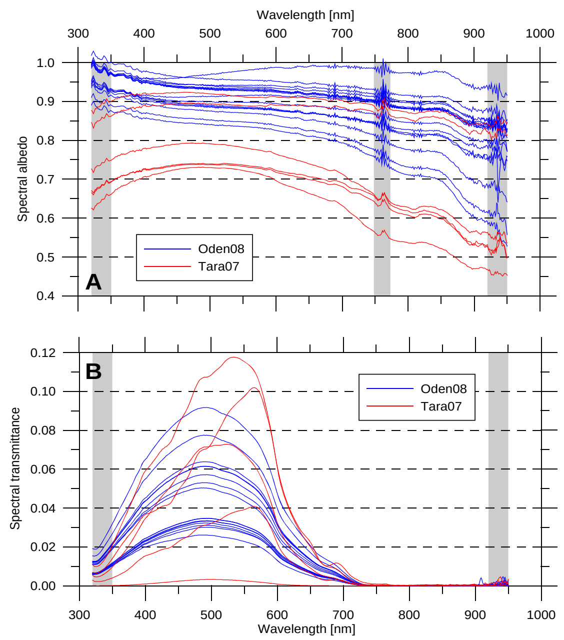

Figure 5: (a) Spectral albedo and (b) spectral transmittance measured during Oden08 and Tara07 (selected times). All spectra are plotted with a spectral resolution of 1 nm, as used for further analysis. Grey-shaded areas mark wavelength ranges of poorer data quality. Genearal differences between spectra relate to different snow and ice conditions. Tara07 transmittance shows additional biological influences.

Results and Conclusions

Sensors, data logger, and their setup are well suitable for usage under challenging climatic conditions, over long times, and during different seasons. The sensors perform particularly well with respect to sensor surface contamination, one of the most challenging aspects for radiation measurements. This allows applications at unmanned stations or minimal of maintainance.

The setup is portable and robust, and can be easily and quickly setup, which is most valuable for deployment under harsh conditions and also supports short observation periods, as during ship stations. The spectral range and other technical features suggest the application of this setup for various interdisciplinary studies, too.

Measured spectra as well as derived albedo and transmittance are of high quality (best from 350 to 920 nm) and show how the vertical partitioning of irradiance changes during different seasons. However, the sensor-specific wavelength grid results in increased noise.

The setup can be improved and extended by including additional sensors or the simultaneous deployment of other autonomous units like Ice Mass-Balance Buoys or cameras. The presented setup allows high temporal resolution monitoring, well suitable for process studies, but does not contain any spatial information.

Deployment

Figure 6: Deployment of under-ice sensor. The sensor is mounted in a metal frame. (a) Deployment for long-term measurements with cable protection through red tube. The albedo station (see also Figure 3d) is visible in the background (Storfjorden, Svalbard, 2009). (b) Deployment for short-term measurements on thin first year ice (Fram Strait, 2008).

References

Nicolaus, M., S. R. Hudson, S. Gerland, and K. Munderloh (submitted), A modern concept for autonomous and continuous measurements of spectral albedo and transmittance of sea ice, Cold Regions Science and Technology.

Nicolaus, M., S. Gerland, S. R. Hudson, S. Hanson, J. Haapala, and D. K. Perovich (in prep.), Seasonality of spectral albedo and transmissivity as observed in the Arctic Transpolar Drift in 2007, Journal of Geophysical Research.

Acknowledgements

We thank the crews of the Swedish ice breaker “Oden” and the schoner “Tara” for supporting our measurements and their cooperation. The work of Kristen Fossan (NPI) and Chris Petrich (U. of Alaska, USA) and their support in constructing and manufacturing different elements for the setups is highly acknowledged. We thank Rüdiger Heuermann and his colleagues from Trios, Oldenburg, Germany for their support of the RAMSES ACC sensors and DSP data loggers.

This study was funded through the DAMOCLES project, financed by the European Union, and by the Norwegian Research Council through the IPY project iAOOS Norway - Closing the Loop and the NorClim project. Additional funding was received from the Norwegian Polar Institute and its ICE Centre.

Contact: marcel.nicolaus@npolar.no or stephen.hudson@npolar.no

AGU Fall Meeting 2009 C41C-0466