ASCOS 2008 (Oden)

Arctic Summer Cloud Ocean Study

Overview over spectral radiation data

by Marcel Nicolaus (Norwegian Polar Institute)

09 September 2009

Description of the set-up and data set

Spectral radiation was measured with TriOS (Oldenburg, Germany) Ramses ACC-2 VIS hyper-spectral radiometers. The radiometers have a sensor-specific wavelength range from approx. 320 to 950 nm with an average spectral resolution of 3.3 nm (191 channels). Presented data are interpolated to a 1-nm grid between 330 and 920 nm, accounting for worse data quality at the edges of the spectra.

The albedo set up consisted of one upward-looking (incident radiation) and one downward-looking (reflected radiation) sensor (Fig. 1). The downward-looking sensor was a pure radiometer (sensor type: SAM) while the upward-looking sensor included additional inclination and pressure sensors (sensor type: SAMIP). The downward-looking sensor was approx. 1 m above the snow surface. During installation and maintenance, stepping onto the snow surface under the sensors was avoided. Initial snow thickness was 0.1 m and freeboard was 0.05 m.

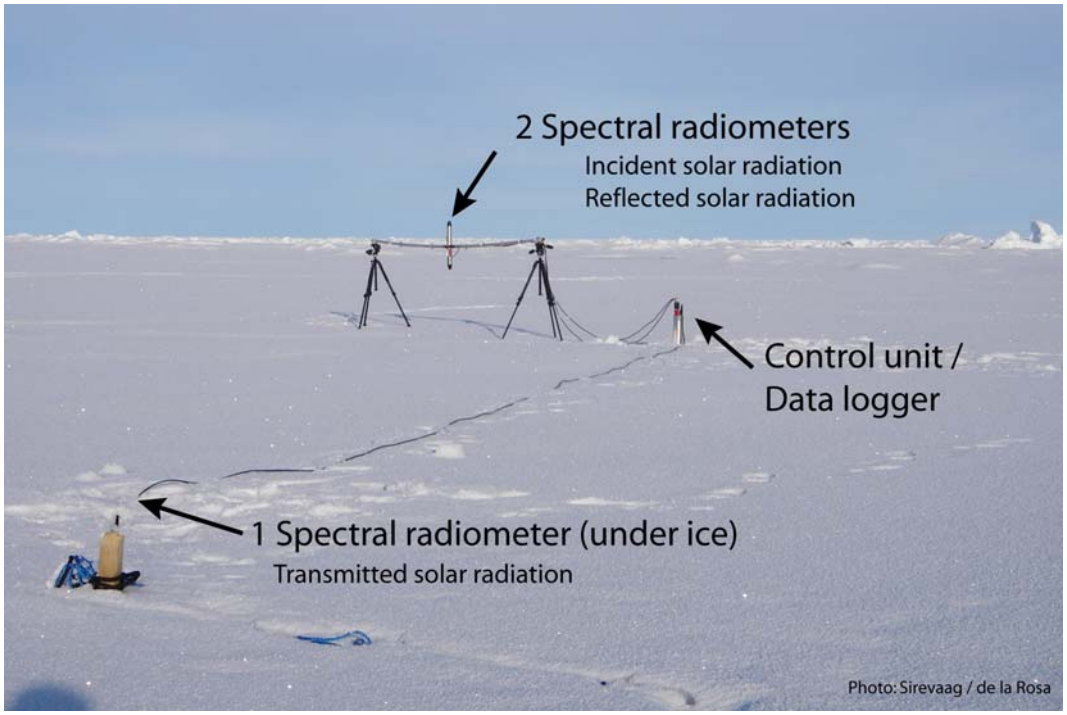

Figure 1: Photograph of the spectral radiation station during ASCOS 2008

The under-ice sensor (sensor type SAMIP) was located approx. 10 m from the main rack (Fig. 1). The sensor was mounted upward-looking (transmitted radiation) in a 13-cm diameter metal frame and deployed through a 20-cm diameter bore hole. After deployment, the surface around the sensor was restored as well as possible, while the borehole re-froze with time. At the beginning of the observations ice thickness was 1.54 m and the sensor was hanging upward-looking approx. 1.0 m under the ice bottom (2.5 m under the water level). Pressure, proportional to depth in water, and inclination were measured, since they could not be observed from the surface.

All data were recorded in 10-min intervals with a TriOS DSP data logger, including the power supply (batteries) for the sensors. All measurements started on 15 Aug 2008 at 14:20 (all times are UTC). Albedo measurements lasted until 01 Sep 2008 at 09:50 and transmissivity until 31 Aug at 19:40. The shorter time span of transmissivity measurements was due to the more time-consuming retrieval of the under-ice sensor. In total, 2410 albedo and 2325 transmissivity spectra were recorded. During the observation period the station drifted from 87°25.304'N / 005°54.33'W to 87°09.6484'N / 010°18.6322'W.

The station was set up and visited daily by Anders Sirevaag and Sara de la Rosa (University of Bergen). Their visits included checks for leveling of the station and condensation or icing on the sensors. In addition, observations of snow properties and general meteorological conditions were performed. The station was oriented in East-West direction (270 deg) and regular observations showed that the orientation varied between 260 and 290 deg.

Solar elevation angle over horizon

All spectral radiation measurements were performed during polar day. Figure 2 shows how the solar elevation angle (elevation angle = 90 deg - zenith angle) varied between 5.5 and 16.1 degree. The observation period comprises 16 full diurnal cycles.

Since spectral albedo depends on the solar elevation angle, it is useful to compare spectra from times of identical solar elevation angle. The elevation of 11.35 degree is highlighted in Figure 2, because this elevation was reached during every day. Disadvantage of these times is that the sun has different azimuth angles, because due to the drift, the elevation angle of 11.35 degrees was reached (usually twice a day) at different times of the day. Azimuth angles cover the entire circle of 360 degree, which might influence results when surface properties are anisotropic and the sky was not fully overcast. Rotation of the floe is not considered here, but is also minor compared to daily variations of solar azimuth angle.

The advantage of discussion of highest sun elevation is a constant azimuth angle of 180 deg (south). Due to discrete measurement intervals the mean azimuth angle during highest sun elevation was 178.5 degrees. Again, rotation of the floe is not considered. In addition to this, highest data quality may be expected under highest sun elevations and when absolute radiation fluxes are highest.

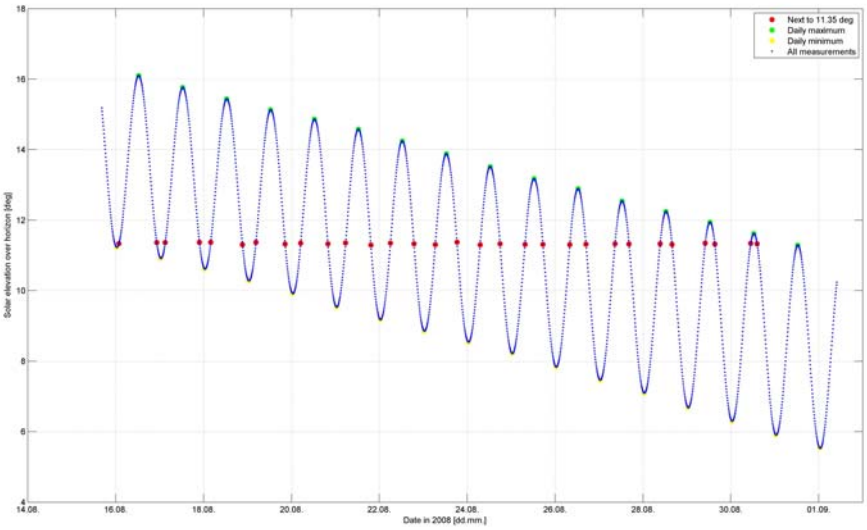

Figure 2: Time series of solar elevation angle. The value of 11.35 degree represents an elevation that was reached every day and might be used for data comparison. In addition, daily maximum and minimum values are marked in green and yellow, respectively.

Spectral albedo and transmissivity

Spectral albedo and transmissivity show the transition from summer to autumn conditions, including freeze-up and new snow events. Figure 3 shows the measured time series with a temporal resolution of 2 h. Figure 4 shows the albedo data set, but all measurements larger 1 are removed. These readings occured mainly during and after times of snow fall when the upward-looking sensor is affected by snow, resulting in underestimated fluxes. No correction has been performed for the tilt of the station. Comparing both Figures, 3 and 4, will help to quantify the effect and duration of snow / ice covers on the sensors. Additionlly, records of cleaning and re-levelling of the sensors can be used for further corrections. Furthermore, albedo readings > 1 occurred during the second half of the observation period for short wavelengths. Reasons for this are not yet found and need to be analyzed further.

The sensors were cleaned on:

16 Aug 11:44 Ice-spicule hanging from “reflected” sensor
23 Aug 07:40 Moisture after period of fog and new snow
29 Aug 19:58

The station was re-levelled on:

18 Aug 16:20 re-levelled
20 Aug 19:57 re-levelled
25 Aug 03:15 adjusted height above snow from 0.92 to 1.00 m (snow fall and sinking)
26 Aug 19:08 re-levelled

The most siginficant envent for albedo during the first 5 days (until 20 Aug) was a snow fall event early on 17 Aug. During these days, transmissivity increased gradually, except the snow fall event, because of warm, wet and thin snow covers. Weather conditions were characterized through fog and temperatures around 0°C.

On 20 Aug, a snow-fall event (approx.1h) with large flakes increased albedo and decreased transmissivity significantly. Additional snow fall afterwards can be recognized in both, albedo and transmissivity, time series. Surface freeze-up started on 20 Aug, and was supported by lower air temperatures on 21 Aug and afterwards. Anyhow, snow thickness decreased to around 1 cm on 22 Aug.

A heavy snow fall event began on 23 Aug around 18:00 (approx. 8 cm new snow) and lead to a significant increase in surface albedo and decrease in the amount of transmitted light. During the snow fall (and some hours afterwards), albedo values exceeded 1 (Figure 4). Afterwards, neither albedo nor transmissivity returned to its earlier values. This snow event caused the most significant changes in surface conditions and radiation fluxes during this observation. It might be considered as the transition from summer to autumn conditions.

Additional snow fall on 25 Aug may be recognized in the sprectal radiation measurements, too. Snow metamorphism and compaction reduced the snow thickness to 3 to 4 cm at the end of the observation period. These processes are not pronounced in the time series of optical measurements as shown in Figure 3. But more intensive analysis of the full resolution data set will most likely reveal their effect on spectral albedo and transmissivity.

Finally, slight drizzle rain decreased albedo on 31 Aug / 01 Sep again, especially in long wavelengths.

More detailed studies using single spectra and their differences and relative changes will most likely reveal more detailed results. These findings can then be related to processes in snow, sea ice, and water.

Acknowledgement
Anders Sirevaag and Sara de la Rosa (University of Bergen) have performed the measurements, recorded additional observations, and regularly maintained the station. This work is highly appreciated, since it was crucial and most valuable for the project. We thank the ASCOS team and the crew of the Swedish ice breaker Oden for supporting these measurements and their cooperation. This study was funded through the NorClim project and internal funds of the Norwegian Polar Institute.

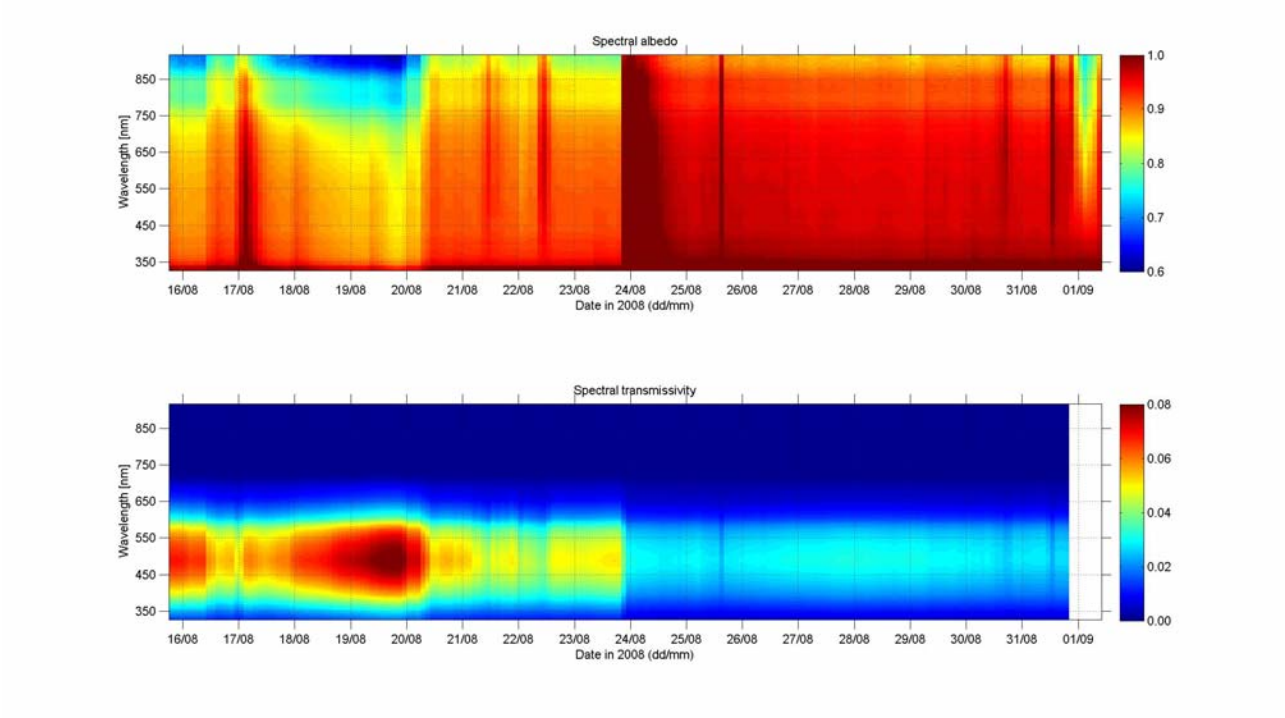

Figure 3: Time series of spectral albedo (top) and transmissivity (bottom). Temporal resolution (of this figure) is 2 hours, starting on 15 Aug 18:00 (UTC). Albedo data between 748 to 773 nm are linearly interpolated due to bad data quality in this wavelength range. No data processing or correction has been performed to treat albedo values > 1.

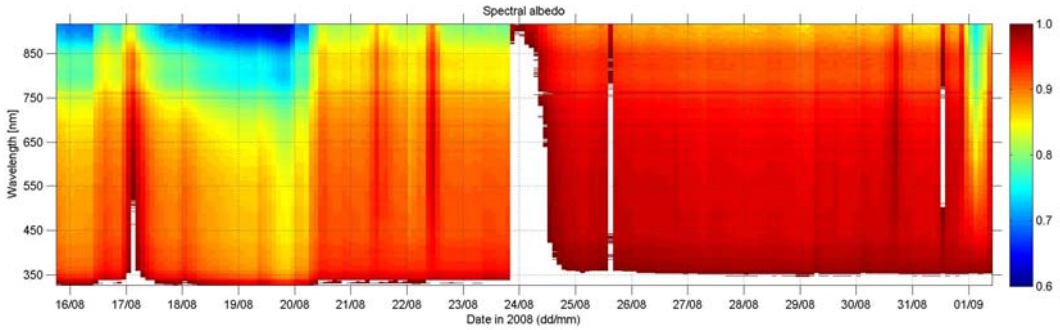

Figure 4: Time series of spectral albedo. Temporal resolution (of this figure) is 2 hours, starting on 15 Aug 18:00 (UTC). Albedo data between 748 to 773 nm are linearly interpolated due to bad data quality in this wavelength range. All albedo values > 1 have been removed (white parts).

Description of Matlab data files

File: ASCOS_spectral.mat

Variable	Dimension	Description
t:	[2410x1]	Time vector, for transmission variables use only 1:2325
wl:	[591x1]	Wavelength vector [330:1:920] (in nm)
incom_int:	[2410x591]	Spectral data incident radiation (in $W/m^2/nm$)
refl_int:	[2410x591]	Spectral data reflected radiation (in $W/m^2/nm$)
trans_int:	[2325x591]	Spectral data under-ice radiation (in $W/m^2/nm$)
trans_z:	[2325x1]	Depth of under-ice sensor beneath water level (in m)
albedo_corr:	[2410x591]	Spectral albedo data *
albedo_bb_corr:	[2410x1]	Broadband (330-920 nm) albedo data *
transmission:	[2325x591]	Spectral data of transmission
transmission_bb:	[2325x1]	Broadband (330-920 nm) transmission

* albedo data are linearly interpolated between 748 to 773 nm

File: ASCOS_sun.mat

Variable	Dimension	Description
time:	[2423x1]	Time vector
longitude:	[2423x1]	Geographic longitude
latitude:	[2423x1]	Geographic latitude
zenith:	[2423x1]	Solar zenith angle
azimuth:	[2423x1]	Solar azimuth angle

Contact details:

Marcel Nicolaus (marcel.nicolaus@npolar.no) or
Sebastian Gerland (sebastian.gerland@npolar.no)
Norwegian Polar Institute
Polar Environmental Center
Tromsø, Norway