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Marine-Atmosphere Emitted Radiance Interferometer measurements during the Arctic Summer Cloud Ocean Study (ASCOS)

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1. INTRODUCTION

The Arctic Summer Cloud Ocean Study (ASCOS) was an interdisciplinary project focused on the study of the Arctic cloud formation. The ASCOS expedition to the high Arctic Ocean was supported by the Swedish Polar Research Secretariat and the ice-breaker Oden, and was conducted between 1 August and 9 September 2008 mainly in the area near 87°N and 5°W.

Late summer is a transition period in the Arctic when the ice melt season ends and the freeze-up of the Arctic ocean sets in. Radiative processes are of crucial importance in this freeze-up phase of the Arctic as the input of solar energy decreases and a new energy balance has to be established with lower surface temperatures resulting in build up of sea ice. The omnipresent arctic clouds play a critical role in the radiative balance of the Arctic and their formation and properties were the focus of the ASCOS program.

This paper presents measurements of infrared radiation in the Arctic atmosphere made with the Marine-Atmospheric Emitted Radiance Interferometer (M-AERI) during ASCOS as well as radiometric sea/ice surface and air temperatures, and broadband short and longwave atmospheric radiation.

2. Instrument and Data

Marine-Atmospheric Emitted Radiance Interferometer

The Marine-Atmospheric Emitted Radiance Interferometer (M-AERI) is a Fourier transform infrared interferometric spectroradiometer that measures spectra spanning the ~3 to ~18μm wavelength interval with a resolution of ~0.5 cm^{-1}. It uses two infrared detectors cooled to ~78 K by a Stirling cycle mechanical cooler to reduce the noise equivalent temperature difference to levels well below 0.1K. The radiometric calibration of the M-AERI is done using two internal blackbody cavities which are sampled before and after taking each set of oceanic and atmospheric spectra. The control computer integrates the interferometric measurements over a pre-selected time interval, usually a few tens of seconds, to obtain a satisfactory signal to noise ratio. A typical cycle of measurements including two up-looking views of the atmosphere at different zenith angles, one down-looking view of the ocean, and blackbody calibration measurements, takes about ten minutes. The instrument is described more fully by Minnett et al. (2001).

An example of the atmospheric emission spectrum measured by the M-AERI on 22 August 2008 during the ASCOS expedition is shown in Figure 1. Such atmospheric emission spectra contain information about the vertical distribution of the temperature and the water vapor in the lower troposphere.

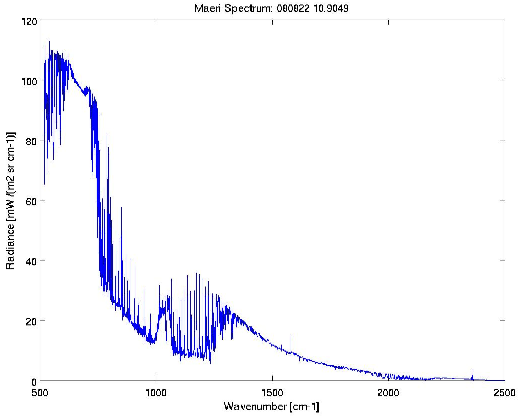

Figure 1. M-AERI spectrum on 22 August 2008.

Measurements taken during cloudy periods contain information about the overlaying clouds. Downward looking spectra (ocean view) are used to retrieve the sea surface skin temperature (SST) or the ice surface temperature (IST).

3. Results

Figure 2a and b show the track of Oden during the ASCOS deployment and the SST (or IST) and the air-sea(ice) temperature difference measured by M-AERI along the track .

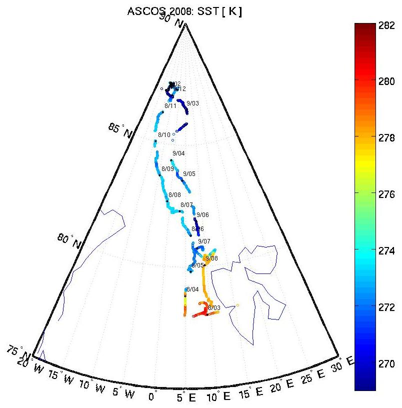

Figure 2a. SST(IST) along the track of Oden from 03 August to 08 September 2008.

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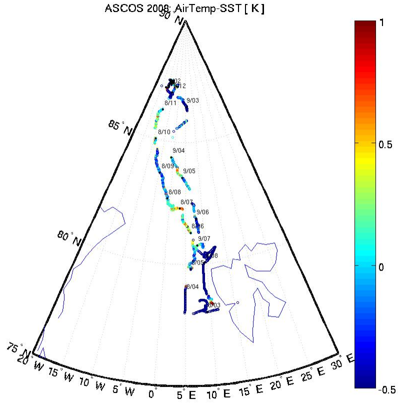

Figure 2a. Air-Sea temperature difference along the track of Oden from 03 August to 08 September 2008

One can see in Fig 2a cooler SSTs during the return track from the high Arctic than on the way North. The air-sea temperature difference is negative most of the time, especially over open water. Figure 3 shows time series of the M-AERI SST(IST) and air temperature during ASCOS.

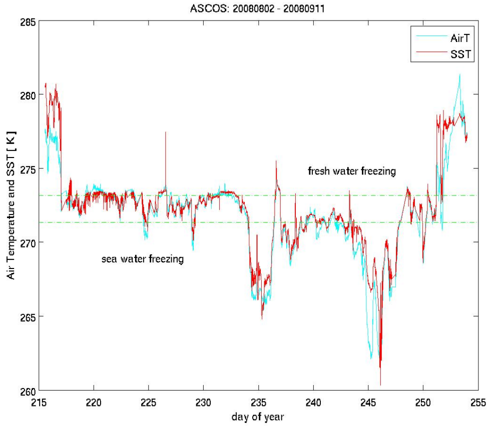

Figure 3. Time series of M_AERI SST(IST) and and Air Temperature during ASCOS.

The temperature time series reveals two periods characterized by distinct surface and air temperatures. These periods correspond to distinct meteorological conditions observed during the deployment. During the first period between 05 August and 20 August 2009 the surface temperature is close to the fresh water melting temperature and the air-sea temperature is mostly positive indicating a heat flux to the surface. After a cold spell around 22 August when air ans snow temperatures plunge to close to -7°C a new regime is established with surface and air temperatures close to the sea water freezing temperature. The air-sea temperature difference in this period is negative on average indicating a heat flux from the surface. Another cold spell takes place towards the end of this period with temperature dropping to -11°C.

Several storm past over Oden during the first period and fog and multi layer clouds were frequent. In contrast, during the second period clouds where typically single layer stratus. Cloud free conditions were rare in either period and usually occurred during the cold spells.

In Figure 1 the range between approximately the wavenumbers 800 and 1200 cm^{-1} represents the atmospheric window. In this range of wavenumbers radiation from upper levels of the atmosphere can reach the surface. When clouds are present radiation in this window is overwhelmed by emission from clouds thus measurements in this range contain information about the clouds aloft.

Figure 4 shows two M-AERI spectra for overcast conditions, one from 12Z of 13 August (warm period) and one from 00Z of 27 August (freeze-up period). Clear sky spectrum obtained from LBLRTM calculation for atmospheric condition of 27 August is also shown.

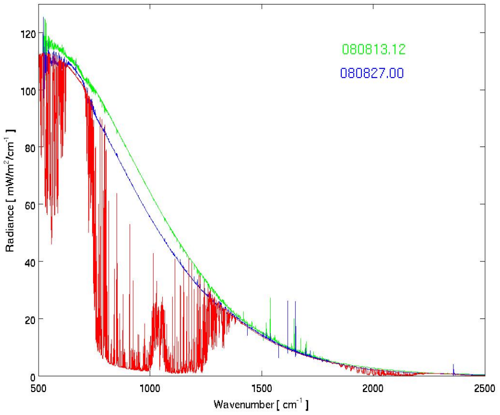

Figure 4. M-AERI spectra for two overcast days, 13 August 12Z and 27 August 00Z, and model clear sky spectrum (red).

In Figure 4, the window region is dominated by cloud emission. Provided the transmissivity of the atmosphere below cloud does not vary greatly between the two days the higher values of radiance in the window region on 13 August indicate an emission from a either warmer or darker (higher emissivity) cloud.

Brightness temperatures corresponding to the radiances shown in Figure 4 and cloud emissivity of 1 are shown in Figure 5.

On both days the brightness temperature is fairly uniform across the window region. This suggests that in both cases the clouds are opaque and emission comes from one level in the cloud. However, there are some clear differences between these two clouds. Firstly, here is approximately 7°C difference between the brightness temperature in the window region between the two days. The second feature that differentiates the two cases is the increase (27 August) or decrease (13 August) of the brightness temperature at the edges of the window region. The atmosphere is less transparent at wavenumbers outside of the window region which means that the radiation reaching the instrument at these wavenumbers must come from close vicinity e.g. lower levels in the atmosphere. Lower brightness temperatures outside the window region such as on 13 August might indicate cloud in the layer inversion.

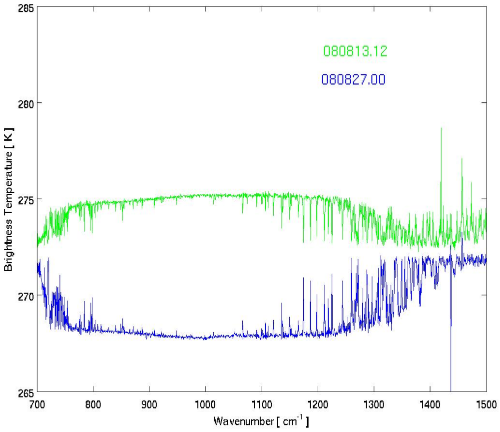

Figure 5. M-AERI window region brightness temperature for two overcast scenes on 13 August 12Z and 27 August 00Z.

4. Summary and Discussion

M-AERI measurements of SST(IST) and air temperature captured transition from melt to freeze-up regime and the reversal of the direction of the heat flux at the surface. On cloudy days, upward looking M-AERI measurement contain information about the clouds above but more research is needed to develop methods of extracting more precise cloud information from M-AERI data.

5. Acknowledgments

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6. References

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