INFLUENCE OF MELT PONDS ON MICROWAVE SENSORS’ SEA ICE CONCENTRATION RETRIEVAL ALGORITHMS

Anja Rösel, Lars Kaleschke, Stefan Kern

Institute of Oceanography
University of Hamburg
Bundesstrasse 53
D-20146 Hamburg
Germany
e-mail: anja.roesel@zmaw.de

ABSTRACT

Melt pond fractions derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) and its corresponding sea ice concentration data set are valuable sources for multiple applications in climate sciences. In this case study, melt pond fractions are used to quantify the uncertainties in sea ice concentration data derived from passive microwave imagery from Advanced Microwave Scanning Radiometer for EOS (AMSR-E) with different retrieval methods. For the test area of the Canadian Archipelago, we found that all AMSR-E algorithms are clearly underestimating MODIS sea ice concentration by around 20-30% during the occurrence of a high melt pond fraction of 50% in mid-June 2011.

Index Terms— Arctic, Canadian Archipelago, sea ice, melt ponds, sea ice concentration, passive microwave sensors, uncertainties, MODIS, AMSR-E, SSM/I

1. INTRODUCTION

In boreal summer, melt ponds are a common feature on Arctic sea ice and they can cover up to 50 to 60% of the sea ice area [1, 2]. On a flat topography of first-year ice and in an early melt stage the melt pond fraction can even rise up to 90% [3]. Melting, caused by shortwave insolation and surface air temperatures above the freezing point during summer, results in the development of melt ponds on the sea ice surface and a decrease of the surface albedo from approximately 0.8 to 0.5 which excites additional heat uptake [4]. — Snow and sea ice melt and, in particular, melt ponds, impact the sea ice concentration (SIC) retrieval using satellite passive microwave (PM) data of sensors like Special Sensor Microwave/Imager (SSM/I) and Advanced Microwave Scanning Radiometer for EOS (AMSR-E). At the microwave frequencies typically used for SIC retrieval, wet snow causes an increase in the measured brightness temperature (TB) and a reduction in the TB polarization difference. Melt ponds act like open water and cause a decrease in TB and an increase in the TB polarization difference. SIC obtained from satellite PM data is therefore known to be negatively biased during summer when melt ponds are present [5, 7, 10, 11, 17]. SIC derived from satellite PM data with various algorithms [6, 8, 9, 7, 15] are the backbone of our current knowledge about Arctic and Antarctic sea ice conditions since the late 70ties. Systematic investigations of the SIC bias caused by melt pond coverage which go beyond the character of a case study are, however, rare [17]. In this paper we present first results of utilizing a 12-year long data set of melt pond coverage on Arctic sea ice derived from Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data [13] for a quantification of the summer-time SIC bias.

2. MODIS MELT POND DATA SET AND SEA ICE CONCENTRATIONS

Due to different spectral properties of snow, ice, and water, the fractional coverage of these distinct surface types can be derived from multispectral sensors like MODIS using a spectral unmixing algorithm [12, 13]. To comply with the physical restrictions, we implement a side condition to constrain the interval of the solution between zero and one. Solving of the algorithm is performed using a multilayer perceptron (MLP) to reduce computational costs.

Arctic-wide melt pond fractions and SIC are derived from a weekly level 3 MODIS surface reflectance product (MOD09A1) on a 12.5 km polar stereographic grid for the melt seasons from 2000-2011 [13]. The MODIS melt pond data set is provided through the Integrated Climate Data Center (ICDC, http://icdc.zmaw.de/).

For our investigation we use daily SIC obtained from AMSR-E data using the ARTIST sea ice (ASI) algorithm [8], the NASA-Team 2 (NT2) algorithm [9], and the Comiso Bootstrap (BT) algorithm [14] for the area of the Canadian Archipelago.

AMSR-E ASI data are provided by ICDC (http://icdc.zmaw.de),
at 6.25 km grid resolution. AMSR-E NT2 and BT data, version V13, are provided through the NSIDC on a 12.5 km grid [15]. For further comparison, AMSR-E ASI data are rescaled on a 12.5 km polar stereographic grid.

3. MELT PONDS INFLUENCING THE MICROWAVE SEA ICE CONCENTRATION RETRIEVALS

The above-mentioned melt pond cover fraction [13] allows a large-scale assessment of summer-time SIC data with regard to the impact by melt ponds. As independent SIC data set we use a by-product of the melt-pond cover fraction retrieval [13, 16]: the MODIS sea ice concentration (MODIS SIC).

For this purpose we perform a case study in the area of the Canadian Archipelago on the weekly data set of 18 June 2011. The study area is a 250 km x 100 km large region around the coordinate 72° N and 110° W (see Figure 1).

In this area the sea ice cover is often dominated by level first-year ice. Our results reveal that the relative melt pond cover fraction can peak at 70% in June (Figure 1 e).

Figure 1, images a) to c), show ASI, NT2, and BT SIC for the chosen region of the Canadian Archipelago. The mean SIC ranges in all three cases from 64% - 72%. Figure 1 d) displays MODIS SIC. Compared to the homogeneous distribution of MODIS SIC, all PM algorithms underestimate the SIC by around 20-30%.

Figure 2 shows the difference NT2 SIC minus MODIS SIC for the data sets of June 18, 2011. This map reveals large areas with a SIC under-estimation of NT2 SIC compared to MODIS SIC which coincide with areas of high melt pond cover fraction (Figure 1 e). Note, however, that differences can be both, negative and positive. A similar statement can be made for ASI and BT SIC maps.

Figure 3 shows the temporal evolution of satellite PM SIC, MODIS SIC and MODIS melt pond cover fraction averaged for the shown area of the Canadian Archipelago (Figure 1) for the melting season 2011.

Starting in mid-May, all PM retrieved data exhibits nearly 100% SIC, while the MODIS SIC starts with 93%. In the second half of May, the ASI SIC shows a decrease of 6-7% with a subsequent increase in end of May and beginning of June. In the first half of June all PM SIC are around 95%, the MODIS SIC is 88%. In mid-June, when the MODIS melt pond fraction shows a steep increase from below 20% to more than 50%, all PM SIC decrease by between 15% (NT2) and 25% (BT and ASI) within one week. Afterwards all PM SIC increase again, taking an average value of 81%. The MODIS SIC, in contrast, decreases continuously.

From end of June until beginning of August, PM SIC and MODIS SIC show an offset of around 20%. Melt pond fraction reaches its maximum in end of June with 53% and shows only a slight decrease until August. Then is stays on a constant level at 40%.

4. DISCUSSION AND CONCLUSION

As shown in Figure 1, the MODIS melt pond fractions can be used to estimate the influence of melt ponds on the sea ice concentration determination from microwave sensors like AMSR-E. In our example, all chosen AMSR-E SIC retrieval algorithms are underestimating MODIS SIC by an average of 20-30%. Areas with a large melt pond cover fraction (above 30%) show a lower SIC in the AMSR-E derived data sets than the MODIS SIC indicates. There are differences between the satellite PM data based algorithms (not shown).

The SIC shown in Figure 1 a) to c) are of daily temporal resolution, i.e. represent the conditions of June 18, 2011, while the MODIS SIC is an 8-day composite, starting on June 18. This may cause some of the differences in Figure 2 that cannot be linked to a high melt pond cover fraction in Figure 1 e. Progress of the melt, compaction or opening of the sea ice cover by wind and currents, and redistribution of the sea ice during the 8-day MODIS period can cause substantial differences in the 8-day composite MODIS SIC compared to the 1-day PM SIC.

The bias of 6-7% between MODIS SIC and PM SIC which is in particular visible before the strong melt-pond cover fraction increase has been described in [13]. After the PM SIC have dropped and returned back to around 80% at the end of June, the bias between MODIS SIC and PM SIC becomes 15-20%, decreasing slowly until mid August.

Our case study brings up a number of questions for further studies. (1) Why do microwave data-based sea ice concentrations return back to relatively high sea ice concentration values (around 80%) after the drop around June 18, although the melt pond fraction is still on a high level. It is known that melt pond drainage occurs after a first maximum of the melt pond coverage [18]. As a consequence, the melt pond area decreases and therefore an increase of the PM SIC back to higher values could be expected. However, our melt pond cover fraction shows no indication of such an intermediate decrease in melt pond cover fraction. (2) Why is the above-mentioned reduction in PM SIC more pronounced for Comiso BT and ASI SIC than for NT2 SIC? (3) What causes the bias of 20% between PM SIC and MODIS SIC during the melting period and why does this bias decrease with melt season duration? (4) How does this situation develop in other years than 2011, and what would be the results of this comparison when carried out in the open Arctic Ocean?

Further analysis on this topic should utilize SIC data on the same spatial sampling, ideally daily MODIS SIC and melt pond cover fractions. Additionally, a detailed comparison of MODIS melt pond and MODIS SIC with AMSR-E SIC of different ice conditions could help to understand the appearance of the bias between both.

This study demonstrates that analyses of MODIS data with regard to melt pond cover fraction and sea ice concentration can...
help to quantify biases in summer-time biases in microwave observation based sea ice concentrations. In particular does the most pronounced increase in melt pond cover fraction coincide with a distinctive drop in microwave sea ice concentrations obtained with BT and ASI algorithms.

5. REFERENCES


Fig. 1. Comparison of a) AMSR-E ASI, b) AMSR-E NASA-Team 2, c) AMSR-E Bootstrap, and d) MODIS sea ice concentrations in the Canadian Archipelago. Image e) displays the MODIS melt pond fraction. All images are from June 18, 2011.

Fig. 2. Difference of AMSR-E NASA-Team 2 and MODIS sea ice concentrations from the data sets of June 18, 2011.

Fig. 3. Sea ice concentrations from AMSR-E ASI (ASI), AMSR-E NASA-Team 2 (NT2), AMSR-E Bootstrap (BT) algorithms, MODIS (MODIC), and absolute melt pond fraction from MODIS (abs MODMP) for the area of the Canadian Archipelago (see Figure 1) for 2011.