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Detection and quantification of sea-ice melt

Introduction

The **mass and energy balance of sea ice** are strongly connected through the transfer of solar radiation from the atmosphere through snow and sea ice into the ocean. Recent studies show that a major **uncertainty** in quantification of the sea ice mass balance is related to the **timing and duration of the melt season** as well as the very limited knowledge of the **characteristics of the snow layer** on top. Therefore, we are working on (1) improving our understanding of **radiative transfer into and through Arctic and Antarctic sea ice** and its impacts on sea-ice melt, and (2) improving existing and developing new remote sensing tools and data products. This allows for estimates of **sea-ice melt and freeze rates**, and **large-scale estimates of heat fluxes** in and under sea ice. Here we show **established methods** for melt onset detection on sea ice based on passive microwave data, and we present first **new ideas** for future improvements for onset detection methods.

Surface properties and melt onset detection

ARCTIC

- **Snow melts completely** during summer – resulting in a melt pond covered surface
- Almost **simultaneous snow-melt onset** in the entire Arctic
- During melt onset: Formation of liquid water within the snow pack
  > **Increasing** surface emissivity **ε** and brightness temperature T_B, decreasing backscatter coefficient σ^0 (for MYI)
  > Melt onset detection based on the **sensitivity of T_B to liquid water content in the snow pack**

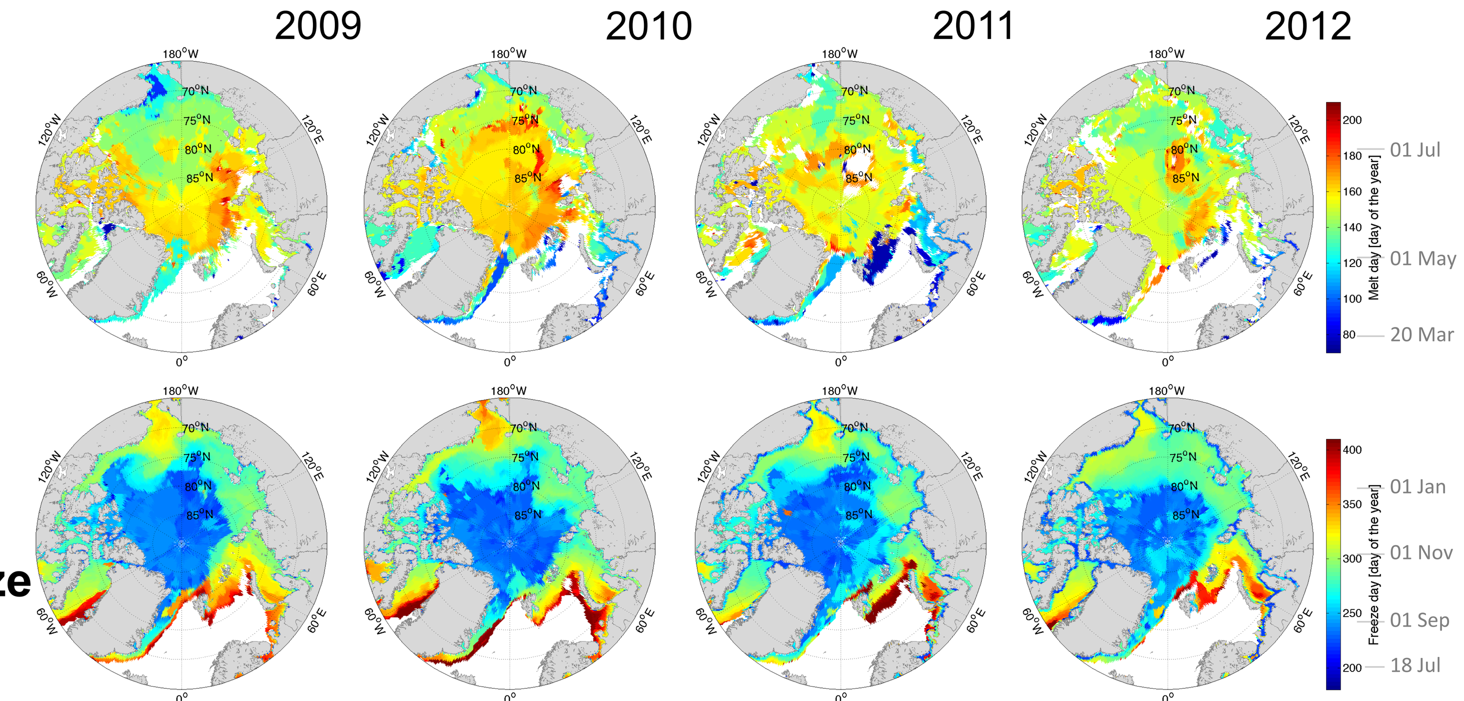

Figure 1: Early melt onset (EMO) and early freeze onset (EFO) from 2009 onwards [Markus et al.,2009 updated].

ANTARCTIC

- **Persistent snow cover** throughout the summer
- **Snow evaporation** dominates the snow thinning, whereas sea-ice melt is characterized by **lateral and bottom melt**
- Strong **metamorphosis of snow** causes increasing formation of superimposed ice and ice-layers in the snow pack
- Summer melt defined through enhanced **diurnal freeze-thaw cycles** in snow wetness, emissivity ε, brightness temperature T_B

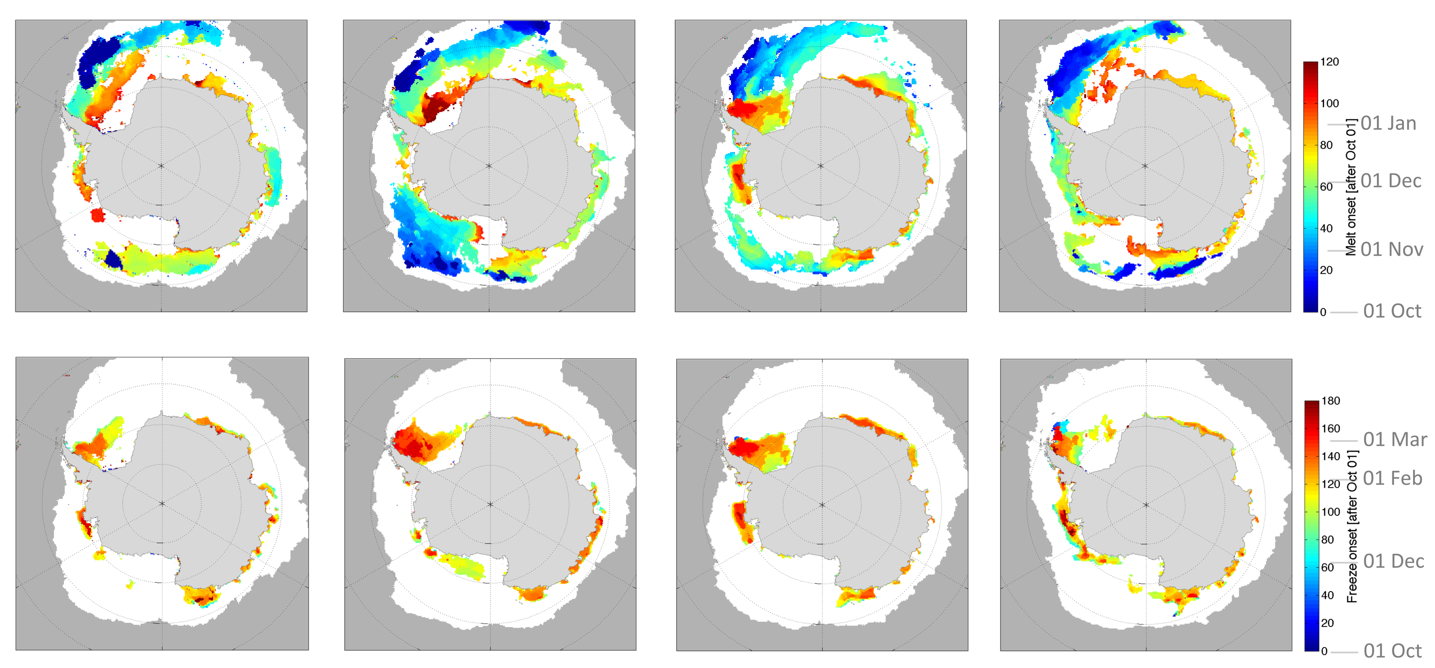

Figure 2: Early melt onset (EMO) and early freeze onset (EFO, only for perennial sea ice) from 2008/2009 onwards detected by a Melt Detection Algorithm MeDeA [Willmes et al.,2009, updated]. The white area represents the maximum sea ice extent in the given season.

> **Detection limits** through weak diurnal cycles, strong ice drift, …

First ideas of data improvements

Applying MeDeA [Willmes et al., 2009] in areas of …

- Strong diurnal freeze-thaw cycles
- Low summer temperatures ($T_{2m} < 0°C$)
- Weak melt pond coverage

> Comparable surface conditions as on Antarctic sea ice

Applying melt onset routine by **Markus et al. [2009]** in areas of…

- Weak diurnal freeze-thaw cycles
- Strong surface snow melt

> Comparable surface conditions as on Arctic sea ice

- How to handle sea ice drift/ deformation, polynias, … ?

Application for energy balance calculations

Seasonality in 2011

- **4 months** account for **96 %** of the total annual solar heat input through sea ice

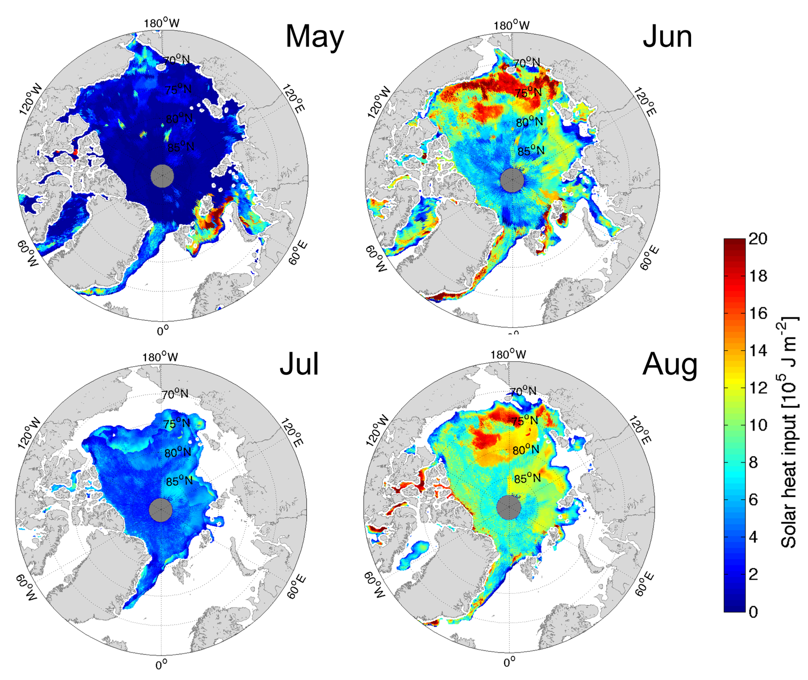

Figure 3: Solar heat fluxes under Arctic sea ice from May to August 2011 [Arndt&Nicolaus, subm.].

Annual trend from 1979 to 2011

- Light transmission increases by **1.5% per year** Arctic-wide since 1979
- The **strongest trend** is derived for **June** (4.8×10^{19} J per year)

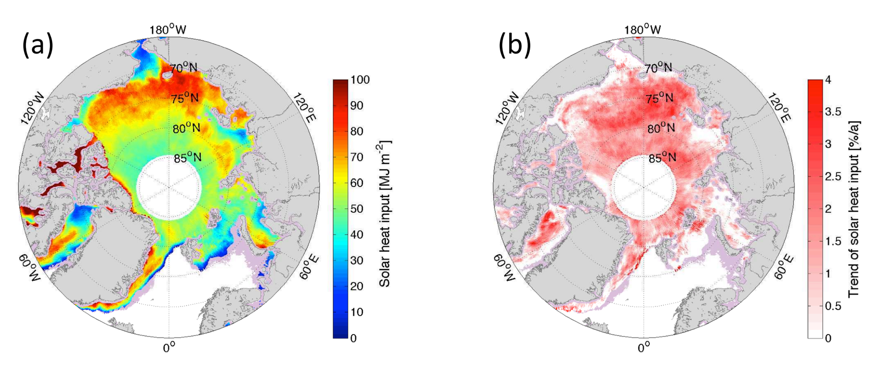

Figure 4: Annual solar heat input through Arctic sea ice.
(a) Average and (b) trend from 1979 to 2011.
The trend is corrected for the trend in sea ice concentration. Purple shaded areas were not covered with sea ice during the maximum extent in all years [Arndt&Nicolaus, subm.].

Key questions for light transmittance in the Antarctic

- How do snow cover properties change during an annual cycle?
- Which sea ice and snow cover classification is reasonable for Antarctic sea ice?
- How can the stronger Antarctic sea ice drift be included in the transmittance parameterization?

> Deriving and estimating **seasonality and trends** of **light transmission** through Antarctic sea ice

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