

Stefanie Arndt, Marcel Nicolaus

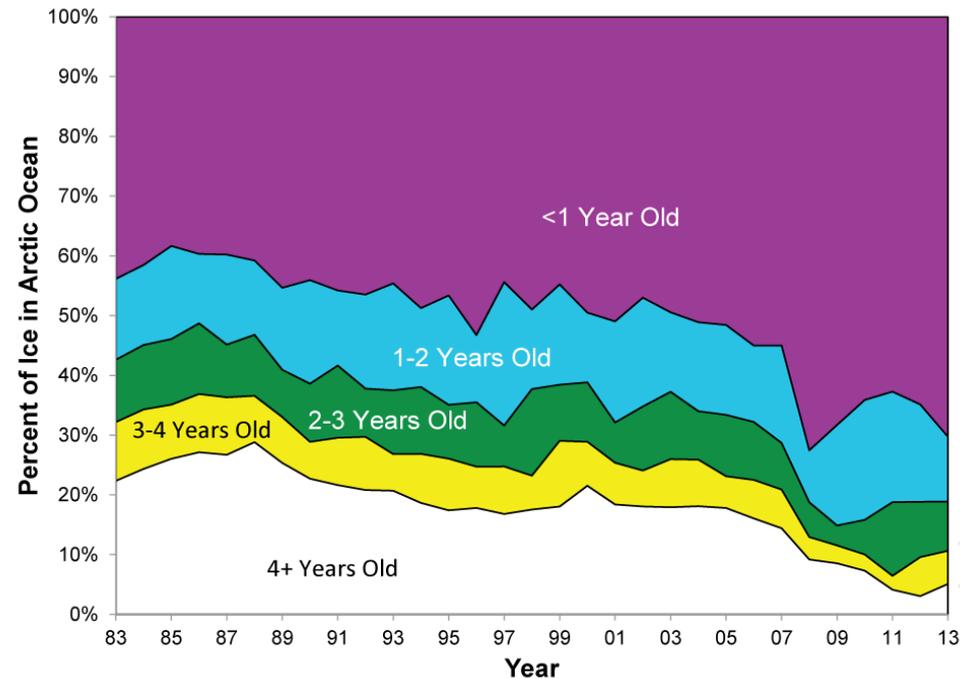


Increasing solar radiation under  
Arctic sea ice –  
Seasonality and spatial distribution

10 March 2014

# Motivation

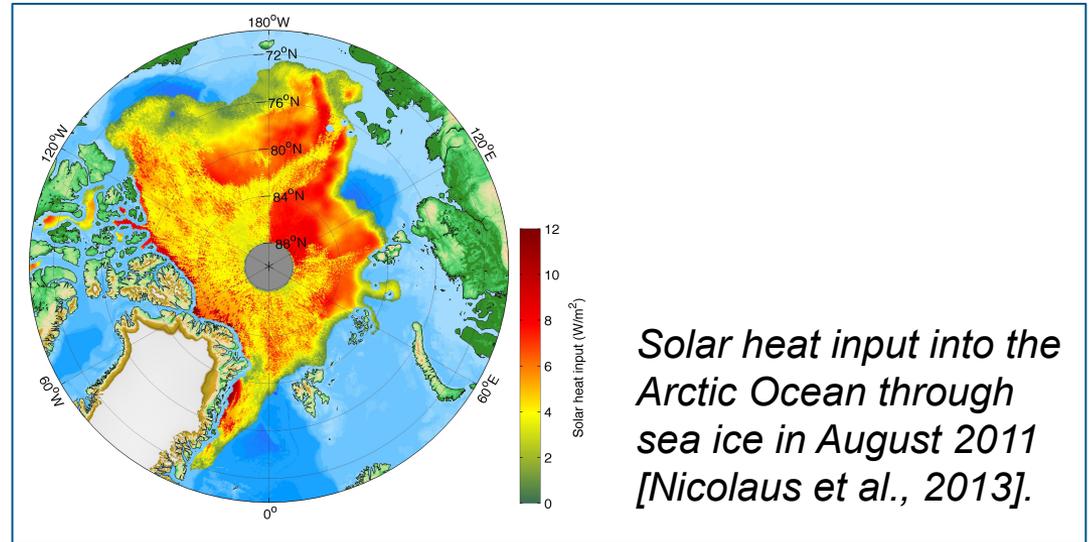
- Arctic sea ice is getting **thinner**, younger, and **more seasonal**
- Observed **decrease in surface albedo** [Perovich et al., 2011], **earlier melt onset**, and **longer melt season** [Markus et al., 2009]
- > **Increase in sea ice/snow melt**, and light **absorption** and **transmission**
- > Changes affect the ice-associated ecosystem



NSIDC courtesy J. Maslanik and M. Tschudi, University of Colorado

# Motivation

- First **up-scaling** of transmitted heat fluxes through Arctic sea ice in summer by *Nicolaus et al.* [2012,2013]

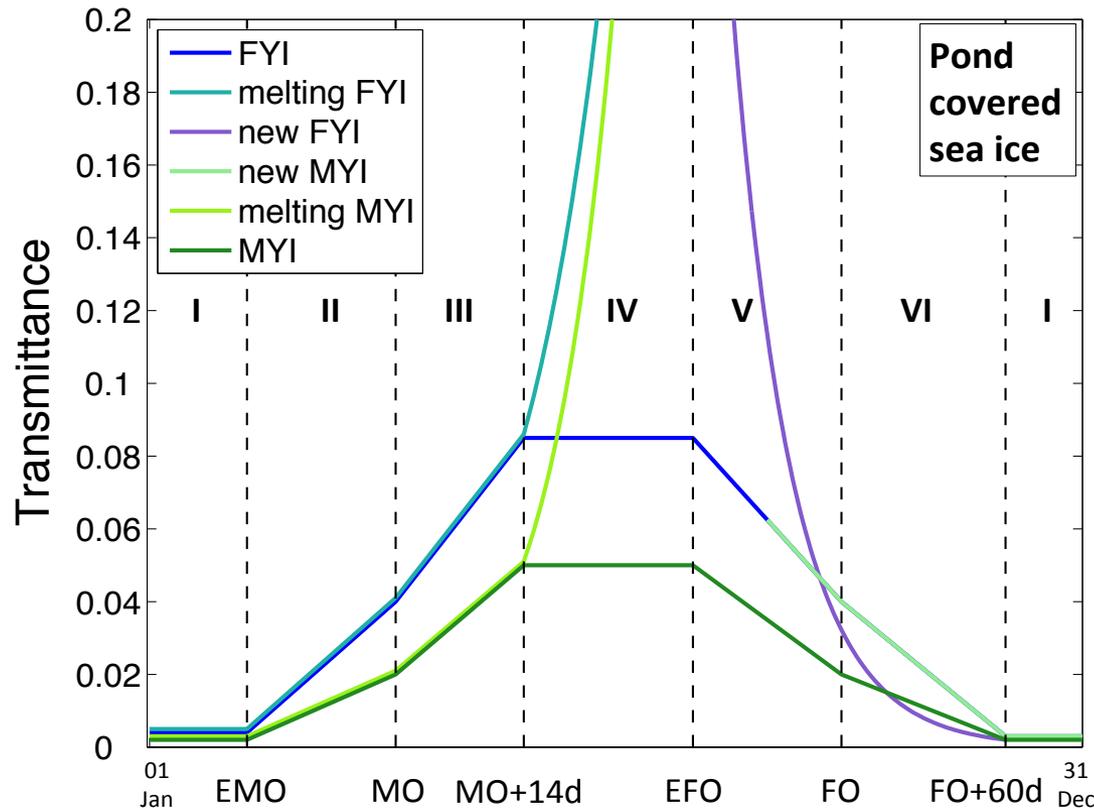


- > Extending and generalizing the method by new a parameterization to quantify **large-scale, multi-seasonal, and interannual changes** in the radiation transfer through Arctic sea ice [Arndt&Nicolaus, *subm. in JGR*]

# Method

## New up-scaling method for calculation of under-ice radiation

### Parameterization

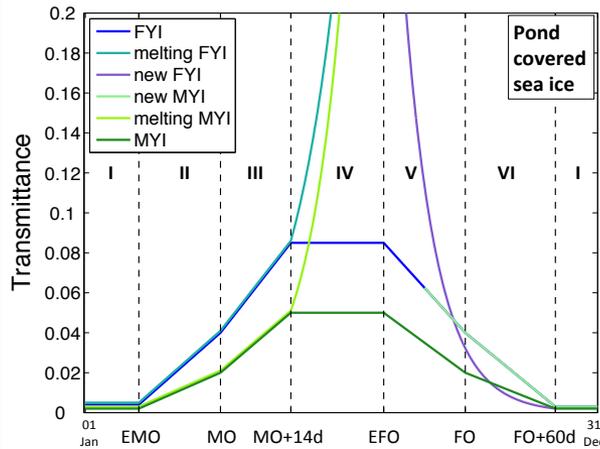


- I Winter
- II Early melt
- III Continuous melt
- IV Summer
- V Fall freeze-up
- VI Continuous freeze

*Total transmittance of pond covered sea ice.*

## New up-scaling method for calculation of under-ice radiation

### Parameterization

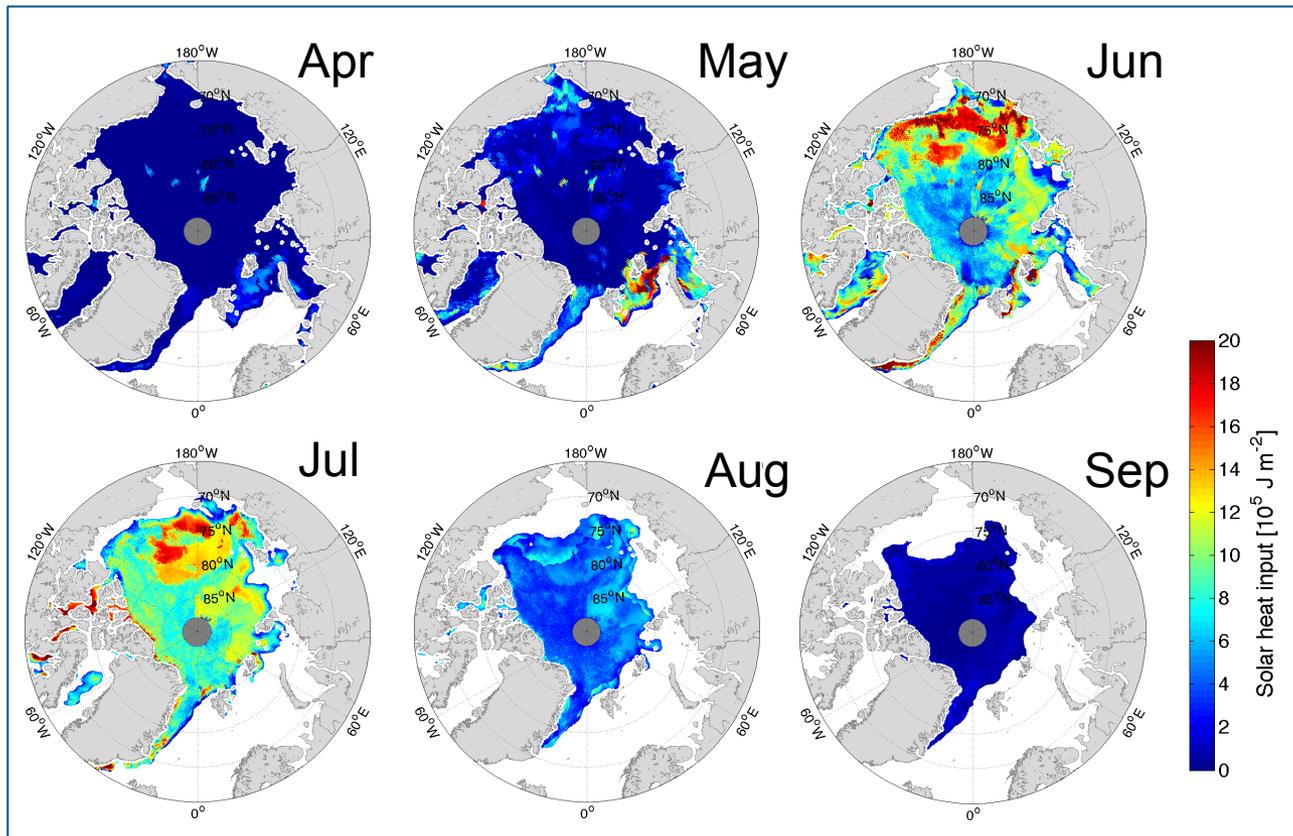


*Total transmittance of pond covered sea ice.*

### Data sets

- Sea ice concentration [OSI SAF]
- Sea ice age [Maslanik et al., 2007, 2011]
- Downward surface solar radiation [ECMWF]
- Melt/ Freeze onset dates [Markus et al., 2009]
- Melt pond fraction [Rösel et al., 2012]

# Seasonality of transmitted heat fluxes



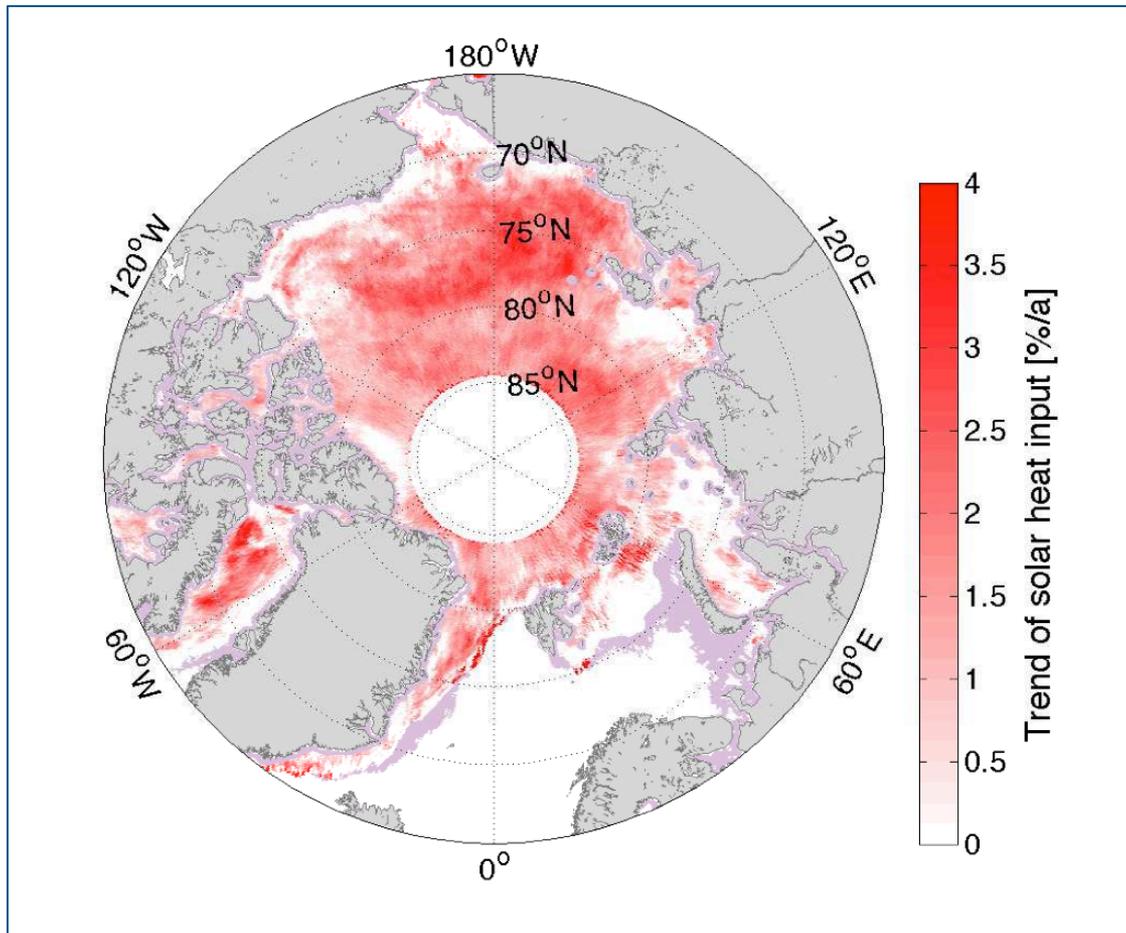
- **96 %** of the annual under-ice radiation are transmitted in only 4 months (May to August)  
 $\cong 51.2 \times 10^{19} \text{ J}$
- Highest fluxes in **June** ( $20.9 \times 10^{19} \text{ J}$ )

Monthly mean of transmitted heat fluxes through Arctic sea ice in 2011.

[Arndt&Nicolaus, *subm. in JGR*]

# Annual and monthly trends

## Annual trends

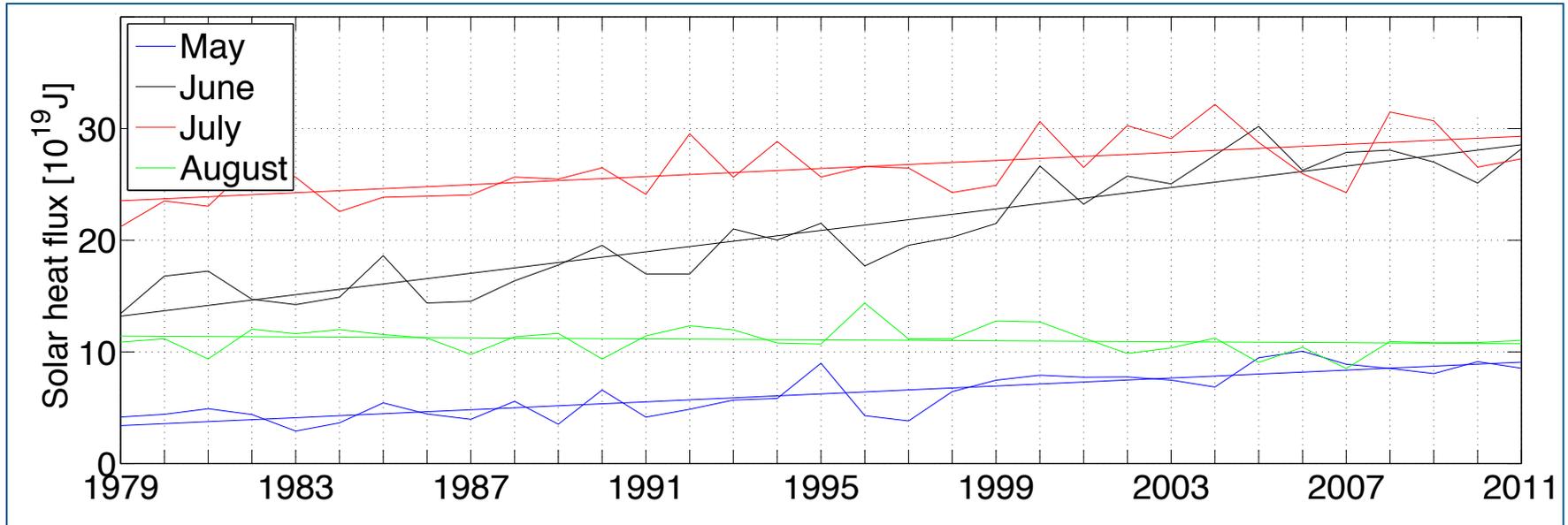


- Light transmission increases by **1.5% per year** Arctic-wide since 1979

*Trend in annual total solar heat input through Arctic sea ice from 1979 to 2011.*

# Annual and monthly trends

## Monthly trends

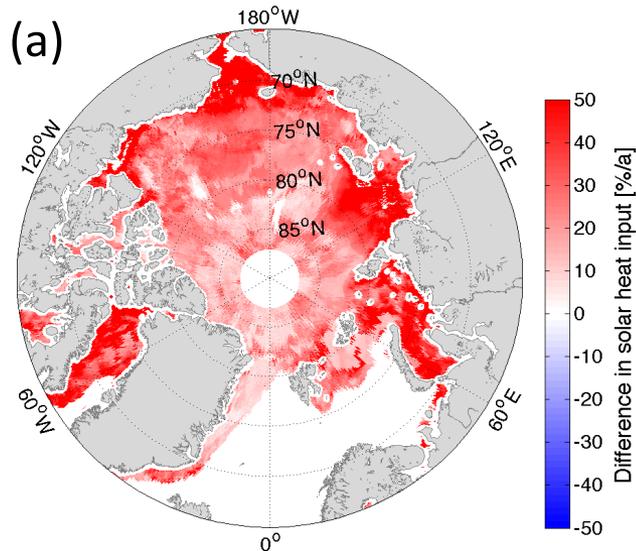


*Monthly Arctic-wide solar heat input through Arctic sea ice from 1979 to 2011.*

- Strongest increase in **June by 2.3% per year**

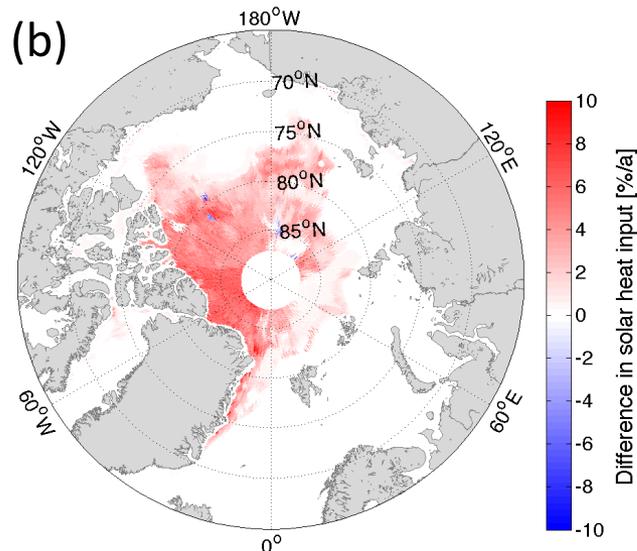
# Sensitivity studies

## Melt onset – 14 days



Increase of **24 %** of transmitted under-ice radiation

## Freeze onset + 14 days



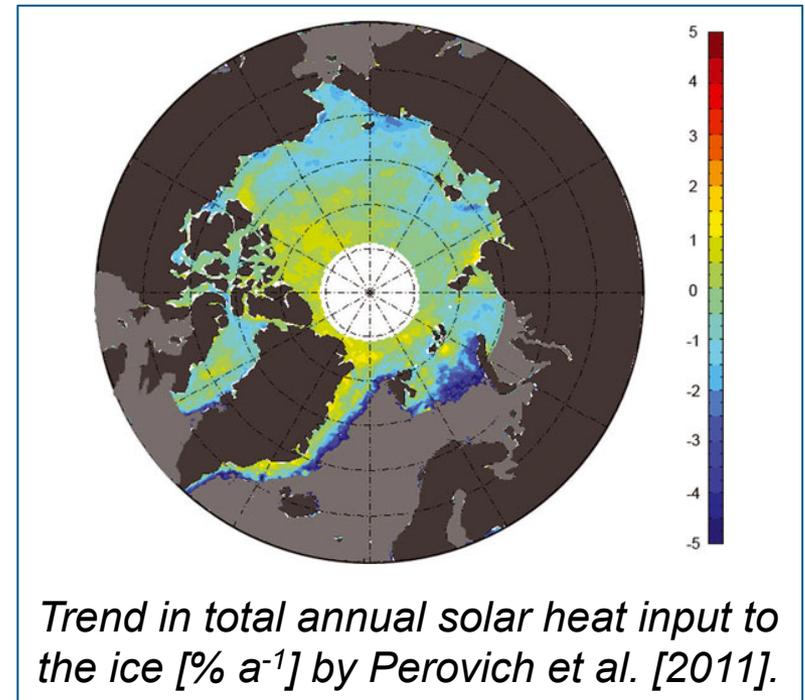
Increase of **1 %** of transmitted under-ice radiation

*Changes in total solar heat input through sea ice in 2011.*

(c) Assuming **only FYI** in the entire Arctic in 2011, transmitted under-ice radiation increases by another **18 %**.

# Conclusions

- Changes in **sea ice properties** have a large impact on the **energy budget**
- The additional energy input into the sea ice and upper ocean impacts e.g.
  - **Heat storage** in the ocean mixed layer
  - **Melt season** duration/ timing
  - **Melting** processes
  - **Bio-geo-chemical** processes
- Comparison with **surface radiation** trends [*Perovich et al., 2011*]:
  - Larger trend in light transmission than absorption
  - Additional **transmittance-melt feedback mechanism**



- How **big** are the effects of a changing physical environment on the ecosystem and **coupled climate system** exactly?

(paper in prep. by Fernandez et al.)

- How does the data product change with an improved Arctic-wide **snow depth** and **sea ice thickness** data product?

- How can the developed Arctic-based method be transferred to **Antarctic surface processes**?

(see Poster Session A, location number 008)



## 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.

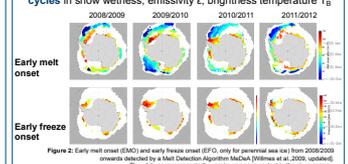
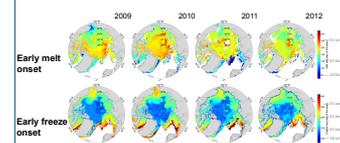
### ARCTIC

### Surface properties and melt onset detection

### ANTARCTIC

- 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  $\epsilon$**  and brightness temperature  $T_b$ , decreasing backscatter coefficient  $\sigma^0$  (for MYI)
  - > Melt onset detection based on the **sensitivity of  $T_b$  to liquid water content in the snow pack**

- 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  $\epsilon$ , brightness temperature  $T_b$



### First ideas of data improvements

- |                |  |                                |   |
|----------------|--|--------------------------------|---|
| Applying MeDaA | <ul style="list-style-type: none"> <li>Strong diurnal freeze-thaw cycles</li> <li>Low summer temperatures (<math>T_{sum} &lt; 0^\circ\text{C}</math>)</li> </ul> | Applying melt onset routine by | <ul style="list-style-type: none"> <li>Weak diurnal freeze-thaw cycles</li> <li>Strong surface snow melt</li> </ul> |
|----------------|--|--------------------------------|---|



**Thanks for your attention!**