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

10 March 2014

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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
Motivation

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

  ![Solar heat input into the Arctic Ocean through sea ice in August 2011](image)

  [Nicolaus et al., 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

- Transmittance
- FYI
- Melting FYI
- New FYI
- New MYI
- Melting MYI
- MYI

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

Total transmittance of pond covered sea ice.

[Arndt&Nicolaus, subm. in JGR]
New up-scaling method for calculation of under-ice radiation

Parameterization

- Winter
- Early melt
- Continuous melt
- Summer
- Fall freeze-up
- Continuous freeze

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) ≈ 51.2×10^{19} \text{ J}

- Highest fluxes in June (20.9×10^{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.

[Arndt&Nicolaus, subm. in JGR]
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

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

[Arndt&Nicolaus, subm. in JGR]
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

Trend in total annual solar heat input to the ice [% a⁻¹] by Perovich et al. [2011].
Outlook

- **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)*
Thanks for your attention!