ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

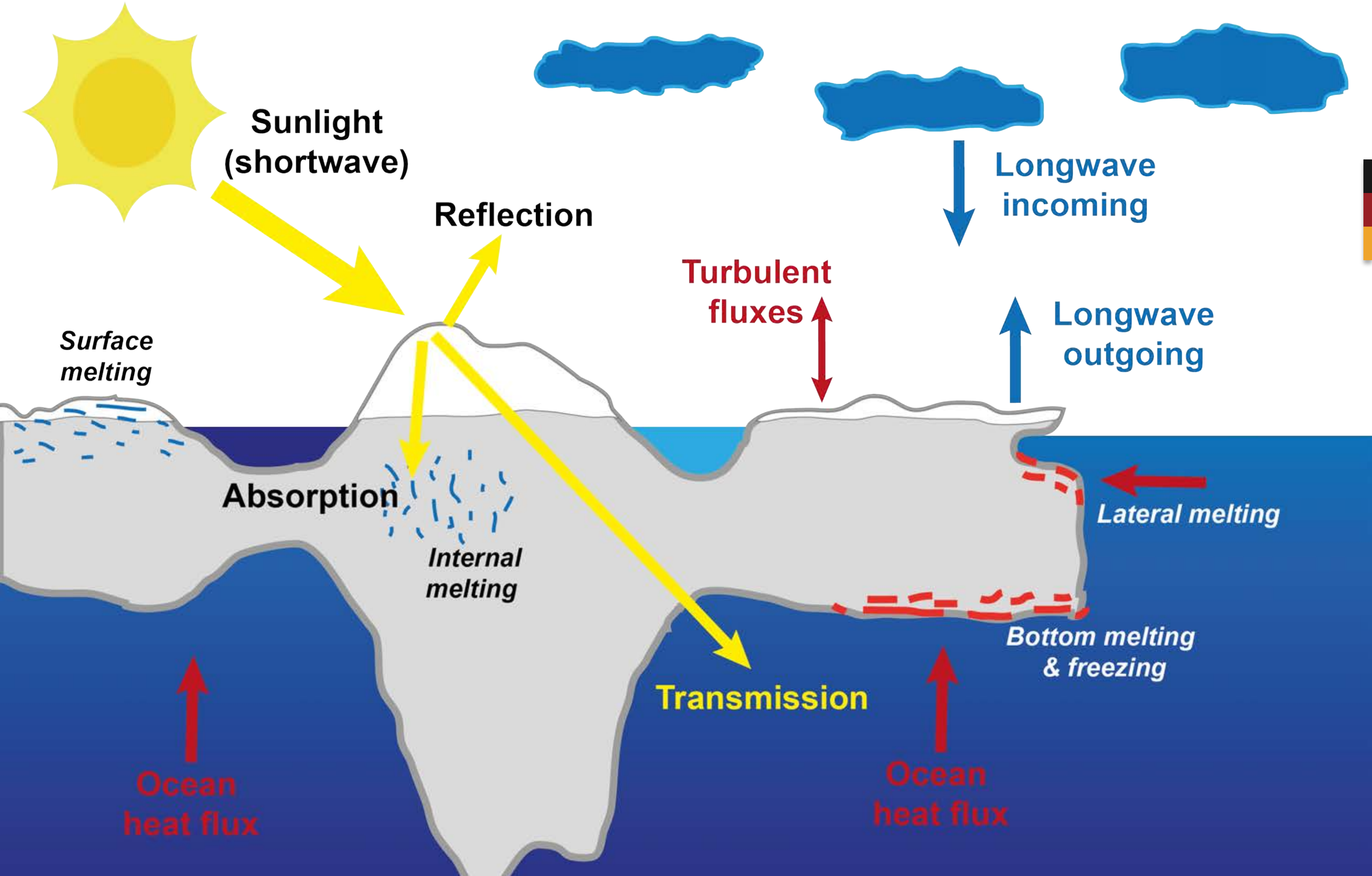
Marcel Nicolaus, Stefanie Arndt, Christian Katlein

Changes, variability, and seasonality of sea ice energy budgets

24 Sep 2014

HELMHOLTZ
GEMEINSCHAFT

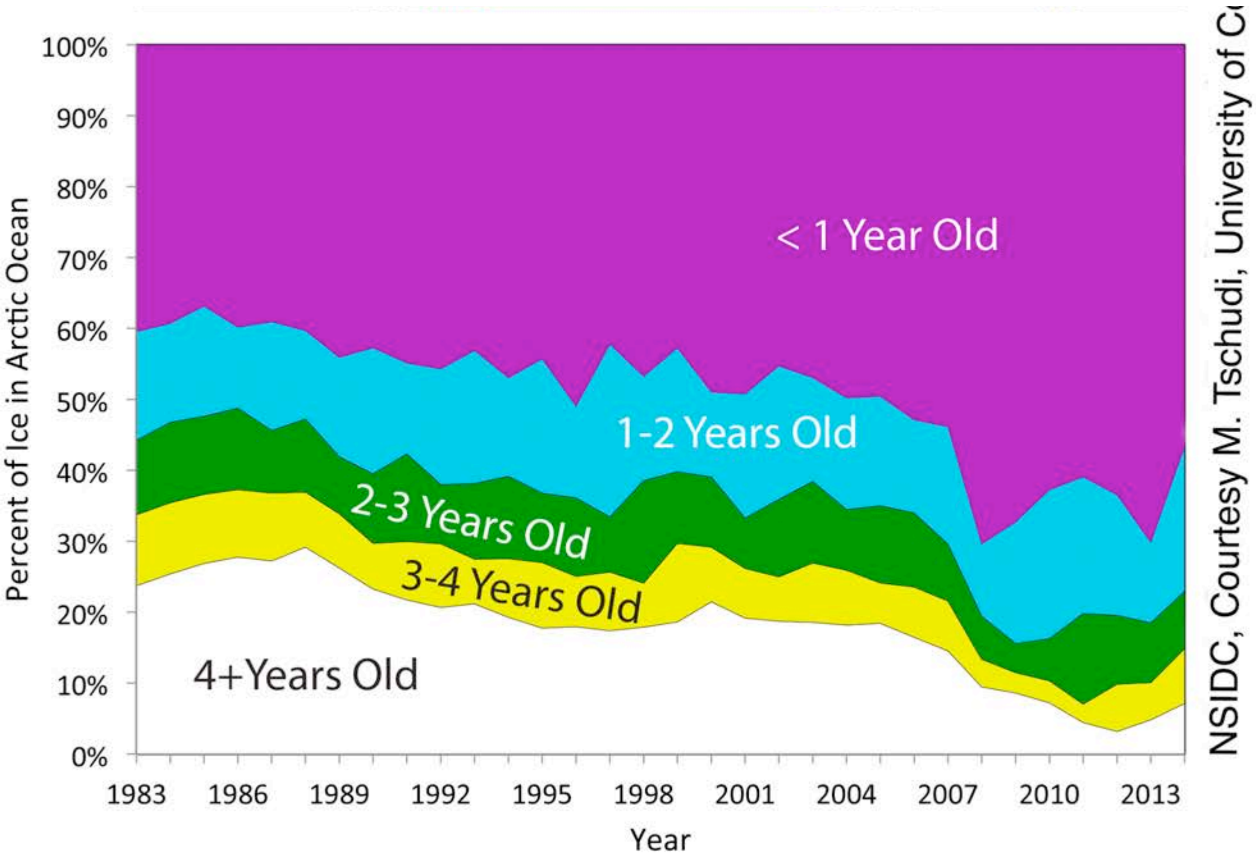
Sunlight and Transmittance



Snow Rules

- Physical properties
  - Thermal
  - Optical
- Surface characteristics
  - Melt ponds
  - Satellite signatures
- Mass balance
  - Snow depth
  - Snow density / mass
- Fresh water

Changes: The Ice Age Proxy



- Surface properties
- Physical properties: Drift and Dynamics
- Thickness distributions
- Habitat changes

Albedo Changes

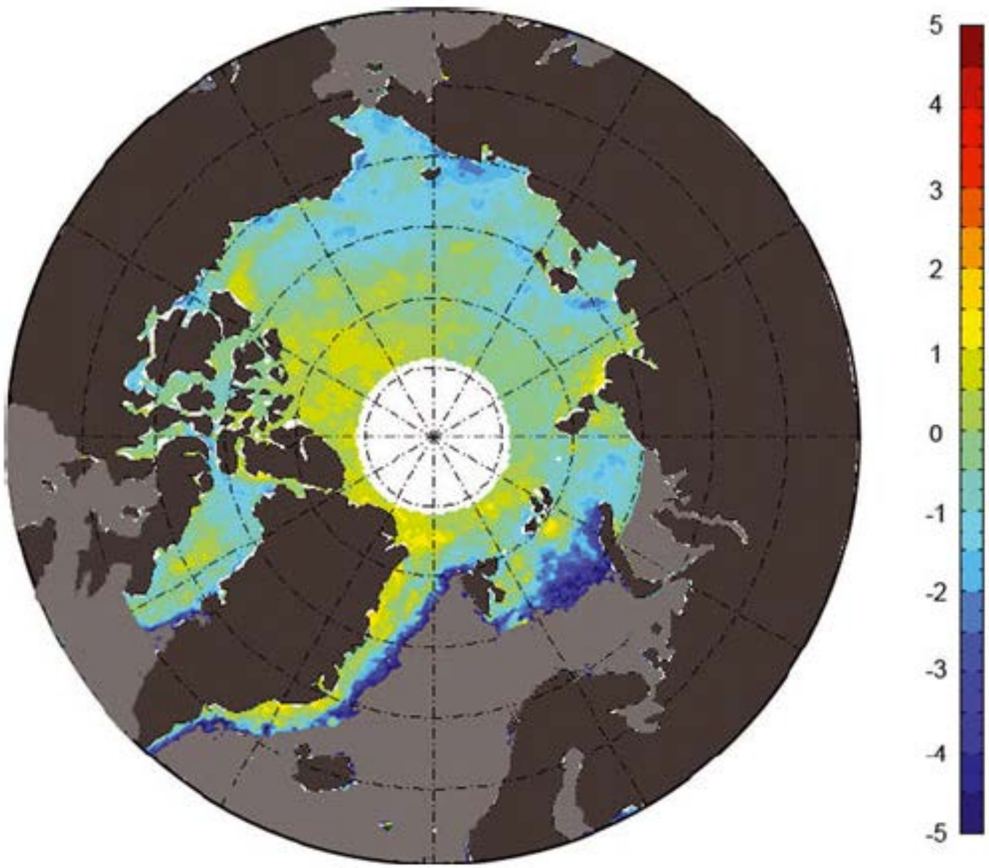


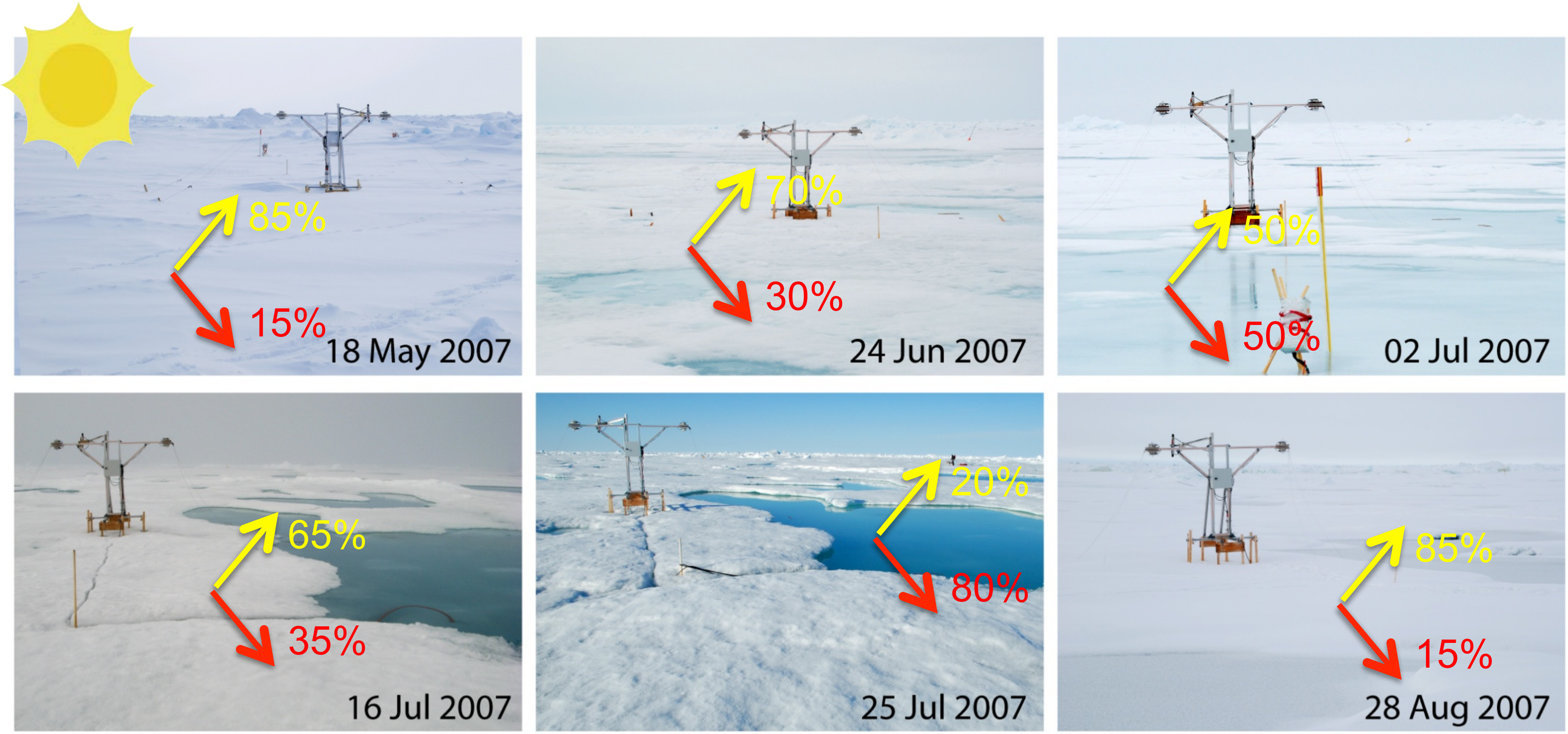
Fig. 2. The trend in total annual solar heat input to the ice within a gridcell, Q_i. The units are $\% \, a^{-1}$.

- Decrease in surface albedo
- Increase of solar heat input (1-2 %/year)

=> Develop maps and trends for in- and under-ice fluxes

Perovich et al. (2011, AOG)

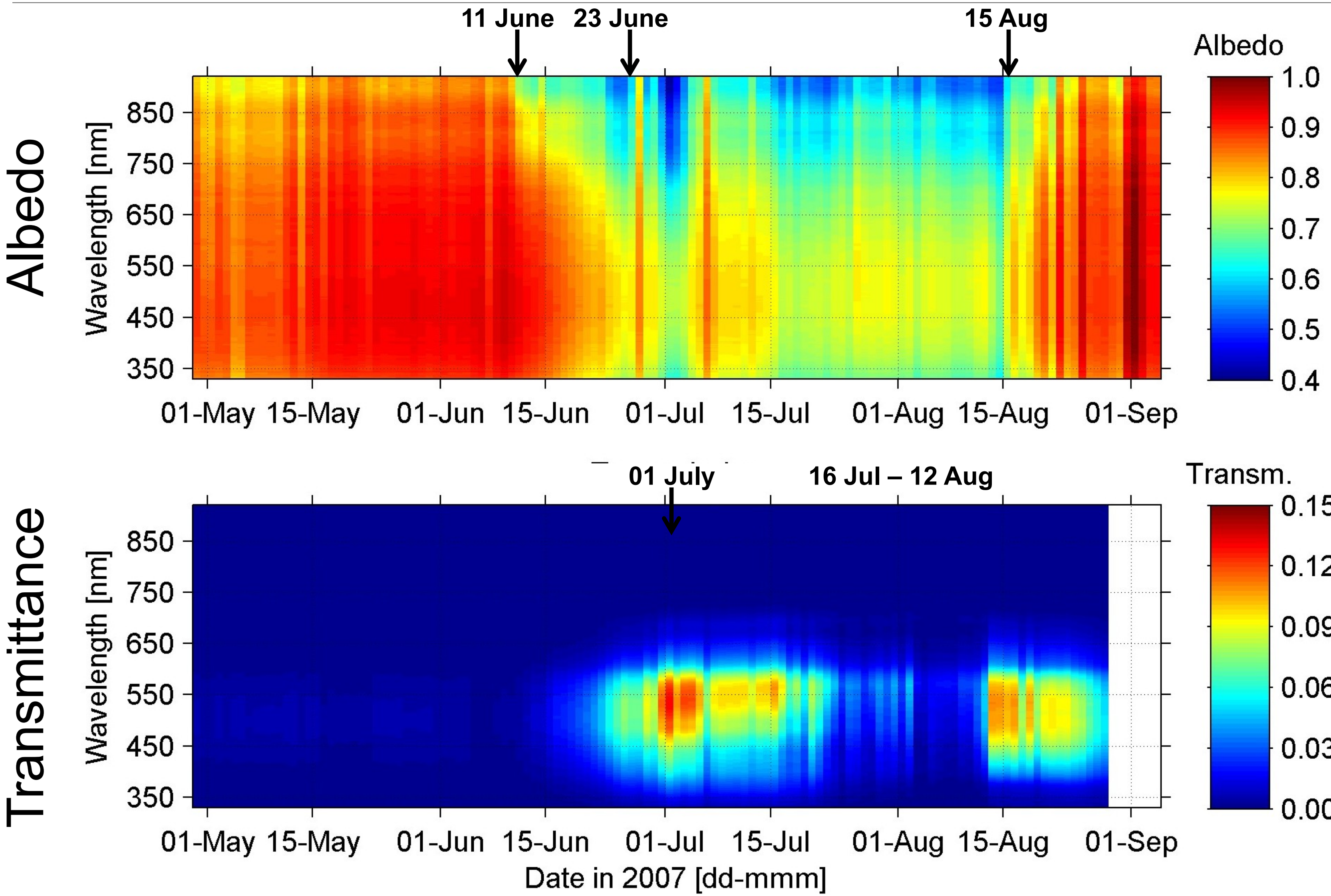
Seasonality



- Results from the drift of Tara
- At one drifting MYI site
- Great time series, no spatial variability

Nicolaus et al. (2010, JGR and CRST)

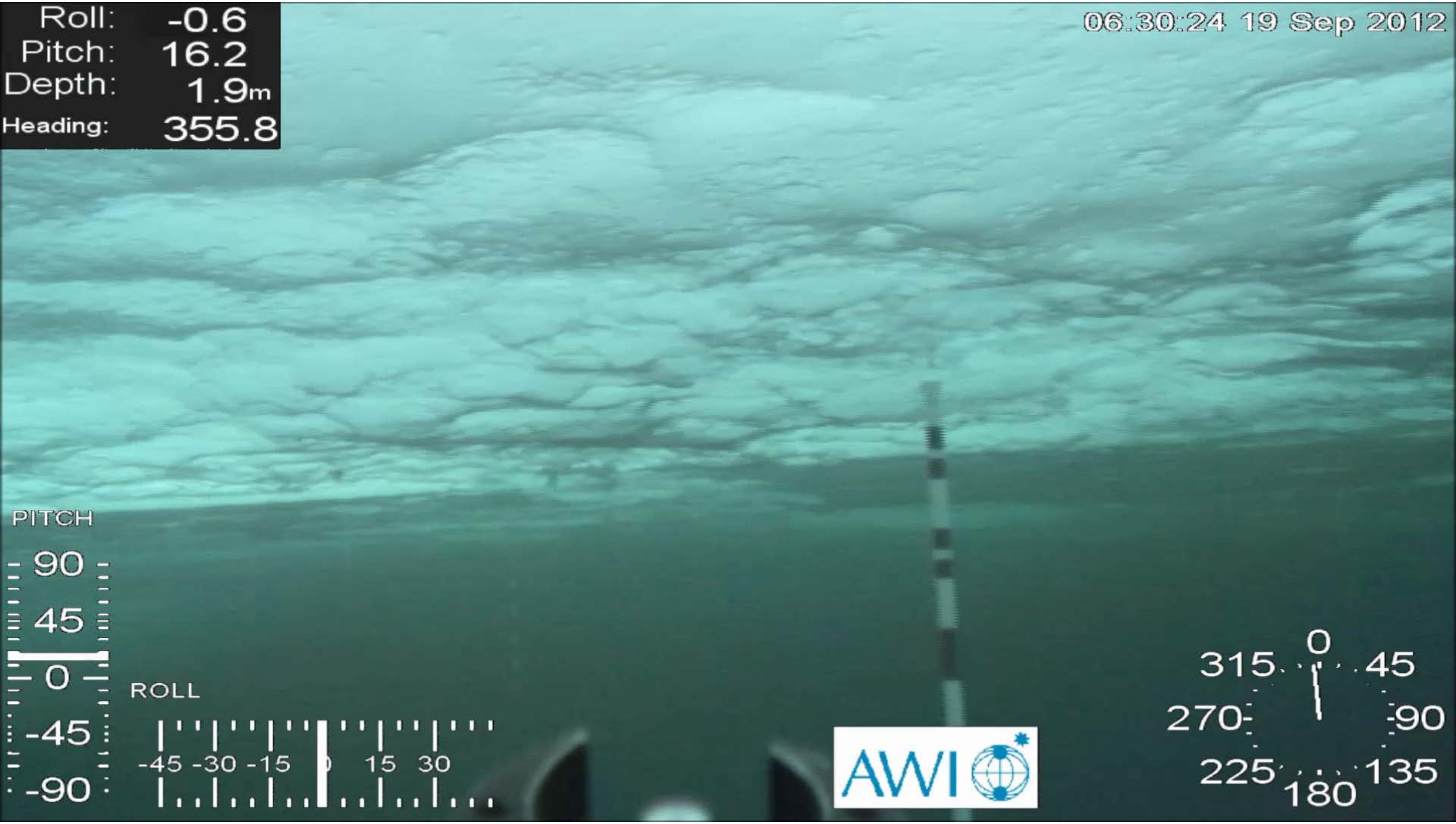
Seasonality at Tara



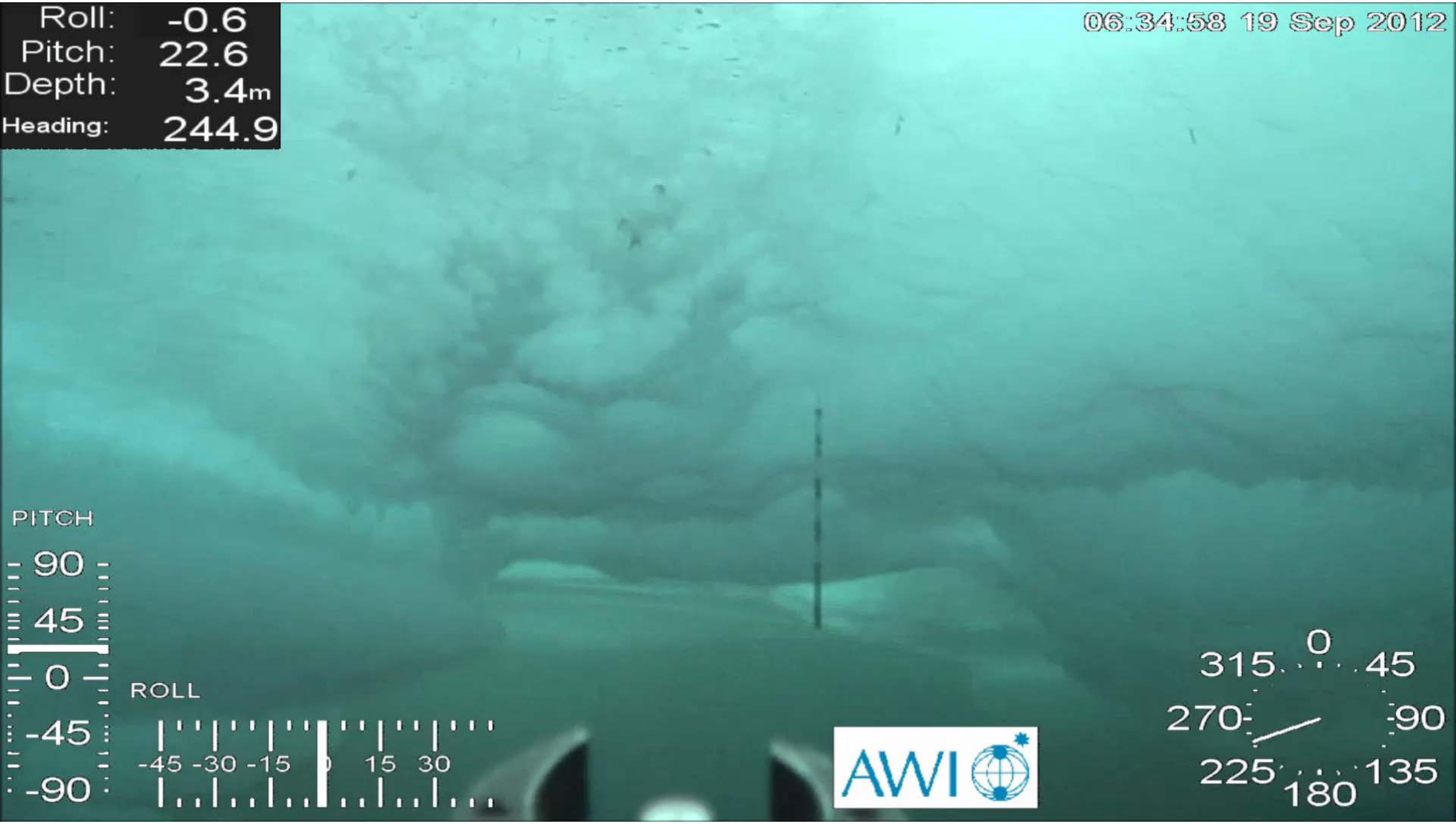
Nicolaus et al. (2010, JGR and CRST)

Under-Ice Investigations

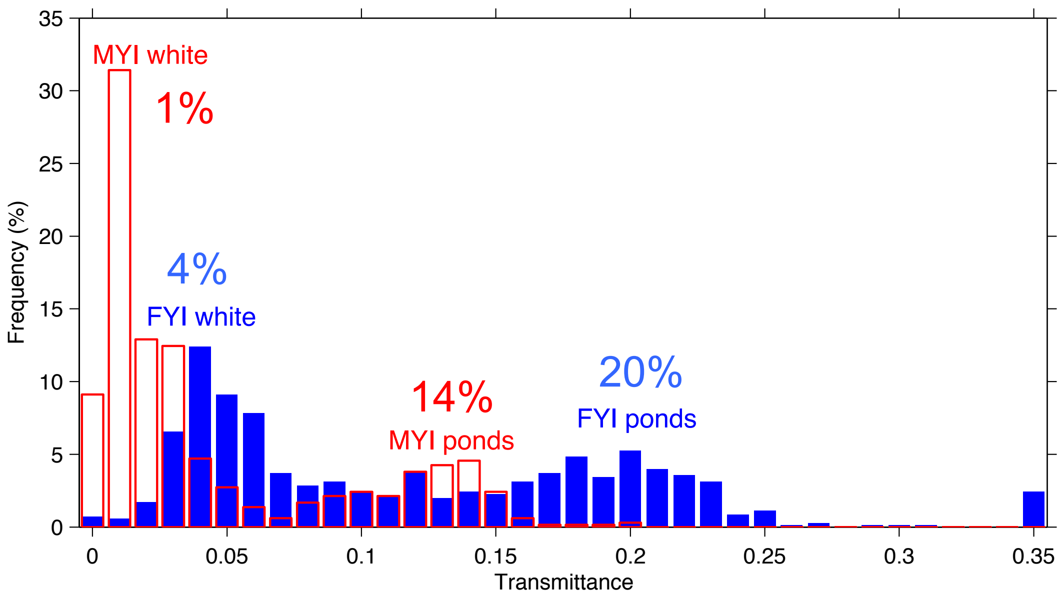
View from Below: Level Ice

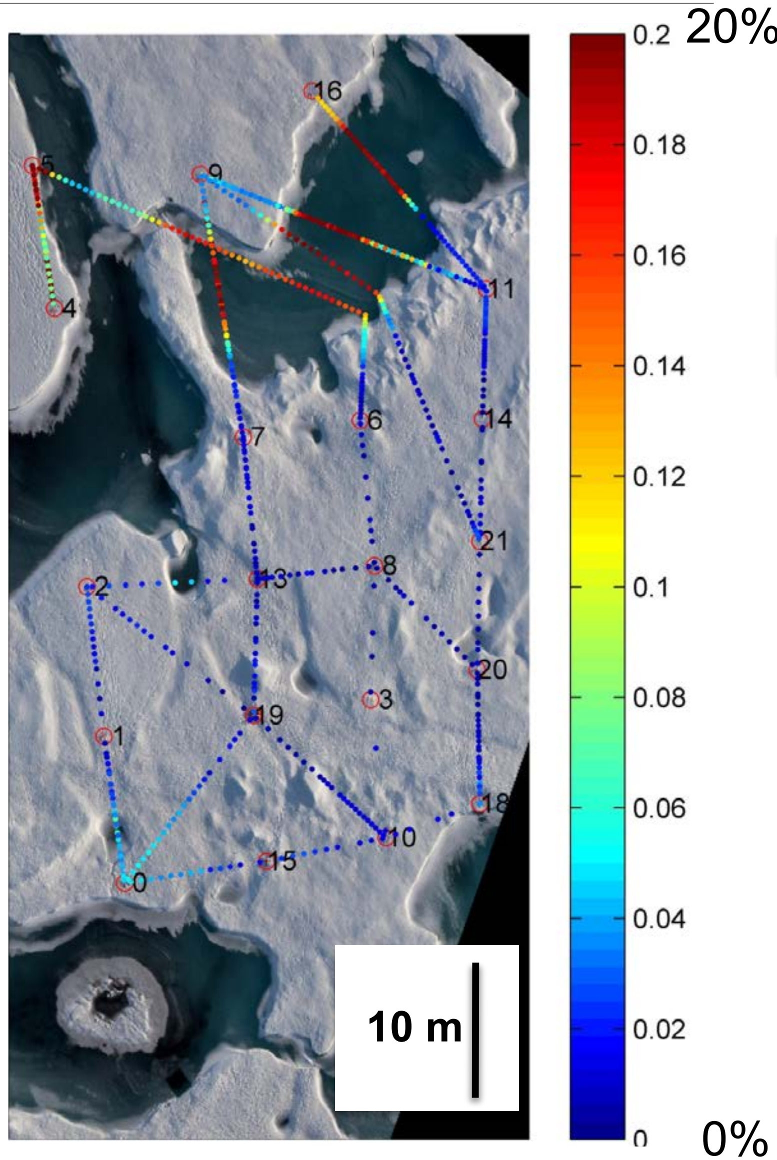


View from Below: Ridged Ice



Transmittance through Sea Ice

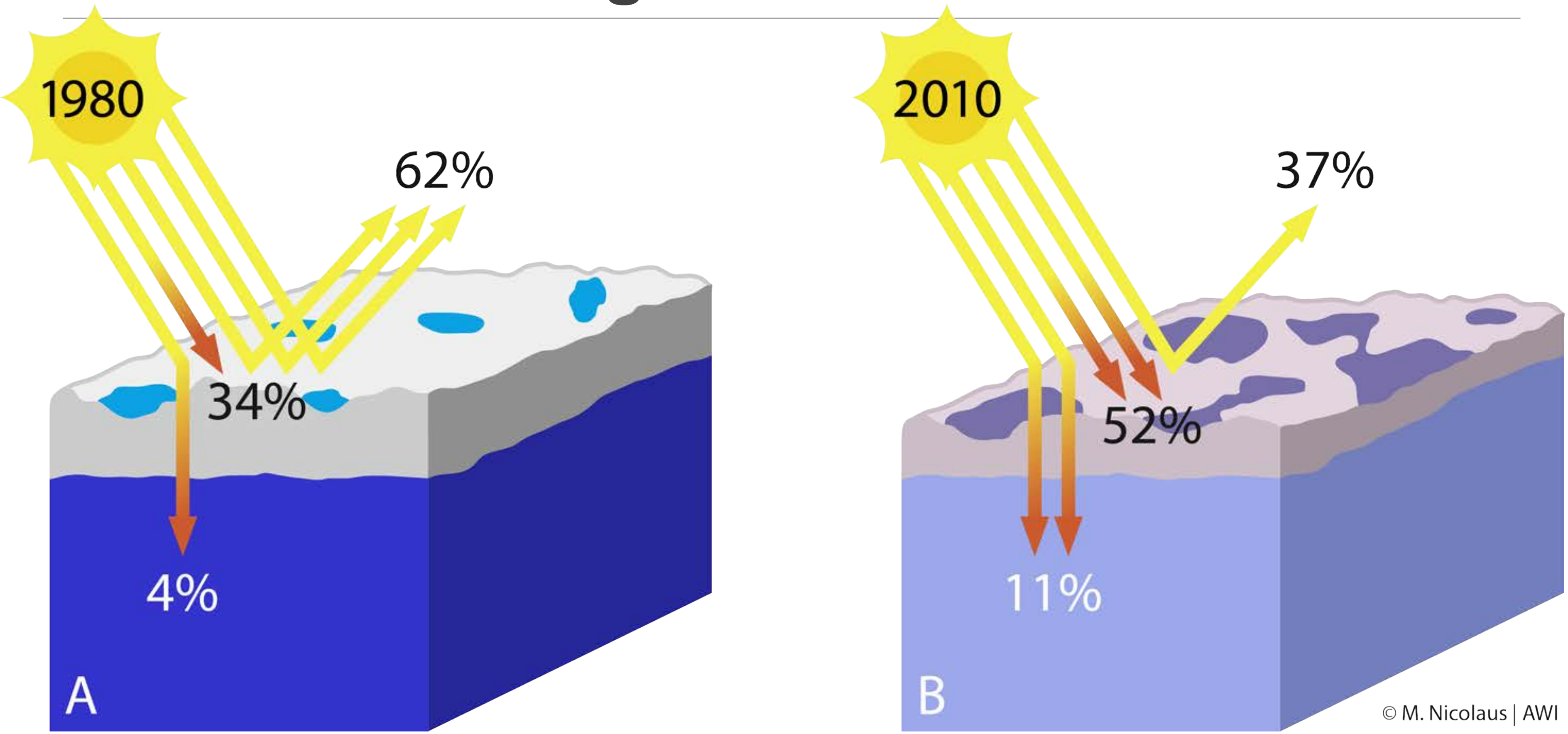




- 40% ponds on FYI: 11%
- 23% ponds on MYI: 4%

Nicolaus et al. (2012 & 2013, GRL)

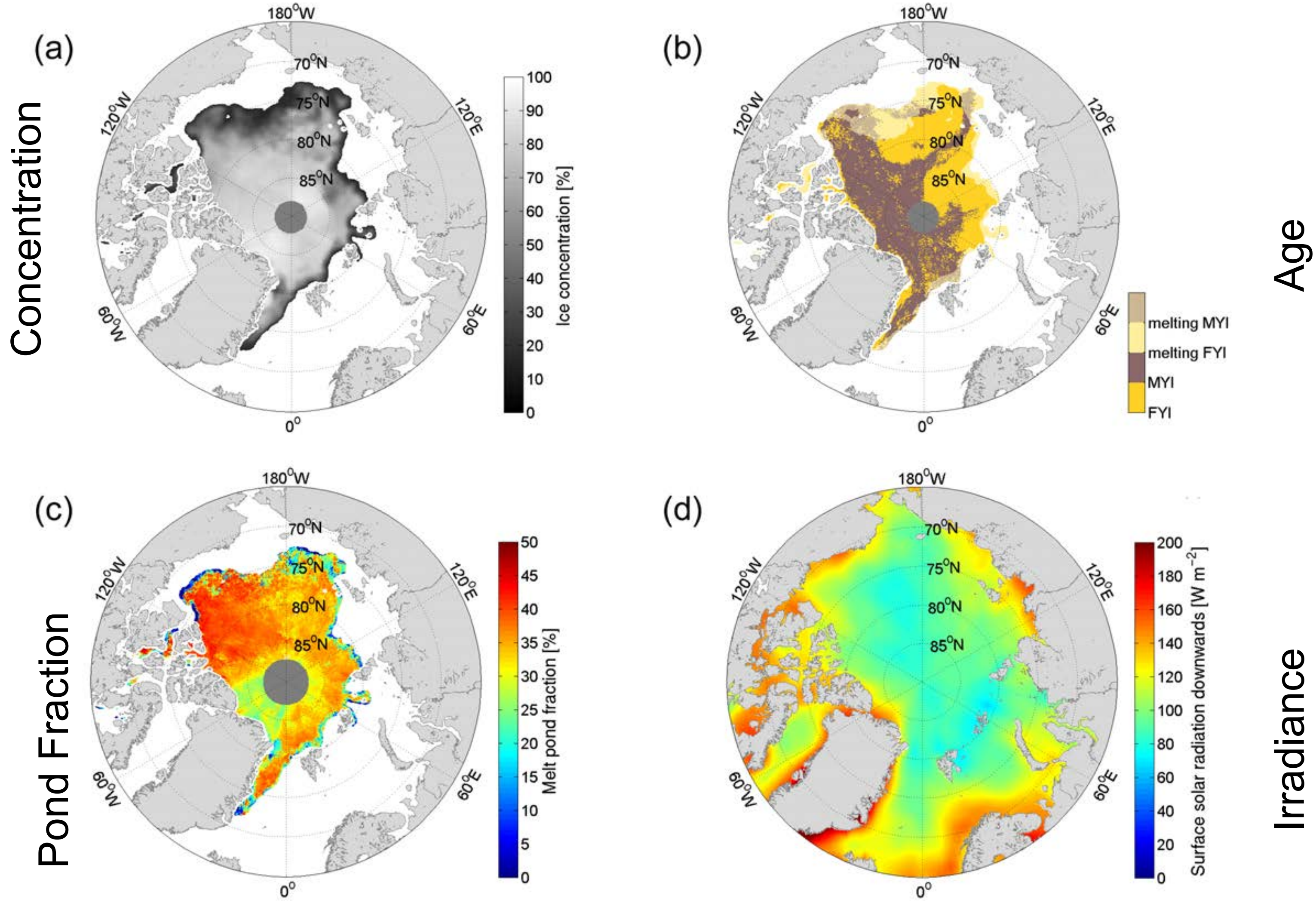
Observed Changes in Summer



Transmission:	+ 200%
Albedo:	- 50%
Absorption	+ 50%

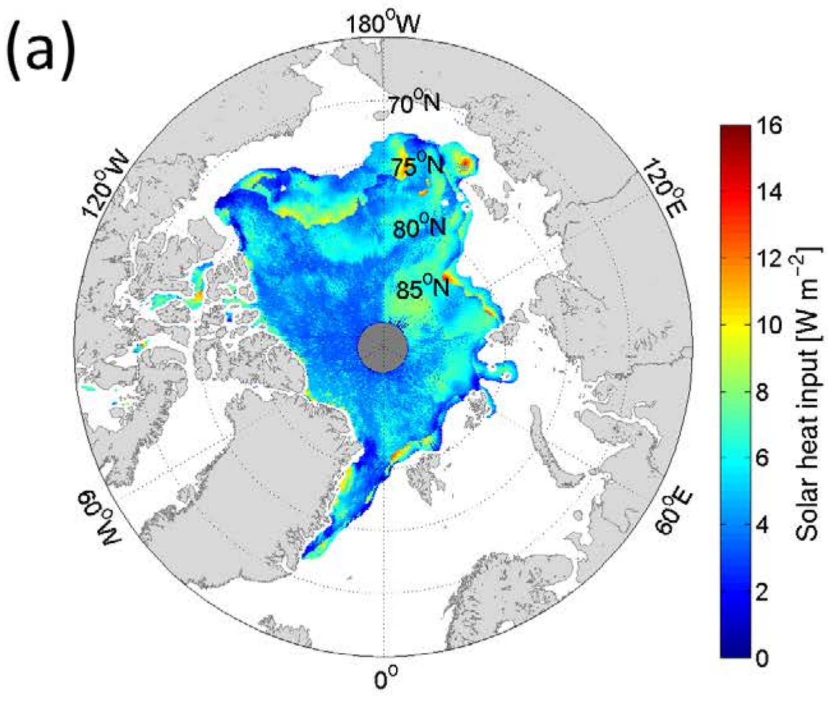
Nicolaus et al. (2012 & 2013, GRL)

August 2011 – Upscaling



Nicolaus et al. (2012 & 2013, GRL)

August 2011 – Fluxes into the ocean



Sea ice only

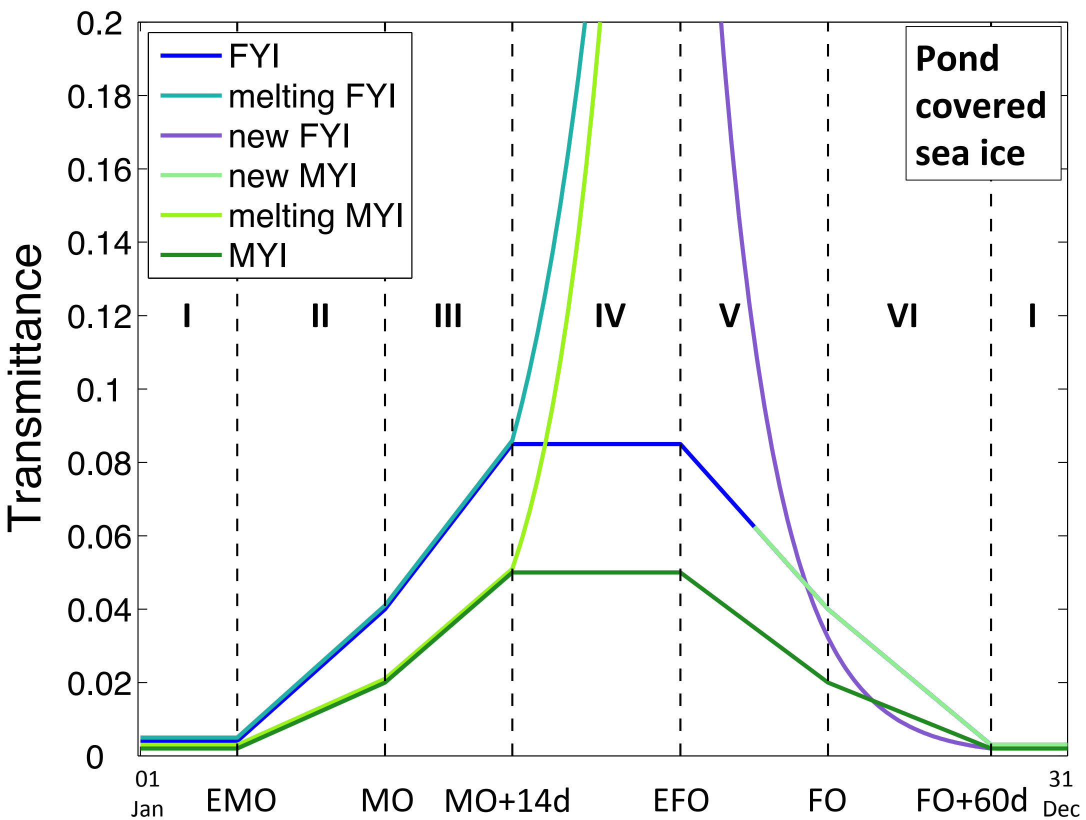
Ice + Ocean

Nicolaus et al. (2012 & 2013, GRL)

Seasonality of Transmittance

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

Parameterization



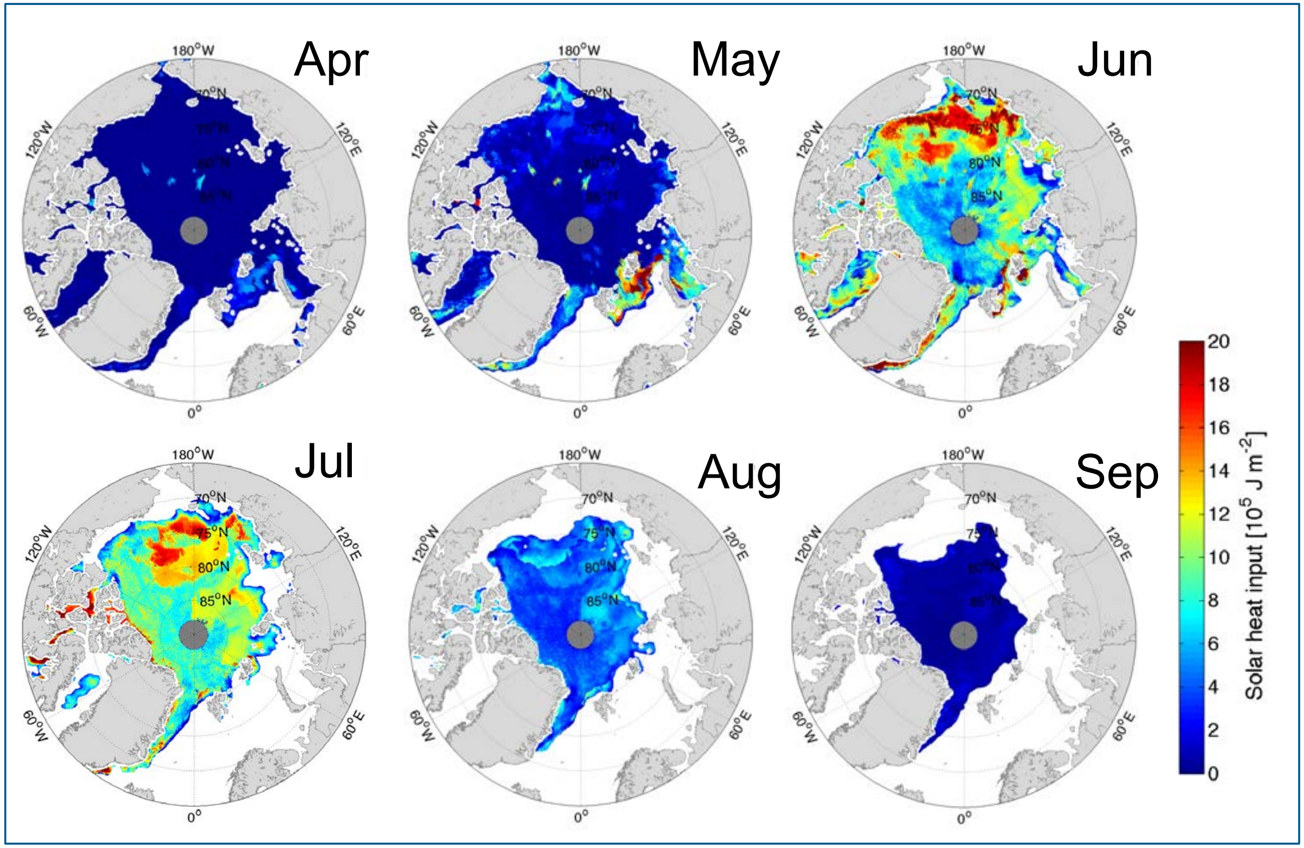
I Winter
II Early melt
III Continuous melt
IV Summer
V Fall freeze-up
VI Continuous freeze

Total transmittance of pond covered sea ice.

Arndt & Nicolaus (2014, TCD)

Seasonality of Transmitted Fluxes

- **Add parameterization of transmittance for the entire year 2011**



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

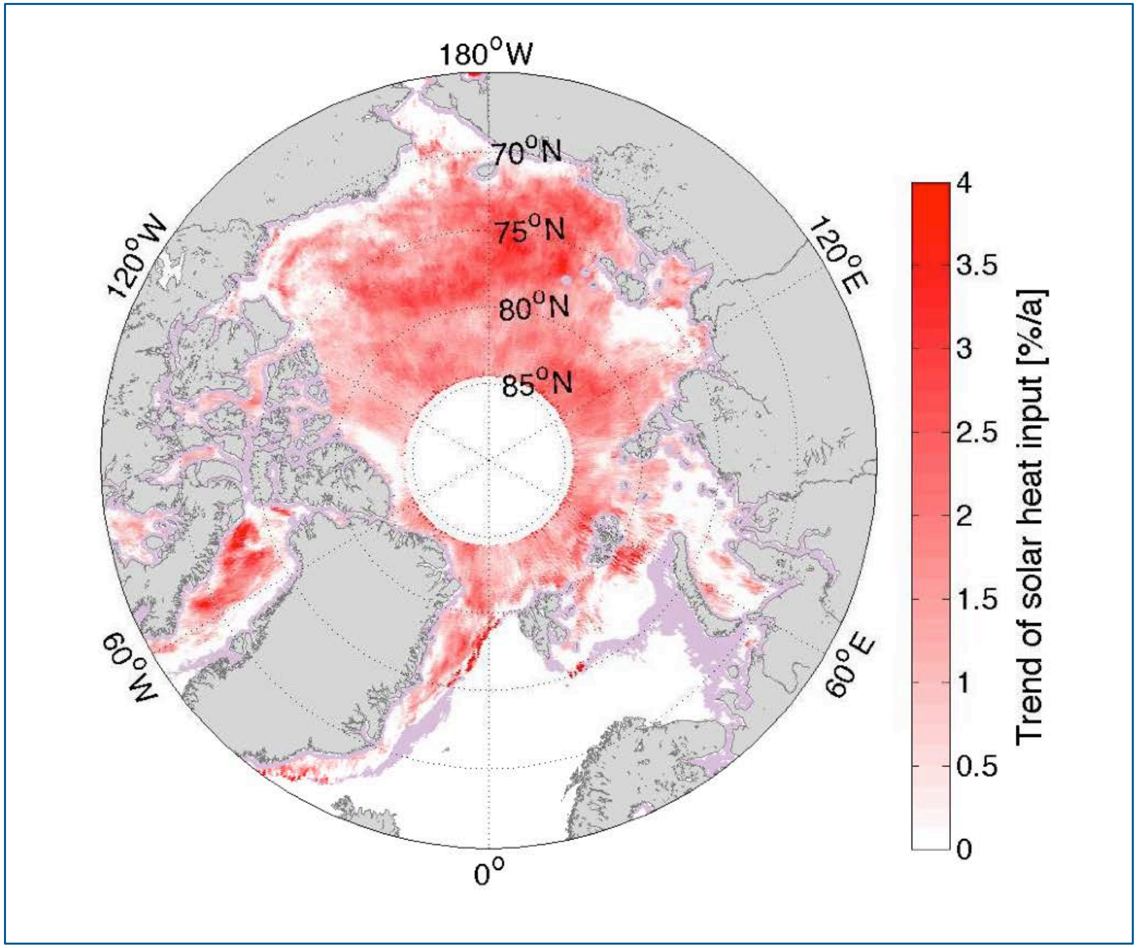
- **Surface flux** is same order of magnitude as ocean heat flux
- **96 %** of the annual under-ice radiation are transmitted in only 4 months (May to August)
- Highest fluxes (= melt rate) in **June**

Monthly mean of 20×10^5 Jm^{-2}
≙ 20 cm sea-ice melt/month

Arndt & Nicolaus (2014, TCD)

Annual Trend (Sea Ice Only)

- **Apply to all years 1979-2011**



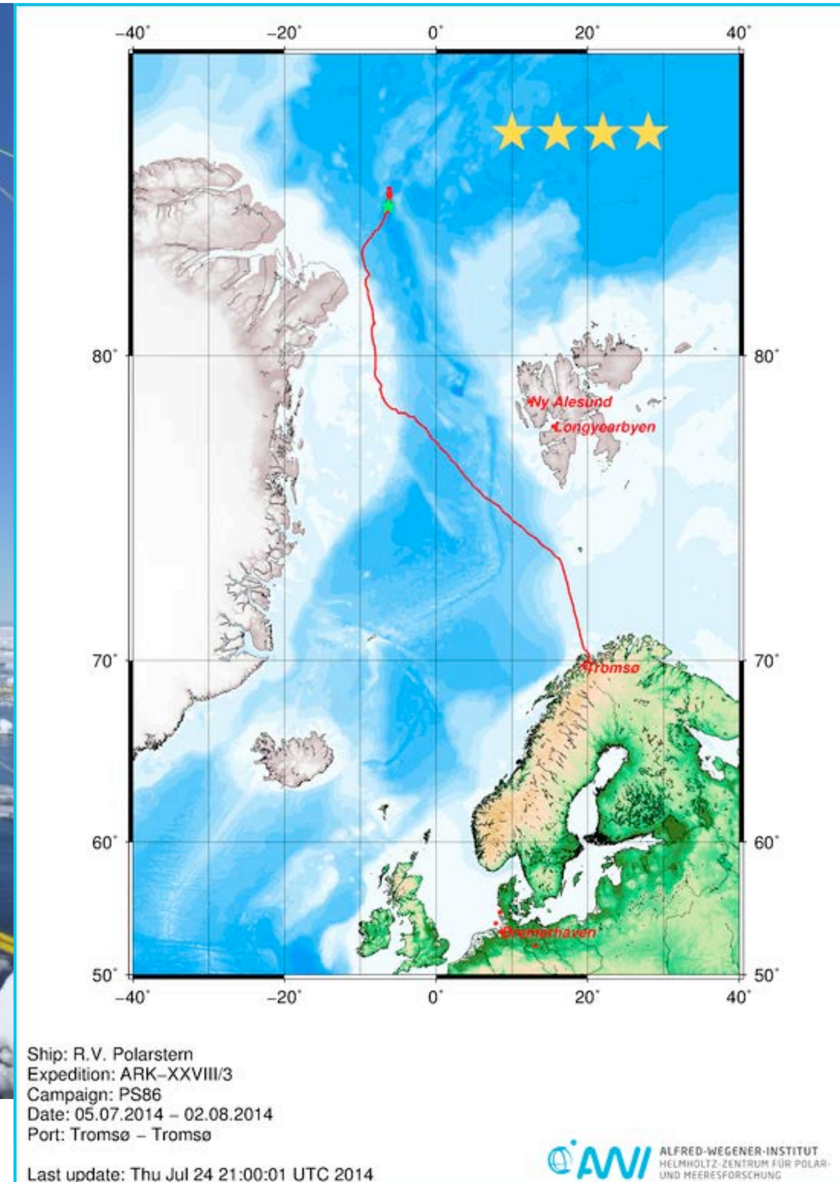
- Light transmission increases by **1.5% per year** Arctic-wide since 1979
- Over 32 years: 1.6 times more warming and melt

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

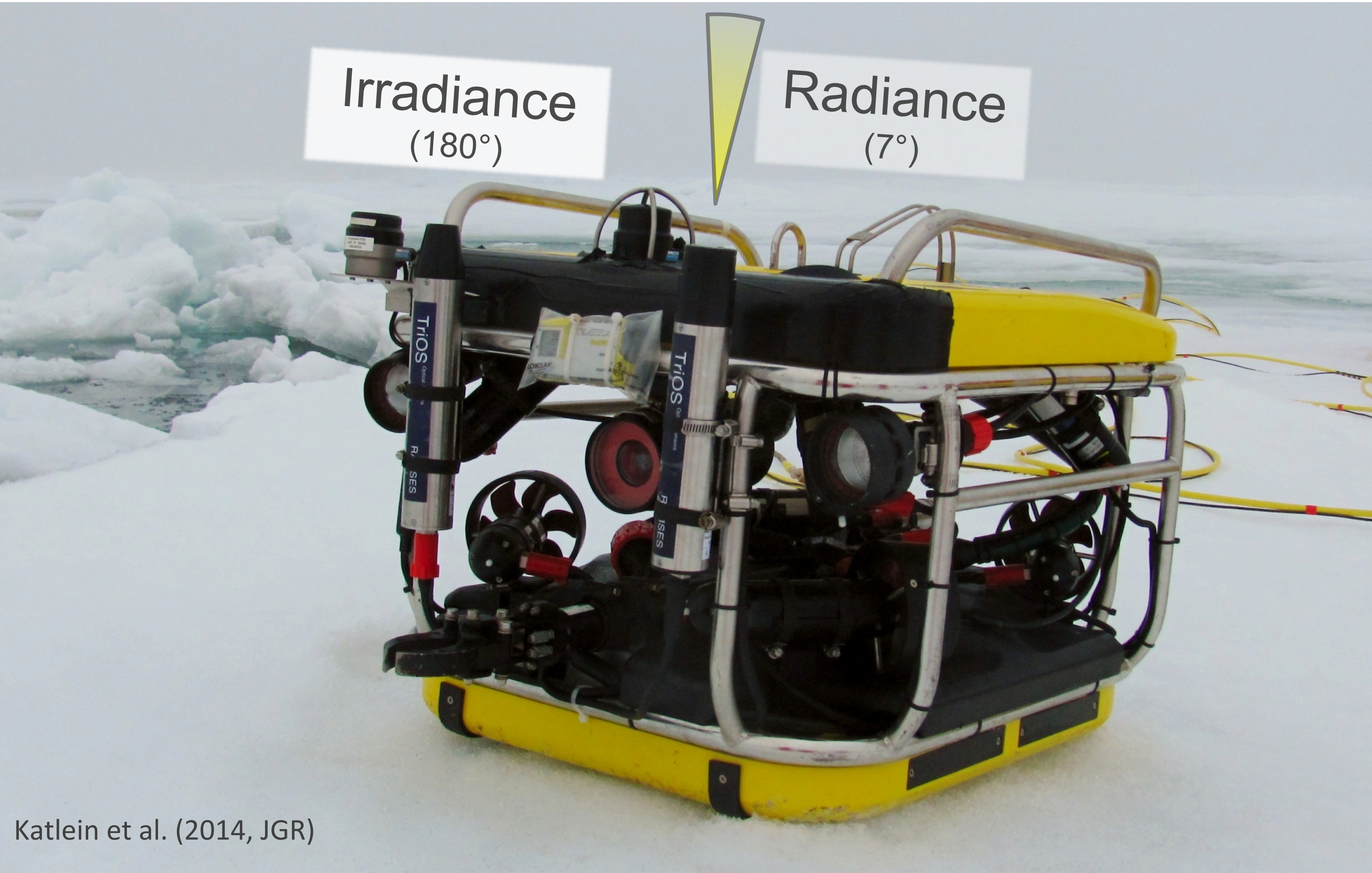
Arndt & Nicolaus (2014, TCD)

Recent AUV mission

Photo: Christian Katlein



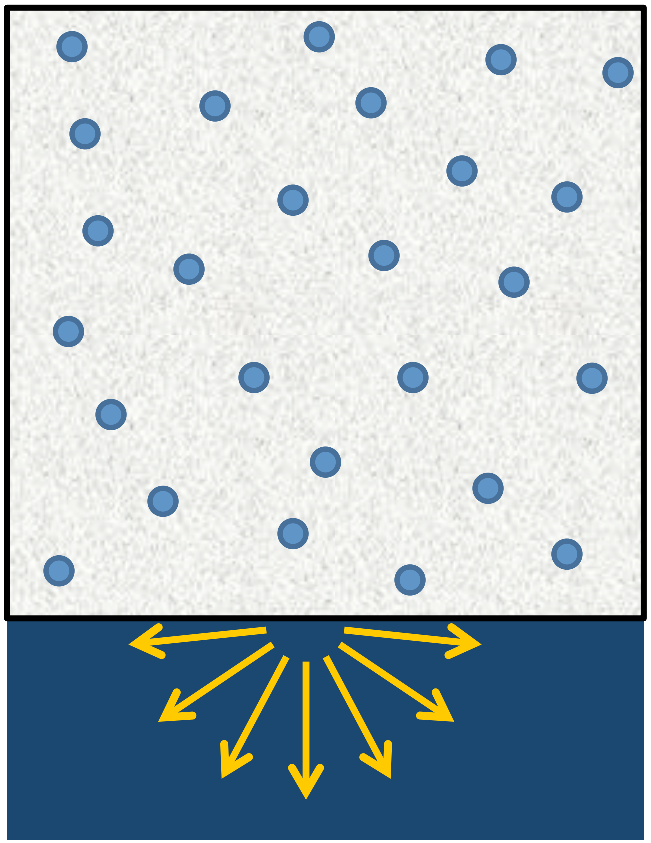
Optical Properties - Scattering



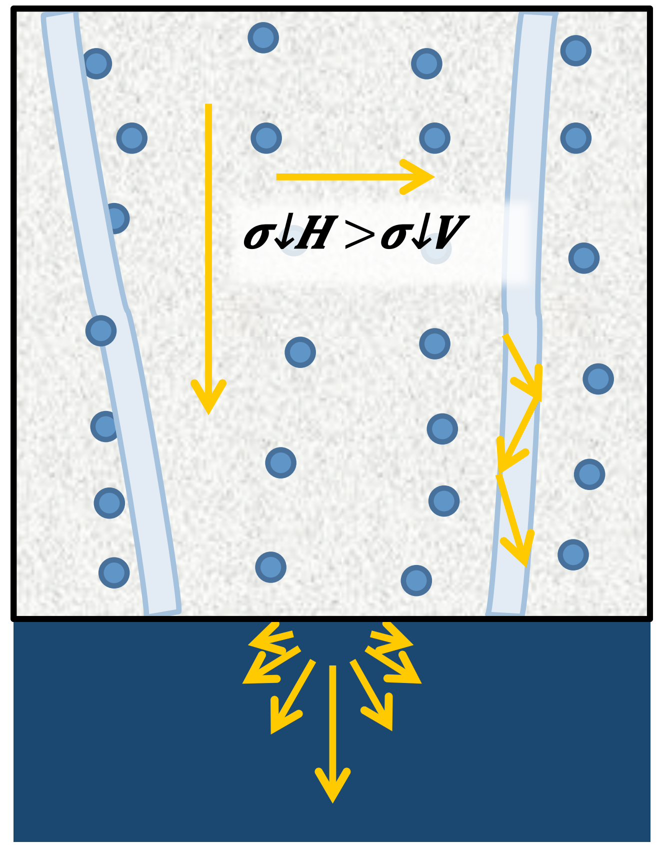
Katlein et al. (2014, JGR)

Irradiance / Radiance

- Isotropy C=π=3.14
- Mostly used, but overestimation of irradiance by >50%



- Anisotropy C<2.5
- More realistic fluxes



Katlein et al. (2014, JGR)

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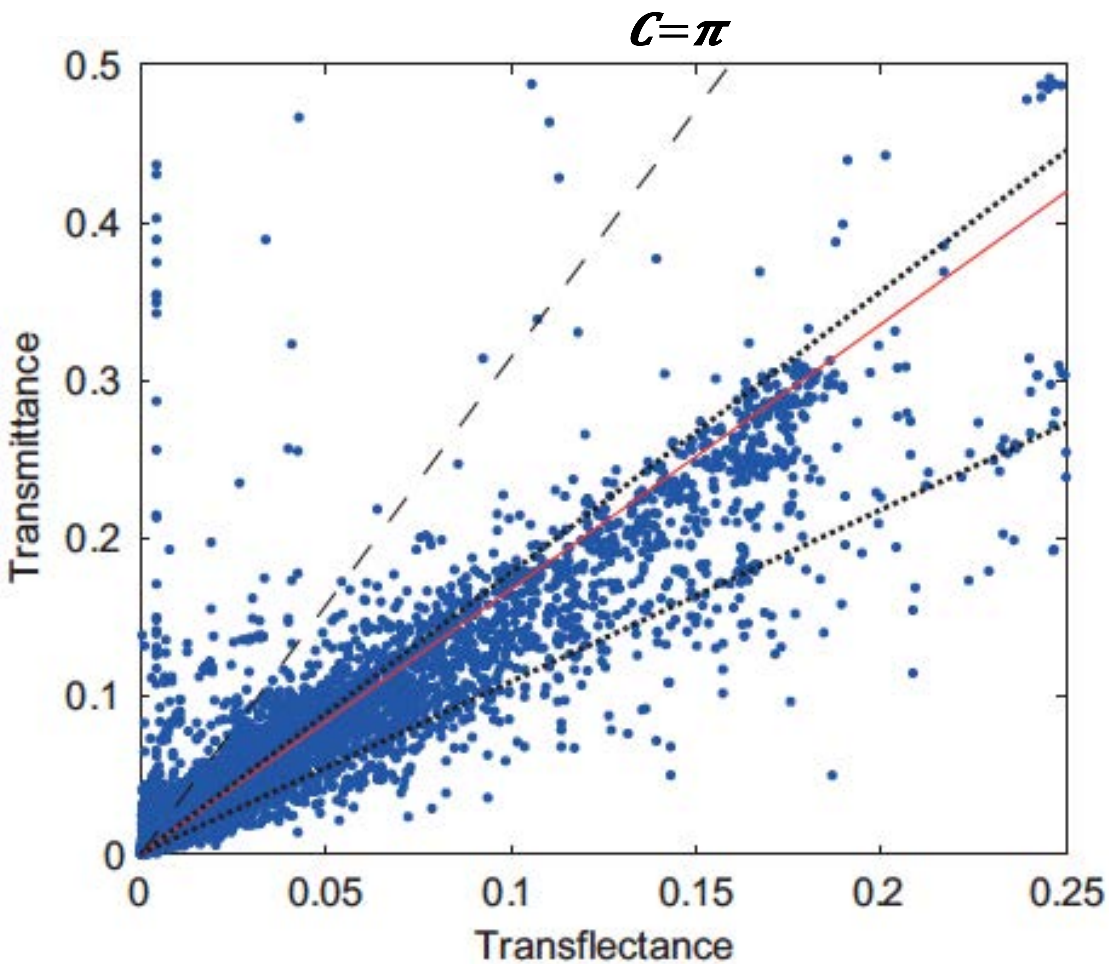


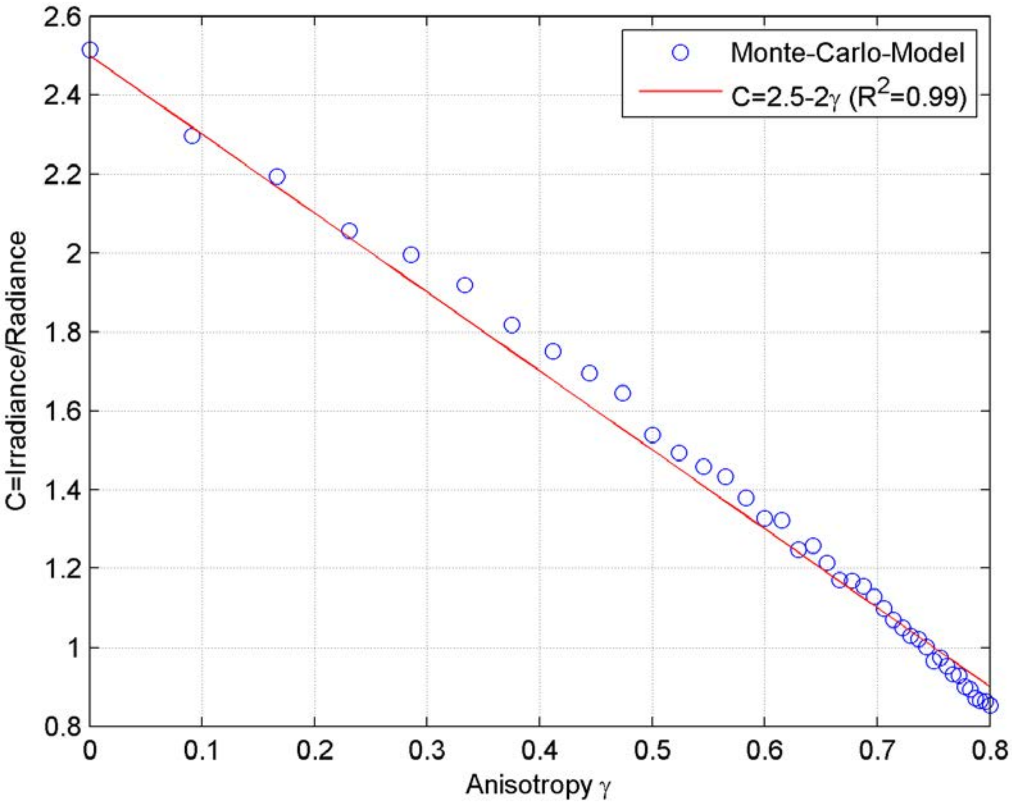
Katlein et al. (2014, JGR)

Parameterization of C=Irrad/Rad

- Best fit of anisotropy

$$C(\gamma)=2.5-2\gamma$$

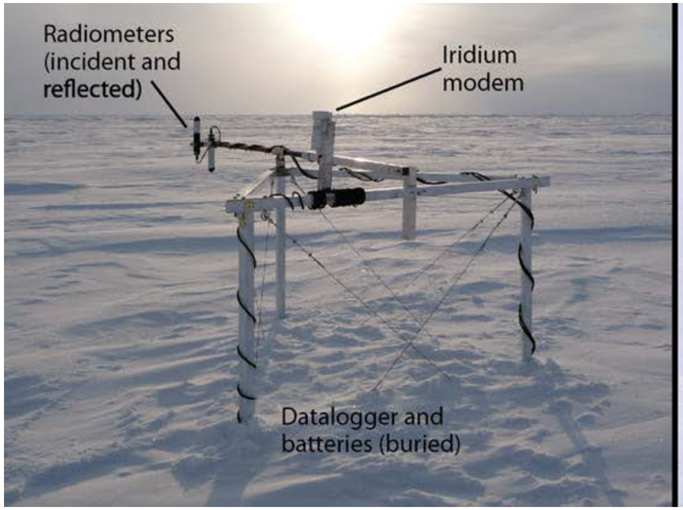
- Error < 5%
- For isotropic case C=2.5
    - Boundary effect

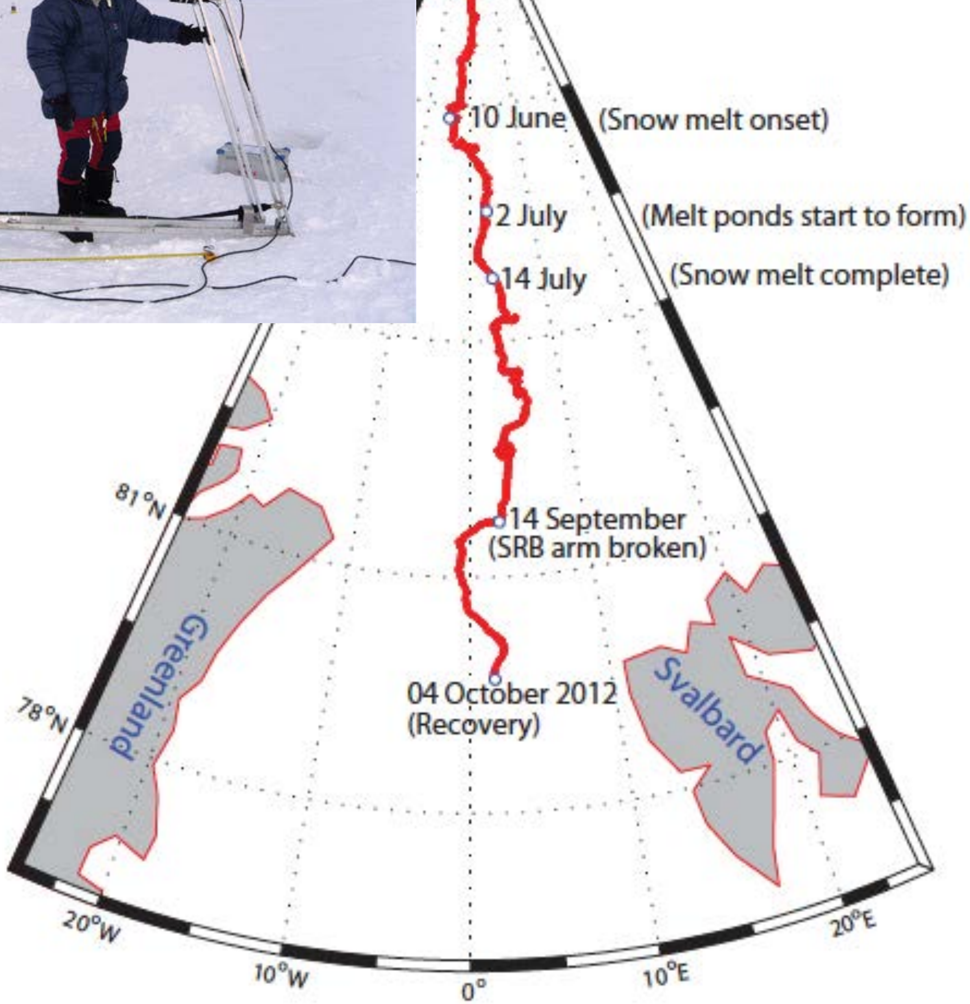


- **Correct conversion** of radiance to irradiance is possible: anisotropy needed

Katlein et al. (2014, JGR)

Spectral Radiation Buoy

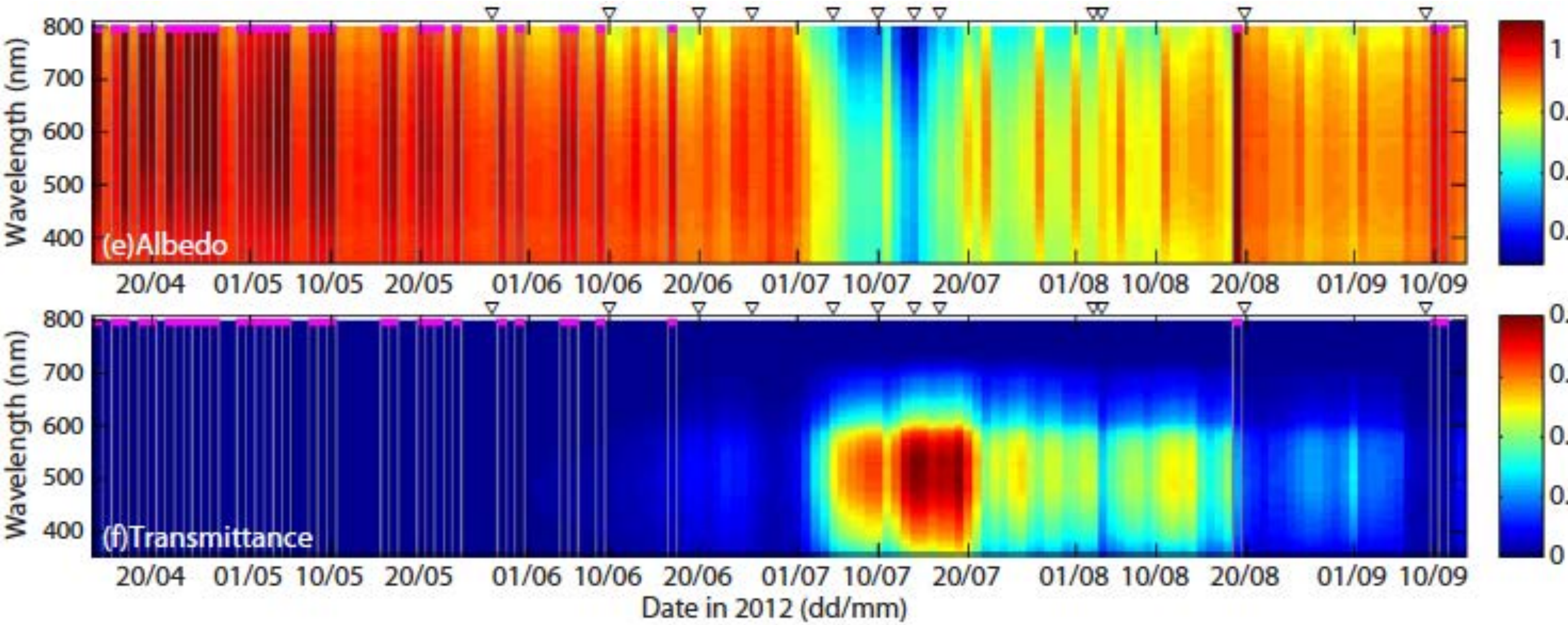




- **Fully autonomous measurements**

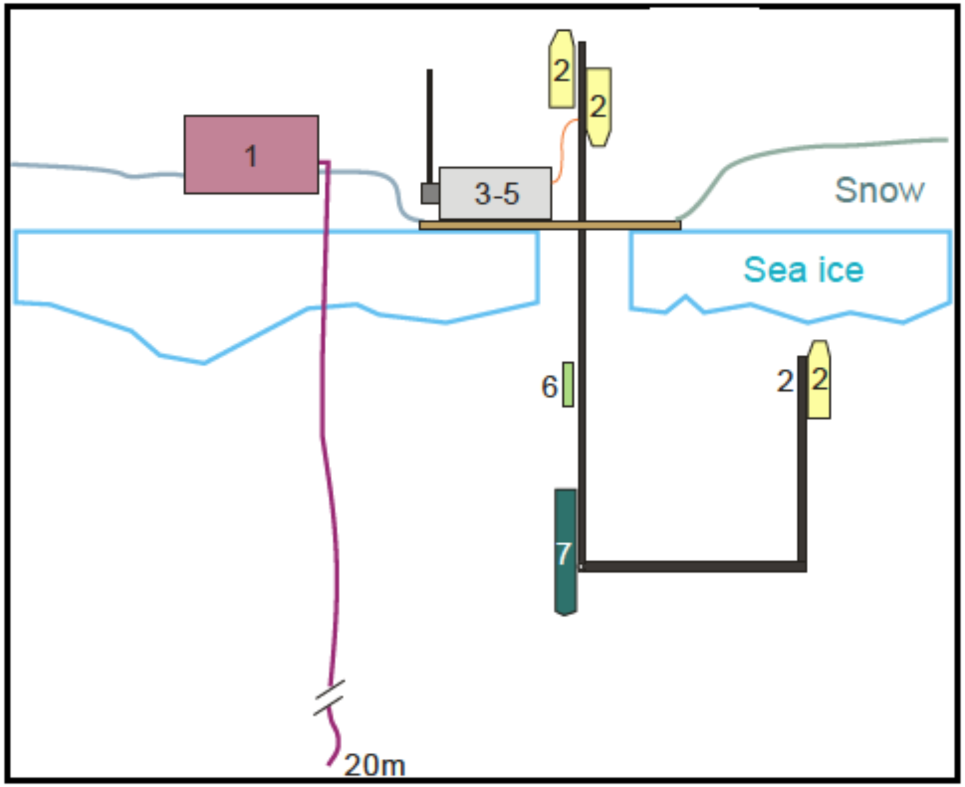
Wang et al. (2014, JGR)

Spectral Radiation Buoy



Wang et al. (2014, JGR)

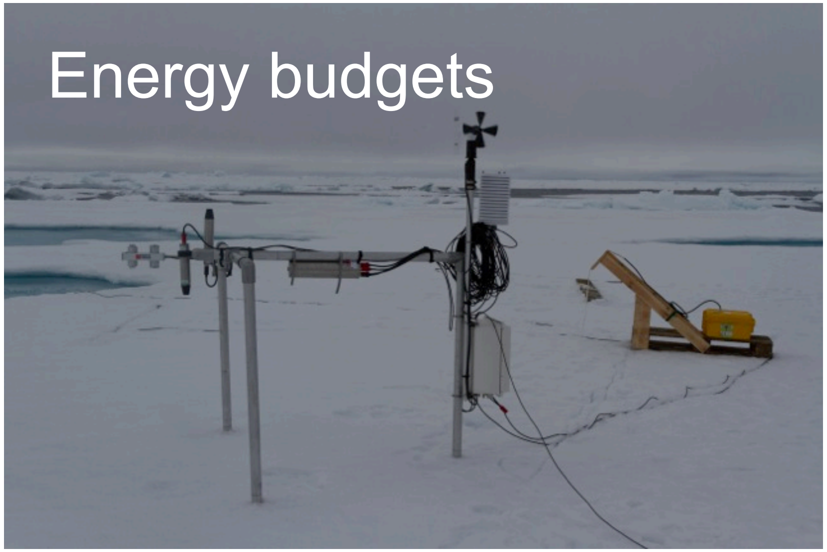
Bio-Physical Observatory (drifting)



- Instrumentation
  - 1 Thermistor Buoy
  - 2 Spectral Radiation Buoy
  - 3-5 Data Transmission
  - 6 CTD
  - 7 ADCP
- Deployment 2014/15

Figure: H. Flores

Autonomous Stations (Buoys)



Summary

- Snow rules and we need better snow data sets
- Seasonality of light transmission
  - Highest fluxes in June
  - 96% in 4 summer months only (May-Aug)
- Trends in light transmission
  - Increase of 1.5% / year
  - Strongly related to the loss of multi-year sea ice
- Optical properties of sea ice
  - Scattering is anisotropic
  - Conversion of radiance to irradiance is possible (use $C<2.5$)
- Future directions
  - Similar studies for Antarctic sea ice
  - Towards AUV measurements
  - More connection to biological studies (primary production)
  - Applications in GCMs