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

Marcel Nicolaus and colleagues

Observing Arctic Sea Ice and its Changes

10 June 2014

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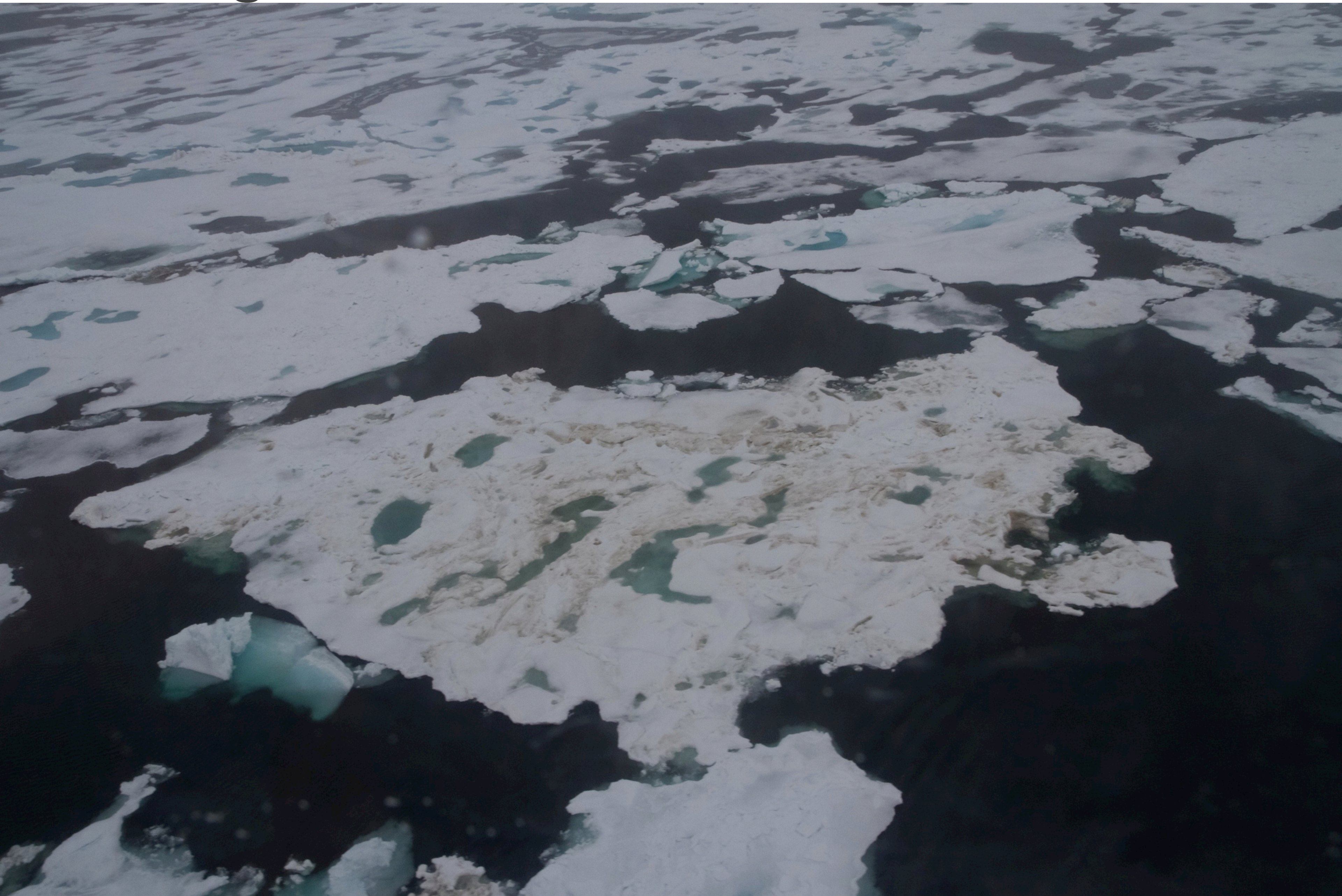
GEMEINSCHAFT

New Sea Ice

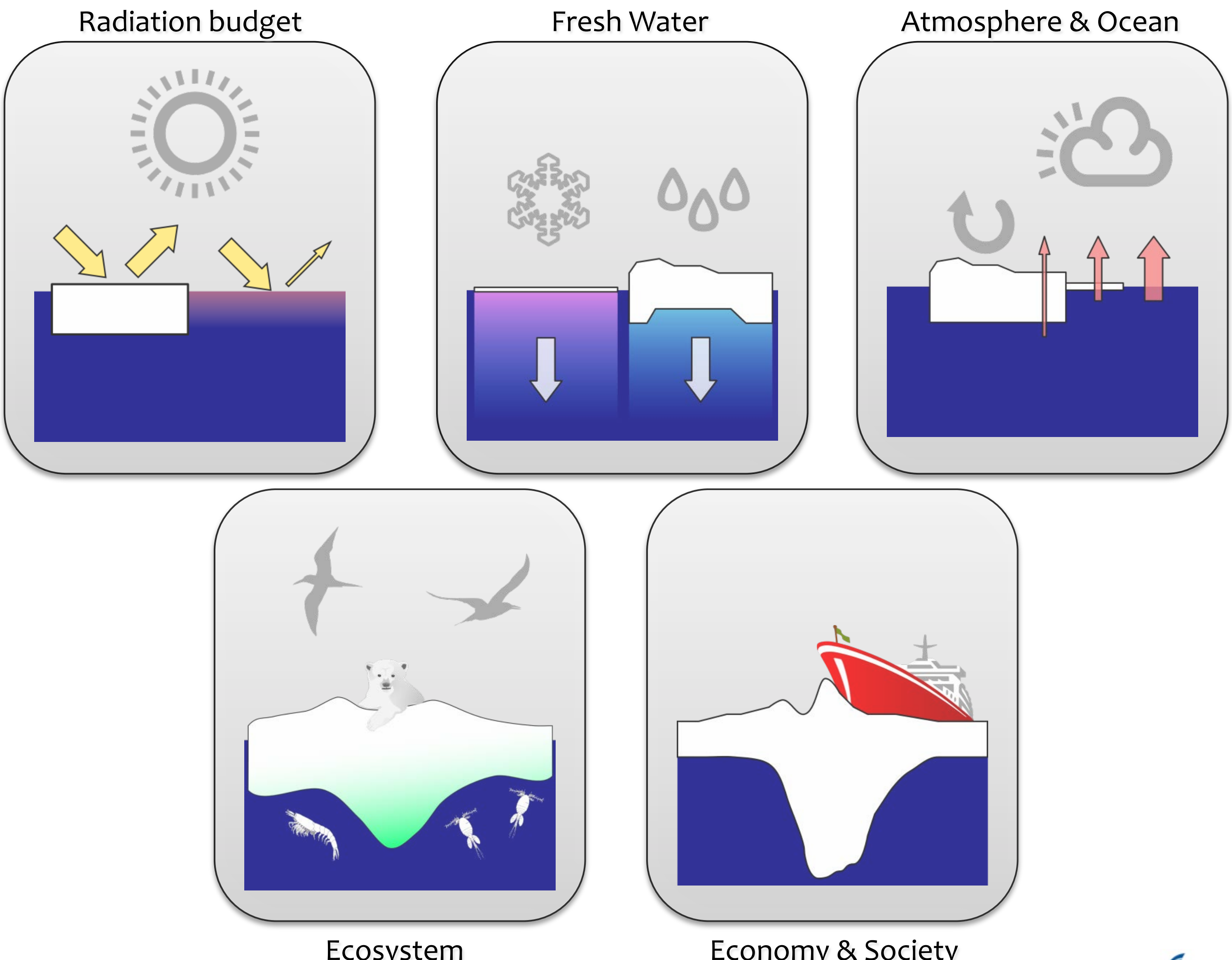
Deformed Sea Ice

Melt Ponds

Melting / Rotten Sea Ice



Importance of Sea Ice

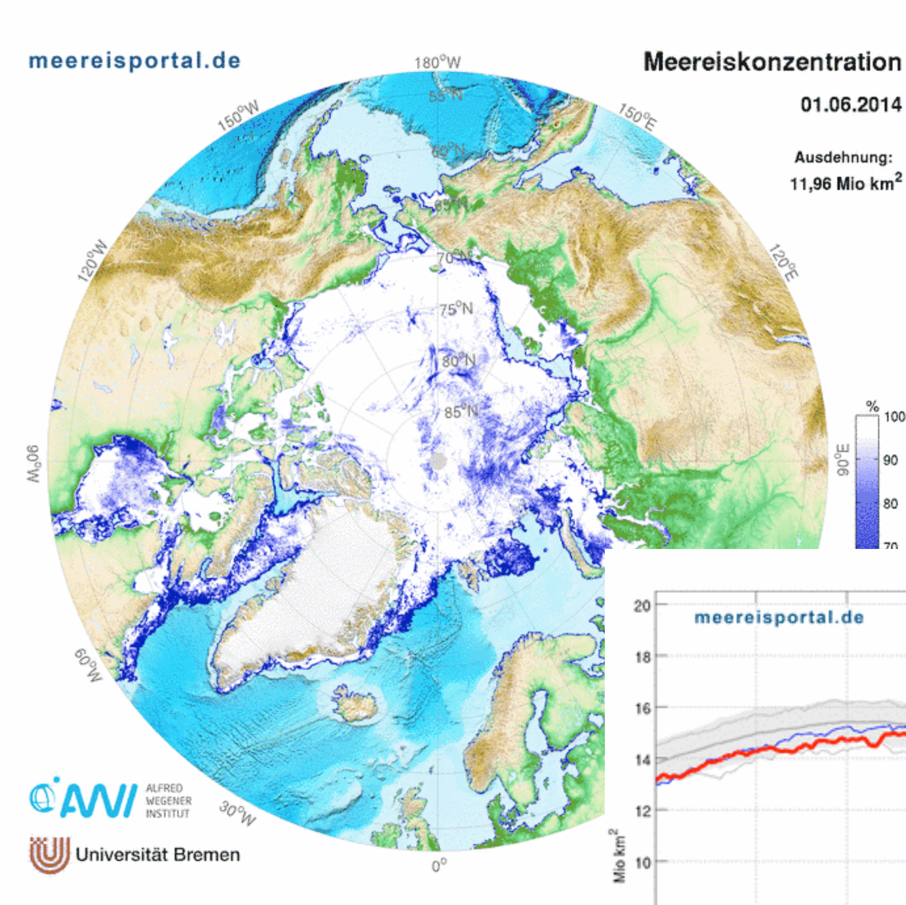


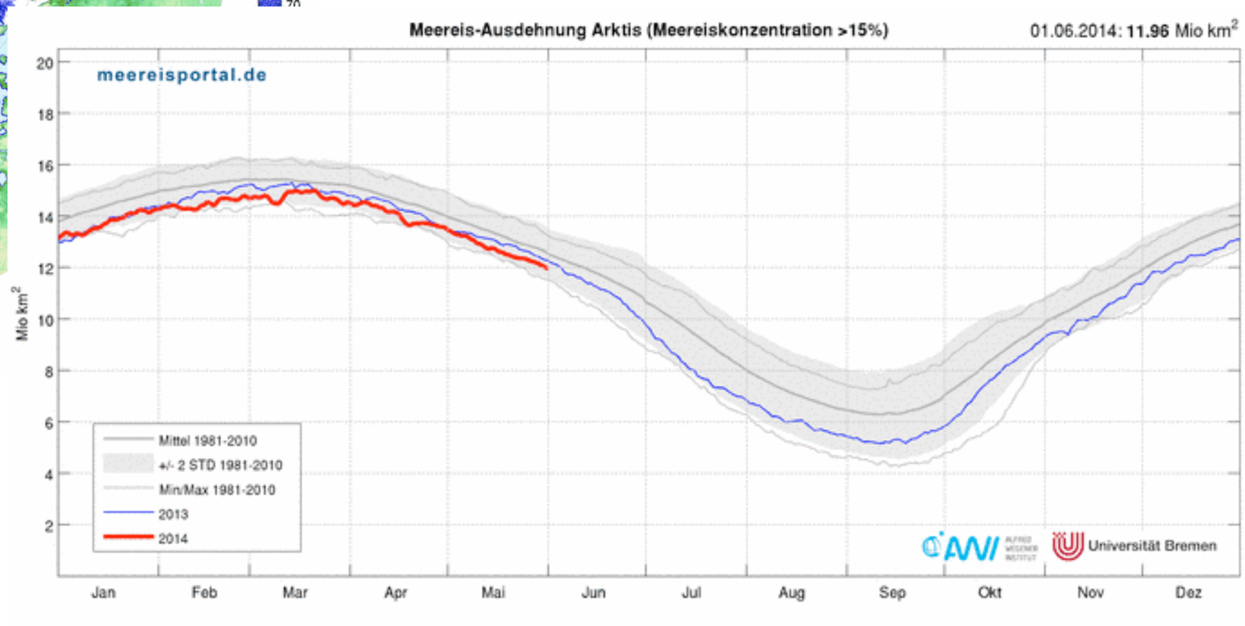
Courtesy: S. Hendricks

Snow Rules

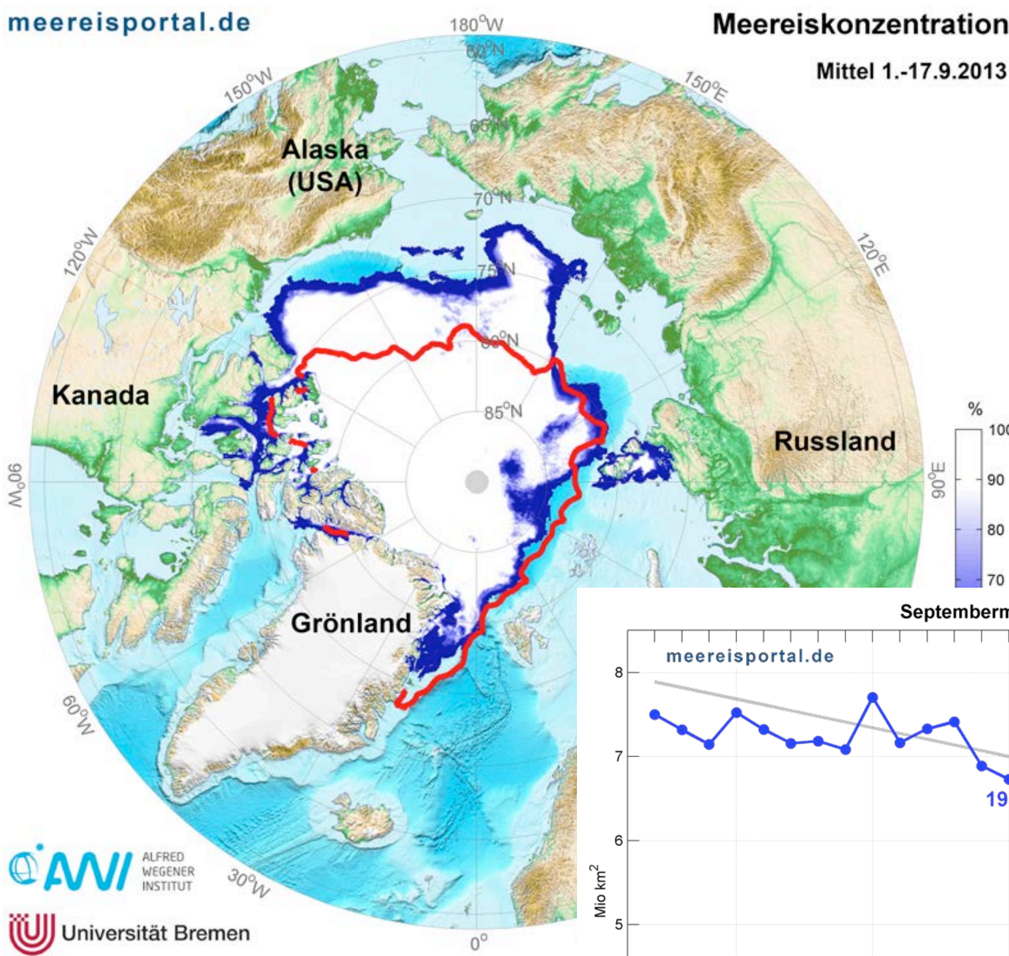
- Physical properties
  - Thermal
  - Optical
- Surface properties
  - Melt ponds
  - Remote sensing
- Mass balance
  - Direct: Snow ice
  - Indirect: Methods
- Snow is fresh water

Sea Ice Today





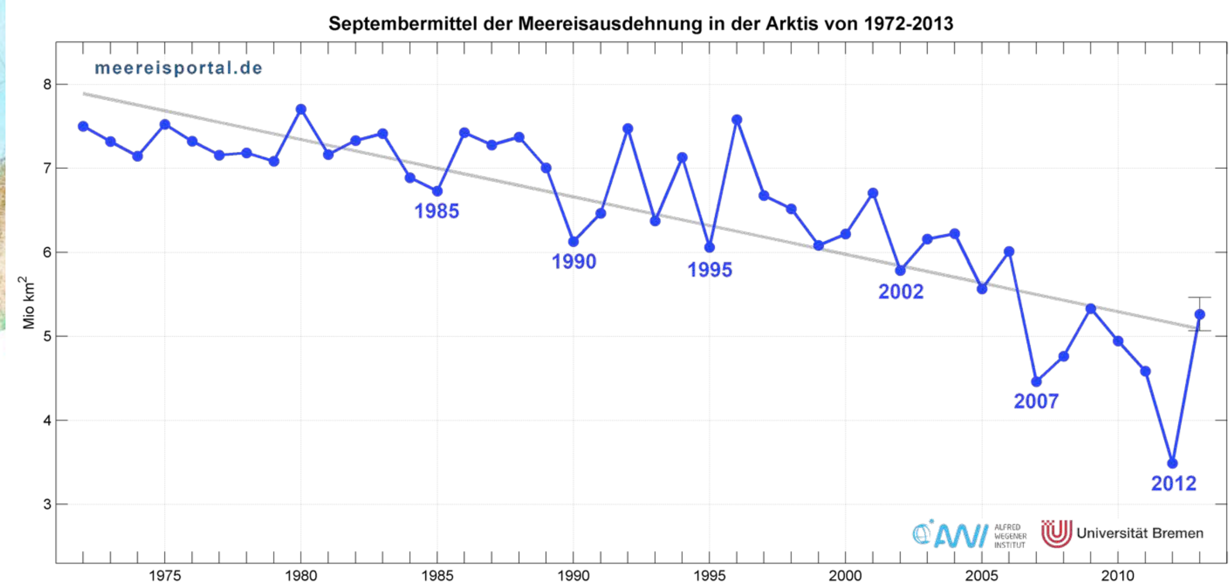
Variability and Trends



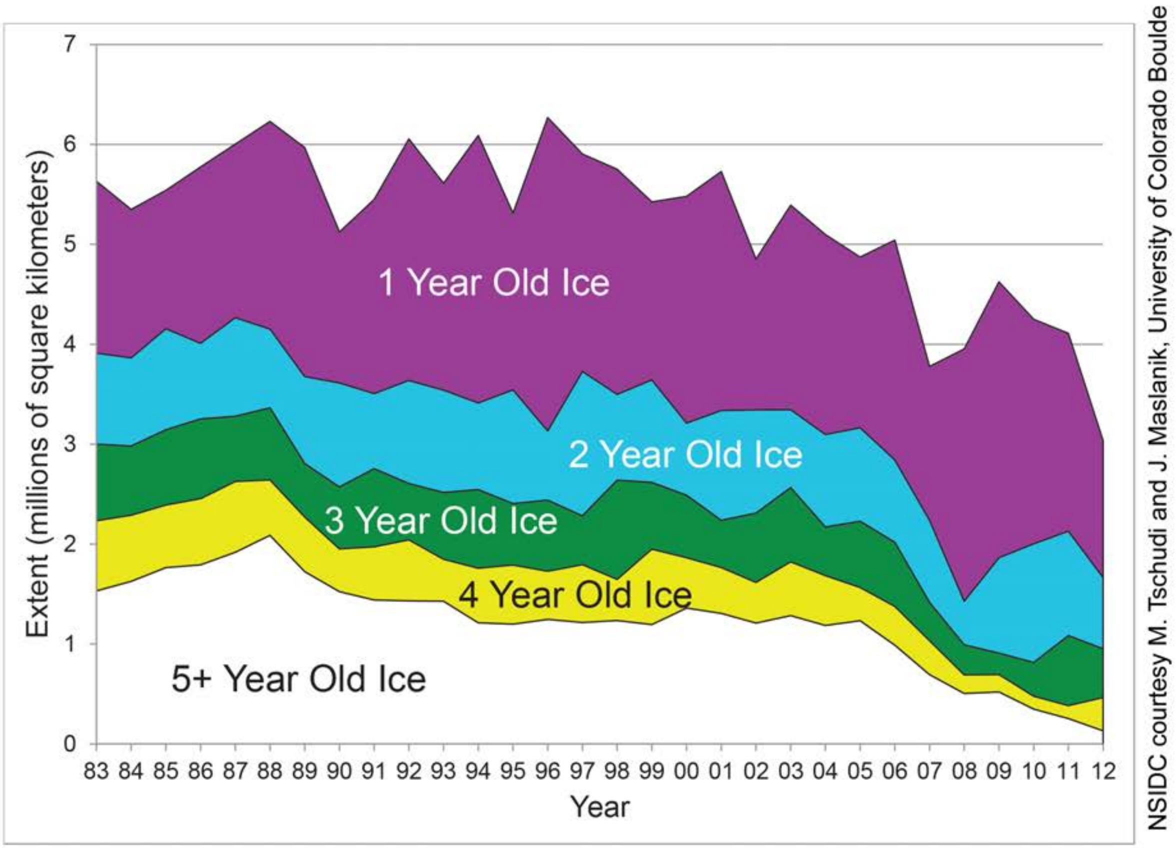
- March: -2,6% / decade
- Sep.: -13,0% /decade
- Total : - 4,6% / decade

- Reasons & Background ?

=> ground measurements

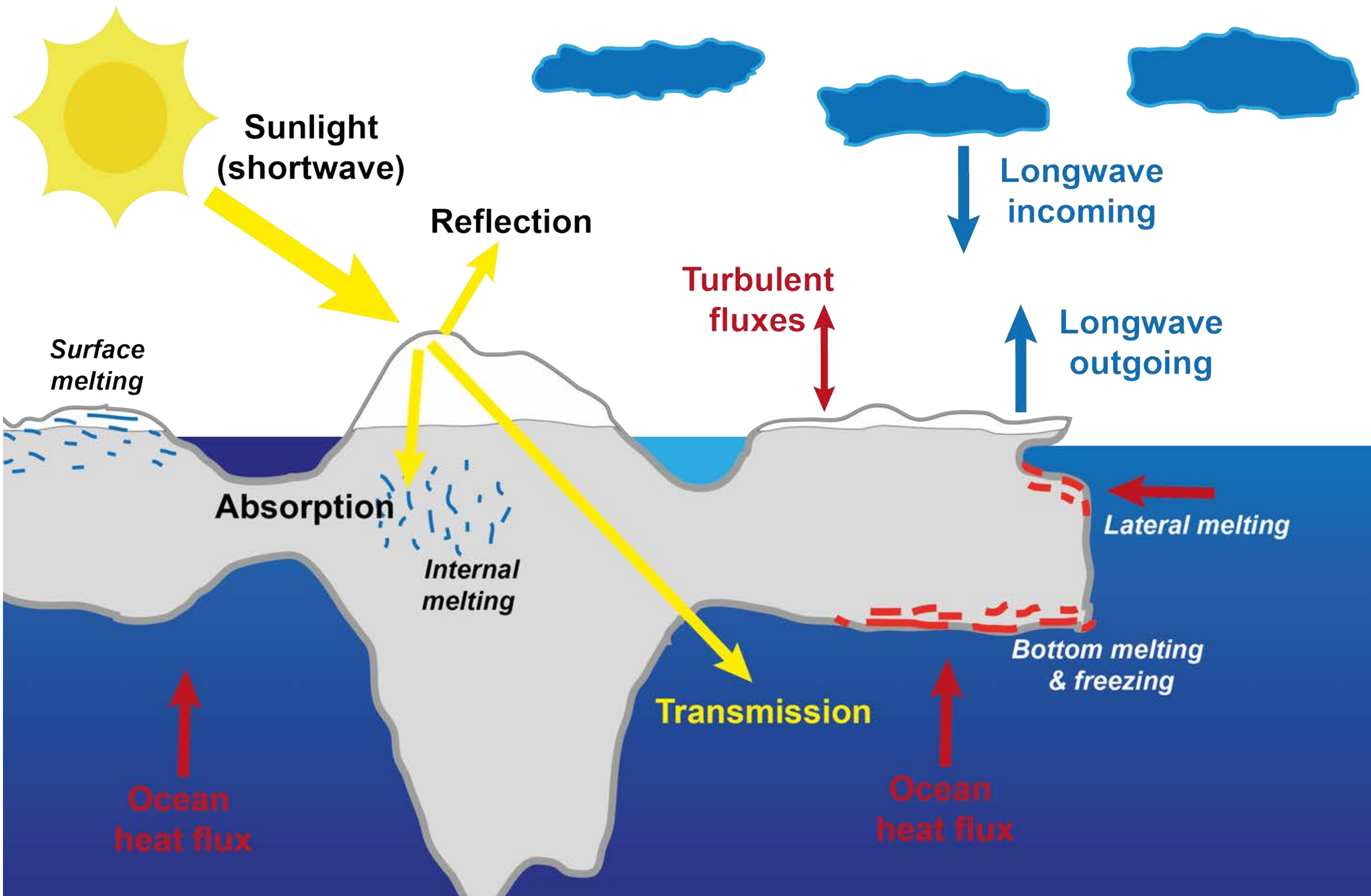


Younger and More Seasonal Sea Ice

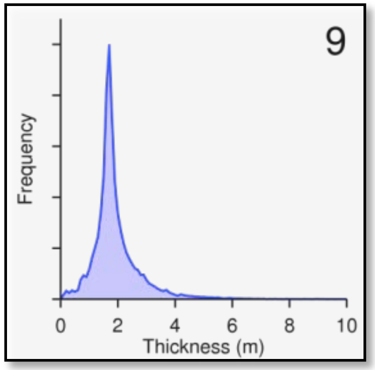


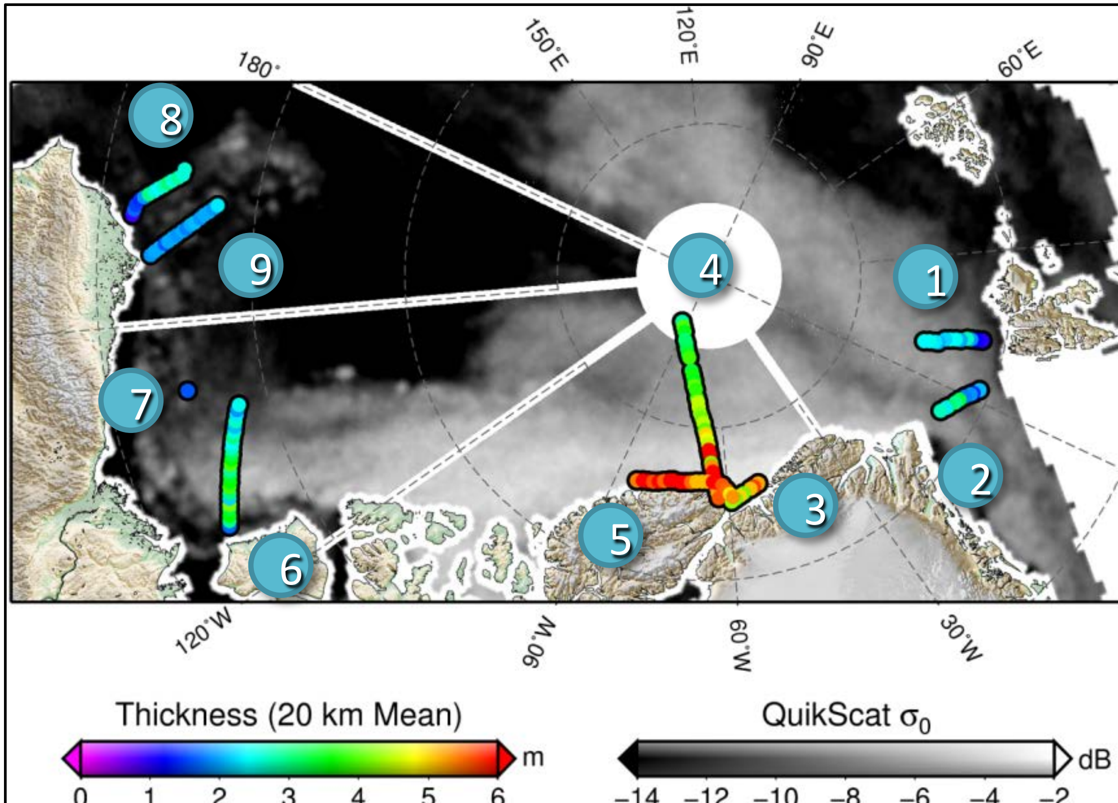
- Surface properties
- Habitat changes
- Physical properties: Drift and Dynamics
- Thickness distributions

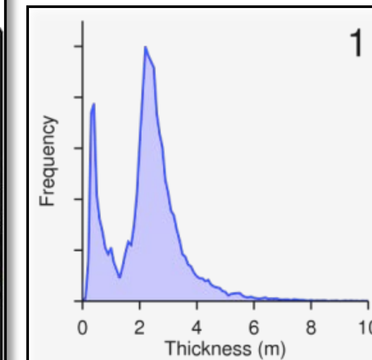
Sea Ice Mass and Energy Budgets

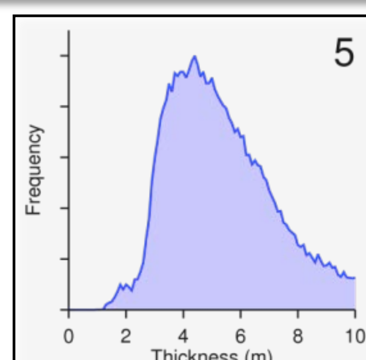


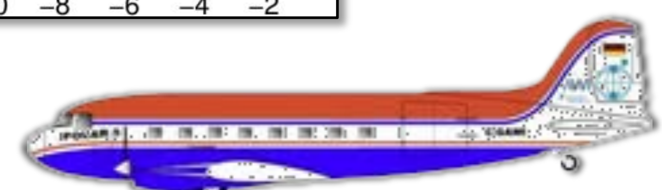
Sea Ice Thickness from Polar5







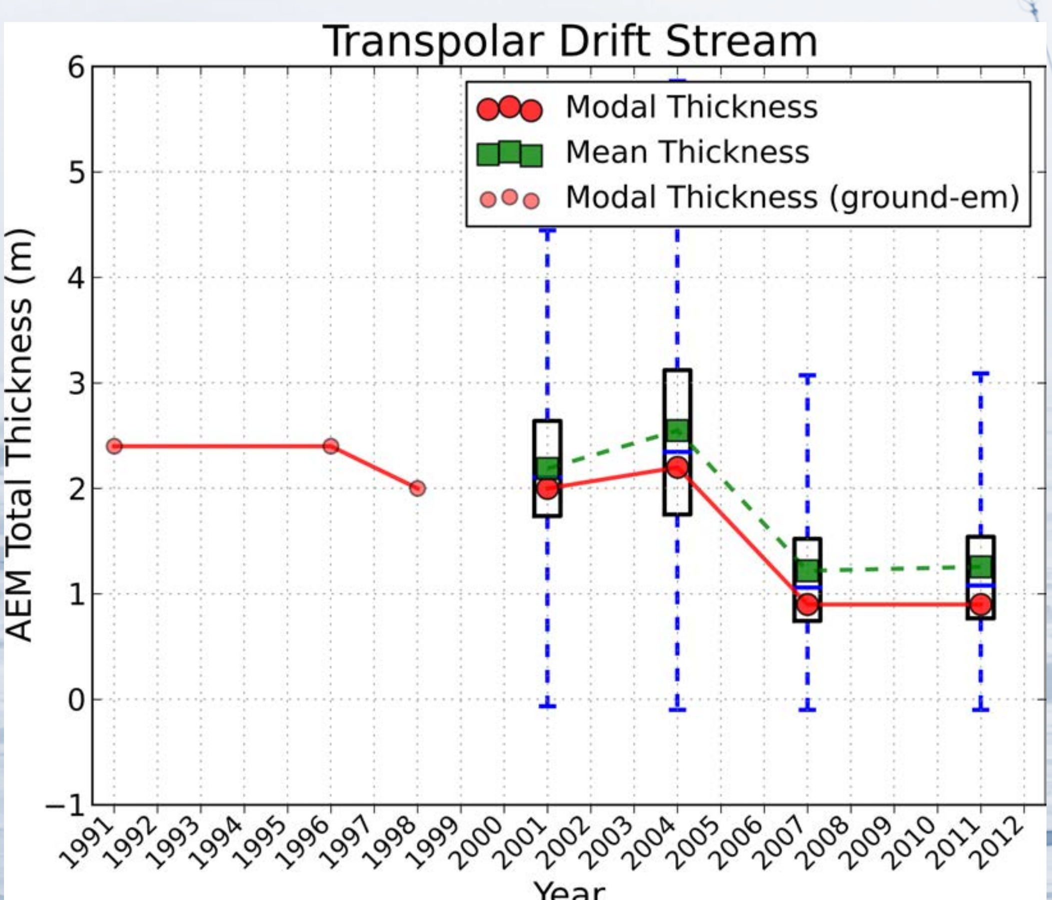


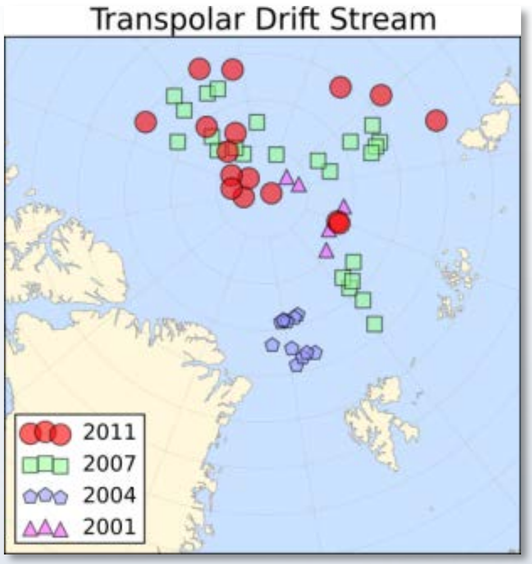


PAMARCMIP since 2009

Haas et al. (2010)

Thickness in Transpolar Drift

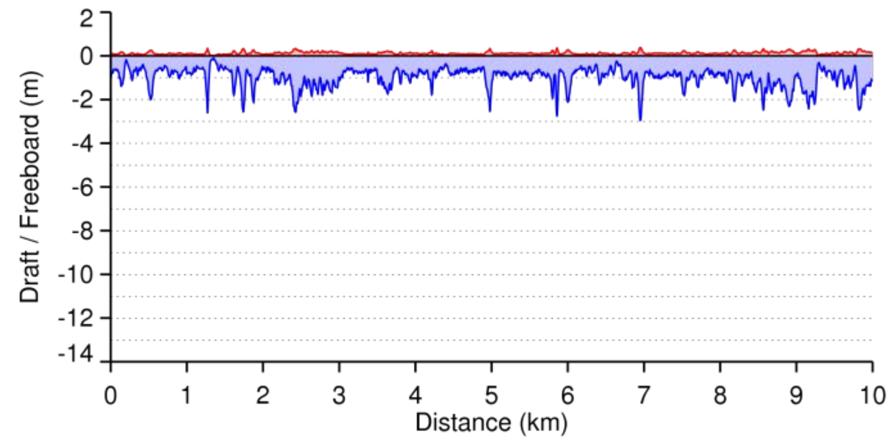


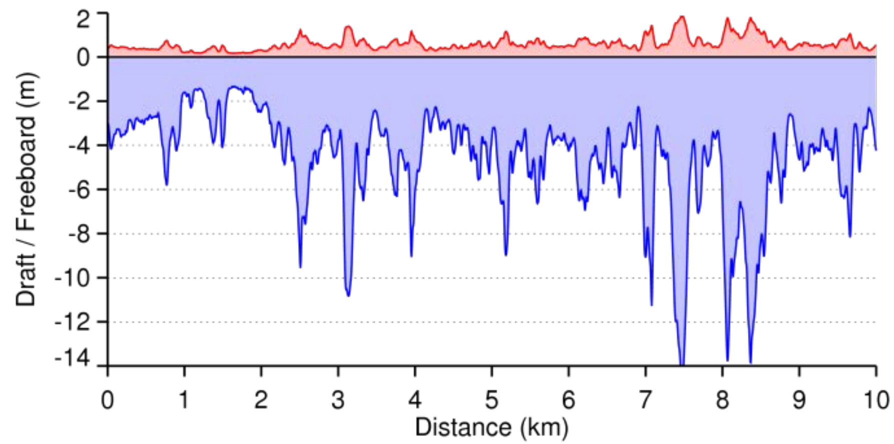


Figures: S. Hendricks

Sea Ice Thickness Results

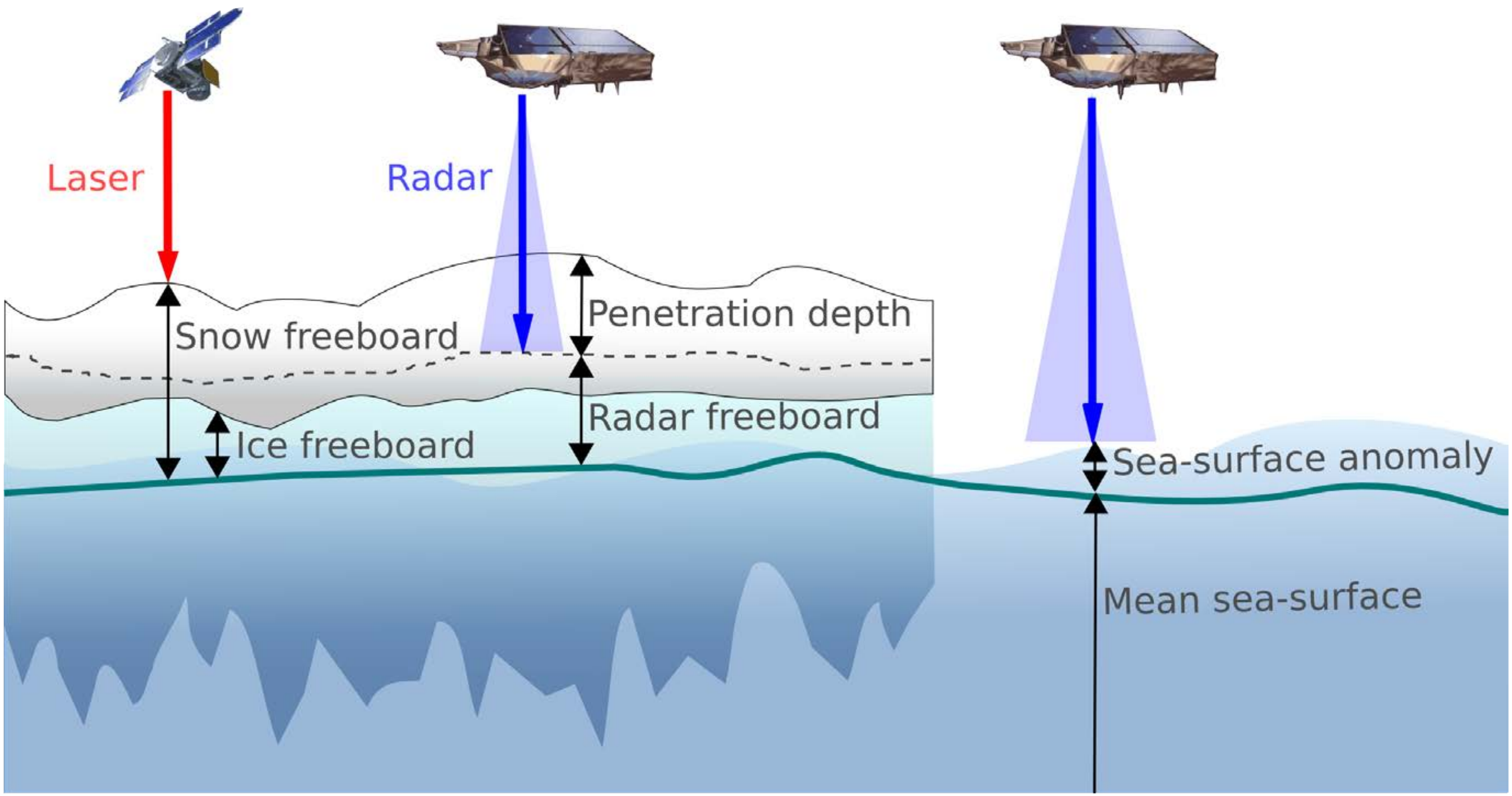
- Thickness
  - 1960s: approx. 3,0 m
  - 2000s: approx. 2,0 m
  - Now: approx. 0,9 m
- Volume
  - Decrease autumn: 4300 km3
  - Decrease winter: 1500 km3
- Changes in sea ice properties
- Predictions (Models): Loss of summer sea ice in this century





Figures: S. Hendricks

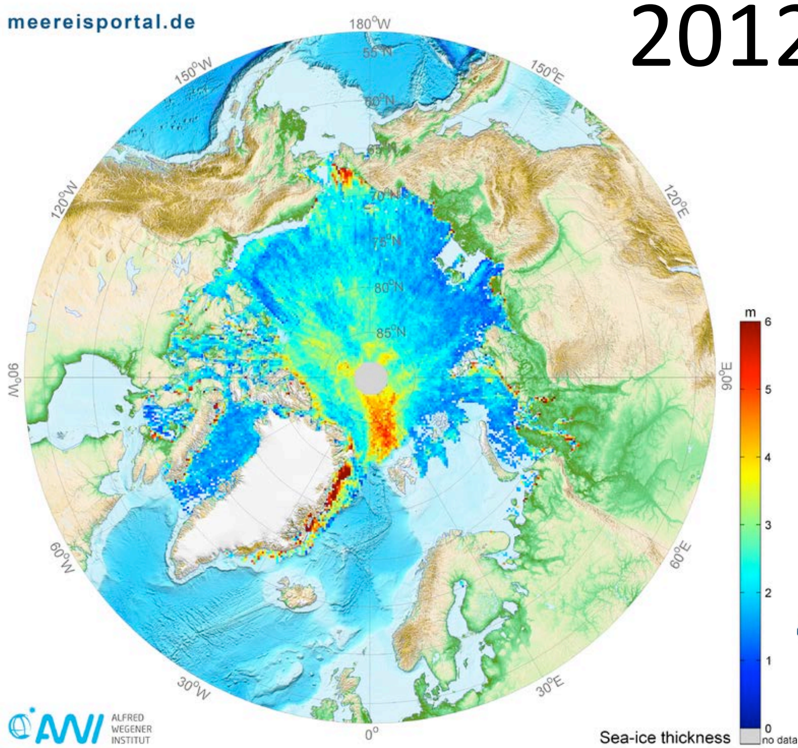
Sea Ice Thickness from Satellites



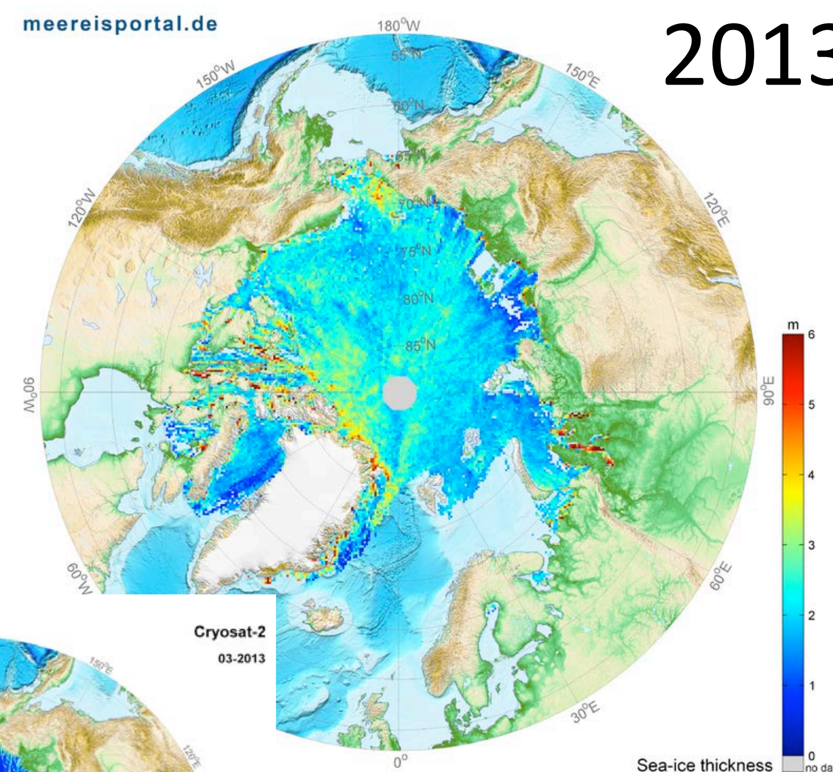
Ricker et al. (submitted, AOG)

Sea Ice ThickenessCryoSat-2

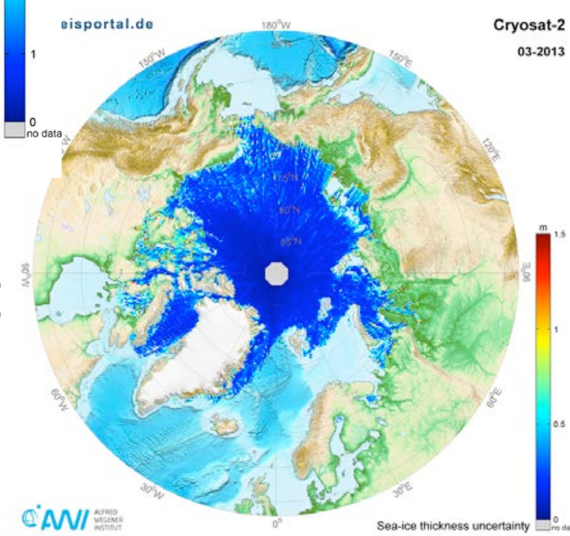
2012



2013



Uncertainty:



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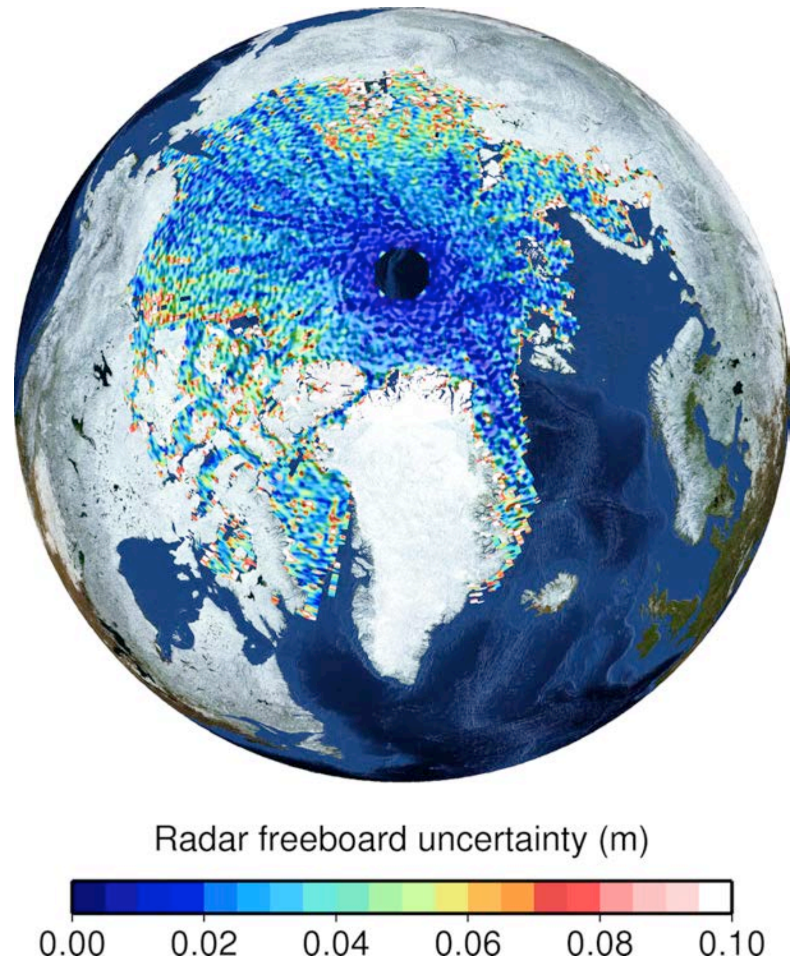
Freeboard Uncertainties

Freeboard uncertainty

- Radar penetration
- Sea-surface anomaly
- Speckle noise



Ricker et al. (submitted, AOG)

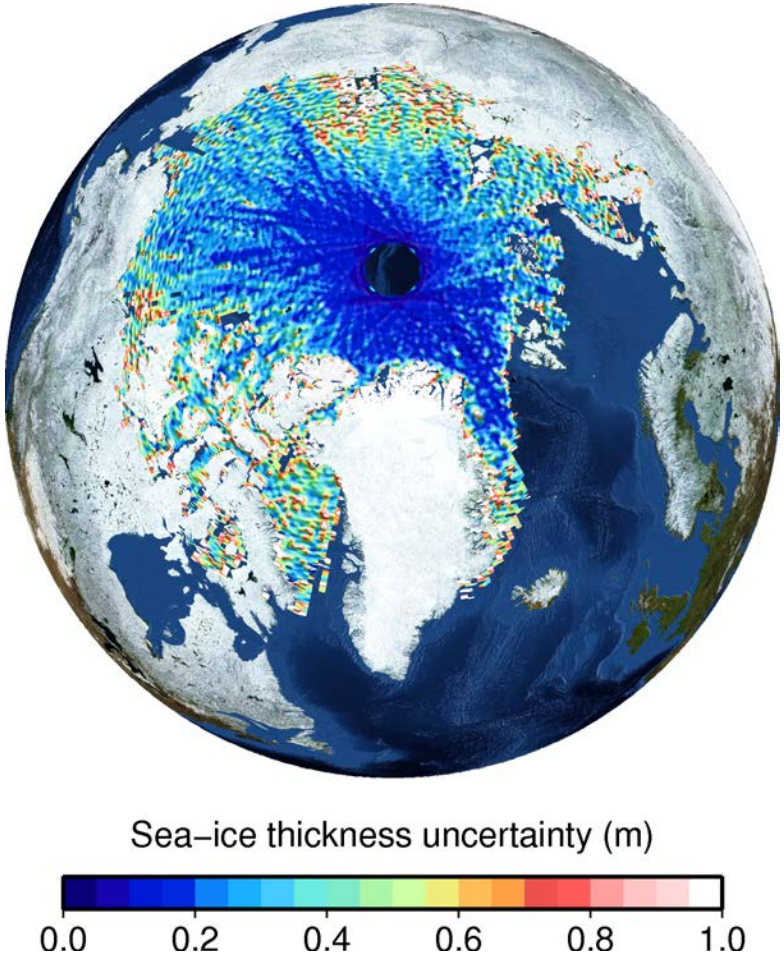
Thickness Uncertainties

Freeboard uncertainty

- Radar penetration
- Sea-surface anomaly
- Speckle noise

Thickness uncertainty

- Snow depth
- Radar freeboard
- Radar penetration
- Snow / ice density



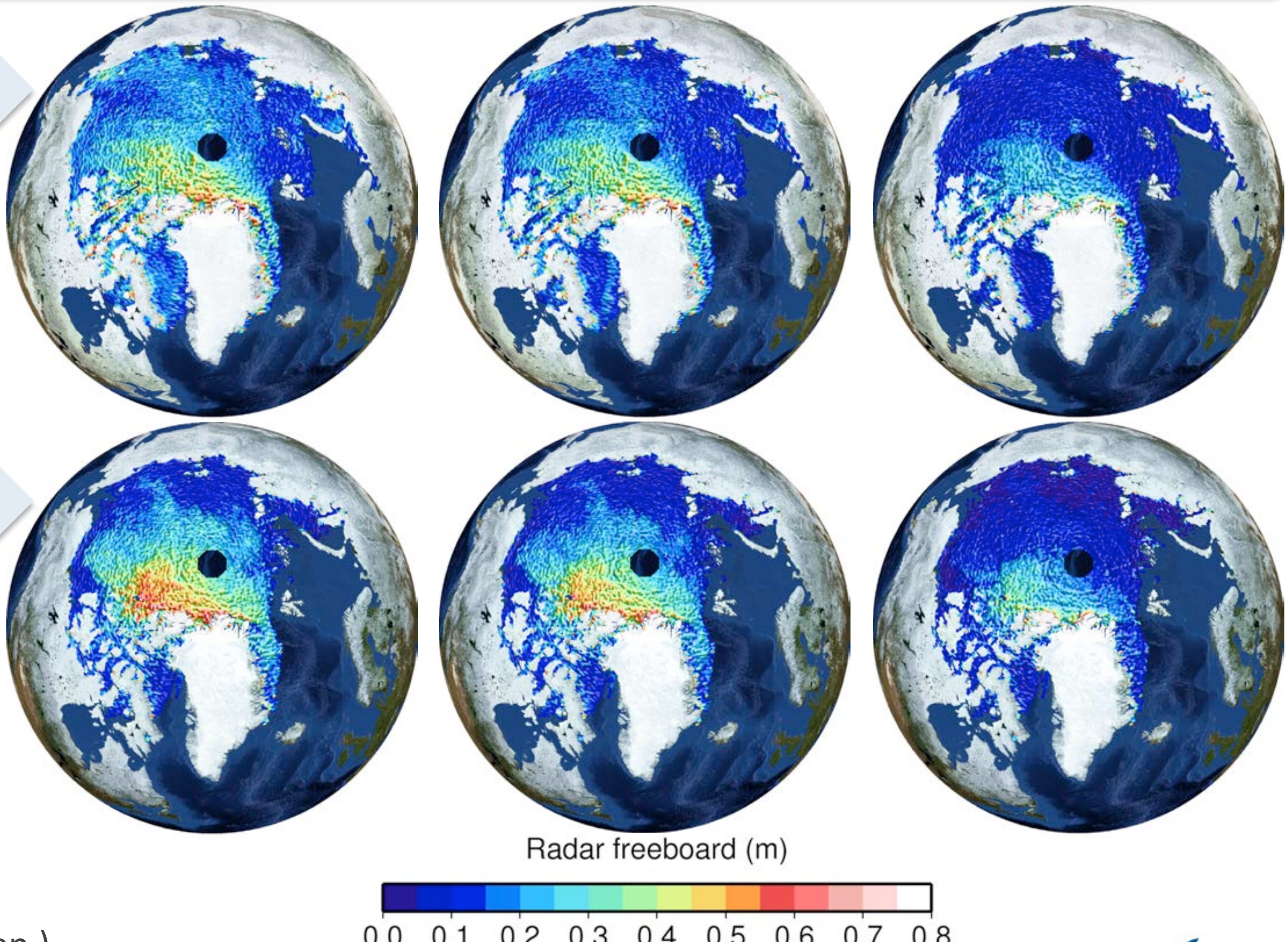
Ricker et al. (submitted, AOG)

Varying retracker thresholds

Threshold: **40 %** **50 %** **80 %**

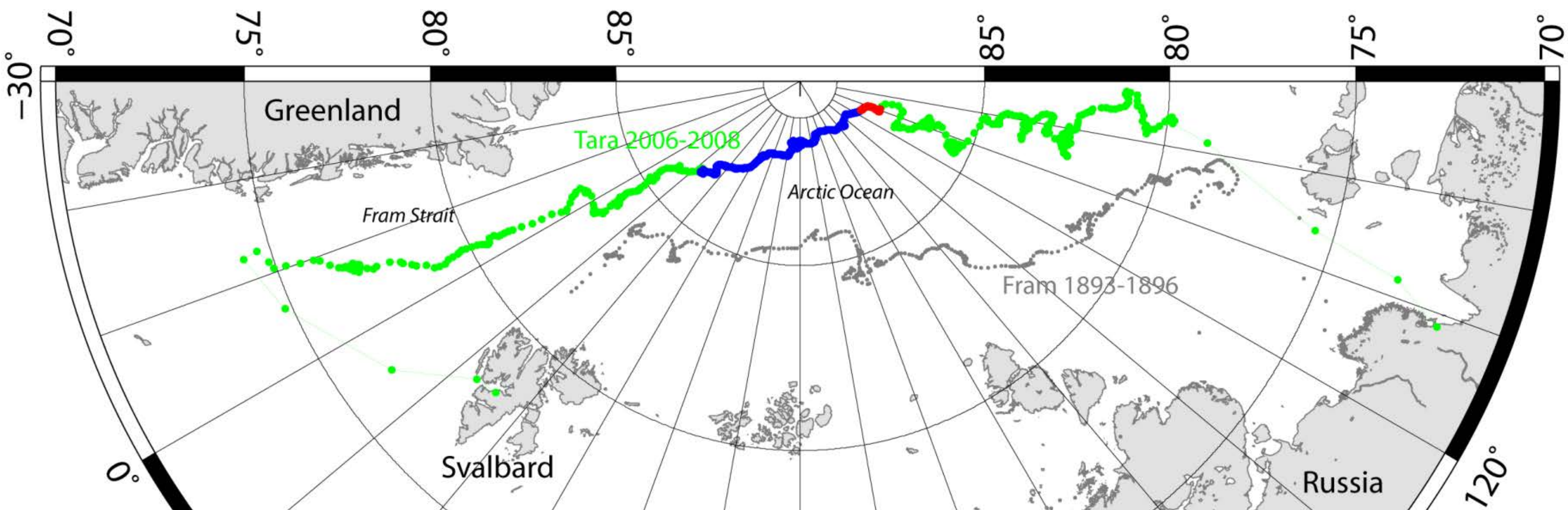
Mar 2013

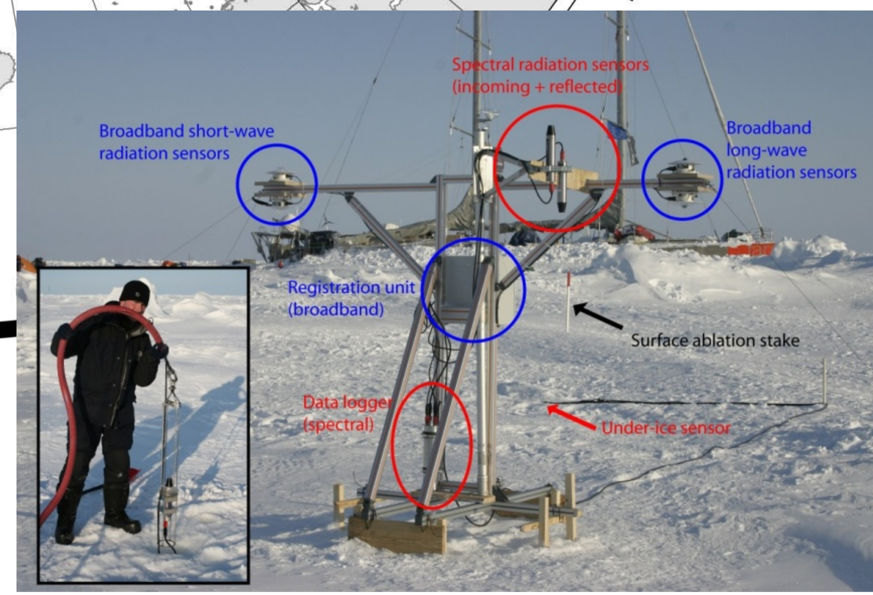
Nov 2013



Ricker et al. (in prep.)

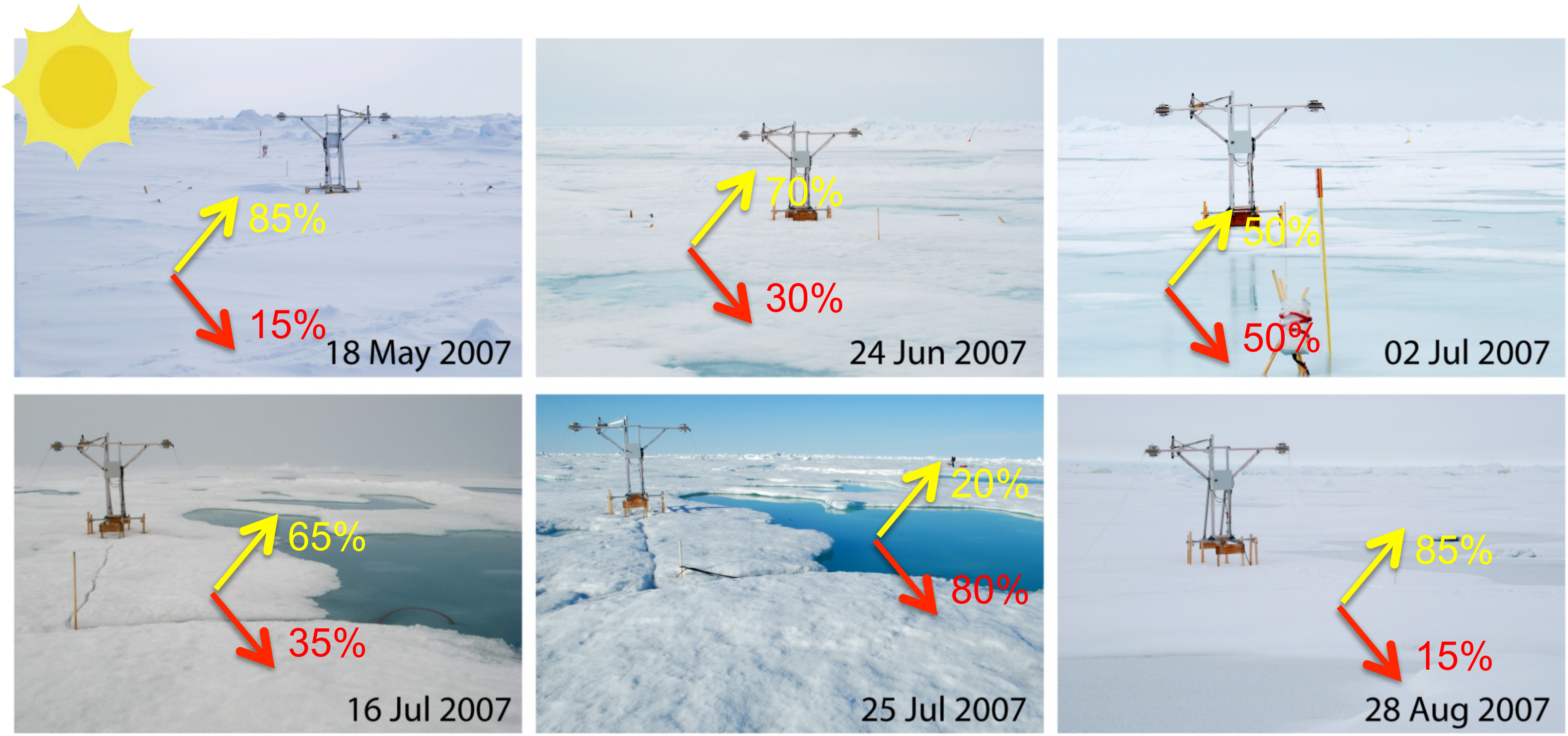
Drift of Tara





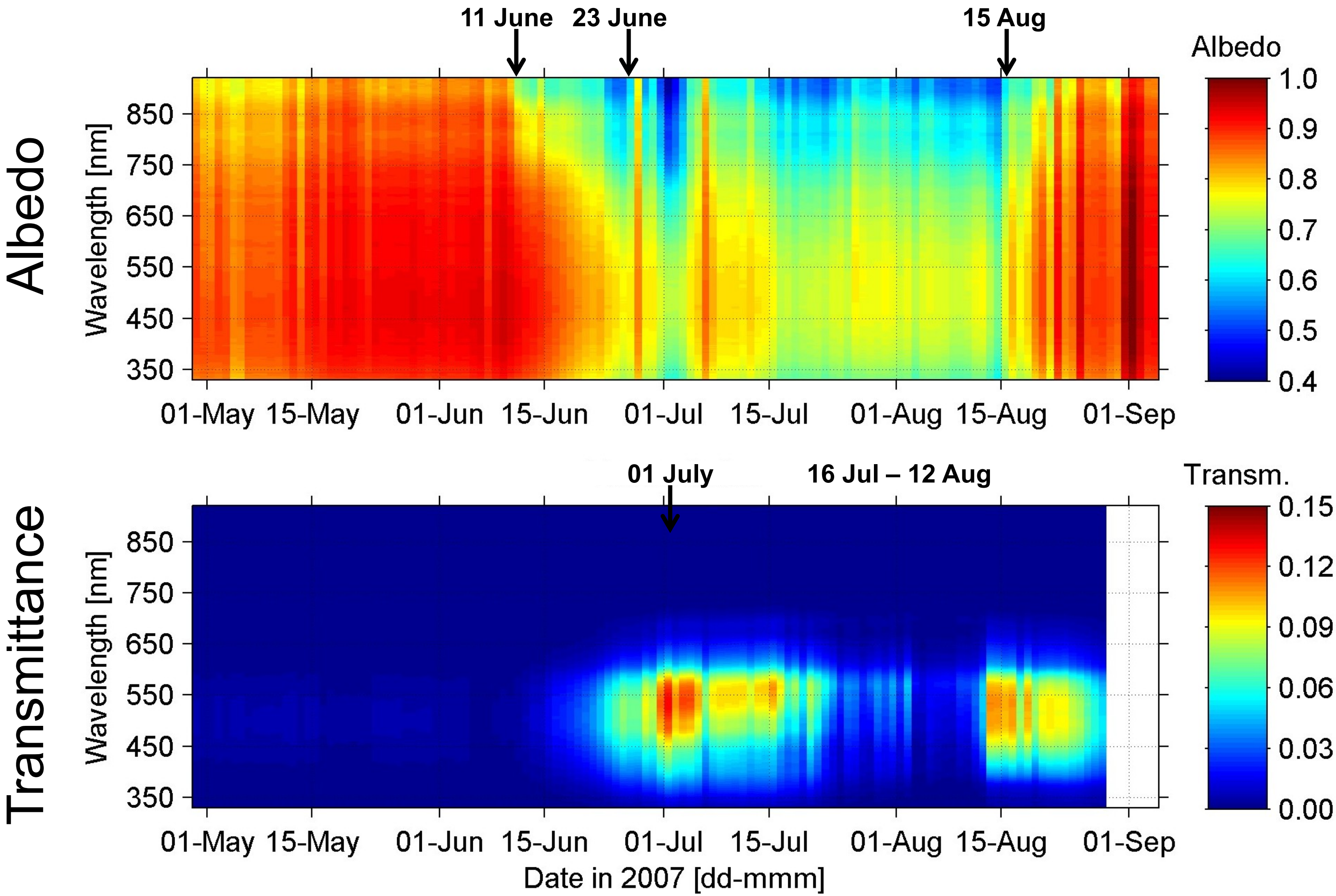
Nicolaus et al. (2010, JGR)

Seasonality of Arctic Sea Ice



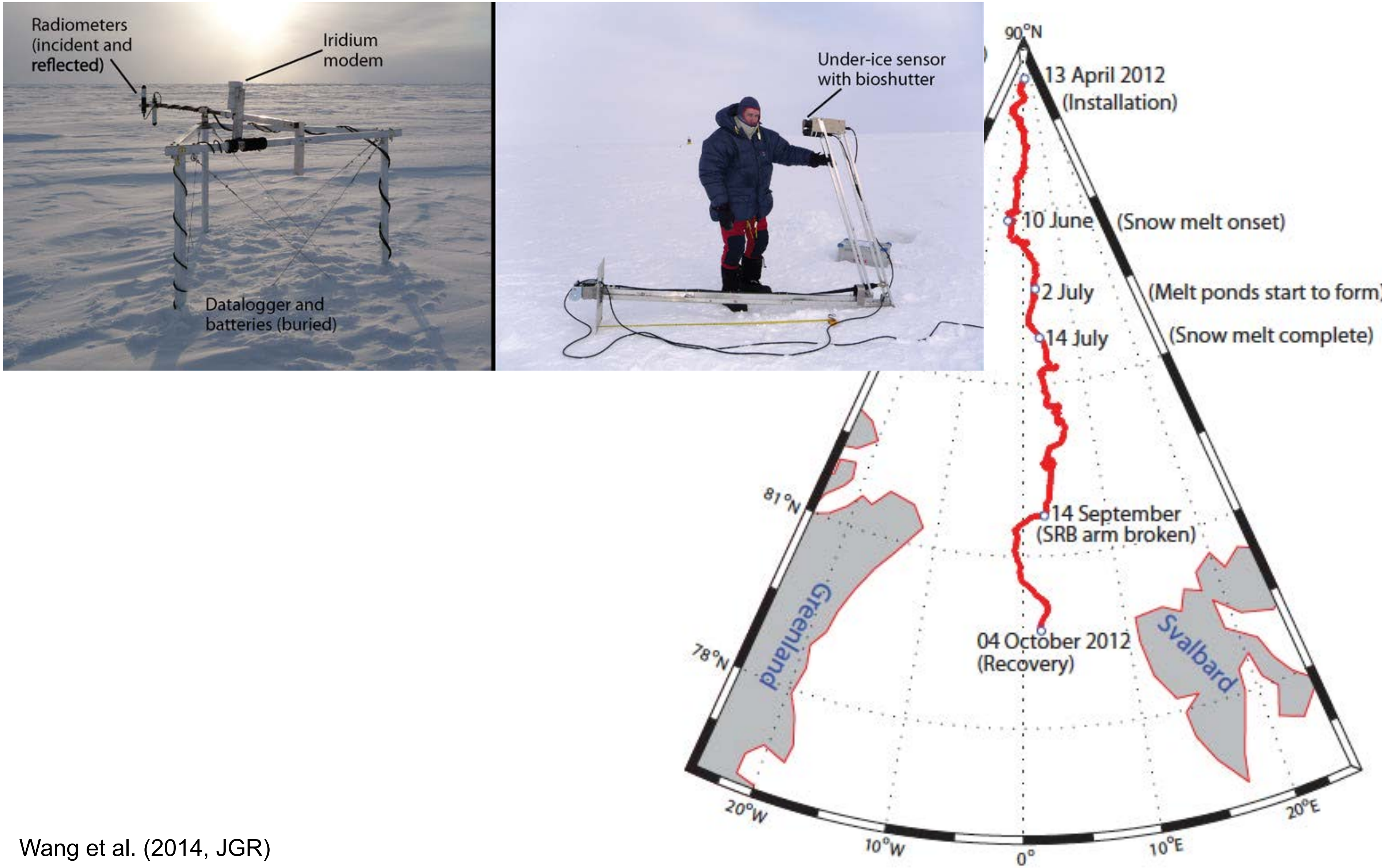
Photos: Nicolaus et al. (2010, JGR)
Methods: Nicolaus et al. (2010, CRST)

Spectral Albedo & Transmission



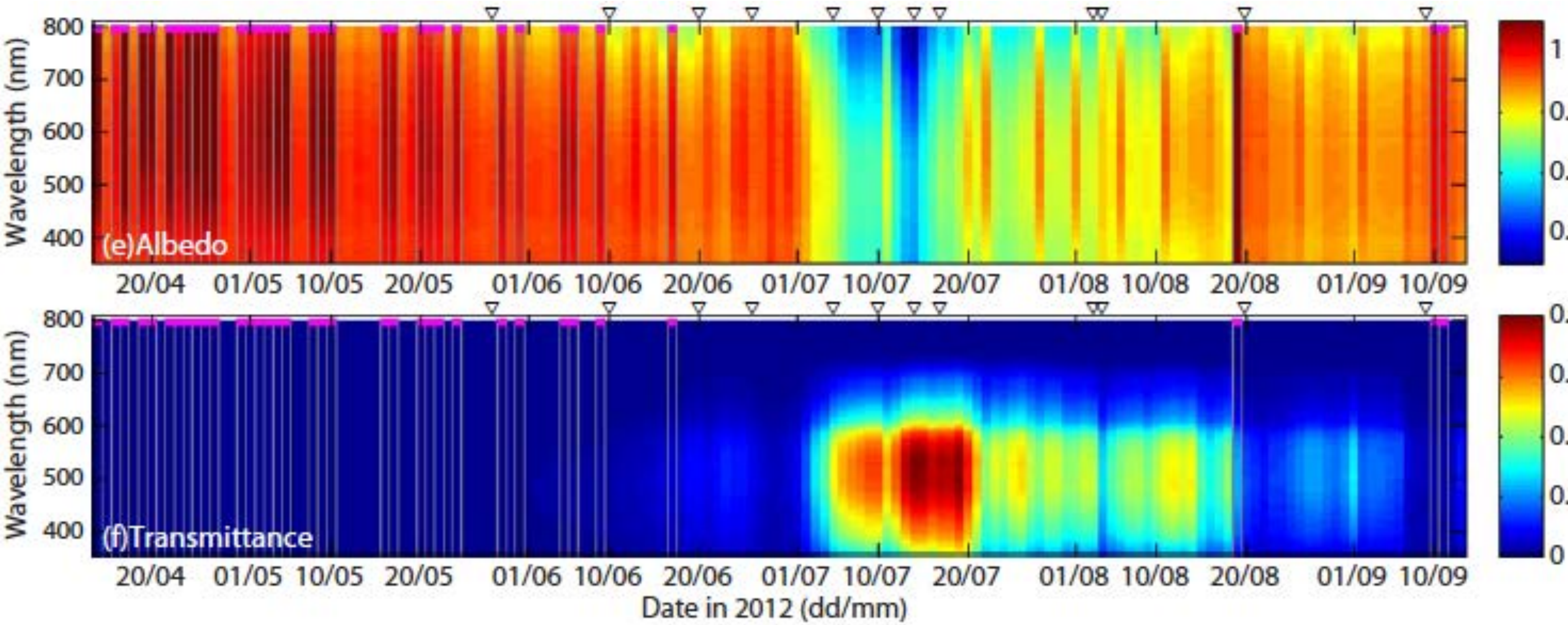
Nicolaus et al. (2010, JGR)

Spectral Radiation Buoy



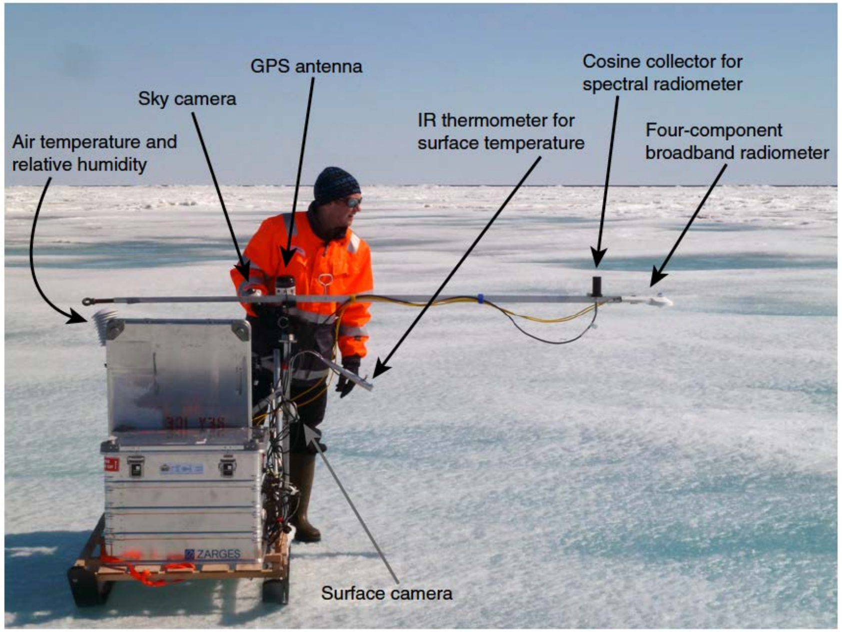
Wang et al. (2014, JGR)

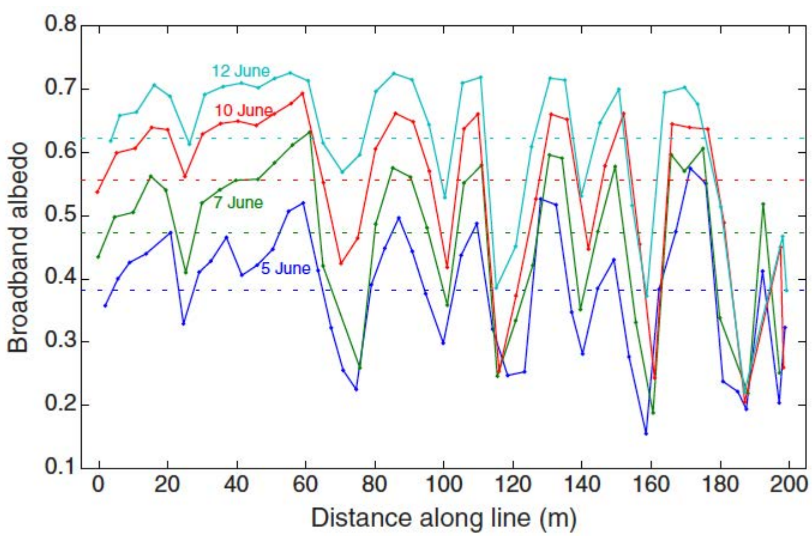
Spectral Radiation Buoy



Wang et al. (2014, JGR)

Albedo & Energy Budgets

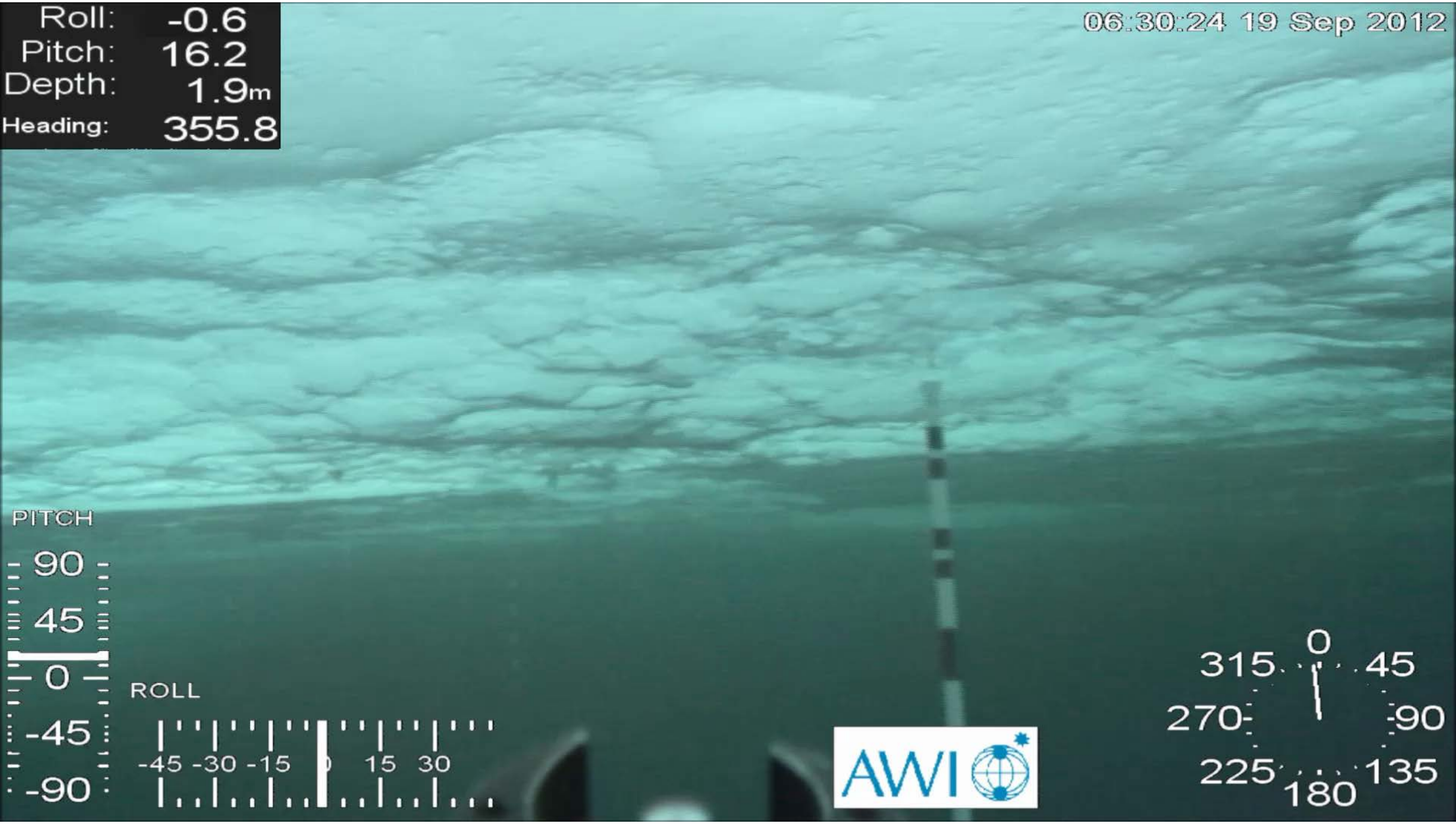




From: Hudson et al. (2012)

Under-Ice Investigations

View from Below: Level Ice



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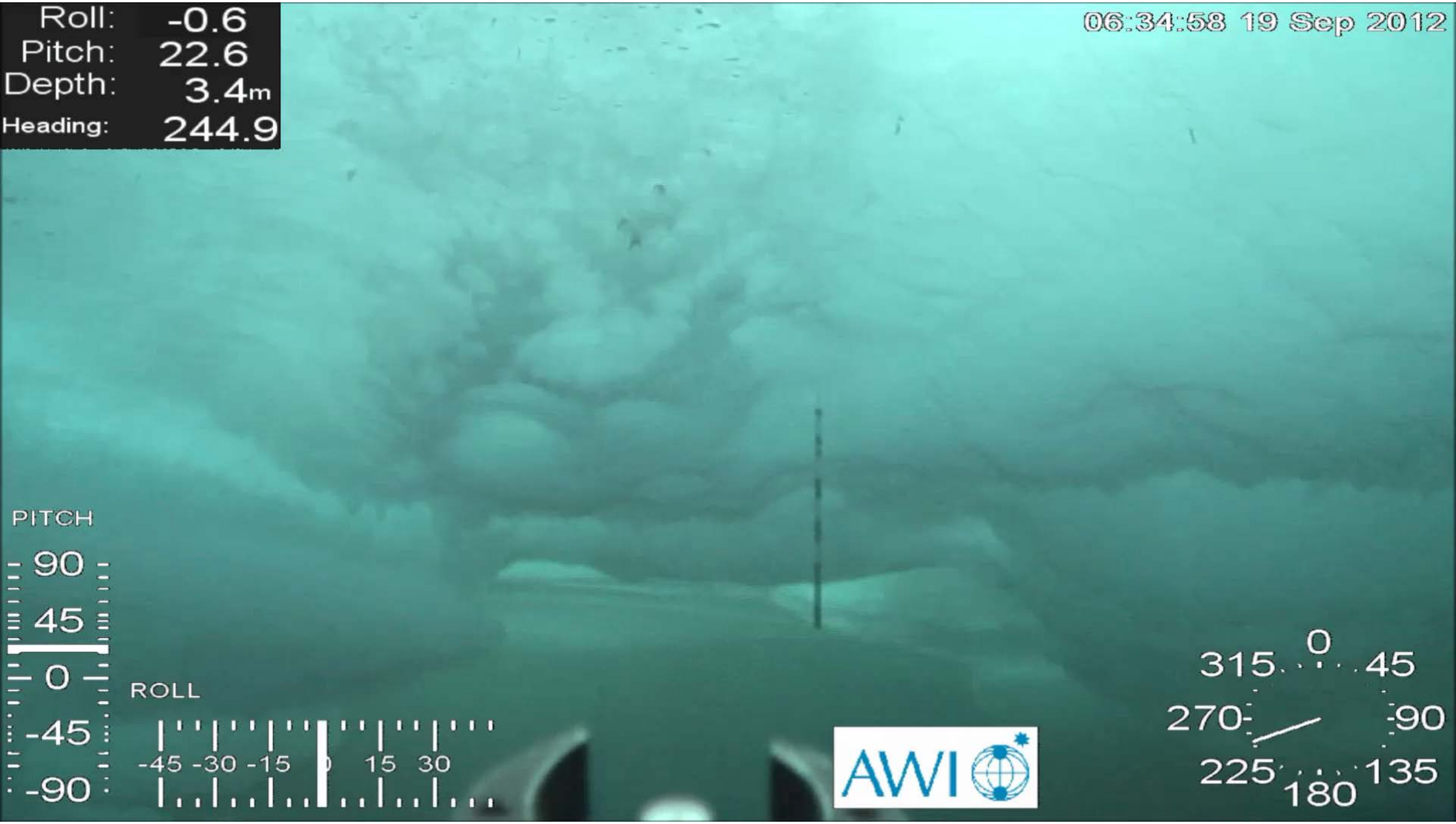
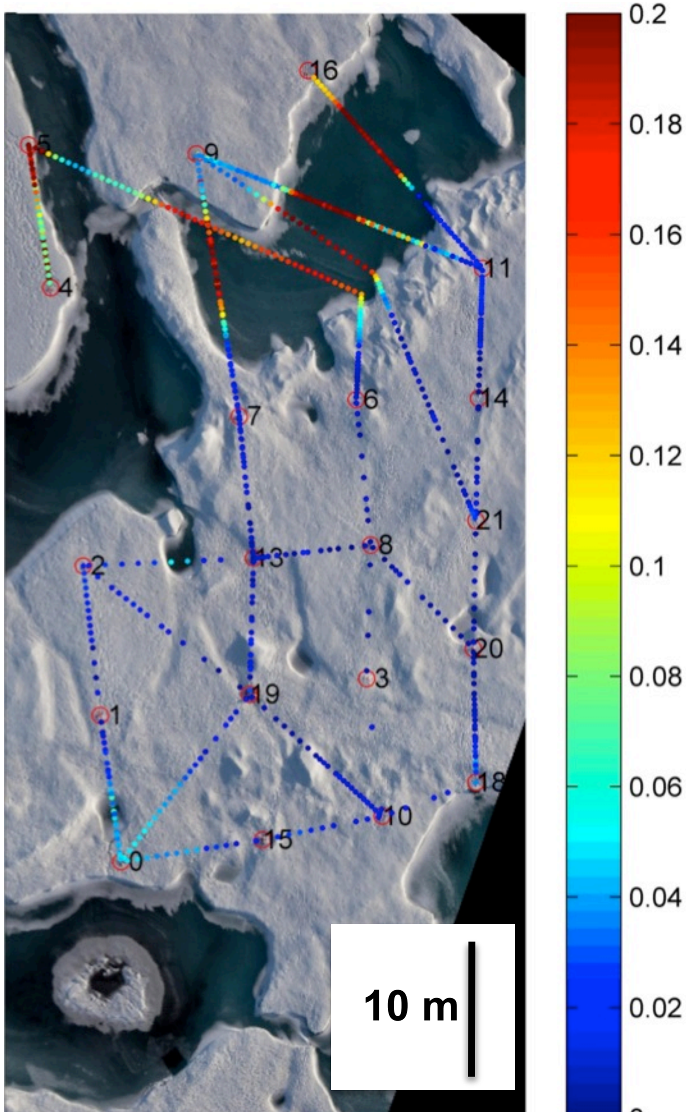
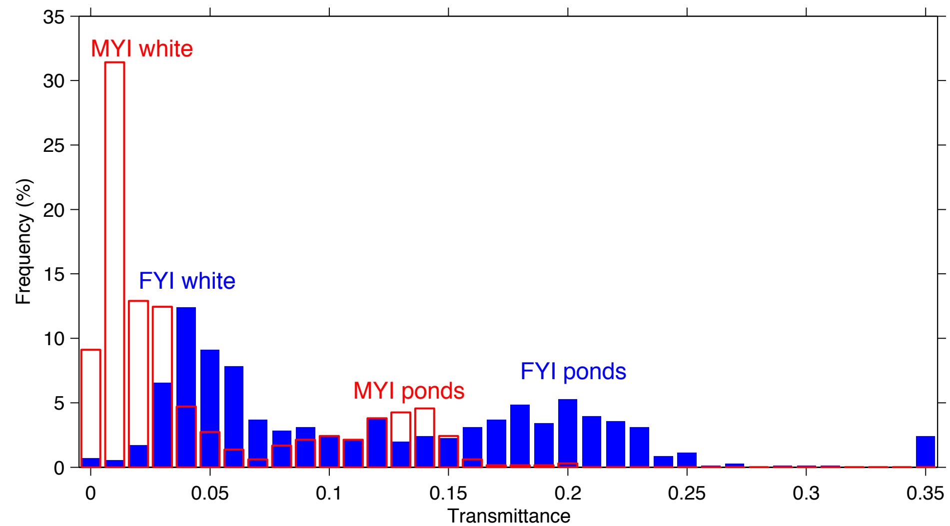
View from Below: Level Ice



Spatial Variability of Light



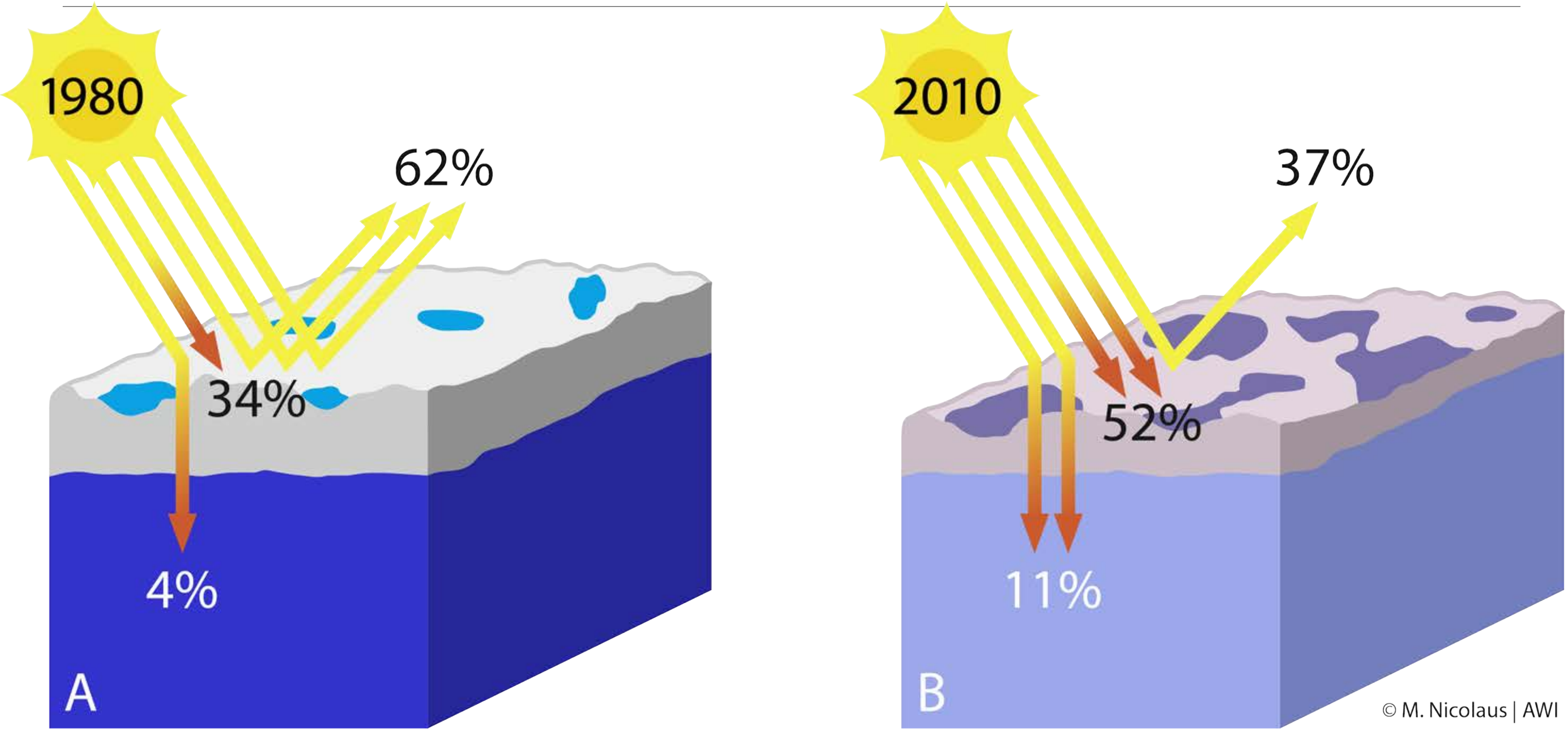
Nicolaus et al. (2012 & 2013, GRL)



Main result:

- Light penetration into and through sea ice will increase in a changing Arctic

Observed Changes

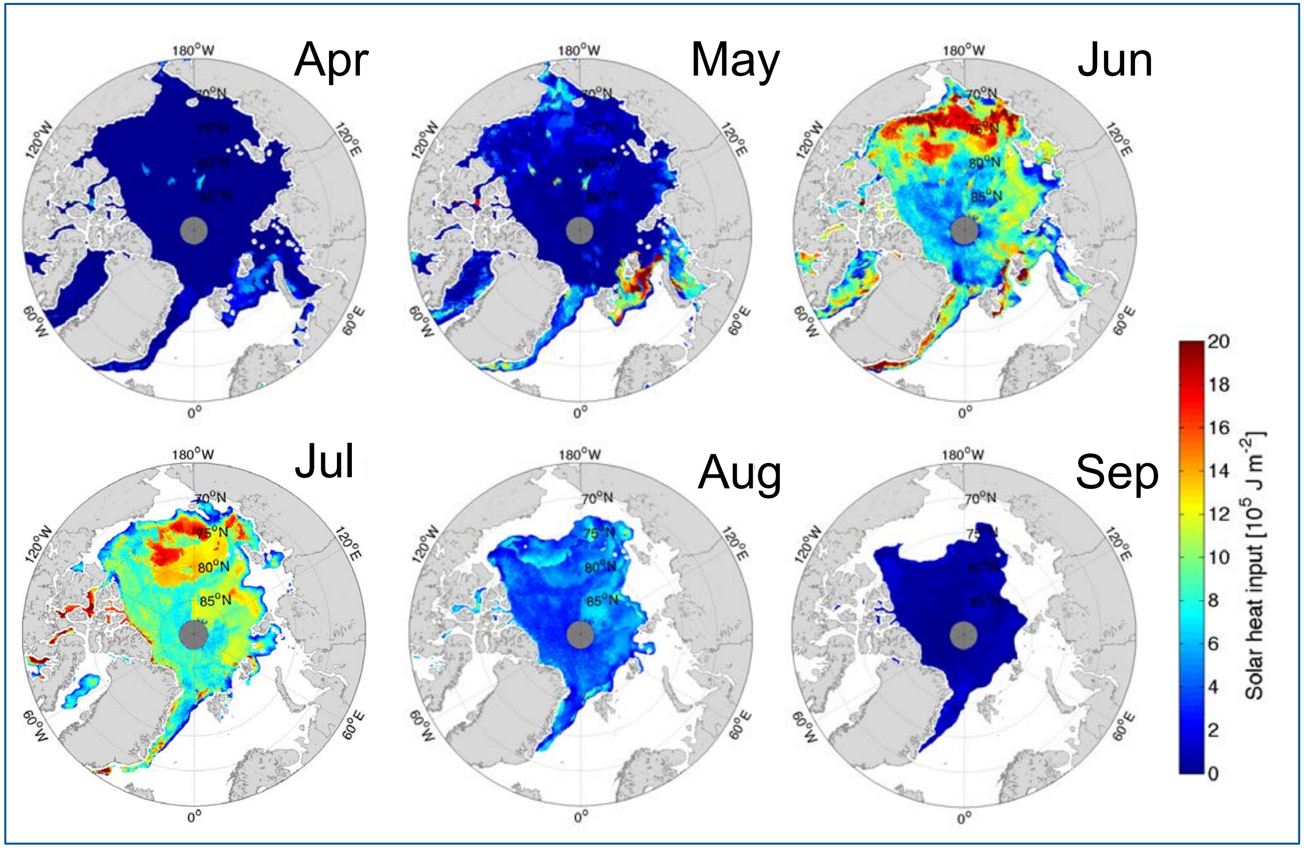


Transmission:	+ 200%
Albedo:	- 50%
Absorption	+ 50%

Nicolaus et al. (2012 & 2013, GRL)

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.

- **96 %** of the annual under-ice radiation are transmitted in only 4 months (May to August)

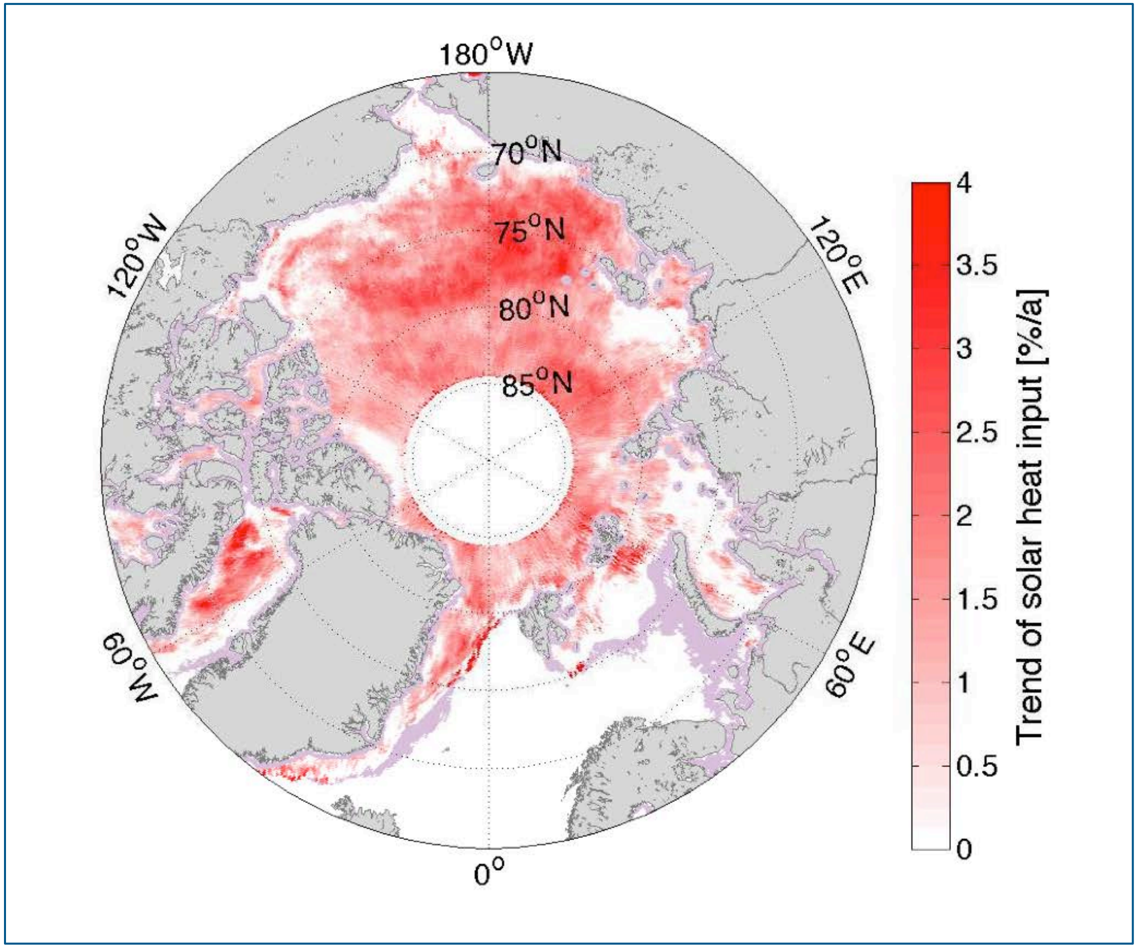
  ≙ **51.2×10^{19} J**

- Highest fluxes in **June** (20.9×10^{19} J)

Arndt et al. (submitted, JGR)

Annual Trend (Sea Ice Only)

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

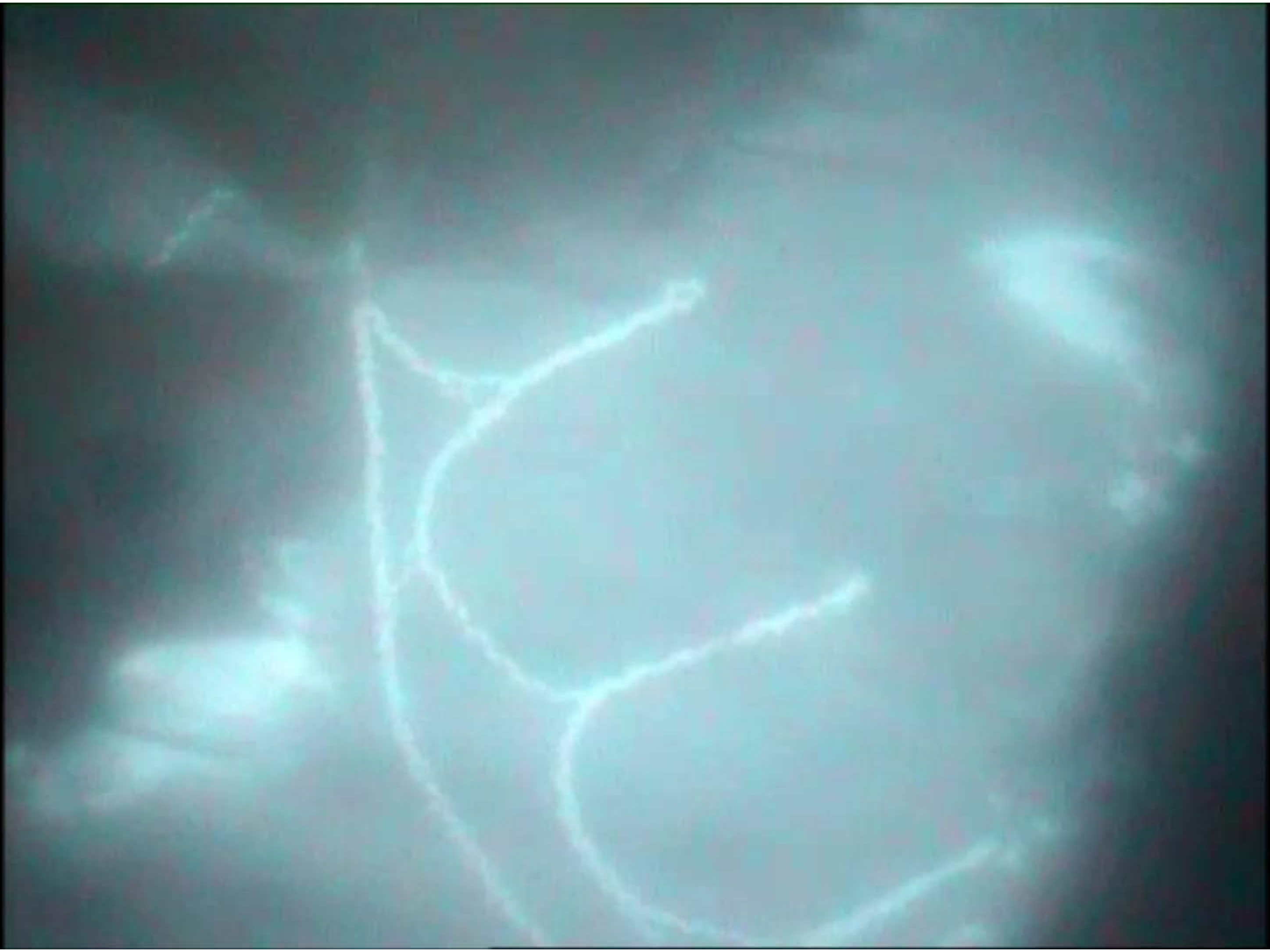


- Light transmission increases by **1.5% per year** Arctic-wide since 1979

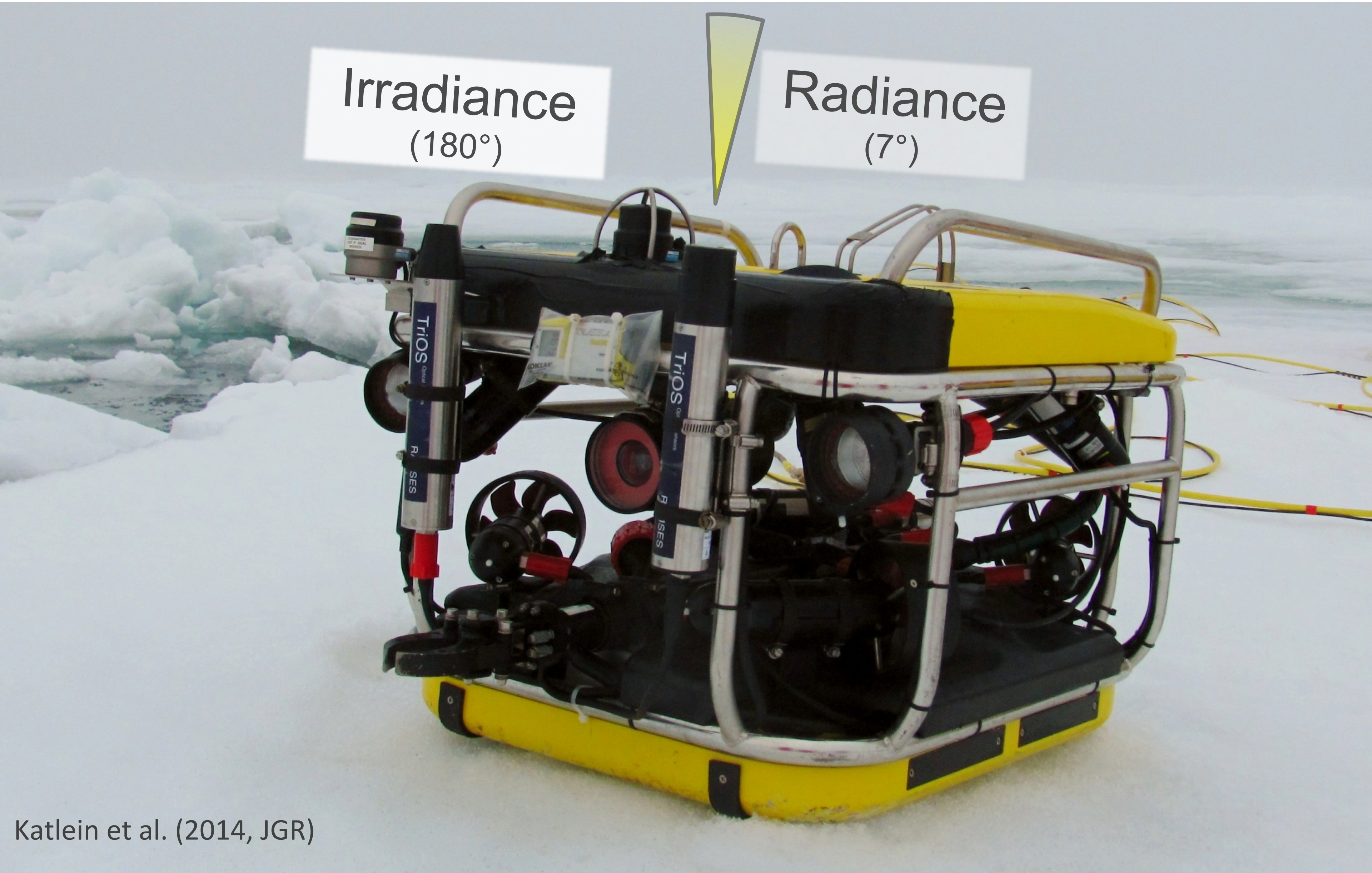
Trend in annual total solar heat input through Arctic sea ice from 1979 to 2011.

Arndt et al. (submitted, JGR)

Impact of Snow



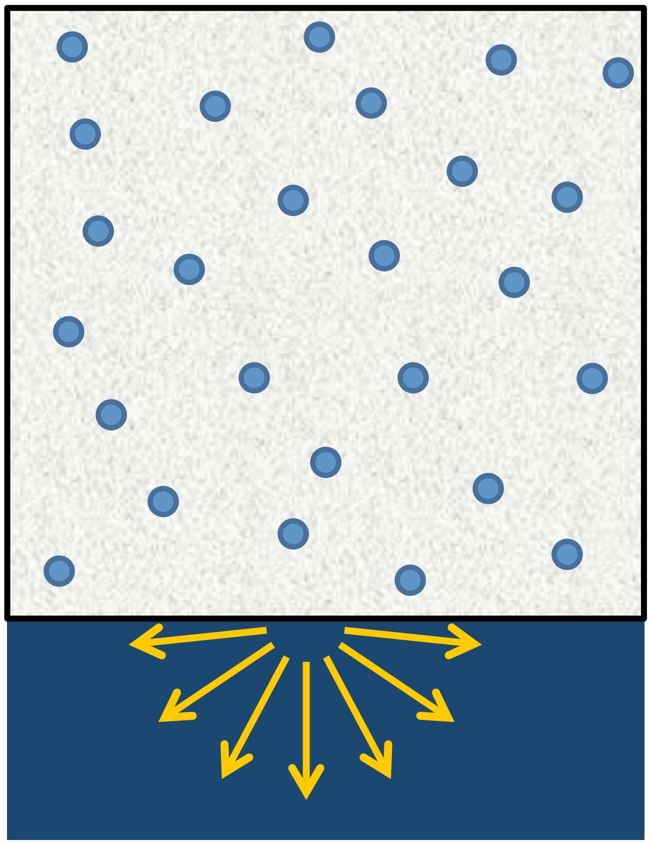
Optical Properties - Scattering



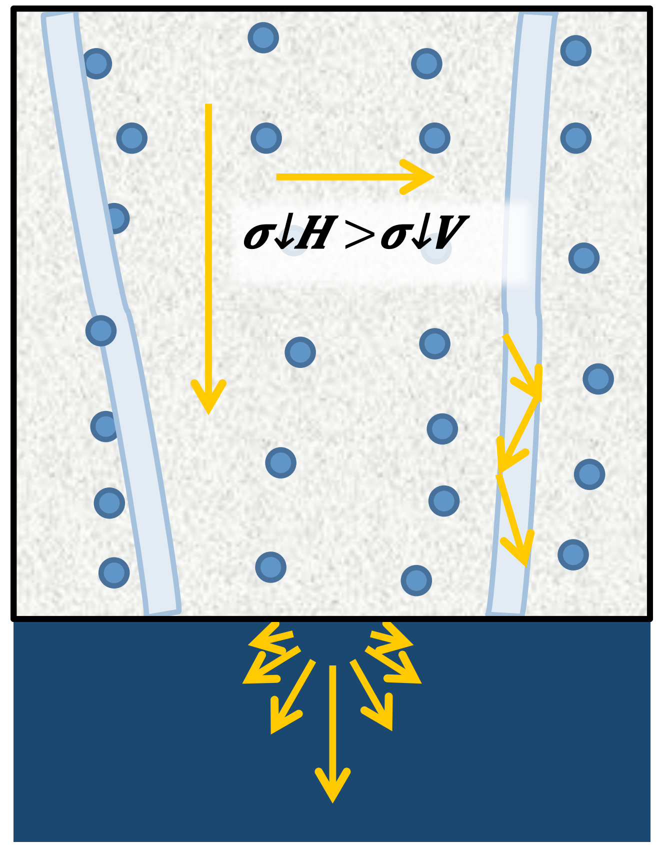
Katlein et al. (2014, JGR)

Irradiance / Radiance

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



- Anisotropy C<2.5
- More realistic fluxes



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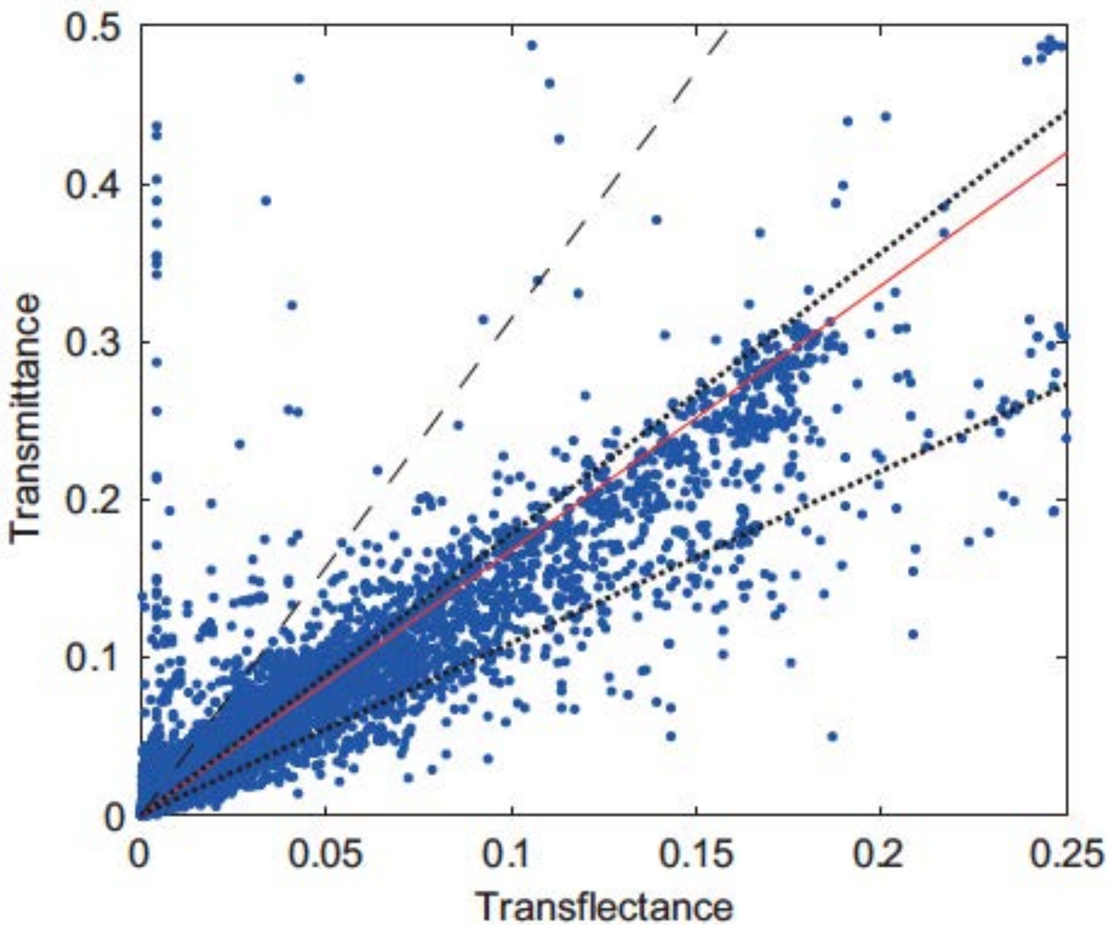
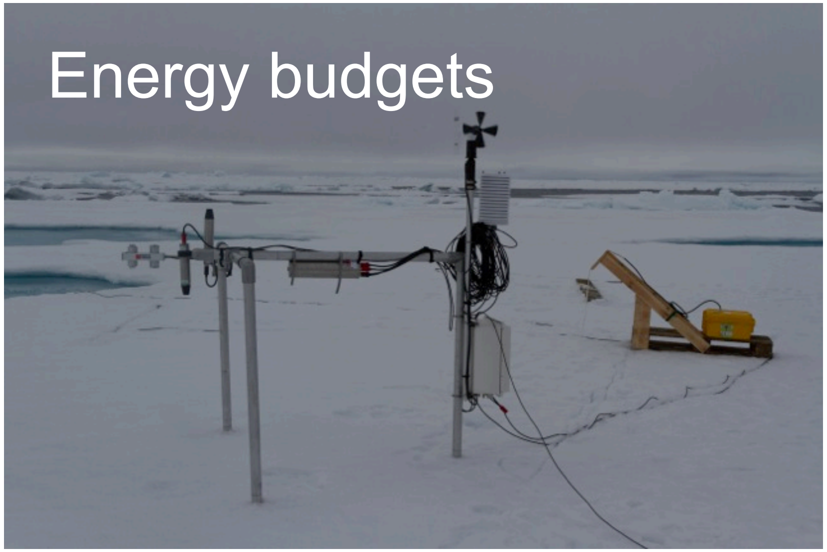
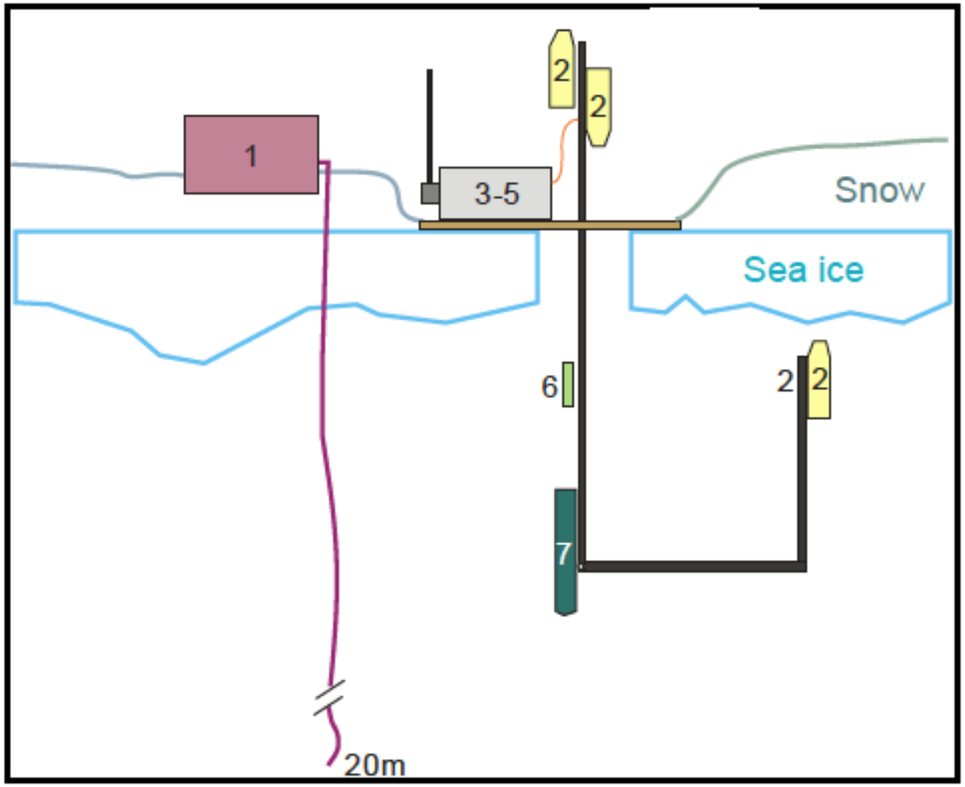


Katlein et al. (2014, JGR)

Autonomous Stations (Arc & Ant)



Bio-Physical Observatory (drifting)



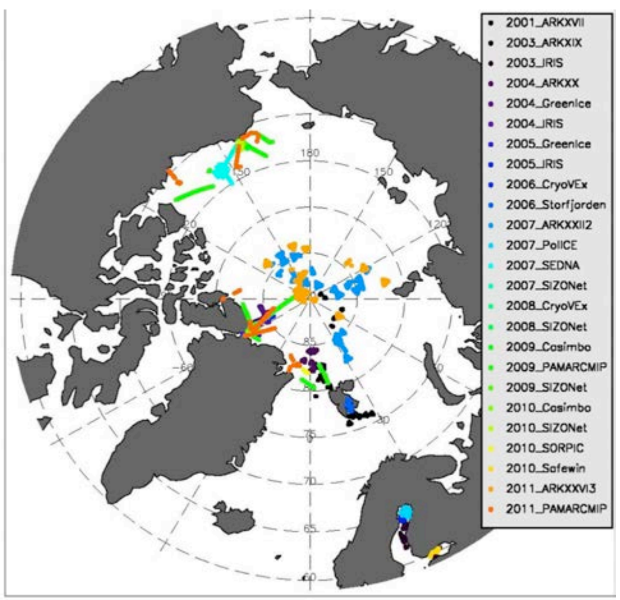
- Instrumentation
  - 1 Thermistor Buoy
  - 2 Spectral Radiation Buoy
  - 3-5 Data Transmission
  - 6 CTD
  - 7 ADCP
- Deployment 2014/15

Figure: H. Flores

AWI Sea Ice Data Online

PANGAEA®

Data Publisher for Earth & Environmental Science



- Sea-ice Concentration
- Sea-ice Thickness
- Snow depth
- Buoy tracks and data
- Information portal (in German only)

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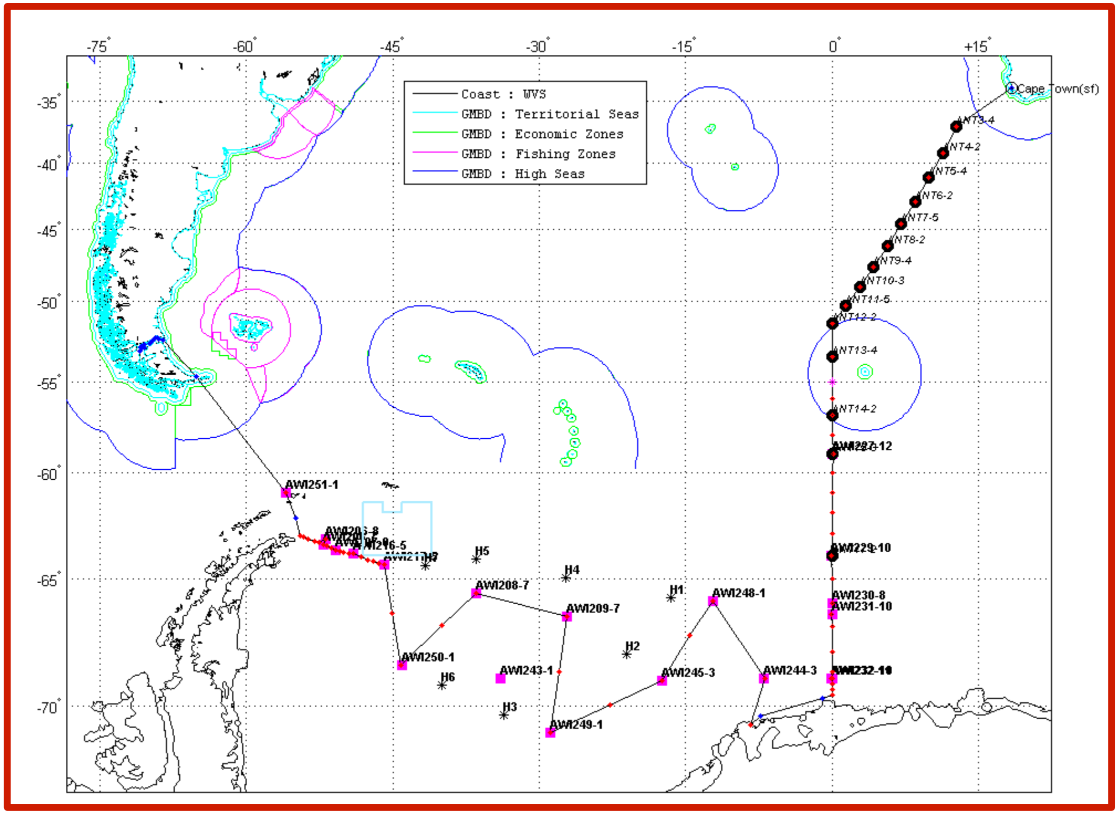
From a “white” to a “blue” ocean

- Changes in sea ice properties
  - Sea ice volume
  - Physical properties of sea ice (thickness distribution, drift, strength)
  - Sea ice energy budget (snow cover, ponds, albedo, transmittance)
  - Sea ice dynamics and drift
- Consequences
  - Changes of atmospheric and oceanographic circulation with impacts on lower latitudes
  - Loss of multi-year sea ice, changes in seasons
  - Changes in fresh-water budget
  - Impacts on primary productivity and eco-system consequences (still uncertain)
- Changes in (potential) use
  - Shipping (commercial, military, S&R, tourism)
  - Extraction of raw materials

Future Topics and Plans

- Main Objectives
  - Identify and understand sea ice change
    => to evaluate consequences for the climate- and ecosystems
  - Predicting and projecting Arctic sea ice change
    => potential impact on society
  - Quantifying sea ice mass- and energy-balance
    => impact for ocean, ecosystems, and geo-chemical cycles
- Main collaboration
  - Sea ice surface: Melt Ponds, Snow cover (melt)
  - Sea ice thickness: CryoSat-2 & SMOS
  - Common projects: ESA, Meereisportal, EU
  - Others? (Antarctic work)

Polarstern ANT XXX/3 2014/15



Cape Town 1.12.2014 – Punta Arena 1.2.2015

- Sea Ice Physics
  - Sea Ice Thickness (Bird)
  - Sea Ice Optics (ROV)
  - Buoy deployments
  - Ship Observations
- Sea Ice Ecosystem
- Ocanography
- Neumayer Supply