

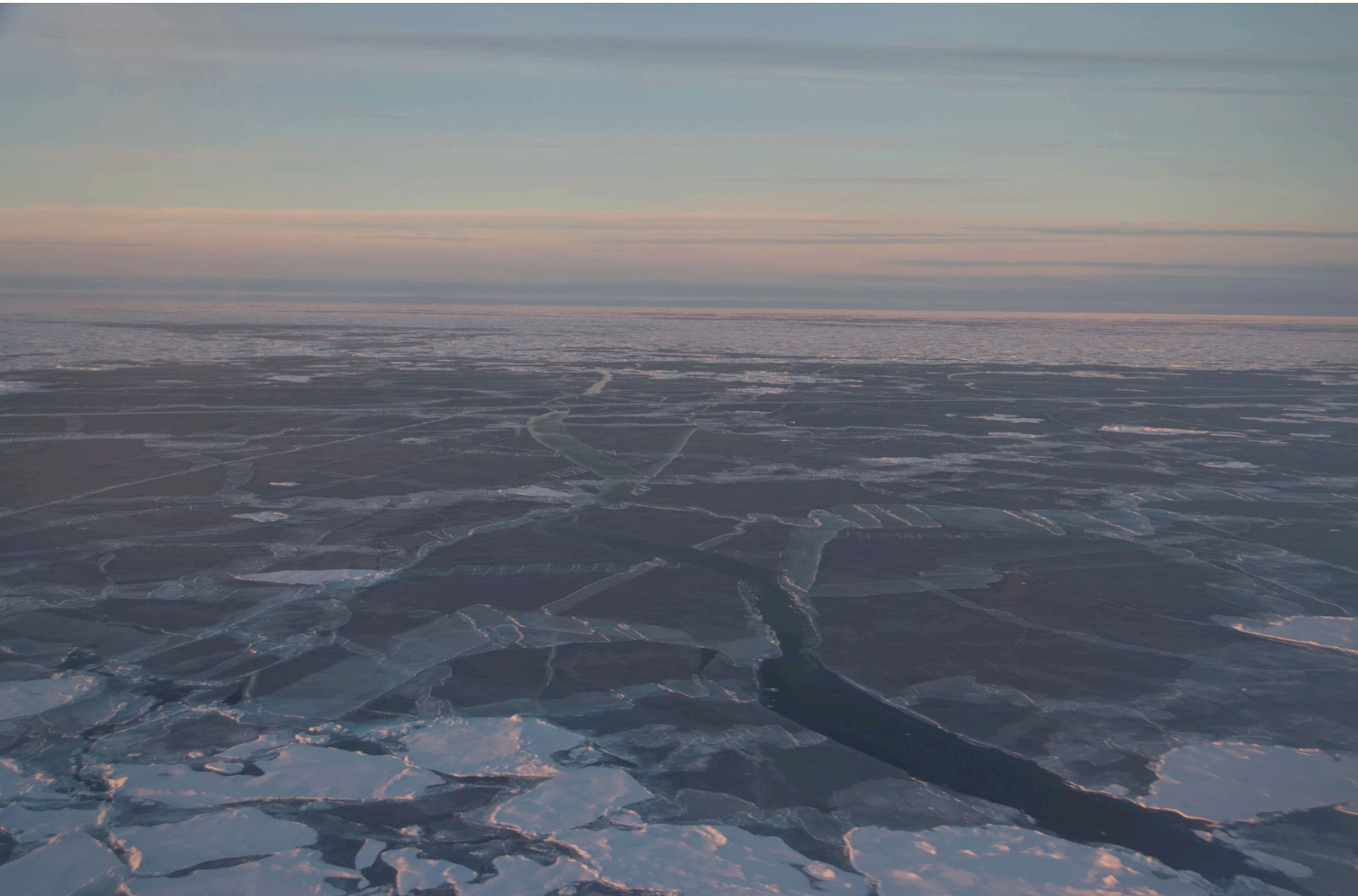
**Marcel Nicolaus and colleagues**



10 June 2014

# Observing Arctic Sea Ice and its Changes

# New Sea Ice



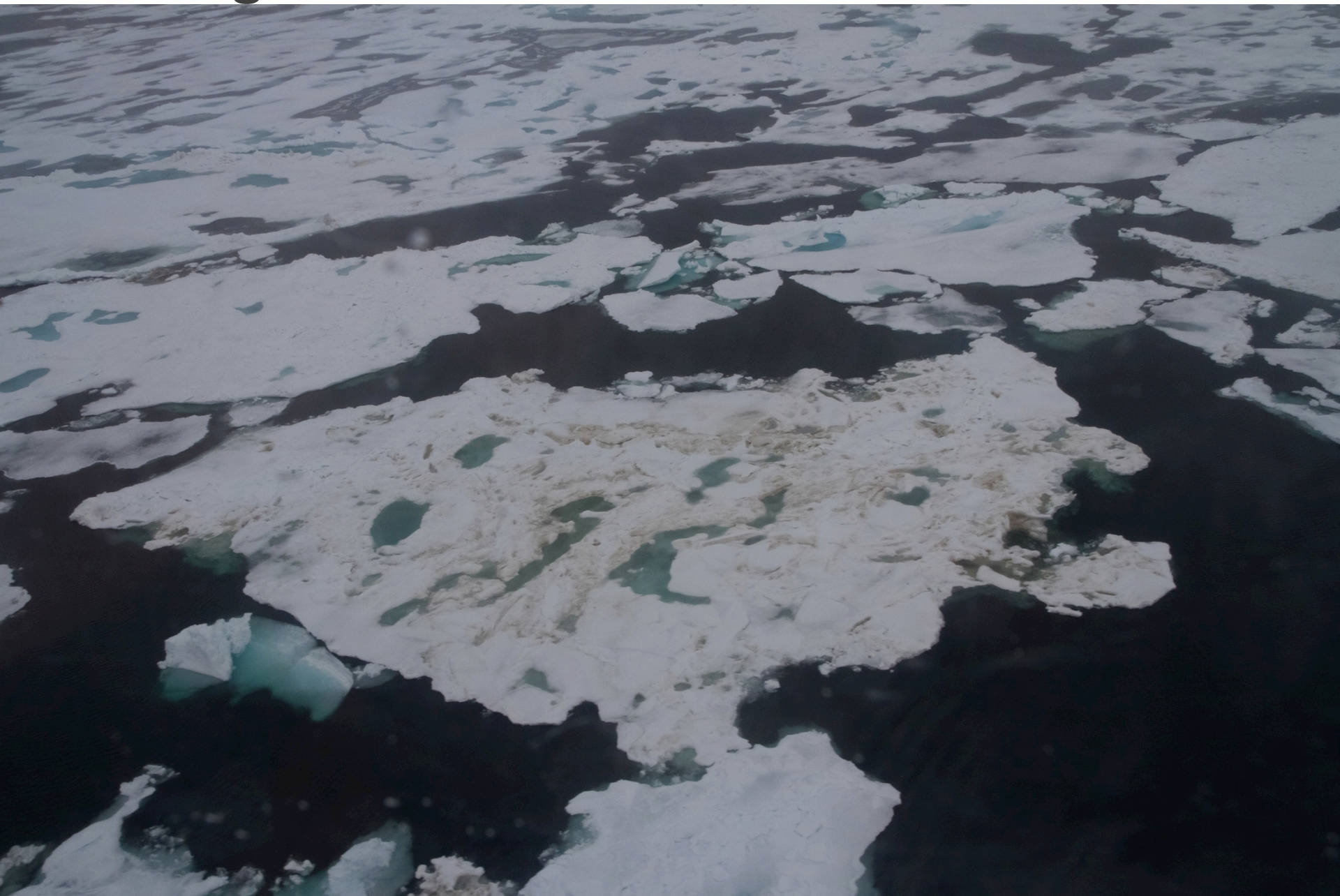
# Deformed Sea Ice



# Melt Ponds

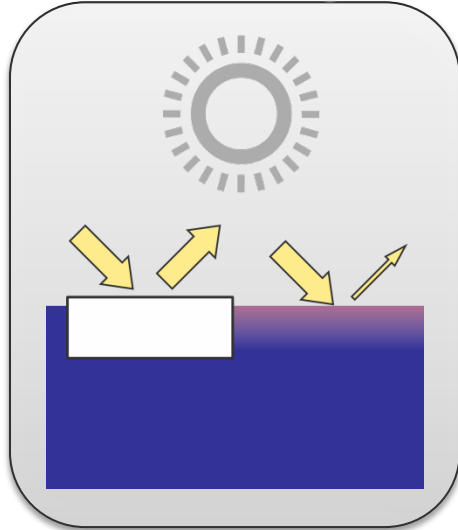


# Melting / Rotten Sea Ice

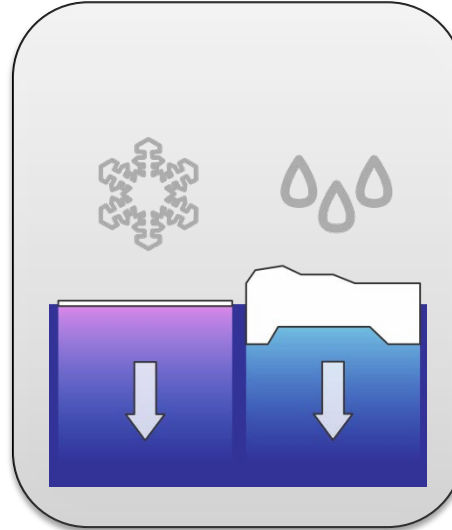


# Importance of Sea Ice

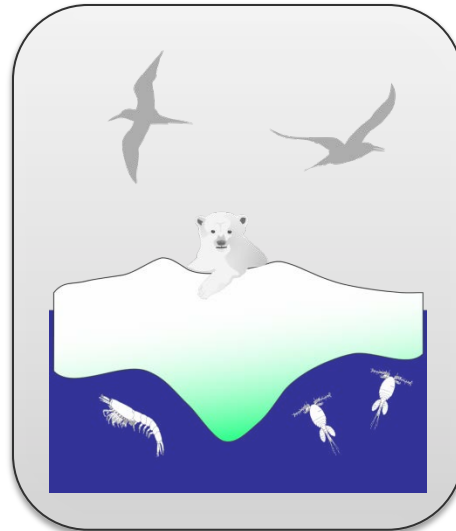
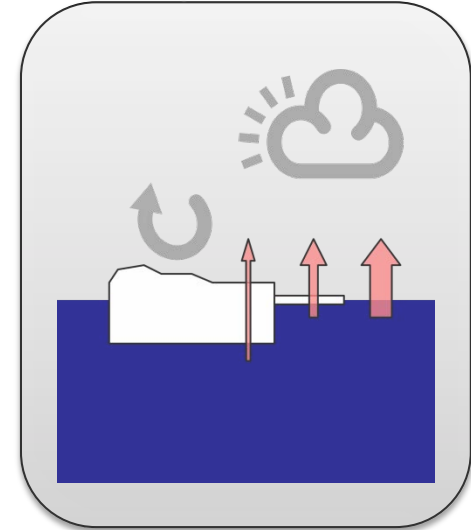
Radiation budget



Fresh Water



Atmosphere & Ocean



Ecosystem



Economy & Society

# Snow Rules



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

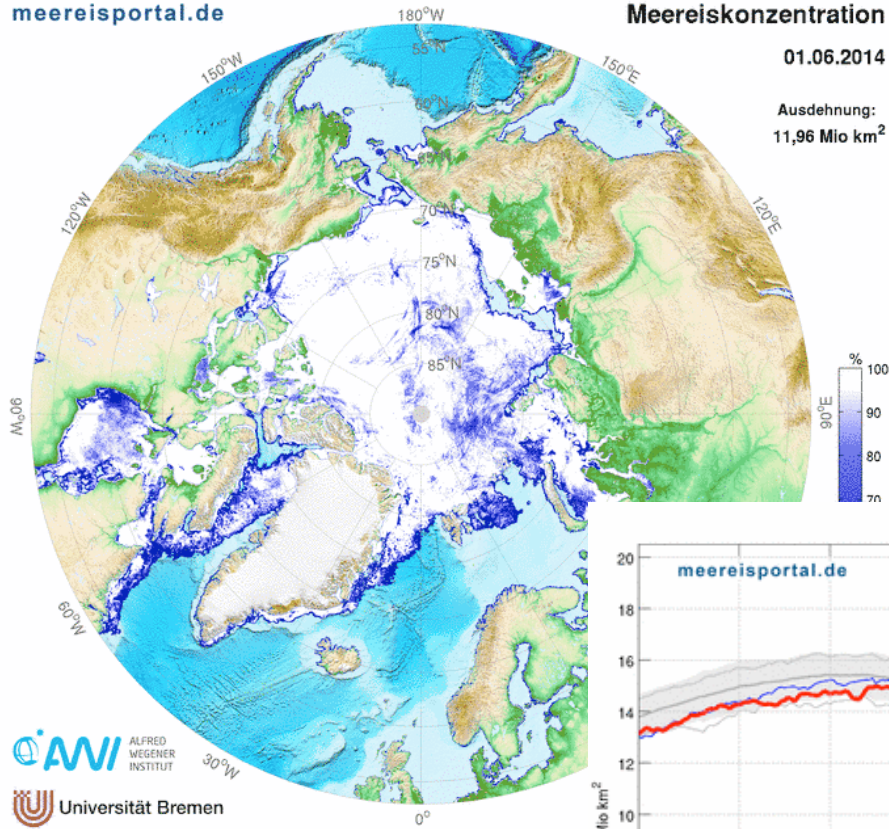
# Sea Ice Today

meereisportal.de

## Meereiskonzentration

01.06.2014

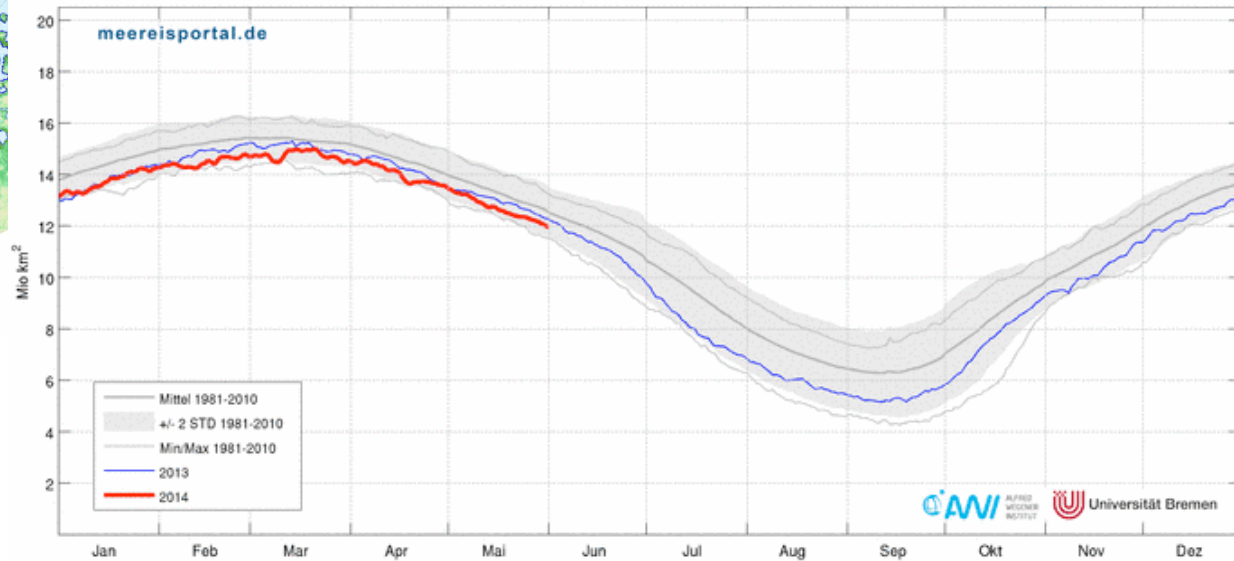
Ausdehnung:  
11,96 Mio km<sup>2</sup>



AWI ALFRED WEGENER INSTITUT  
Universität Bremen

## Meereis-Ausdehnung Arktis (Meereiskonzentration >15%)

01.06.2014: 11.96 Mio km<sup>2</sup>



AWI ALFRED WEGENER INSTITUT  
Universität Bremen

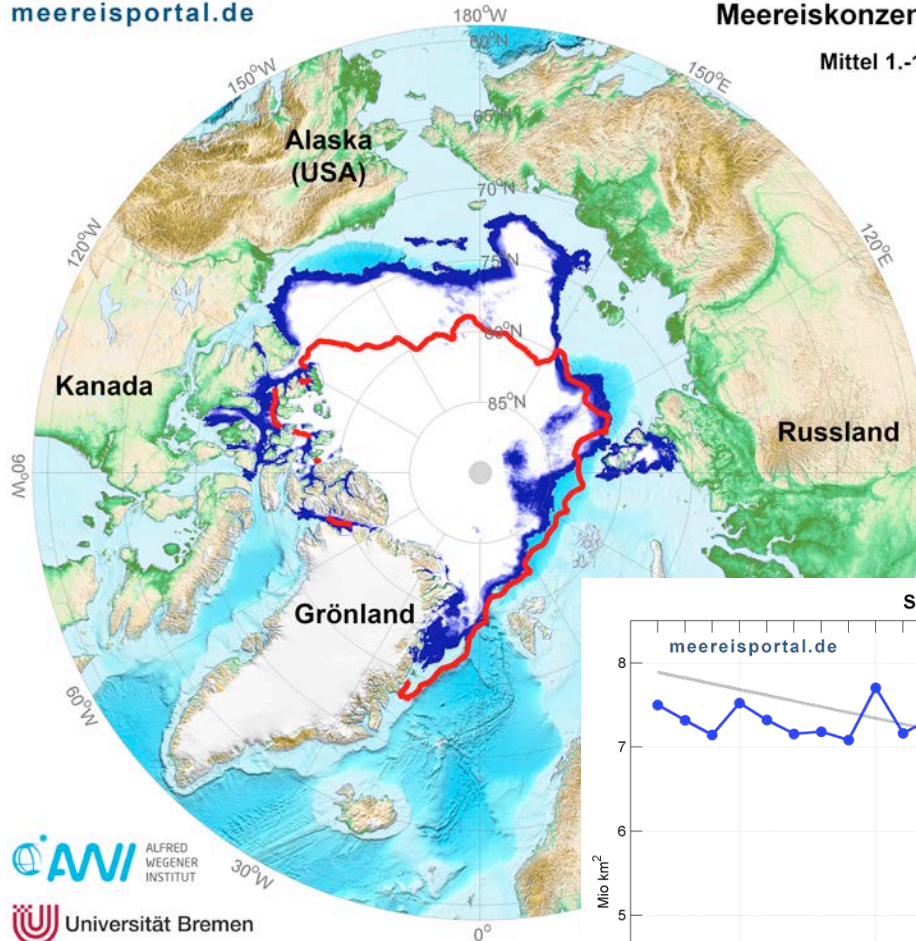


# Variability and Trends

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## Meereiskonzentration

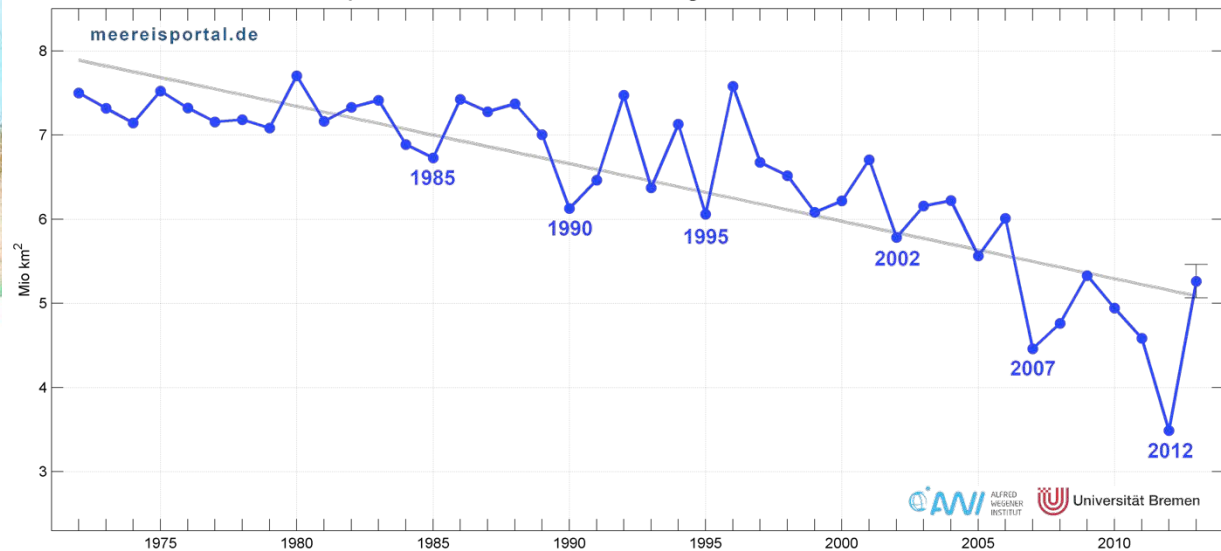
Mittel 1.-17.9.2013



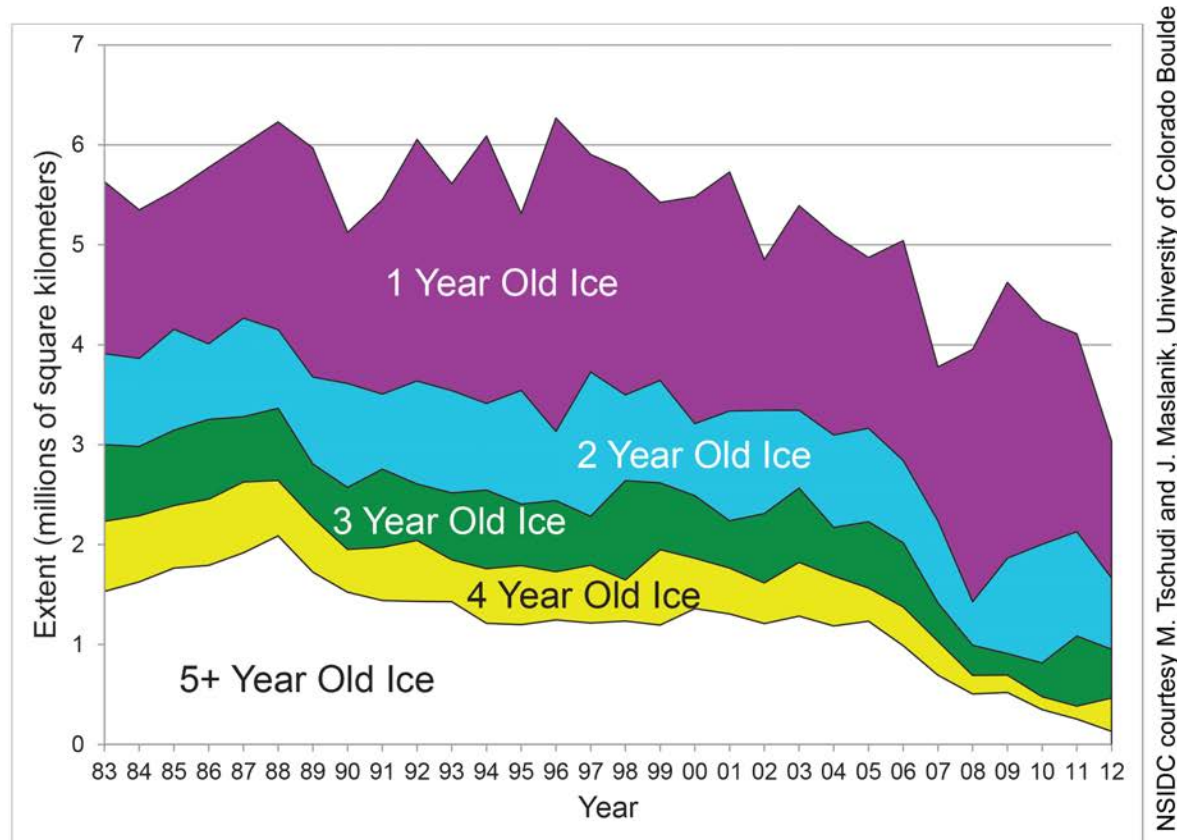
- March: -2,6% / decade
- Sep.: -13,0% /decade
- Total : - 4,6% / decade

• Reasons & Background ?  
=> ground measurements

Septembermittel der Meereisausdehnung in der Arktis von 1972-2013

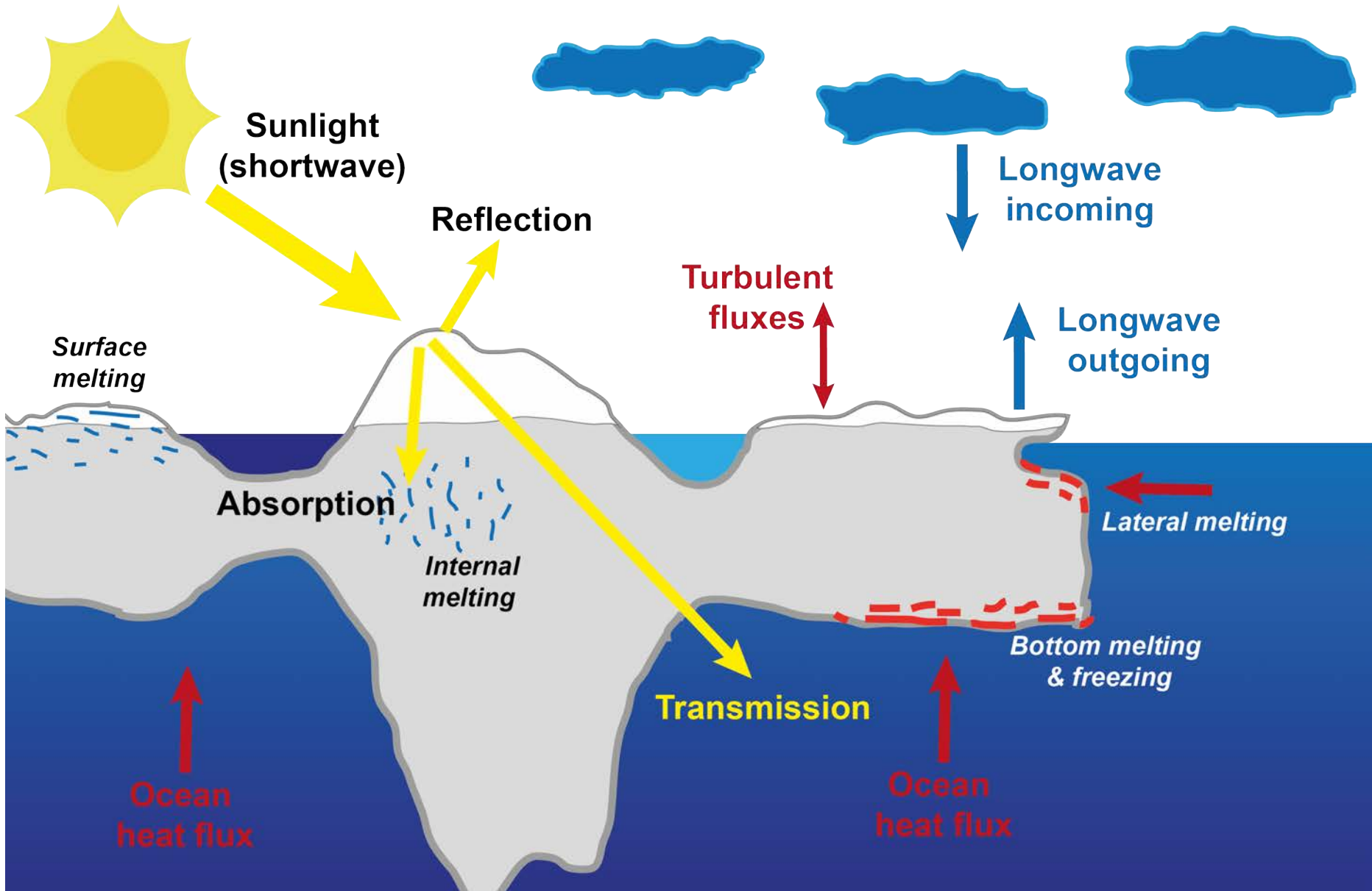


# Younger and More Seasonal Sea Ice

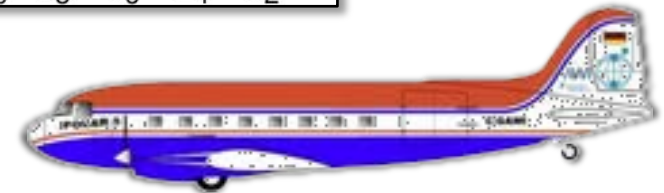
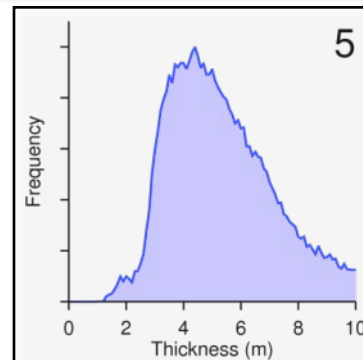
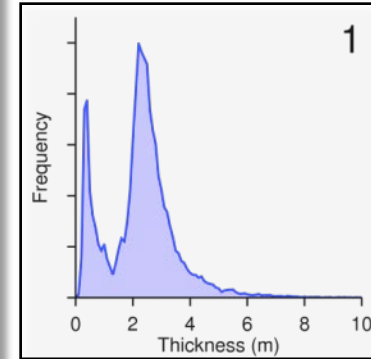
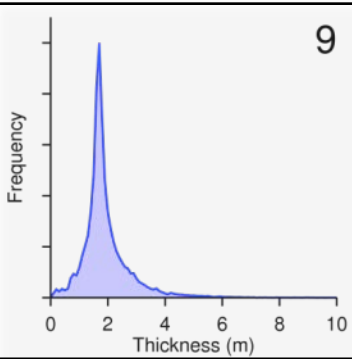
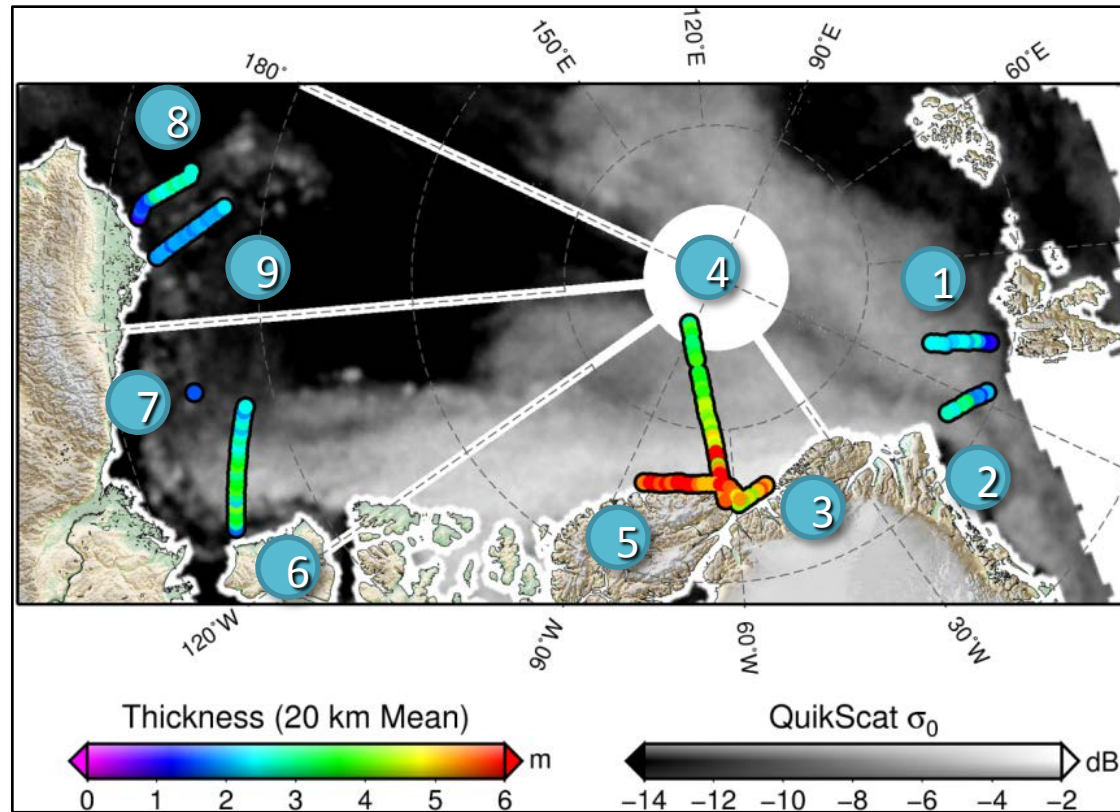


- Surface properties
- Habitat changes
- Physical properties: Drift and Dynamics
- Thickness distributions

# Sea Ice Mass and Energy Budgets

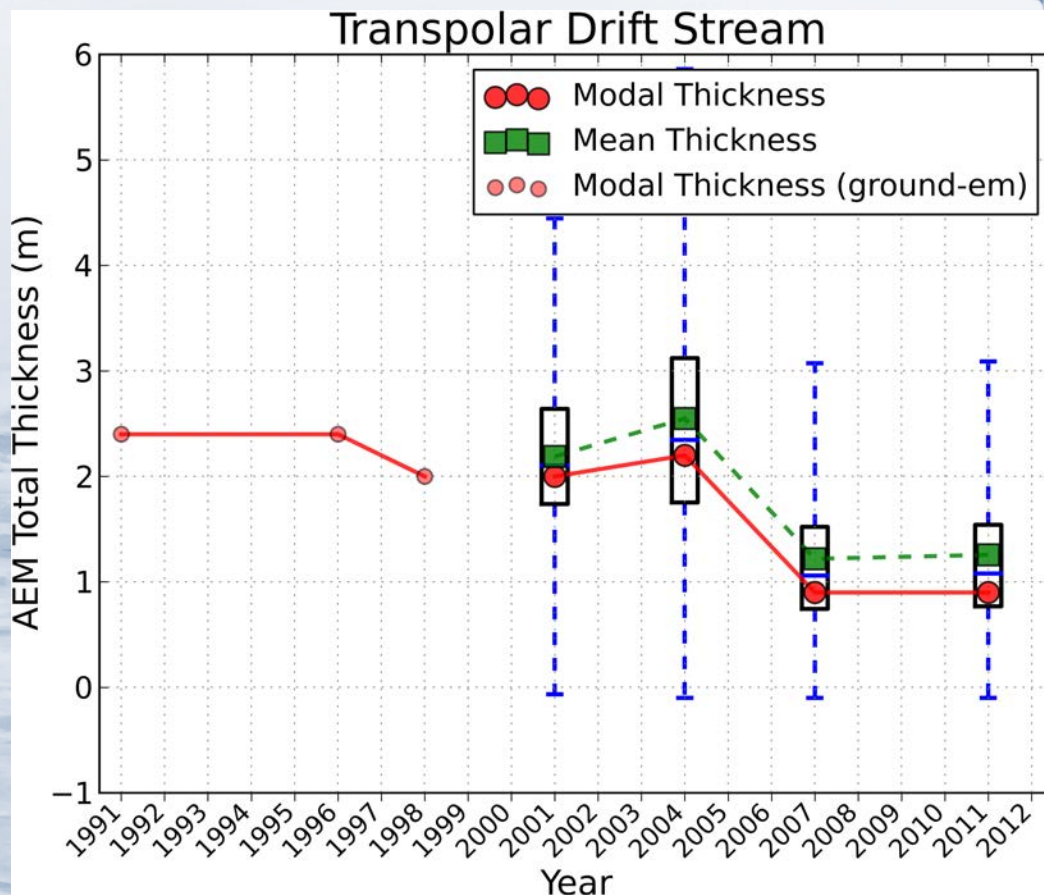
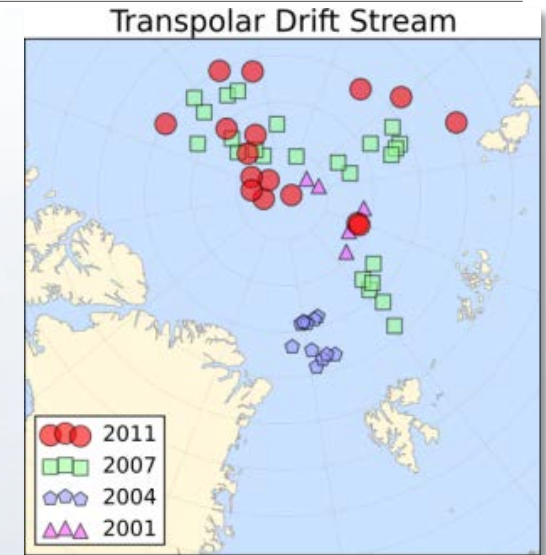


# Sea Ice Thickness from Polar5



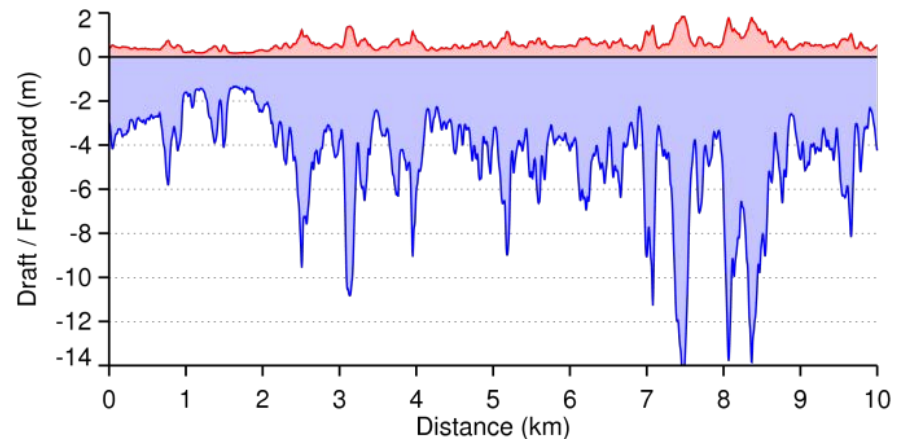
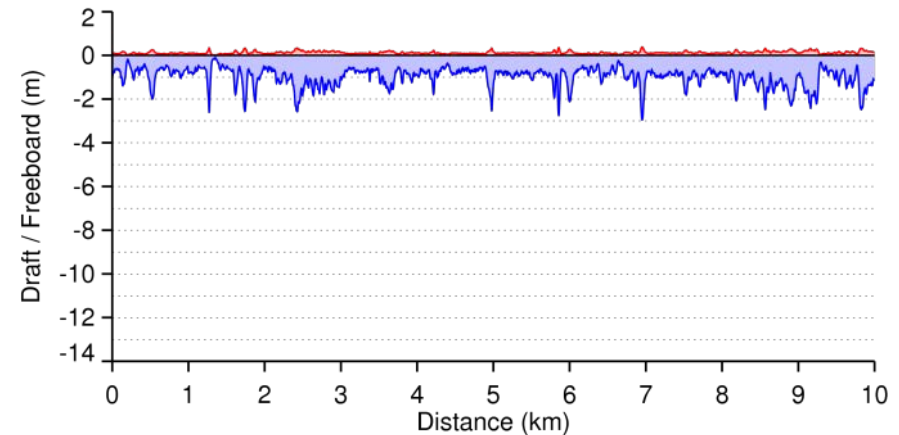
PAMARCMIP since 2009

# Thickness in Transpolar Drift

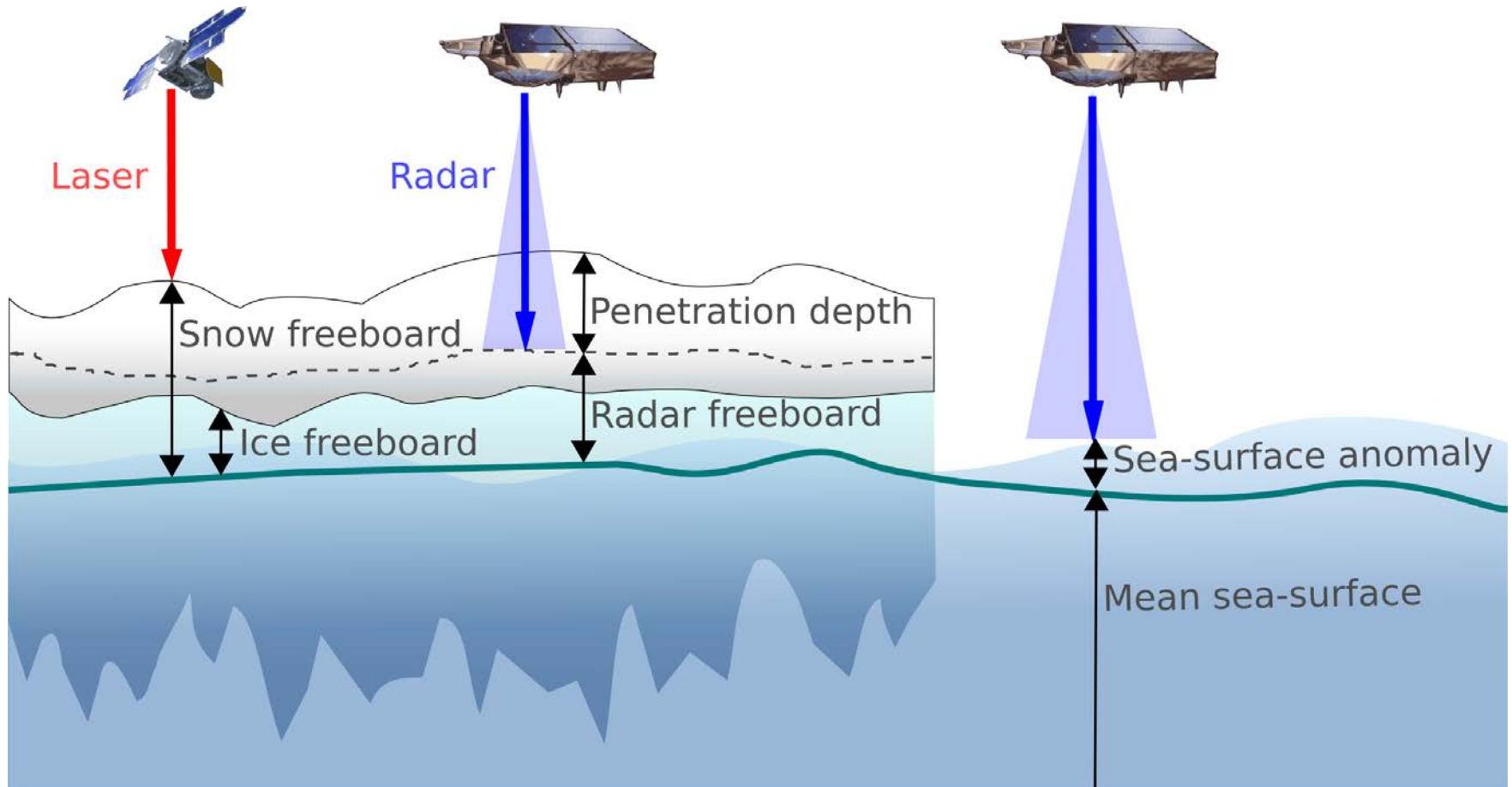


# Sea Ice Thickness Results

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



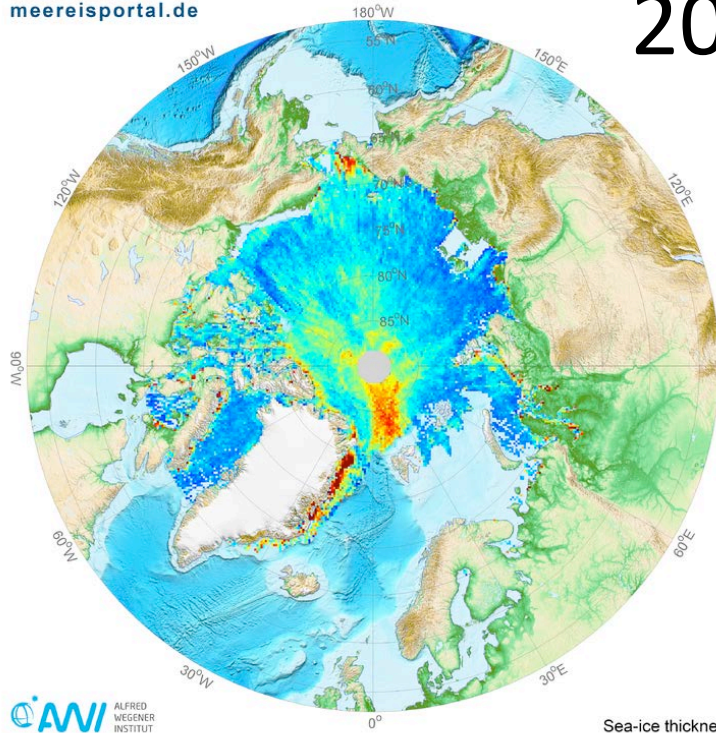
# Sea Ice Thickness from Satellites



# Sea Ice Thickness CryoSat-2

meereisportal.de

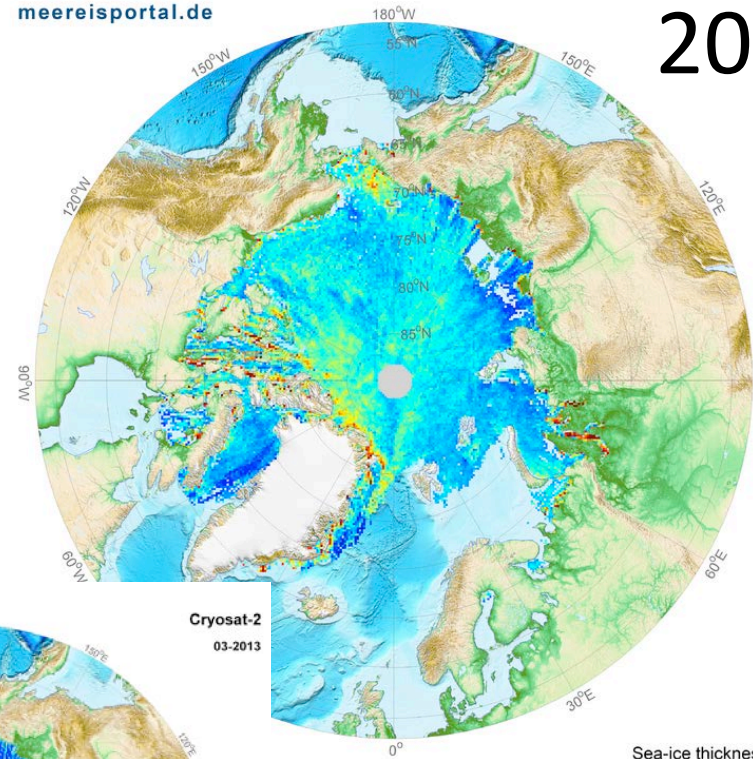
## 2012



Sea-ice thickness

meereisportal.de

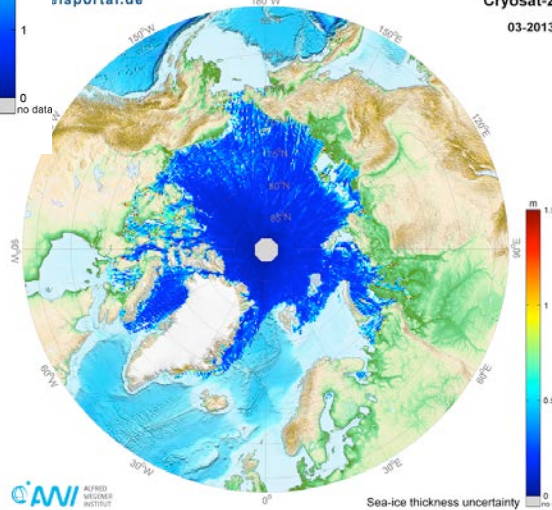
## 2013



Sea-ice thickness

meereisportal.de

CryoSat-2  
03-2013



Sea-ice thickness uncertainty

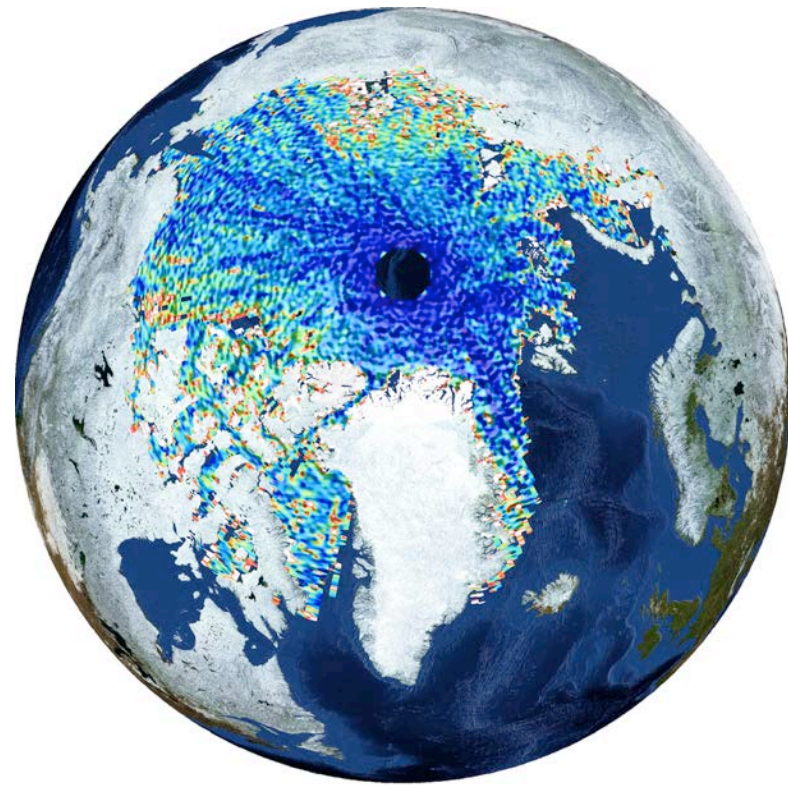
## Uncertainty:



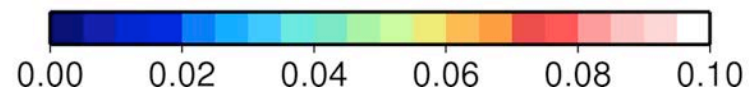
# Freeboard Uncertainties

## Freeboard uncertainty

- Radar penetration
- Sea-surface anomaly
- Speckle noise



Radar freeboard uncertainty (m)



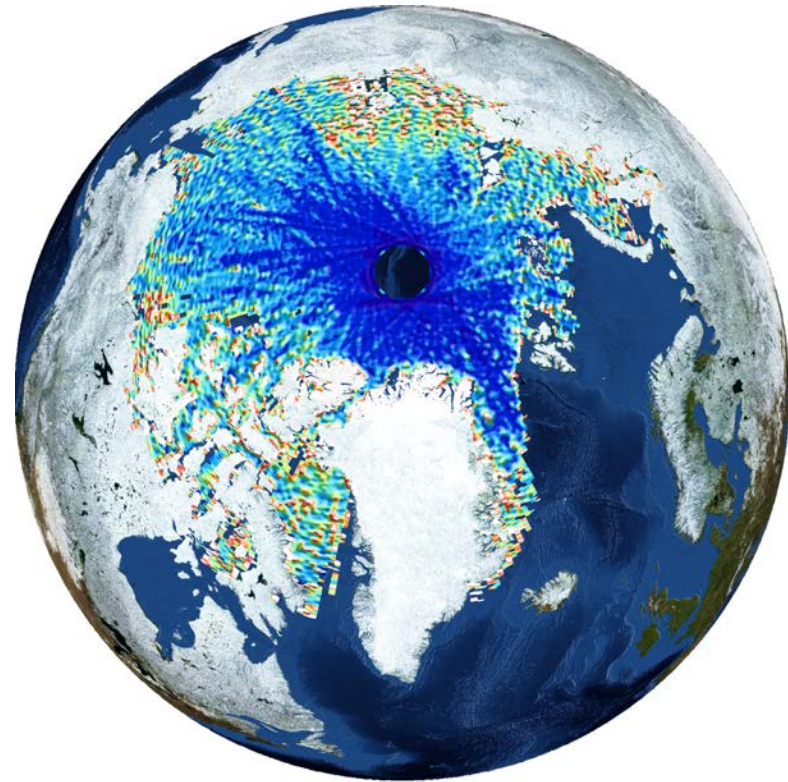
# Thickness Uncertainties

## Freeboard uncertainty

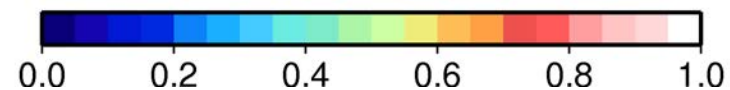
- Radar penetration
- Sea-surface anomaly
- Speckle noise

## Thickness uncertainty

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



Sea-ice thickness uncertainty (m)



# Varying retracker thresholds

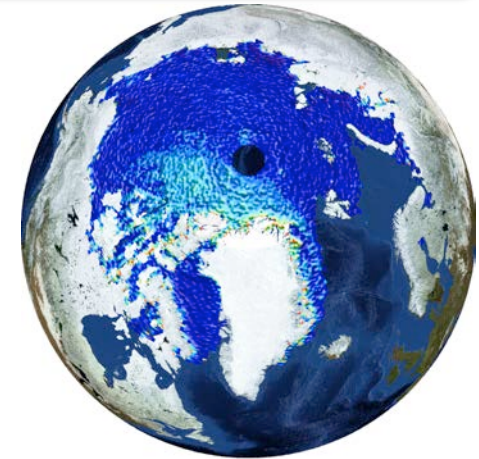
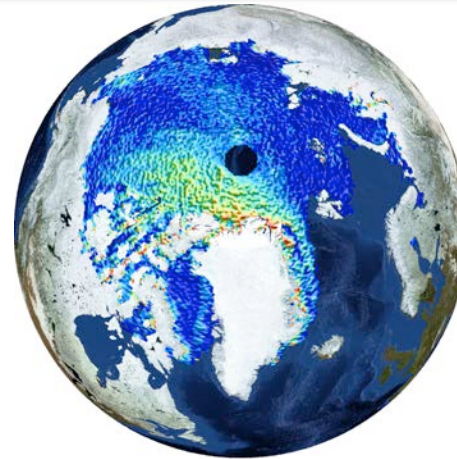
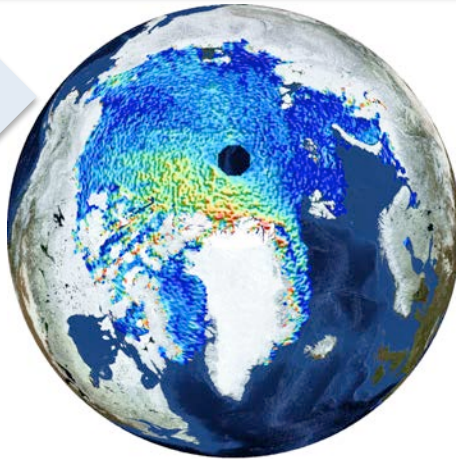
Threshold:

40 %

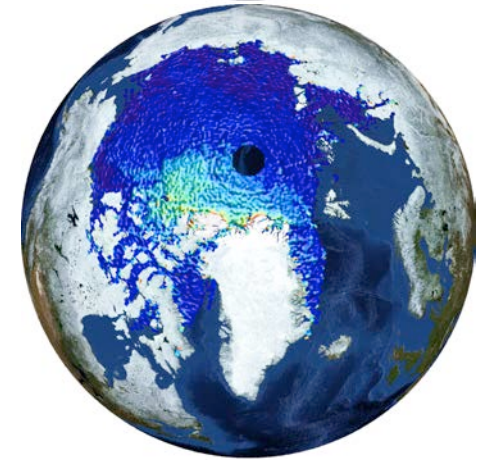
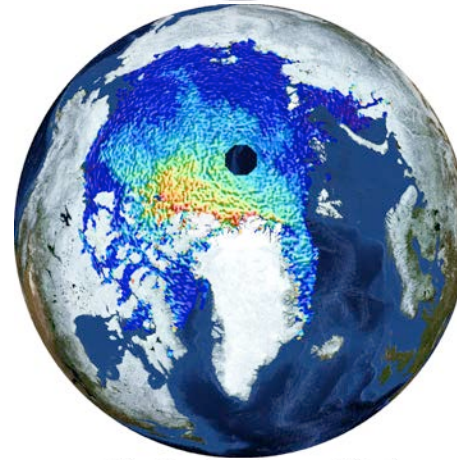
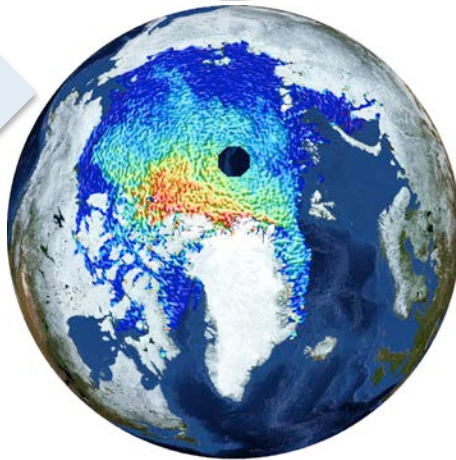
50 %

80 %

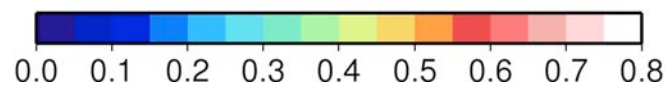
Mar 2013



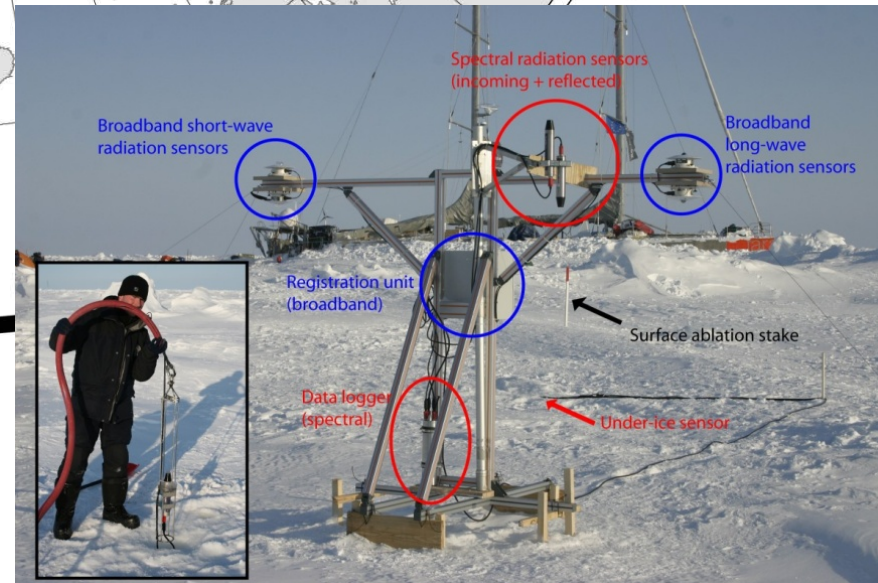
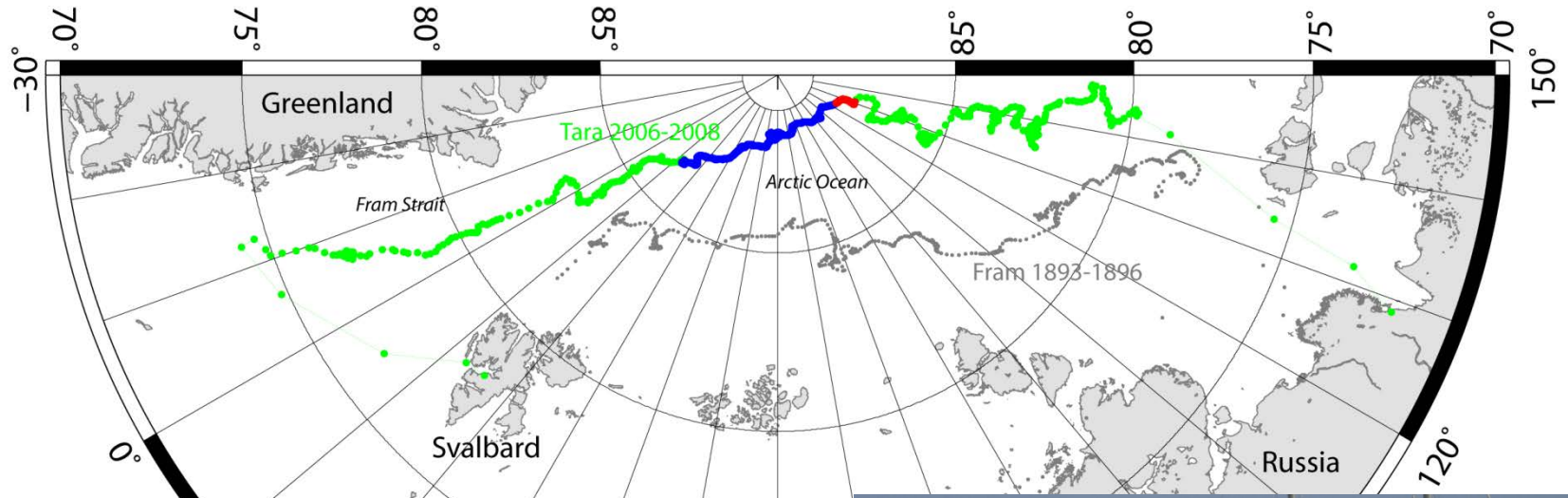
Nov 2013



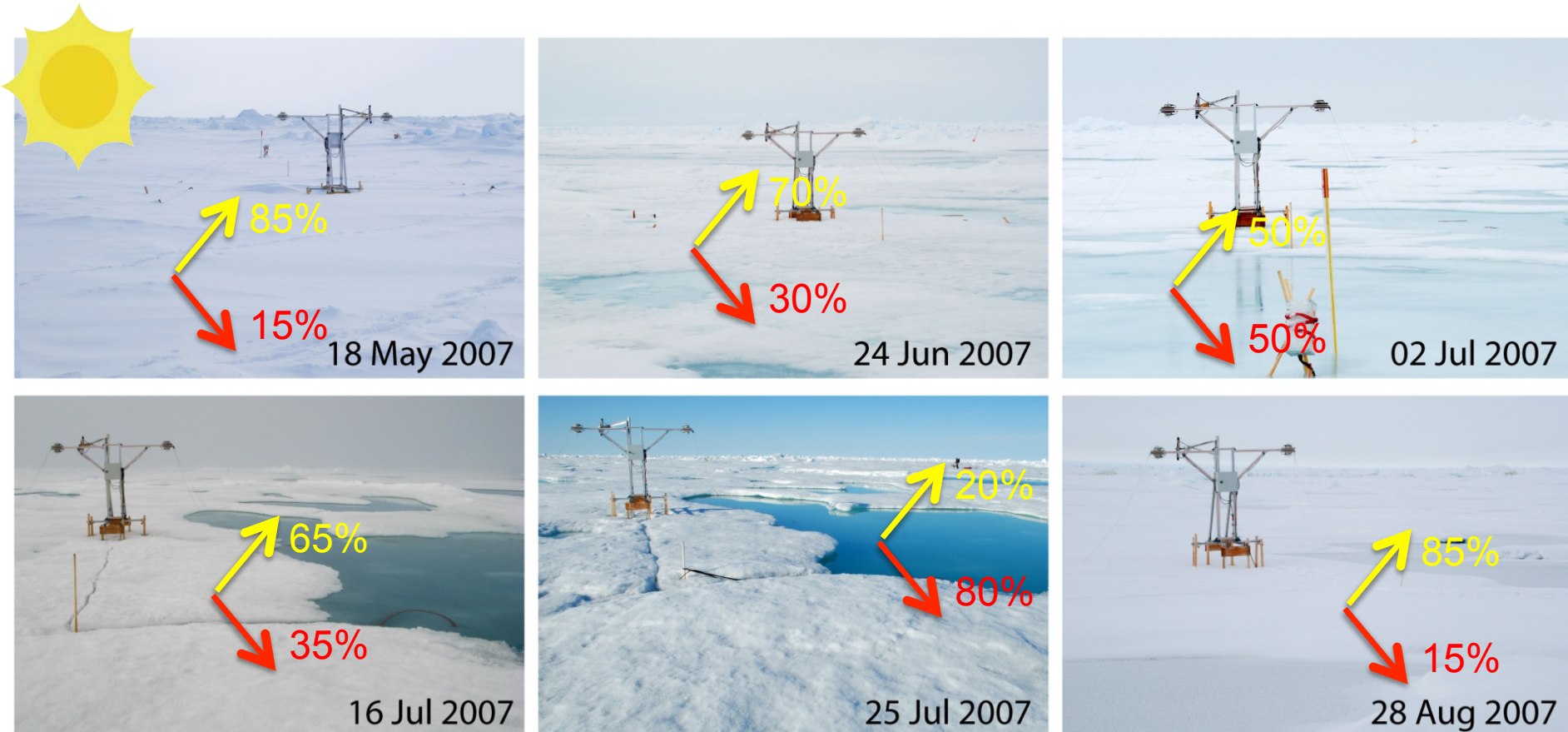
Radar freeboard (m)



# Drift of Tara

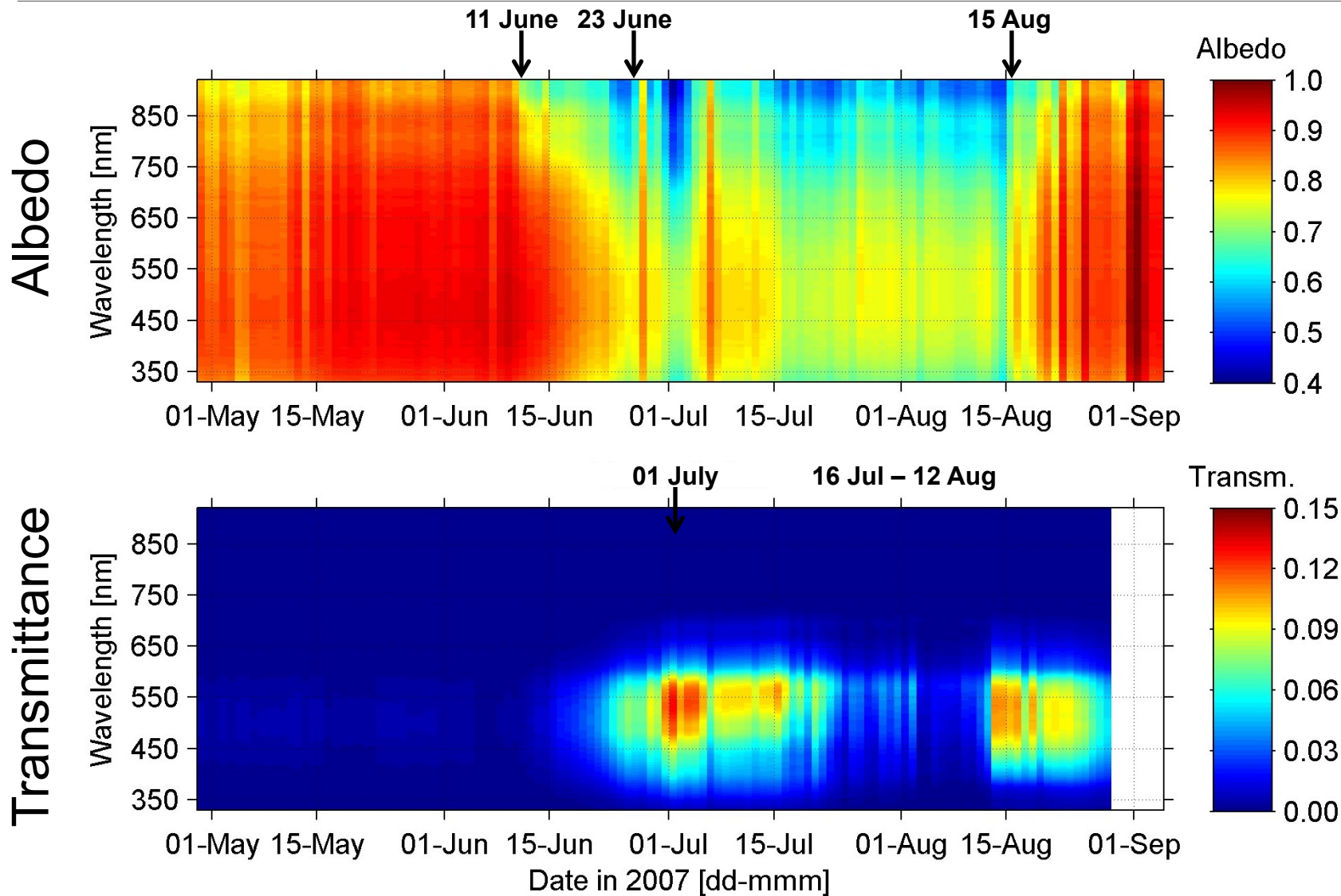


# Seasonality of Arctic Sea Ice

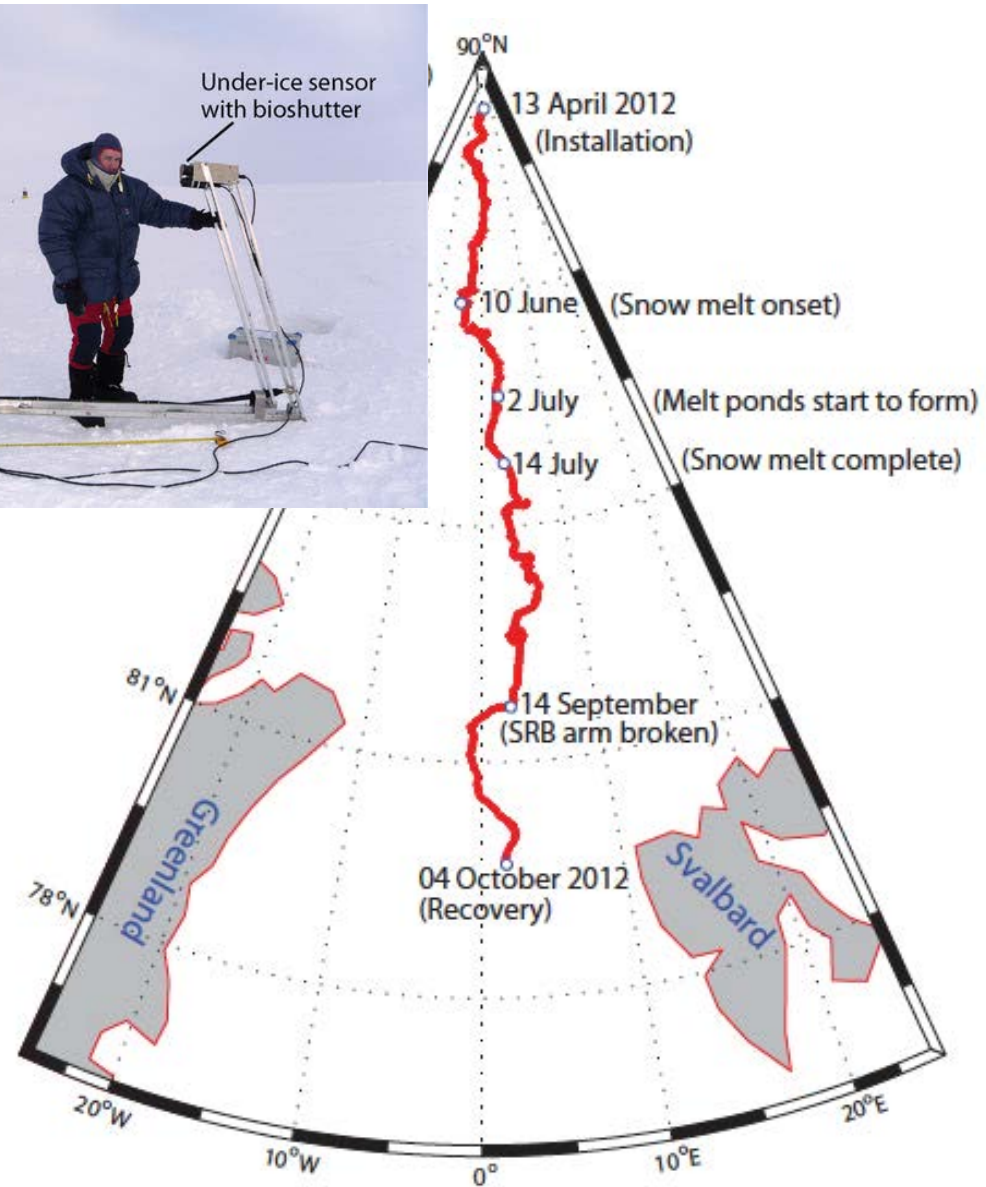
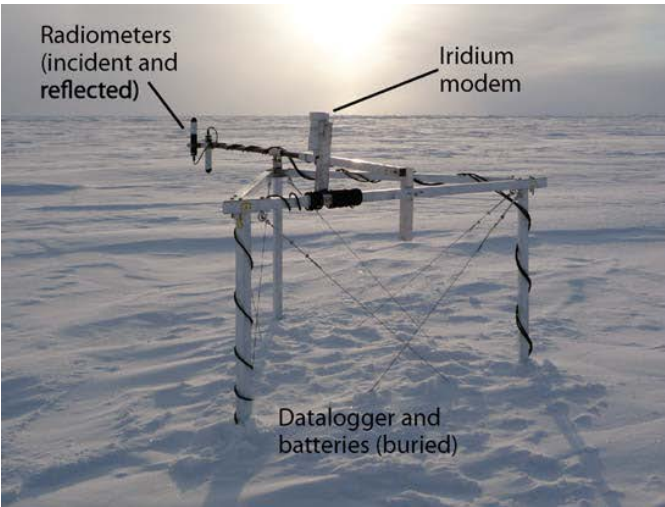


Photos: Nicolaus et al. (2010, JGR)  
Methods: Nicolaus et al. (2010, CRST)

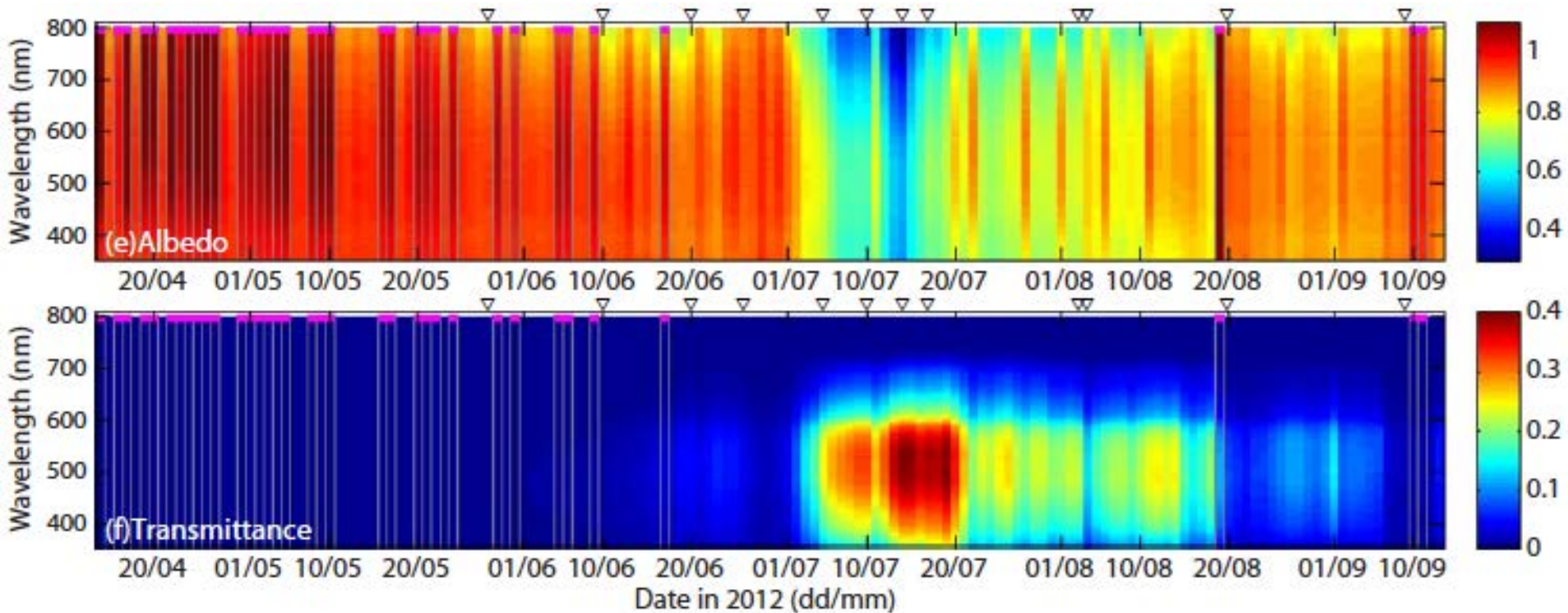
# Spectral Albedo & Transmission



# Spectral Radiation Buoy

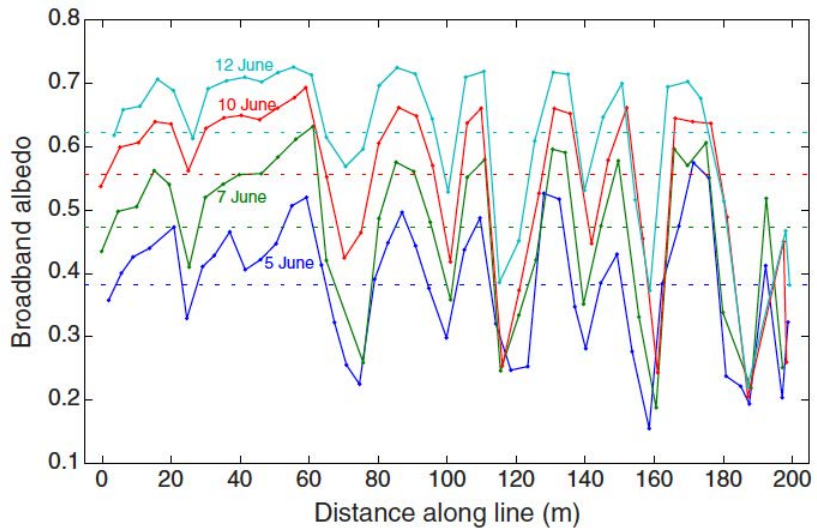
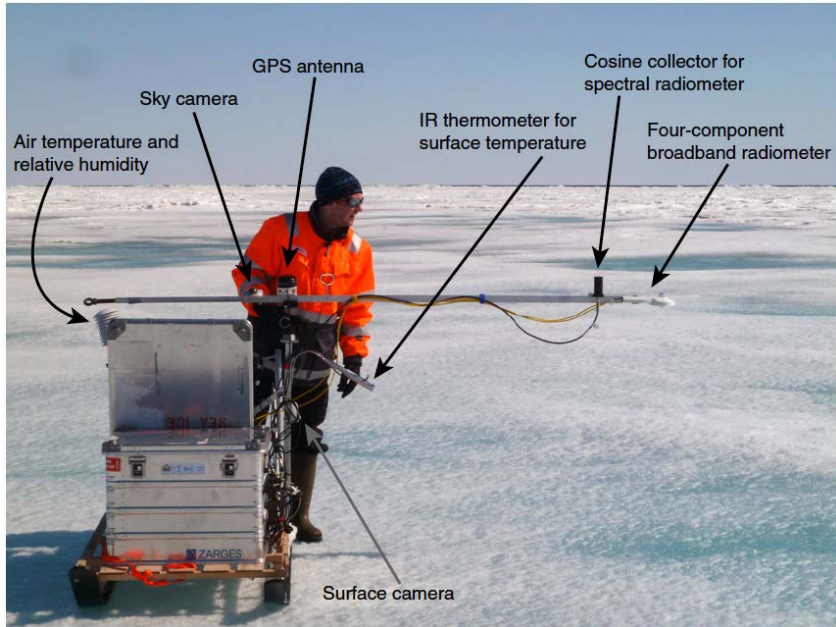


# Spectral Radiation Buoy





# Albedo & Energy Budgets



# Under-Ice Investigations

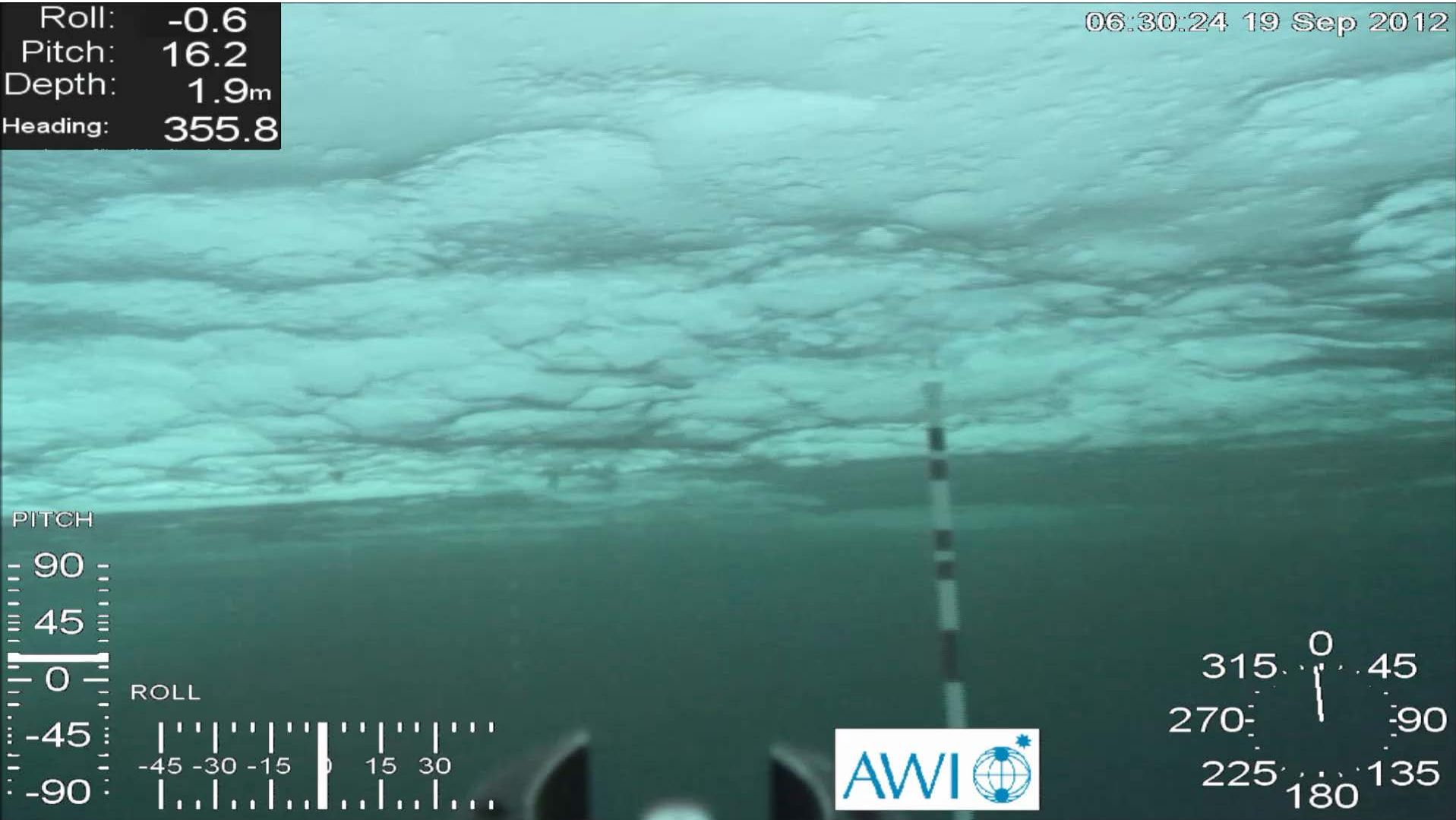


# View from Below: Level Ice



Roll: -0.6  
Pitch: 16.2  
Depth: 1.9m  
Heading: 355.8

06:30:24 19 Sep 2012

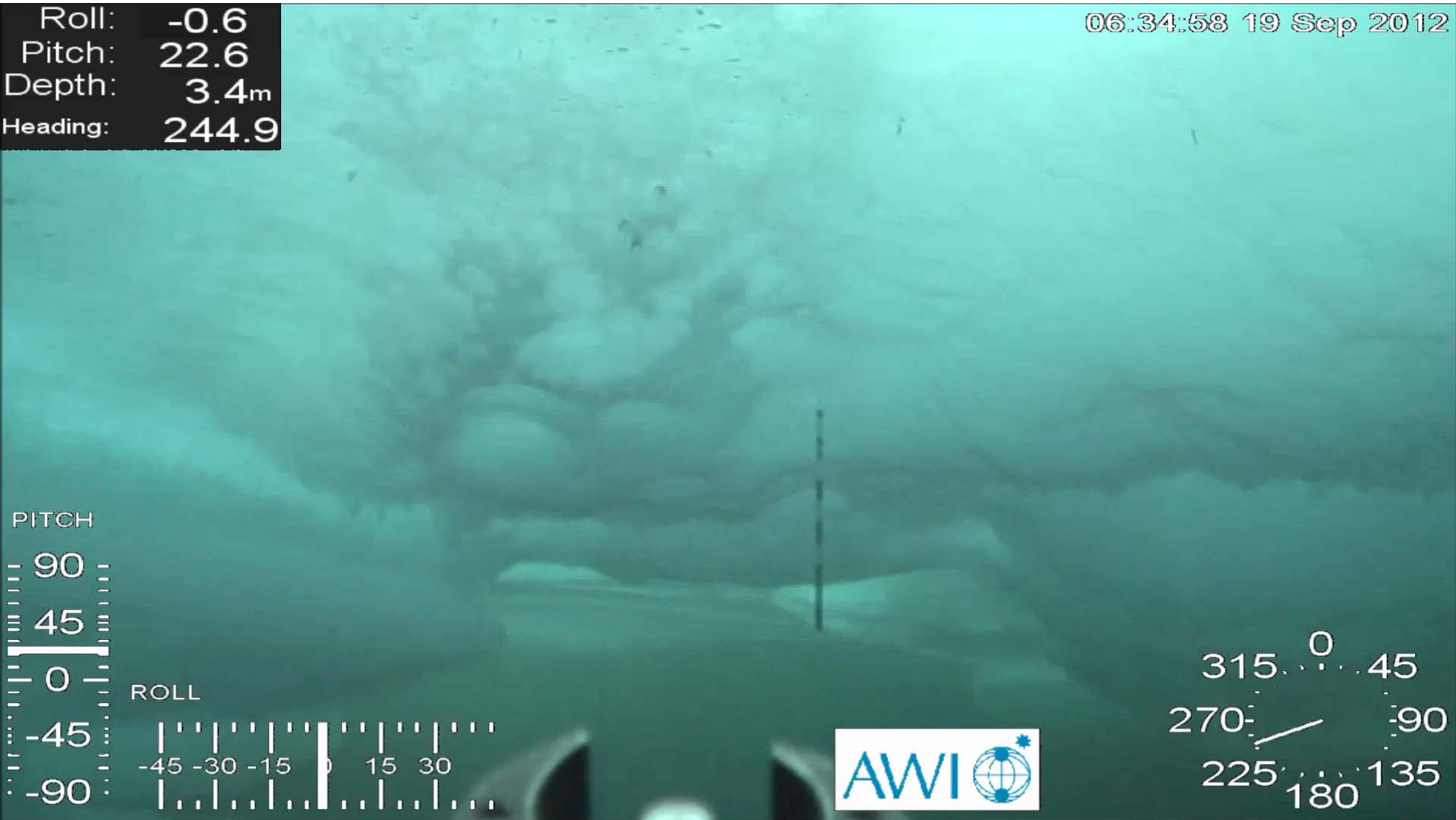


# View from Below: Level Ice

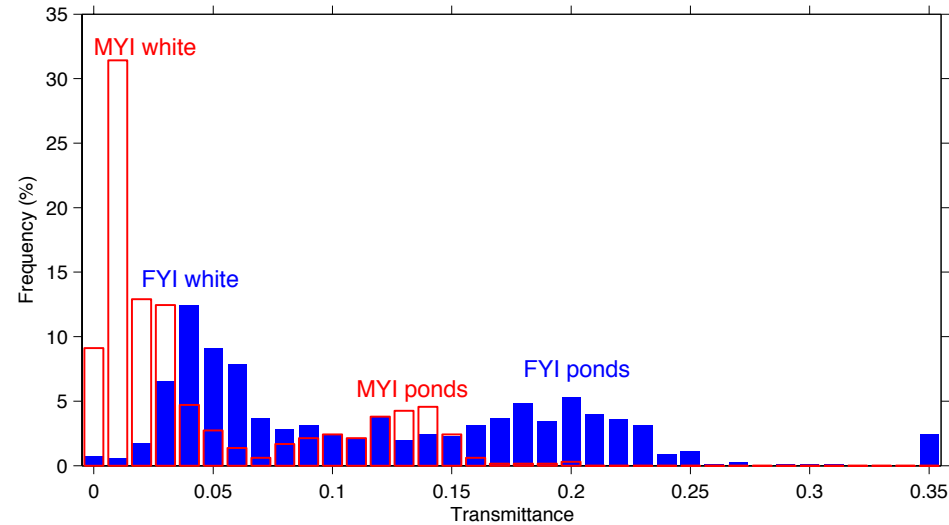
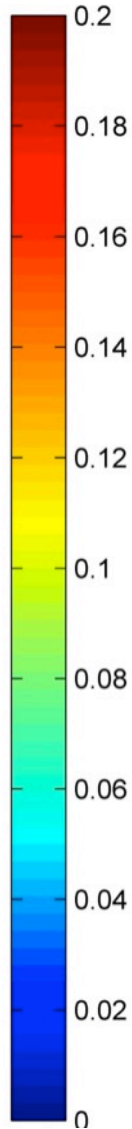
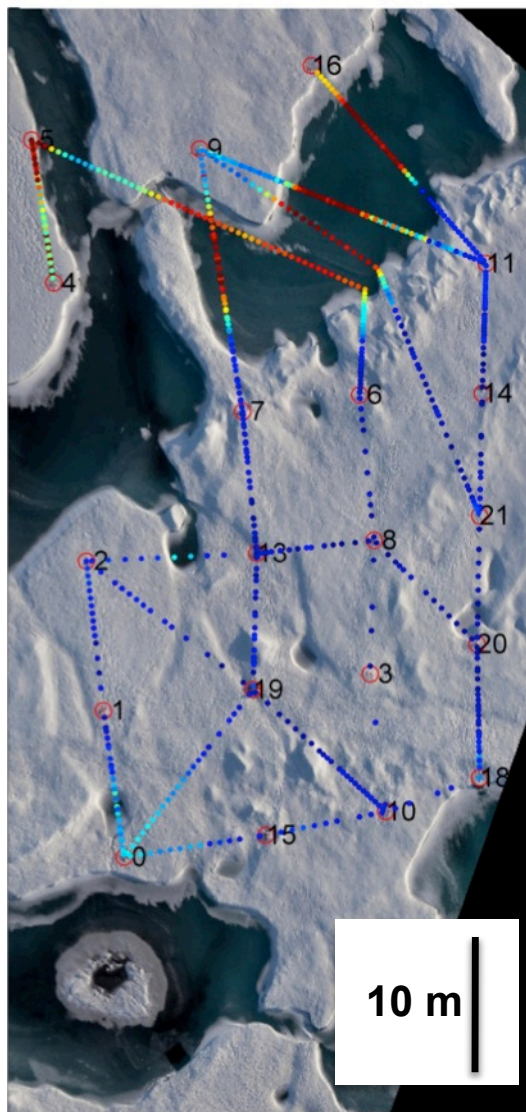


Roll: -0.6  
Pitch: 22.6  
Depth: 3.4m  
Heading: 244.9

06:34:58 19 Sep 2012



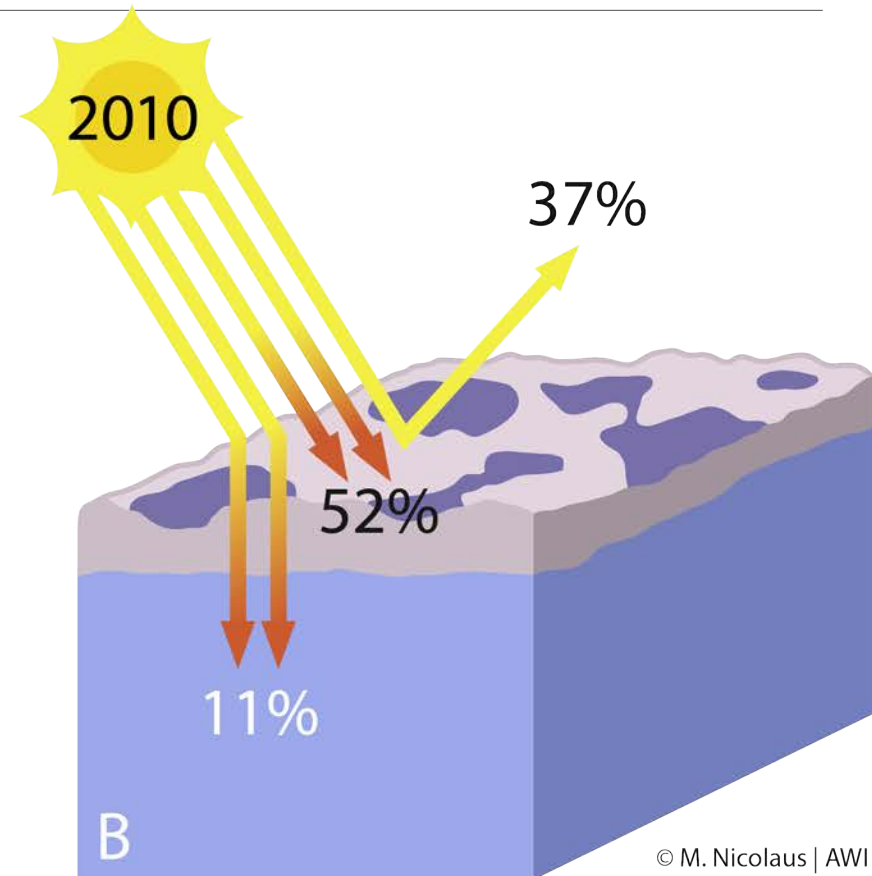
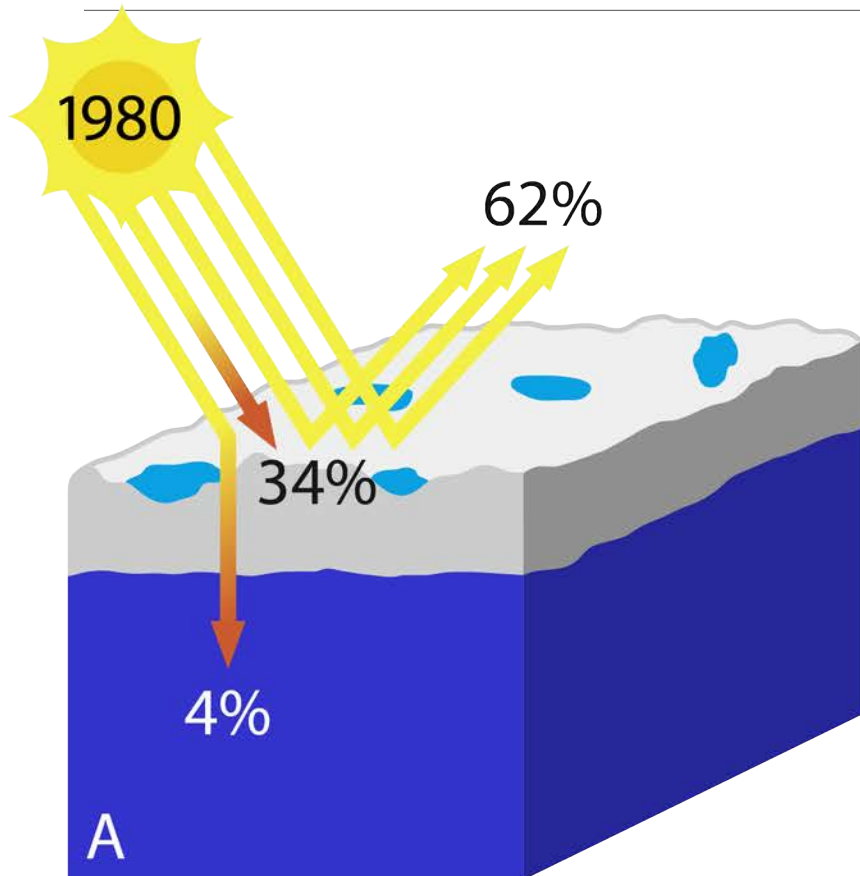
# Spatial Variability of Light



Main result:

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

# Observed Changes

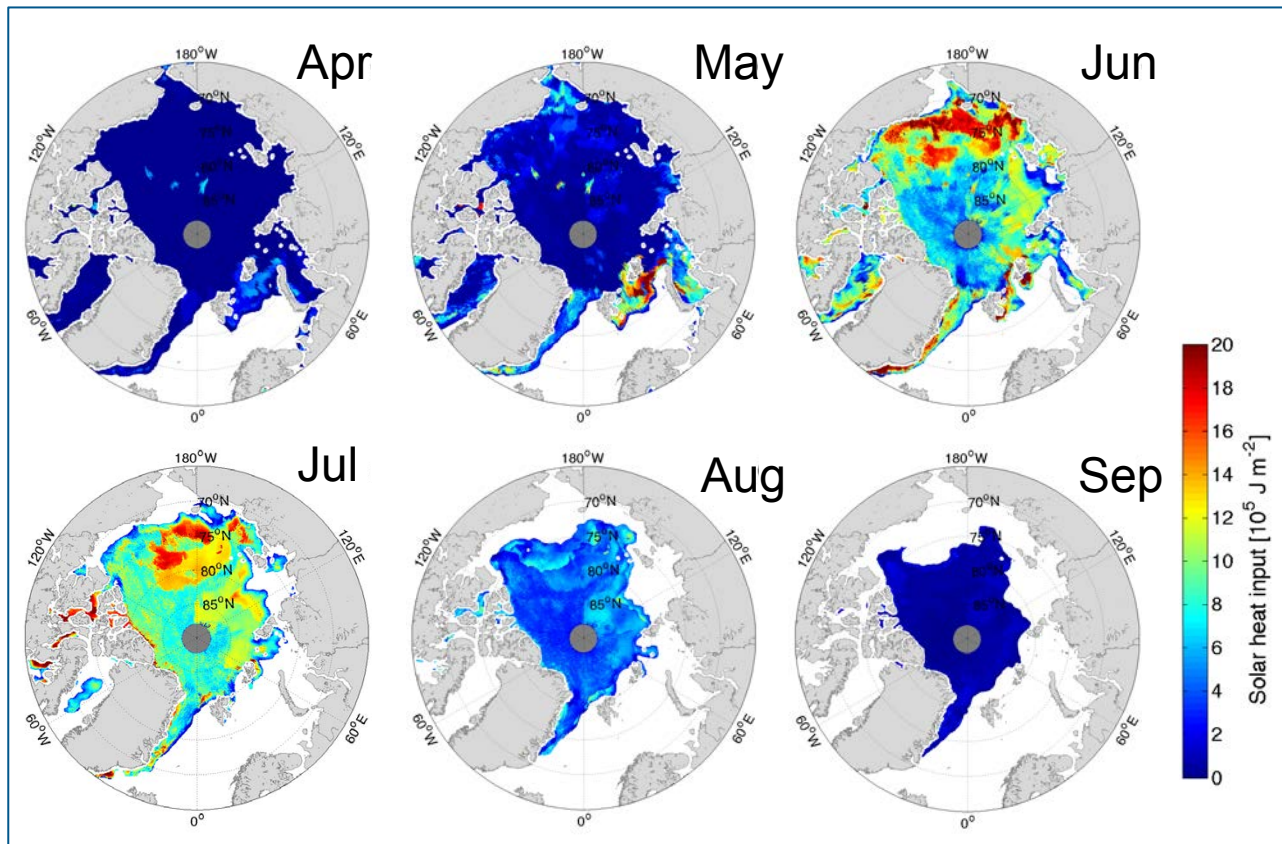


© M. Nicolaus | AWI

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

# Seasonality of Transmitted Fluxes

- Add parameterization of transmittance for the entire year 2011

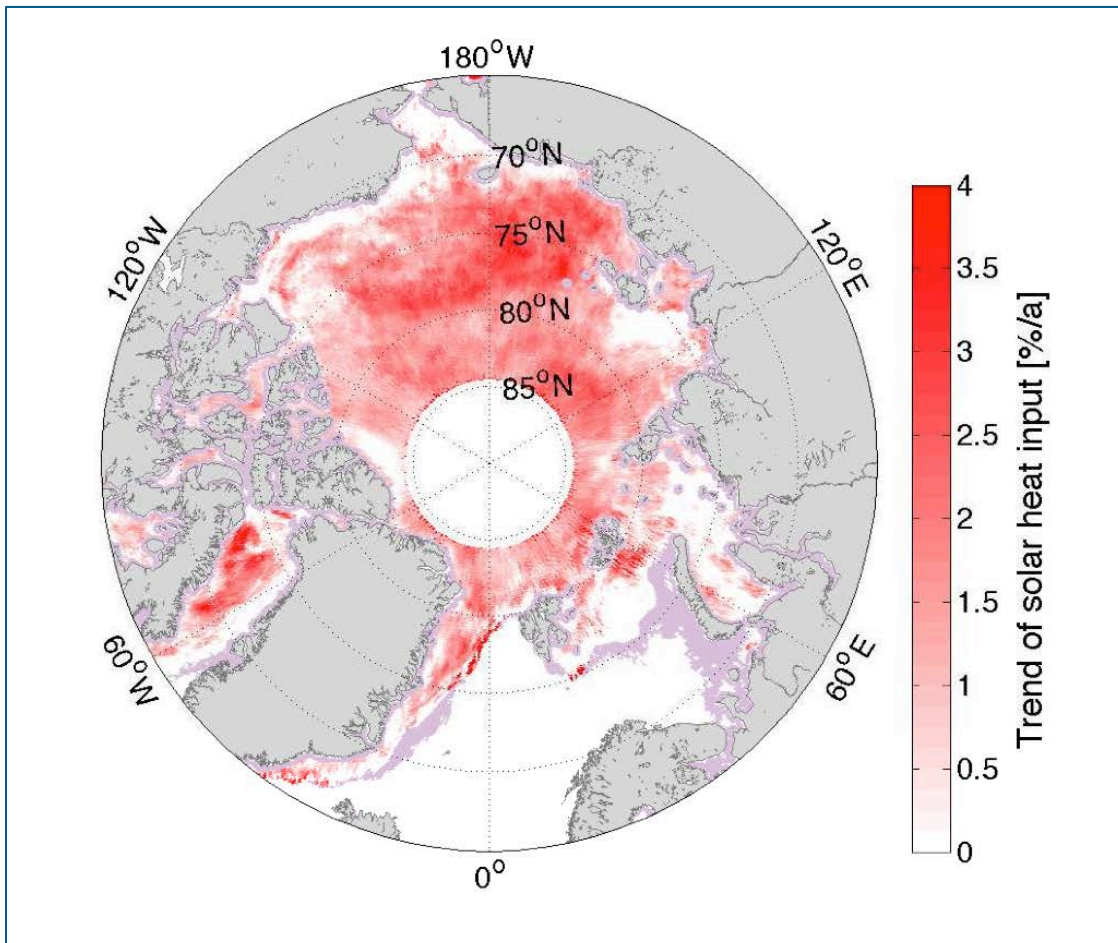


- **96 %** of the annual under-ice radiation are transmitted in only 4 months (May to August)  
 $\cong 51.2 \times 10^{19} \text{ J}$
- Highest fluxes in **June** ( $20.9 \times 10^{19} \text{ J}$ )

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

# Annual Trend (Sea Ice Only)

- Apply to all years 1979-2011

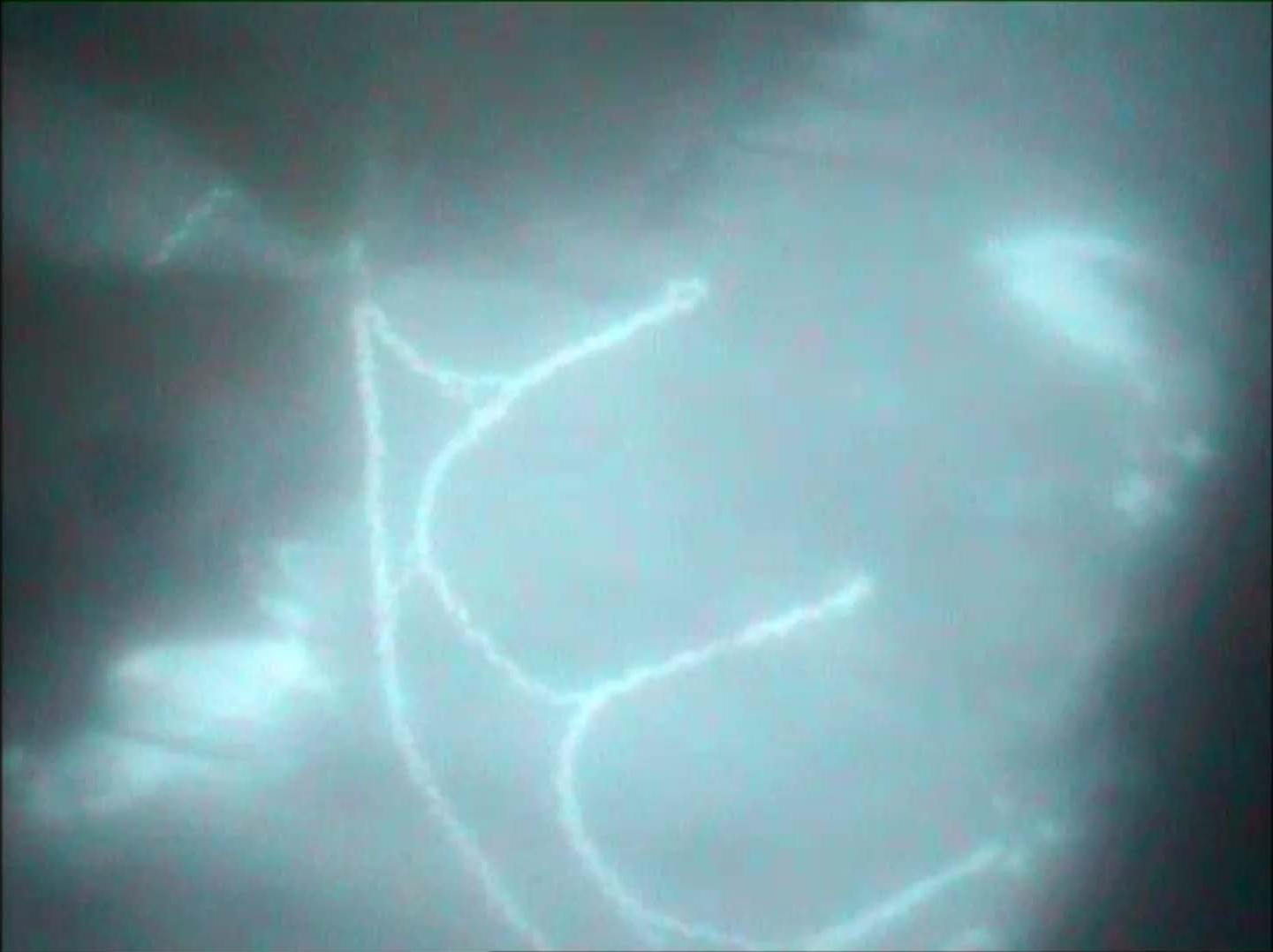


- Light transmission increases by **1.5% per year** Arctic-wide since 1979

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



# Impact of Snow

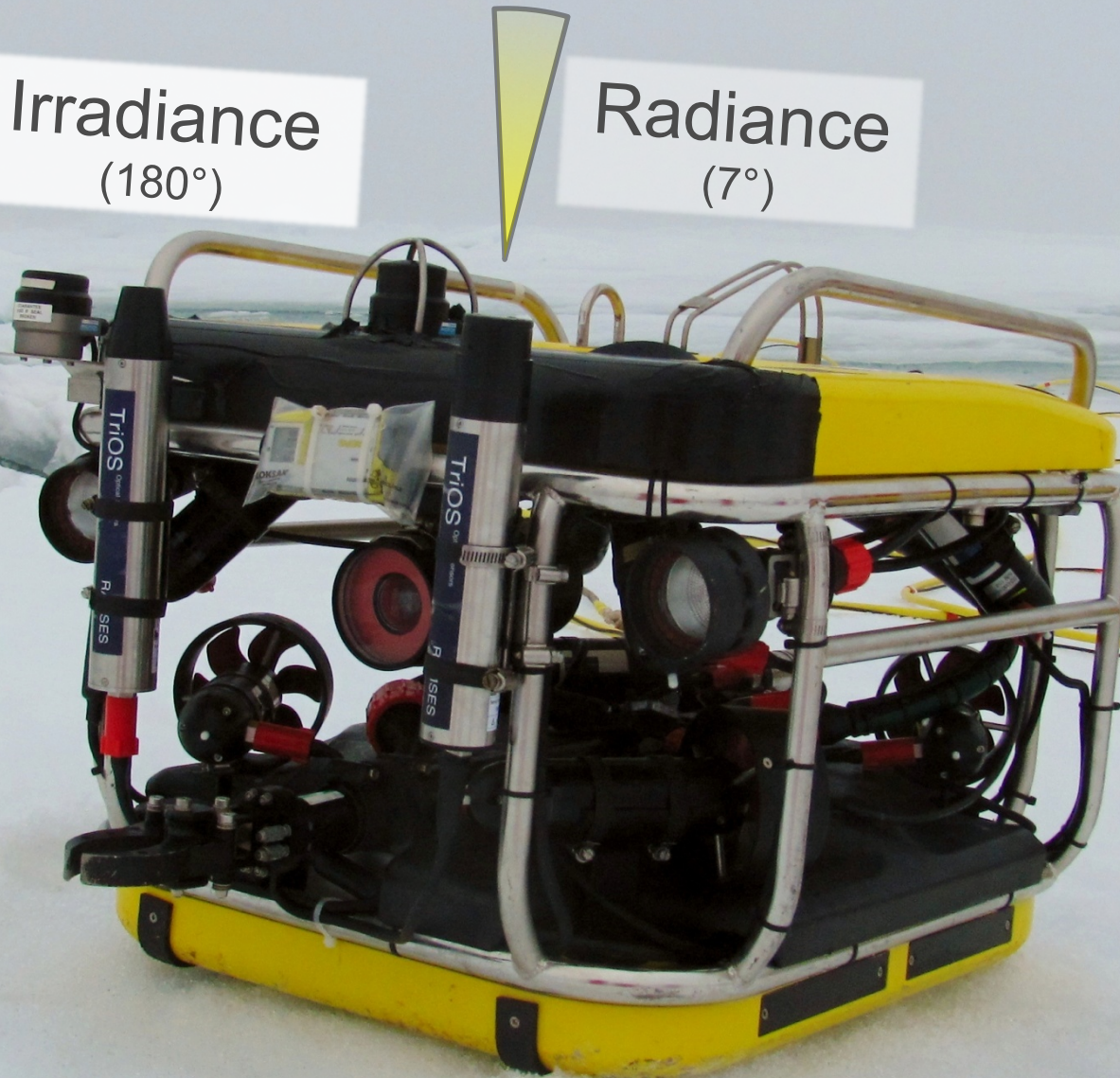


# Optical Properties - Scattering



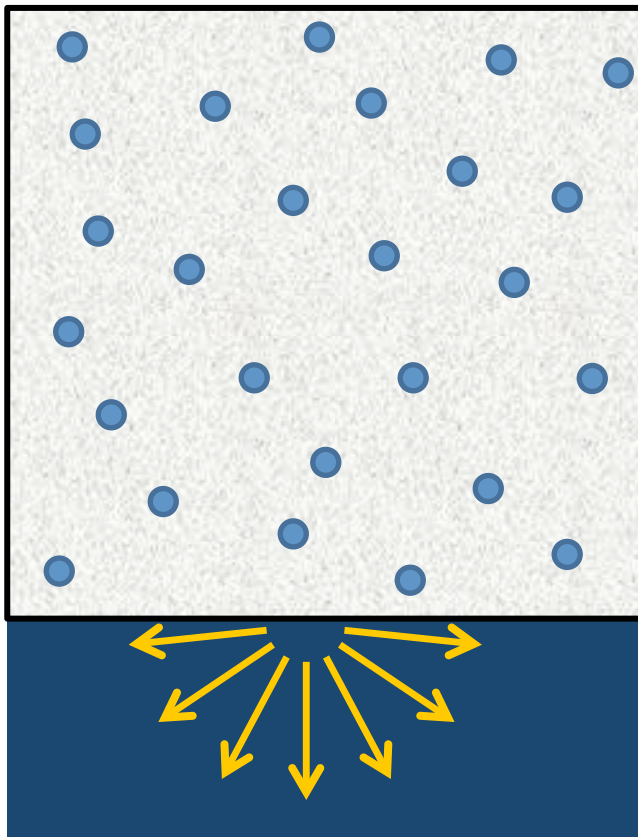
Irradiance  
(180°)

Radiance  
(7°)

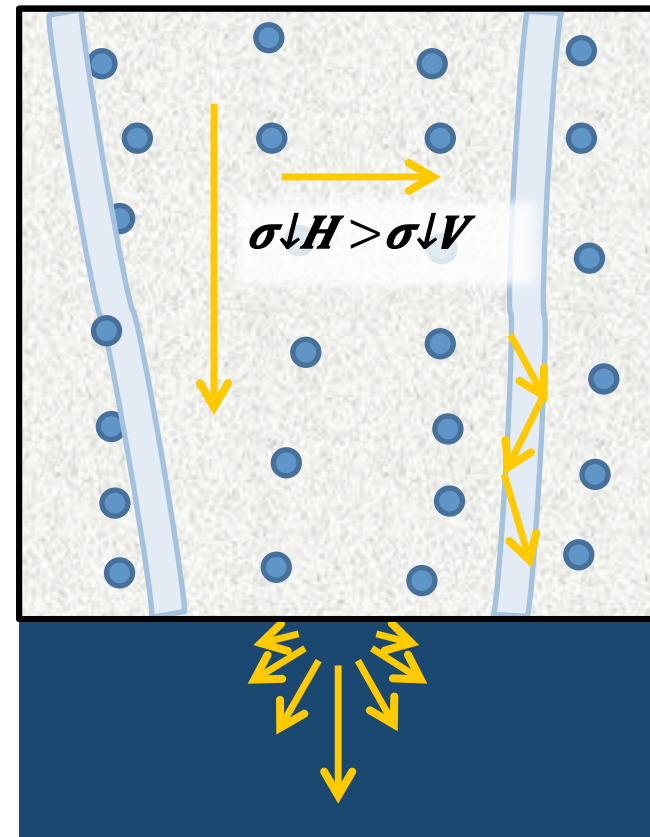


# Irradiance / Radiance

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

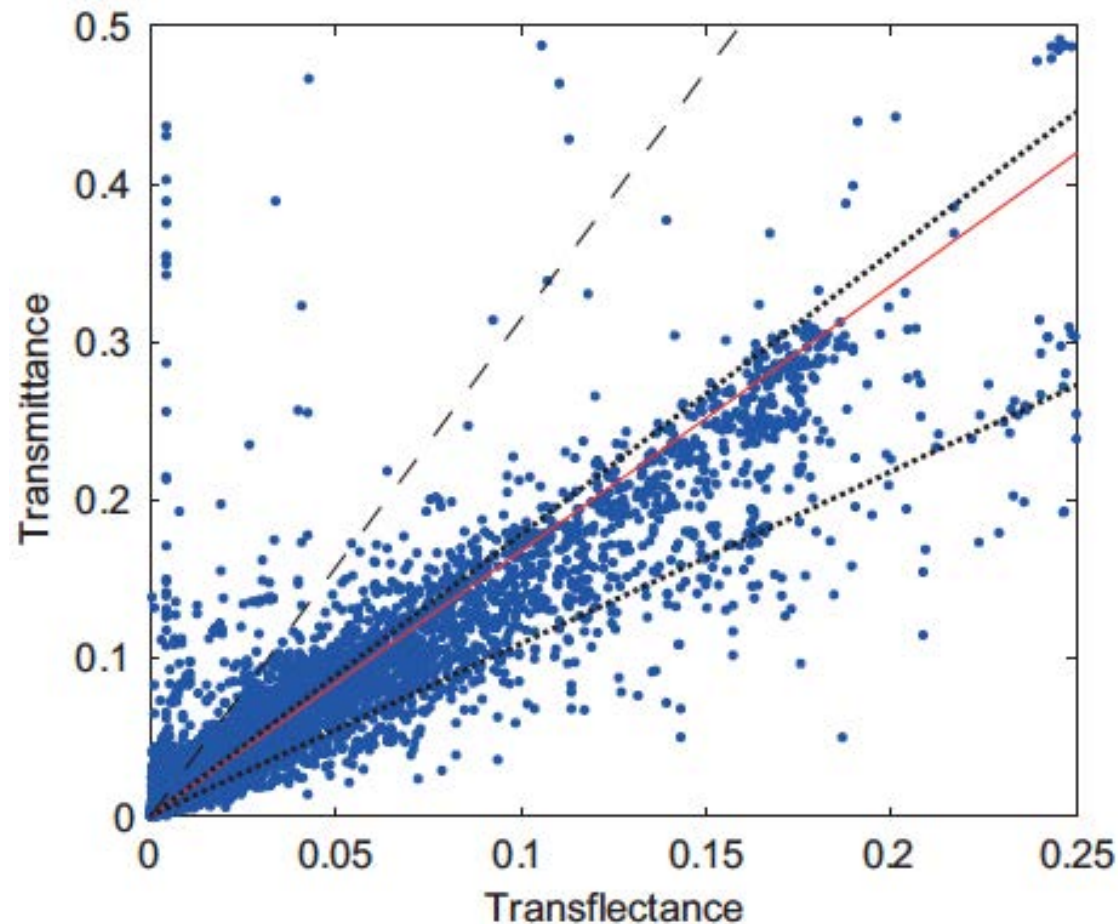


- Anisotropy  $C<2.5$
- More realistic fluxes



# Irradiance / Radiance

- Isotropy  $C=\pi=3.14$
- Mostly used, but overestimation of irradiance by >50%
- Anisotropy  $C<2.5$
- More realistic fluxes



# Autonomous Stations (Arc & Ant)



## Sea-Ice Thickness



## Snow Depth

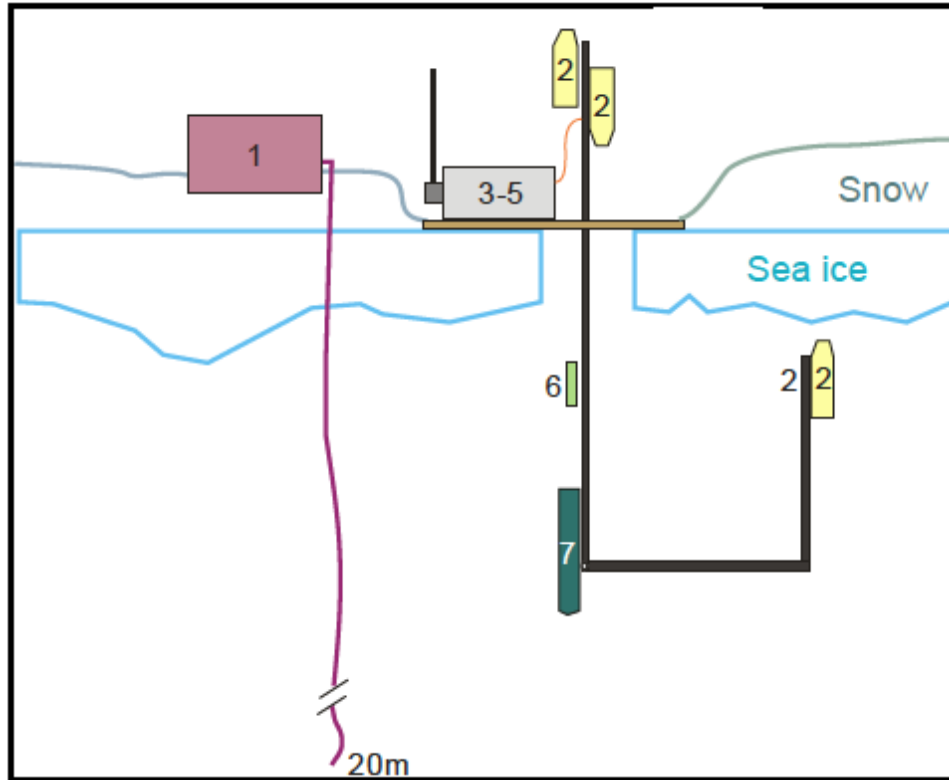


Photo: A. Mahoney (U Alaska)

## Energy budgets



# Bio-Physical Observatory (drifting)



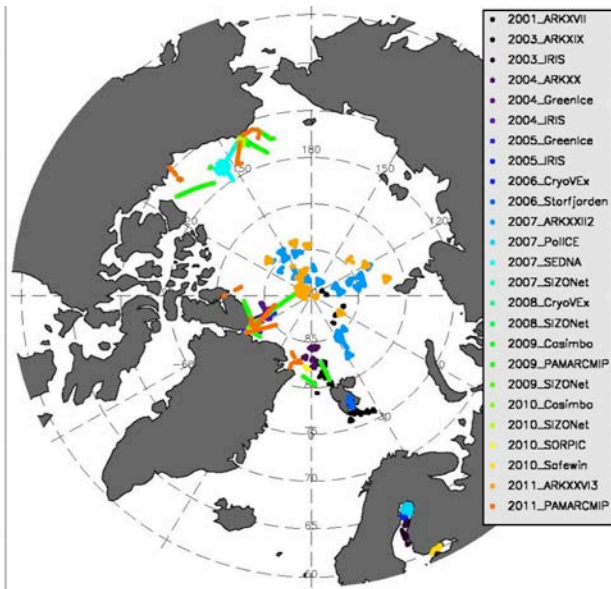
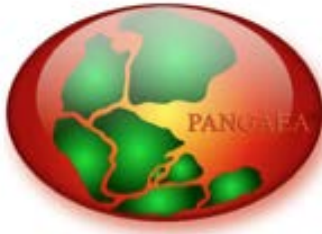
- Instrumentation
  - 1 Thermistor Buoy
  - 2 Spectral Radiation Buoy
  - 3-5 Data Transmission
  - 6 CTD
  - 7 ADCP
- Deployment 2014/15

# AWI Sea Ice Data Online



PANGAEA®

Data Publisher for Earth & Environmental Science



meereisportal.de

AWI

Startseite Meeresswissen Meeressbeobachtung Meeressmodellierung MeeressExpedition DatenPortal

Aktuelles und Aktivitäten

- Archiv Kurzmeldungen
- Pressemittelungen
- meereisportal.de in den Medien

CryoSat Meeressprodukt

Feedback zum Meeressportal

- Feedback Formular

Glossar

Direkt zu ...

Suchen

Aktuelle Meeresskarten

Aktuelle MeeressExpedition

Aktuelle PolarsternExpedition  
ANT XX006 (8.6.-12.8.2013)

Kooperationspartner

IUP

Das Meeressportal

Das Meeress der Polargebiete Arktis und Antarktis bedeckt circa 7 Prozent unseres Planeten, eine Fläche, die größer ist als Europa. Doch diese 7 Prozent haben einen verhältnismäßig großen Einfluss auf das globale Klima. Meeress steuert insbesondere den Wärme- und Süßwasseraustausch der polaren Ozeane und spielt somit eine entscheidende Rolle im Klimasystem der Erde. Struktur, Volumen und Flächenausdehnung von Meeress sind außerordentlich differenziert und variabel. Aufgrund dieser physikalischen Eigenschaften besitzt Meeress einen erheblichen Einfluss auf den Energiehaushalt der Erdoberfläche. Meeress ist ein sehr komplexes Gebilde, gehört aber gleichzeitig zu einem der sicherlich interessantesten und einflussreichsten Materialien auf unserem Planeten. Zudem ist Meeress ein ganz besonders faszinierender Lebensraum, unerlässlich für das Ökosystem der Polargebiete.

meereisportal.de ist eine Initiative des Alfred-Wegener-Instituts, Helmholtz Zentrum für Polar- und Meeressforschung, in Kooperation mit der Universität Bremen (Institut für Umweltphysik) mit dem Ziel, alle wichtigen und aktuellen Informationen rund um das Thema Meeress zusammenzubringen und für die Öffentlichkeit verfügbar zu machen. Das Portal bietet hierfür umfangreiche Hintergrundinformationen, aufbereitetes Datenmaterial, sowie den direkten Zugriff auf die Datenbasis.

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

# 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



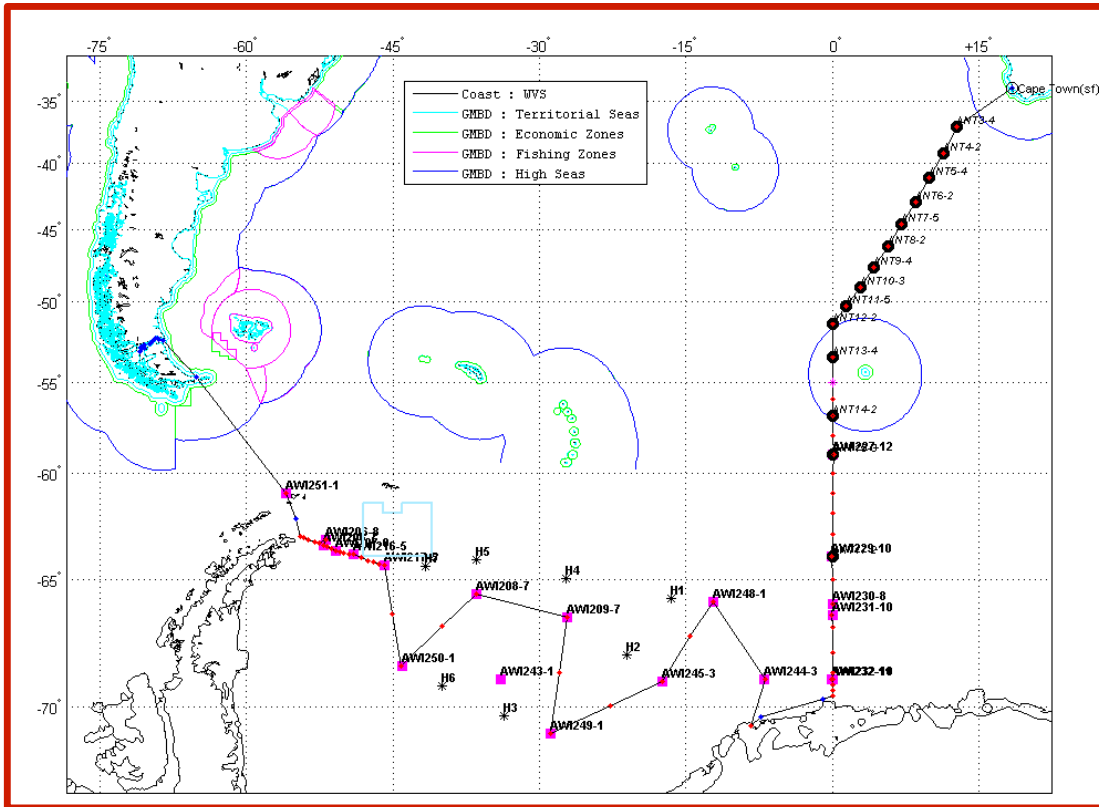
# Future Topics and Plans

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- 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



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

Cape Town 1.12.2014 – Punta Arena 1.2.2015