Observing Arctic Sea Ice and its Changes

10 June 2014

Marcel Nicolaus and colleagues
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

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

Meereiskonzentration
01.06.2014
Ausdehnung:
11,96 Mio km²
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 Thickness from Polar5

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 Thickness

CryoSat-2

2012

2013

Uncertainty:
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

<table>
<thead>
<tr>
<th>Threshold:</th>
<th>40 %</th>
<th>50 %</th>
<th>80 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar 2013</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
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<tr>
<td>Nov 2013</td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>

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

Albedo

Transmittance

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
View from Below: Level Ice
Main result:

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

Nicolaus et al. (2012 & 2013, GRL)
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

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

\[ 51.2 \times 10^{19} \text{ J} \]

- Highest fluxes in June \((20.9 \times 10^{19} \text{ J})\)

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

Arndt 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

- Irradiance (180°)
- Radiance (7°)

Katlein et al. (2014, JGR)
Irradiance / Radiance

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

- **Anisotropy** $C<2.5$
  - More realistic fluxes

Katlein et al. (2014, JGR)
Irradiance / Radiance

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

- Anisotropy $C < 2.5$
- More realistic fluxes

Katlein et al. (2014, JGR)
Autonomous Stations (Arc & Ant)

Sea-Ice Thickness

Snow Depth

Energy budgets

Photo: A. Mahoney (U Alaska)
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

- 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

- **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