Sea Ice of the Arctic and Antarctic: How Remote Sensing Specialists See It

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Why are we interested in sea ice?

• …regulates exchanges of heat, moisture, momentum and matter between the ocean and the atmosphere.
• …has a much higher reflectivity than the open ocean surface.
• …affects marine traffic and offshore operations, settlements, economy, biological habitats…

Ice properties can vary rapidly in response to weather and climate.
Record Arctic ice melt 'like a giant slushie'  

11:52 AM Tuesday Aug 28, 2012

The sea ice in the Arctic Ocean has melted to its smallest point ever in a milestone that may show that worst-case forecasts on climate change are coming true, US scientists said today.

The extent of ice observed at the weekend broke a record set in 2007 and will likely melt further with several weeks of summer still to come, according to data from the National Snow and Ice Data Center and the Nasa space agency.

The extent of Arctic sea ice on Aug. 26, 2012, the day the sea ice dipped to its smallest extent ever recorded in more than three decades of satellite measurements.  

Photo / NASA
Decrease of Arctic Summer Sea Ice Extent

Average Monthly Arctic Sea Ice Extent September 1979 - 2014

+13.3% per decade

http://nsidc.org/
Arctic Sea Ice Seasonal Variations

Arctic Sea Ice Extent
(Area of ocean with at least 15% sea ice)

Extent (millions of square kilometers)

Jun  Jul  Aug  Sep  Oct

2014  2013  2012  2011  2010

1981–2010 Average  ±2 Standard Deviations

National Snow and Ice Data Center, Boulder CO

02 Oct 2014

http://nsidc.org/
Decrease of Arctic Sea Ice Thickness

Source: Kwok & Rothrock, GRL, 2009
...and around Antarctica?

Increase of Antarctic Winter Sea Ice Extent

Average Monthly Antarctic Sea Ice Extent
September 1979 - 2014

+1.3% per decade

http://nsidc.org/
Antarctic: Sea Ice Extent Summer/Winter

Total extent = 3.8 million sq km

http://nsidc.org/
How did/do we get this information?
Satellite Sensors

Examples:

ASCAT on MetOP

SIRAL on Cryosat-2

TerraSAR-X

AMSR2 on GCOM-W1
Image Products *Retrieved* From Satellite Data

- **sea ice extent, concentration**
  - passive microwave radiometer
  - (extent: scatterometer)
  
  [Link](http://www.seaice.dk/N/)

- **sea ice thickness**
  - altimeter (≥ 1m)
  - passive microwave radiometer

[Link](http://spaceinimages.esa.int/Images/2011/06/Arctic_sea-ice_thickness)
Passive Microwave Radiometer

... measures thermal radiation of the Earth’s surface in the range 1-100GHz

Source: Carsey, 1992
...ice concentration is retrieved using mixture formulas:

\[ T_B = (1-C)\varepsilon_w T_w + C\varepsilon_i T_i \]

→ combination of different channels

Problems:
- melting conditions
- unknown ice type composition
- unknown snow cover properties
### Altimeter (Laser, Radar)

<table>
<thead>
<tr>
<th></th>
<th>Cryosat-2</th>
<th>ICESAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>spatial resolution</td>
<td>250 m along track</td>
<td>170 m</td>
</tr>
<tr>
<td></td>
<td>1.5 km across track</td>
<td></td>
</tr>
<tr>
<td>accuracy</td>
<td>≈ 20-70 cm</td>
<td>1-3 cm freeboard</td>
</tr>
<tr>
<td>thickness</td>
<td></td>
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Measuring Sea Ice Thickness using Satellite Laser and Radar Altimeters

- Snow Freeboard
- Snow \( \rho_s h_s \)
- Sea Ice \( \rho_i \)
- Water \( \rho_w \)

Sea Ice Thickness
Altimeter: *Retrieval* of Sea Ice Thickness

- separate radar echos: “FY- and MY-ice” versus “open water and thin ice”

- freeboard: subtract travel times over water from travel times over ice

- conversion of freeboard into thickness (hydrostatic equilibrium, required: ice and water densities, snow mass)

**Thickness** \( t_E \) of ice with snow load of mass \( m_S \) per unit area:

\[
t_E = \frac{\rho_W}{\rho_W - \rho_E} f_E + \frac{1}{\rho_W - \rho_E} m_S
\]

\( \rho_E, \rho_W \) - ice and water density
How strong are variations of the ice parameter (to be retrieved) reflected in the signal that is received by the satellite instrument? (sensitivities…)

Which additional parameters (aside from the one of interest) do influence the measurements? (meteorological conditions, snow and ice properties)

How accurate are the retrieval algorithms?
We Need to Measure On the Ice!!

Field-Expedition 2013 (K063, W. Rack & co-workers)

Snow parameters determined:
- thickness
- density
- grain sizes
- stratigraphy
- hardness

Photos: W. Rack, Gateway Antarctica
We Need The Regional View From Satellite!

Radar Image
TerraSAR-X (TSX)
ScanSAR Mode
100 km swath,
20 – 50 m resolution
Region:
McMurdo Sound / Ross Sea
... Sometimes at Even Higher Spatial Resolution

Color composites of TSX-images acquired at different polarizations (stripmap-mode, swath width 15 km, resolution 5-20 m)
SNOWonICE

• Project funded by the New Zealand – Germany Science and Technology Programme

• Subject: Retrieving properties of sea ice snow cover from data of different satellite instruments

• Emphasis is on radar and optical sensors with high spatial resolution (25-100 m)
Be curious!

Thank you for your attention!