Observing Arctic Sea Ice Change

Christian Haas
Decreasing Arctic sea ice extent in September

- Ice extent is decreasing, but regional patterns are very different every year
• Strong seasonal variability
• Smaller, decreasing trends in winter
Arctic sea ice decline

- Strong decline in summer
- Climate models (IPCC) underestimate actual rate of decline
- Tipping points?
• “The surplus heat needed to explain the loss of Arctic sea ice during the past few decades is on the order of 1 W/m². Observing, attributing, and predicting such a small amount of energy remain daunting problems”

Kwok and Untersteiner, 2011
Arctic versus Antarctic sea ice trends

- Arctic sea ice shrinkage due to increasing air temperatures?
- Antarctic expansion related to stratospheric vortex and ozone hole
Why do we care?

• Arctic Amplification -> impact on ice sheets/caps and permafrost
• Better access to the Arctic
• Consequences for local, regional, global eco- and human systems
Arctic Amplification

- Through snow and ice-albedo feedback Arctic warms more rapidly than any other region
- Impacts on permafrost, Greenland ice sheet and Arctic glaciers (SEA LEVEL RISE), regional (and global?) weather
Arctic Amplification
“Thin ice feedback”

- Figure shows observed Sep-Nov temperature anomalies (2003-2007 minus 1979-2007), and corresponding September anomalies in the number of days with ice cover (dark blue bars) and in ice concentration (black line).

- Warming due to
  - longer ice-free season
  - thinner ice

Serreze et al., 2009
Other observations of sea ice change

- Ice drift
- Ice age
- Ice thickness
Ice drift and thickness

- Ice drift mainly governed by mean wind patterns
- Dependent on sea level pressure
Increased ice drift speed and deformation

• International Arctic Buoy Program Data

• Ice mean speed has increased over the last 29 years: +17% per decade in winter, +8.5% in summer

• Changed ice rheology?

Rampal et al., JGR, 2009
Retreat of the oldest, thick multiyear ice
Arctic Sea Ice Is Thinning
Ice depth levels in autumn

2005
1980

DEPTH IN FEET
0 3 6 9 12 15 18

climatecentral.org
Upward looking sonar (ULS): Military nuclear submarines of USA & UK since 1958
EM thickness sounding

\[ Z_i = u_{\text{EM}} - u_{\text{Laser}} \text{ (snow/ice)} \]
Airborne Sea Ice Observatory

- Real-time ice thickness surveying and other airborne and satellite remote sensing
- Buoy deployments to observe sea ice drift (TC approved)
Typical AEM thickness profile
Processes changing the ice thickness distribution

Thorndike et al., 1975
Flato & Hibler, 1995
Hopkins, 1998
etc
Artctic thickness snapshot, April 2009
Ice thickness north of Ellesmere Island between 83°N and 84°N, 2004 - 2014

- Mean thickness decreased from 5+ m to <4 m
- Modal thickness decreased from >4 m to ≈3 m
- Large variability in 2008-2010 may be due to redistribution of old MYI

Maslanik et al., GRL, 2011

Ice thickness north of Ellesmere Island between 83°N and 84°N, 2004 - 2014

- Mean thickness decreased from 5+ m to <4 m
- Modal thickness decreased from >4 m to ≈3 m
- Large variability in 2008-2010 may be due to redistribution of old MYI

Maslanik et al., GRL, 2011
Satellite laser and radar altimetry

**Principle:** \( F = h_{\text{ellip}} - D_{\text{laser}} - h_{\text{geoid}} - \Delta h \)

\( \Delta h \): Ocean dynamic topography

- **“ICESat” & “CryoSat”**
- **NASA & ESA**
- Method relies on assumptions of snow and ice density and snow thickness
Synthesis of North Pole ice thickness changes from ULS, ICESat, and EM

- Note seasonal and regional differences

Lincoln Sea, Canada

Kwok & Rothrock, 2009; Haas, 2006 & updated
Skidoo EM thickness surveys

- “Community based” observations in Canadian Arctic
- Close collaboration with local hunters and Canadian Rangers
• “Discovery” of thin ice in fjords
• Due to enhanced ocean heat flux
• Possible future polynyas?
Polynyas and primary productivity

Melling, Haas, Brossier, unpublished
Home Bay, Baffin Island (May 2014)
The Future
Consequences

• Easier shipping?
• Better access to natural resources?
• Threat to Canadian Sovereignty?
• “Last refuge” for sea ice
Northwest Passage & Northern Sea Route

- 46 vessels used NSR in 2012, 34 in 2011, 4 in 2010
- 53% cargo increase from 2011
- Included first fully loaded LNG tanker

Shipping distance from Yokohama, Japan, to Rotterdam, Netherlands (nautical miles)

- Through the Suez Canal: 5,615 miles
- Through the Panama Canal: 11,309 miles
- Around the Cape of Good Hope: 14,735 miles

Snow Forts: To defend its claims in the Arctic, Russia plans to build a deepwater naval port in Narvik and a new cold-weather combat training center in Resolute Bay, while also expanding satellite surveillance. Other countries are rattling sabers in the region. Russia, for example, has resumed strategic bomber flights over the Arctic and last summer dispatched two military vessels to the disputed waters off the Svalbard Islands.

(Polar Express) The fabled Northwest Passage opened this summer for the second time in history—and the second year in a row. The Northeast Passage (also called the Northern Sea Route) over Eurasia first fully opened in 2005; shipping is already extensive within that region, particularly in the Barents Sea. Yet both routes, sought by ancient mariners, are likely to be used for only a few years. By 2025, if not before, most ships in the Arctic will likely sail straight over the pole, avoiding coastal states jurisdictions and shaving still more miles off their journeys. Much of the world’s international shipping will revert itself as a result.

The New Entrepreneurs: Singapore’s location, amid key shipping lanes from East Asia to Europe, has enabled the country to become the richest in Southeast Asia. As sea lanes like the Bering and戴维straits become busier, ports towns like Dutch Harbor, Alaska (population 4,000), and Hammerfest, Norway (population 9,000), are likely to grow from off-the-way fishing ports into key shipping hubs. Russia recently committed $7 billion to port development in Murmansk. Places like Singapore or Panama, which is currently investing more than $5 billion to expand its canal, may see trade disappear from their doorsteps.

(Financial Freedom) Retreating ice is revealing up to 31 billion barrels of oil and natural gas off Greenland’s eastern coast, plus signs of enormous mineral deposits—gold, diamonds, zinc, and more—on land. Keen to establish their rights to these resources, 57,000 Greenlanders (more of them Inuit), whose territory has been protected by Denmark since 1791, will vote this month on a referendum for self-rule. Greenland will probably become the first country born from climate change.
Multiyear ice in the Northwest Passage

Ice thickness survey in 2011
Ship-based ice thickness surveys

- Ship performance & design; Exploration activities & ice management
Ship performance and ramming

Haas et al., 1999

V = 17.6 - 5.9 Z_i  
\( r = -0.92 \)
Observing Arctic Sea Ice Change

- Sea ice is an important part of the climate system and closely interacts with and controls the Arctic atmosphere.
- Disappearance of Arctic sea ice in summer seems likely – just when is completely unclear.
- Present trend is a consequence of preconditioning towards thinner, younger ice and superimposed interannual variability.
- Need for observation system comprising in-situ, airborne, and improved satellite data of the ocean-ice-atmosphere system.