Ice core reconstruction of past sea ice

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Overview

• How can we go beyond the instrumental period?

• What are the proxies?

• How has Antarctic sea ice changed since 1900?
  • How does this relate to Antarctic climate?
Antarctic sea ice

• Regional differences in sea ice extent and sea ice duration
  • Increased in Weddell and Ross Sea
  • Reduced in Bellingshausen

• But, observational period is short and sea ice is often poorly constrained in climate models

Why do we need longer records?

...to place recent changes in context
Ice core proxies

- A chemical species (or other) with a sea ice source or concentration dependent on sea ice conditions

- Isotopes
- Snowfall
- Sea salts
- MSA
- Halogens

\[^{18}\text{O}\text{ evaporates more easily than }^{16}\text{O}^{\text{\scalebox{0.7}{\footnotesize\text{\textendash}}}}\]

\[^{18}\text{O}\text{ is preferentially removed by precipitation}^{\text{\scalebox{0.7}{\footnotesize\text{\textendash}}}}\]
• Dimethylsulphide (DMS) produced by phytoplankton
• Oxidised to methanesulphonic acid (MSA) preserved in ice cores

Abram, Wolff & Curran, 2013
Sea ice proxy - Halogens

- Bromine and iodine species (Br\(^-\), BrO\(^-\)\(_3\), I\(^-\) and IO\(^-\)\(_3\) )
- “Bromine explosions”
  - source of Br from first year sea ice
- Iodine
  - instrumental and satellite measurements of high iodine in Antarctic coastal sea ice zone
Arctic - Halogens

- NEEM ice core
- Br enrichment
  - highest during Holocene (warm)
  - greatest extension of first year sea ice
- lowest during stadials (cold)
- complete coverage of Arctic ocean by multi-year sea ice

Dimethylsulphide (DMS) produced by phytoplankton
Oxidised to methanesulphonic acid (MSA) preserved in ice cores

Abram, Wolff & Curran, 2013
• **Positive**
  - Bellingshausen Sea and Indian sector
  - MSA dominated by source
  - onshore winds
  - positive MSA-Sea ice relationship

• **Negative**
  - Weddell Sea
  - MSA dominated by transport direction
  - cold offshore winds
  - negative MSA-Sea ice relationship

• **Other**
  - Amundsen and Ross Sea
  - elevated MSA from polynas
  - where summer sea ice persists
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Proxy for sea ice

SIE r=0.64, Chlorophyll r=0.5

Thomas, E. R., and Abram, N (2016), Ice core reconstruction of sea ice change in the Amundsen-Ross Seas since 1702 AD, GRL
Transport pathways

Thomas and Bracegirdle, Climate Dynamics, 2015
Transport pathways

- A persistent and deep ASL enhances southerly (offshore) winds over the southern Ross Sea
- Cooling surface air temperatures, opening up polynas and creating a region of strong sea ice production
Sea ice reconstruction

1998/99 strong El Nino

Thomas, E. R., and Abram., N (2016), Ice core reconstruction of sea ice change in the Amundsen-Ross Seas since 1702 AD, GRL
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Regional sea ice

Thomas and Abram (2016); Abram et al., (2010); Murphy et al., (2014)
Thomas et al., (2017) Regional Antarctica snow accumulation over the past 1000 years, *Climate of the Past*

Medley and Thomas (in prep)
Summary

• Chemistry of Antarctic ice cores can reconstruct past climate

• Ferrigno MSA is a robust proxy for SIC and winter SIE in the Amundsen-Ross Sea

• Estimated ~1º northward expansion of winter SIE during the 20th century and an overall expansion of ~1.3º since 1702
  • largest 50 and 30-year trends occurred at the end of the 20th century, with the highest absolute values observed during the mid-1990s.

• SIE in the Amundsen-Ross Sea explains a large amount of the decadal variability in surface temperatures in the western Antarctic Peninsula

• ...AND the large increase in SMB in Antarctic Peninsula since 1900 AD
Thomas et al., (2017) Regional Antarctica snow accumulation over the past 1000 years *Climate of the Past*

Medley and Thomas (in prep)