POLAR SCIENCE
FOR PLANET EARTH

Ice core reconstruction of past sea ice

Elizabeth Thomas

British Antarctic Survey, Cambridge, CB3 0ET

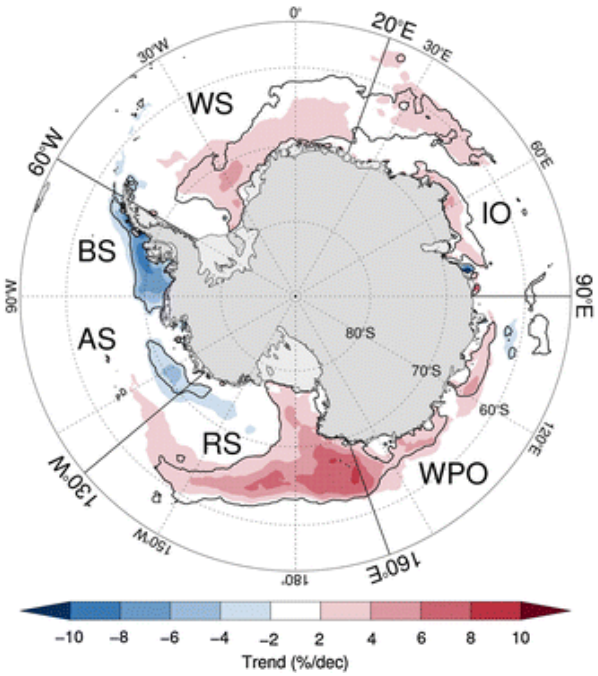
British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

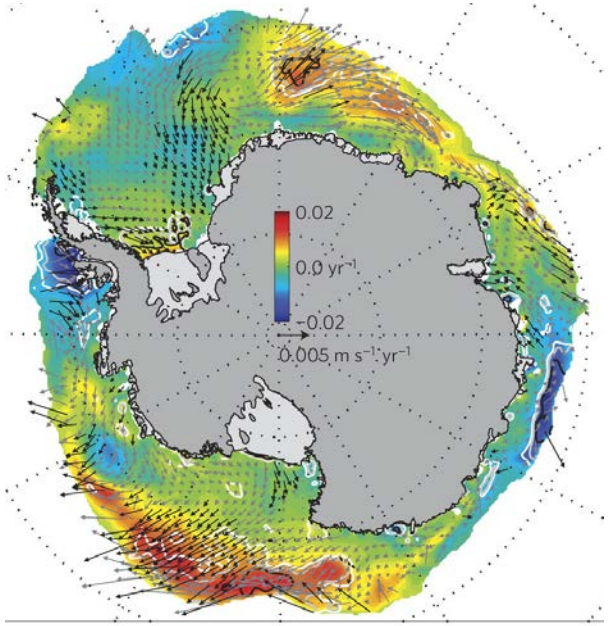
Overview

- 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

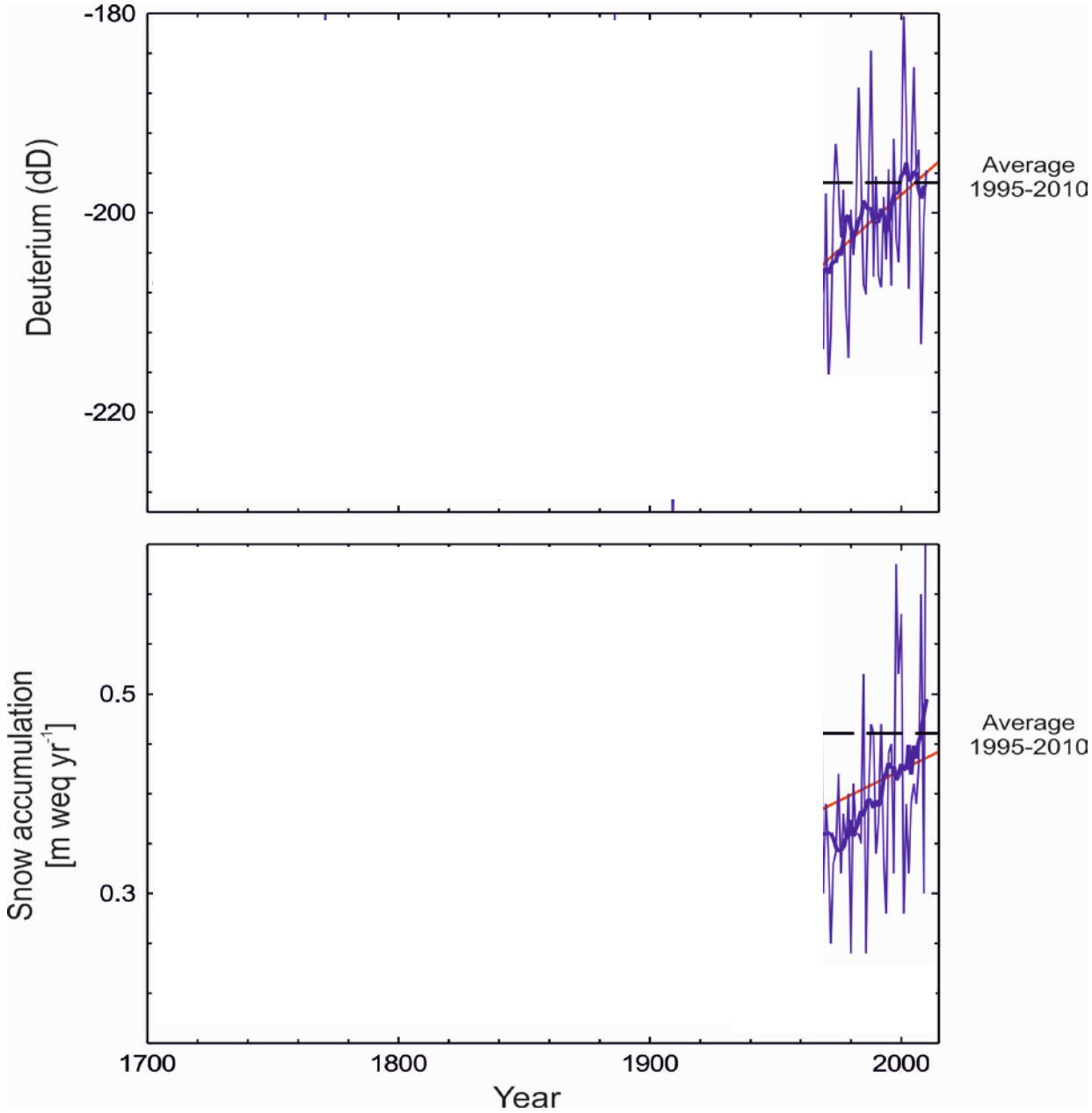




Turner et al., (2016), Holland and Kwok (2012)

Why do we need longer records?

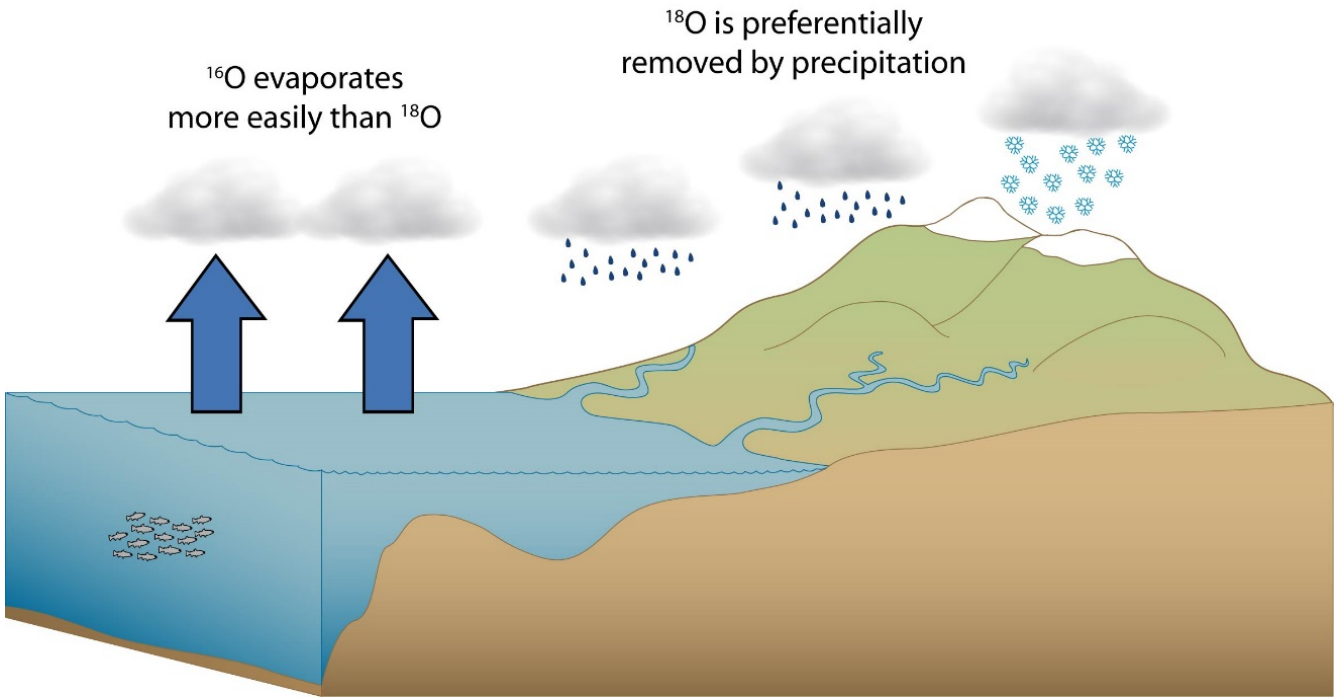
...to place recent changes in context



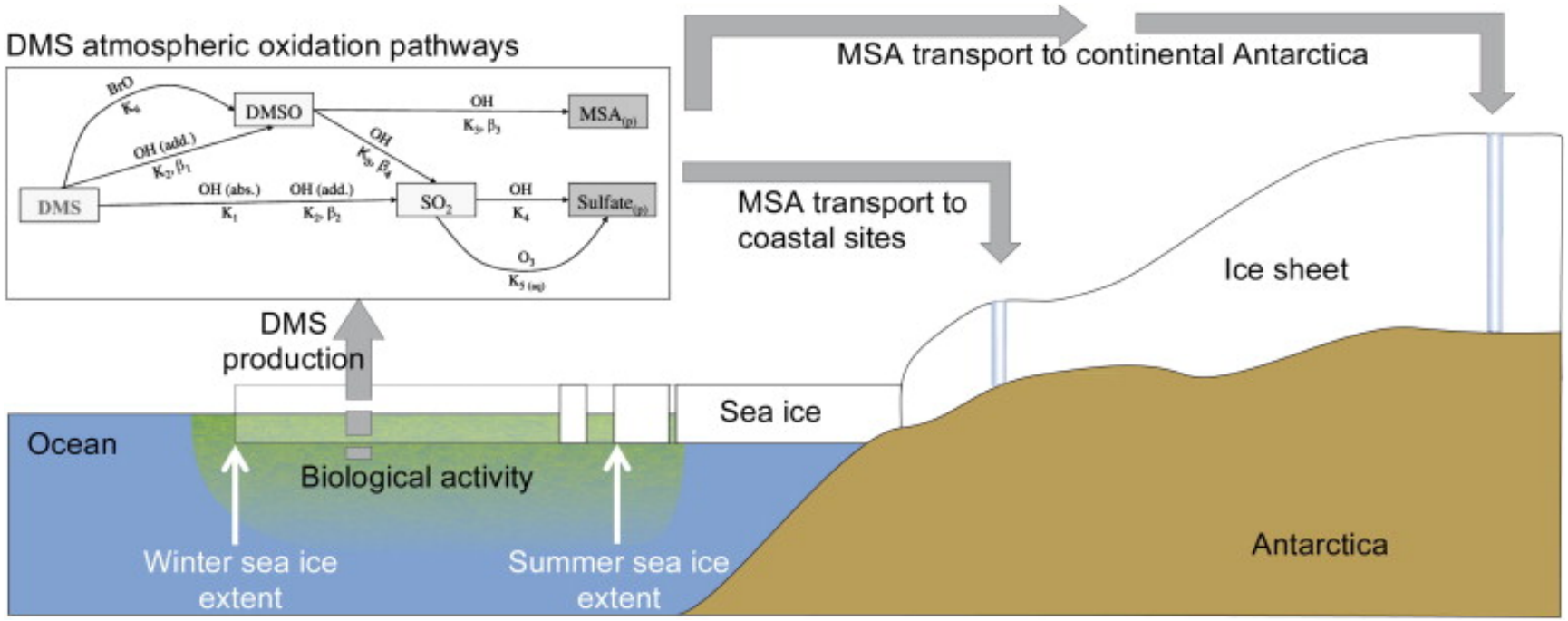
Ice core proxies

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

- Isotopes
- Snowfall
- Sea salts
- MSA
- Halogens



Sea ice proxy - MSA



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

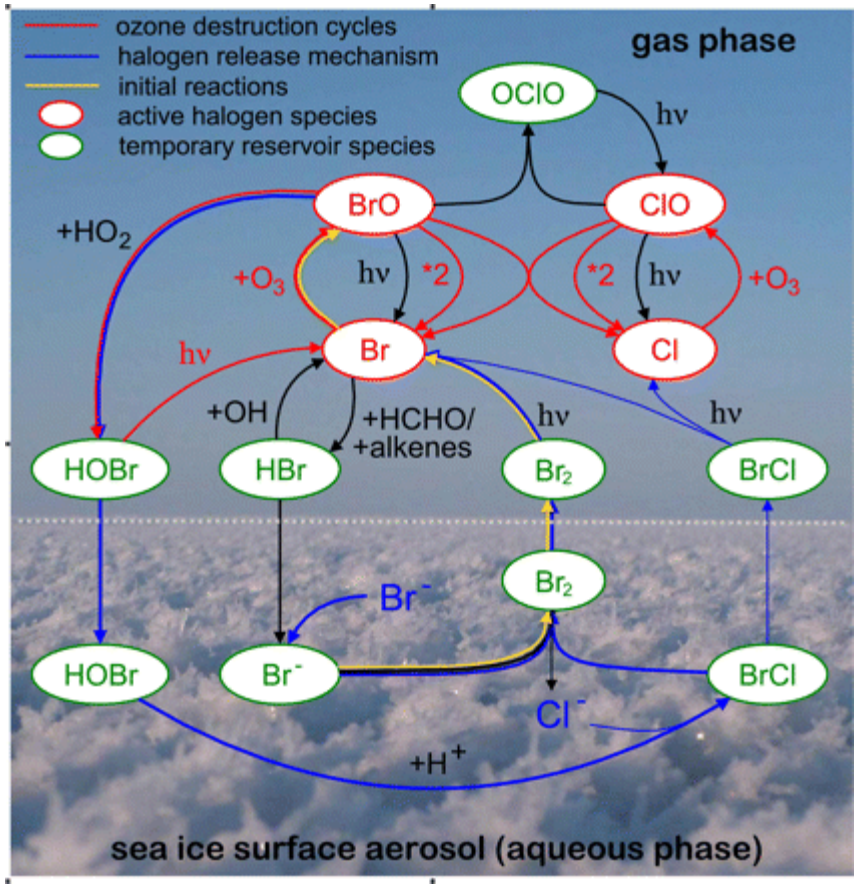
Abram, Wolff & Curran, 2013

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

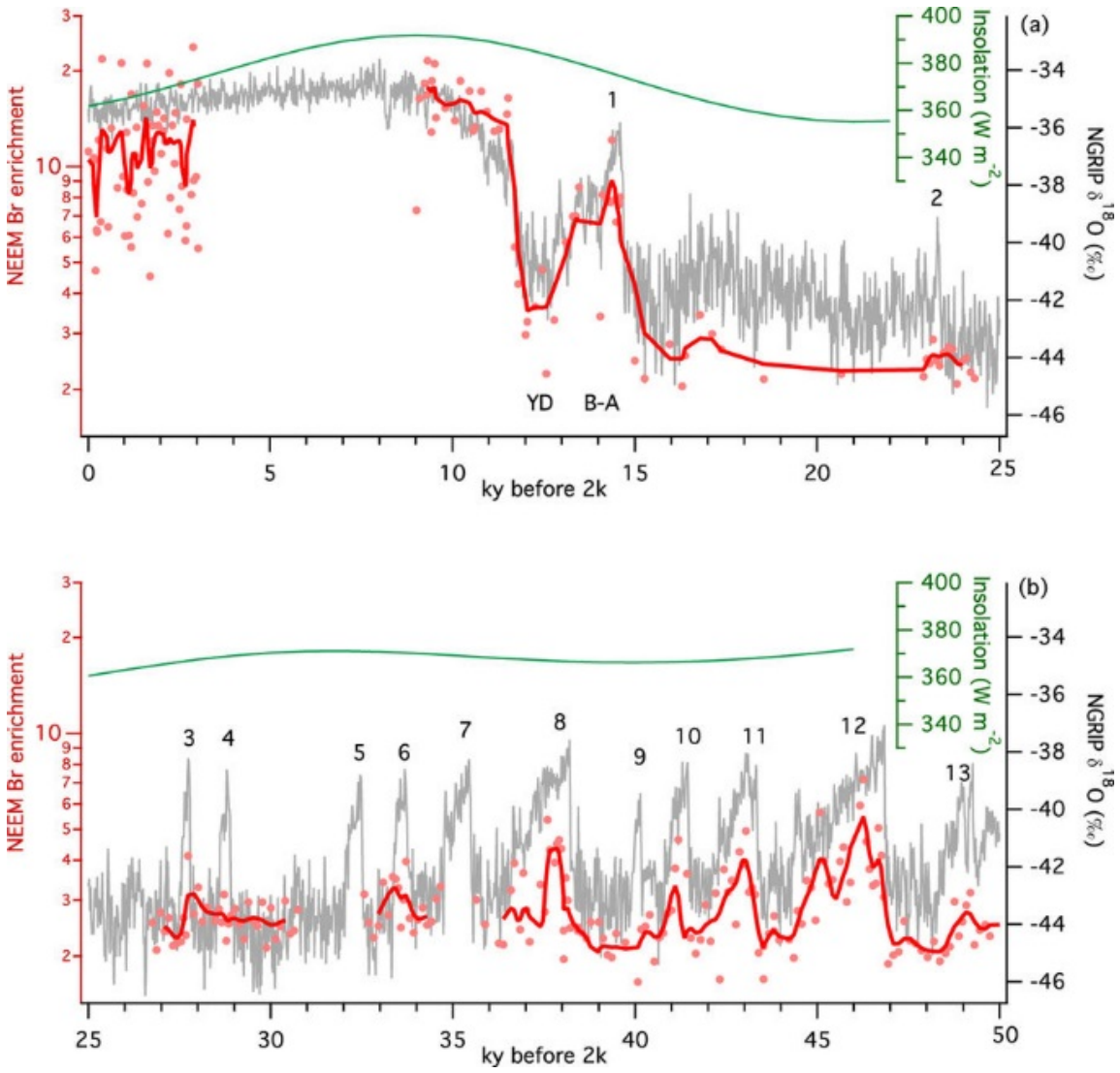
- Iodine
  - instrumental and satellite measurements of high iodine in Antarctic coastal sea ice zone



Arctic - Halogens

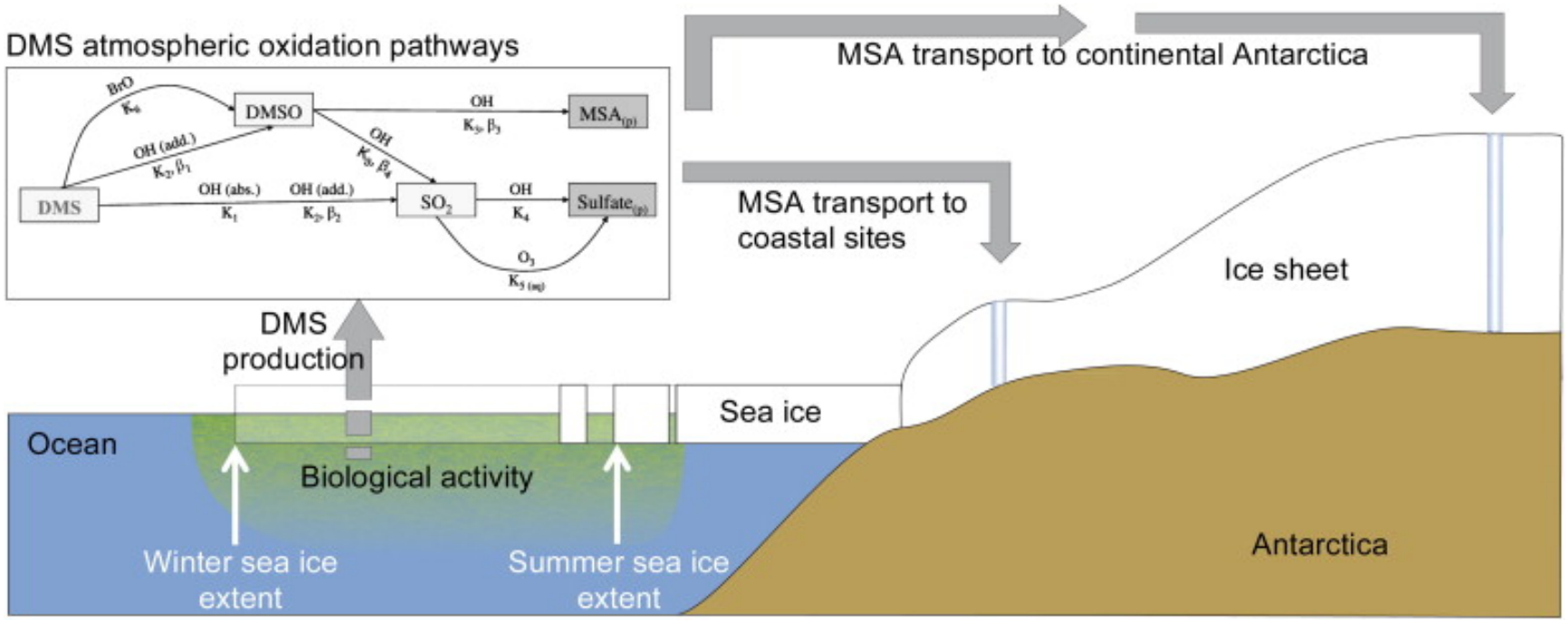
- NEEM ice core
- Br enrichment
  - highest during Holocene (warm)
  - greatest extension of first year sea ice

  - lowest during stadials (cold)
  - complete coverage of Arctic ocean by multi-year sea ice



Spolaor, A. *et al.* (2016) Canadian Arctic sea ice reconstructed from bromine in the Greenland NEEM ice core. *Sci. Rep.* **6**

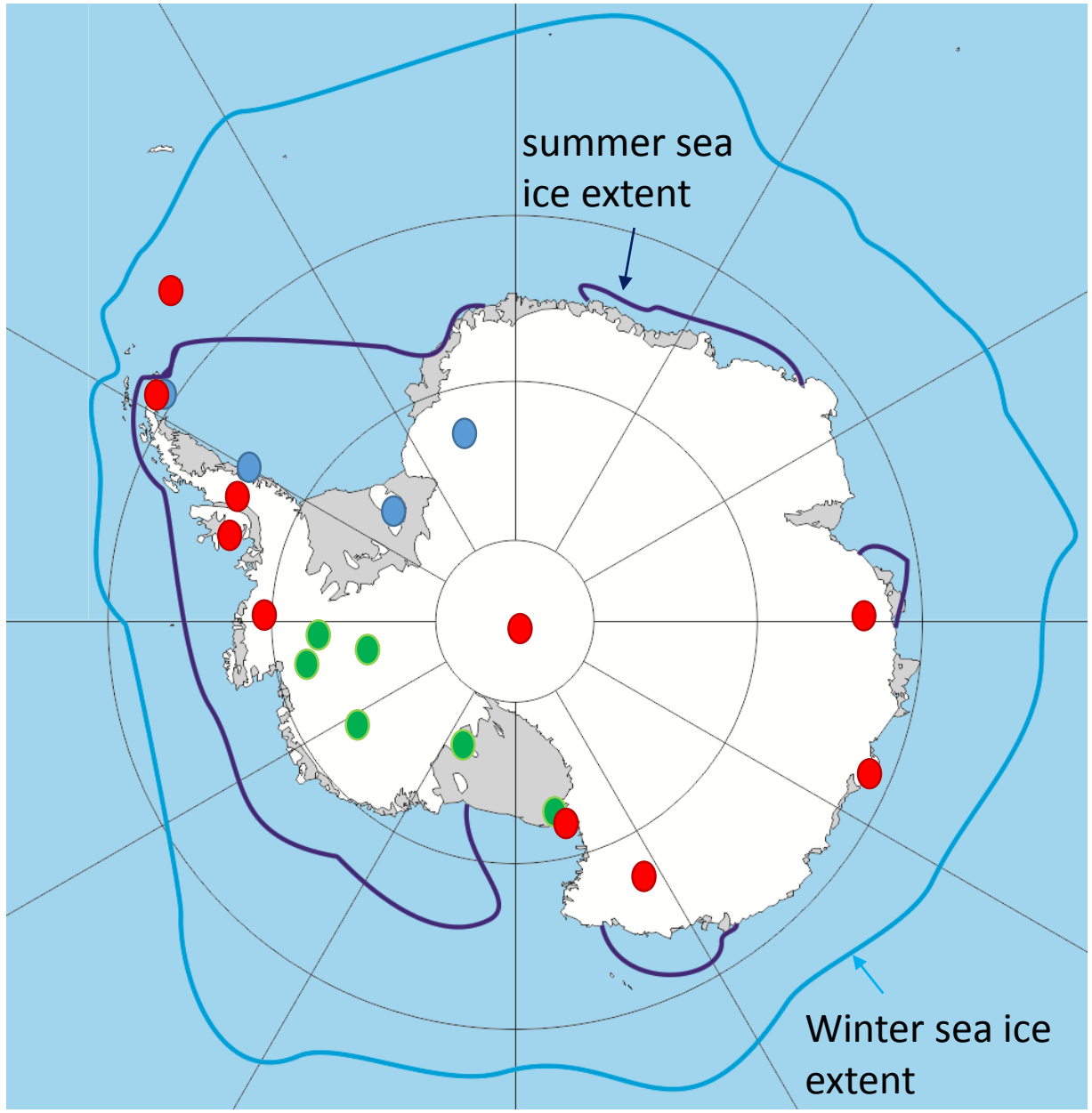
Sea ice proxy - MSA



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

Abram, Wolff & Curran, 2013

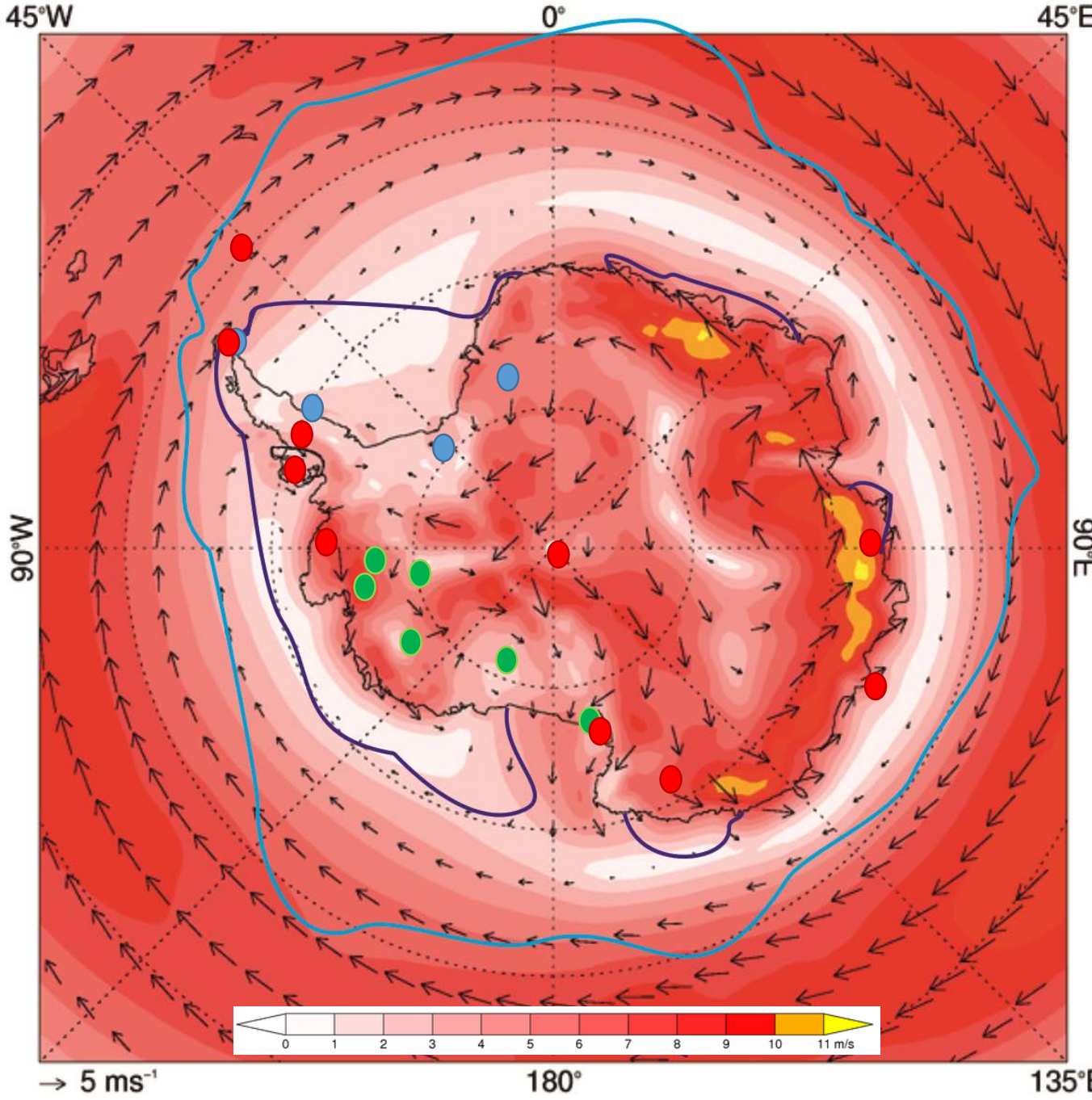
- Positive
  - Bellingshausen Sea and Indian sector
  - MSA dominated by source
  - onshore winds
  - positive MSA-Sea ice relationship
- Negative
  - Weddell Sea
  - MSA dominated by transport direction
  - cold offshore winds
  - negative MSA-Sea ice relationship
- Other
  - Amundsen and Ross Sea
  - elevated MSA from polynas
  - where summer sea ice persists



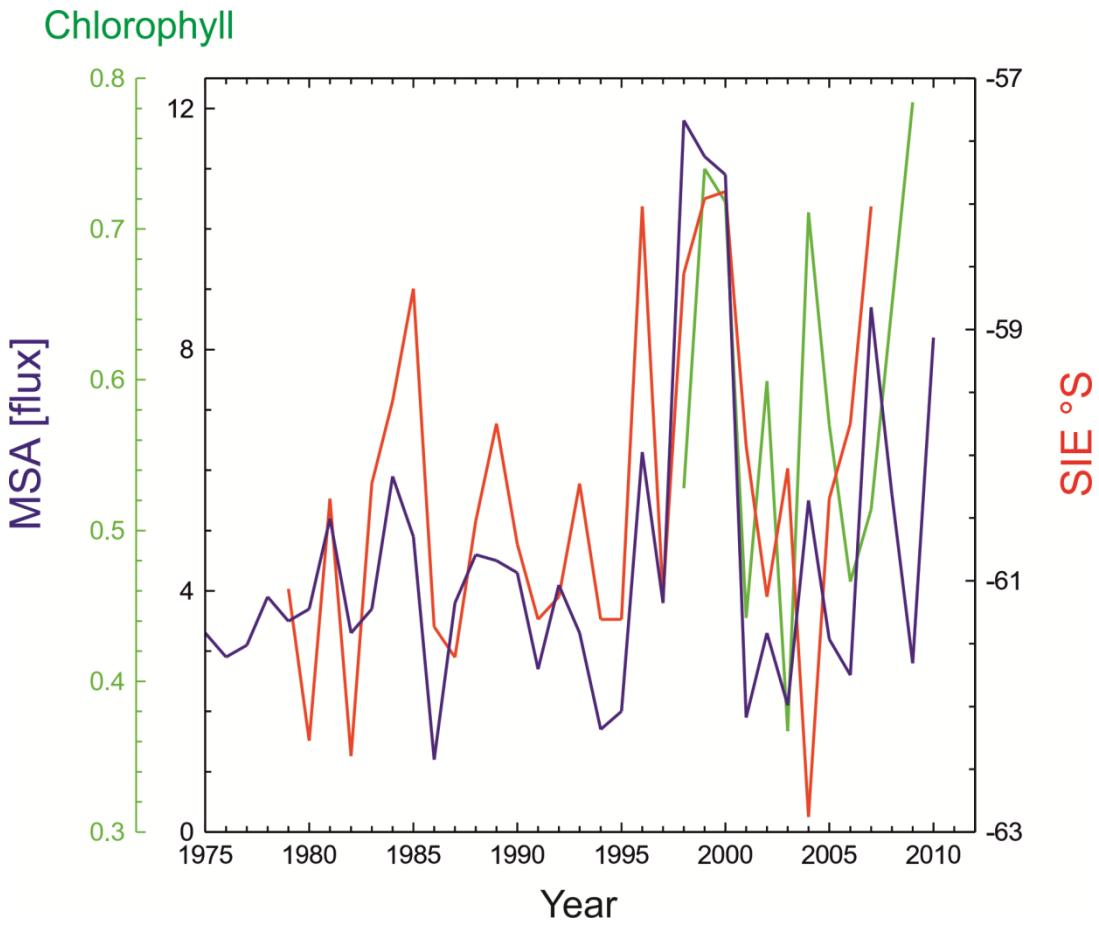
- Positive
  - Bellingshausen Sea and Indian sector
  - MSA dominated by source
  - onshore winds
  - positive MSA-Sea ice relationship

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

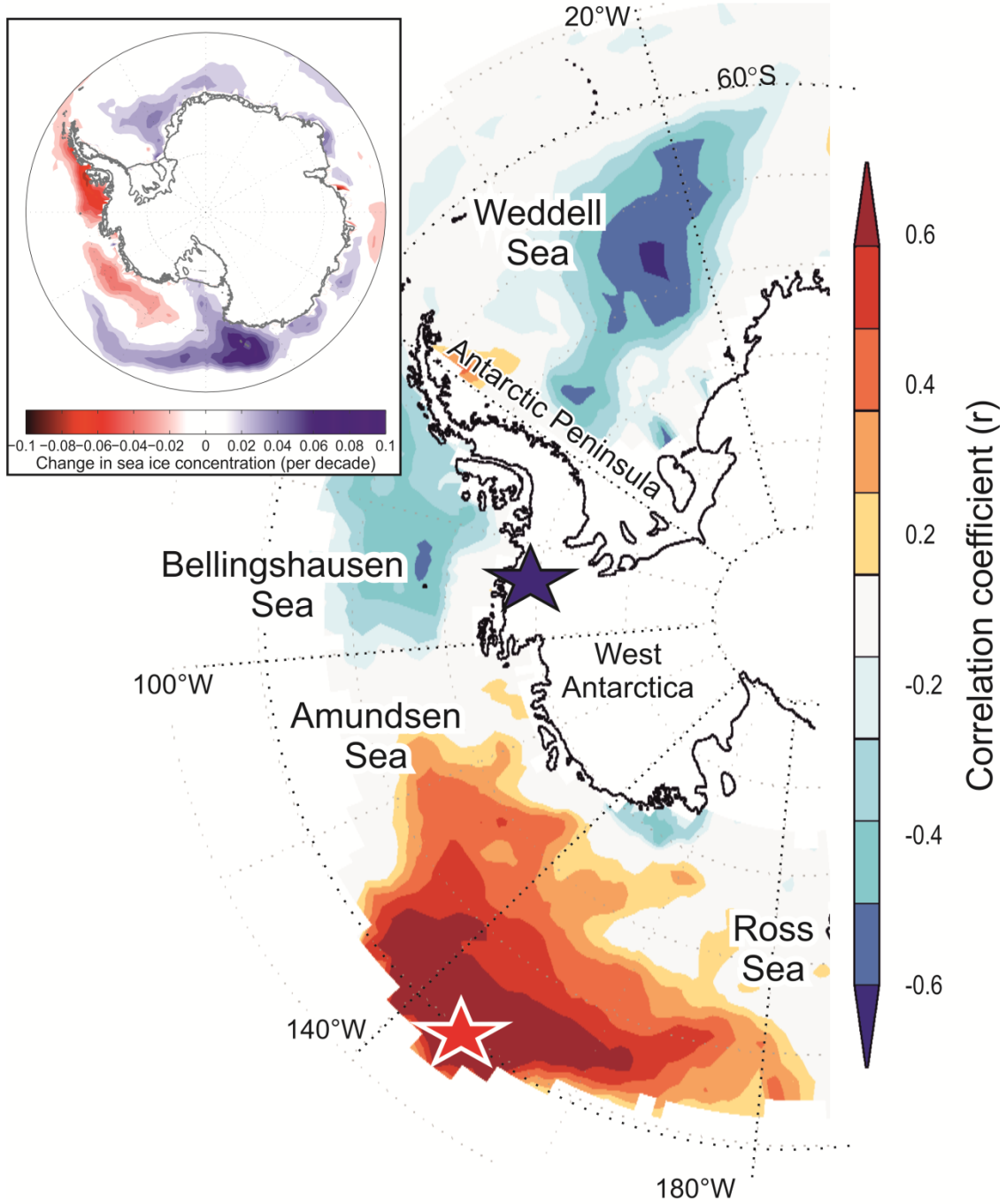
- Other
  - Amundsen and Ross Sea
  - elevated MSA from polynas
  - where summer sea ice persists



Proxy for sea ice

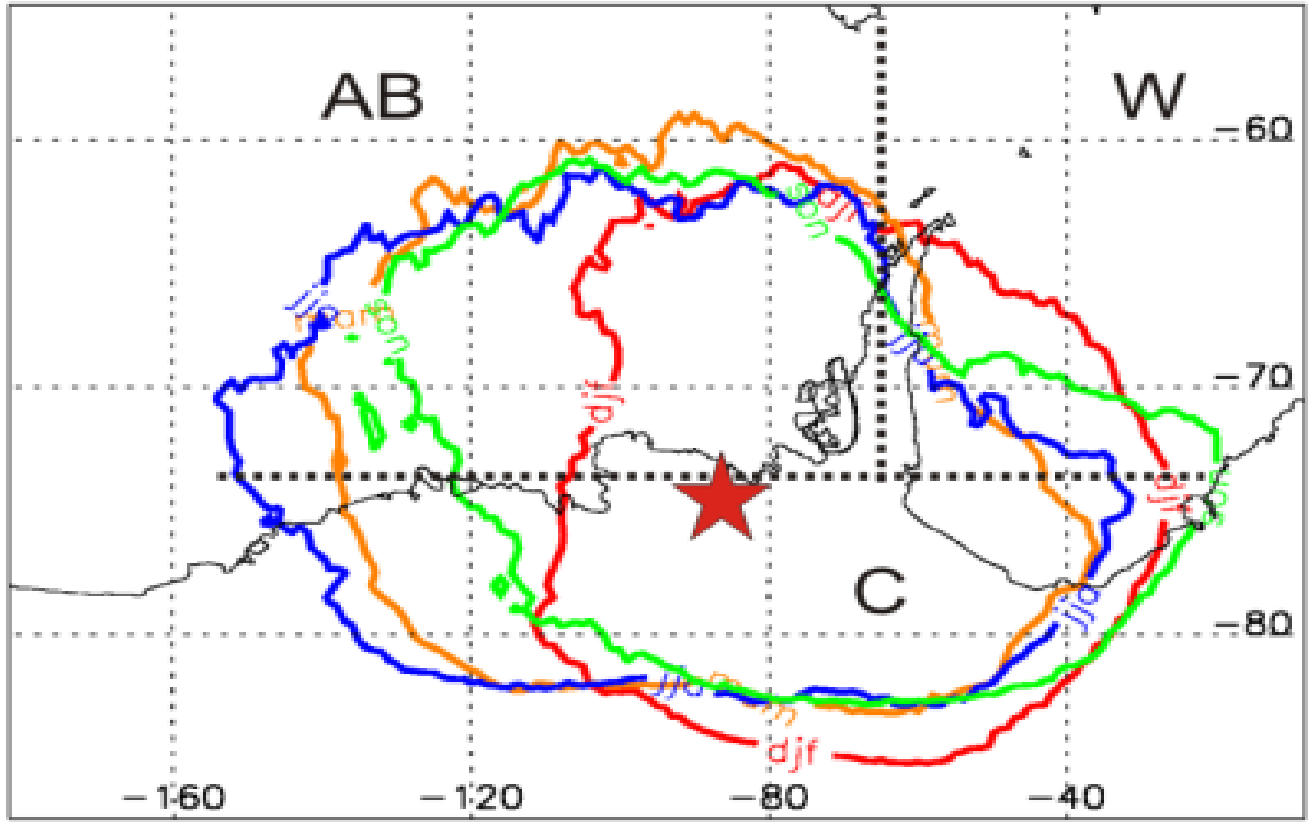


SIE r=0.64, Chlorophyll r=0.5



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

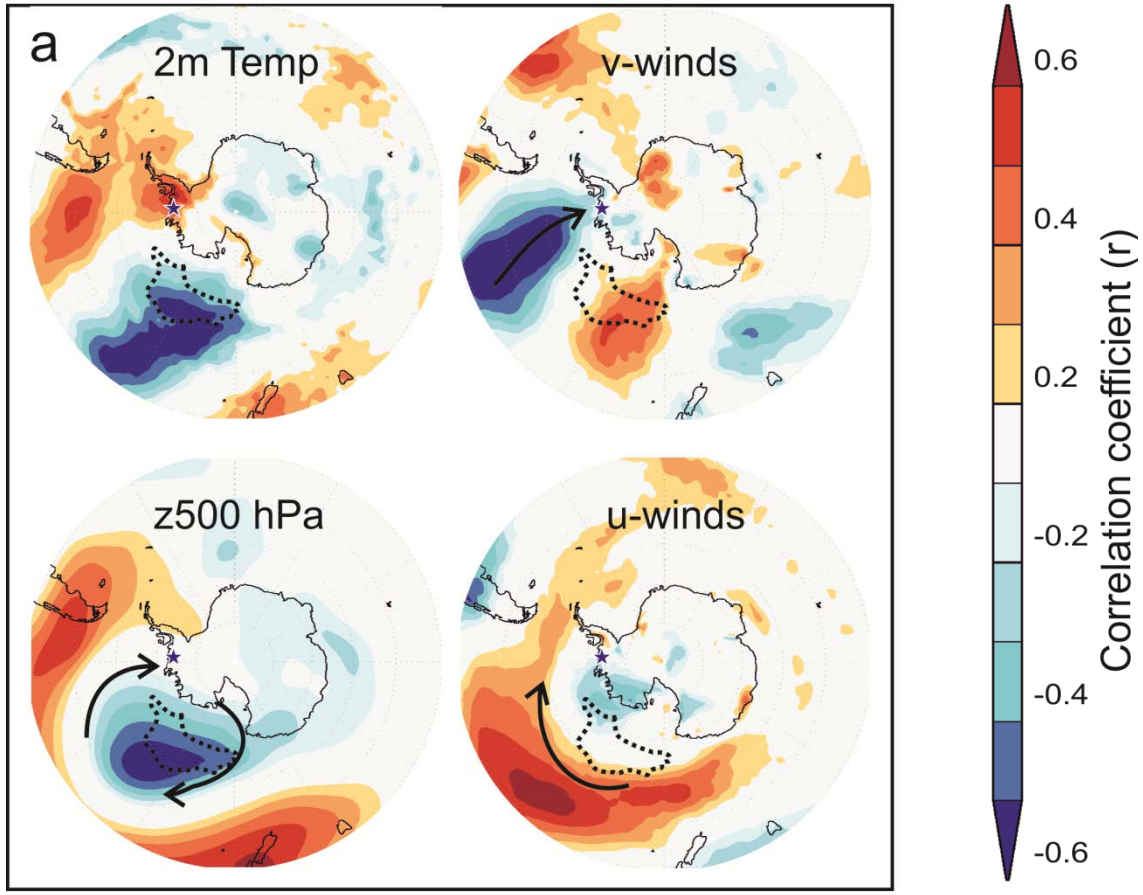
Transport pathways



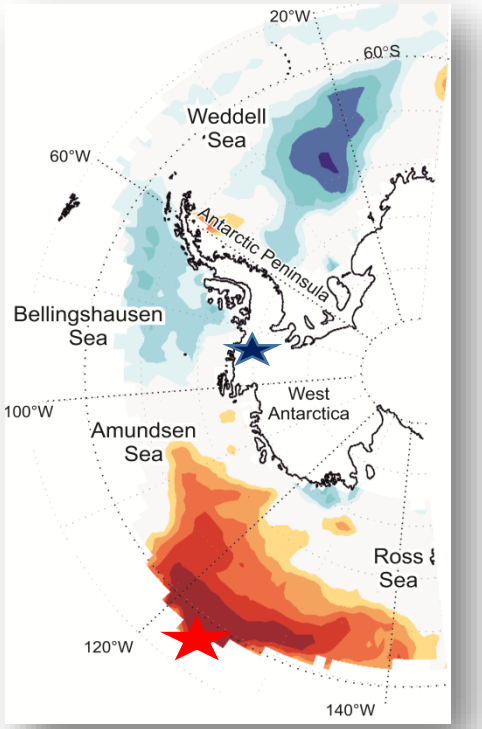
Thomas and Bracegirdle, Climate Dynamics, 2015

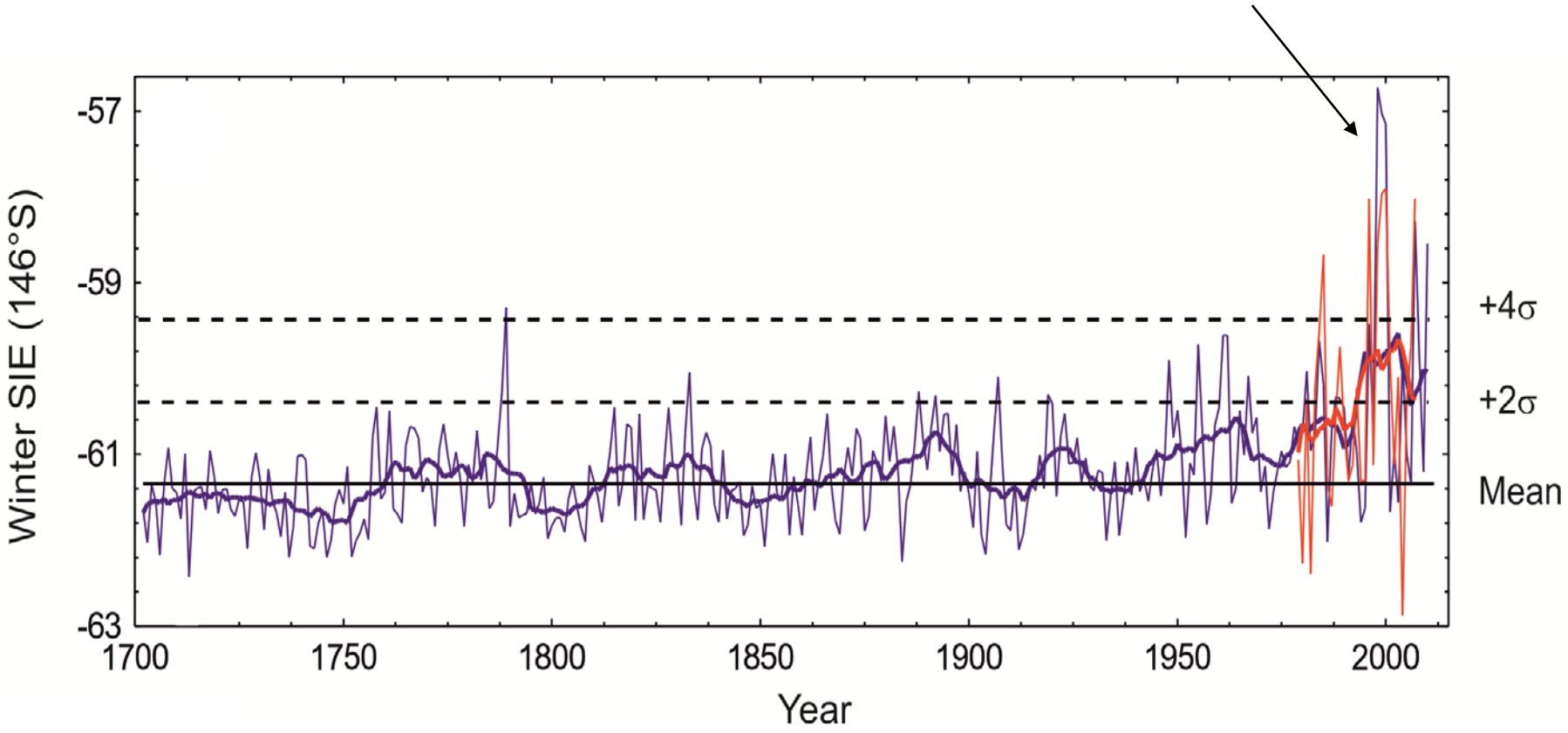
Transport pathways

- 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

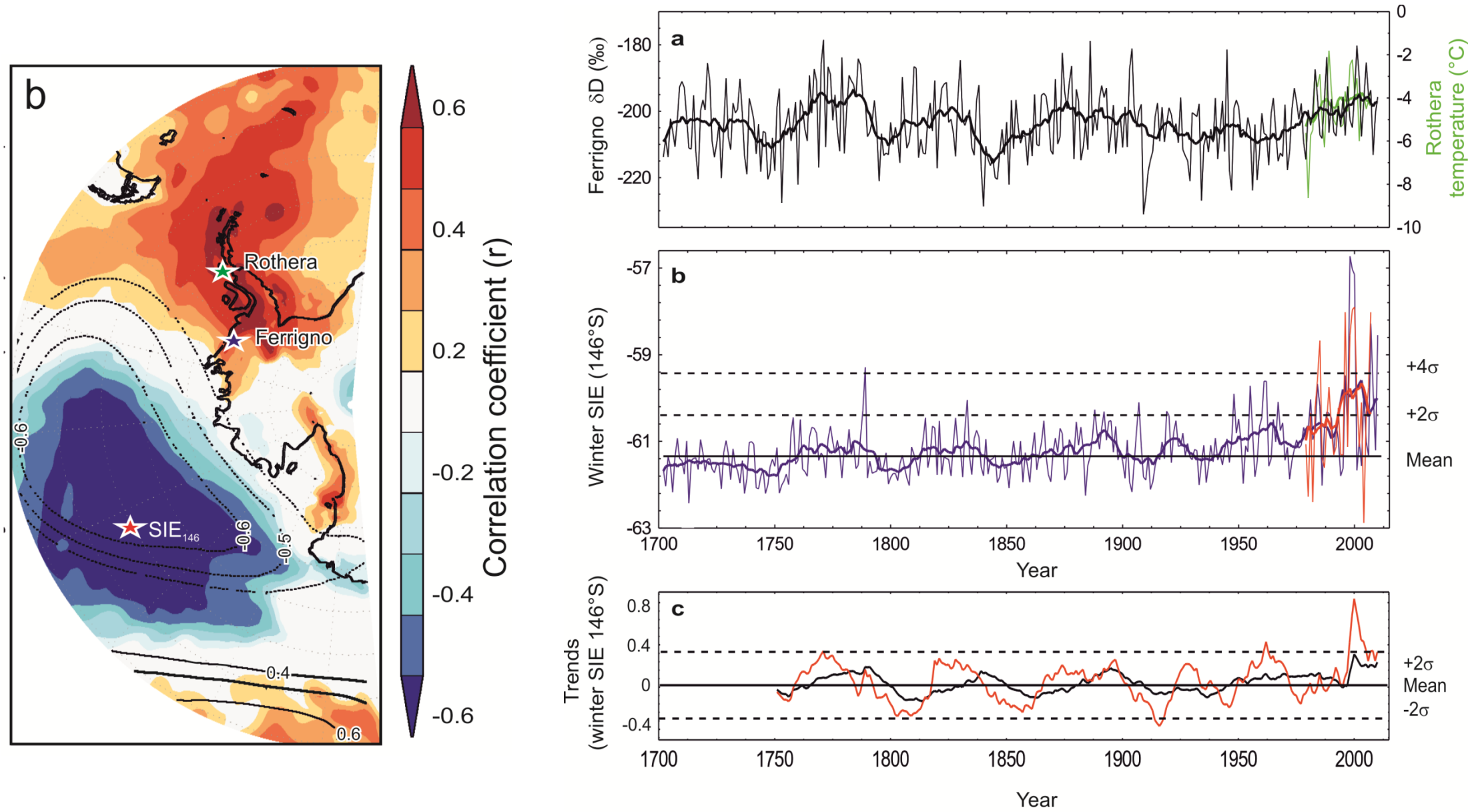


Sea ice reconstruction



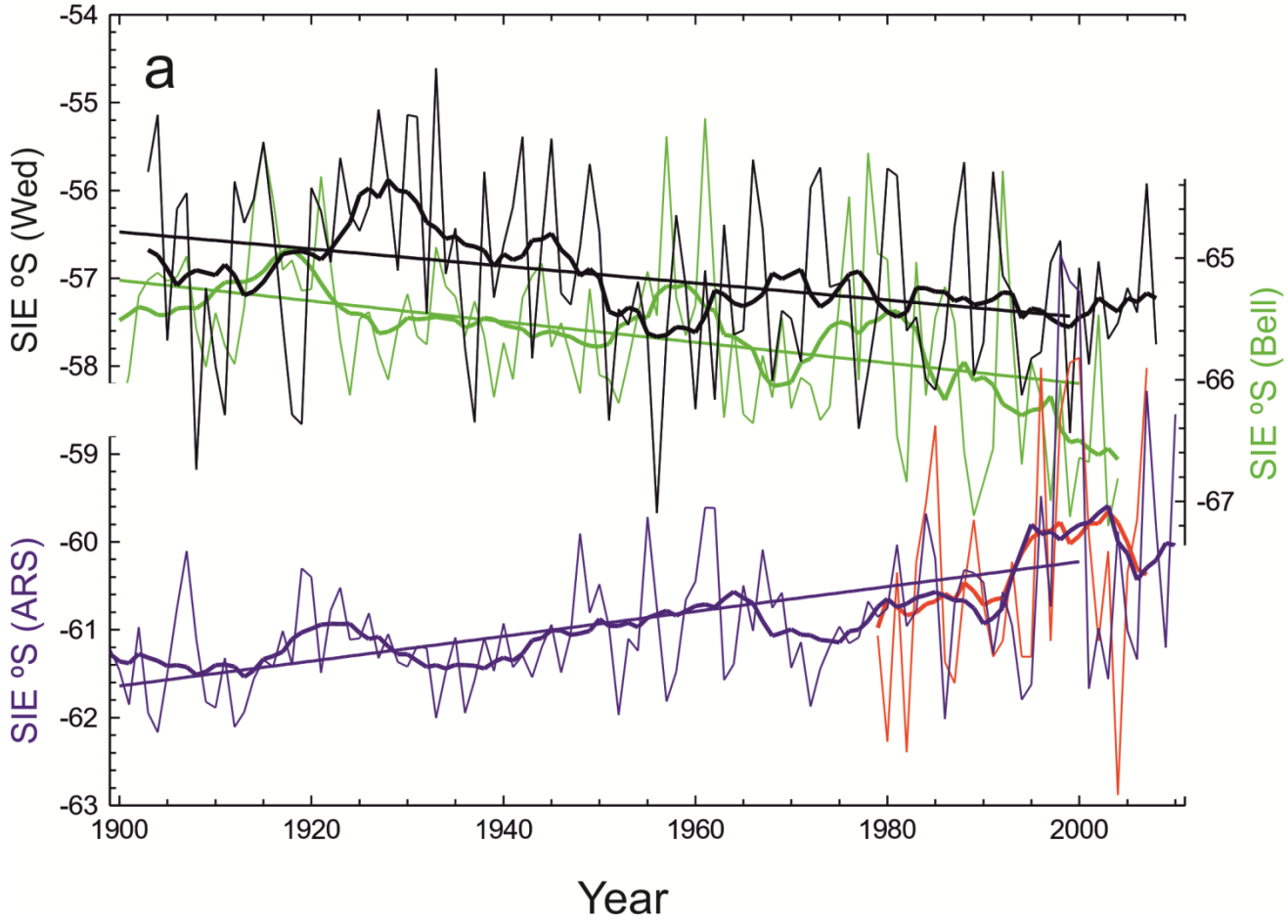


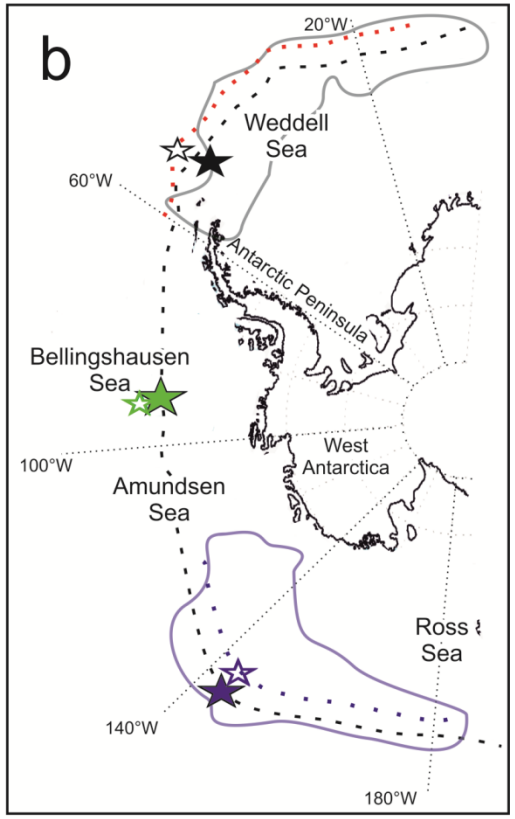
Thomas, E. R., and Abram., N (2016), Ice core reconstruction of sea ice change in the Amundsen-Ross Seas since 1702 AD, GRL



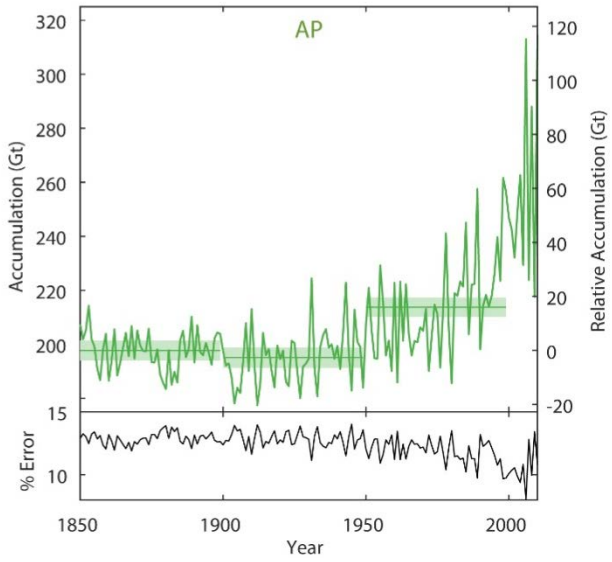
Thomas, E. R., and Abram., N (2016), Ice core reconstruction of sea ice change in the Amundsen-Ross Seas since 1702 AD, GRL

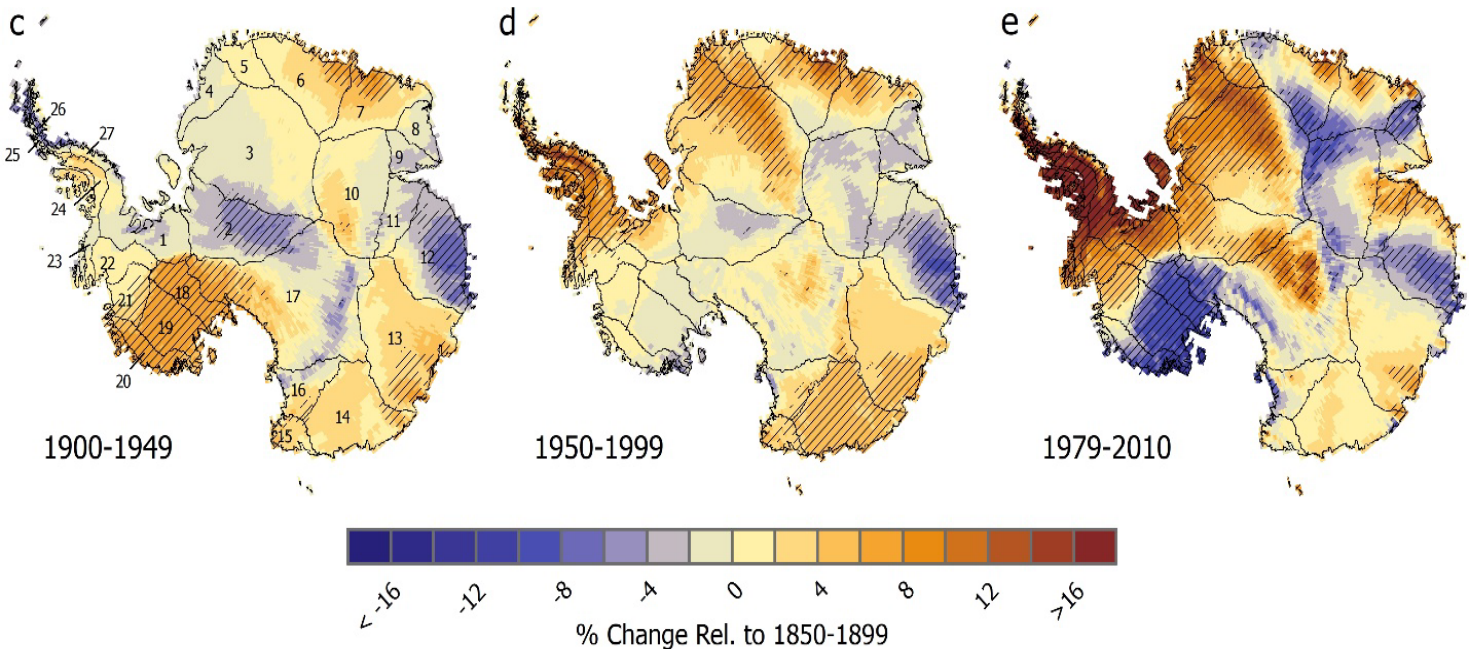
Regional sea ice

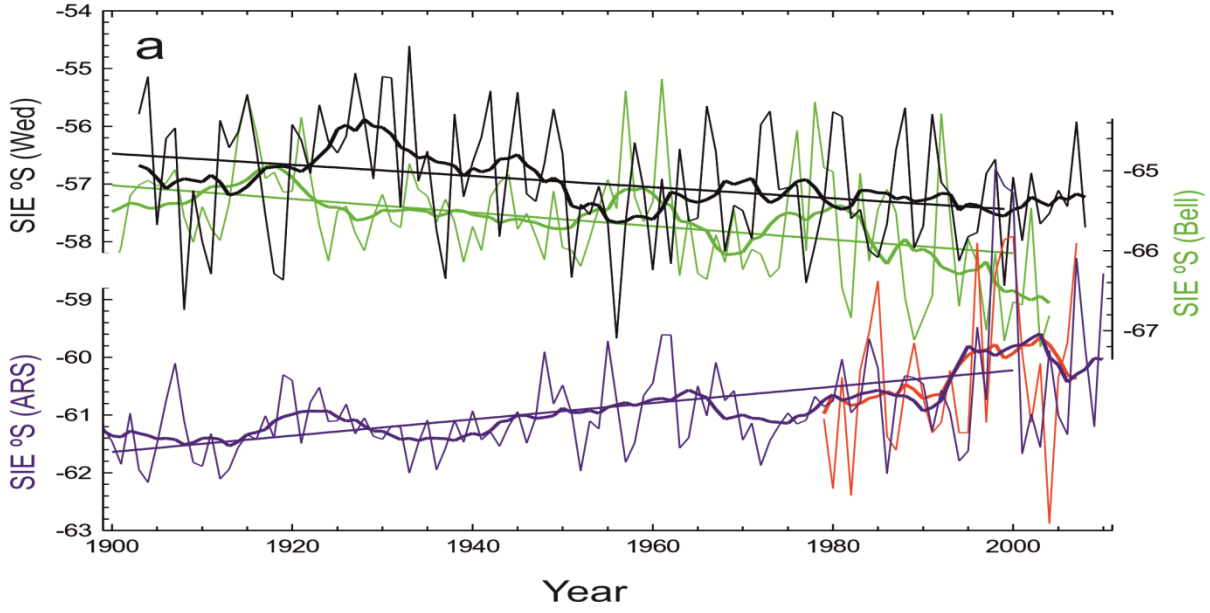




Thomas and Abram (2016); Abram et al., (2010); Murphy et al., (2014)





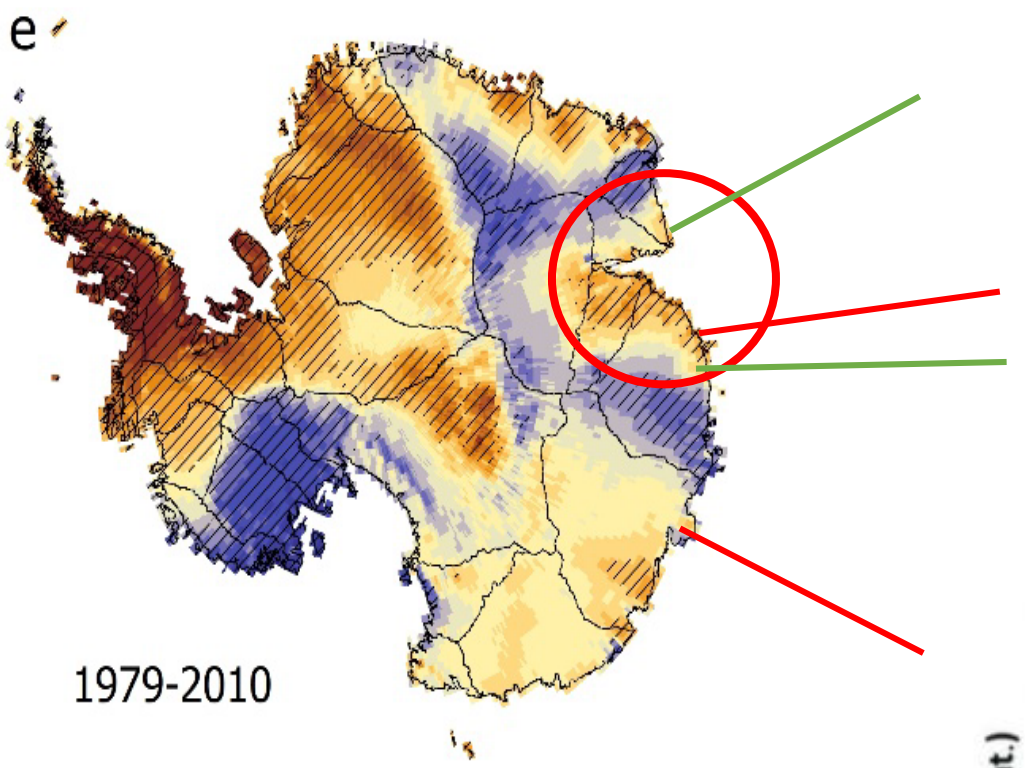


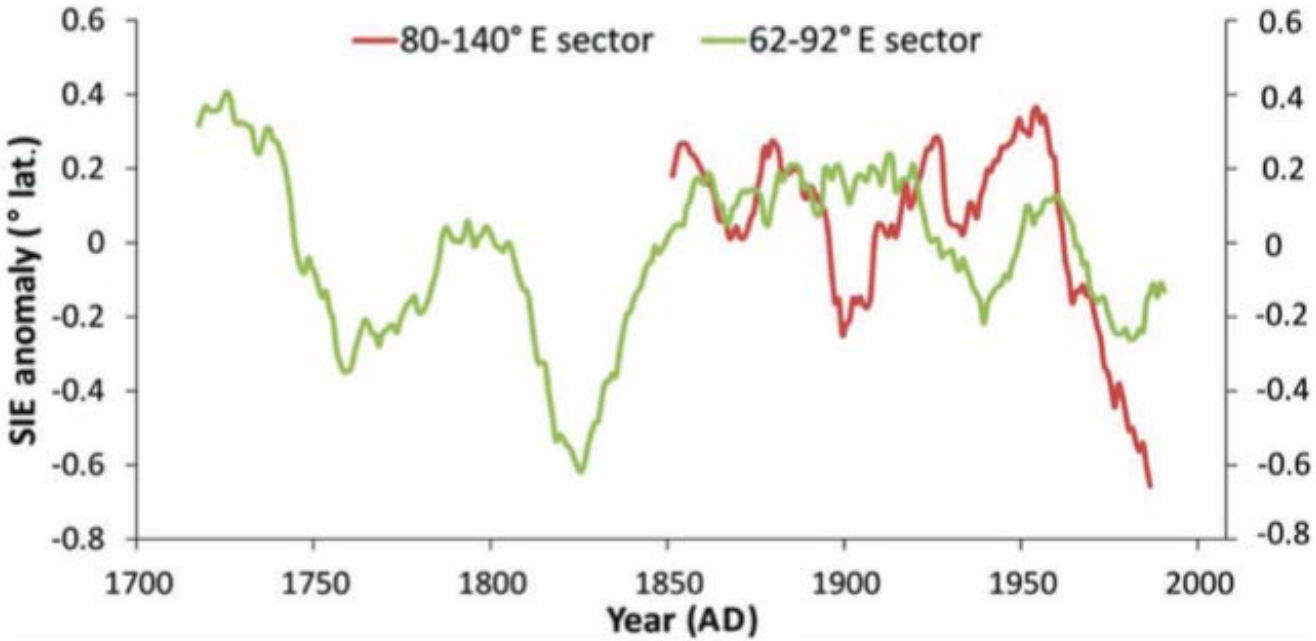
Thomas et al., (2017) Regional Antarctica snow accumulation over the past 1000 years, *Climate of the Past*

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)