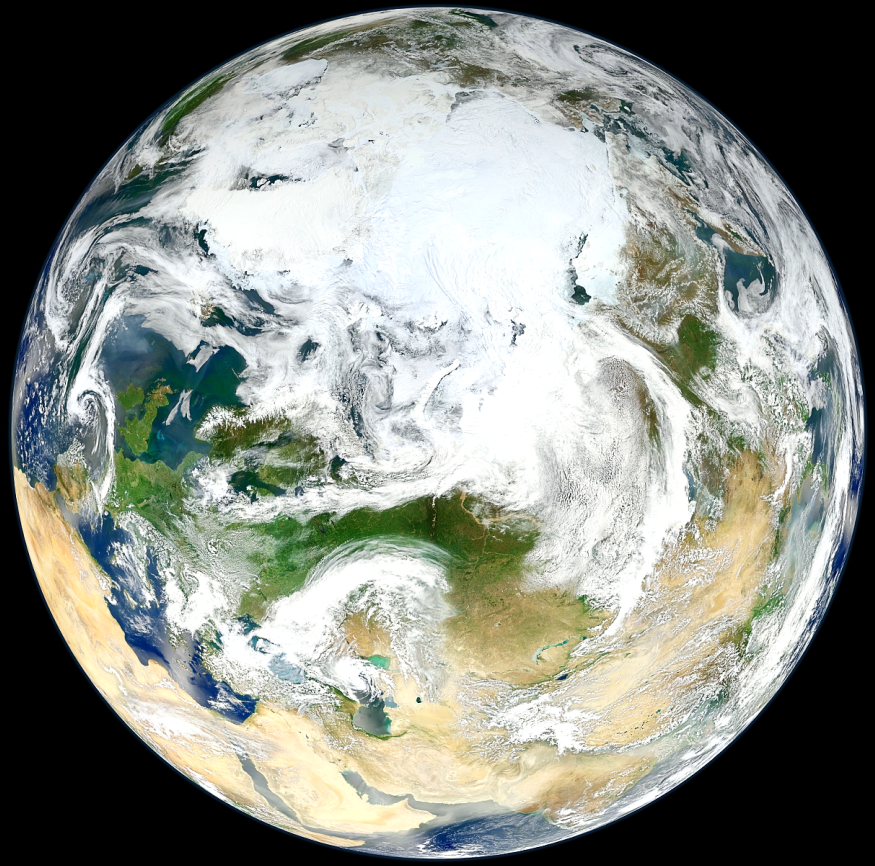

15+ years of sea level in the polar oceans from Envisat and CryoSat-2

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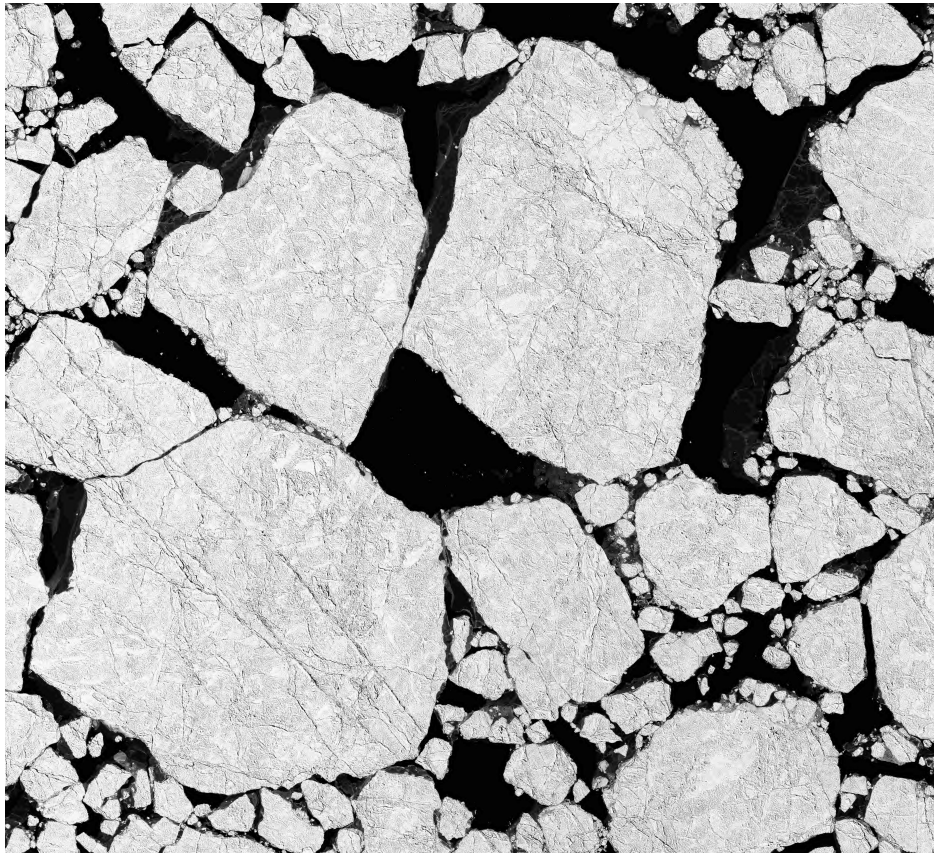
California Institute of Technology

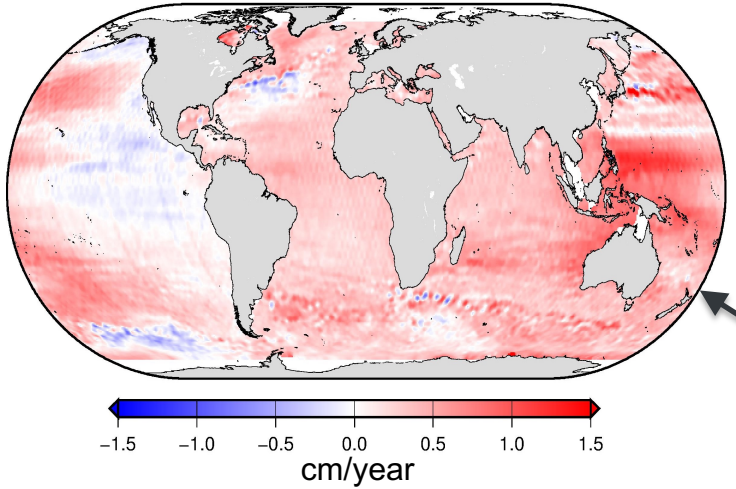
Background

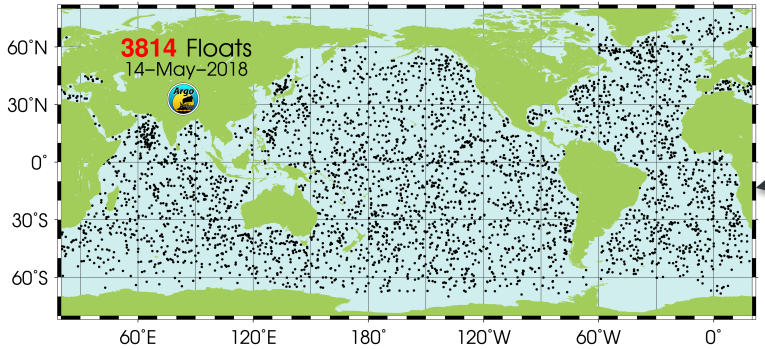
Why study polar sea level?

- The polar oceans are essential for understanding climate change
- Arctic region is experiencing rapid climate change
  - Arctic sea ice loss
  - ‘Arctic amplification’
- Southern Ocean is a climatically important region
  - water mass modification, surface fluxes, sea ice formation, glacial input
  - Driving Antarctic ice sheet melt



Why study polar sea level?





- Sea level an important indicator of global climate change
  - Reflects a host of processes and acts as a 'bulk' measure of ocean column properties
- **<u>But</u>**: it is poorly measured in the polar oceans due to
  - Conventional altimetry does not cover the polar oceans or fails due to sea ice
  - *In situ* data (tide gauges, ARGO, etc.) more difficult due to harsh conditions/expense

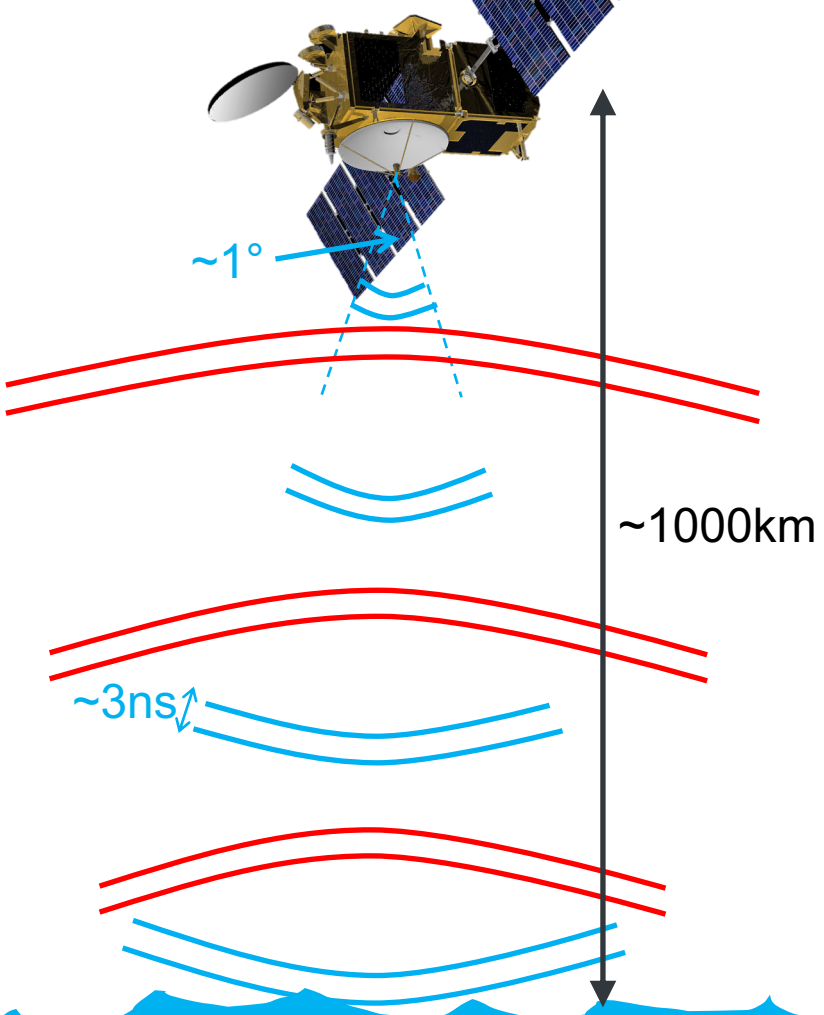
Method

Method

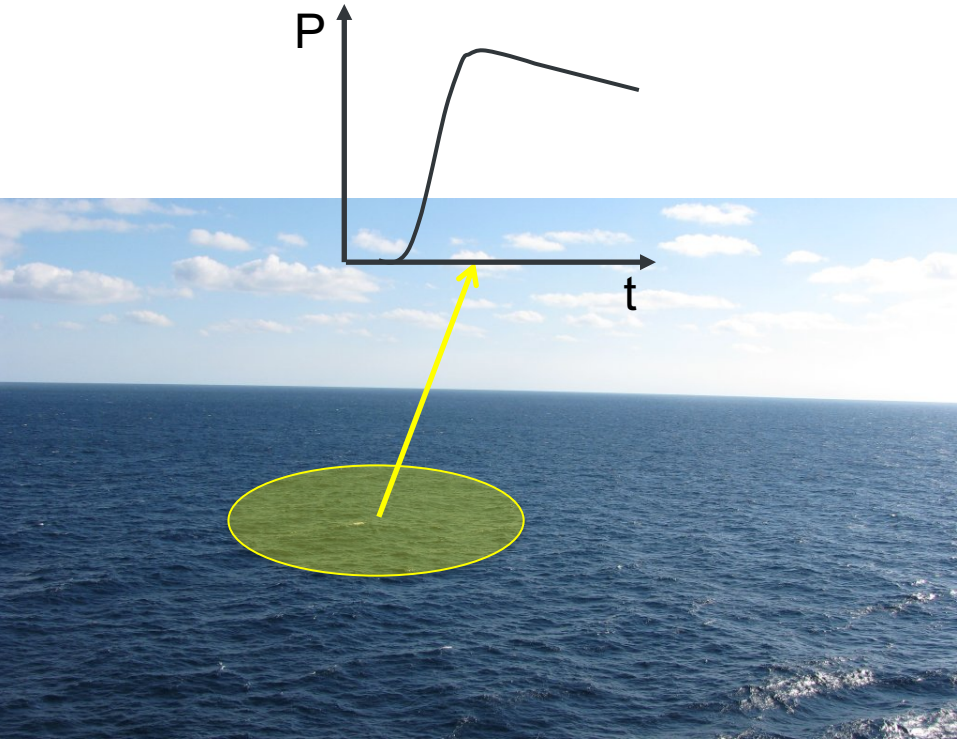
<u>Conventional altimetry</u>

- Satellite orbiting at ~1000km
- Emit radar pulses to surface
- Receive the reflected pulses and estimate the two-way travel time, convert to range
- Combine this with:
  - Satellite altitude
  - Geophysical corrections

→ Get sea surface height



Method

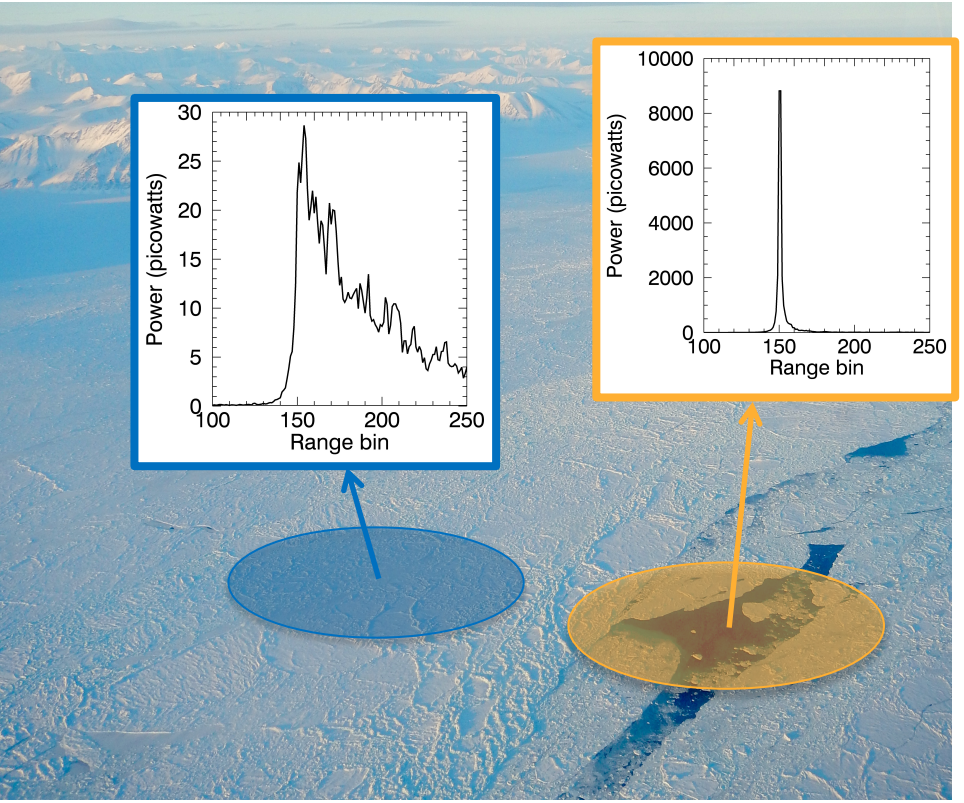


- Open ocean has well-known radar scattering properties
  - Homogeneously rough
  - Known decorrelation scales

Method

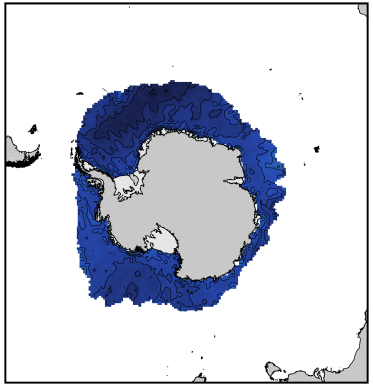
- Open ocean has well-known radar scattering properties
  - Homogeneously rough
  - Known decorrelation scales
- Sea ice scattering is highly *inhomogeneous*
  - Leads (cracks) appear very bright (specular; mirror-like)
  - Deformation features (e.g., ridging)

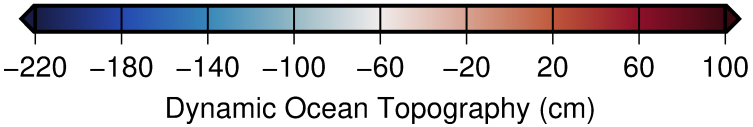
Method



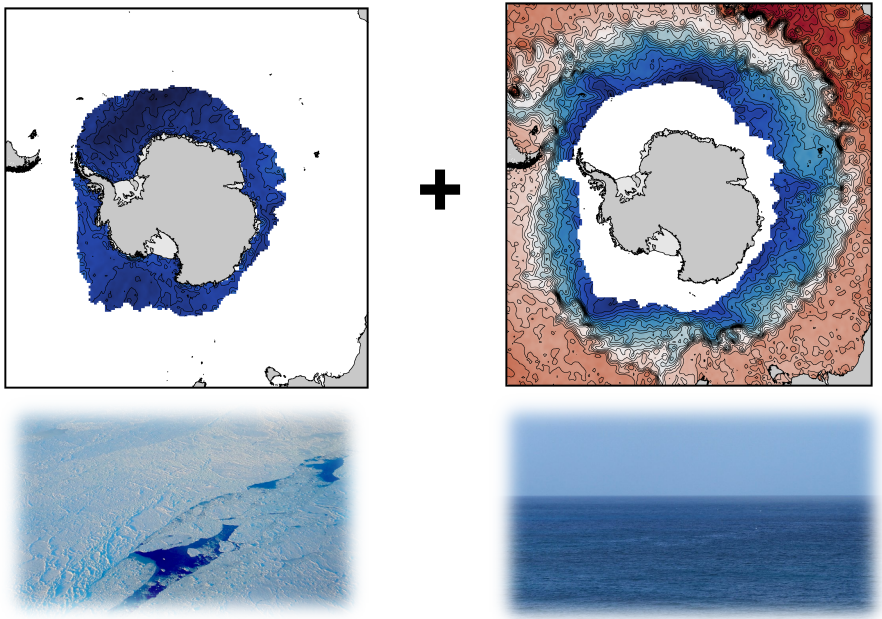
- Open ocean has well-known radar scattering properties
  - Homogeneously rough
  - Known decorrelation scales
- Sea ice scattering is highly *inhomogeneous*
  - Leads (cracks) appear very bright (specular; mirror-like)
  - Deformation features (e.g., ridging)
- Different scattering properties allows to distinguish between surface types

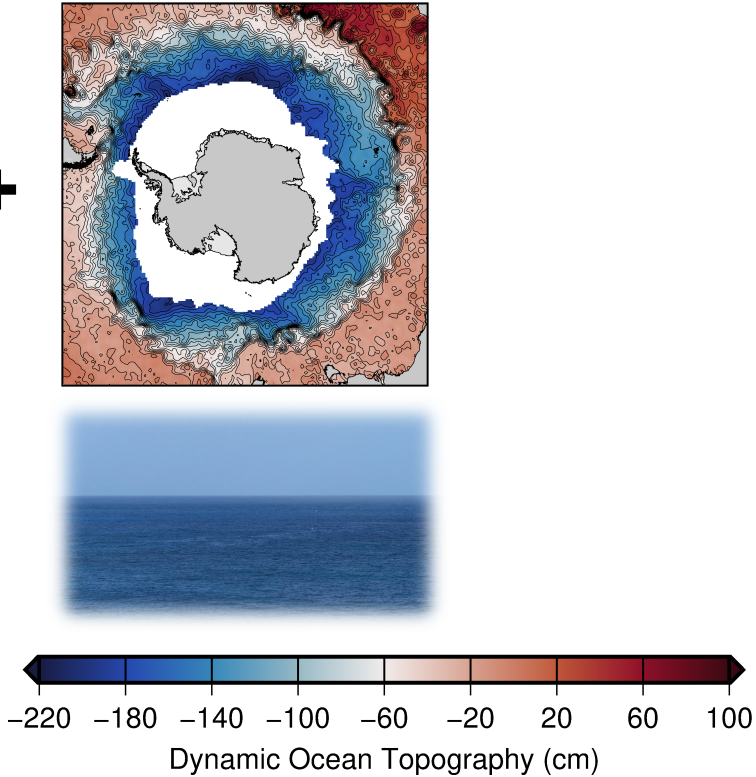
Method



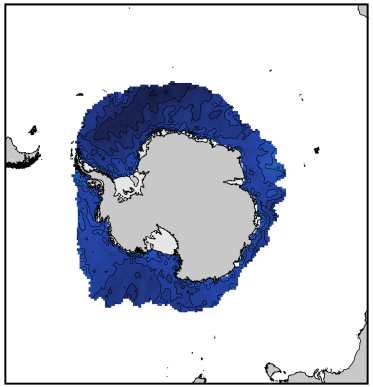


Method





Method



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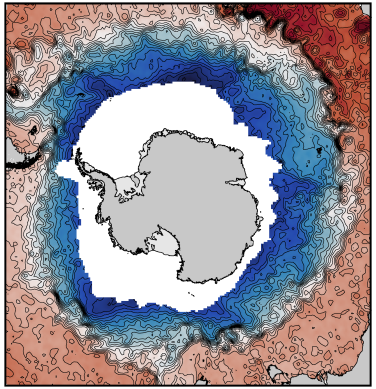

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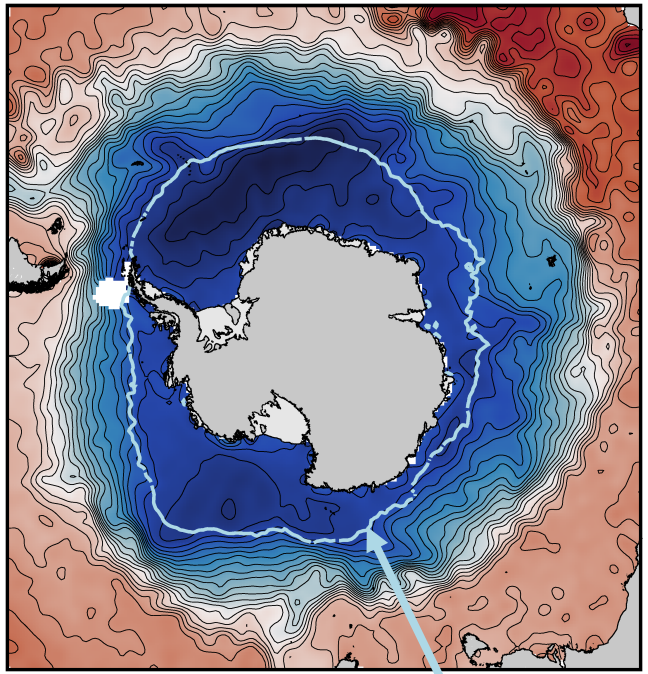
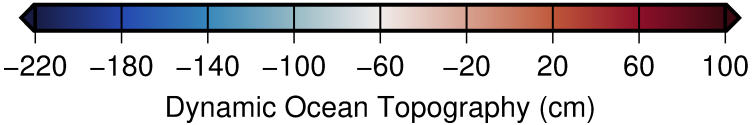
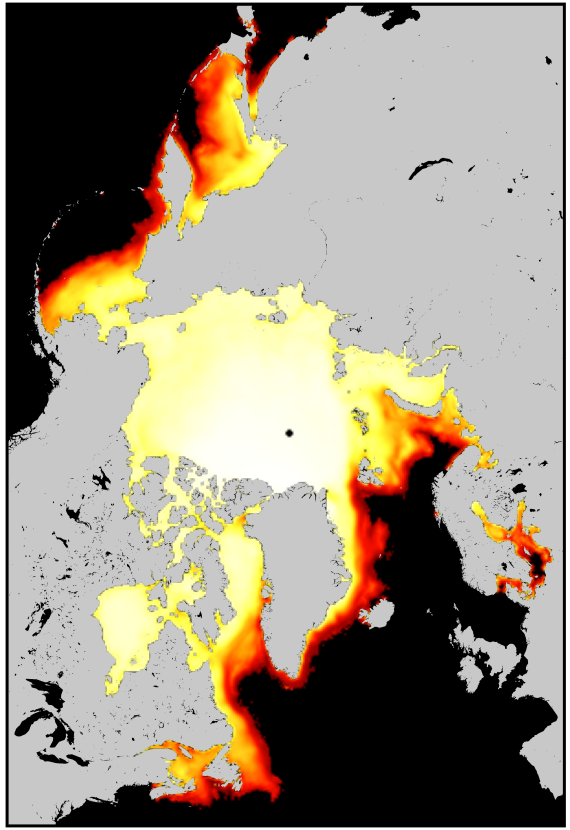
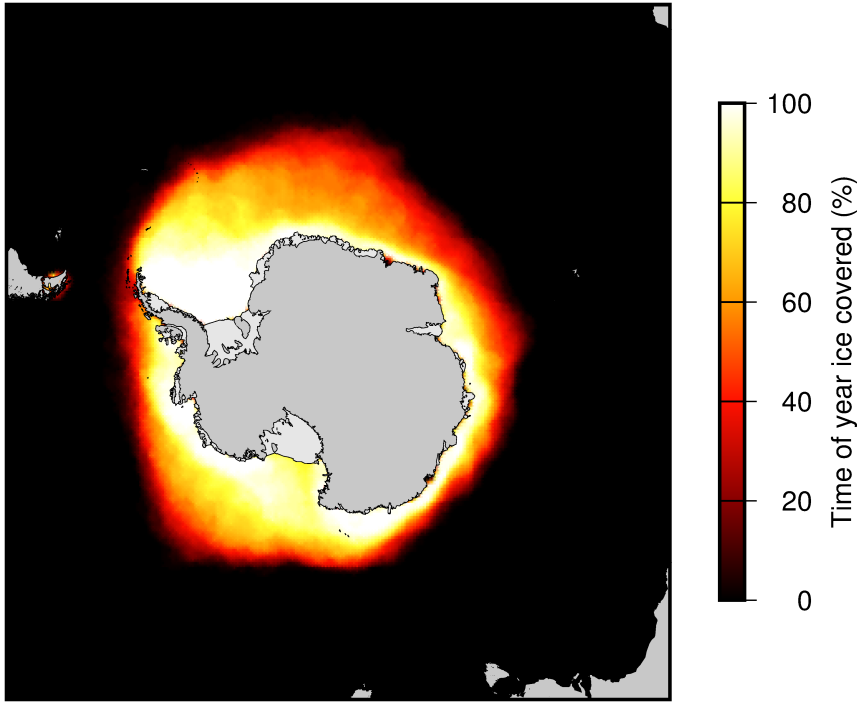

Ice edge


−220 −180 −140 −100 −60 −20 20 60 100
Dynamic Ocean Topography (cm)

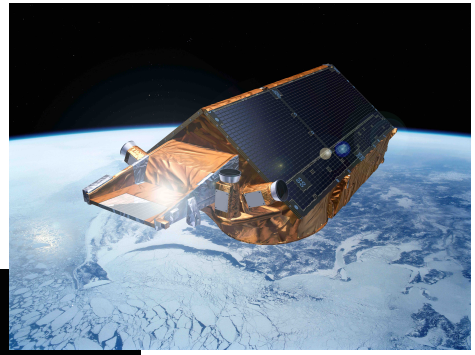
Method





Data

Data



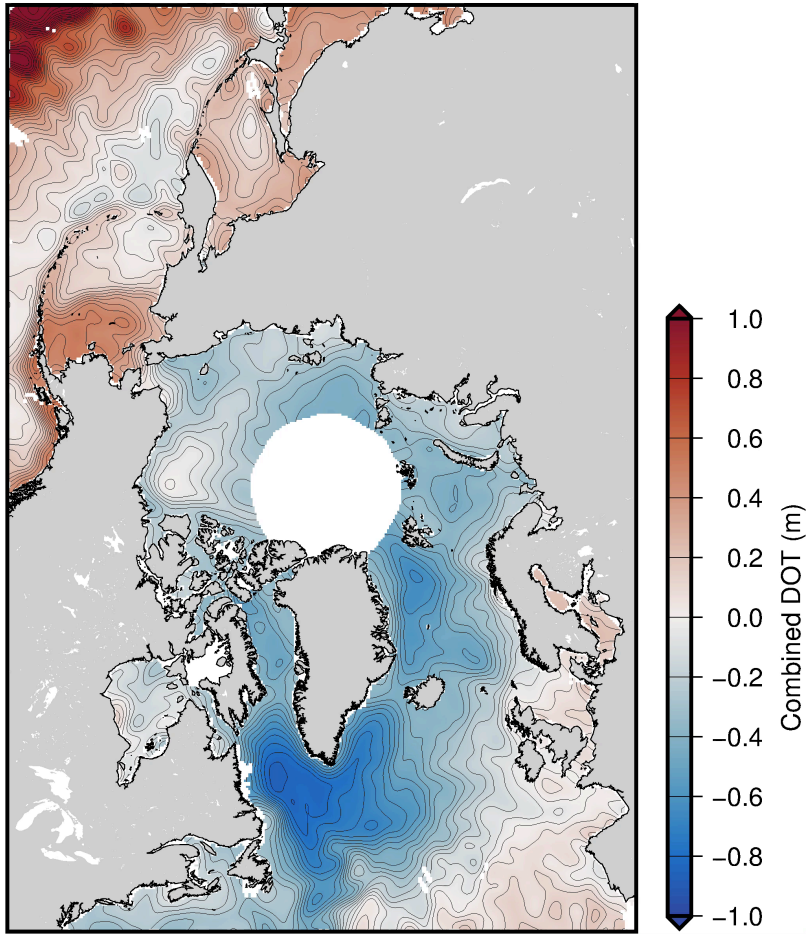
2010—

2002-2012

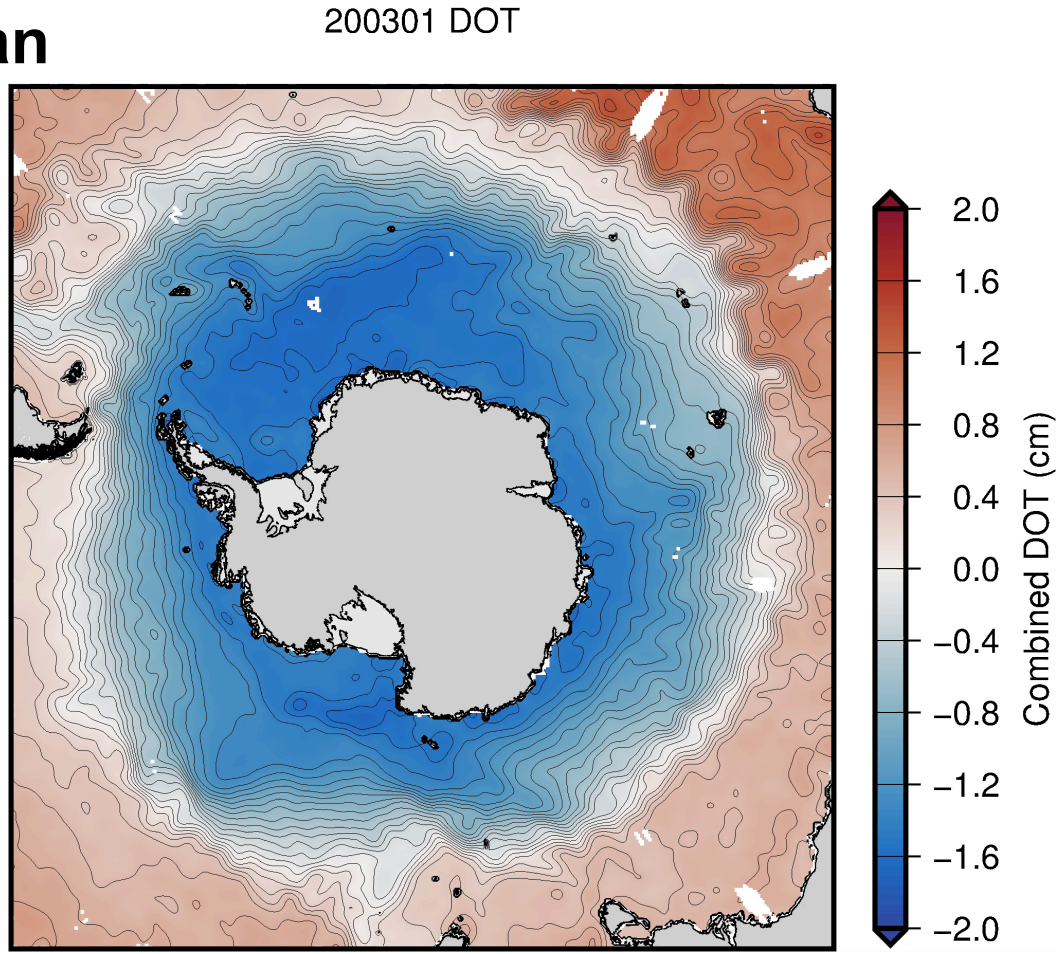
- Previously:
  - Used Envisat+CryoSat-2 for the Arctic Ocean 2003-2014
  - CryoSat-2 only for the Southern Ocean 2011-2016
- Make use of Envisat (2003-2010) and CryoSat-2 (2011-2018)
- Ice-covered ocean processed in-house at JPL
- Open ocean data taken from RADS

A new time series

Arctic Ocean

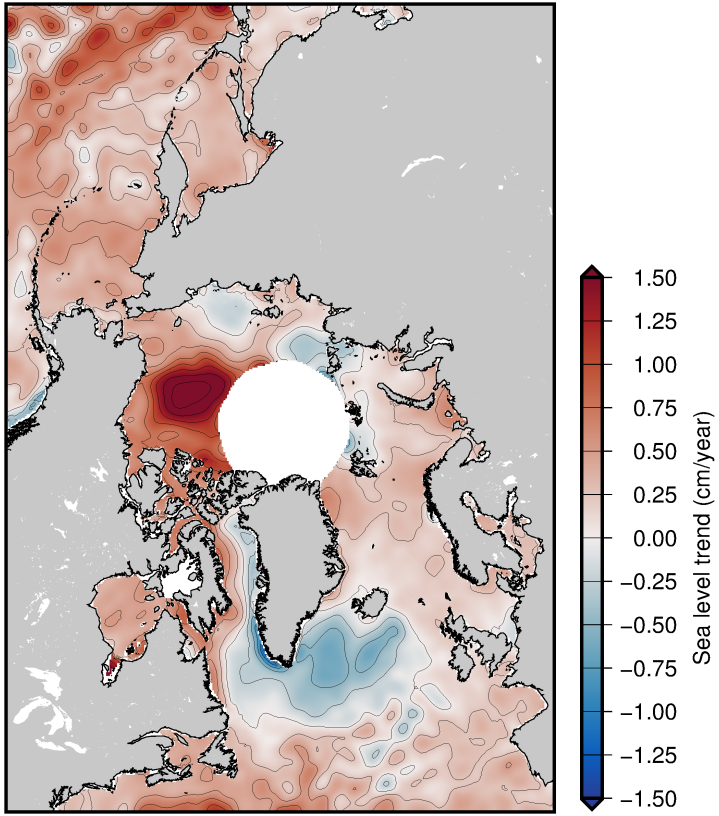


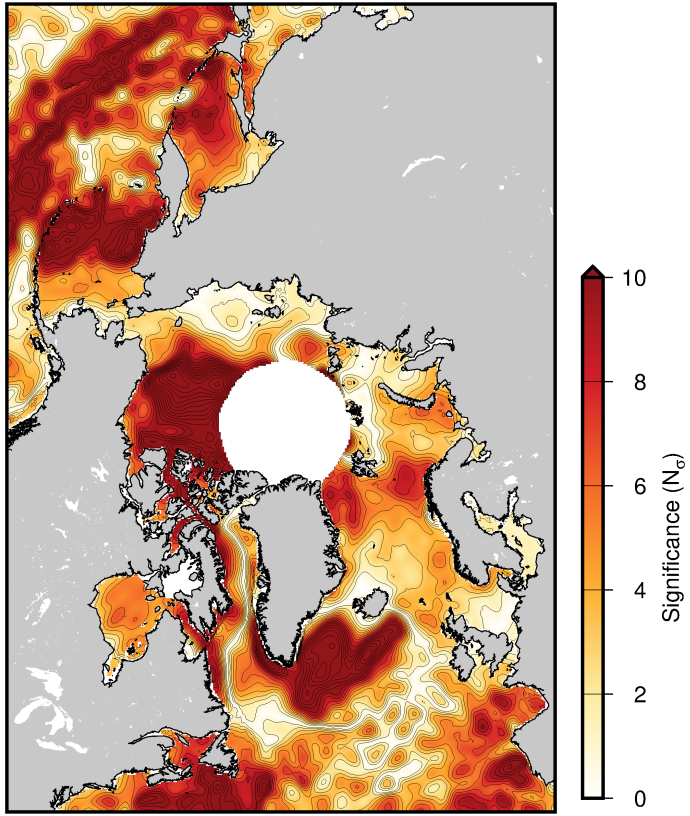
Southern Ocean



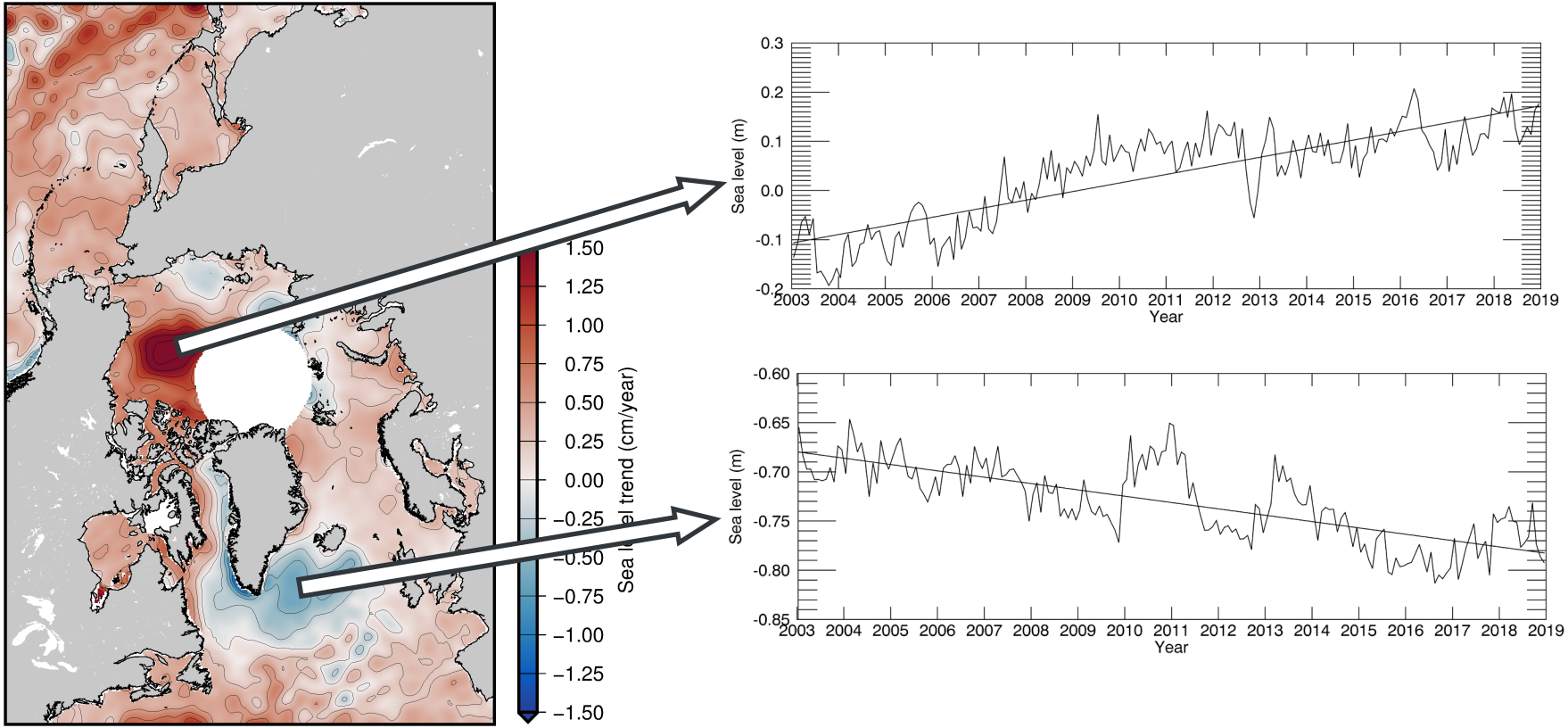
Results

Trends: Arctic Ocean

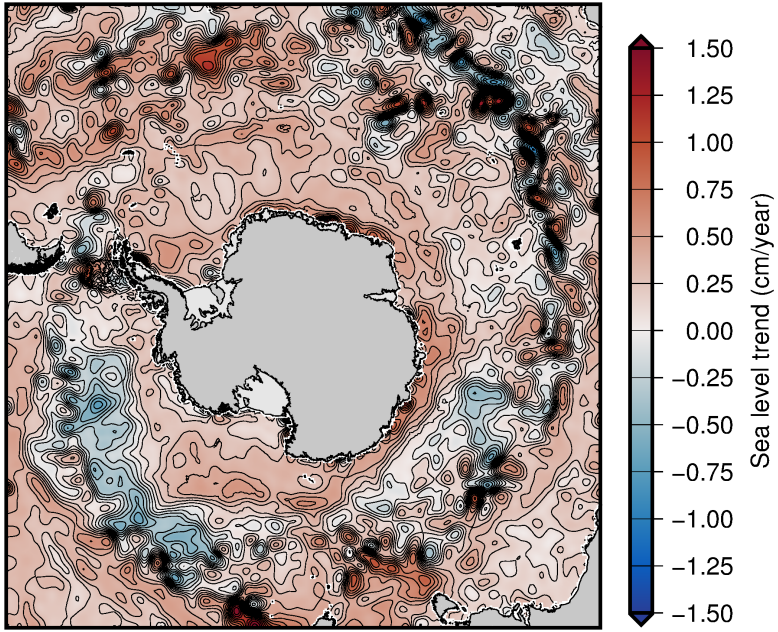


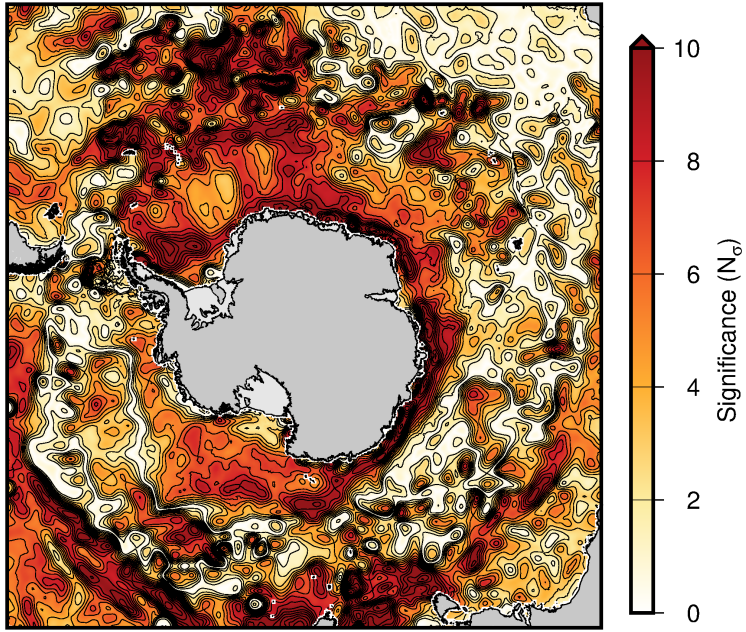


Trends: Arctic Ocean

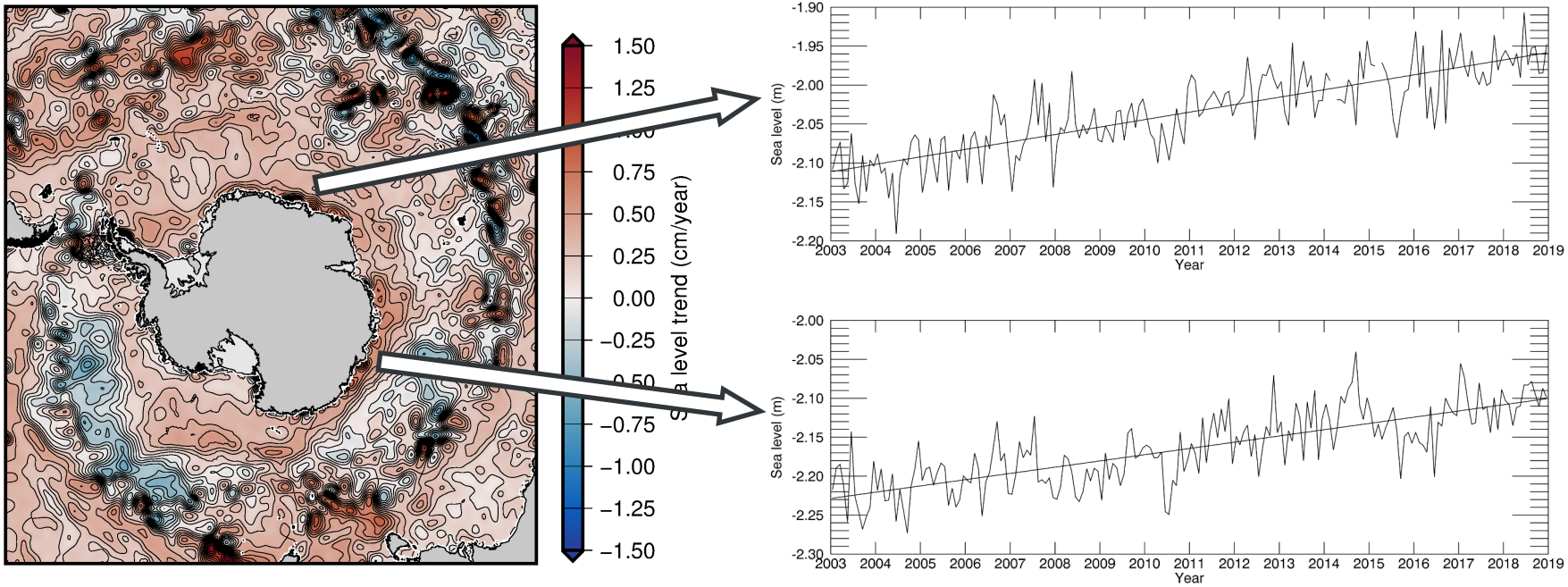


Trends: Southern Ocean



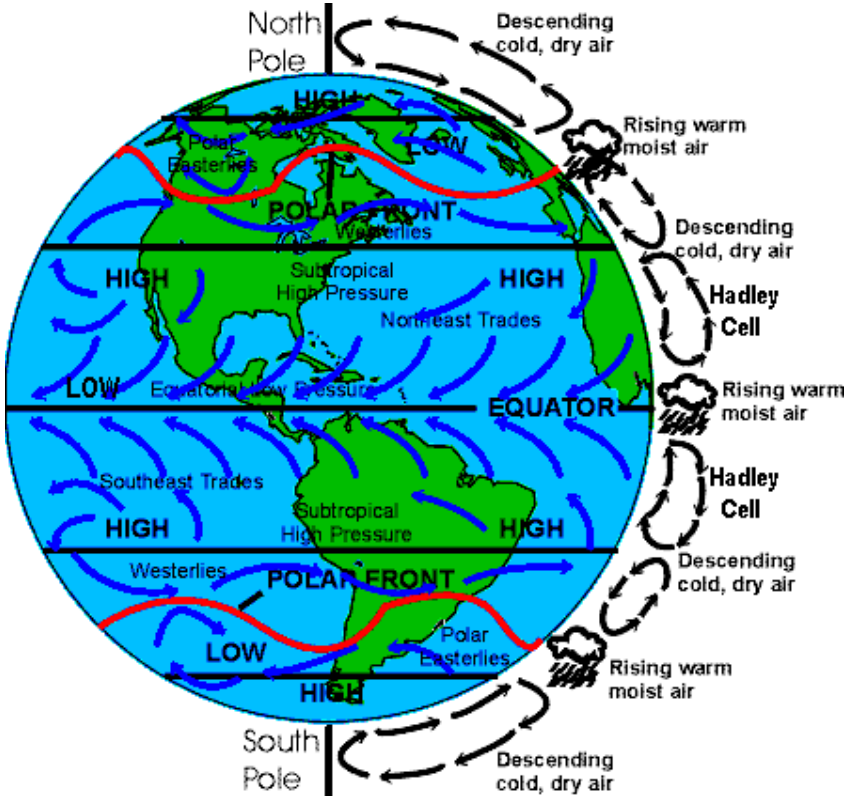


Trends: Southern Ocean

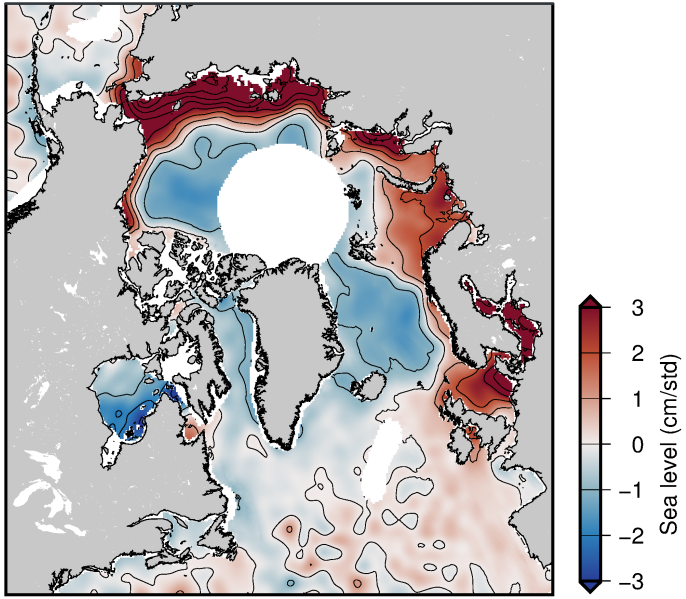


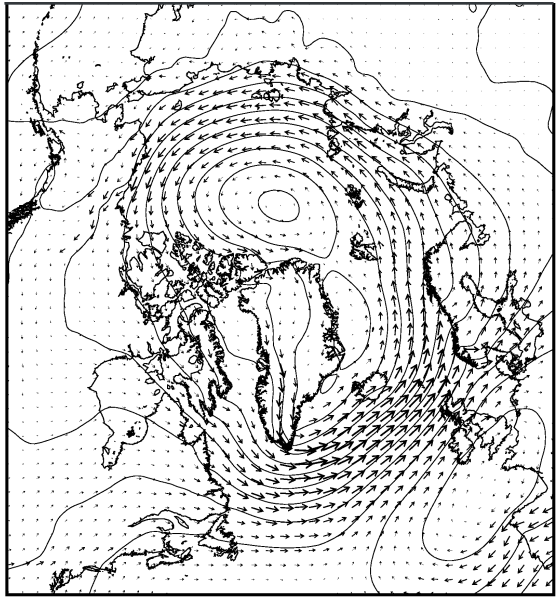
Climate Variability

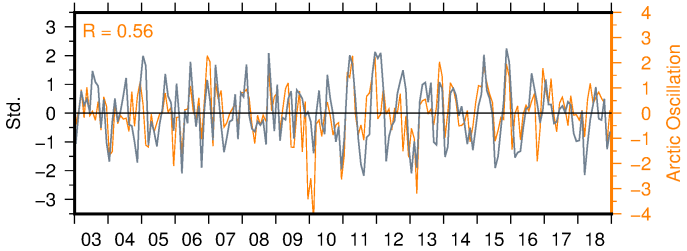
- Remove:
  - Secular change (trends, decadal variability); seasonal cycle
  - Looking at sub-seasonal, month-to-month variability
- Do Principal Component Analysis:
  - Leading modes of variability in Arctic and Southern Oceans
  - Project Principal Components onto sea level pressure



Climate Variability: Arctic Ocean

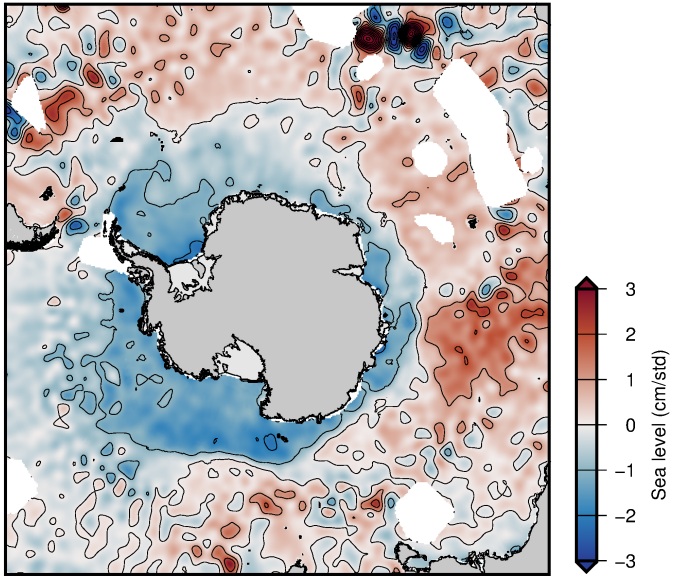


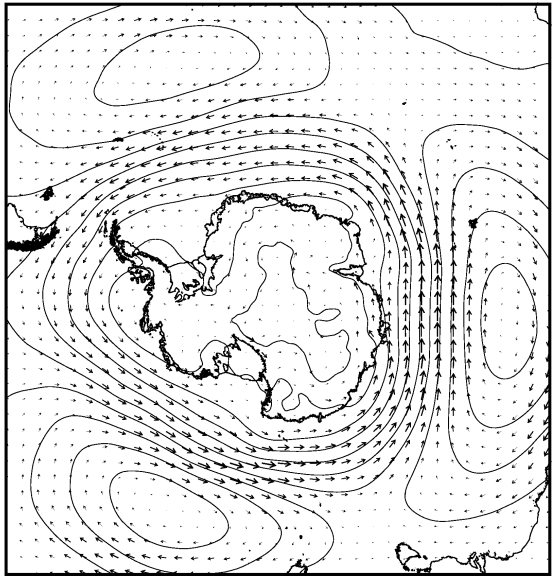


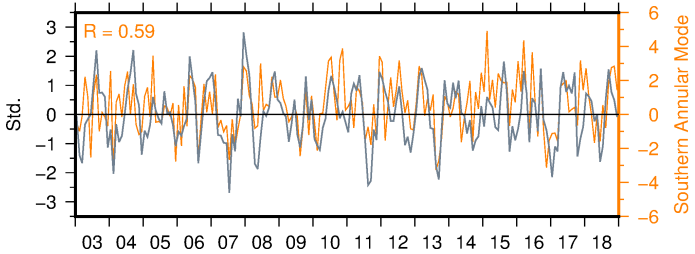


- Arctic variability dominated by Arctic Oscillation
- First mode of extra-tropical climate variability
- Oscillation of strength of polar high
- Drives on/off-shelf transport

Climate Variability: Southern Ocean







- Southern Ocean variability dominated by Southern Annular Mode
- Leading mode of Southern hemisphere climate variability
- Drives deepening of polar trough by contraction and strengthening of westerlies

Conclusions

Conclusions

- Sea level is an important climate indicator, but under-sampled in the ice-covered ocean
- Can reconstruct sea level in the ice-covered oceans from data in leads and combine with conventional altimetry to get global fields
- Significant trends in both polar/sub-polar oceans:
  - Arctic Ocean – Beaufort Gyre and sub-polar gyre show large changes
  - Southern Ocean – Strong trends on the shelves of East Antarctica
- Subseasonal monthly variability is dominated by leading modes of northern/southern hemisphere climate variability:
  - Arctic Oscillation – Drives on/off-shore transport
  - Southern Annular Mode – Deepens sea level trough by strengtheningcontraction of westerlies

Acknowledgement: Envisat and CryoSat-2 data were supplied by the European Space Agency (https://earth.esa.int/web/guest/home).

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