OGS National Institute of Oceanography and Applied Geophysics

The role of the Antarctic ice sheet in the regional to global climate system

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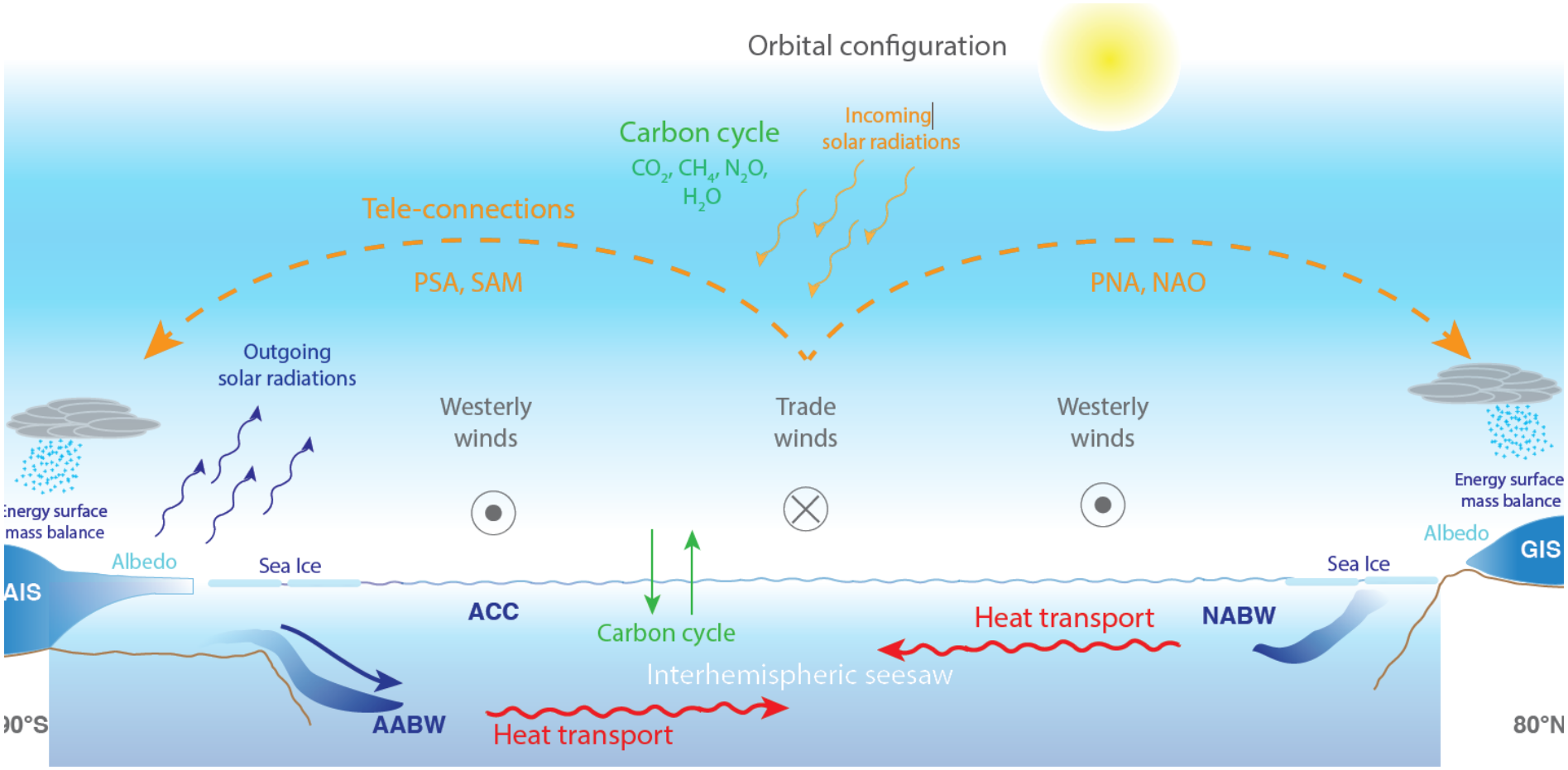
Exploring Polar Dynamics: Insights from the Mid Pleistocene Transition to Future Climate Scenarios

What's the role of the Antarctic ice sheet in the regional to global Climate System?

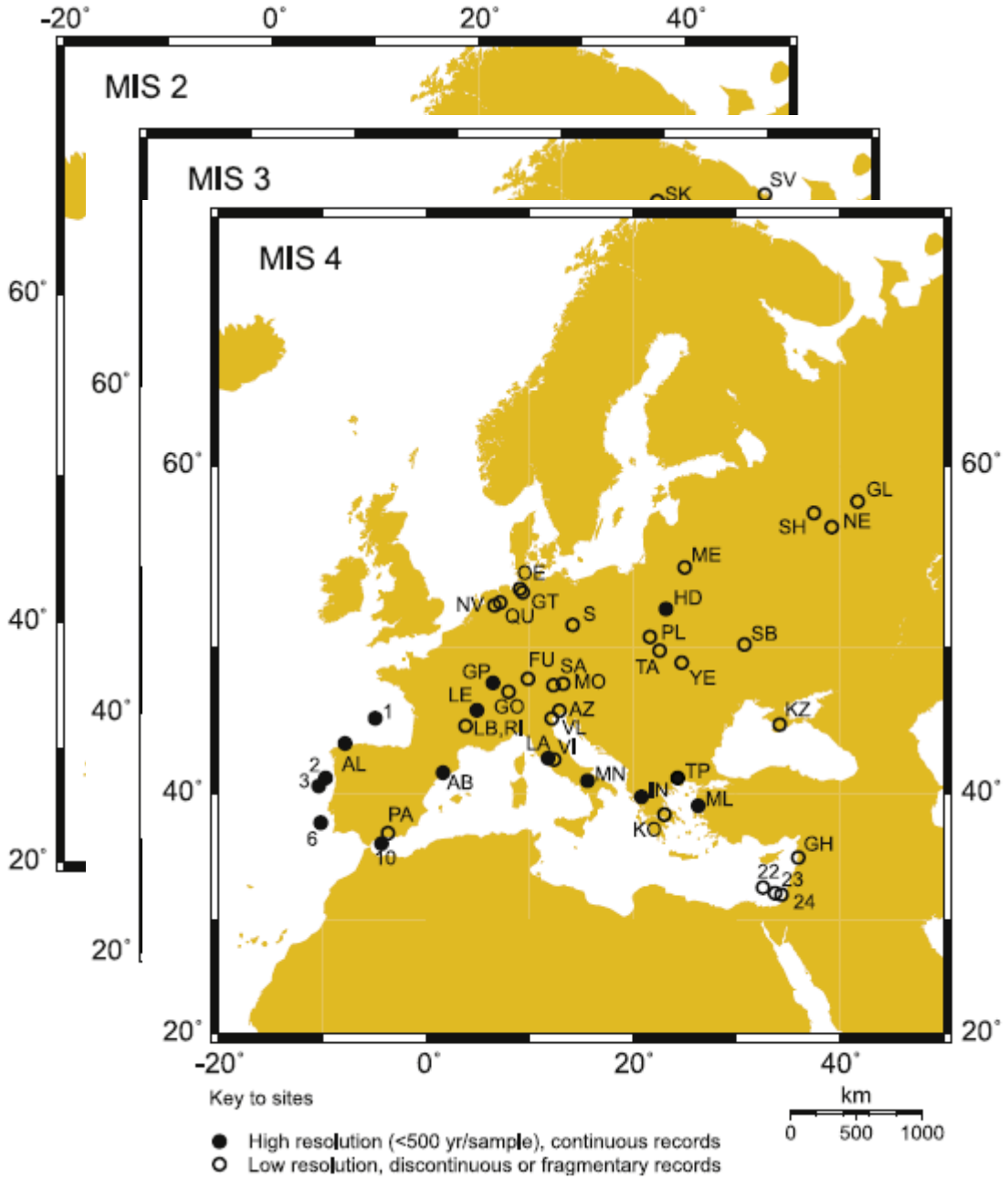
Changes in cryosphere affect the Earth System



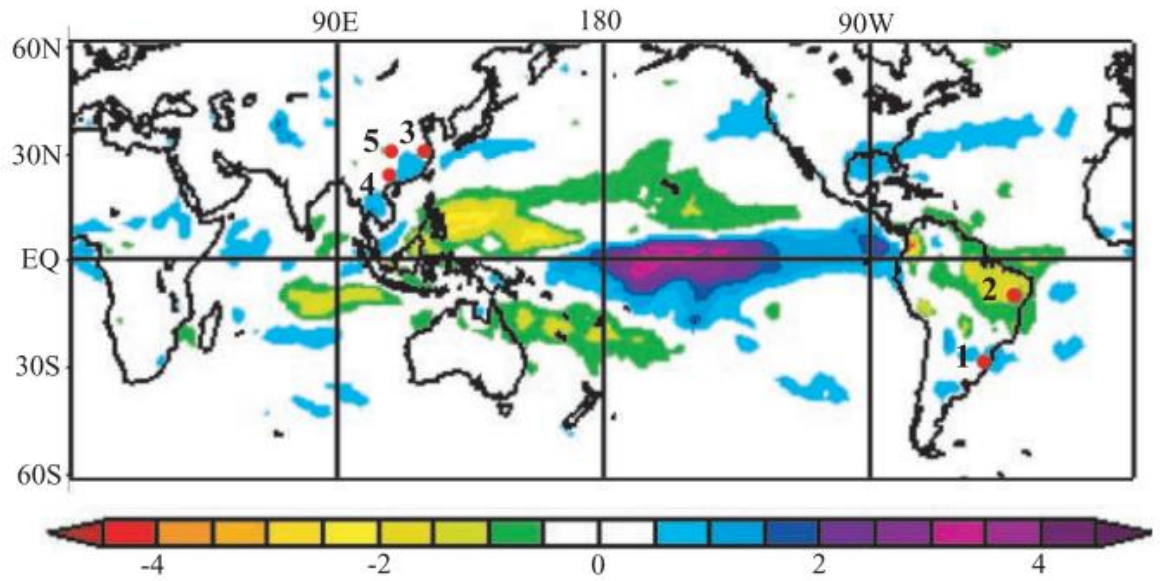
SAM: Southern Annular Mode
PSA: Pacific South-American oscillation
ACC: Antarctic Circumpolar Current

Colleoni et al., 2018 modified

Millennial-scale variability during the last glacial in vegetation records from Europe (Fletcher et al. 2010) - pollen

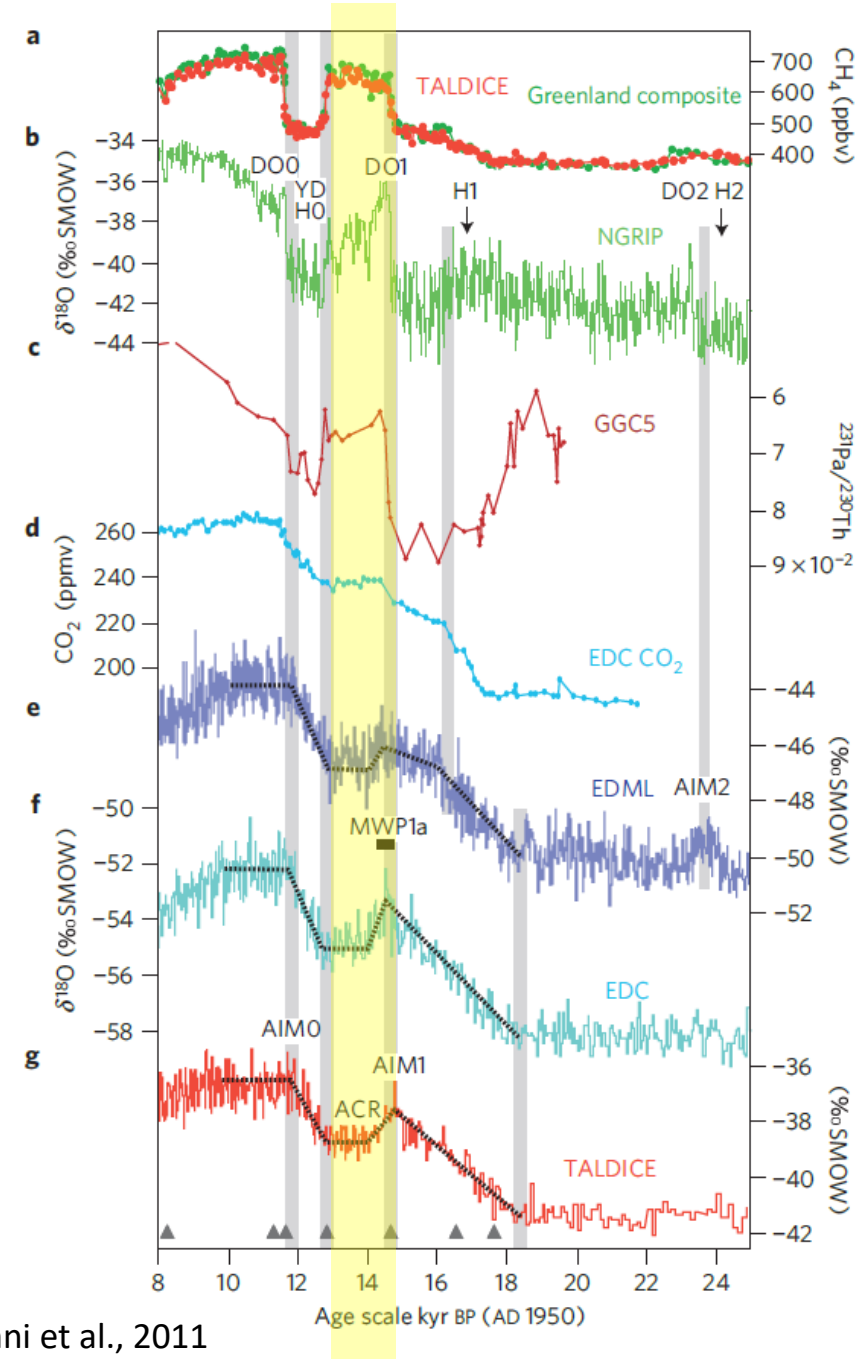


Millennial-scale precipitation changes in southern Brazil over the past 90,000 years (Wang et al. 2007) - speleothems record



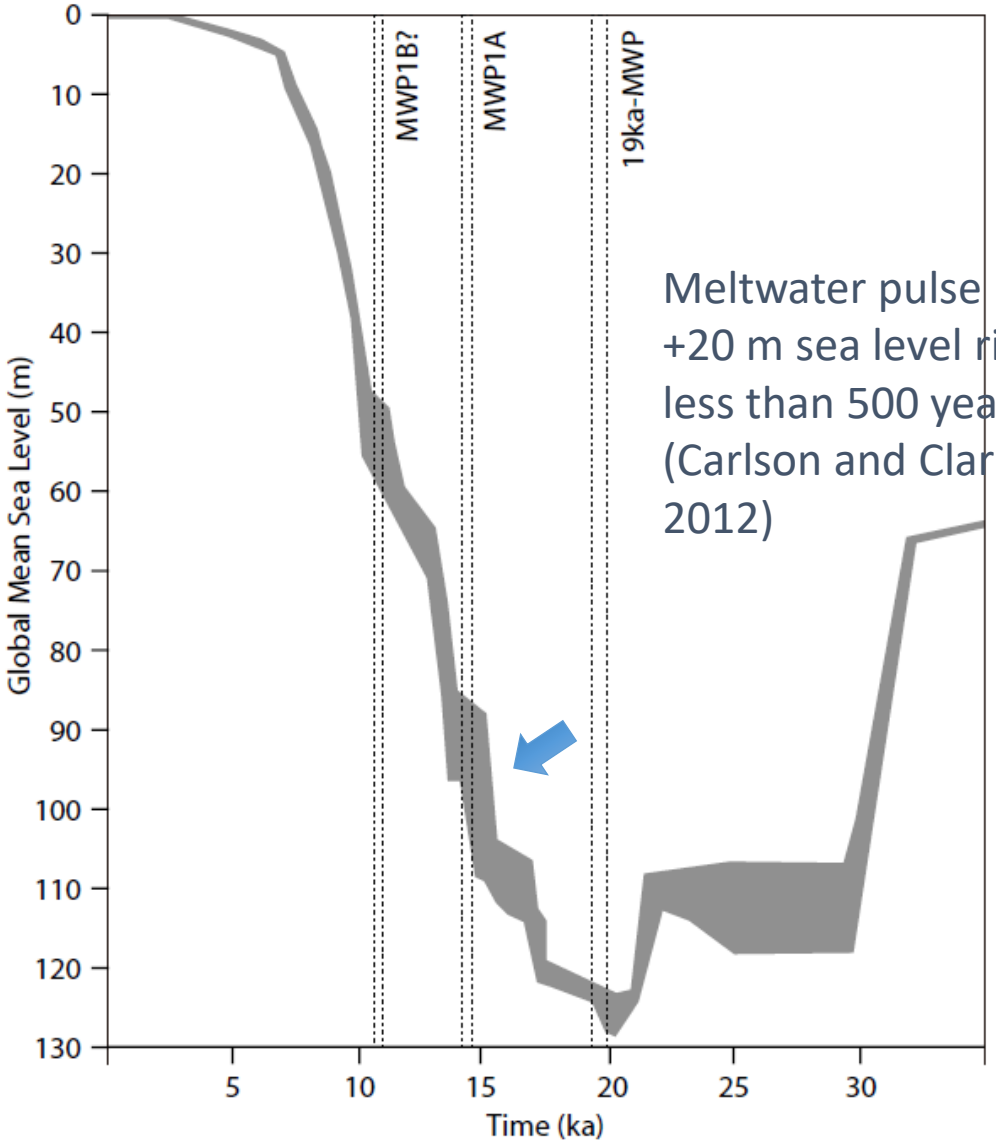
"millennial-scale events seem to be strongly modulated by AMOC changes and associated Inter-Tropical Convergence Zone migration. Through air-sea dynamics, abrupt climate events initiated in the North Atlantic eventually telecommunicate to the low latitudes."

Asynchronous temperature changes between Greenland and Antarctic ice core records during the last glacial period



Stenni et al., 2011

Average sea level record from Great Barrier coral Reef (ODP exp. 325)



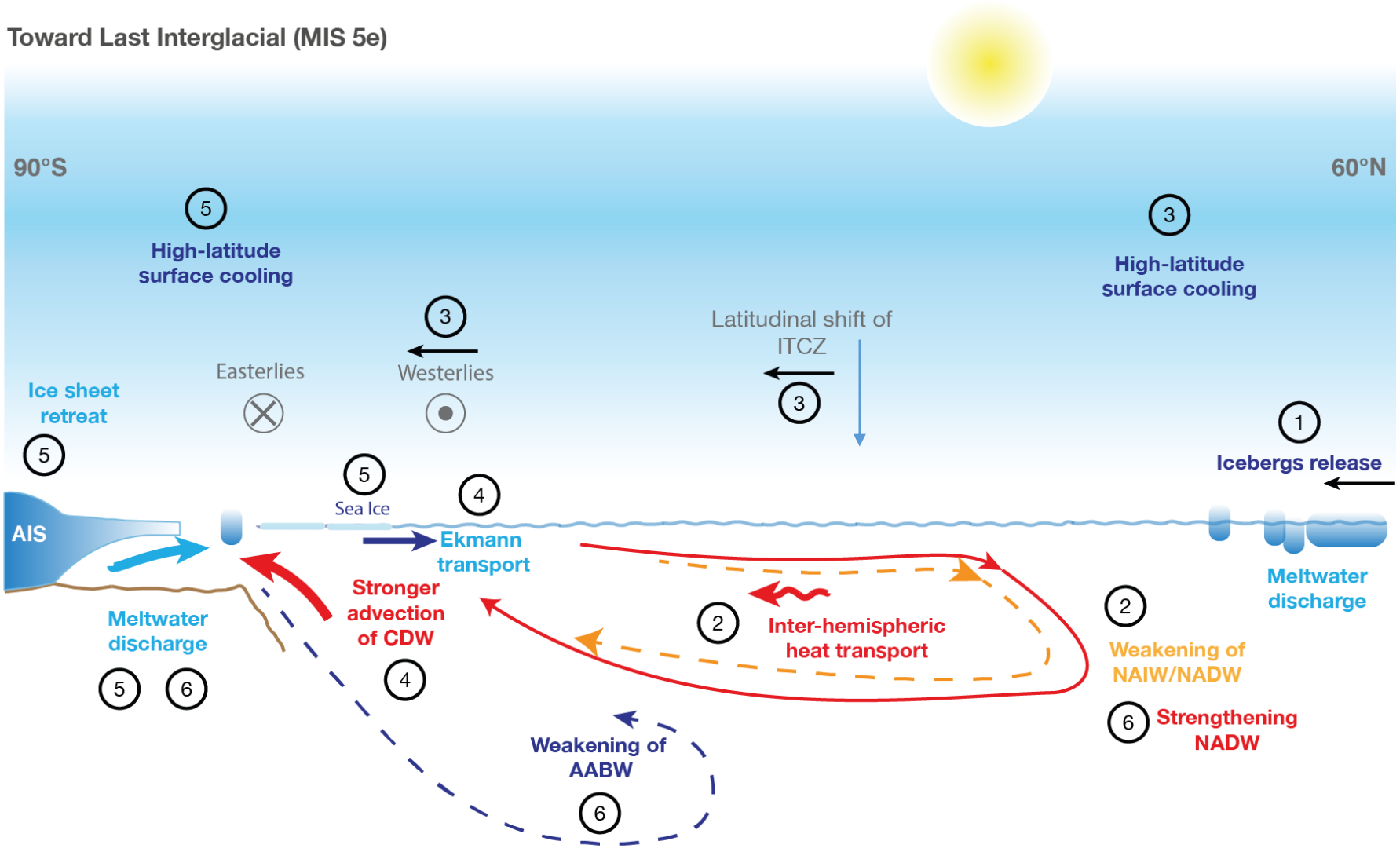
Meltwater pulse 1A = +20 m sea level rise in less than 500 years (Carlson and Clark, 2012)

Yokoyama et al. (2018 and 2019)

Impact of freshwater at global scale: bipolar seesaw

Antarctic Ice Sheet
Ice volume= $27x10^6$ Km^3

Equivalent global sea level= 58.3 m (~22.6 m of marine based ice)

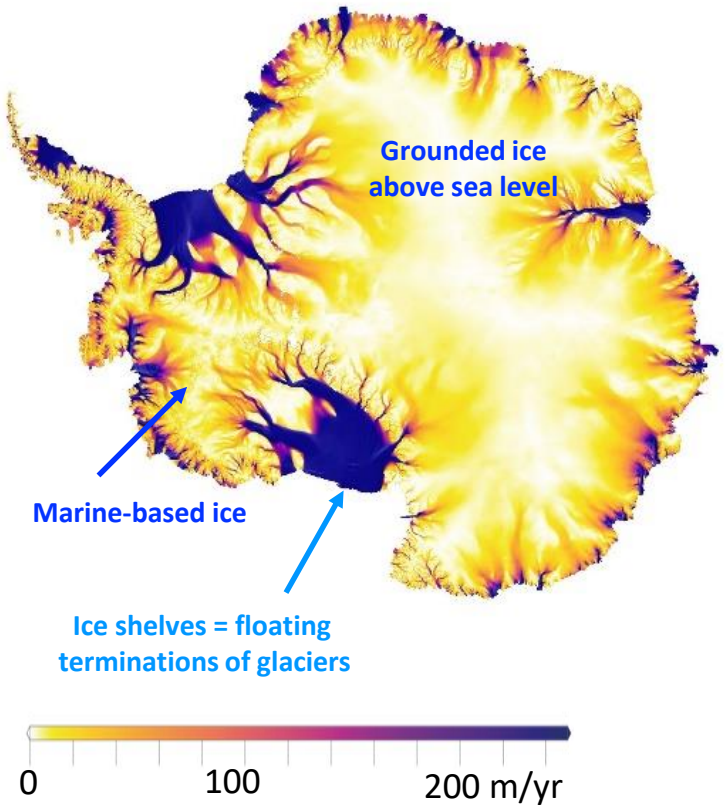


Greenland Ice Sheet
Ice volume= $2.85x10^6$ Km^3

Equivalent global sea level= 7.2 m

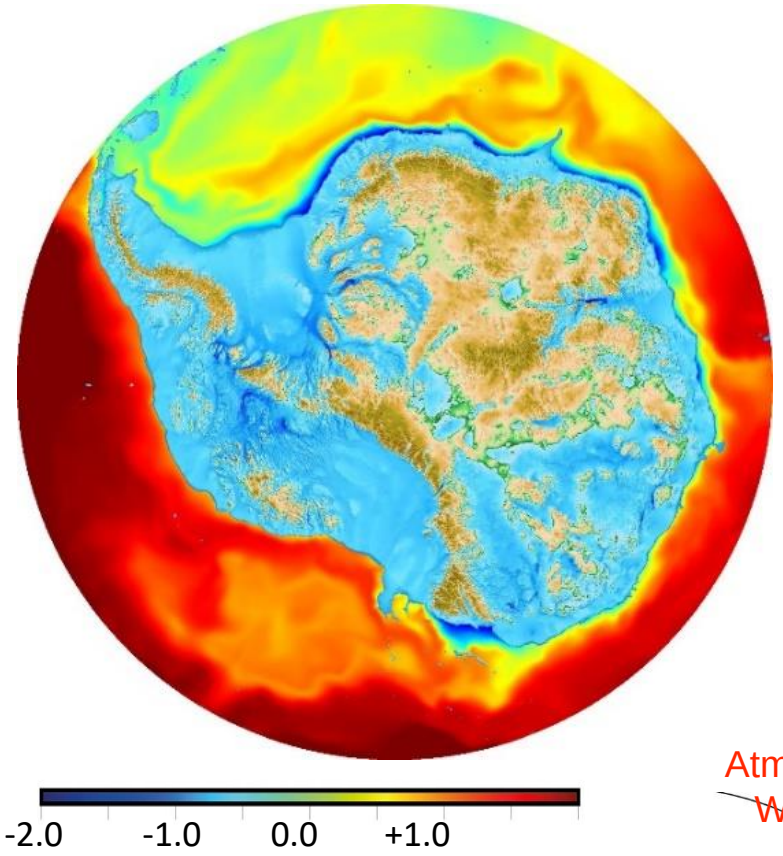
Taylor et al. 2020 Colleoni et al. 2022

Surface Ice velocity (Mouginot et al., 2019)



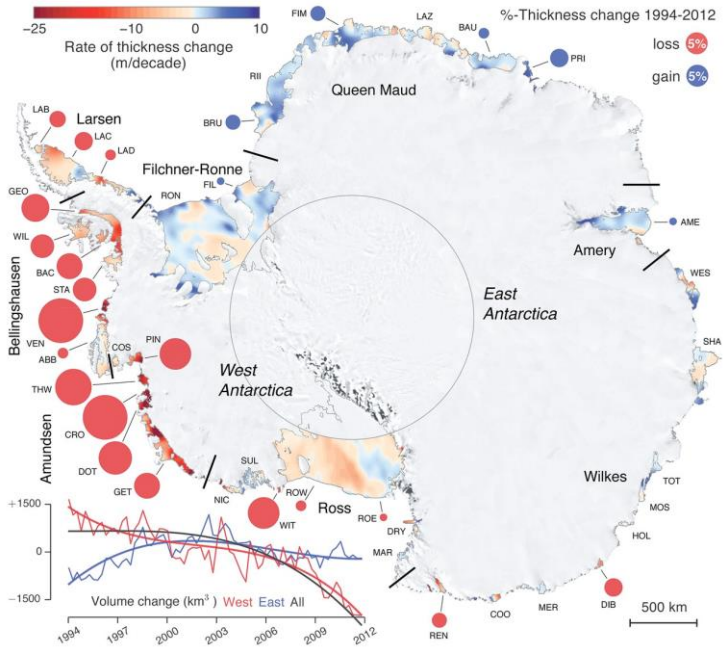
Topography (Bedmachine, Morlinghen et al., 2019)

Southern Ocean State estimates (temperature at 300 m Mazioff et al., 2019)

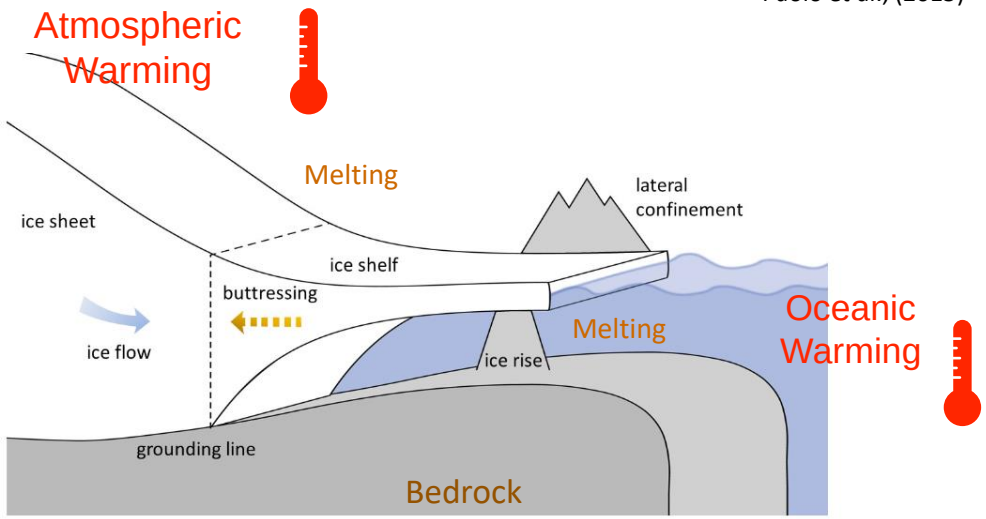


Blue: **below** sea level

Brownish: **above** sea level



Paolo et al., (2015)



Credit: Ronja Reese and Maria Zeitz

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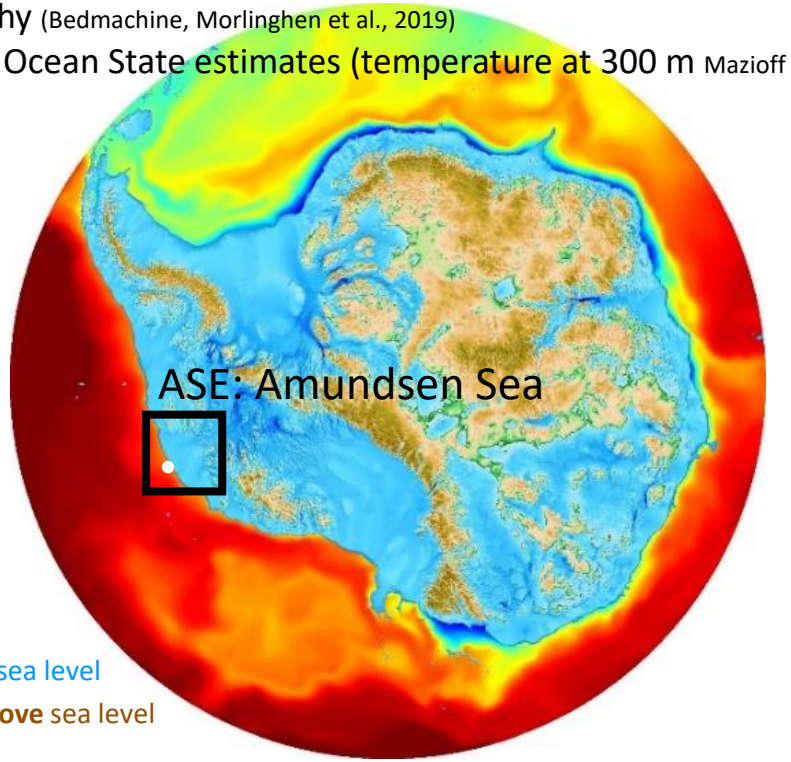

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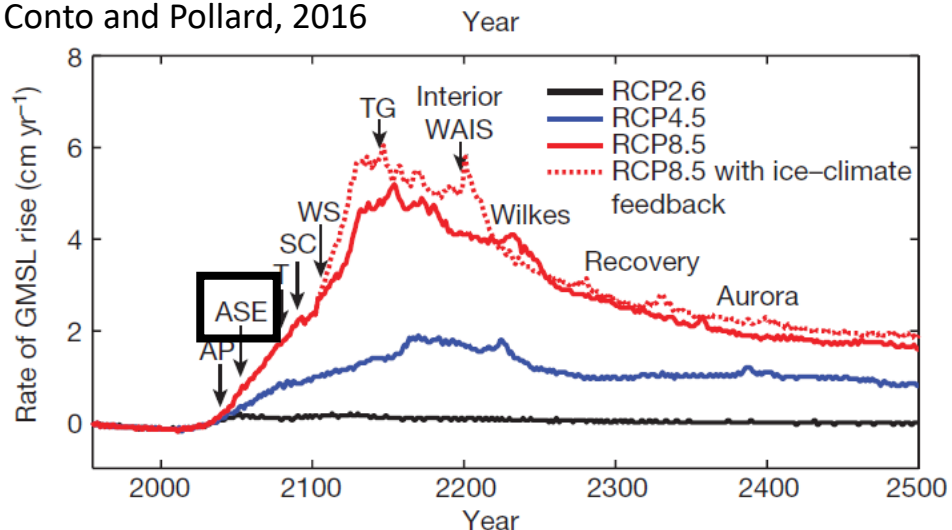
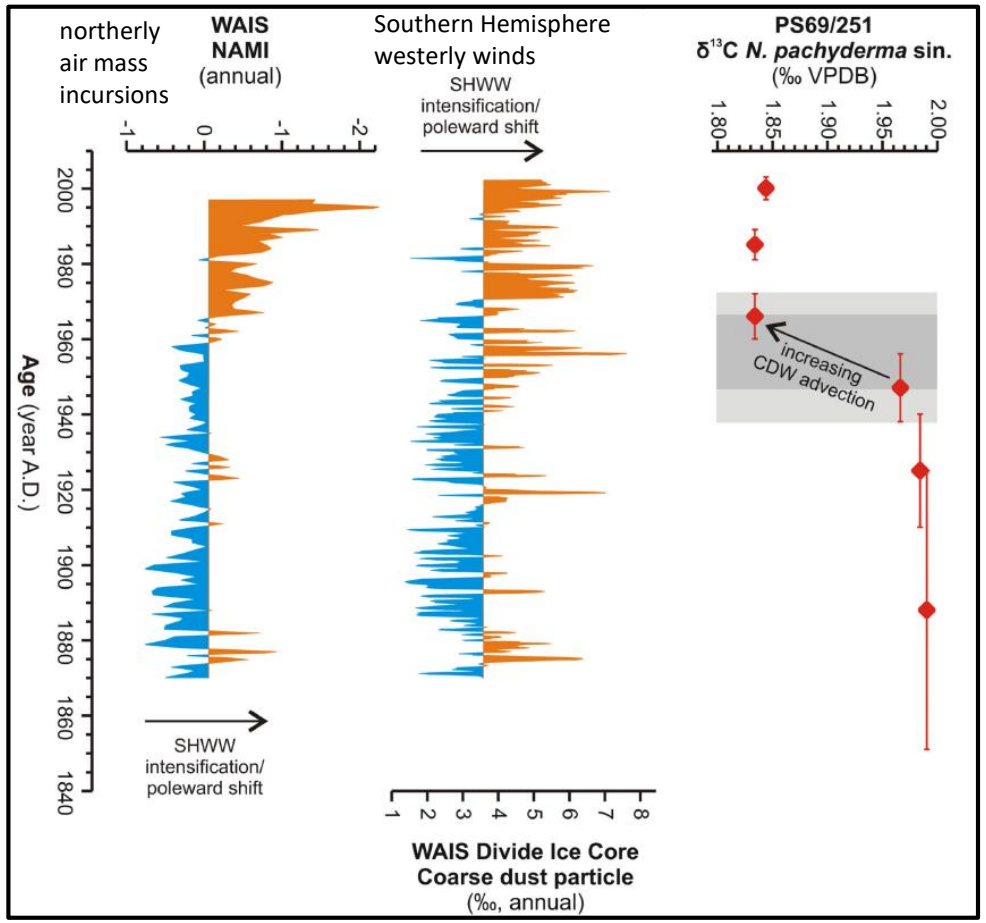
De Conto and Pollard, 2016



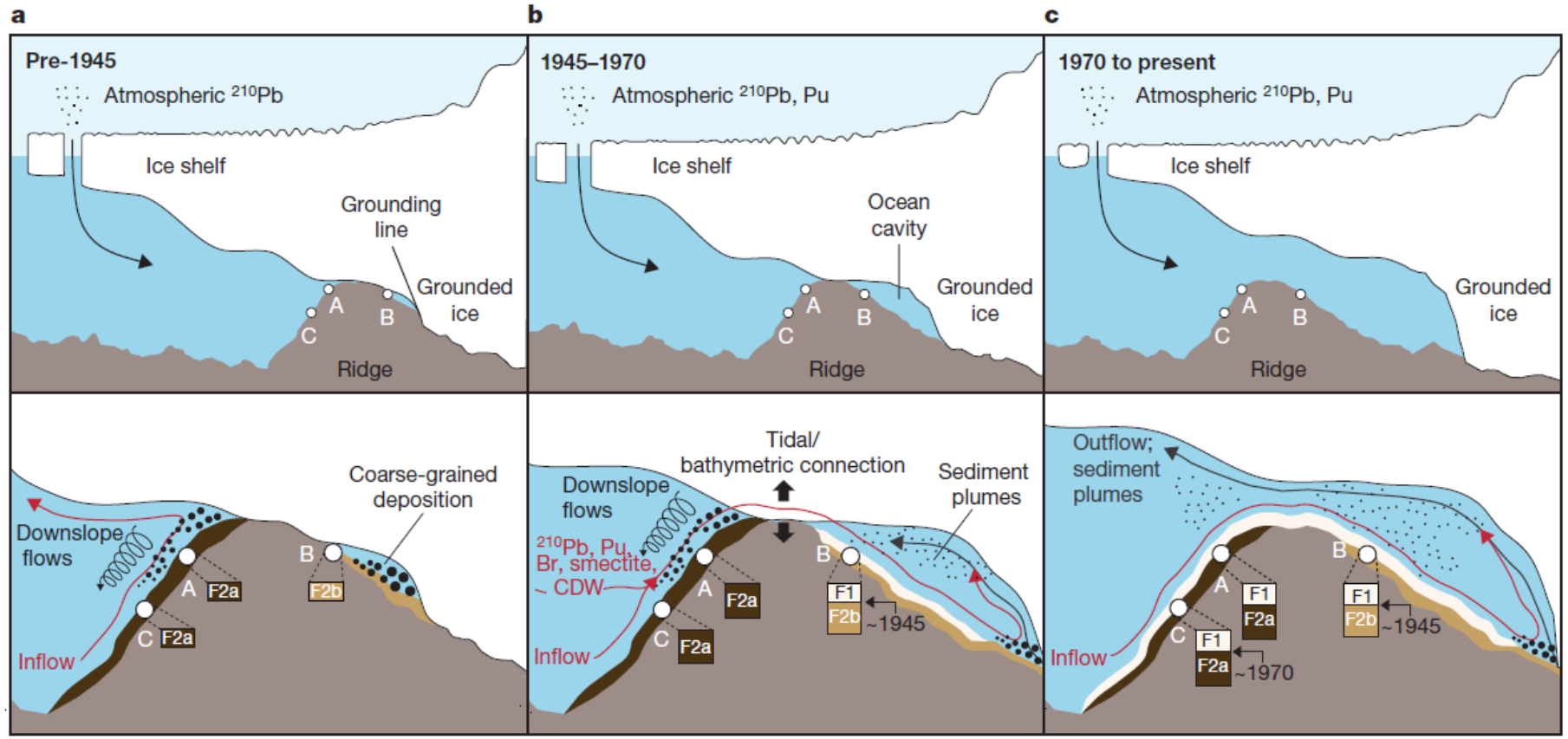
Strengthening of the subpolar jet during deglaciation enhances the advection of CDW towards the continental margins reconstructed from ice and sediment records



Smith et al., 2016 , Hillenbrand et al., 2017

Processes and sedimentation beneath the Pine Island Glacier ice shelf from geological record

- From satellite imagery glacier was last in contact with the ridge in the early 1970s.
- In the mid-1990s, the basal melt rate exceed 50myr-1
- Melting and input of ice from upstream of the grounding line has increased by at least 40% as a result of the glacier's acceleration while the floating tongue has continued to thin



depositing coarse-grained ice proximal sediments

Deposition of fine-grained ice distal sediment
inflow of marine water (CDW)

Stop of downslope flows
deposition of fine-grained open water

Smith et al., 2017

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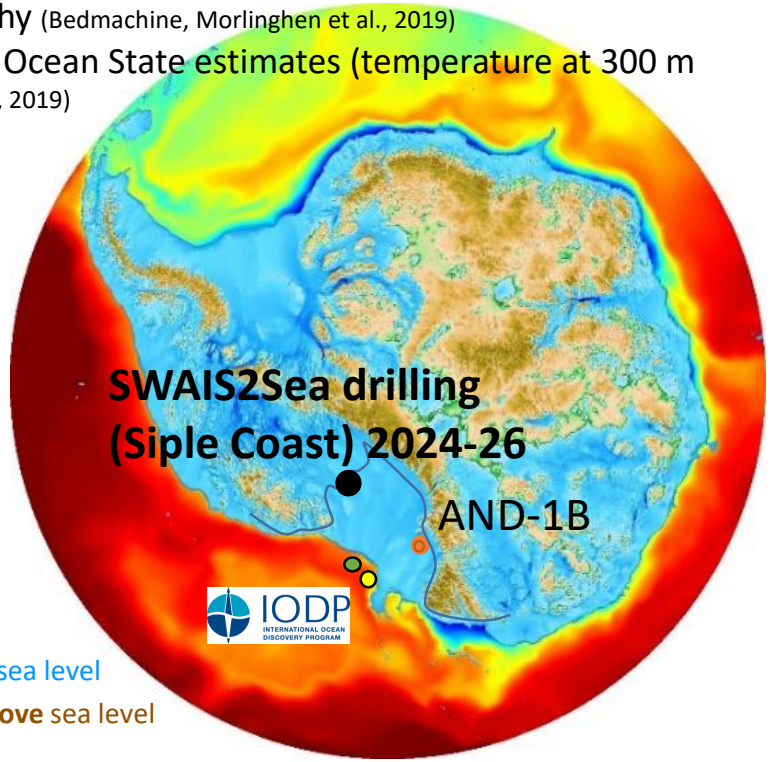

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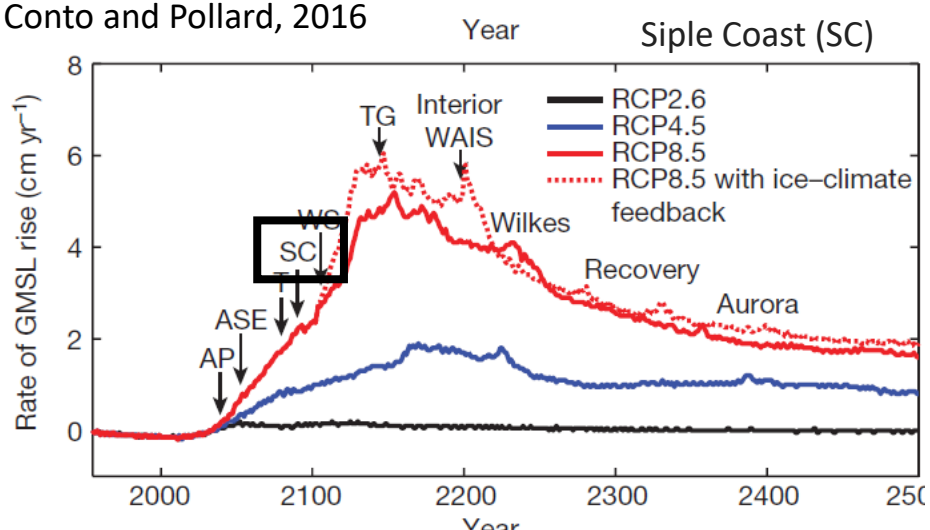

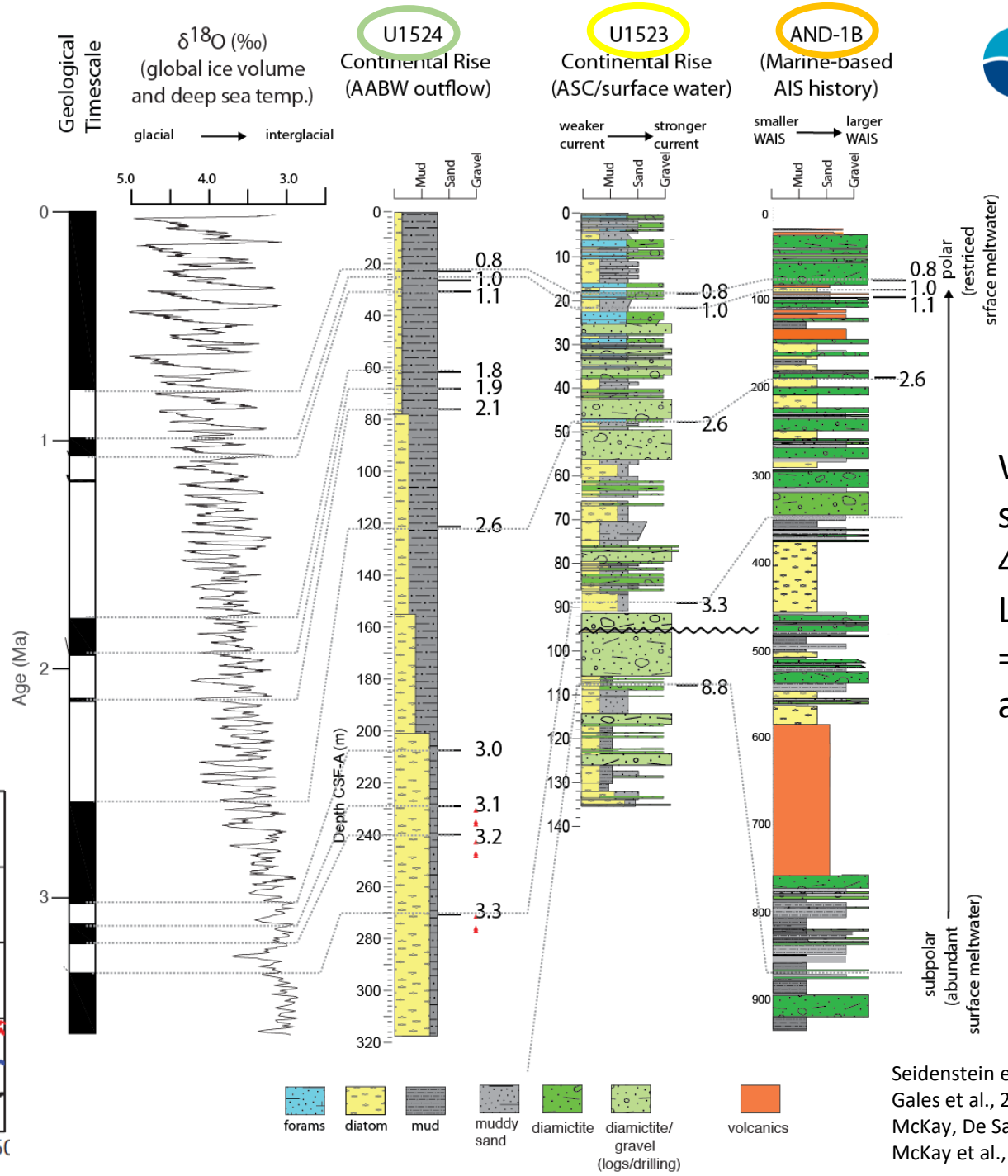

IODP
INTERNATIONAL OCEAN DISCOVERY PROGRAM

After 1.78 Ma:
Drier, colder, stronger ASC

Warm Pliocene superinteglacials
4-5°C > today
Less AABW
=> Polar amplification

Millennial scale changes (analysis are in progress)

Seidenstein et al., 2024
Gales et al., 2023
McKay, De Santis, Kulhanek et al., 2019
McKay et al., 2012

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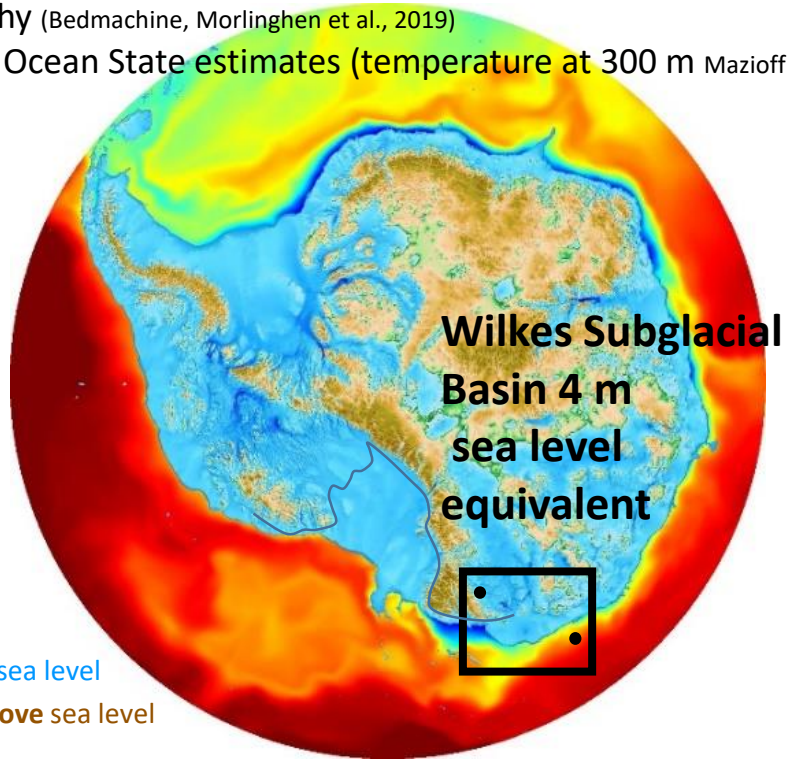
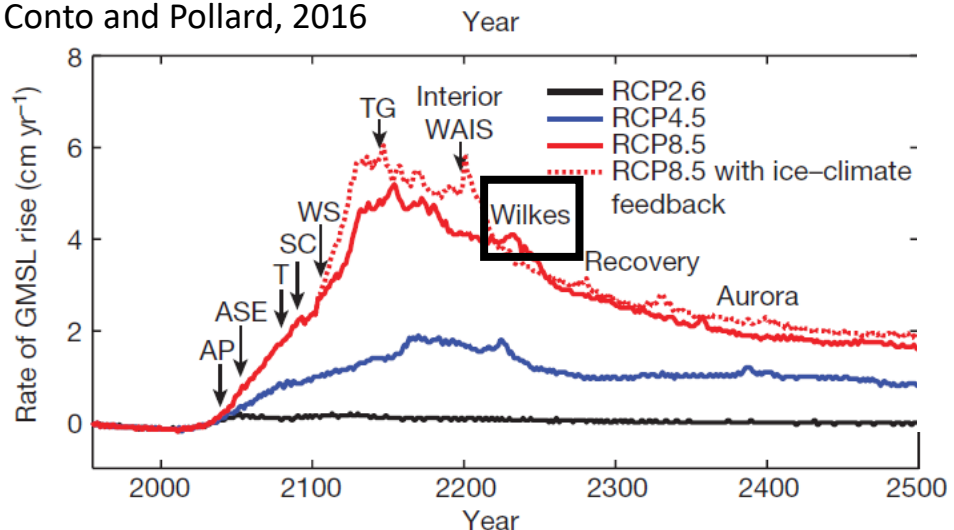
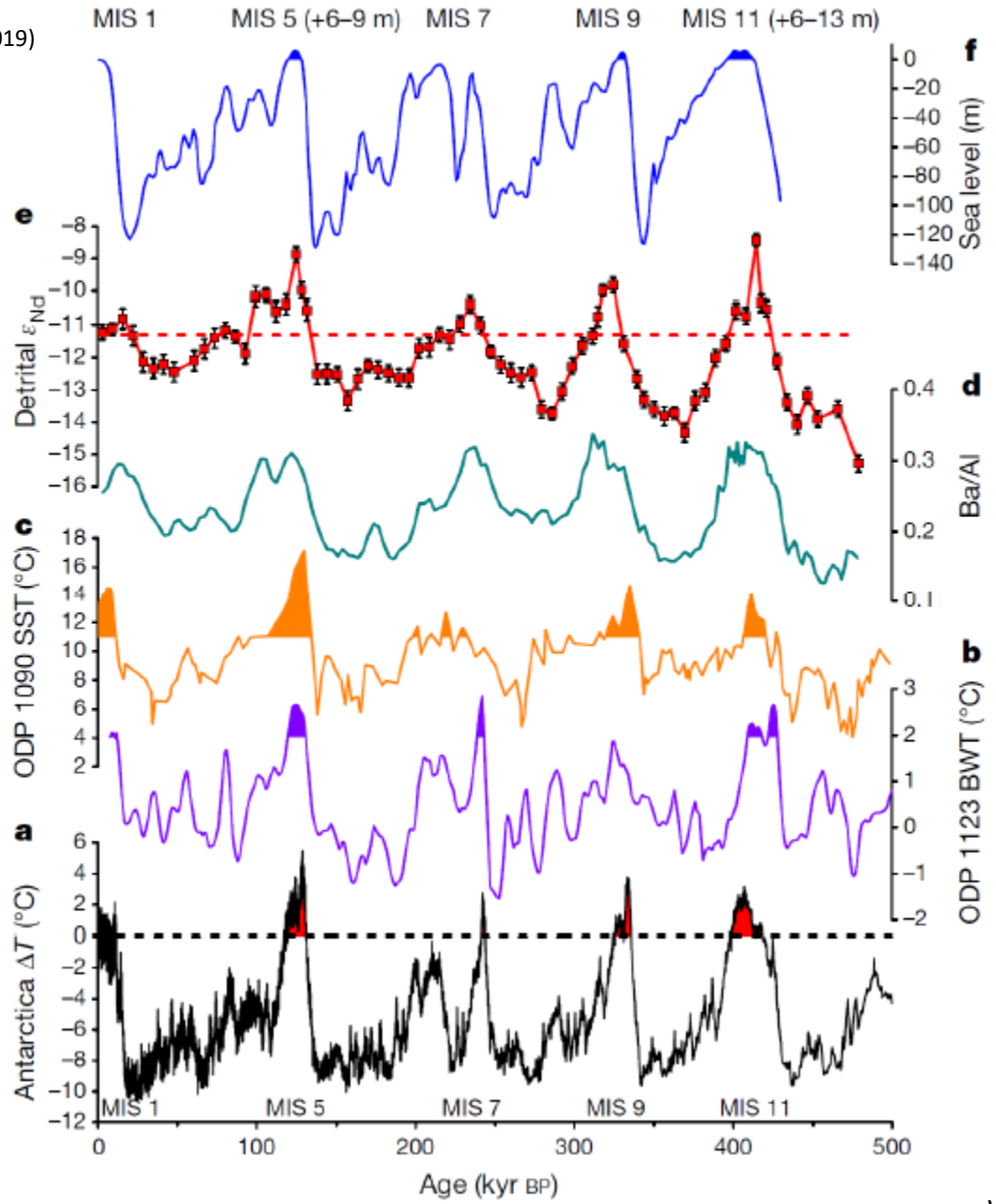


De Conto and Pollard, 2016





MIS 5, MIS 9, MIS 11: ice sheet margin at the Wilkes Basin retreated

MIS 11:
→ ca. 700 kilometres inland = + 3-4 m SLE

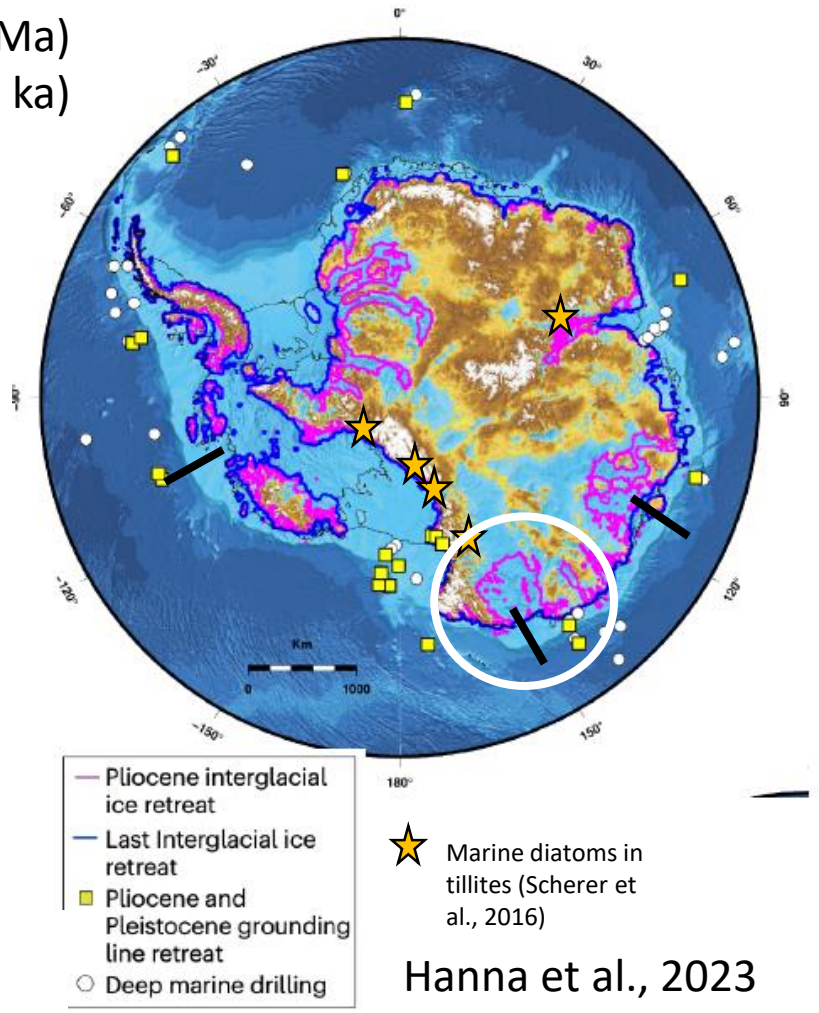
→ ca. + 2°C for 2500

Wilson et al., 2018 *Nature*
Blackburn et al., 2020, *Nature*
Crotti et al., 2020

Simulated Antarctic Ice Sheet retreat during a generic warm interglacial

Pliocene (3.3–3.0 Ma)

The Last Interglacial (~130 ka)



Hanna et al., 2023

EU-PolarNet

Service on building the road map on Ice-Ocean-Lithosphere interplay study

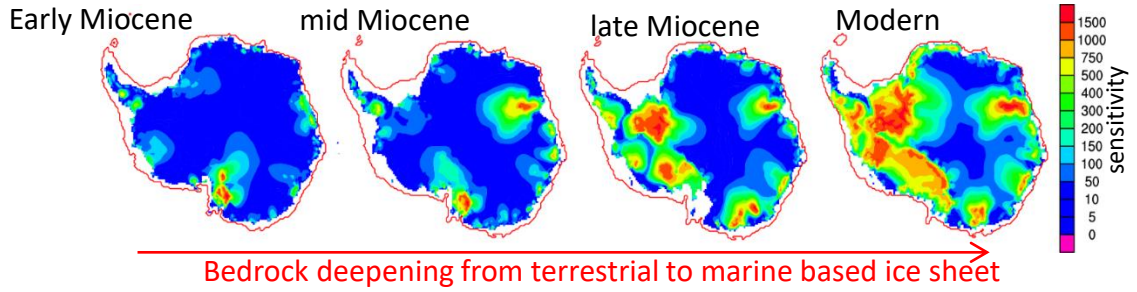
icdp INTERNATIONAL CONTINENTAL SCIENTIFIC DRILLING PROGRAM

ECORD European Consortium for Ocean Research Drilling

ANTARCTIC RINGS

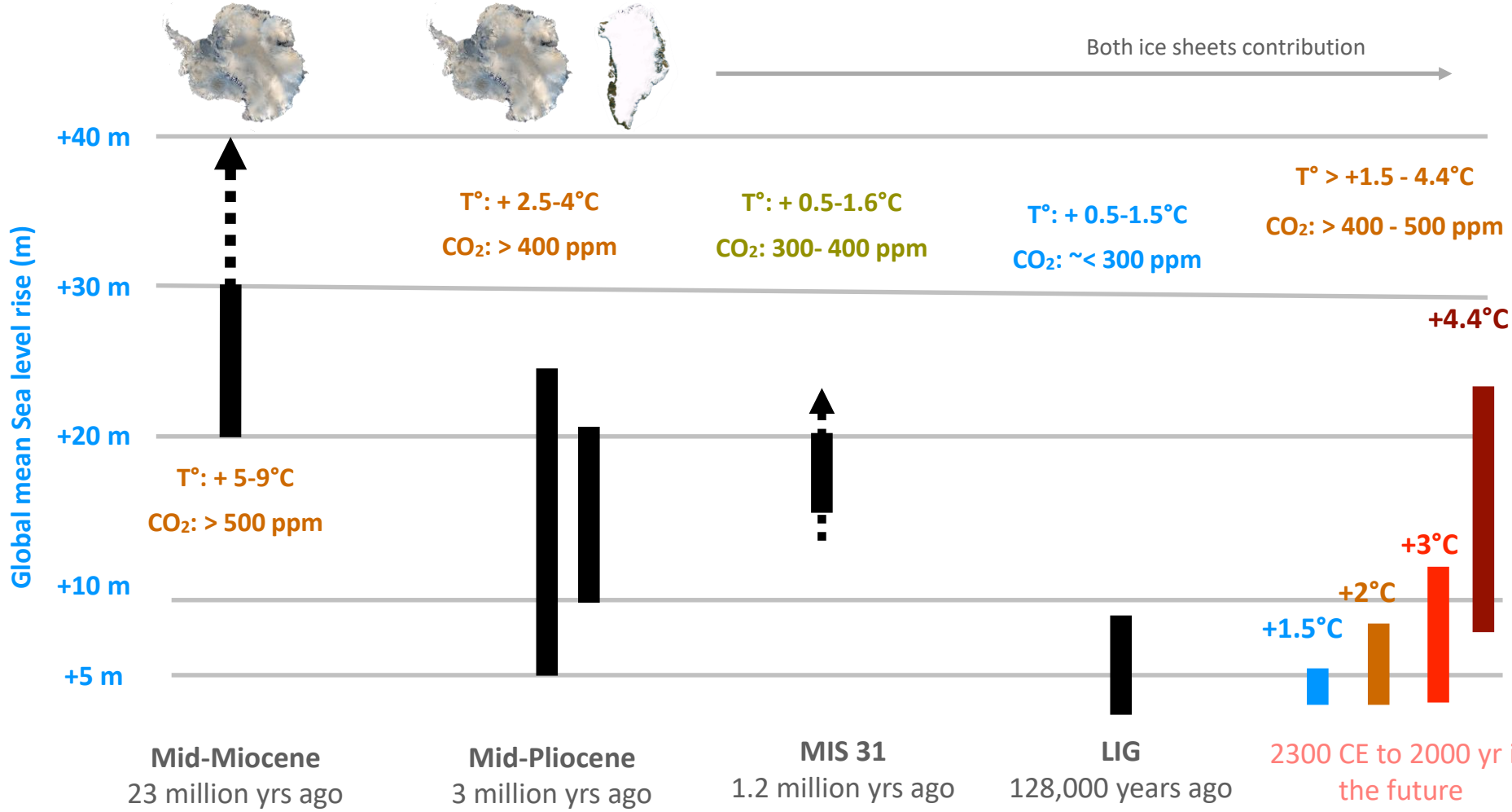
esa

European Commission



Subglacial topography/bathymetry evolution = increase ice sheet sensitivity to ocean warming

Colleoni, F., et al. 2018



After Colleoni et al. (2022)

What will be the impact of the polar amplification of future climate warming?

Northern Hemisphere Ice Sheets played a dominant role **in millennial-scale variabilities** during the late Pleistocene, but geological and **model data suggest a potential contribution of marine Antarctic Ice Sheets as well even earlier (still poorly known).**

IODP Exp 374 (analysis is in progress) drilling projects provides new high resolution Pliocene to the Holocene records from Ross Sea to be compared to Beyond Epica ice cores => but similar records are lacking from all the other sectors

Future abrupt change (thresholds instability crossing): when and how fast?

⇒Need more info from proxy (e.g. paleo-temperature, paleobathymetry, paleo-ice sheet extension) about past evolution of all the Antarctic marine based ice sheets

⇒ Need to better know boundary conditions, physics, mechanism, forcing, feedbacks

⇒ Need high resolution records from different catchment areas around Antarctica to provide constrain to regional and global models