Paleoclimate dynamics: Questions and Applications with FESOM and AWI-ESM

FESOM days 2020, Dec 7

Gerrit Lohmann and colleagues from paleodyn

Paleoclimate dynamics: identifying driving mechanisms of climate change

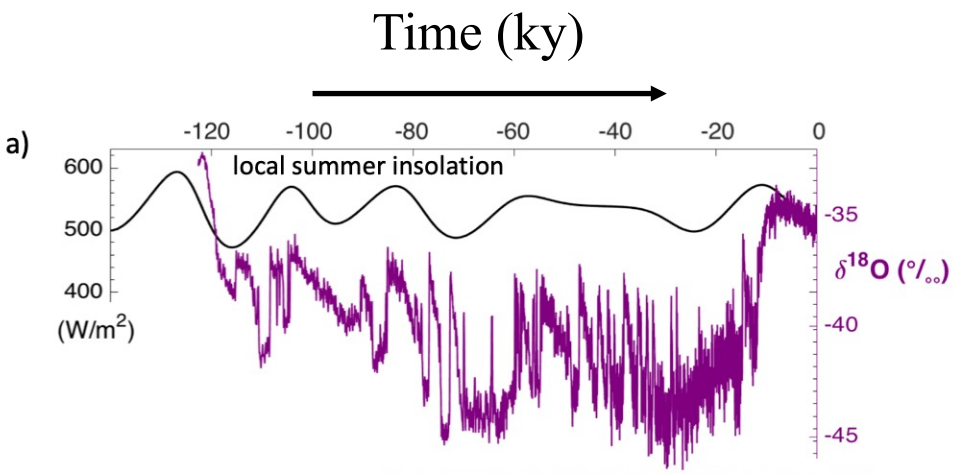
- to identify driving mechanisms for climate change
- external forcing and internal variability
- to test models of the Earth system

Paleoclimate dynamics: identifying driving mechanisms of climate change

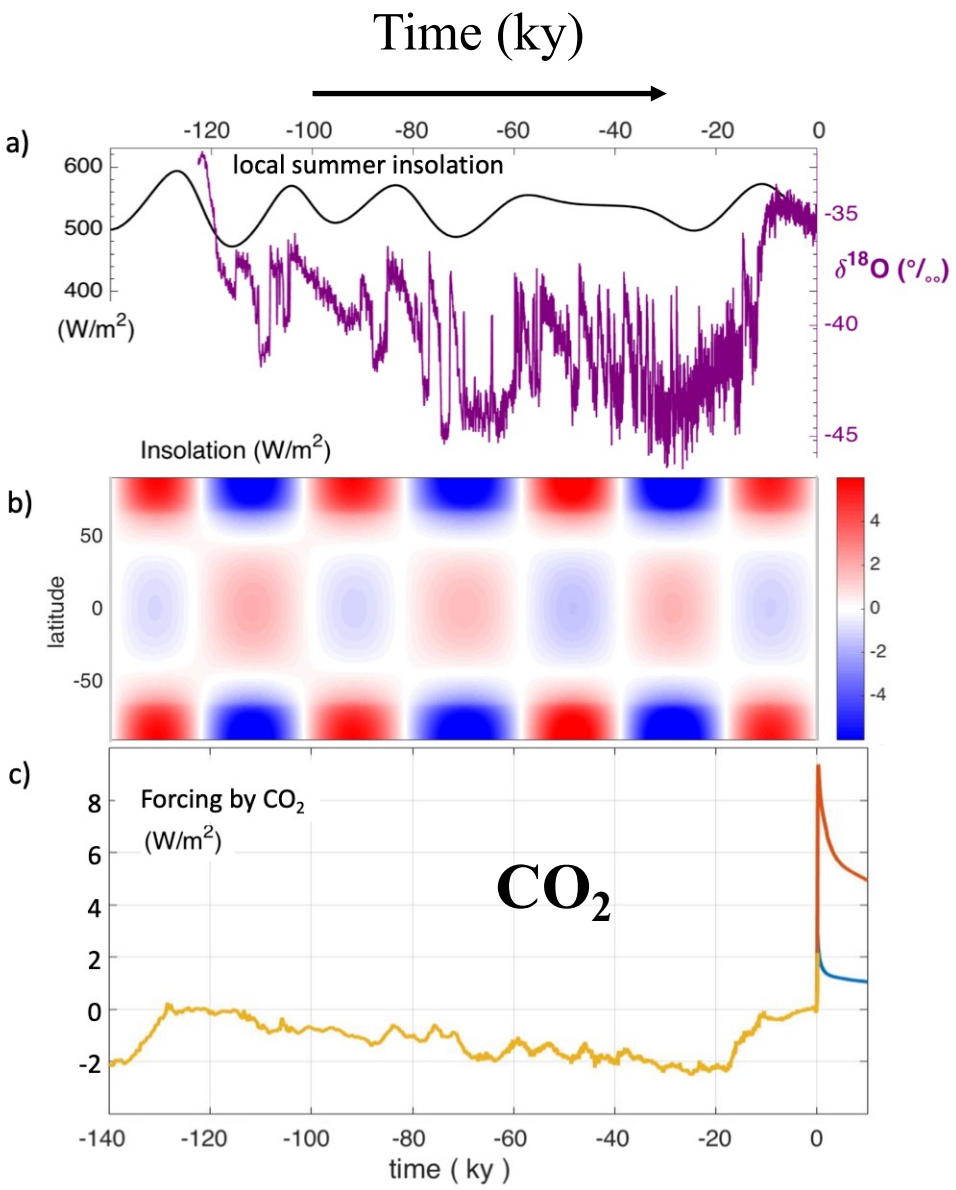
- to identify driving mechanisms for climate change
- external forcing and internal variability
- to test models of the Earth system

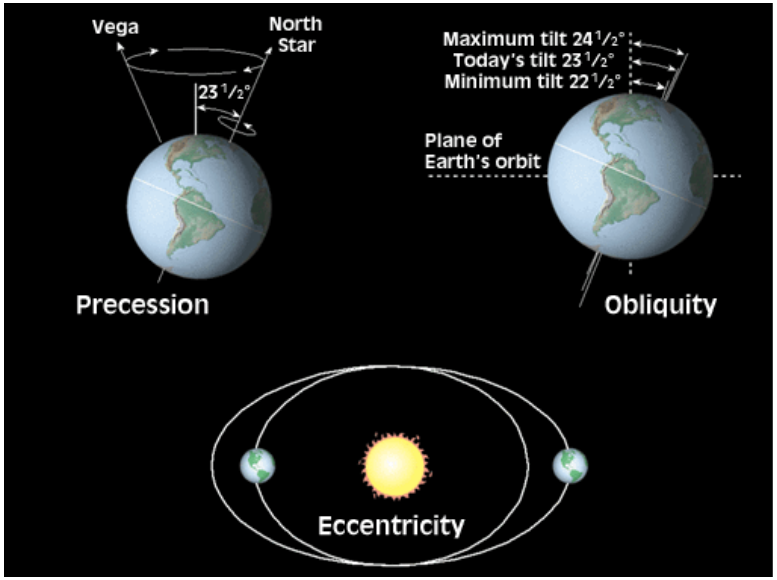
- **Applications: Selected time slices & periods**
- **Questions & Challenges**
- **Model developments with FESOM & AWI-ESM**

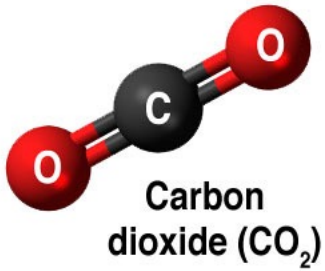
The last 120,000 years



NGRIP, 2004; Berger, 1988

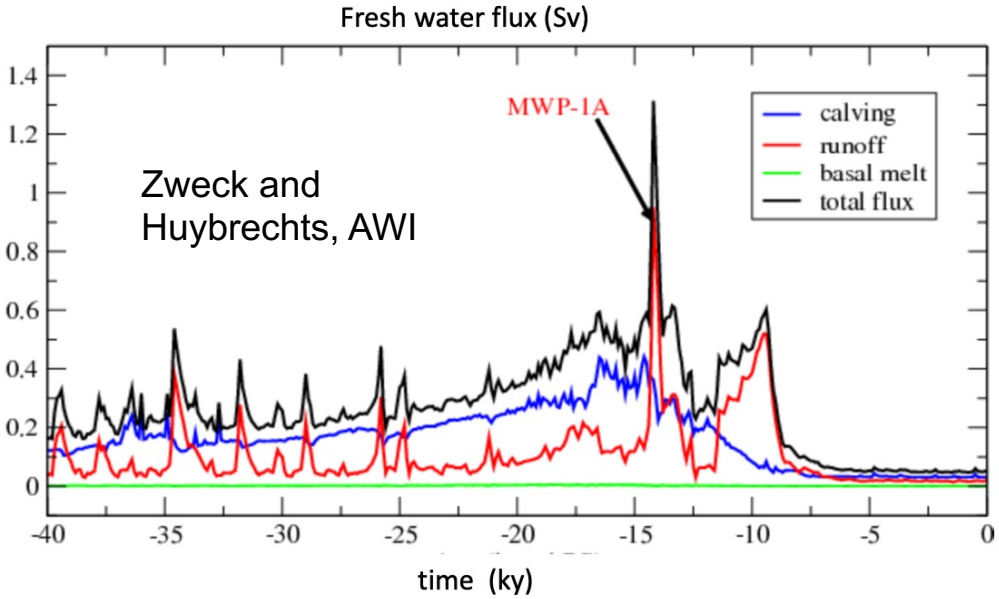






Lohmann et al. (2020) based on NGRIP, 2004; Berger, 1988; Köhler et al., 2017; Archer and Brovkin, 2008

Deglacial Hosing: Ocean response

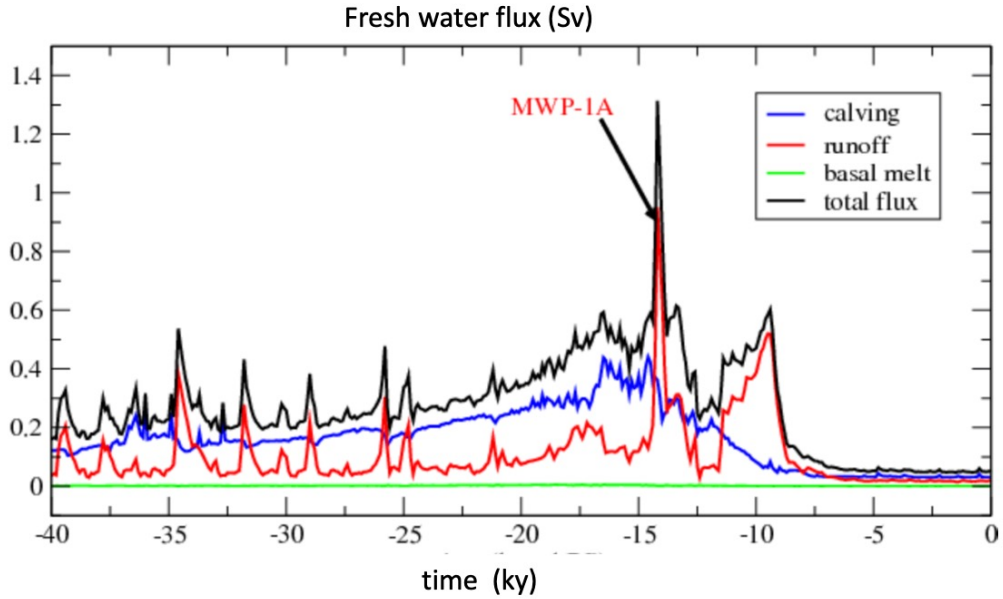


Runoff: Melting of ice (“liquid“)

Calving: Heinrich Events (“solid“)

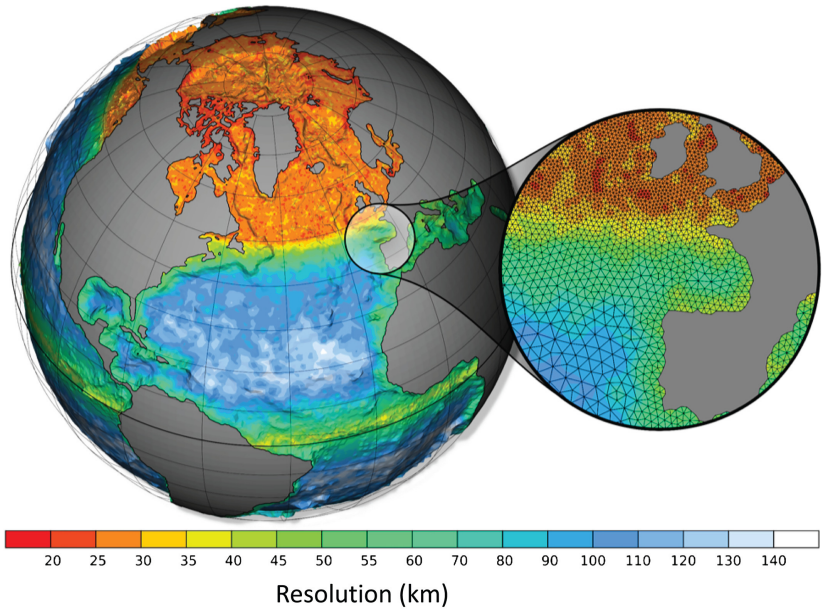
Lohmann et al., Paleoceanography. 2020

Deglacial Hosing: Ocean response



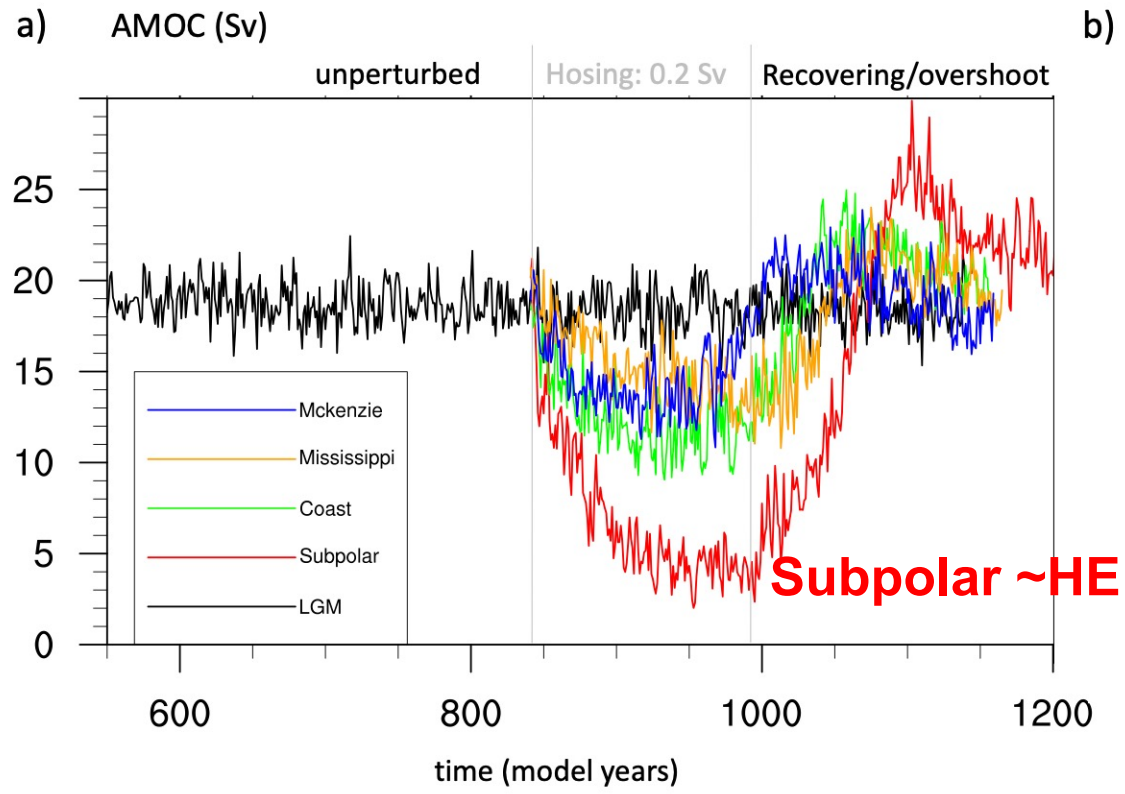
Runoff: Melting of ice (“liquid“)

Calving: Heinrich Events (“solid“)

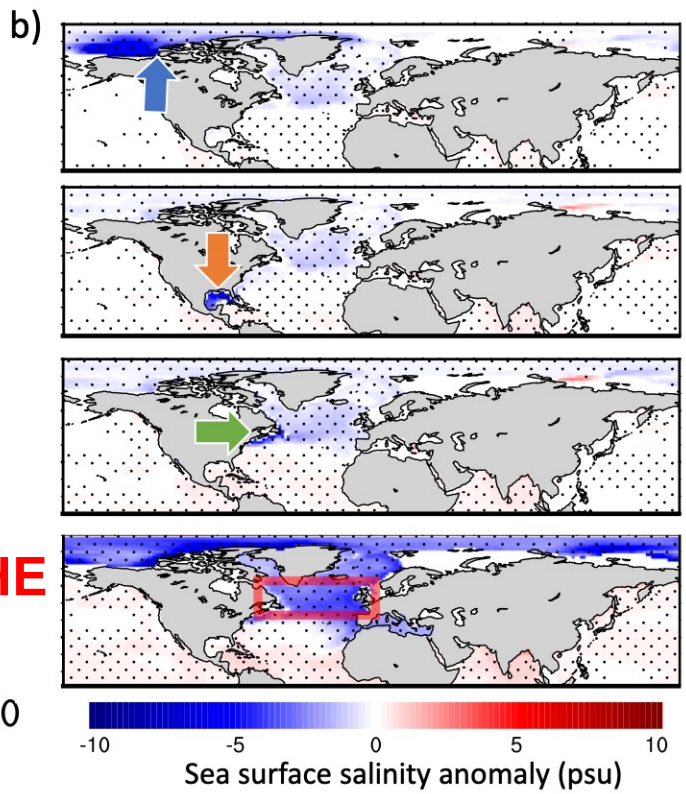


Lohmann et al., Paleoceanography. 2020

Deglacial Hosing: Ocean response



Subpolar ~HE

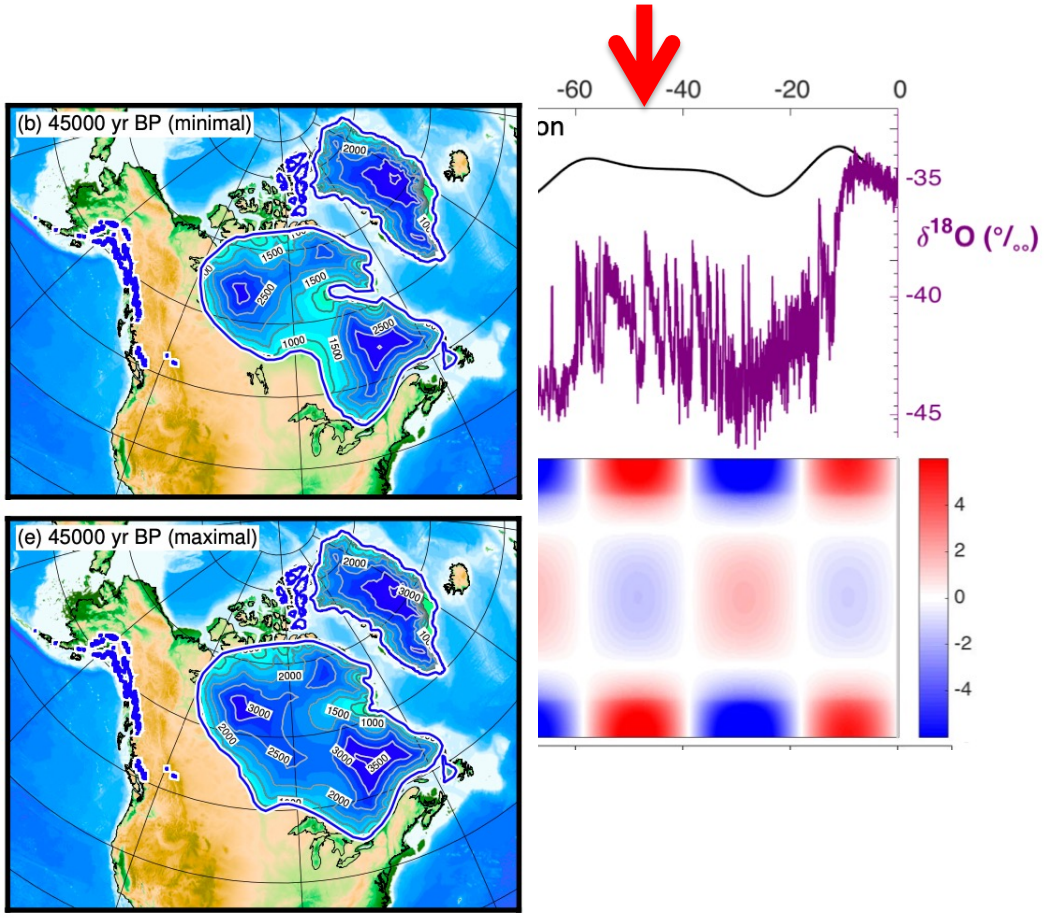


AWI-ESM1

Lohmann et al., Paleoceanography. 2020

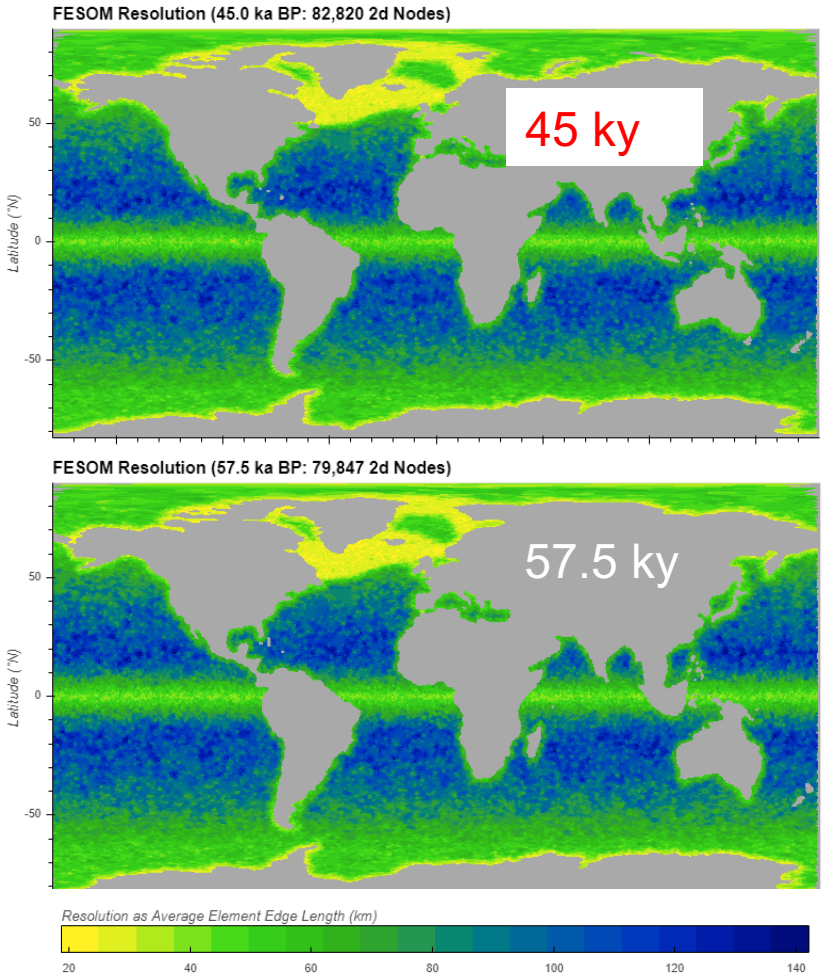
Glacial dynamics

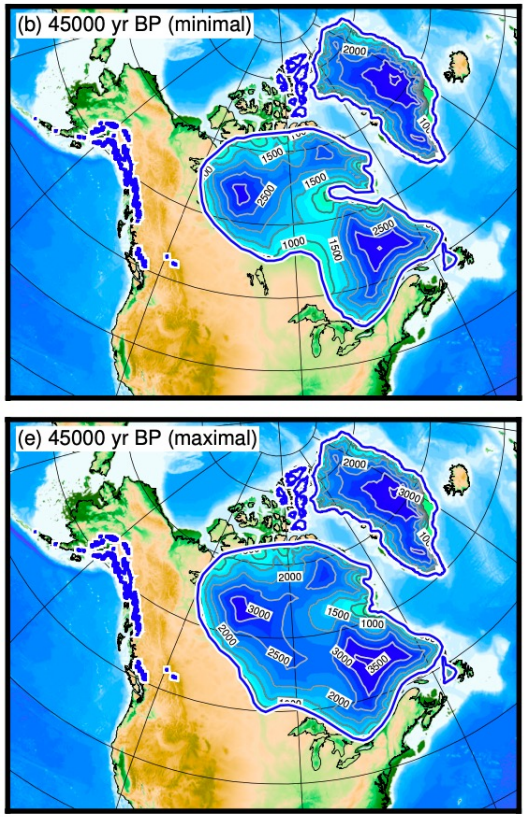
Climate model ?

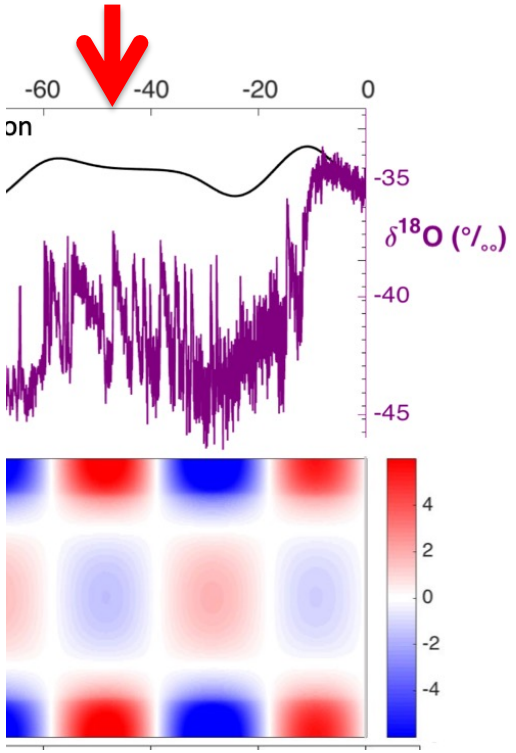


Govan et al., Nat comm

Glacial dynamics



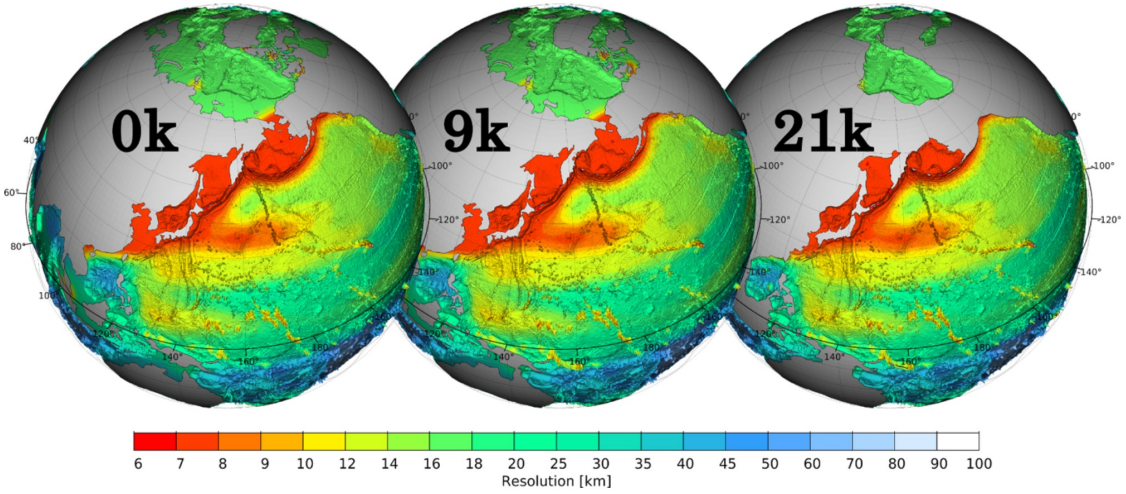


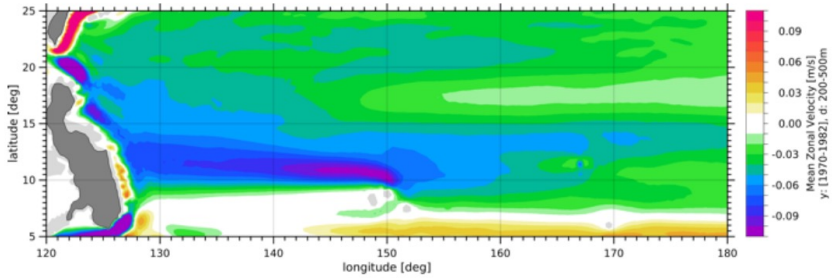


Govan et al., Nat comm

Umesh Dubey, Paul Gierz

Model development NW Pacific





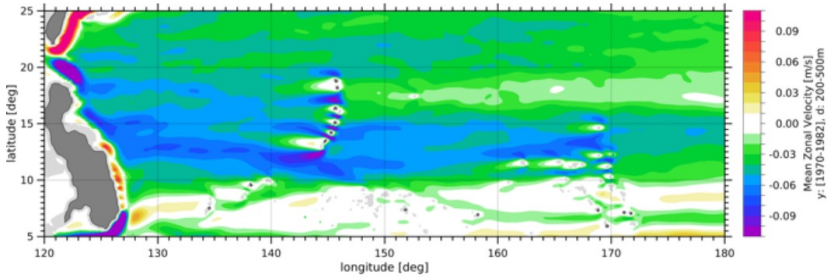


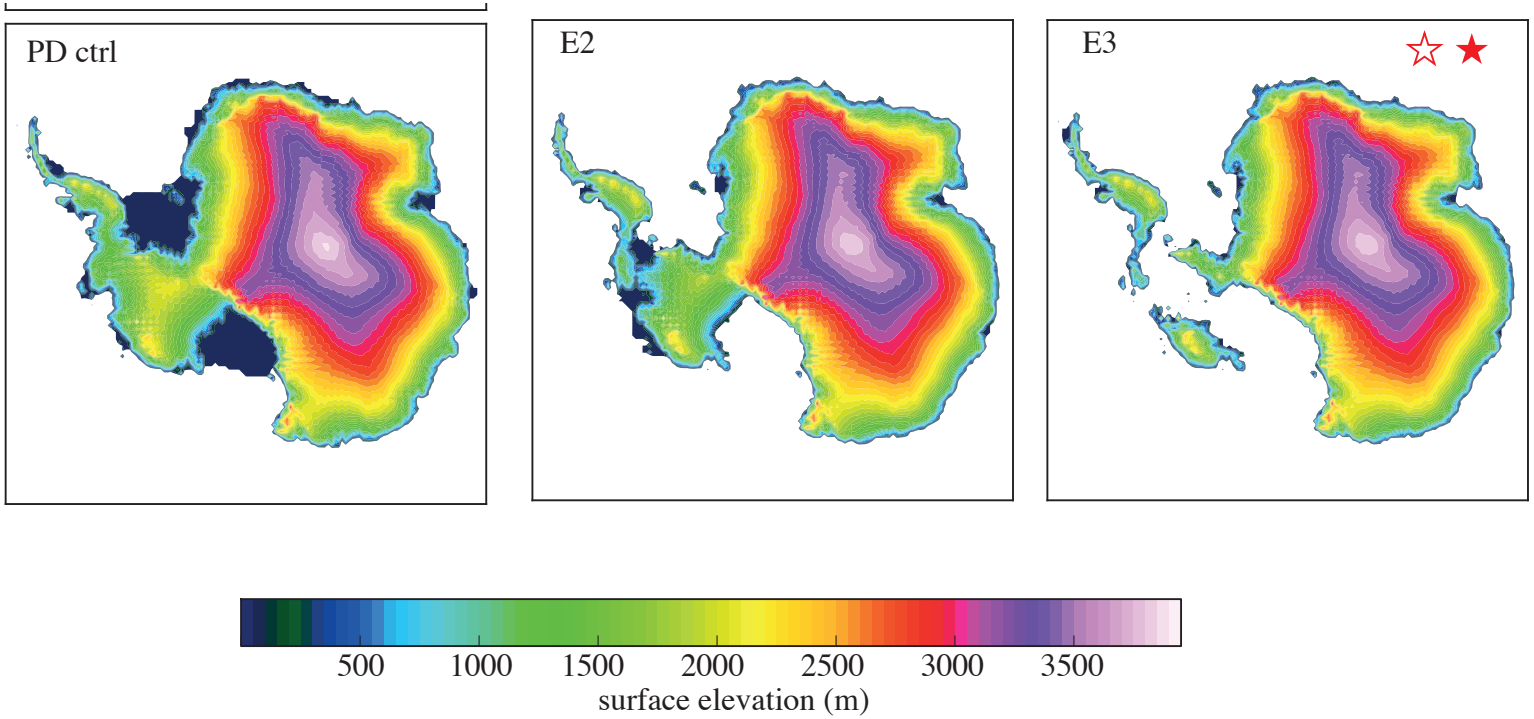
Fig. 7. a)-b): Modeled mean zonal velocity in the western equatorial and subtropical Pacific for a setup with coarse (Fig. 4c) and high resolution (c) in that region.

Patrick Scholz in BMBF
Lohmann, Tiedemann SiGePax

Present

LIG + 2° C
SL: 2-3 m

LIG + 3° C
SL: 3-5 m



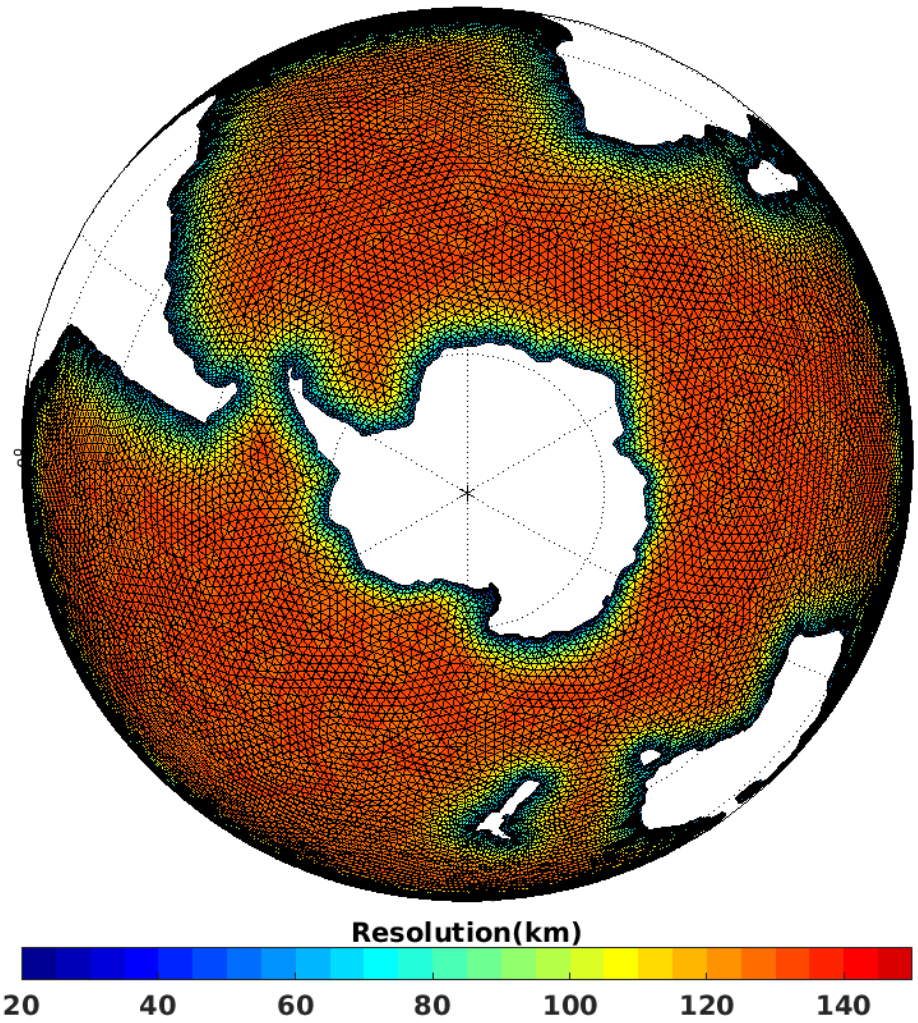
What happens if the West Antarctic Ice Sheet is collapsed?

Stand alone Ice Sheet Model: RIMBAY

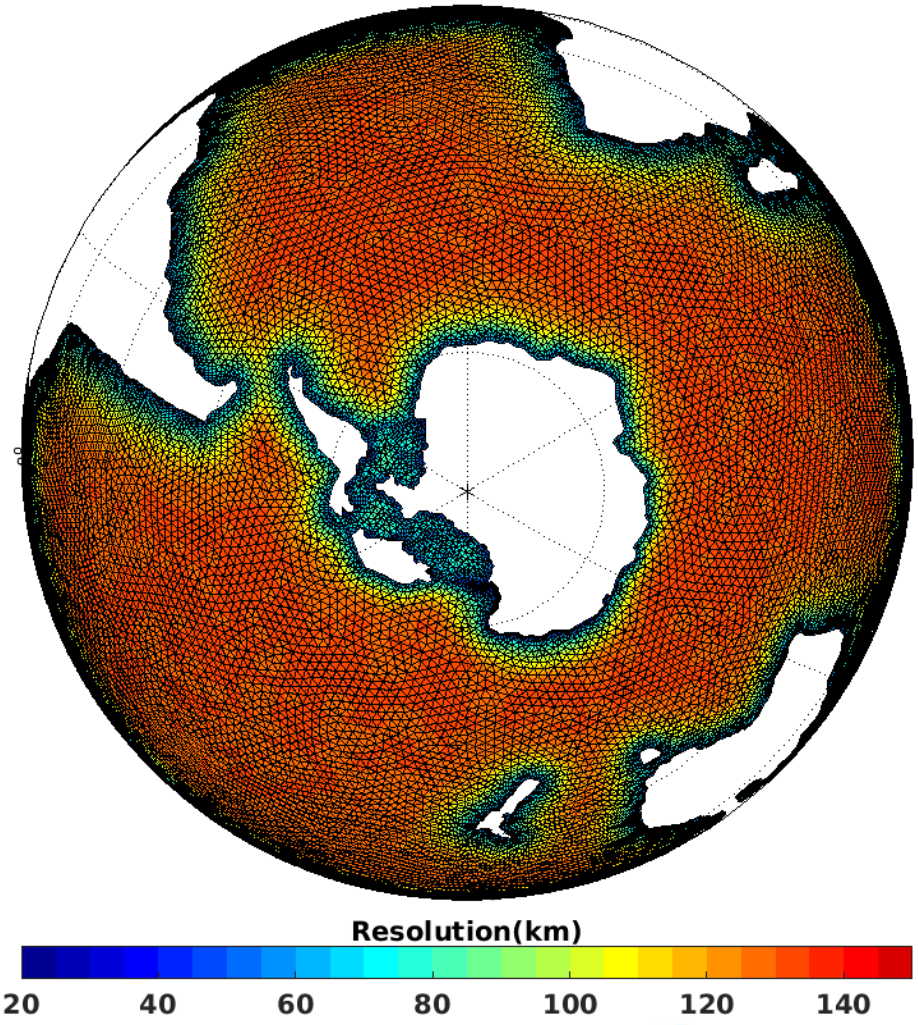
Sutter et al., 2016, GRL

AWI-CM (coupled Atm-Oc-sea ice)

Control Run



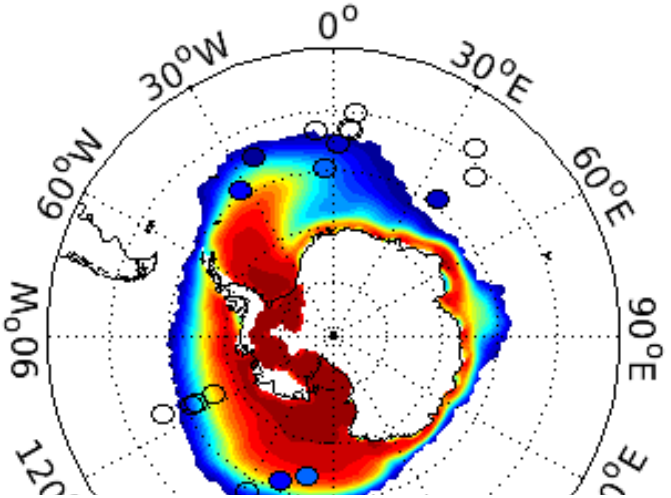
Sensitivity Run



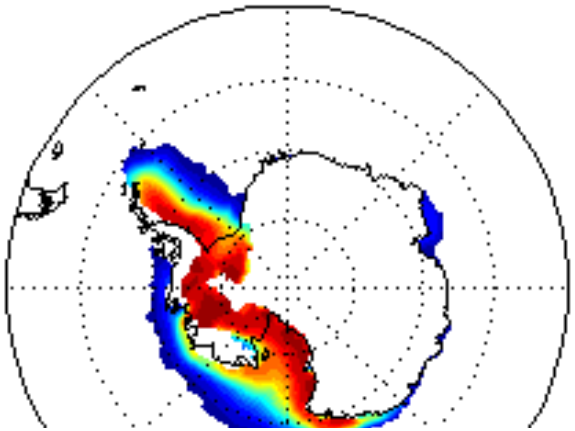
What happens if the West Antarctic Ice Sheet is collapsed?

AWI-CM experiment for the LIG with the new gateway

Austral winter

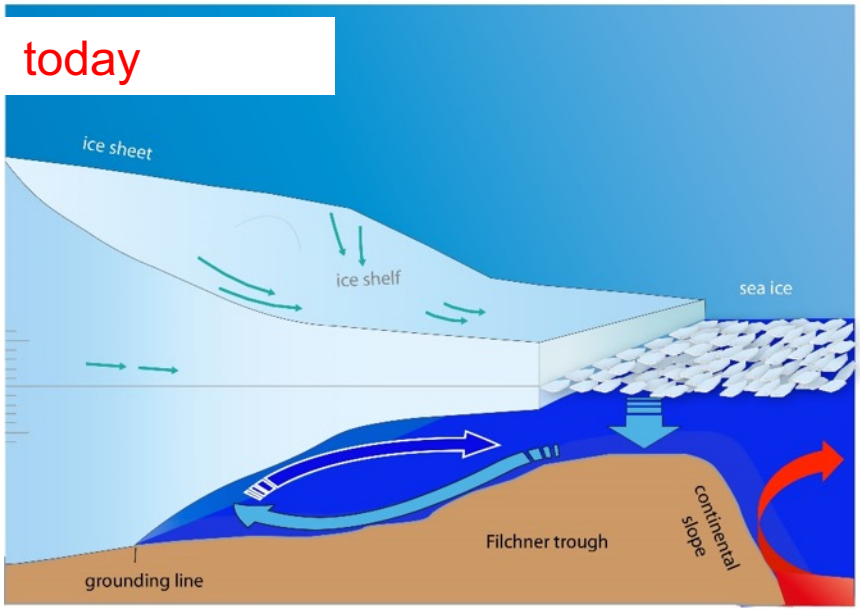


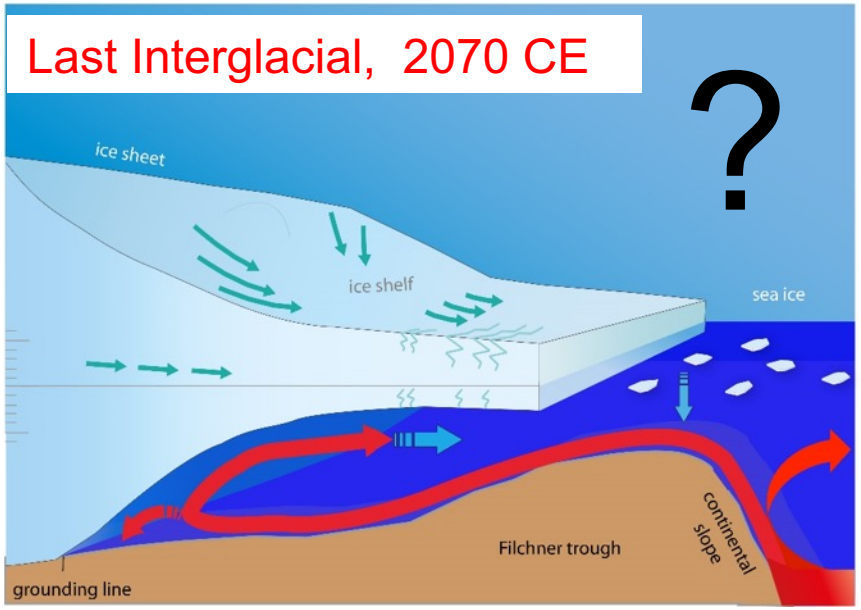
Austral summer



Stabilizing effect by sea ice & surface cooling, however warm subsurface water

Antarctic Ice Sheet: Melting from below

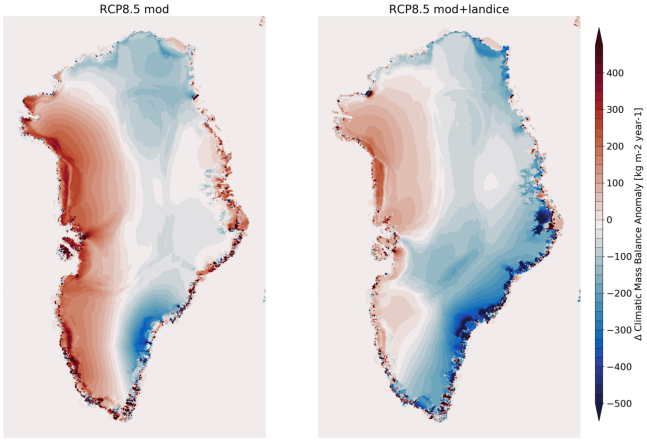


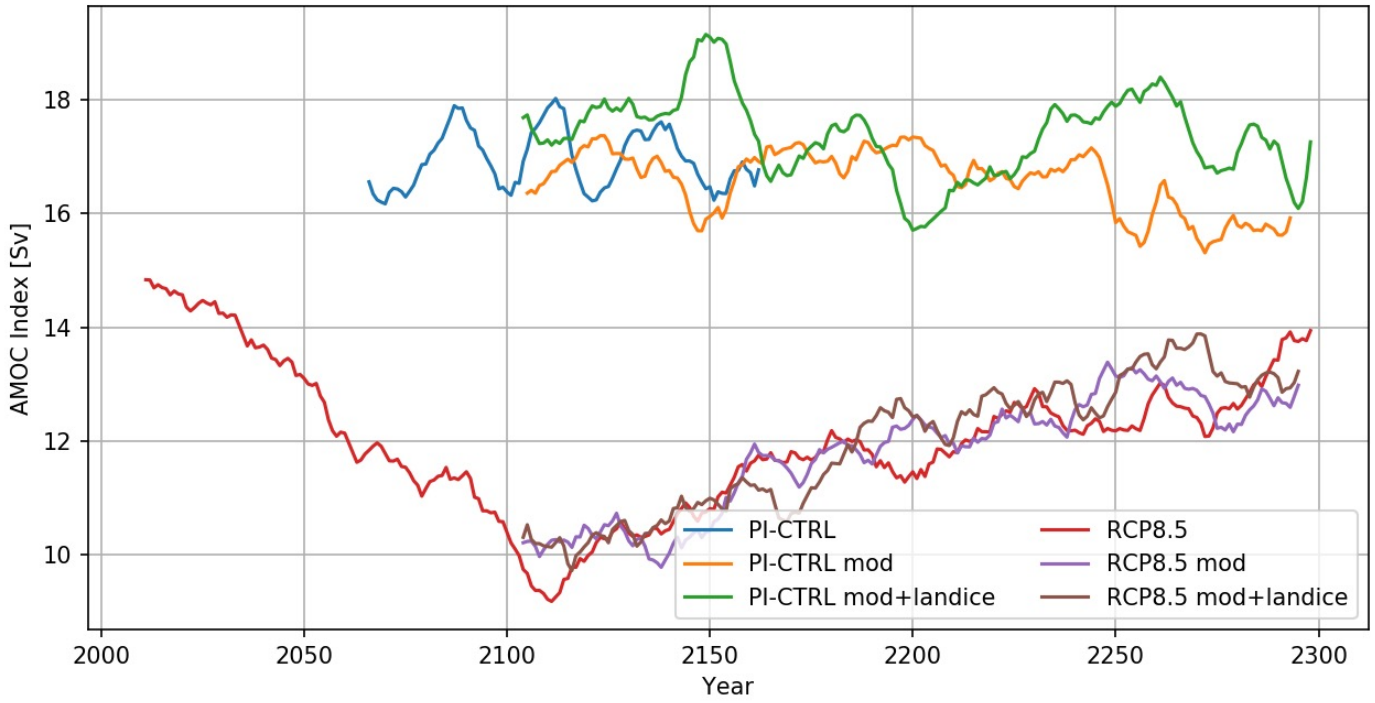


Key processes of solid Earth, ice, ocean & their interaction

- **ocean (eddy-)transports and mixing**
- **ocean–ice-shelf interaction**
- **rheology of solid Earth: Geometry and sea level**

AMOC with Greenland (& AA)





L. Ackermann

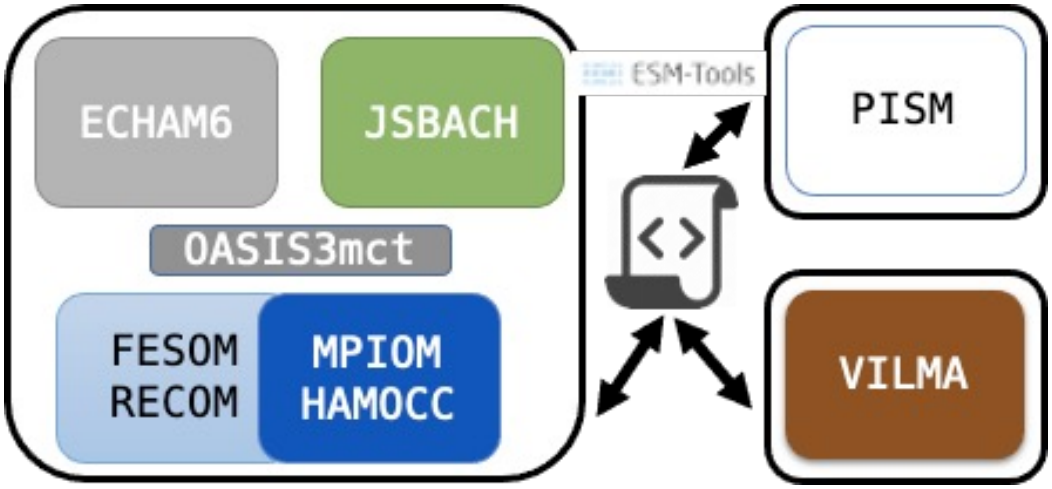
Current Model Developments

Integration of ice sheets

Solid Earth VILMA

PISM-PICO

Modular ESM (esm-tools.net)



Slide from PalMod project

-> Talk of Paul Gierz

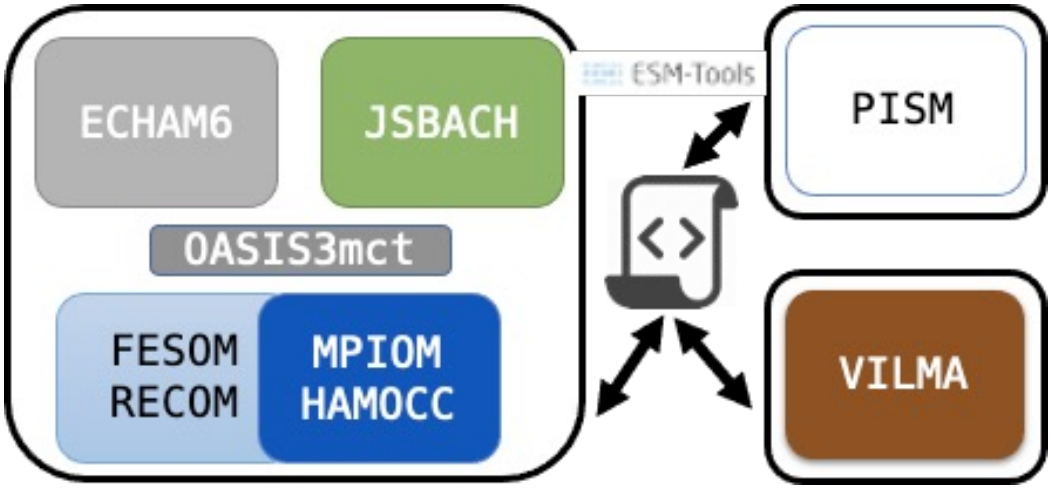
Current Model Developments

Integration of ice sheets

Solid Earth VILMA

PISM-PICO

Modular ESM (esm-tools.net)



Tides: Pengyang SONG, catalytic role of tides in paleoclimate changes

Mixing: Shizhu Wang (2019), Effect of Non-breaking Surface Wave-induced Mixing on Upper Oceans in Glacial and Interglacial Climates

BGC and Tracers

O-18, C-14

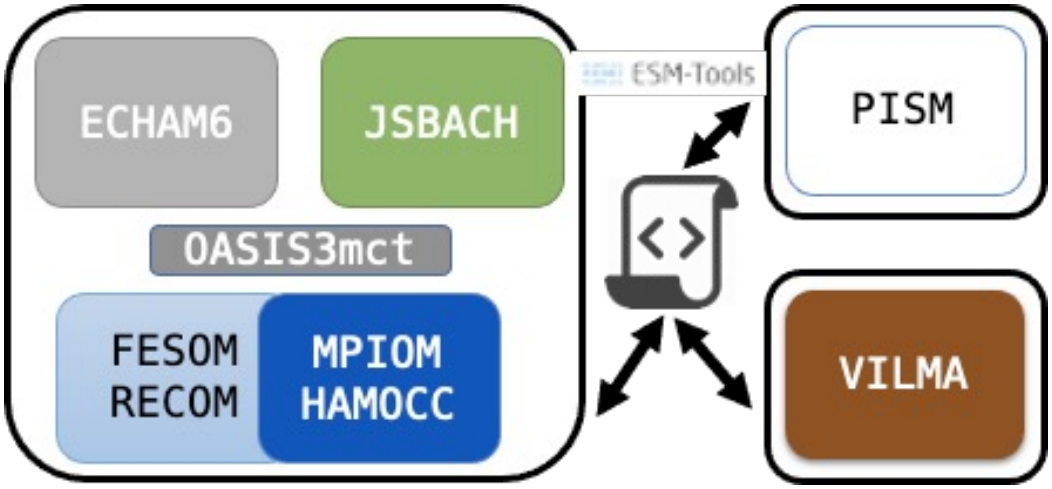
Current Model Developments

Integration of ice sheets

Solid Earth VILMA

PISM-PICO

Modular ESM (esm-tools.net)



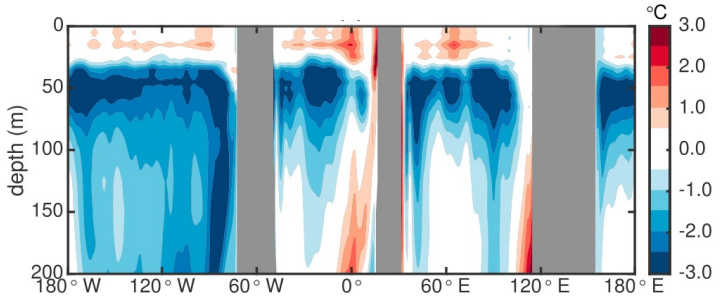
Tides: Pengyang SONG, catalytic role of tides in paleoclimate changes

-> Talk of Pengyang SONG

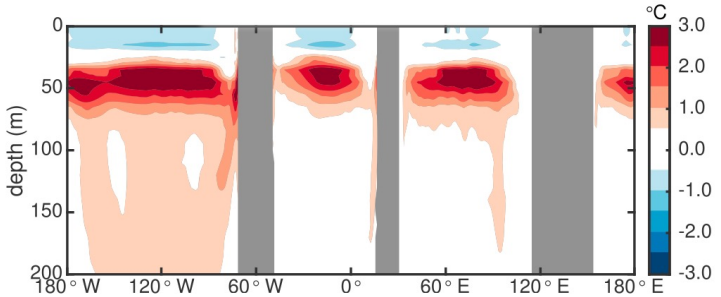
Temperature difference along 30S

Summer

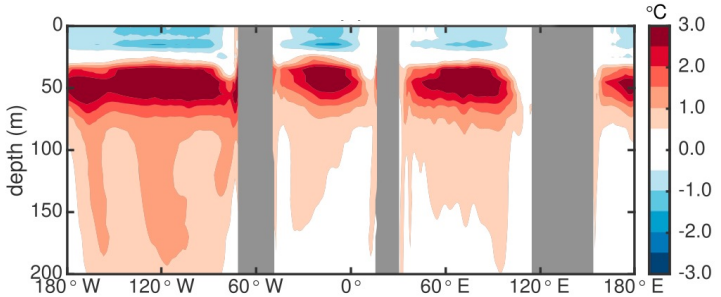
CTRL - World Ocean Atlas 2013



Nonbreaking surface wave -CTRL



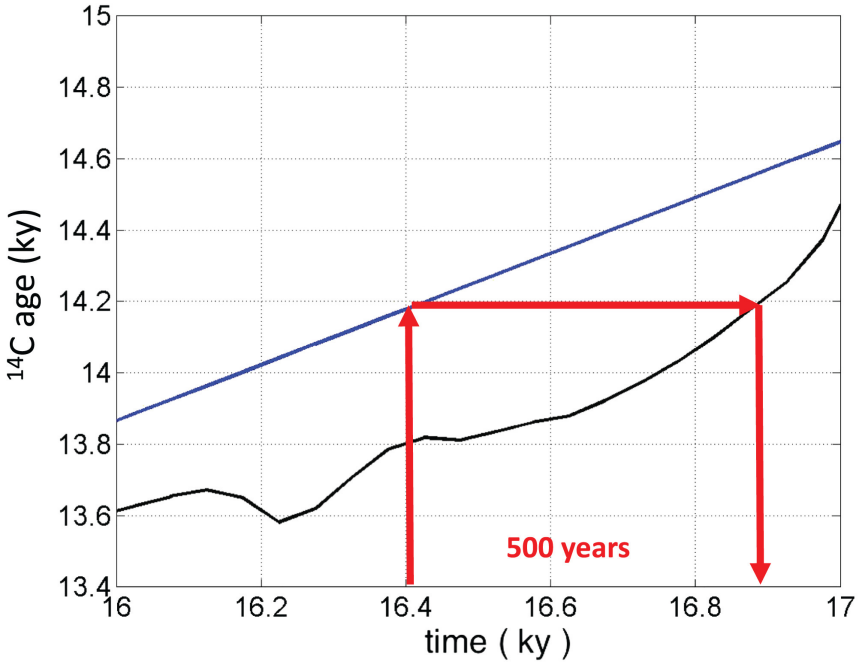
Nonbreaking surface wave
& Shortwave penetration -CTRL

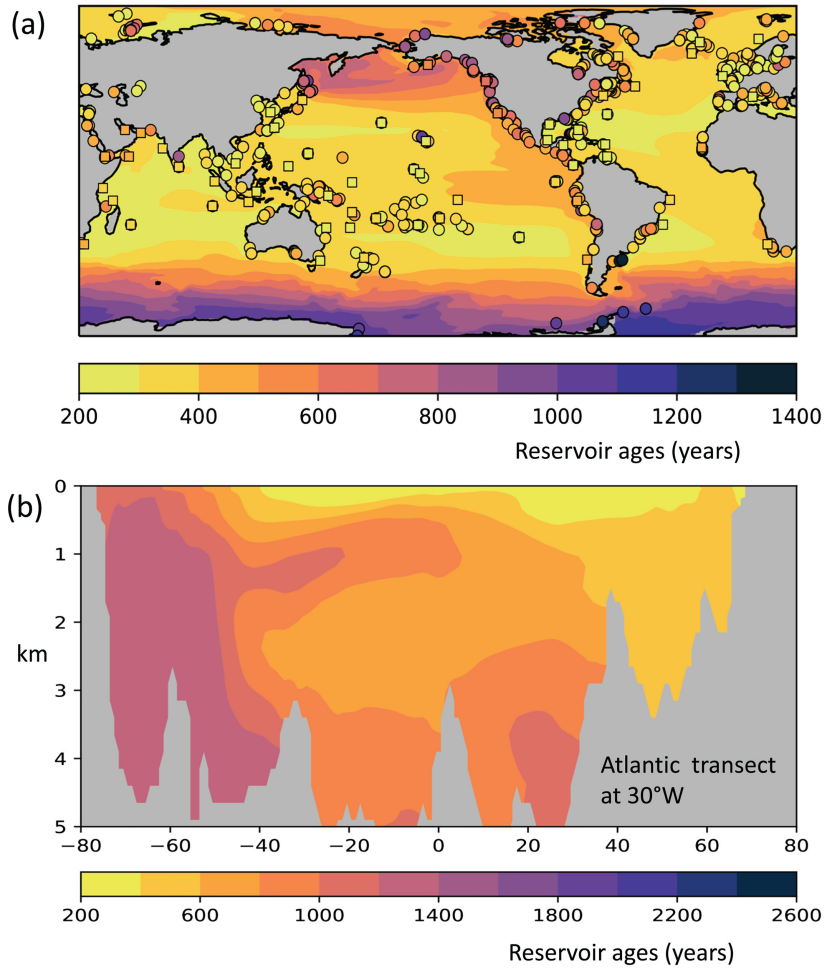


FESOM1+non breaking waves

Wang et al., 2020, JAMES

Reservoir age correction procedure to convert from ^{14}C years to calendar years.





Dating: The “backbone“ of paleoceanography

FESOM2-^{14}C

Lohmann et al., Paleoceanography. 2020

Paleoclimate dynamics: identifying driving mechanisms of climate change

The Crosphere

Feedbacks with ice sheets

Variable land-sea mask

Solid Earth model for sea level

Incorporation of ice cavities (CR)

Permafrost with AWI Potsdam

Tracer models

O-18, C-14, others

Fast C-cycle

AMOC and mixing

Tides, waves, signal propagation

Paleoclimate dynamics: identifying driving mechanisms of climate change

The Crosphere
Feedbacks with ice sheets
Variable land-sea mask
Solid Earth model for sea level
Incorporation of ice cavities
Permafrost with Potsdam

Tracer models
O-18, C-14, others
Fast C-cycle

AMOC and mixing
Tides, waves, signal propagation

Opportunities:
testing model under different conditions beyond the past 100 years
Formalize paleo tests before model releases (PMIP4 already), common high-resolution-runs

Learning about the dynamics of the system
Share experiences and developments
AWI-CM meetings (since 2018)

Model versions

- AWI-ESM1.1 AWI-CM1 + vegetation (PMIP4)
- AWI-ESM1.2 with ice sheet model PISM (Gierz et al., Ackermann et al., Niu et al., 2020)
- AWI-ESM2.1 α : Sidorenko et al. + vegetation (Holocene, LGM runs)
- AWI-ESM2.1 β : Sidorenko et al. + vegetation + fast radiation in ECHAM6, JSBACH (about 90 y/day)

  ~10 applications: MIS3, Glacial inception, partially coupled runs, LIA ini, Miocene, Cretaceous, artificial solar eclipse, Ozone etc.

- AWI-ESM2.1/2 with ice sheet model PISM & ocean improvements (under discussion)

Resolution: T63 in the atmosphere, COREII mesh in the ocean