Climatic Impacts of Changes in Oceanic Gateways Across the Eocene – Oligocene Transition

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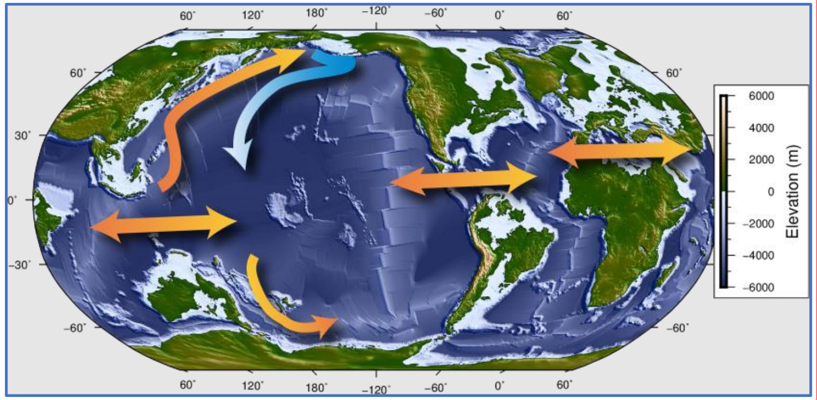
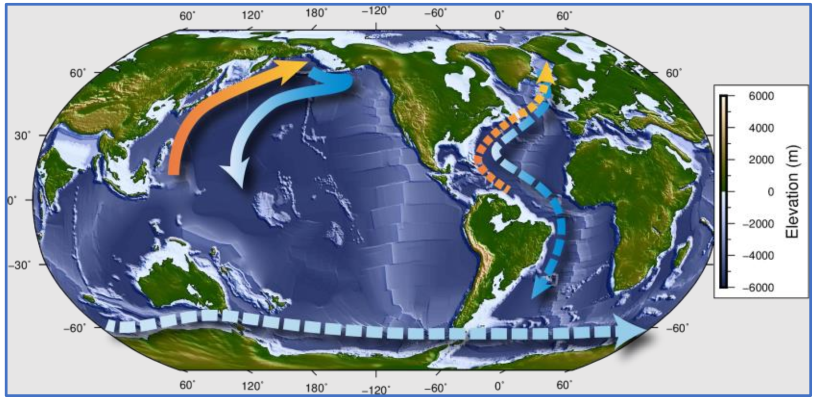
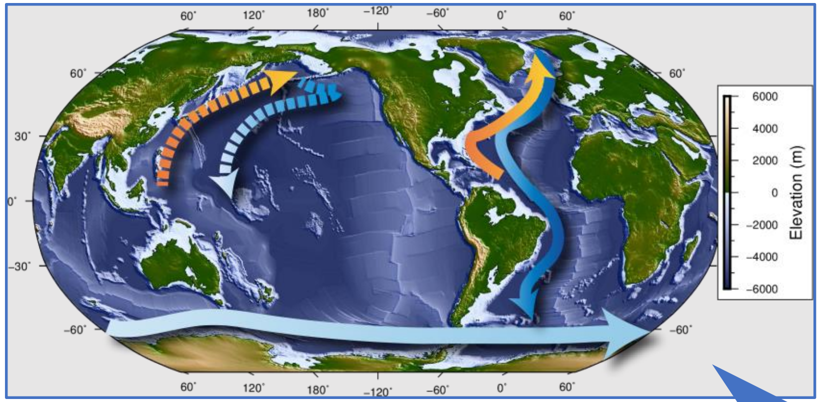
Introduction: changing oceanic gateways and climate







Paleocene | Eocene/Oligocene | Miocene

CAS and Tethys open, NE Atlantic and Southern Ocean closed.

Multiple locations of deep water formation, including lower latitudes. Overturning in North Pacific.
See Hague et al. (2012), Thomas et al. (2014) Ferreira et al. (2018)

Changes in Northern and Southern Hemisphere gateways.

First indications of a proto AMOC (e.g. Abelson and Erez, 2017; Coxall et al., 2018).

Open Fram Strait, Iceland -> island. Full closure of Tethys and shallow CAS.

First indications of a modern-type AMOC. Weakening PMOC.
See Woodruff and Savin (1989), Yang et al. (2014).

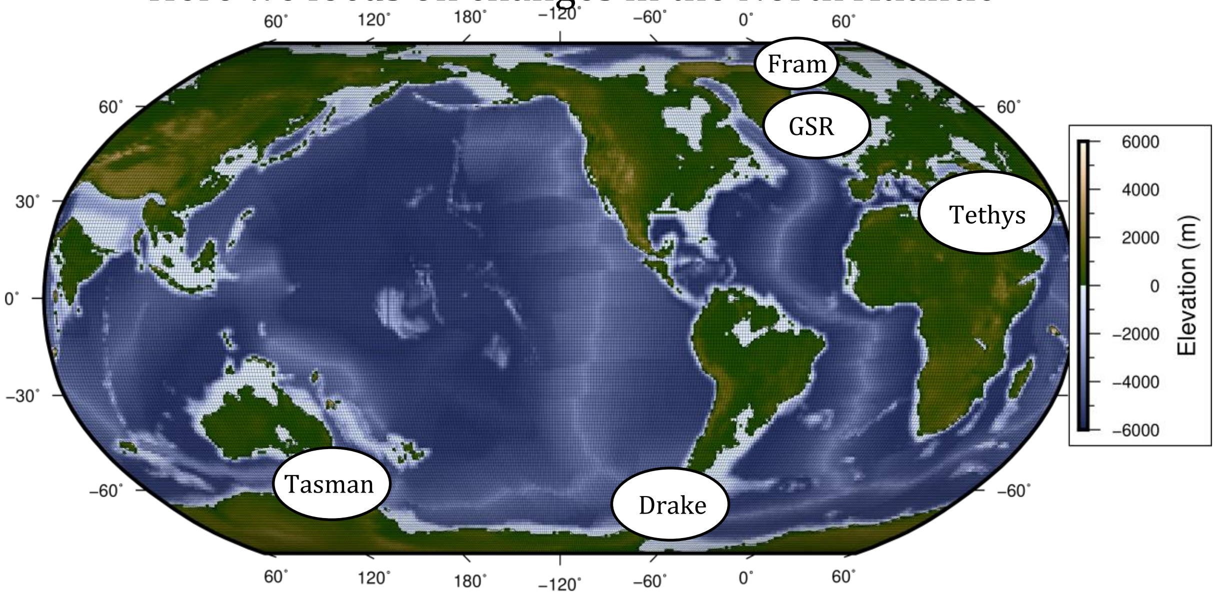
Climate under changing topographic conditions

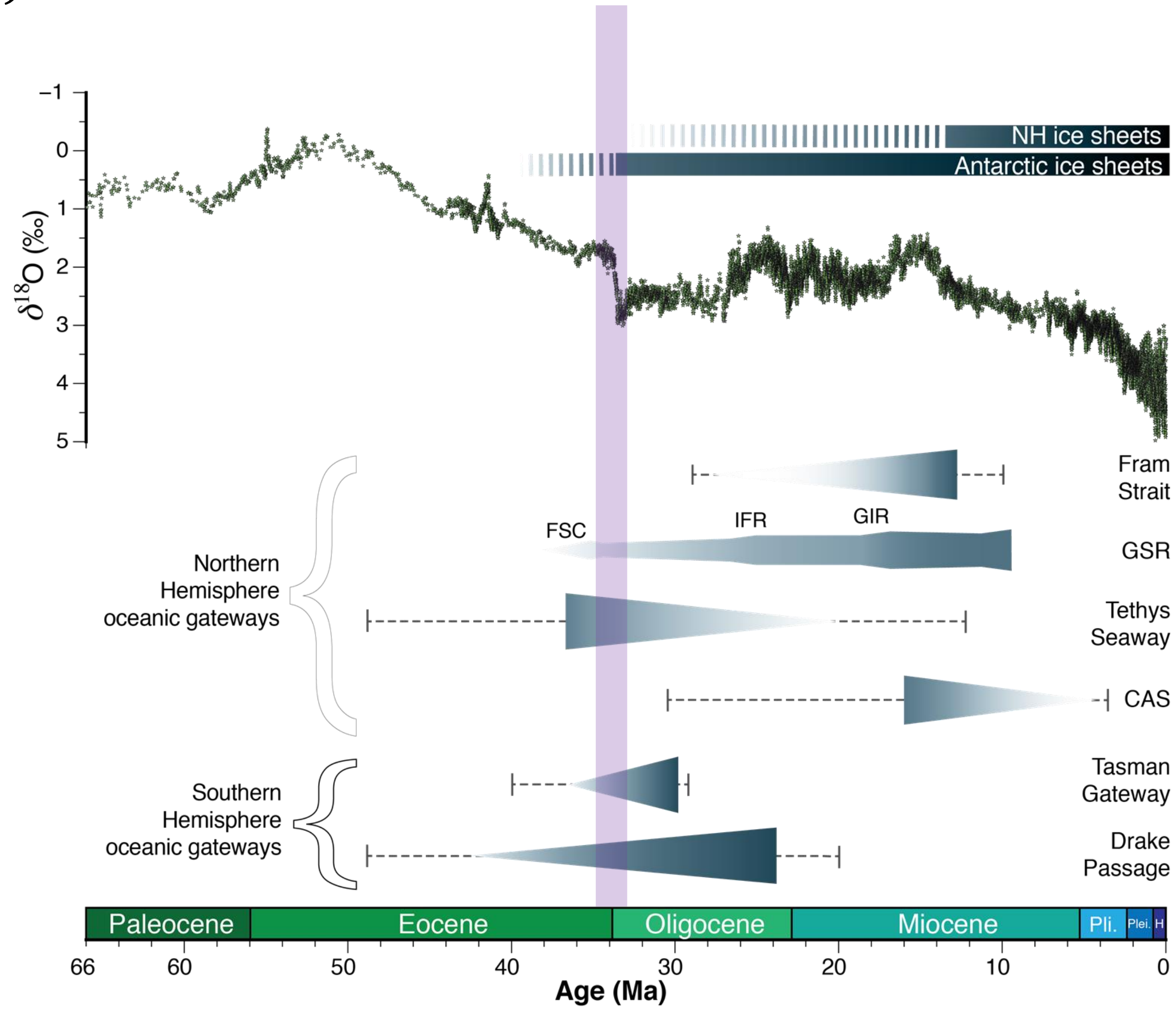
Continuous Global Paleotopography model (66-0 Ma)

- ➢ Focus on North Atlantic – Nordic Seas bathymetry

Climate simulations across EO boundary

- Norwegian Earth System Model - Fast (NorESM-F)
- 34 Ma topography
    - 7 perturbation cases with changing gateway configuration
    - Constant land mask and land topography
    - Constant CO2 at 850 ppm (3 x pre-industrial levels)
- Here we focus on changes in the North Atlantic





Straume et al. in prep.

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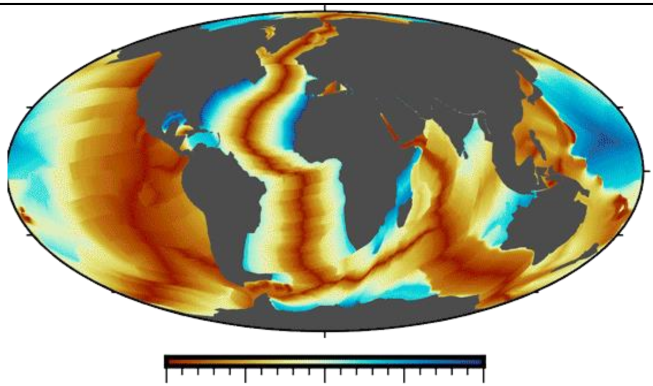
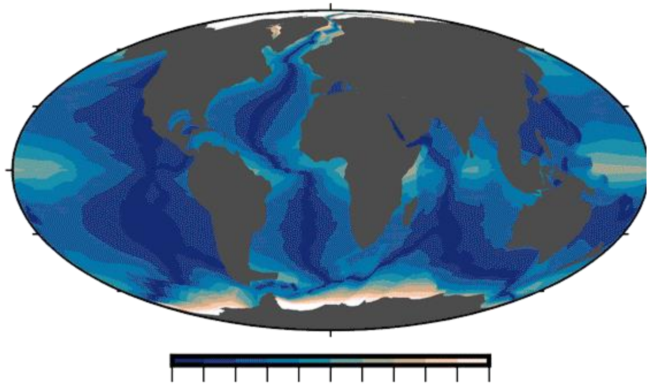
Paleotopography Model

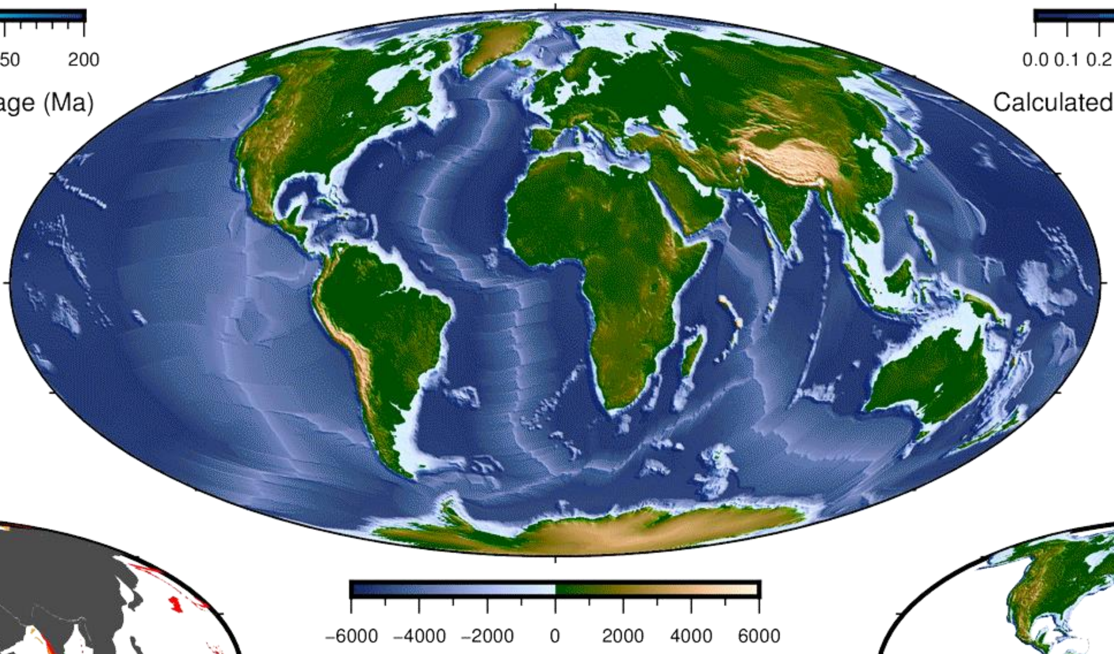


Oceanic lithopsheric age (Ma)

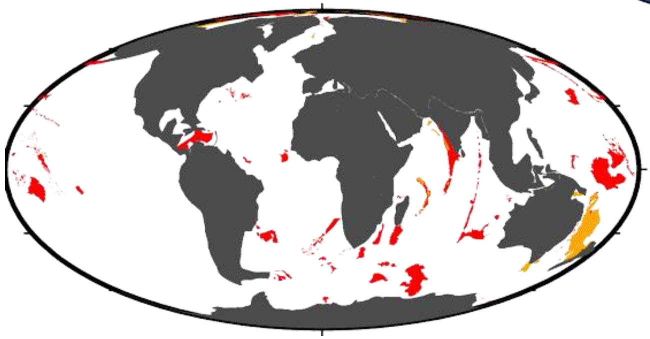


Calculated sediment thickness (km)

1 Ma

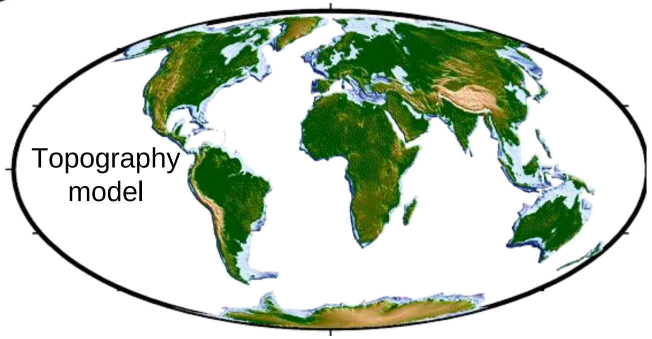


Elevation (m)

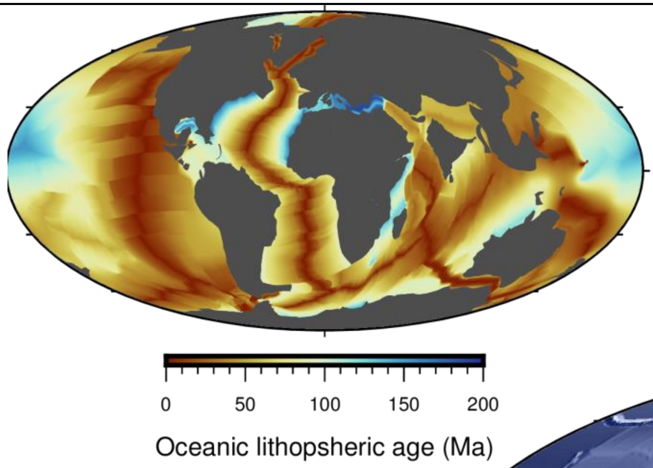


Oceanic plateaus

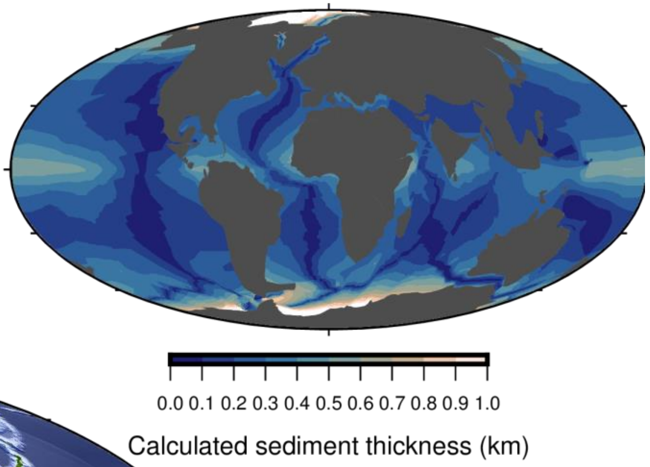
Microcontinents

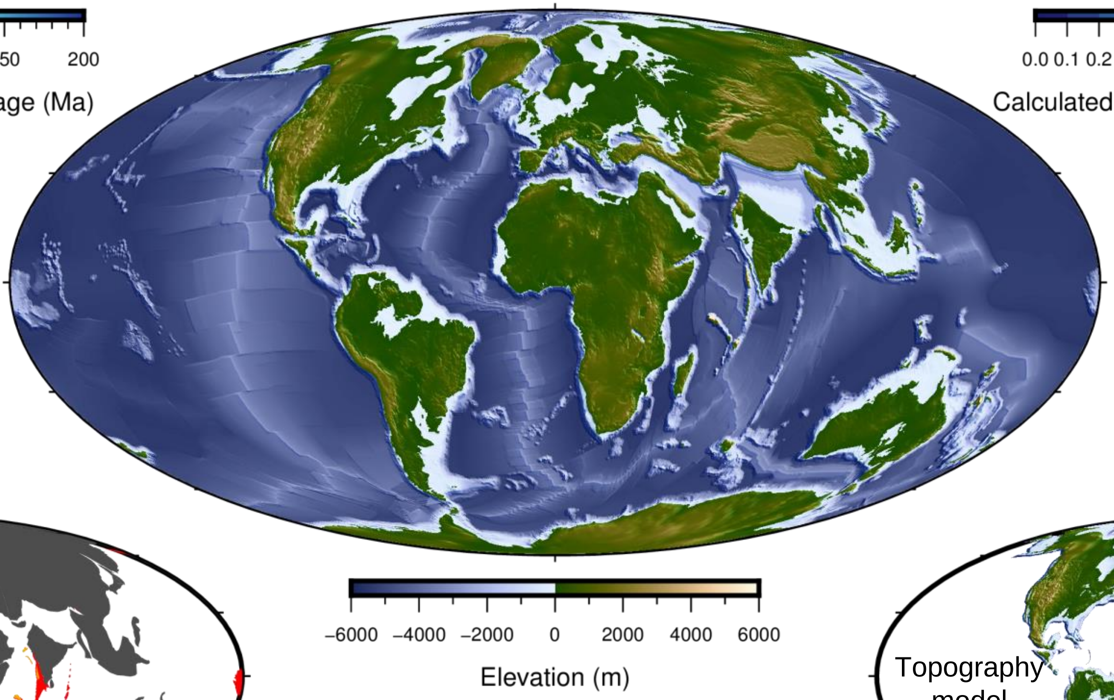


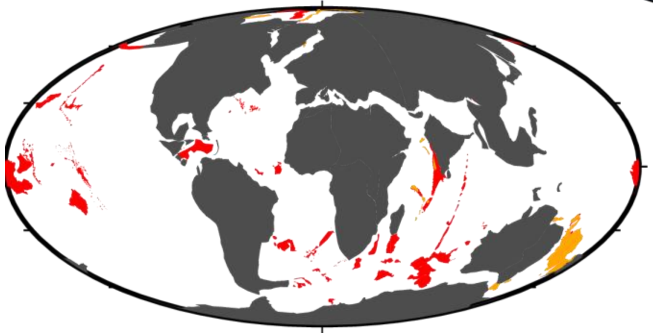
Paleotopography Model



34 Ma

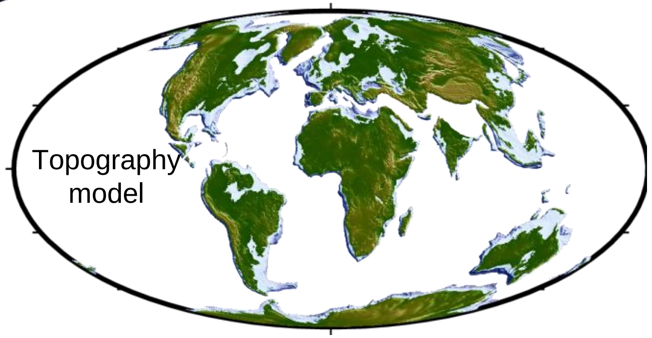






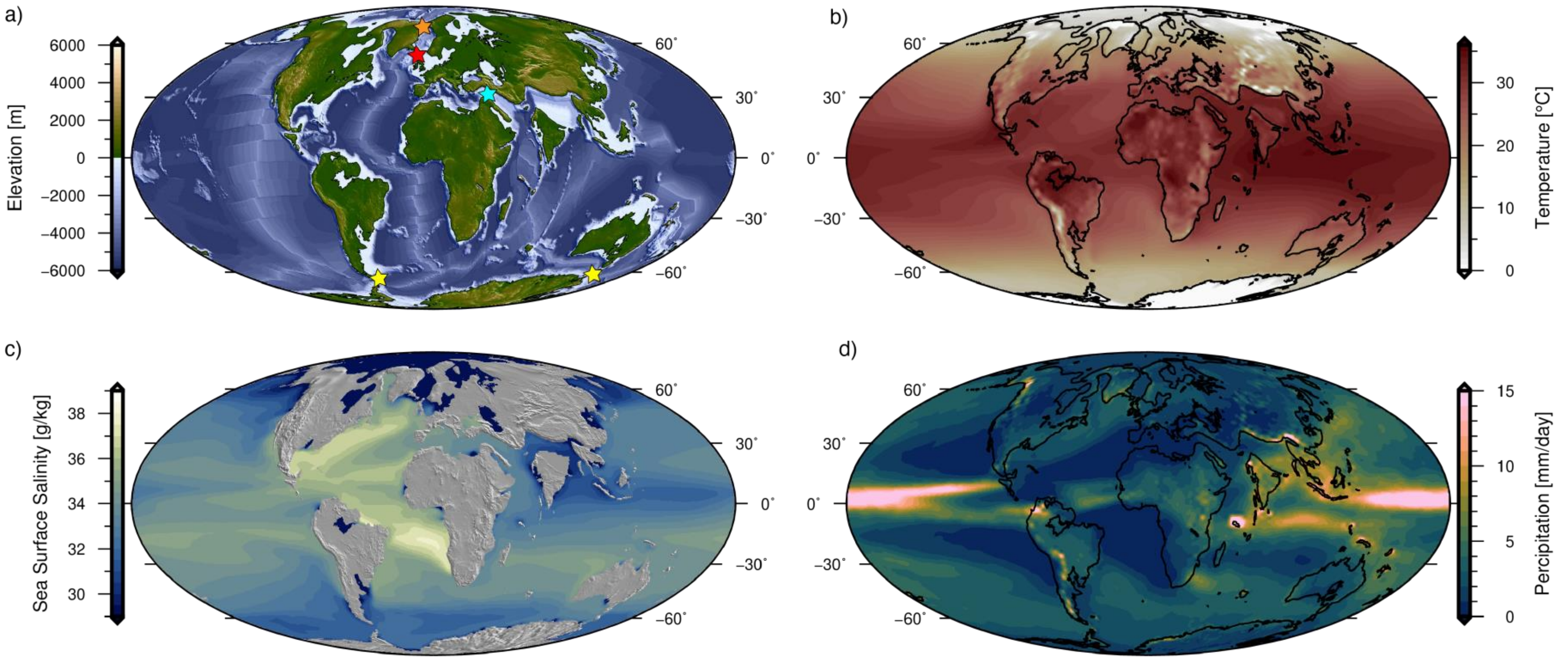
Oceanic plateaus

Microcontinents



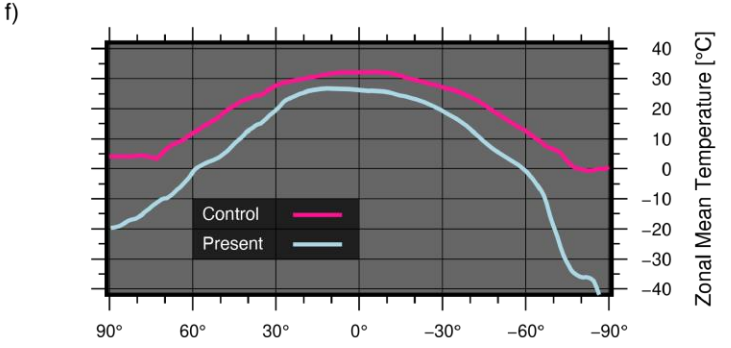
Mean Climate

- Weak equator to pole temperature gradient
  - Annual mean temperature above freezing almost everywhere
- Warm and wet tropics
- Wide dry regions in subtropics
- Saline Atlantic, Fresh Pacific
  - AMOC, no ACC or PMOC
- Very fresh Arctic Ocean

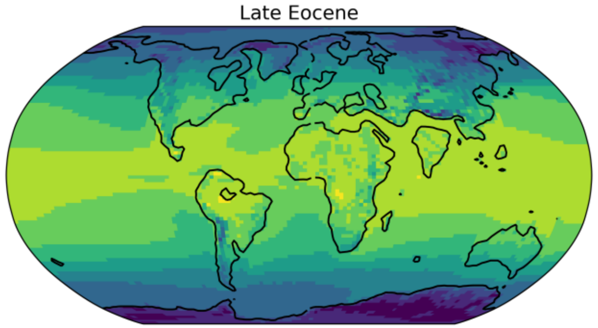


e)

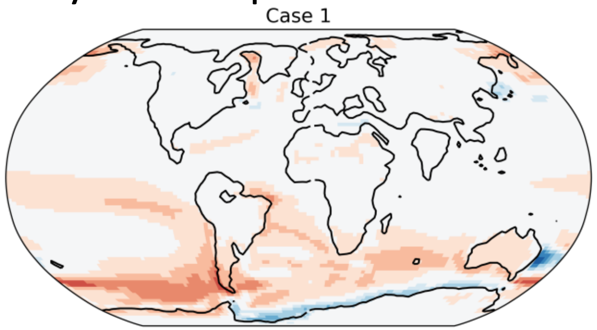
Gateways	Fram Strait	GSR	Tethys Seaway	Drake	Tasman
Shallow/ Deep	10 m/ 150 m	20 m/ 500 m	200 m/ 1000 m	200 m/ 1000 m	200 m/ 1000 m
Control	Deep	Shallow	Deep	Shallow	Shallow
Case 1	Deep	Shallow	Shallow	Deep	Deep
Case 2	Deep	Deep	Deep	Shallow	Shallow
Case 3	Deep	Deep	Deep	Deep	Deep
Case 4	Deep	Deep	Shallow	Deep	Deep
Case 5	Shallow	Deep	Deep	Shallow	Shallow

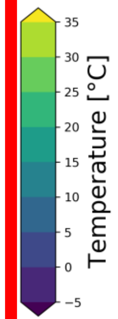


Surface temperature response to changing gateways

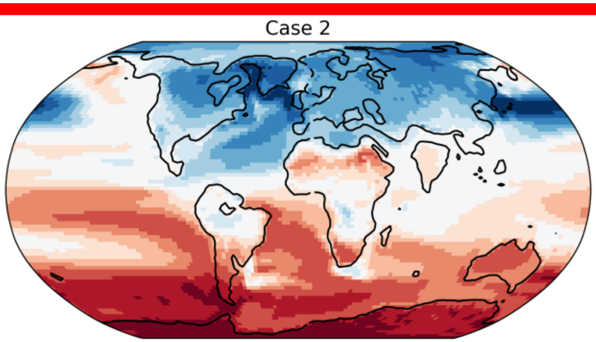


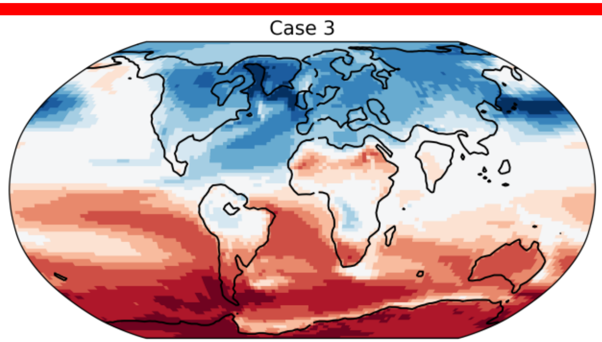
Opening of the Southern Ocean (SO) gateways has only local impact

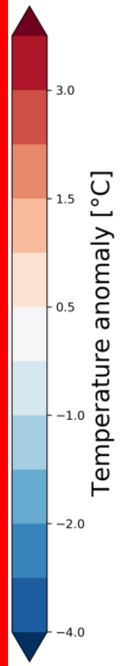


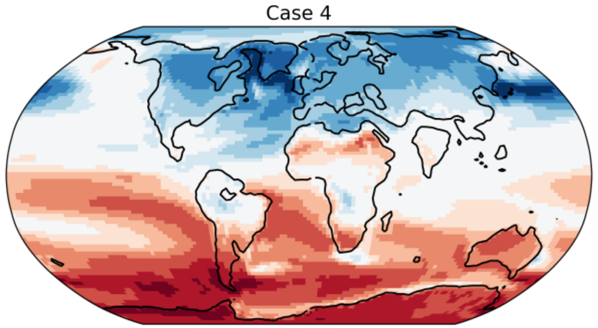


Opening of the GSR leads to AMOC collapse and the classical hemispherically asymmetric cooling/warming and dominates over SO gateway response.

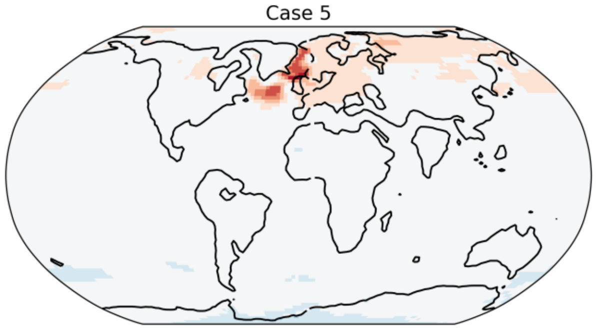








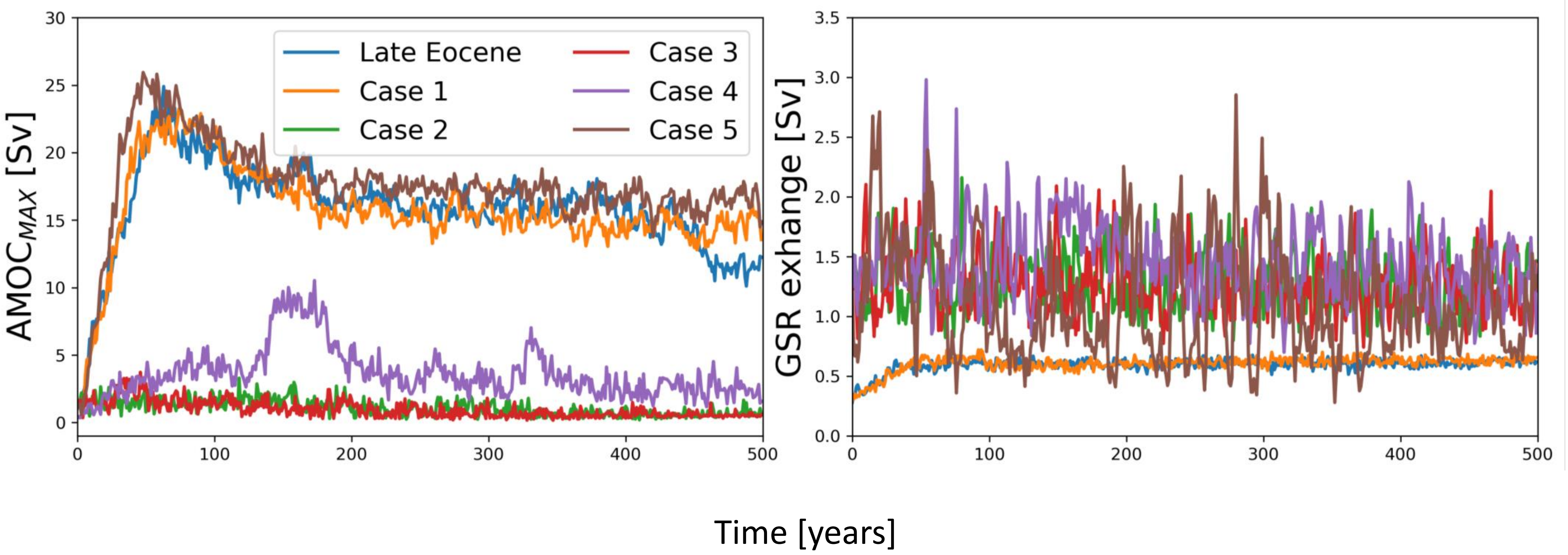
Opening of the Tethys Sea way acts against cooling/warming induced by opening of the GSR (but the signal remains weak).



Closing Fram Strait when GSR is closed leads to additional local warming

Circulation in the North Atlantic/Nordic Seas

- The overturning in the Atlantic (AMOC) is strong when the Greenland-Scotland-Ridge (GSR) is shallow (closed)
  - Additional closure of Fram Strait enhances the impact, although it does not lead to deep water formation within the Nordic Seas
- The overturning is weak when GSR is deep (cases 2-4)
  - Closing the Tethys Sea way (Case 4) leads to a weak pulsating AMOC due to saltier Atlantic, but is not enough to compensate for the increases freshwater transport from the Arctic when the GSR is deep

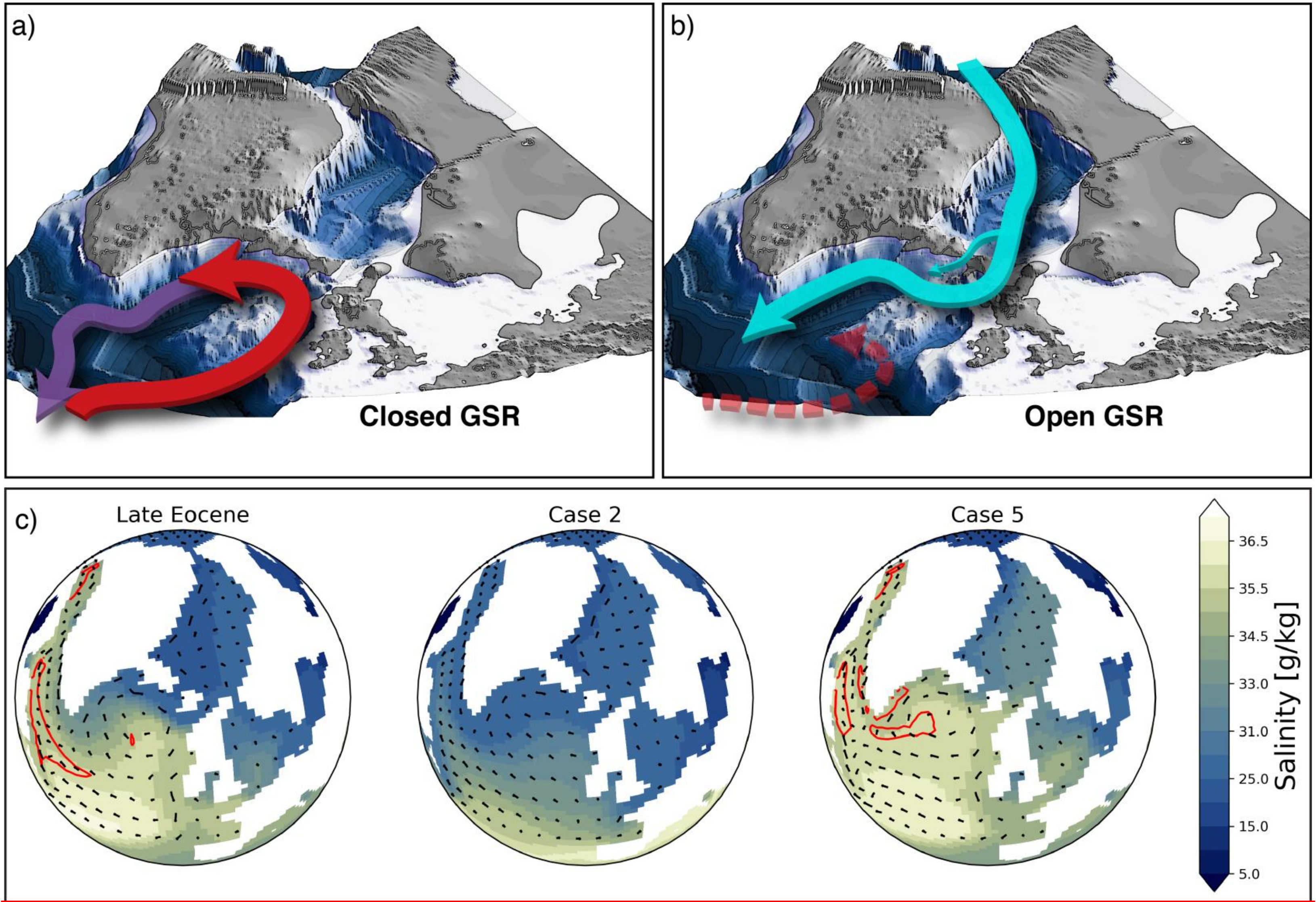


Summary

We have implemented our paleotopography (Straume et al, in review) for the Eocene – Oligocene Boundary (34 Ma) in the NorESM, where we change the configuration of the most important gateways (within error of our topography model).

We find that depth of the Greenland Scotland Ridge (or Fram Strait) controls the freshwater transport from the fresh Arctic to the North Atlantic

When the GSR is shallow (closed) the freshwater transport is small and there is convection and deep water formation in the Labrador/Irminger Seas.



Red contours indicate regions of ocean convection, arrows show surface circulation. Opening GSR (case 2) leads to fresher North Atlantic without convection, closing Fram Strait (Case 5) has a similar impact as closing GSR.