# Arctic closure as a trigger for Atlantic overturning at the Eocene-Oligocene Transition

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## Introduction

The Eocene-Oligocene transition (EOT), about 34 Ma, marks a major climate shift from the greenhouse world to the icehouse world, and the first major ice sheets on Antarctica. The cooling is thought to be primarily driven by a drop in $CO_2$. $\delta^{18}O$ and $\delta^{13}C$ proxies suggest that deep water formation began in the N. Atlantic at this time (1), while Neodymium isotope analyses show that N. Pacific sinking was prevalent in the Eocene, but shut down around the EOT (2). We investigate the effect of lowering $CO_2$ on the climate and ocean circulation, and altering Arctic-Atlantic gateways in the late Eocene.

## Coupled Climate Model

We present a modified version of the GFDL CM2.1 (3), adapted to late Eocene boundary conditions (4). The model uses an ocean horizontal resolution of $1° \times 1.5°$ and an atmosphere resolution of $3° \times 3.75°$. Previous studies of the EOT have generally used coarser resolution, or a more idealised representation of topography. Our model resolution allows a fast running atmosphere for computational efficiency, while better resolving important ocean gateways, especially in the Arctic-Atlantic region.

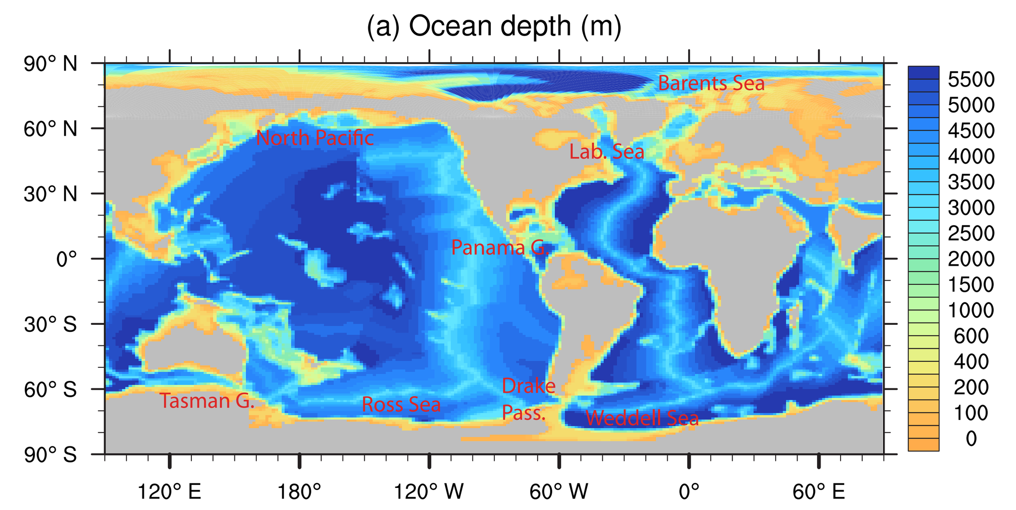


**Figure 1:** Bathymetry in our late Eocene model.

## Arctic-Atlantic Gateways

Paleogeographic reconstructions suggest that the Barents Sea Seaway closed around the EOT (5; 6). We investigate the effect of closing the Arctic-Atlantic gateways as a possible trigger of N. Atlantic sinking. This isolation of the Arctic provides a new trigger of North Atlantic Deep Water formation.

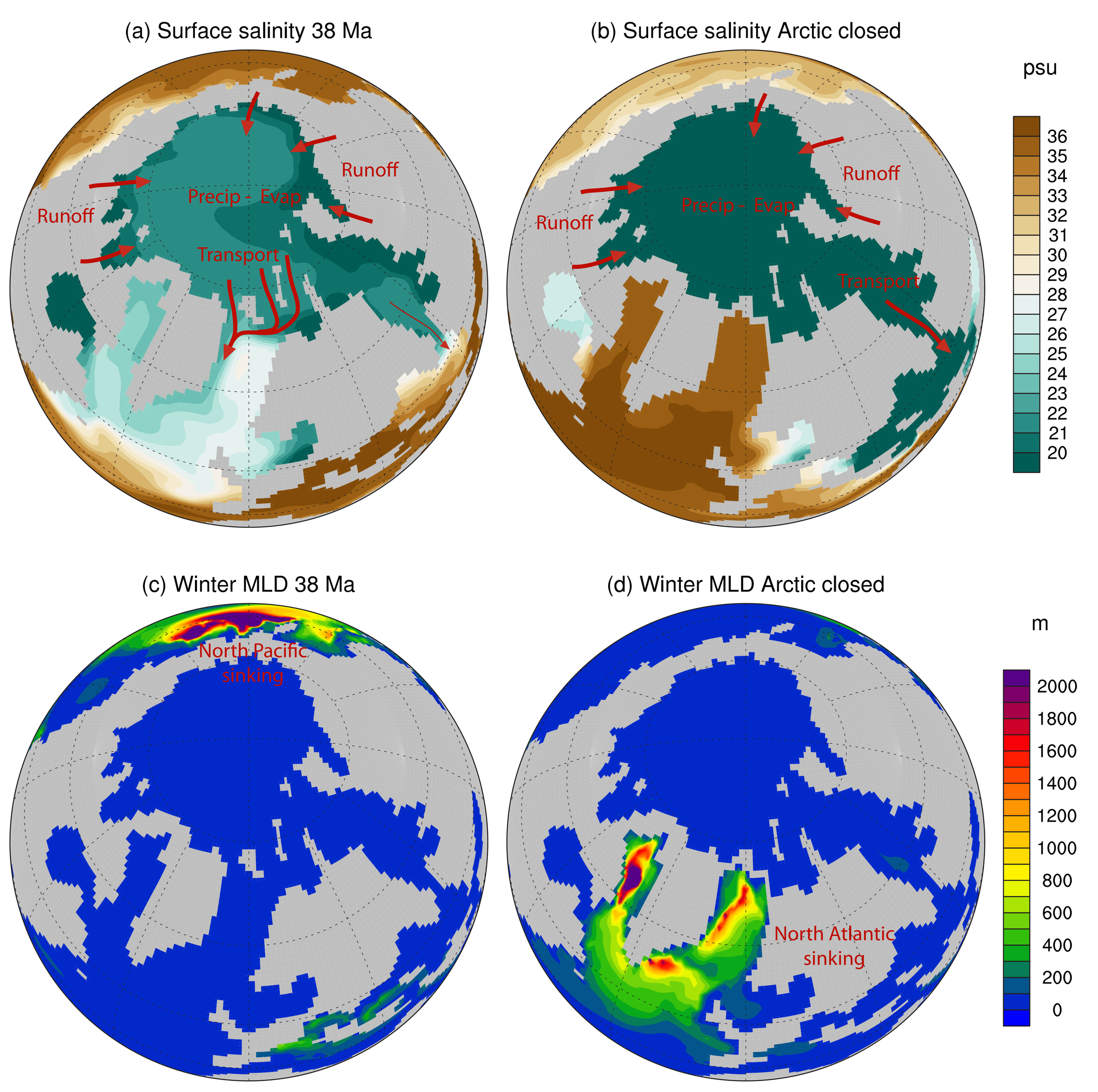


**Figure 2:** Surface salinity, freshwater transport and mixed layer depth.

## Meridional Overturning

In the control run, the North Atlantic is too fresh to sink, whereas sinking occurs in the North Pacific and in the Southern Ocean. When we close the connection between the Atlantic and Arctic Ocean, the freshwater transport from the Arctic is cut off and the salinity of the Atlantic increases dramatically. We then trigger sinking in the North Atlantic, and salt advection away from the North Pacific causes sinking to cease there. This agrees with new evidence from Neodymium isotopes that North Pacific deep water shut down at 36 Ma (2).

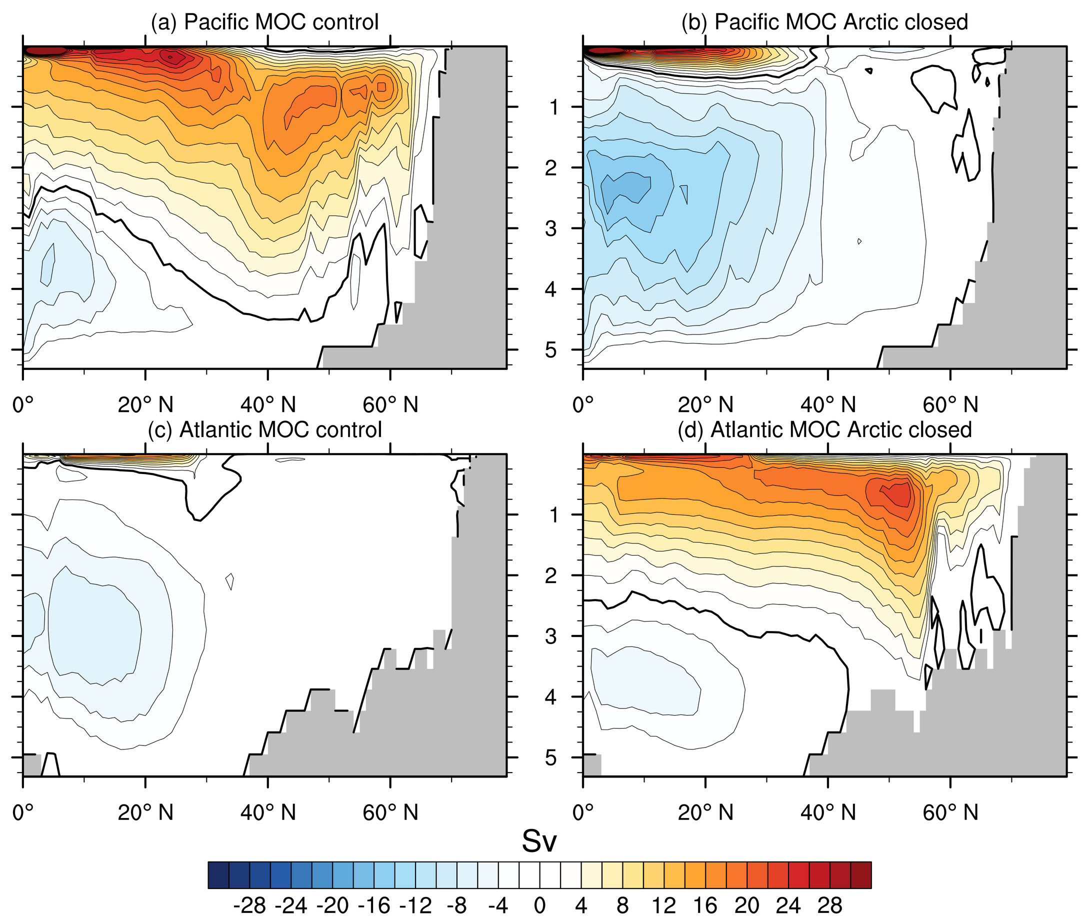


**Figure 3:** Pacific-Atlantic MOC with open and closed Arctic-Atlantic gateway.

## Interbasin Salt Transport

Once an overturning circulation is established, it draws salt away from the passive basin and into the active basin of sinking. This feedback is especially important in the Panama gateway, the main connection between the Atlantic and Pacific. In the control state, salt is transported westward through Panama. With Atlantic overturning, this transport virtually stops.

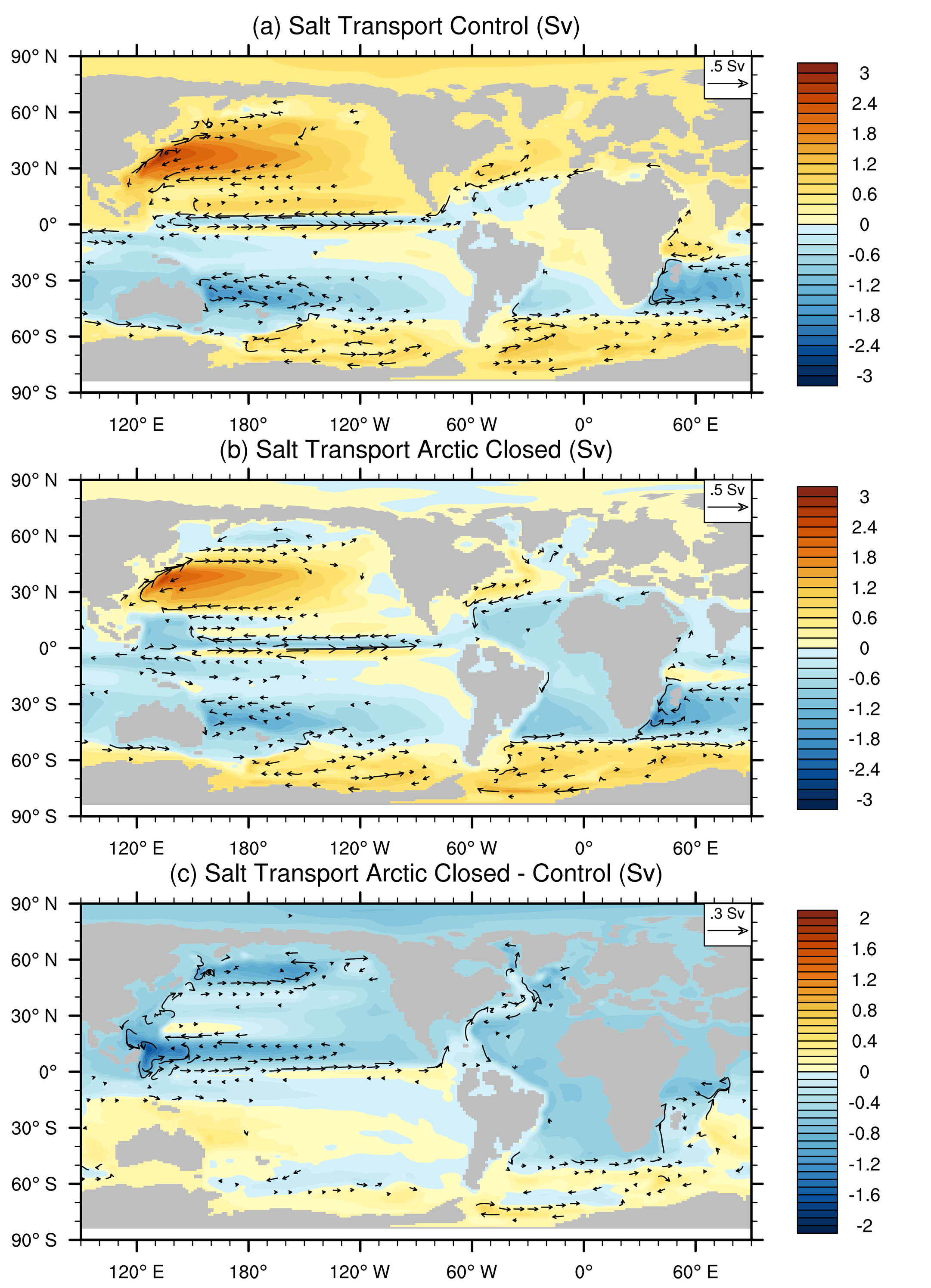


**Figure 4:** Salt transport through Panama gateway is crucial to maintaining the MOC.

## Climate Implications

The switch in overturning from Pacific to Atlantic causes warming in the Atlantic and cooling in the Pacific. It also causes an increase in Precipitation - Evaporation in the Pacific, and a decrease in the Atlantic. This evolution highlights the importance of an accurate reconstruction of late Eocene boundary conditions. The background state of very fresh Arctic conditions (~20 psu) depends on Arctic basin geometry, with no Bering Strait, and shallow connections to the Atlantic. These effects are not captured in previous modelling studies that use modern geography with simple gateway changes.

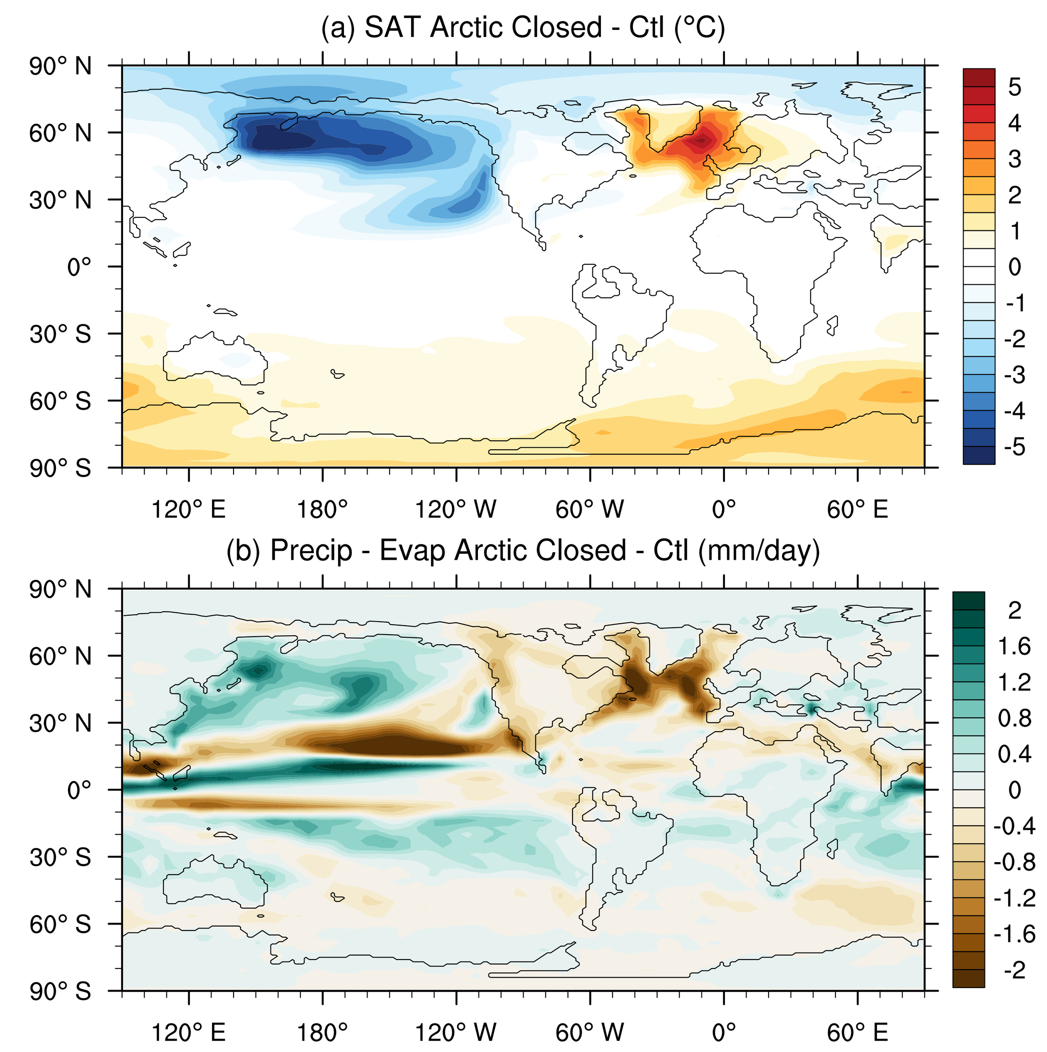


**Figure 5:** Surface temperature and evaporation minus precipitation caused by the overturning switch.

## Conclusion

- We have developed a new late Eocene climate model with higher ocean resolution than previous models.
- In the control run, sinking occurs in the Southern Ocean and North Pacific.
- Closure of the Arctic-Atlantic gateway increases Atlantic salinity and triggers North Atlantic Deep Water formation.
- Salt advection feedbacks cause the Pacific overturning to collapse.
- Our results are supported by proxies of both Atlantic and Pacific overturning.

## References

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