INTERBASIN SALT TRANSPORT IS DRIVING GLACIAL MILLENNIAL-SCALE CLIMATE VARIABILITY THE PACEMAKER MECHANISM

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1. Climate oscillations are triggered by snapshots of last deglacial meltwater discharge patterns.
2. A slow exchange of salt between the Atlantic and other oceans is setting the pace of the oscillations.
3. The slow salt oscillator is coupled to abrupt North Atlantic changes due to disruptions of the AMOC.
4. The coupling involves reversals of vertical and horizontal density gradients, local instabilities and salt advection feedback.
5. The oscillations are a good case study of model produced glacial millennial scale variability.

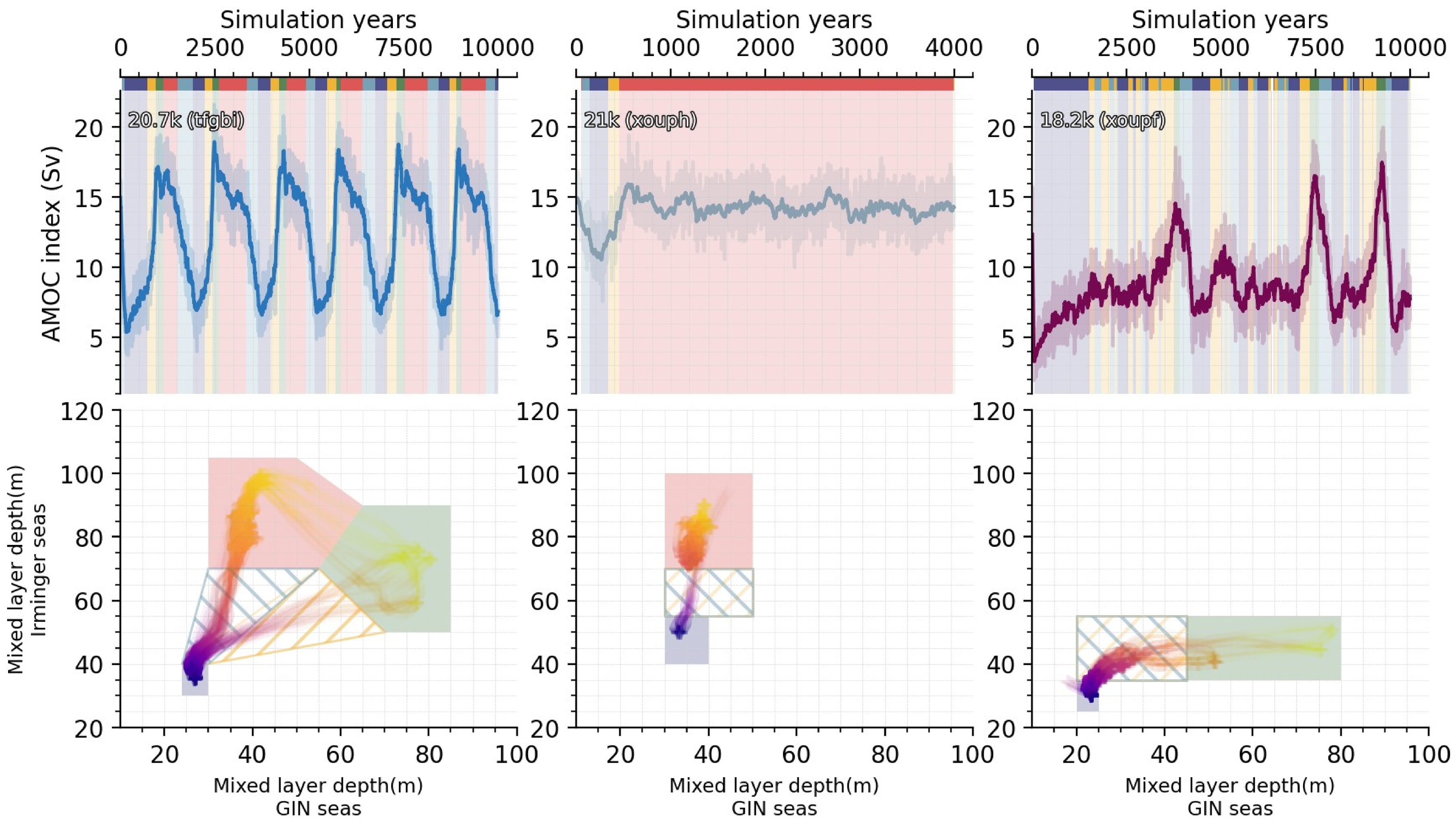
A new set of oscillating glacial simulations

Last glacial maximum simulations on **HadCM3** forced with **meltwater snapshots** derived from GLAC-1D ice sheet reconstruction.

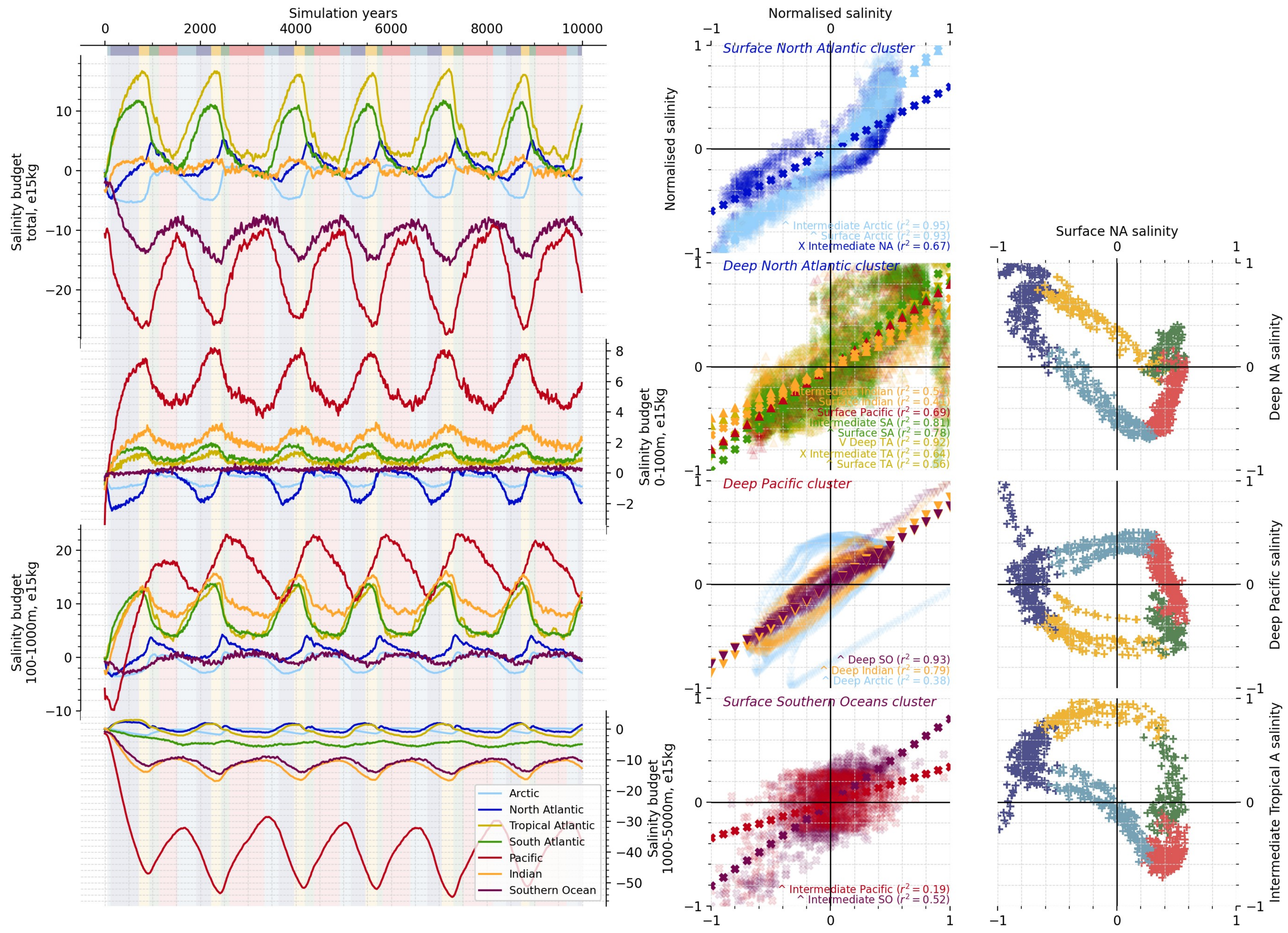
- *20.7k* – **Oscillating simulation**. Moderate discharge from the Laurentide and Eurasian ice sheet in the North Atlantic and Arctic.
- *21k* – **Warm simulation**. Low discharge in the North Atlantic and Arctic.
- 18.2k – **Cold simulation**. High discharge in the Arctic.

Phases : **Cold**, **warming**, **zonal warm**, **meridional warm**, **cooling**.

Top Panel – AMOC index (max overturning circulation at 26.5°N). The vertical spans represent the different phases
Bottom panel – Irminger Sea vs. GIN seas mixed layer depth state space diagram with the modes definition



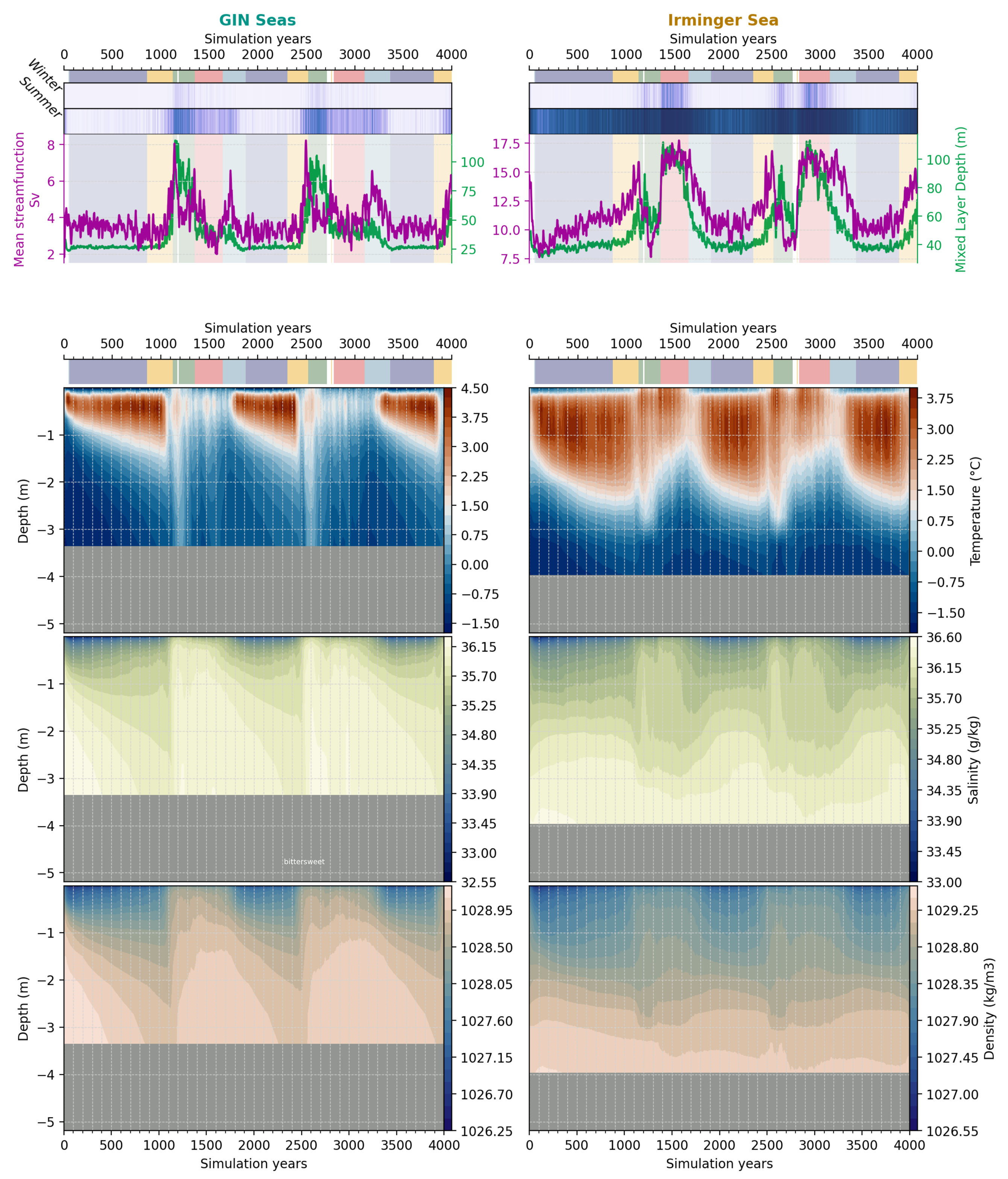
Left – Salinity budget for ocean basins at depths for 20.7 simulation
Middle – Clusters correlations in terms of normalised salinity
Right – Cluster phase plot compared to the surface North Atlantic

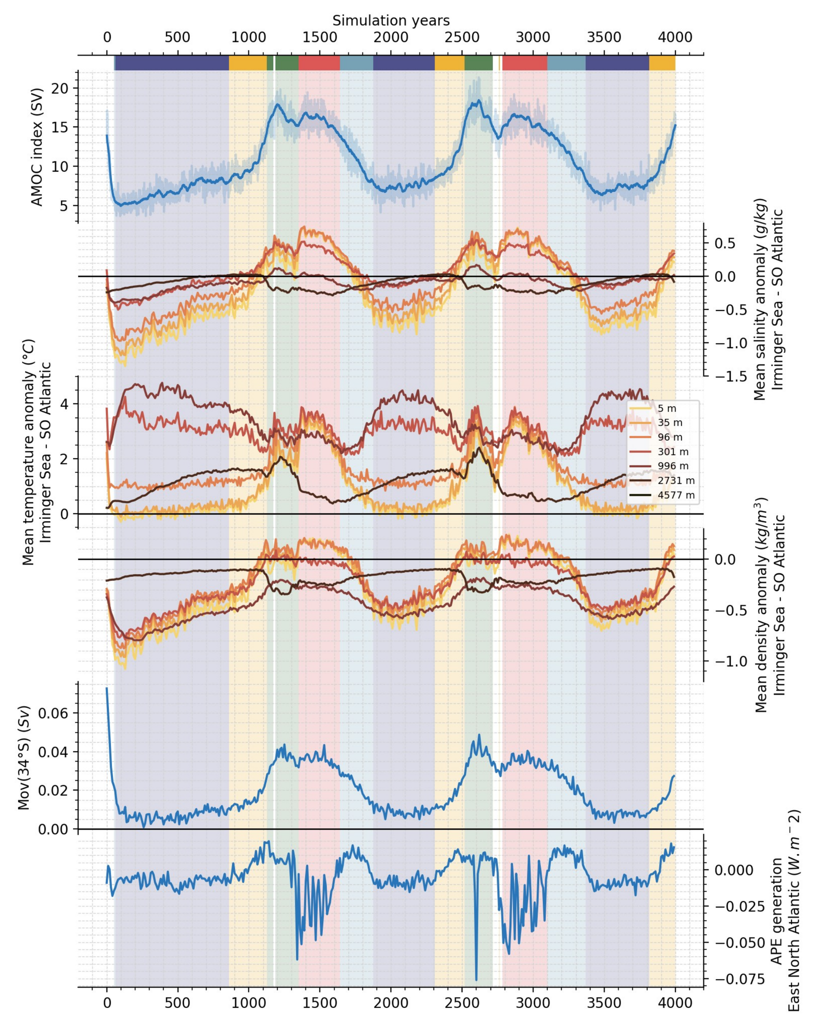


Inter-basins salt exchanges

Surface North Atlantic cluster: surface Arctic
Deep North Atlantic cluster: Tropical, South Atlantic, surface Pacific
Deep Pacific cluster: deep Southern Oceans, deep Indian deep Arctic
Surface Southern Oceans cluster: intermediate Pacific

Top – Winter sea ice, summer sea ice, stream function and mixed layer depth for 20.7k simulation
Bottom – Hovmoller for ocean temperature, salinity and density





AMOC index, temperature, salinity and density gradient between North Atlantic and Southern Oceans, MOV at 32.5°S and available potential energy in East North Atlantic for 20.7k

The Pacemaker mechanism

Cold mode – Salt depleted Atlantic pumps salt from the Pacific. Atantic Meridional Overturning Circulation (AMOC) and North Atlantic stratification increase slowly.

Warming (cold to zonal) – Reactivation Nordic seas convection and abrupt recovery of the AMOC. Salt flux is now from Atlantic to Pacific.

Zonal mode – Unstable East Atlantic due to a strong density meridional gradient. Subpolar gyre intensifies to redistributes salt and temperature.

Meridional mode – Salt depleted Pacific still receives salt from South and tropical Atlantic. Reversal of the zonal Atlantic density gradient weakens the AMOC.

Cooling (meridional to cold) – Negative salt advection feedback accelerates the weakening of the AMOC.

Discussion

1. We assessed the sensitivity of the pace maker mechanism to the global salinity target algorithm by running two sensitivity experiments.
2. The initial perturbation needs to be strong enough to disrupt the Pacific, but small enough to keep one warm mode stable.
3. The processes are highly deterministic and not stochastic.
4. The oscillations resembles Dansgaard-Oeschger events but the experiment design prevent any direct identifications.

Selected references

Ivanovic et al., 2016 – *Transient climate simulations of the deglaciation 21-9 thousand years before present (version 1) – PMIP4 Core experiment design and boundary conditions (Geoscientific Model Development)*
Ivanovic et al., 2018 – *Acceleration of Northern Ice Sheet Melt Induces AMOC Slowdown and Northern Cooling in Simulations of the Early Last Deglaciation (Palaeooceanography)*
Vettoretti et al. 2022 – *Atmospheric CO2 control of spontaneous millennial-scale ice age climate oscillations (Nature)*
Romé et al., 2022 – *Millennial-Scale Climate Oscillations Triggered by Deglacial Meltwater Discharge in Last Glacial Maximum Simulations (Palaeooceanography)*

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