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Effect of Climatic Precession on Dansgaard–Oeschger-like oscillations

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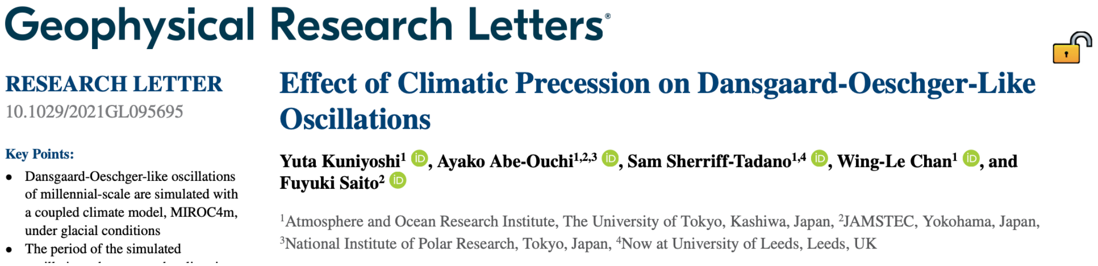
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Effect of Climatic Precession on Dansgaard-Oeschger-Like Oscillations

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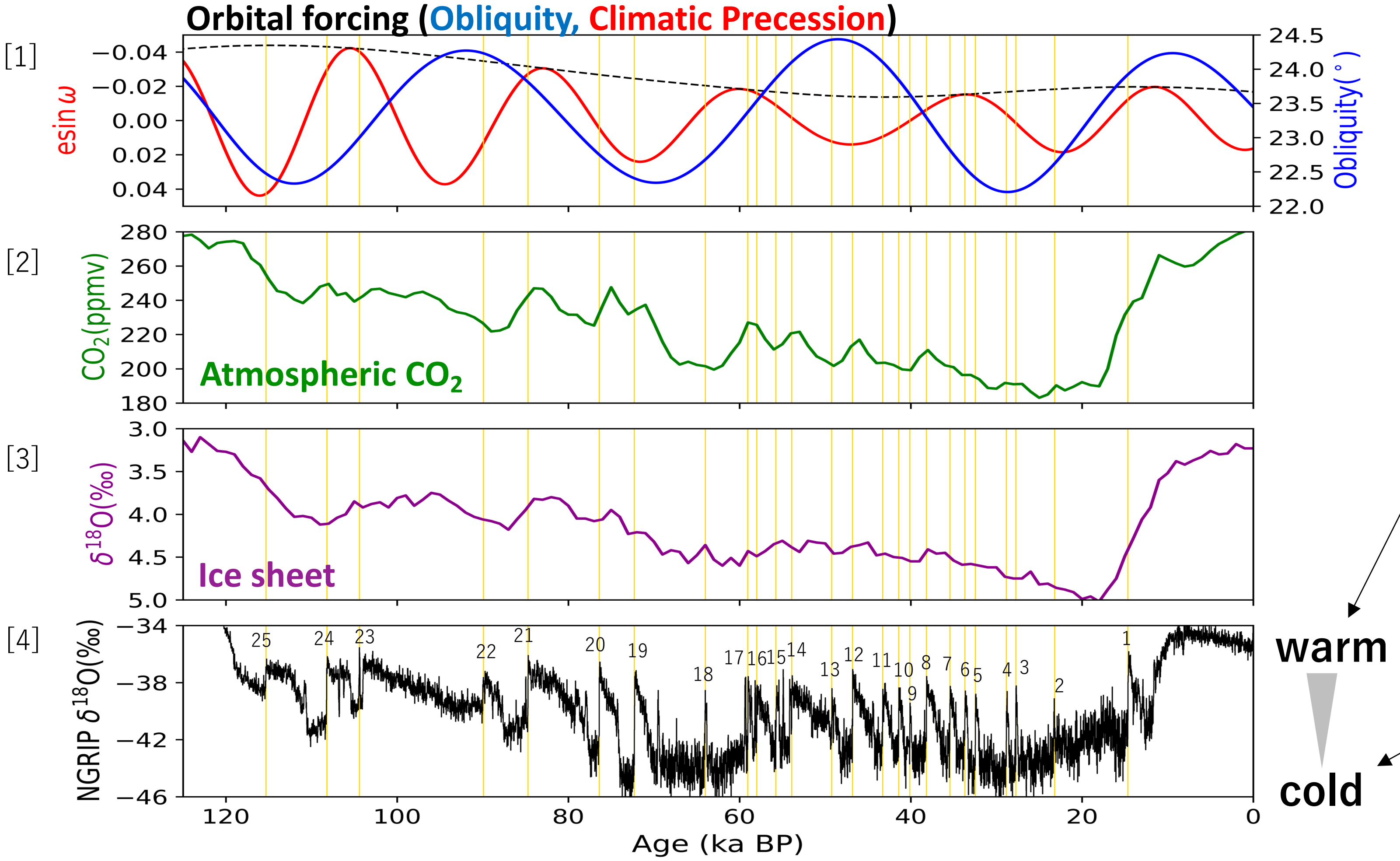
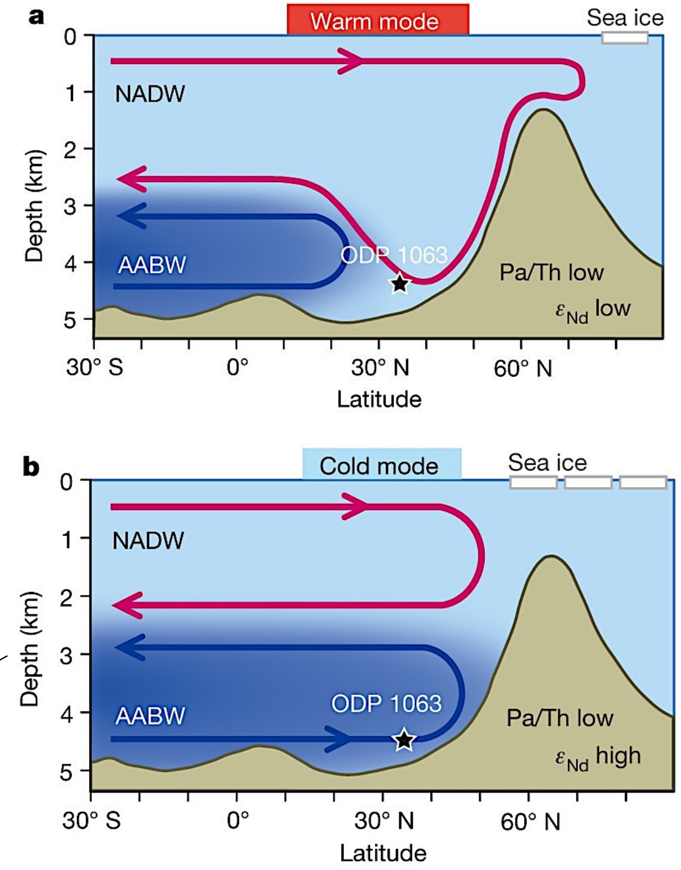
Key Points:
- Dansgaard-Oeschger-like oscillations of millennial-scale are simulated with a coupled climate model, MIROC4m, under glacial conditions
- The period of the simulated

Dansgaard–Oeschger (DO) events (Dansgaard et al.,1982, 1993; NGRIP members, 2004)



AMOC bistable regime (Stommel, 1961)



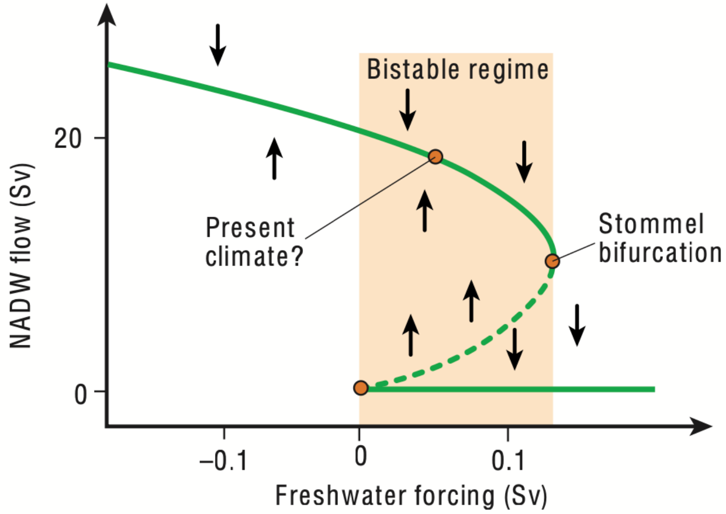
(ref. Böhm et al., 2015)

[1]Laskar et al., 2004
[2]Bereiter et al. 2015
[3]Lisiecki & Raymo, 2005
[4]Rasmussen et al. 2014

- What are the mechanisms for DO events ?
- How do background climate states affect DO events ?

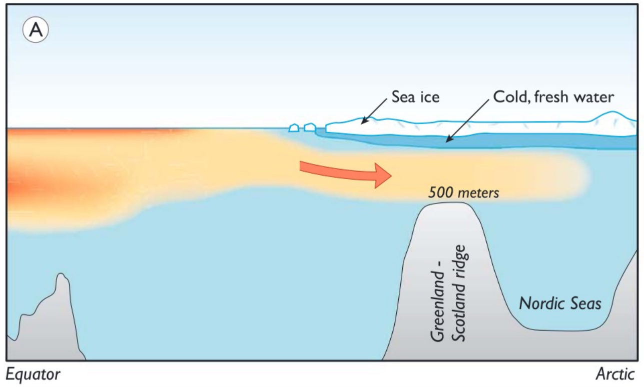
Proposed mechanisms for the AMOC transitions

- **External forcing**
  - **Freshwater forcing**
    (e.g., Manabe & Stouffer, 1995; Ganopolski & Rahmstorf, 2001)
  - **Thermal forcing**
    (e.g., Stouffer & Manabe, 2003; Liu et al., 2005; Buizert & Schmittner 2015; Oka et al., 2012, 2021)



Rahmstorf, 2002

- **Self-sustained oscillations driven by internal feedbacks**
  - **"Salt oscillator"** (Broecker et al.,1990; Peltier & Vettoretti, 2014)
  - **"Deep decoupling"**
    (Winton, 1993; Dokken et al., 2013; Brown & Galbraith, 2016)
  - **Atmosphere-Sea ice-AMOC interactions**
    (Kleppin et al, 2015; Li & Born, 2019; Sherriff-Tadano & Abe-Ouchi, 2020)

Dokken et al., 2013


Objective of this research

1. **Mechanisms for the millennial-scale variability of the AMOC under glacial conditions**
2. **Direct effect of climatic precession on millenial-scale climate variability**

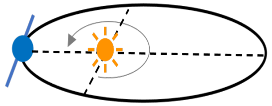
Model & Experimental Design

- **Model: The coupled AOGCM, MIROC4m** (Hasumi & Emori, 2004)

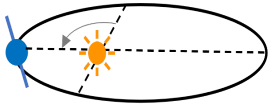
  Resolution **Atmosphere** T42(~2.8°) with 20 vertical levels/ **Ocean** ~1.4° × 1° with 43 vertical levels

- **Experimental Design**

① strong boreal season



② weak boreal season

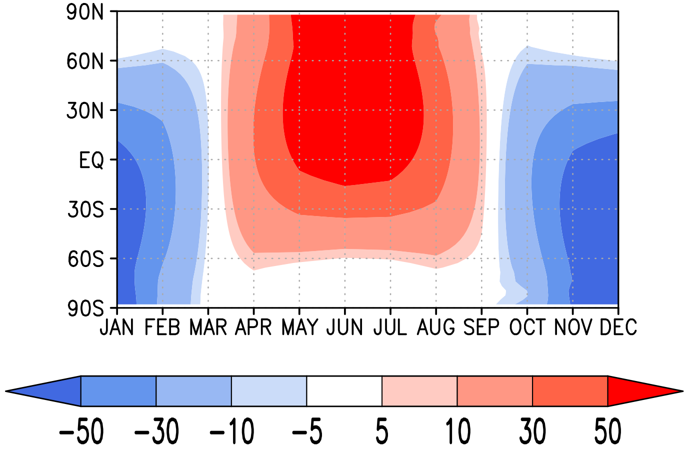


Boundary condition

Ice sheet	CO_2	Obliquity	Eccentricity	Precession
LGM (ICE-5G)	**220 ppm**	**22.949°**	**0.04**	① **Strongest boreal season** (perihelion in summer solstice)
				② **Weakest boreal season** (perihelion in winter solstice)

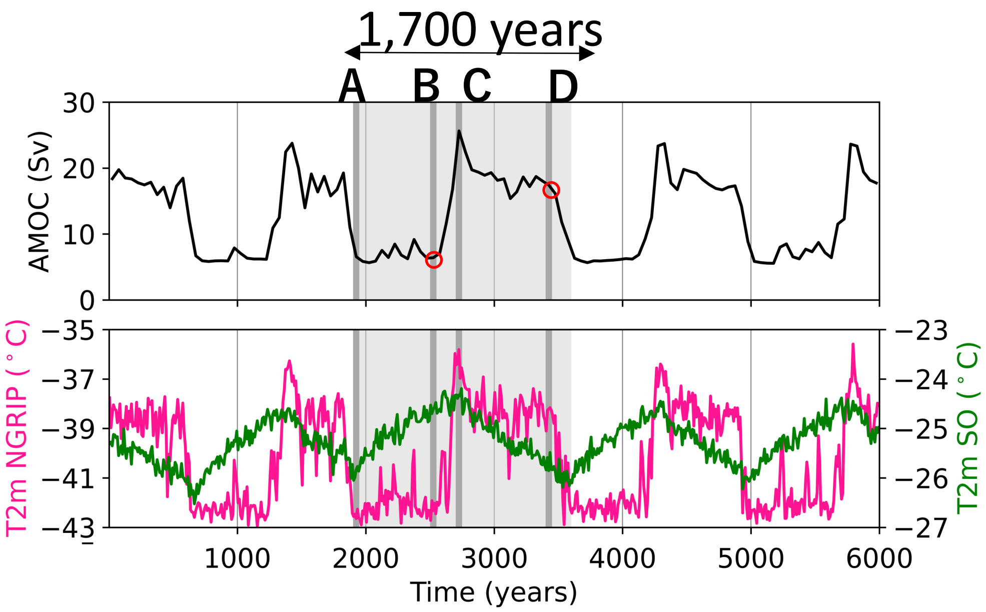
＊used the same initial conditions,
derived from a spin-up which lasted more than 10,000 years & LGM precession.

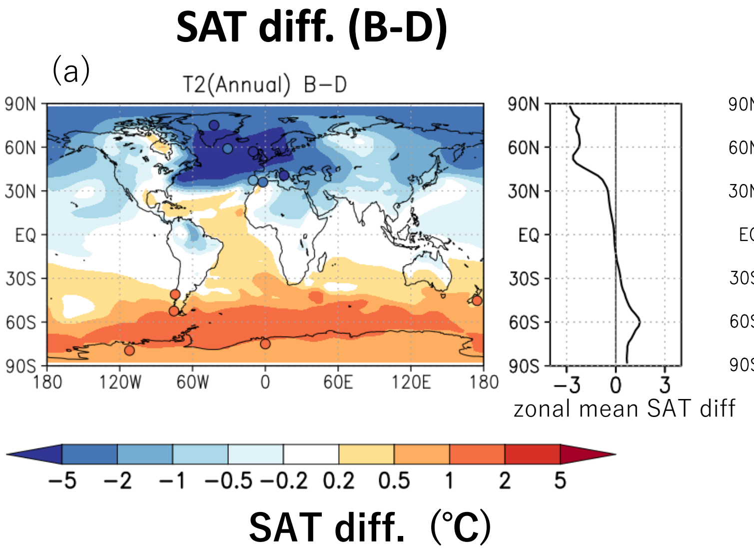
① minus ②

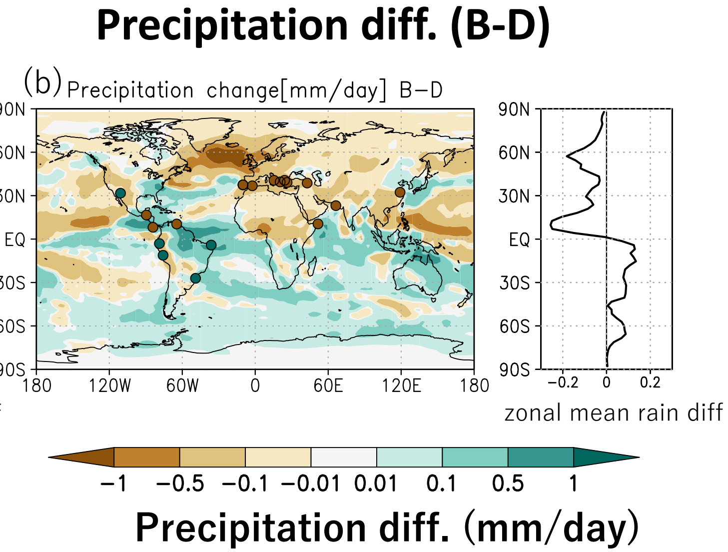


Insolation diff. [W/m^2]

Simulating the self-sustained oscillations under glacial conditions !

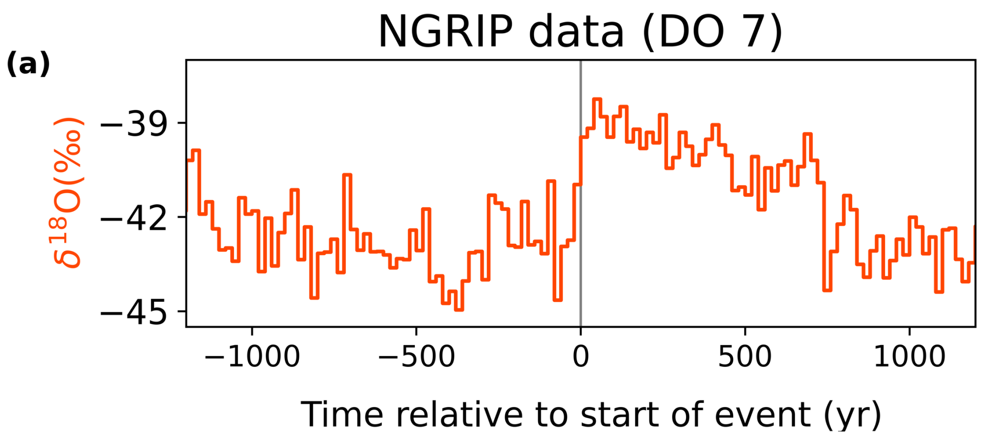


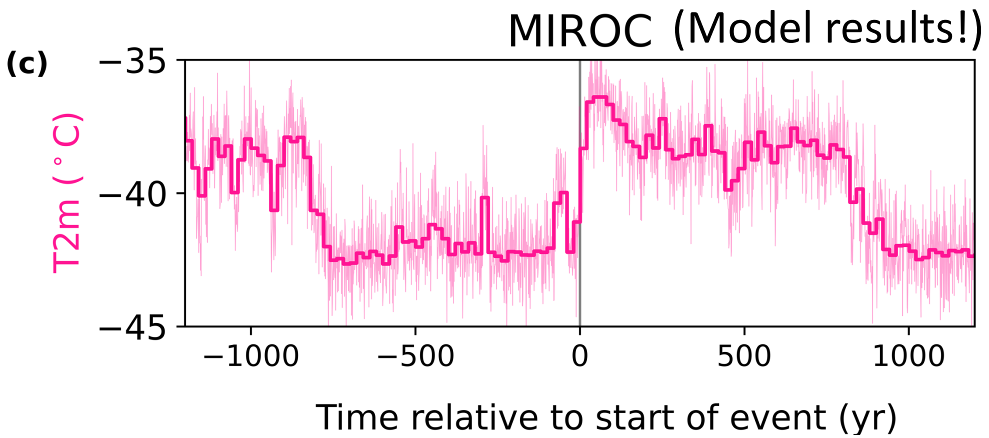




Solid circle indicates the climate changes associated with DO events (Menviel et al., 2020)

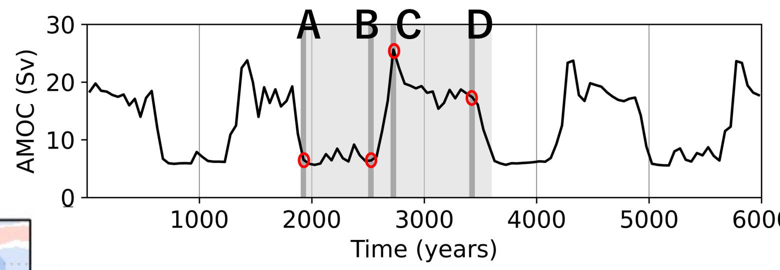
Comparison with the NGRIP data

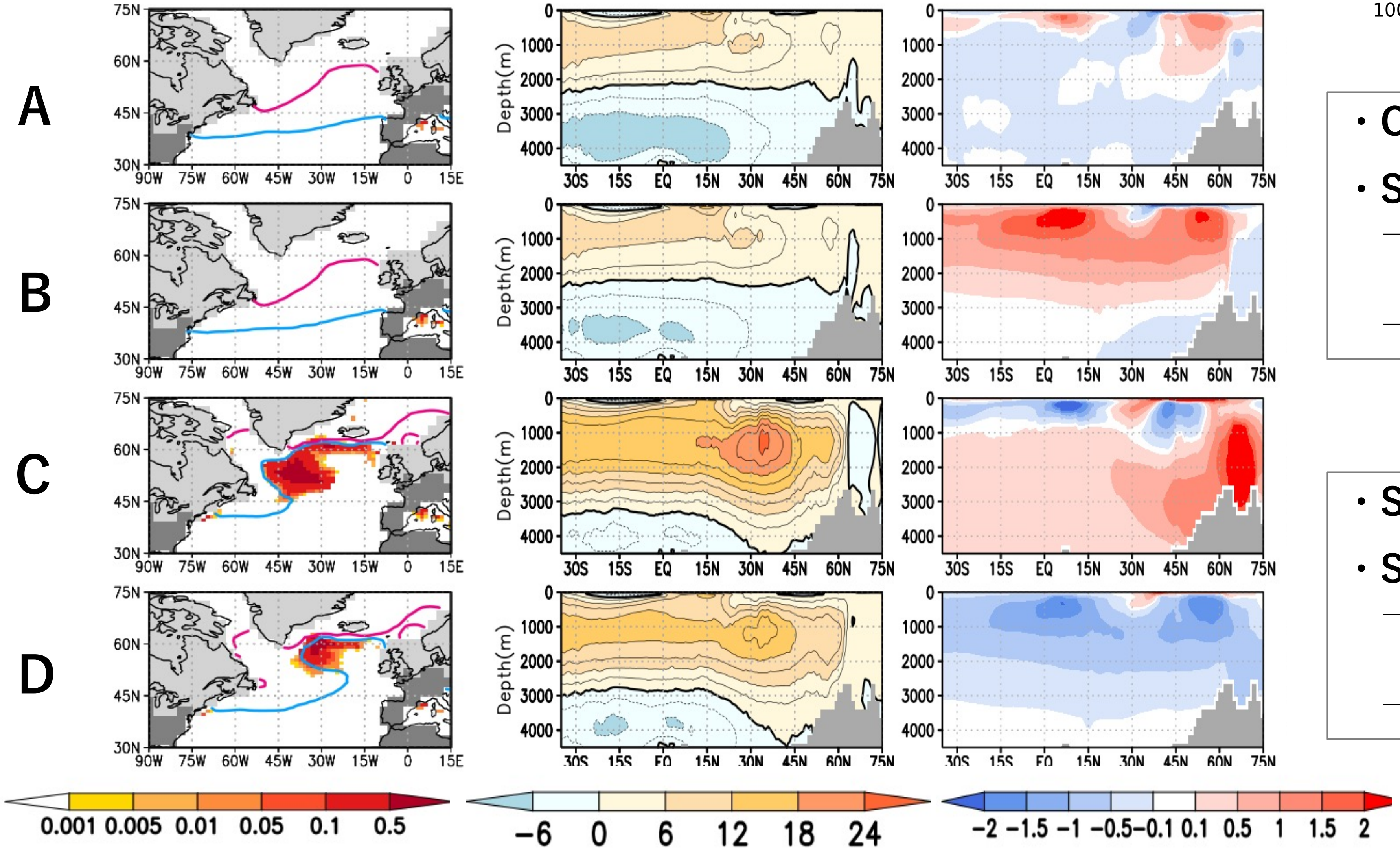




Results

Changes in Sea-ice / AMOC / Subsurface Temp.





Frequency of convection at 900m
(contour) 15% SIC —Mar. —Sep.

AMOC(Sv)

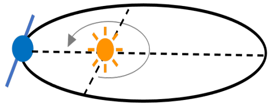
Atlantic zonal mean
potential temperature anomaly (°C)

- **Cover sea ice**
- **Subsurface warming**
  →Weaken stratification of the North ATL
  →AMOC recovery

- **Sea ice retreats**
- **Subsurface cooling**
  →Strengthen stratification of the North ATL
  →AMOC collapse

Effect of Climatic Precession on DO-like oscillations

① Strong boreal



AMOC (a)

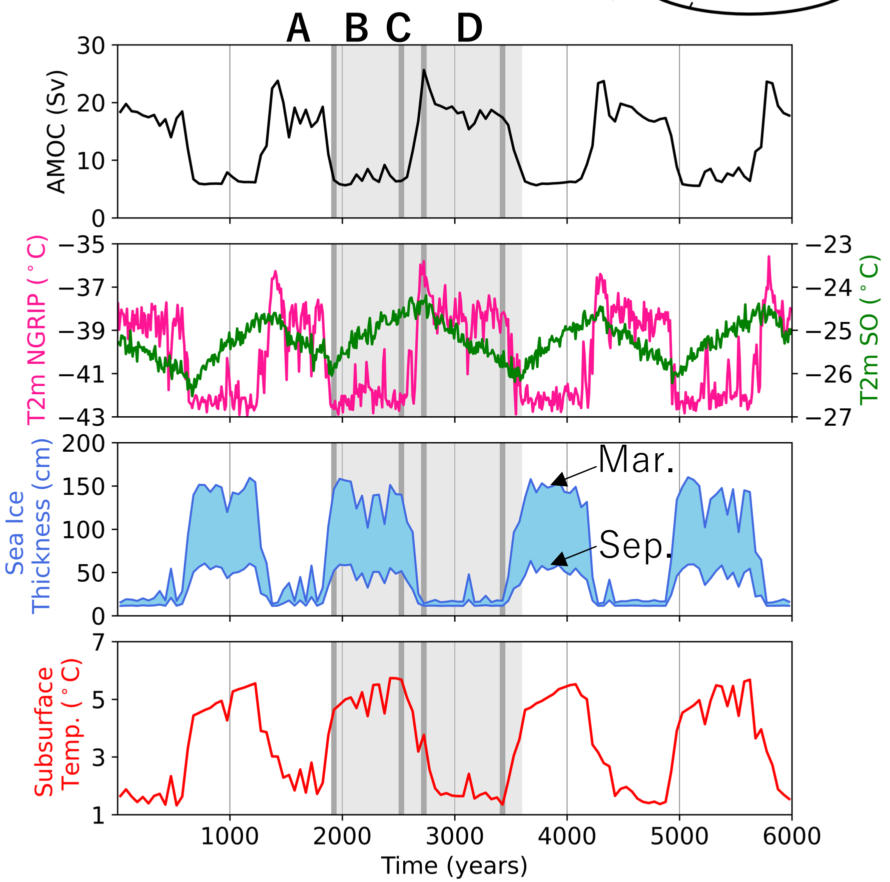
SAT (b)

— Greenland

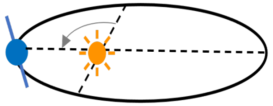
— SO

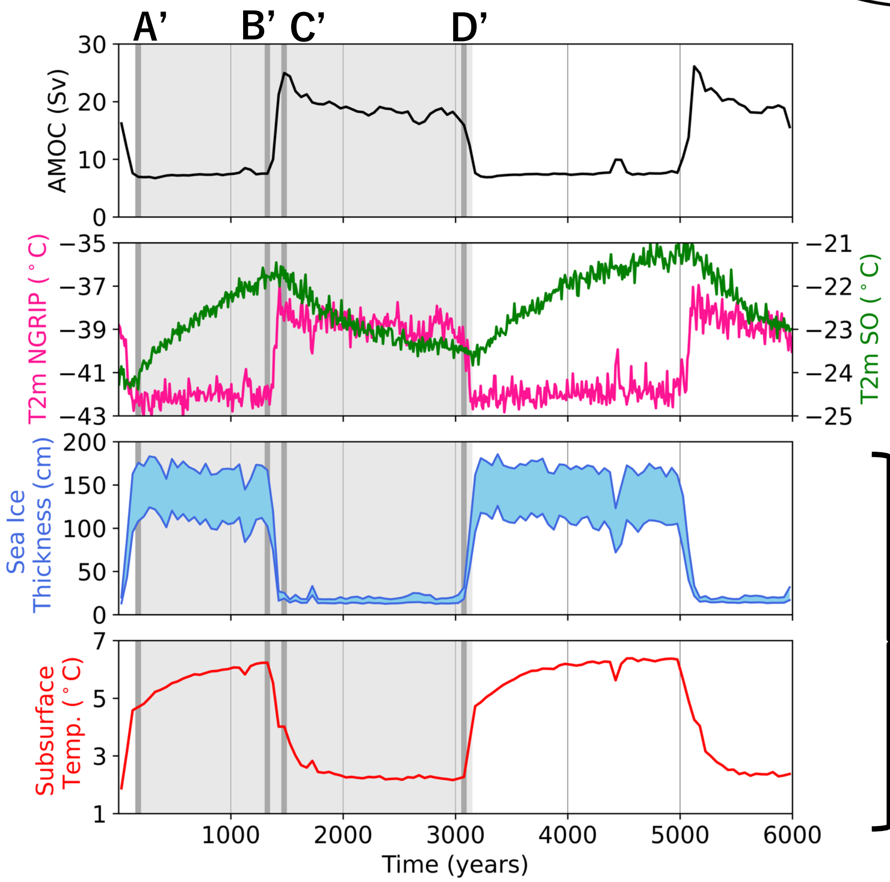
SI thickness (c)

Subsurface Temp. (d)

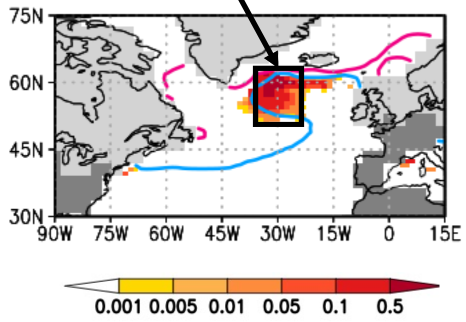


② Weak boreal





Averaging area (35W-25W, 52N-63N)



Frequency of Convective Adjustment

During stadial, thicker sea ice in both summer & winter → prolong the duration of the stadial

During interstadial, slow cooling of the subsurface → prolong the duration of the interstadial

Discussion & Conclusions

Mechanism for the self-sustained oscillation

Sea ice change & Subsurface temperature change in North ATL drive the oscillation.

- **“Deep decoupling oscillation” (Winton, 1993) works under glacial conditions.**
  - Brown & Galbraith (2016) have shown this process in GFDL-CM2Mc with PI icesheet.
  - Consistent with proxy reconstructions (Sadatzki+, 2019, 2020; Ezat+ 2014)

Effect of climatic presession

The periodicity lengthens as the precession shifts to weaker boreal seasonality

through changes in sea ice thickness and subsurface temperature in the North Atlantic.

- Further information in Kuniyoshi et al. (2022) GRL

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