Simulation of the climate and ocean circulations in the Middle Miocene Climate Optimum by a coupled model FGOALS-g3

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Motivation

- The warm climate in the Middle Miocene Climate Optimum (MMCO) could be an analogue for future global warming;
- The widespread forests in the MMCO led to significant radiative balance change, but the MMCO warmth attributing to albedo vs CO2 is controversial;
- The opening of the Panama and Tethys Seaways in the MMCO induced global ocean circulation reorganization. The resulted changes and underlying mechanism are still on debate.

Ocean changes

Table2. The volume (Sv) and freshwater (10^9 kg/s) transports from Tethys Seaway and the Panama Seaway into the North Atlantic.

Seaways	Tethys	Panama
Volume	11.94	21.23
Freshwater	-0.39	0.22

- Passing through the Tethys and Panama Seaway, waters from the Pacific and Indian Ocean converge in the western North Atlantic.
- Enhanced Gulf Stream flows more poleward, contributing to the disappearance of sea ice and stronger deep convection near Greenland.

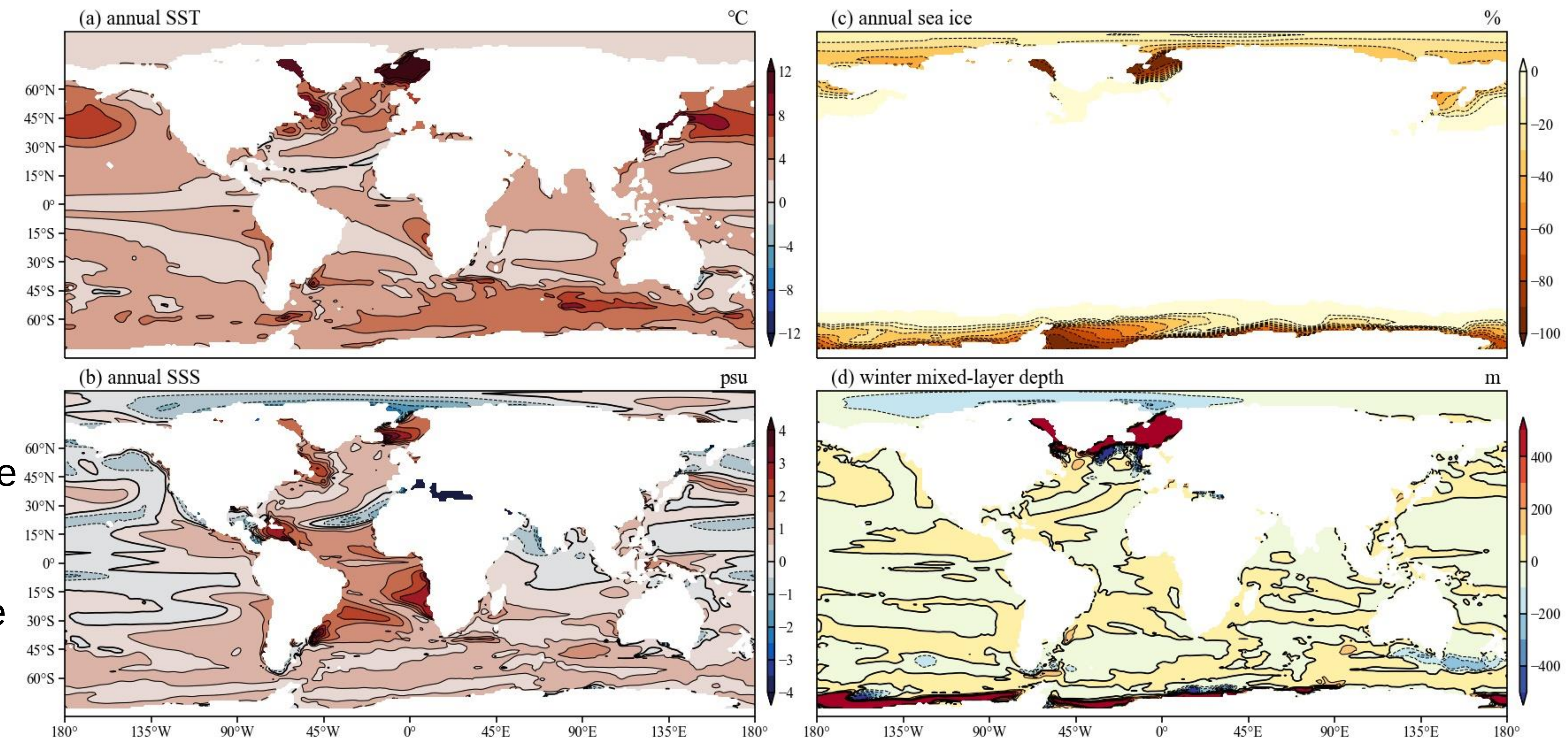


Fig 3. The annual SST (a), SSS (b) and (c) and the winter mixed-layer depth differences between the MMCO_400 and PI.

Conclusions

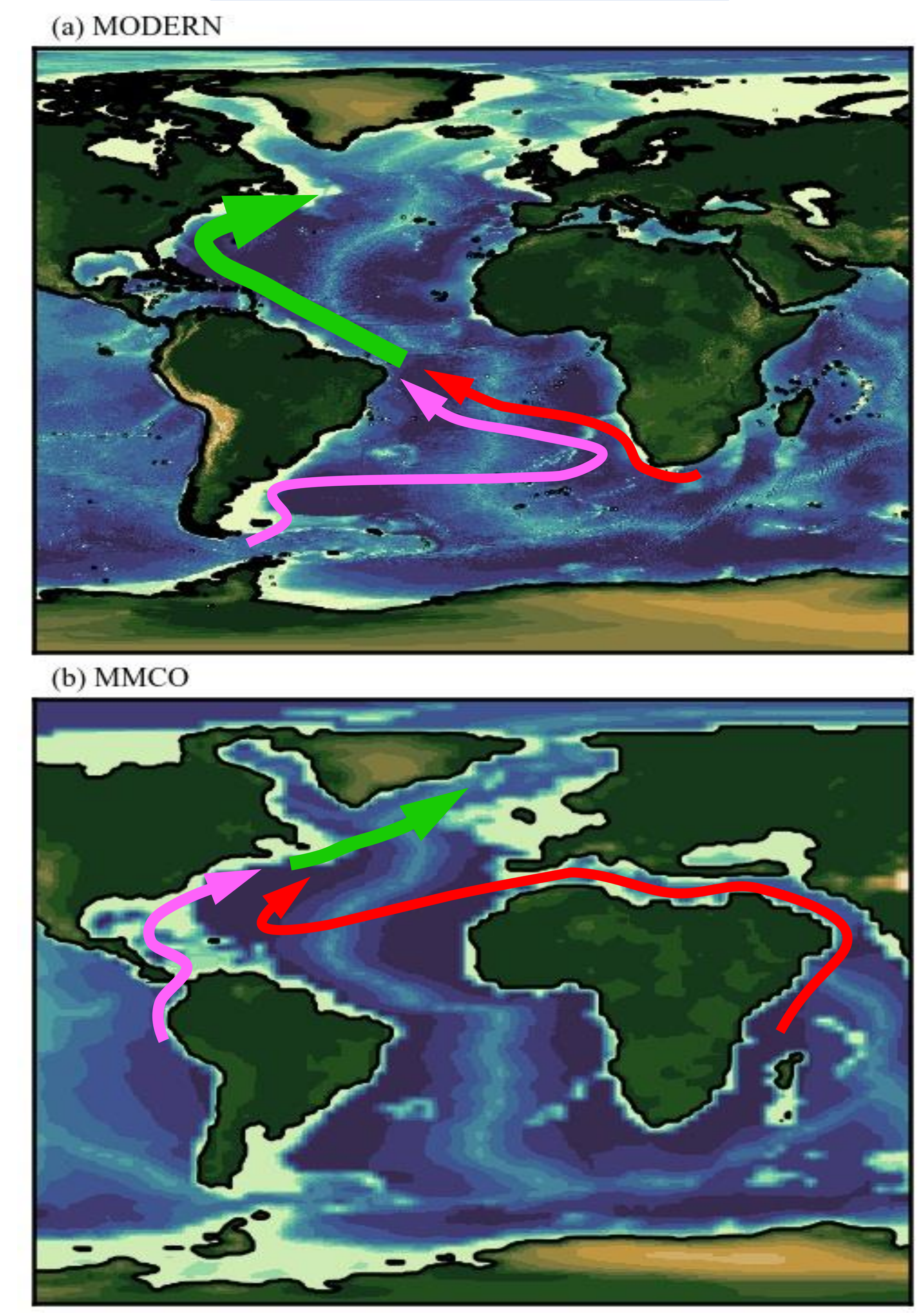


Fig 5. Schematic diagram of the upper ocean currents in the Atlantic. The modern result is from Rühs et al (2019).

- The warmth in the MMCO simulated is mainly caused by the lower surface albedo and the higher CO_2 concentration.;
- Under the strong AMOC simulation, the opening of the Tethys Seaway and Panama Seaway provides "shortcuts" for the waters of the AMOC's upper limb.

Experiments

- MMCO geography and vegetation data from Frigola et al (2018);
- Two simulations: MMCO and pre-Industrial control;
- Coupled model FGOALS-g3 (Flexible Global Ocean-Atmosphere-Land System Model Grid-point version 3).

Table1. Experiments setup.

Experiments	PI	MMCO_400
CO_2(ppmv)	280	400
Topography	Modern	MMCO
Bathymetry	Modern	MMCO
Vegetation	Modern	MMCO
Integration	1000yrs	1000yrs

The last 100-years model outputs are used for analysis.

MMCO warmth

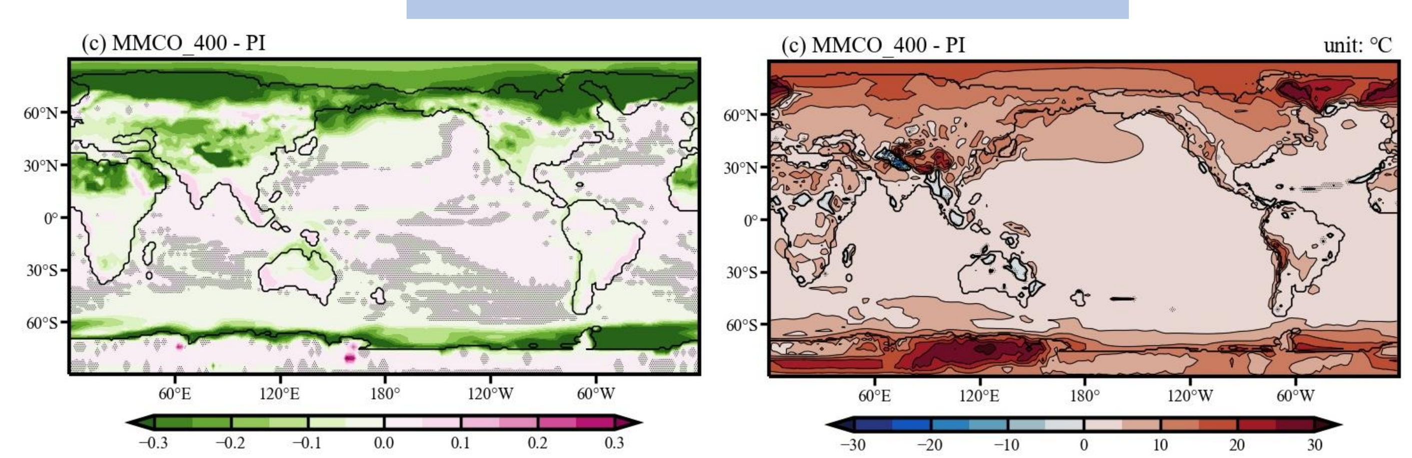
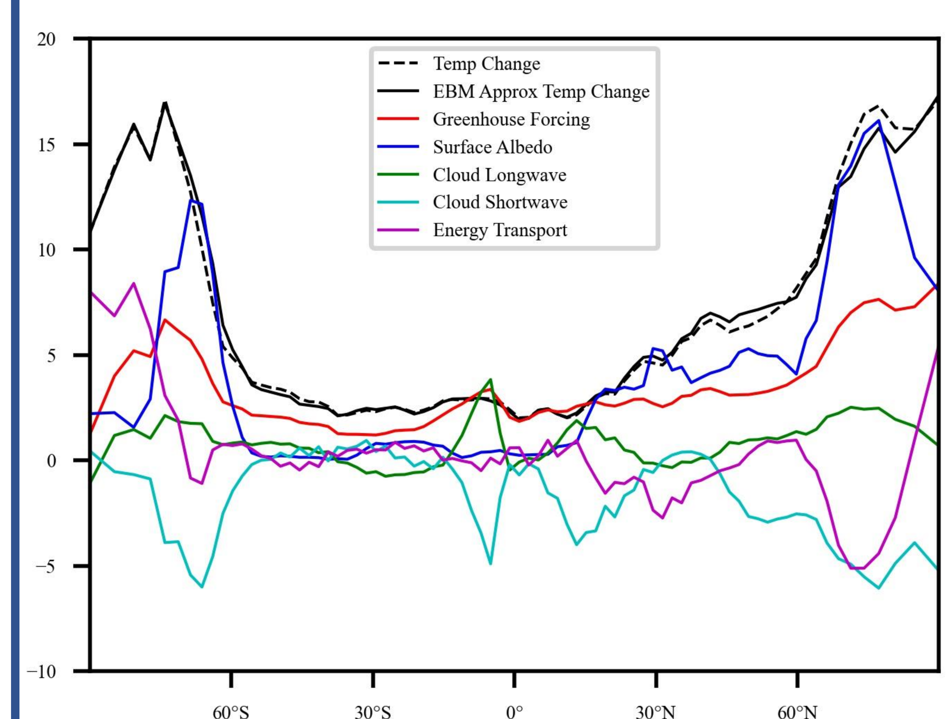


Fig 1. The surface albedo (left) and surface temperature (right) differences between the MMCO_400 and PI.



The MMCO climate is 4.7℃ warmer the PI. According to the Energy Balance Model(EBM) analysis, changes in surface albedo and greenhouse effect individually contribute ~2.7℃.

Fig 2. The result of the EBM analysis.

Thermohaline circulation

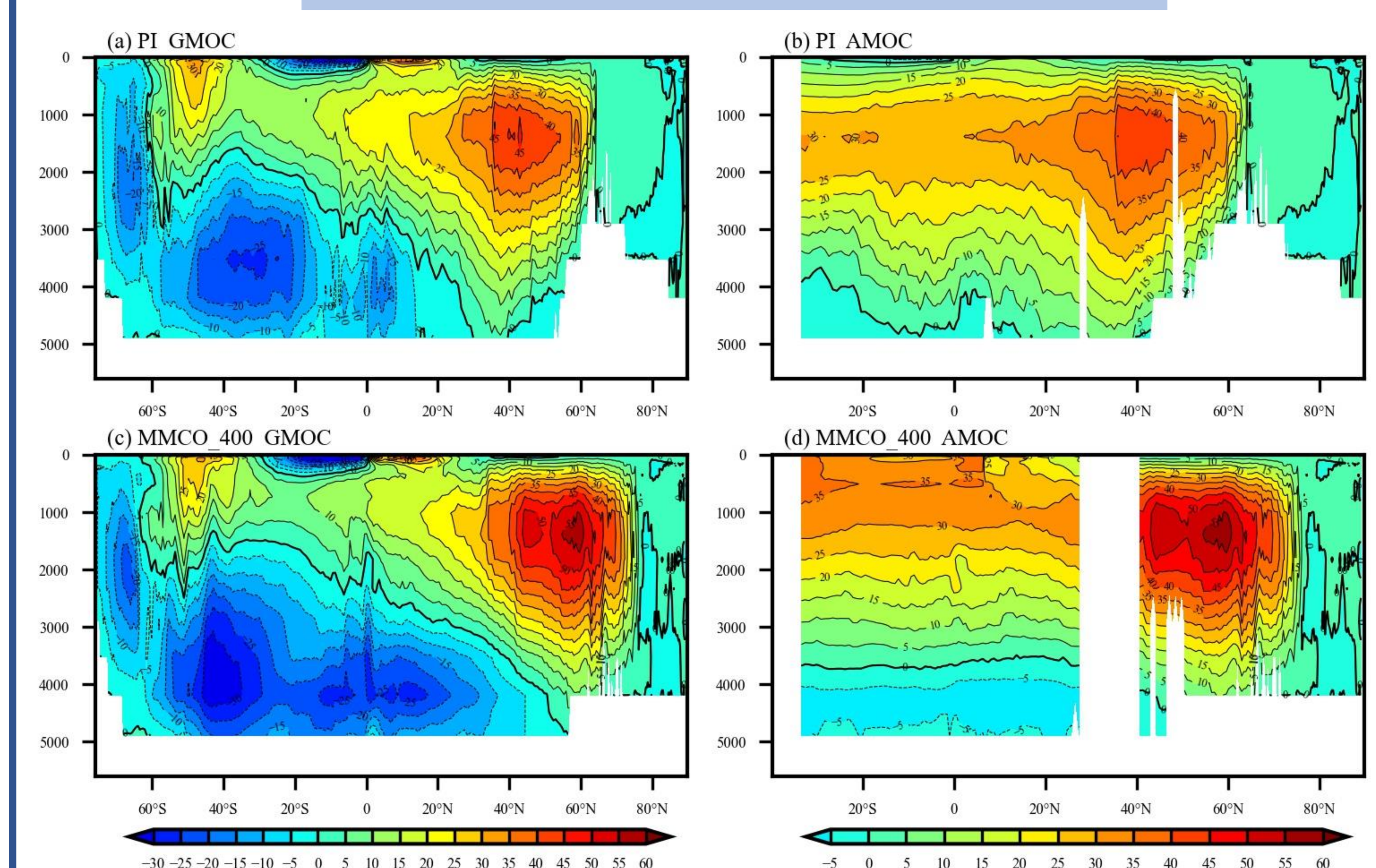


Fig 4. Global and (b) Atlantic Meridional Overturning Circulation (MOC, Sv) for PI. (c)-(d) are the same as (a)-(b) but for the MMCO.

For more detailed information: Wei, J., Liu, H., Zhao, Y., Lin, P., Yu, Z., Li, L., et al. (2023). Simulation of the climate and ocean circulations in the Middle Miocene Climate Optimum by a coupled model FGOALS-g3. *Palaeogeography, Palaeoclimatology, Palaeoecology, 617, 111509.*

Reference:
Frigola, A., Prange, M., & Schulz, M. (2018). Boundary conditions for the Middle Miocene Climate Transition (MMCT v1.0). *Geosci. Model Dev., 11(4), 1607-1626. https://doi.org/10.5194/gmd-11-1607-2018*
Rühs, S., Schwarzkopf, F. U., Speich, S., & Biastoch, A. (2019). Cold vs. warm water route – sources for the upper limb of the Atlantic Meridional Overturning Circulation revisited in a high-resolution ocean model. *Ocean Sci., 15(3), 489-512. https://doi.org/10.5194/os-15-489-2019*