Stability of the AMOC depends on the background climate

Aixue Hu, Gerald A. Meehl, Ayako Abe-Ouchi, Weiqing Han, Bette Otto-Bliesner, Nan Rosenbloom

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Present: Bering Strait is a narrow (~150 km) and shallow (~50 m) pathway connecting the Pacific and the Arctic between Alaska and Siberia. On average, about 0.8 Sv fresher North Pacific water flows through this strait into the Arctic, subsequently into the North Atlantic.
AMOC Hysteresis: Open BS vs. Closed BS

Theoretical AMOC hysteresis diagram

AMOC hysteresis diagram in CCSM3

Hu et al., PNAS, 2012

FW added between 20°N and 50°N
A 0.1 Sv FW change = 500 years
Max FW = 0.42 Sv CBS and 0.44 Sv for OBS
Model and Experiments:

Here we use the National Center for Atmospheric Research Community Climate System Model version 3.

Atmospheric model (CAM3): T42 (2.8 degree), 26 hybrid levels
Land model (CLM3): T42
Ocean model (POP): 1 degree, 40 levels
Sea ice model (CSIM5): 1 degree

Climate boundary condition: present day, 15 kyr BP

Hysteresis Experiments:

4 sets simulations with two experiments in each set. Within each set, the two experiments are carried out with everything identical, except one with an open Bering Strait (OBS) and the other with a closed one (CBS).
PD simulations: 2 sets – PD1 and PD2

Following Rahmstorf et al. (2005), the freshwater forcing is added uniformly in the Atlantic between 20 and 50°N at an initial rate of 200m³/s or 100m³/s, with a linear annual increment of 200/100m³/s. So it takes 500/1000 model years for the freshwater forcing to increase by 0.1 Sv. Each of the model simulations shown here run for 4400/8800 years. Hereafter we name them: PD1 and PD2

15 kyr BP simulations: 2 sets – MG1 and MG2

Following Stouffer et al. (2006), the freshwater forcing is added uniformly in the Atlantic between 50 and 70°N at an initial rate of 100m³/s, with a linear annual increment of 100m³/s. So it takes 1000 model years for the freshwater forcing to increase by 0.1 Sv. Each of the model simulations shown here run for 3000/2400 years. MG1 and MG2
AMOC hysteresis cycle

MG1

AMOC index (Sv, 10^6 m^3/s)

Freshwater Forcing (Sv, 10^6 m^3/s)

MG2

AMOC index (Sv, 10^6 m^3/s)

Freshwater Forcing (Sv, 10^6 m^3/s)

PD1

AMOC index (Sv, 10^6 m^3/s)

Freshwater Forcing (Sv, 10^6 m^3/s)

PD2

AMOC index (Sv, 10^6 m^3/s)

Freshwater Forcing (Sv, 10^6 m^3/s)

CBS: black, red
OBS: blue, green

0.07 Sv

0.28 Sv

0.07 Sv

0.20 Sv
AMOC hysteresis in CLIMBER-2

Red lines: FW added in NA between 50-70°N; Black lines: FW added in NA between 20-50°N

Present day condition Glacial condition

Ganopolski and Rahmstorf, Nature, 2001

CLIMBER-2

Glacial condition

Ice Volume Equivalent Sea Level, m

50-70°N; 120-50°N
Bering Strait volume transport (OBS)
Zonal Mean Salinity/MSF Diff when AMOC Collapses (MG)

MG1

MG2
1850-2005: historically observed; 2006-2300: RCP8.5; 2301-2600: \( \text{CO}_2 \) fixed at 2300 level; 2601-2895: reversed RCP8.5; 2896-3050: reversed historical observed \( \text{CO}_2 \).
Summary

• AMOC hysteresis depends on the background climate.
• The status of the Bering Strait (open vs. closed) plays a crucial role on determining the AMOC hysteresis behavior.
• With an open BS, there is no clear hysteresis of the AMOC.
• With a closed BS, there is AMOC hysteresis.
• Our results suggest that the frequent occurrence of the abrupt climate change events during last glacial time may be related to the AMOC hysteresis; and the Holocene stable climate may at least partially related to the lack of AMOC hysteresis.
• Strong thermal forcing, e.g. CO$_2$, could also cause the collapse of the AMOC.
Zonal Mean Temperature Diff when AMOC Collapses (PD)

Pacific

CBS-OBS

Atlantic

psu

Depth (m)

30S 0 30N 60N

60N 30N 0 30S 60S

Pacific

CBS-OBS

Atlantic

psu

Depth (m)

30S 0 30N 60N

60N 30N 0 30S 60S
AMOC and PMOC Index

MG1

Blue, red: CBS; Black, green: OBS
Blue, black: AMOC; red, green: PMOC

Model year

AMOC (Sv, 10^6 m^3/s)

MG2

Blue, red: CBS; Black, green: OBS
Blue, black: AMOC; red, green: PMOC

Model year

PMOC (Sv, 10^6 m^3/s)

PD1

Blue, red: CBS; Black, green: OBS
Blue, black: AMOC; red, green: PMOC

Model year

AMOC (Sv, 10^6 m^3/s)

PD2

Blue, red: CBS; Black, green: OBS
Blue, black: AMOC; red, green: PMOC

Model year

PMOC (Sv, 10^6 m^3/s)