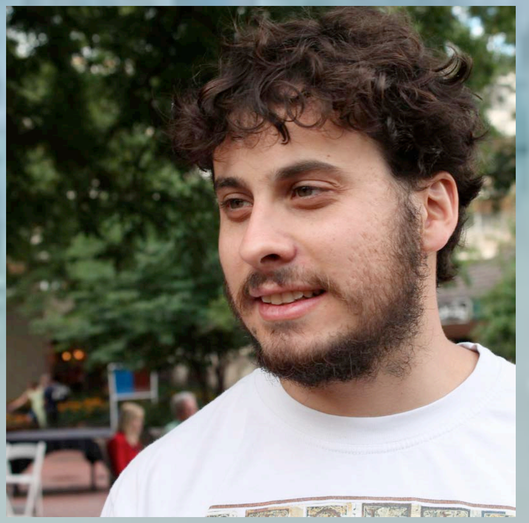
Carbon Isotope Constraints on Paleo AMOC: Strength vs Depth

Andreas Schmittner, Juan Muglia



Award 1634719

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Motivation

Question: How well do carbon isotopes ($\delta^{13}C$ and radiocarbon) constrain AMOC properties?

Goal: Investigate effects of AMOC strength and depths separately.

Strategy: Compare equilibrium simulations of isotope-enabled model, which fill AMOC strength vs AMOC depth phase space, with sediment data from the Last Glacial Maximum (LGM)

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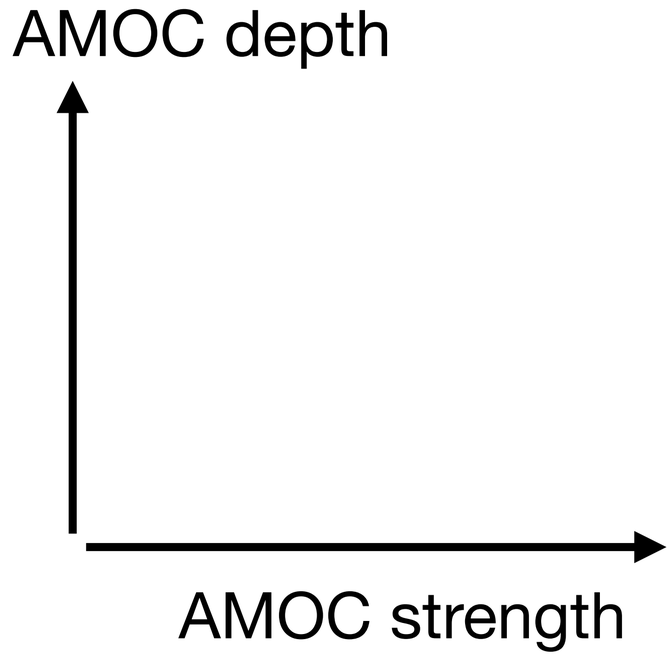
Carbon isotope constraints on glacial Atlantic meridional overturning: Strength vs depth

Juan Muglia [a], Andreas Schmittner [b]



Methods

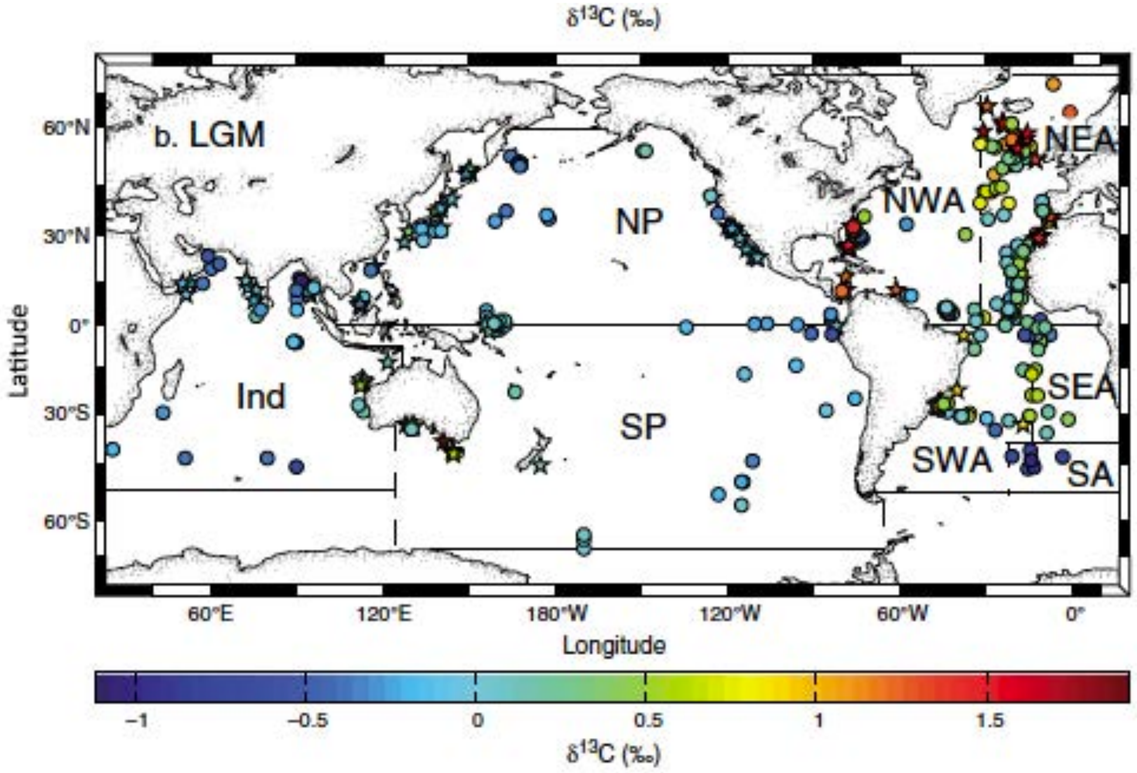
Climate Model

- Oregon State University version of University of Victoria model (OSU-UVic)
- Model of Ocean Biogeochemistry & Isotopes (MOBI) includes $\delta^{13}C$ and radiocarbon ($\Delta^{14}C$)
- LGM Boundary Conditions
- Vary Southern Ocean buoyancy fluxes
- Add freshwater fluxes in North Atlantic

Sediment Data

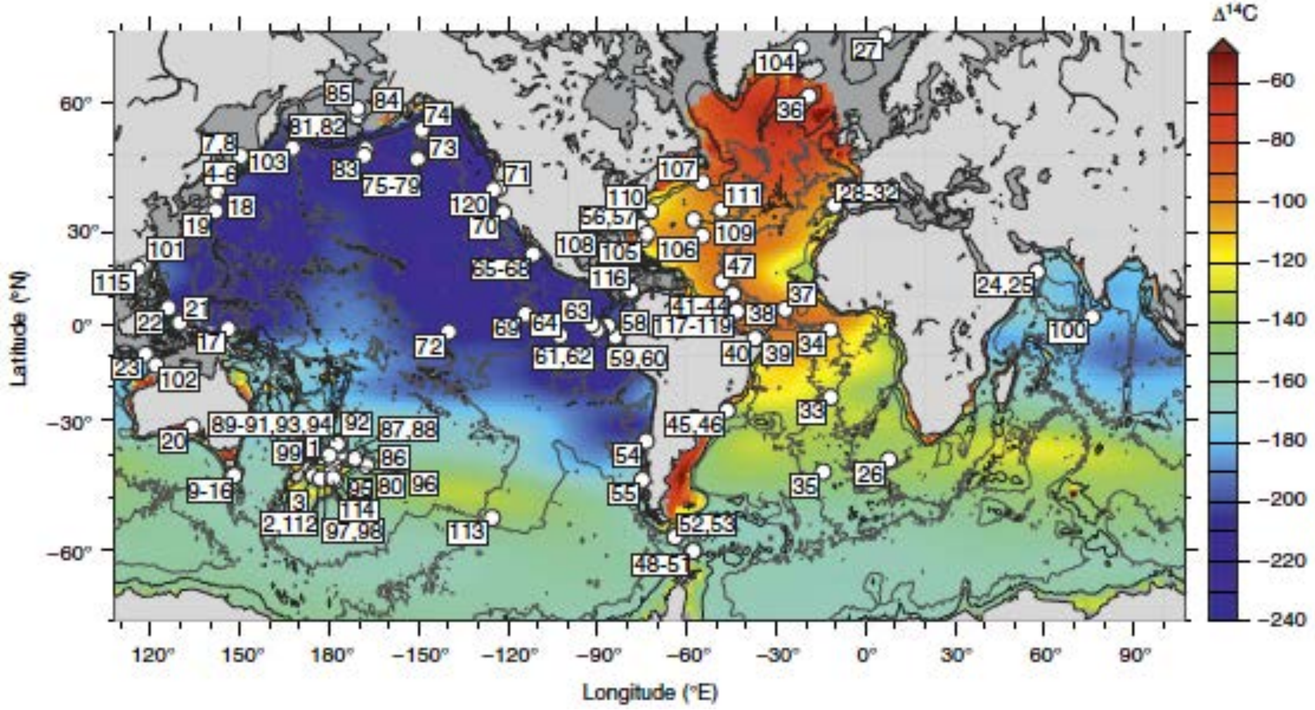
δ¹³C (Peterson et al., 2014)

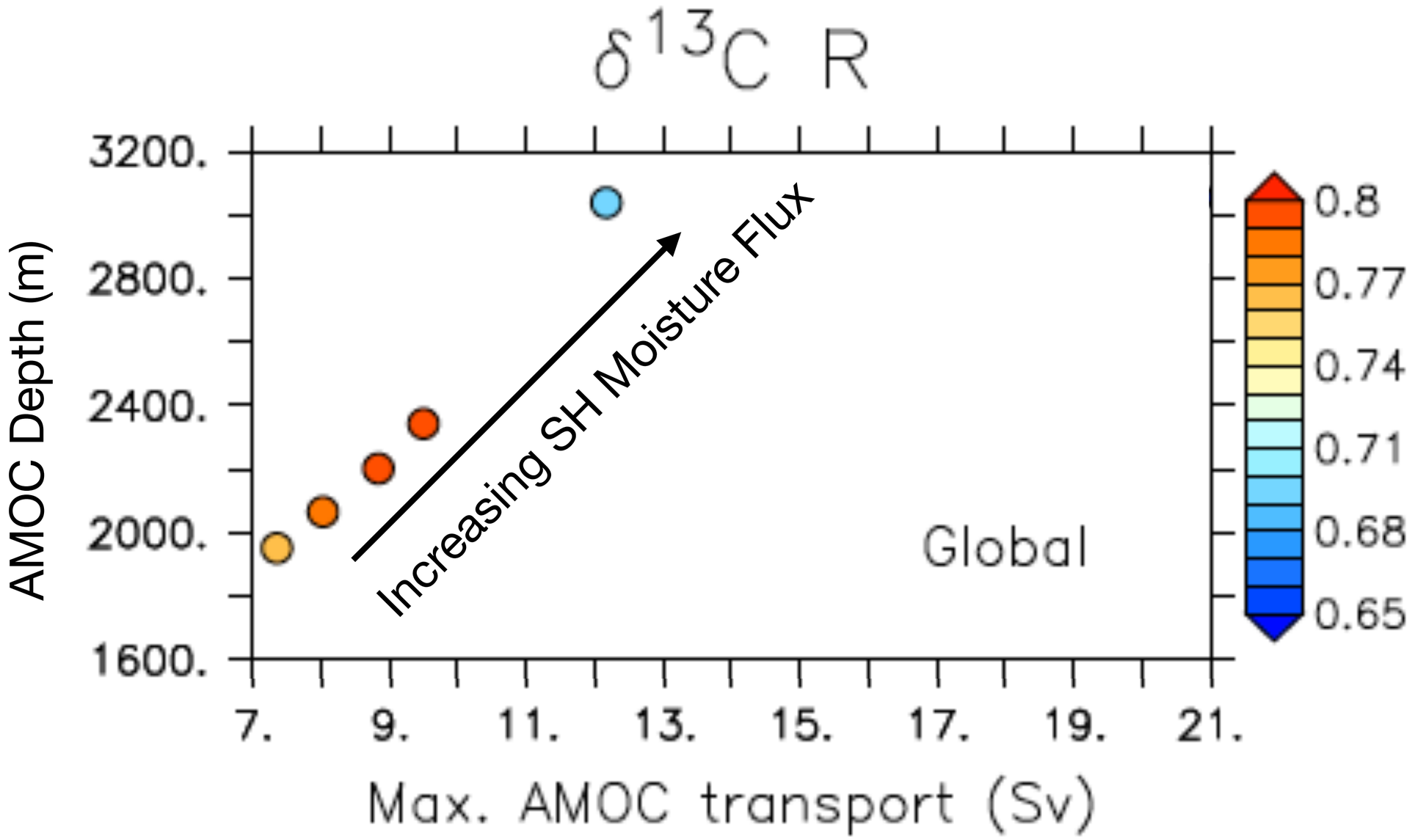
N=434

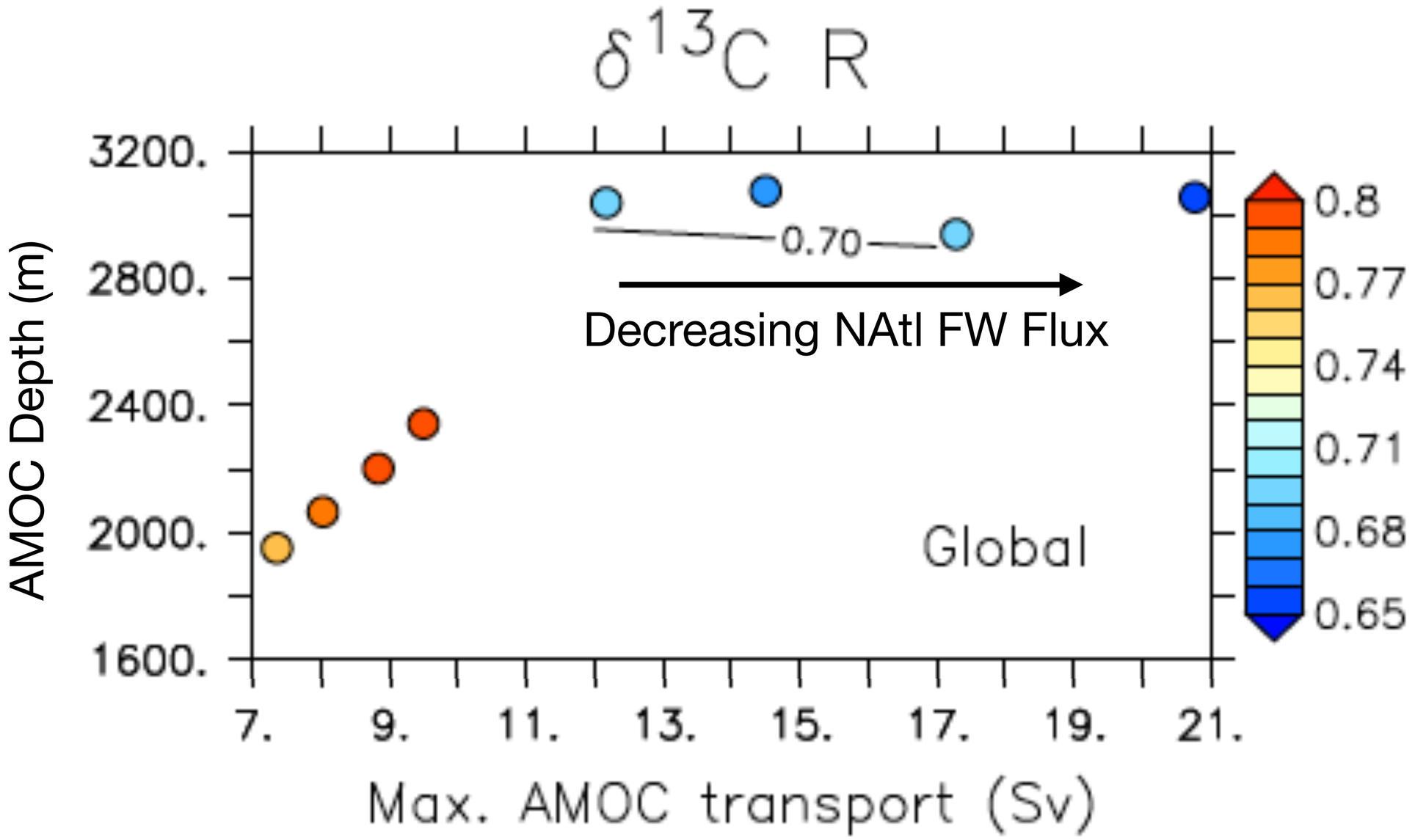


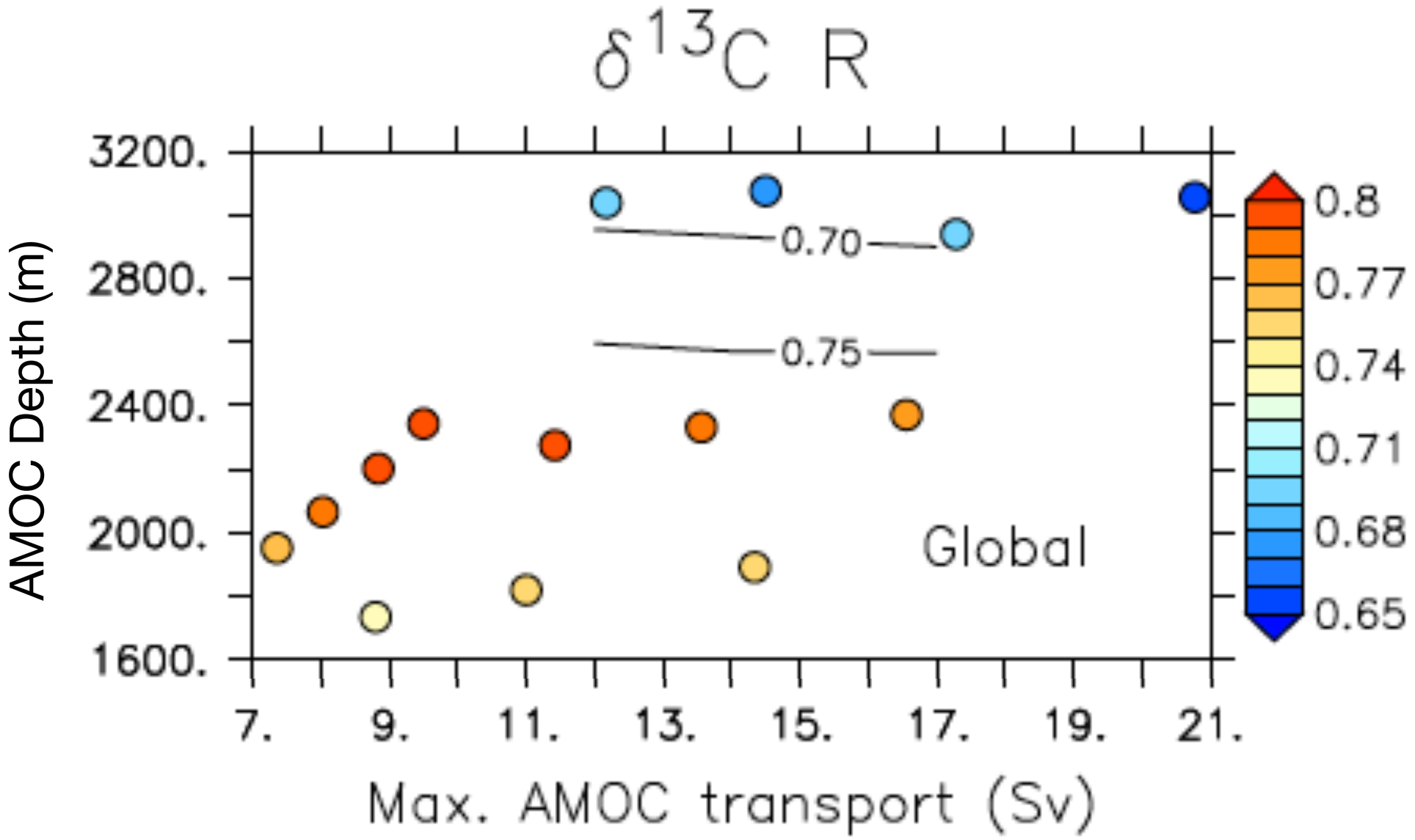
Radiocarbon (Skinner et al., 2017)

N=246




δ13C R
AMOC Depth (m)
3200.
2800.
2400.
2000.
1600.
7.
9.
11.
13.
15.
17.
19.
21.
Max. AMOC transport (Sv)
Increasing SH Moisture Flux
Global
0.8
0.77
0.74
0.71
0.68
0.65

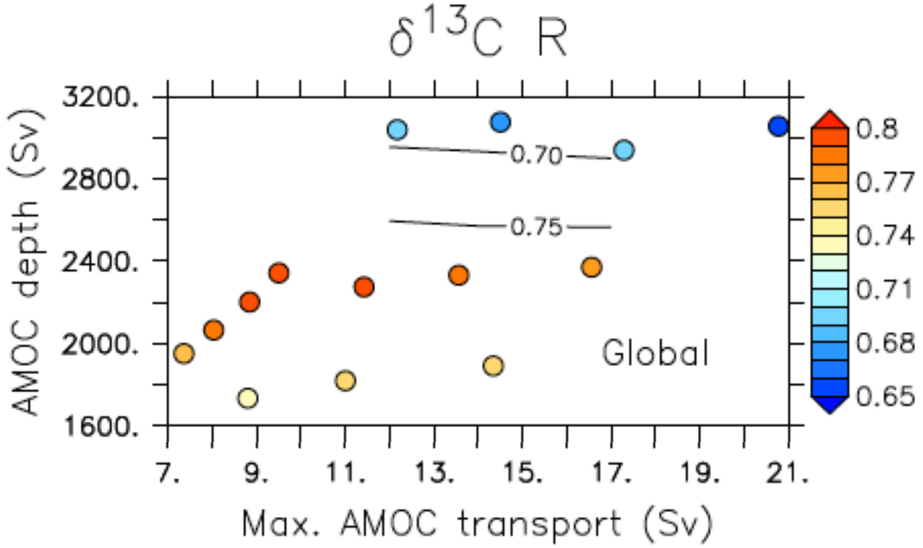

δ13C R
3200.
2800.
2400.
2000.
1600.
AMOC Depth (m)
0.70
Decreasing NAtl FW Flux
Global
0.8
0.77
0.74
0.71
0.68
0.65
7.
9.
11.
13.
15.
17.
19.
21.
Max. AMOC transport (Sv)


δ13C R
AMOC Depth (m)
3200.
2800.
2400.
2000.
1600.
0.70
0.75
Global
0.8
0.77
0.74
0.71
0.68
0.65
7.
9.
11.
13.
15.
17.
19.
21.
Max. AMOC transport (Sv)

$\delta^{13}C$

Correlation coefficient depends mostly on AMOC depth.

Correlation Coefficient

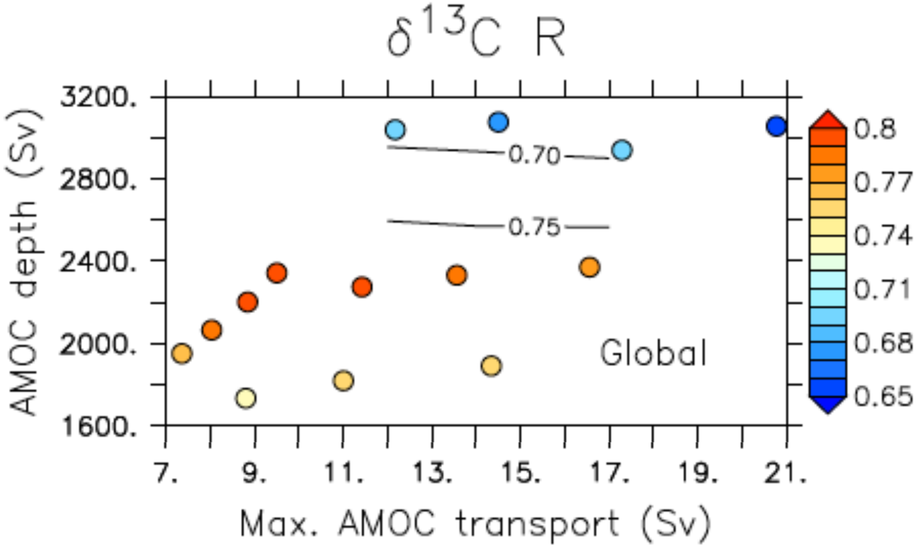


$\delta^{13}C$

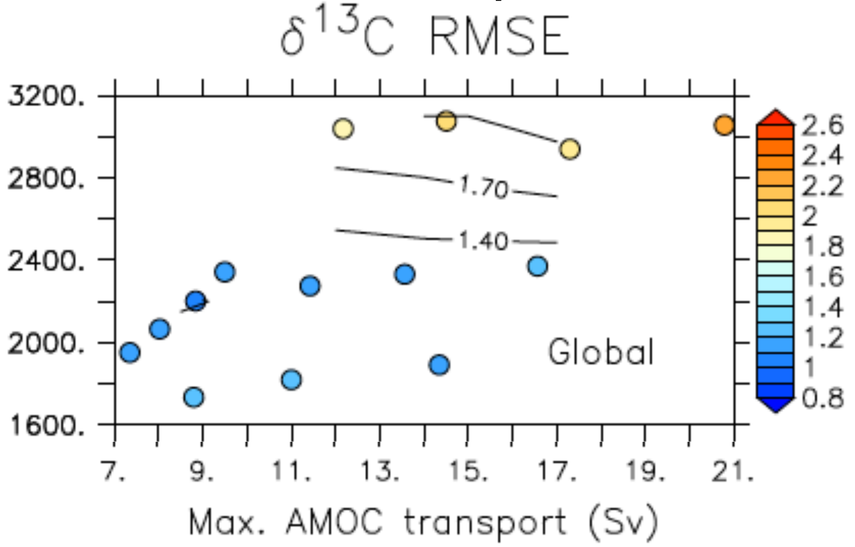
Correlation coefficient depends mostly on AMOC depth.

RMS error depends mostly on AMOC depth.

Correlation Coefficient



Root-Mean-Squared Error



RMS error is normalized by estimated combined model & data errors (0.28 ‰ based on modern data).

An RMSE <~1 indicates consistency between model and data.

$\delta^{13}C$

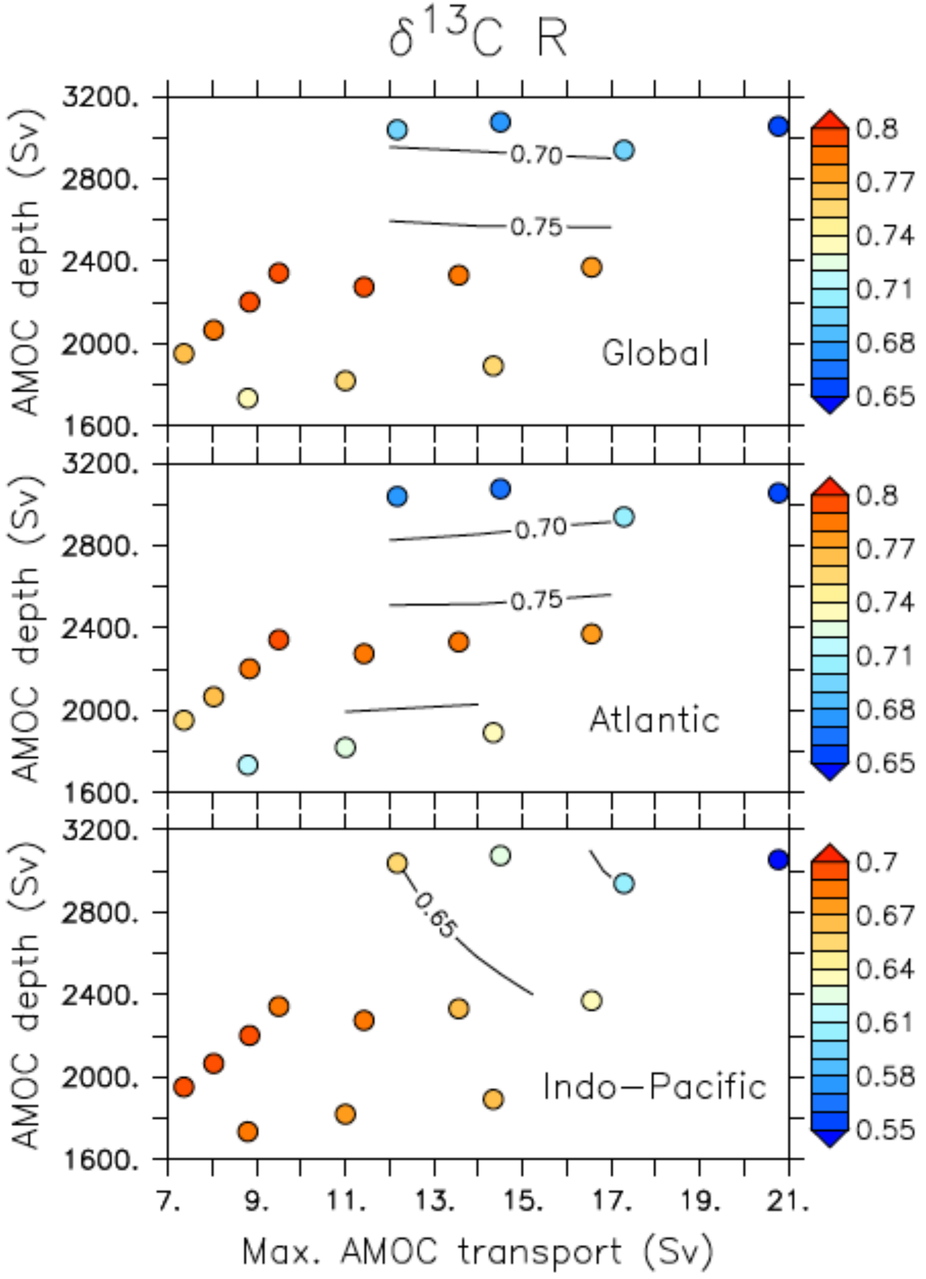
Correlation coefficient depends mostly on AMOC depth.

RMS error depends mostly on AMOC depth.

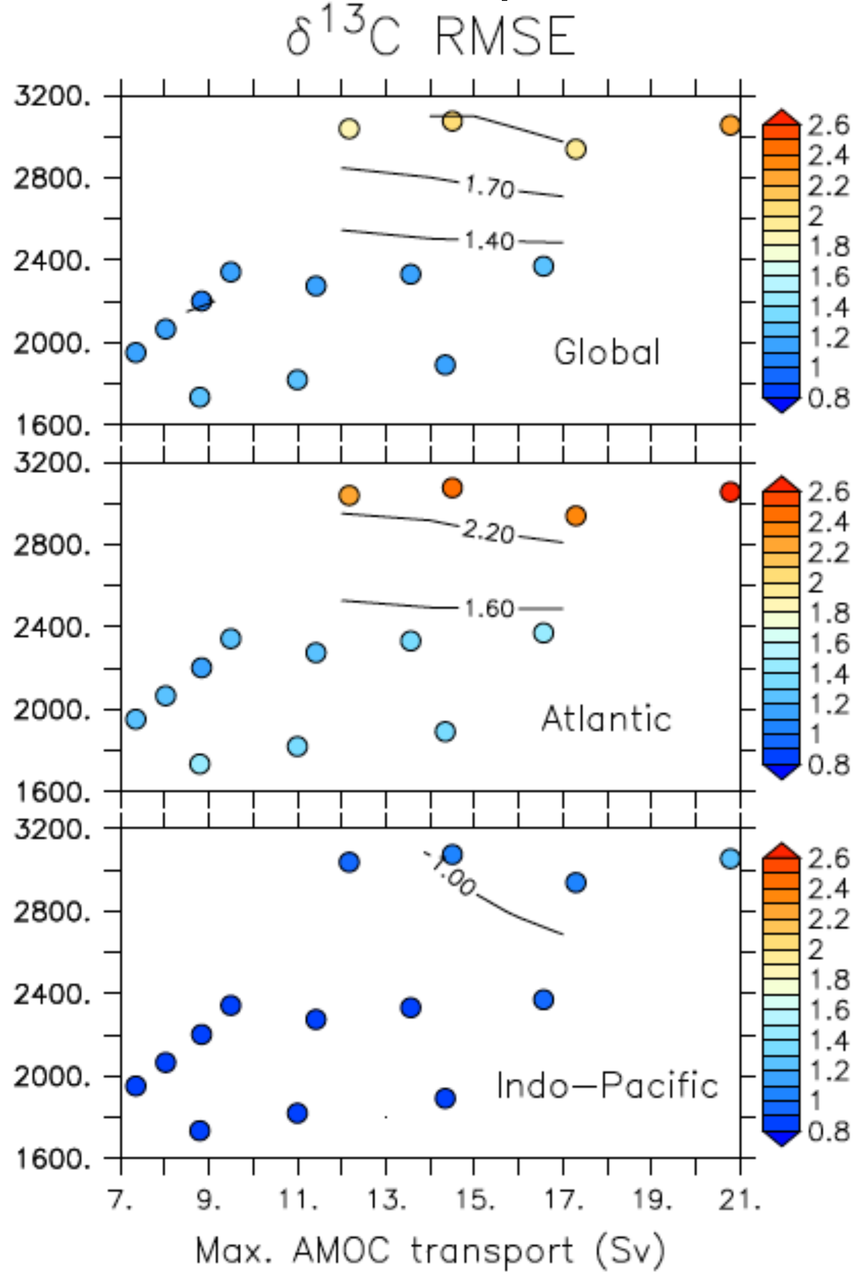
Global fit dominated by Atlantic.

Indian-Pacific data seem to slightly favor week AMOC.

Correlation Coefficient



Root-Mean-Squared Error

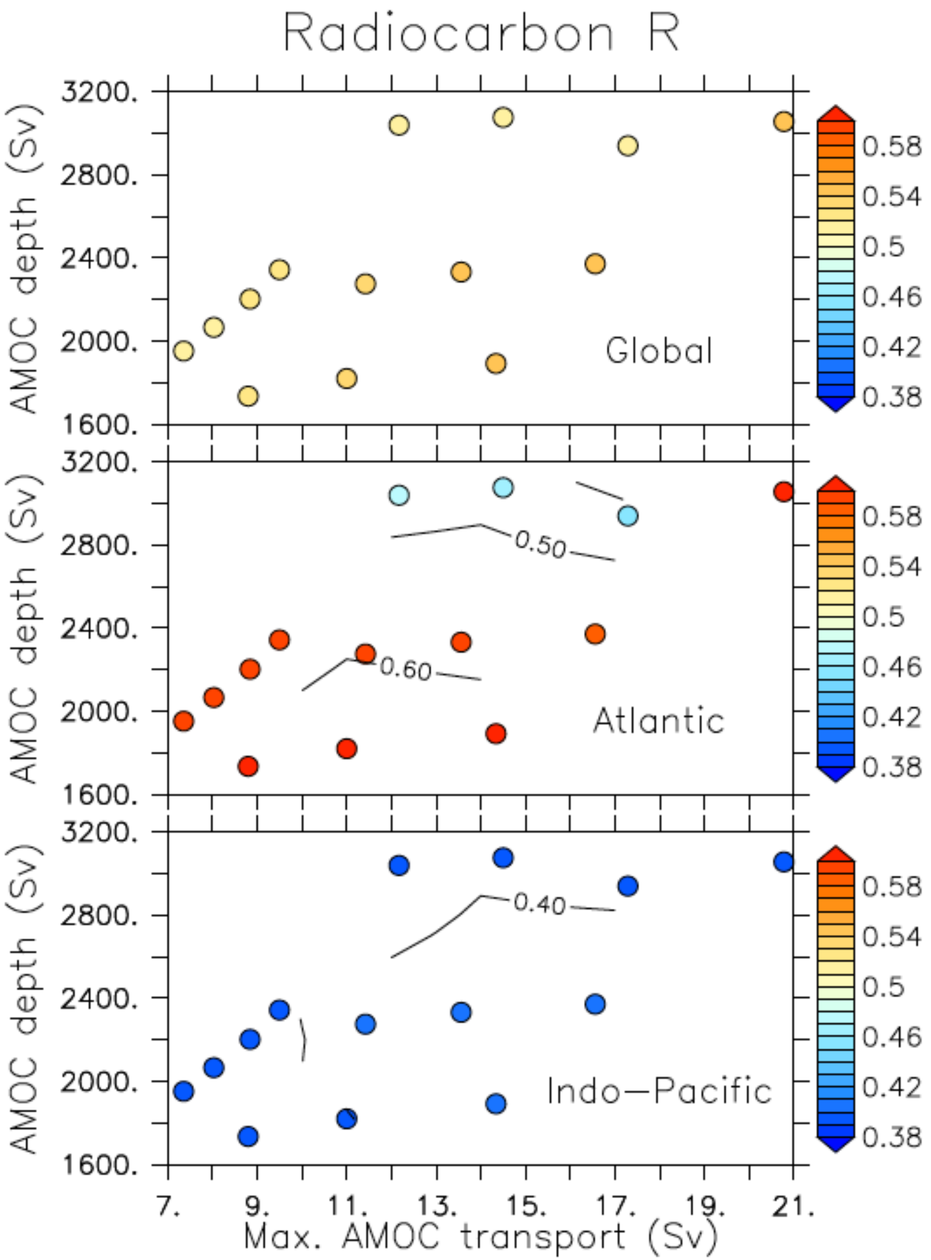


Radiocarbon

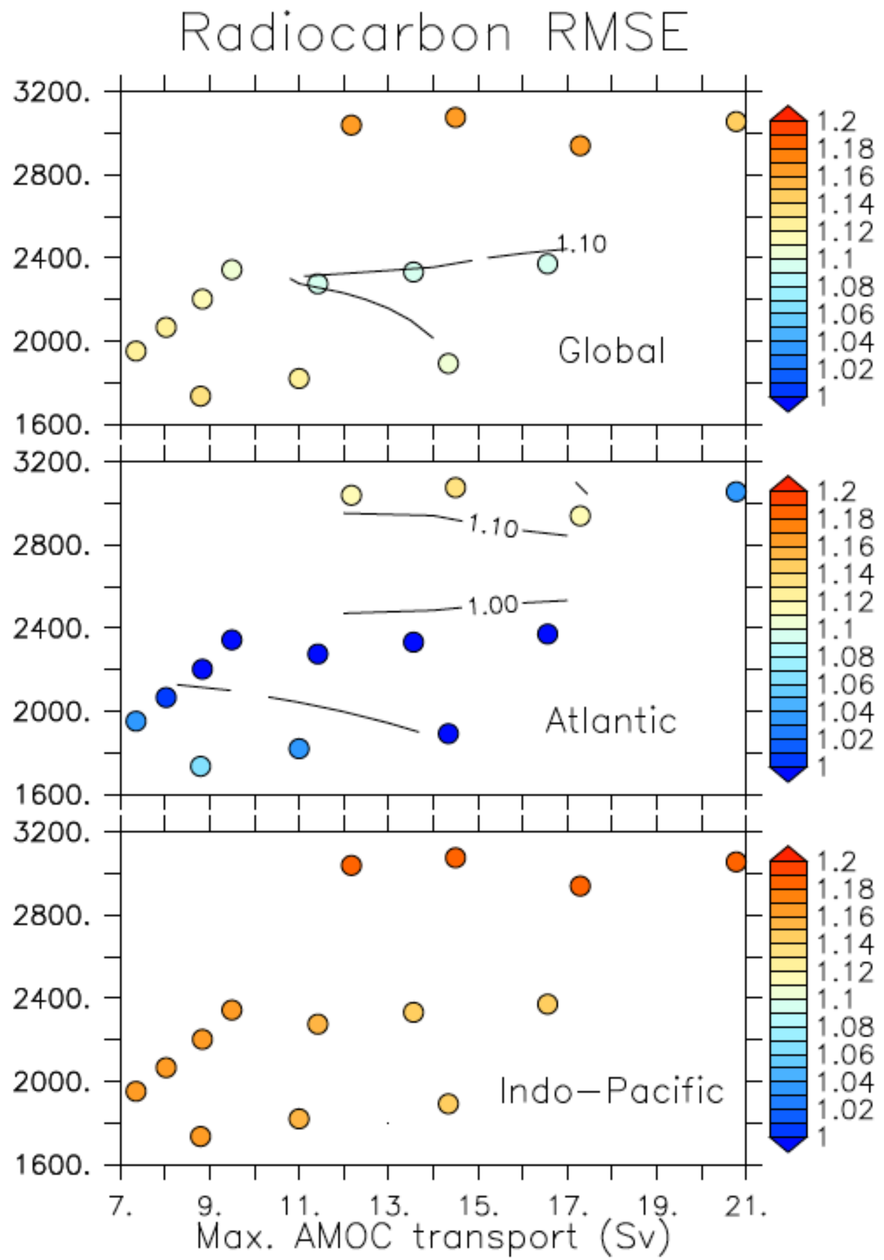
Correlation coefficient relatively insensitive.

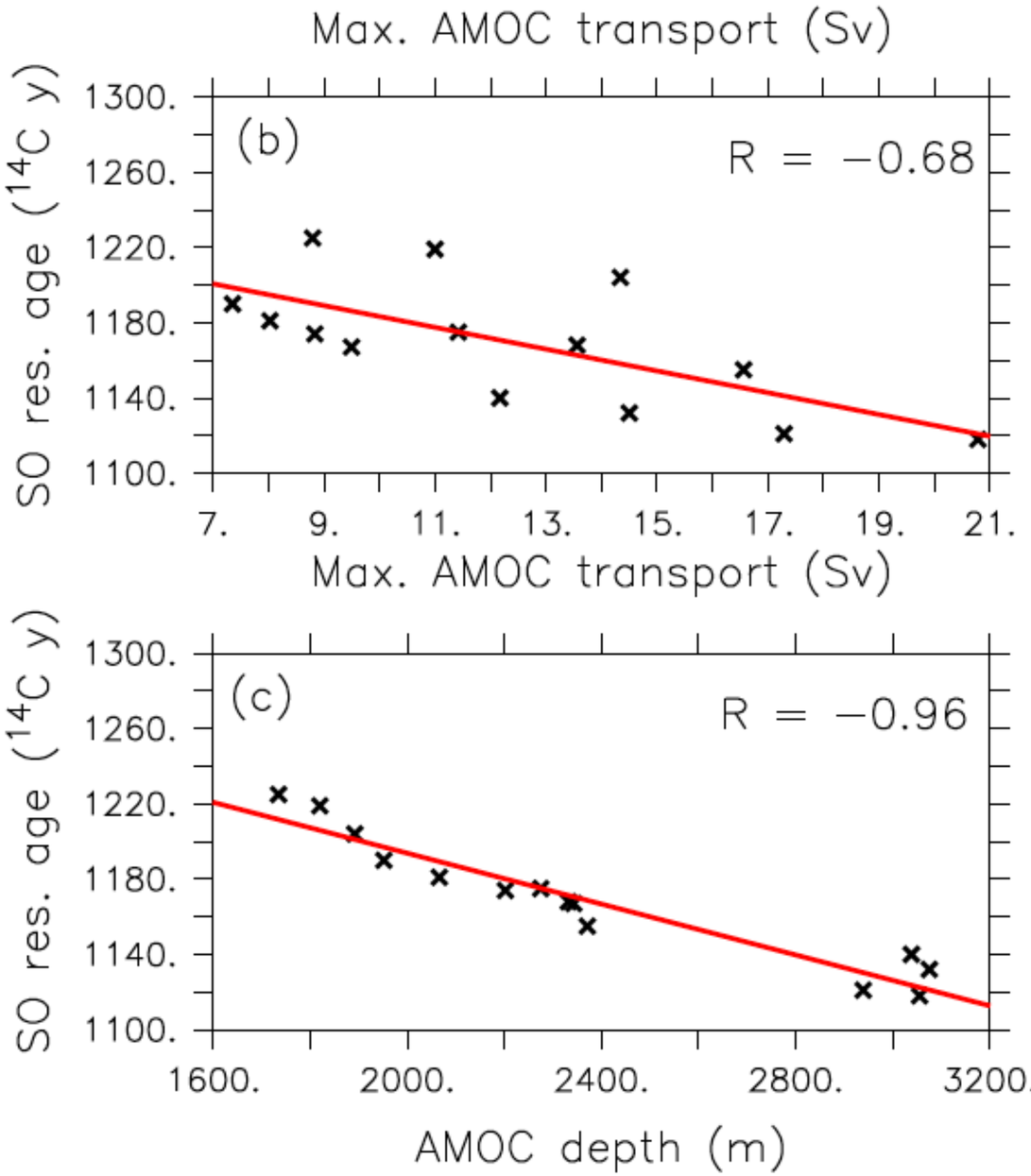
RMS error mostly depends on AMOC depth.

Correlation Coefficient

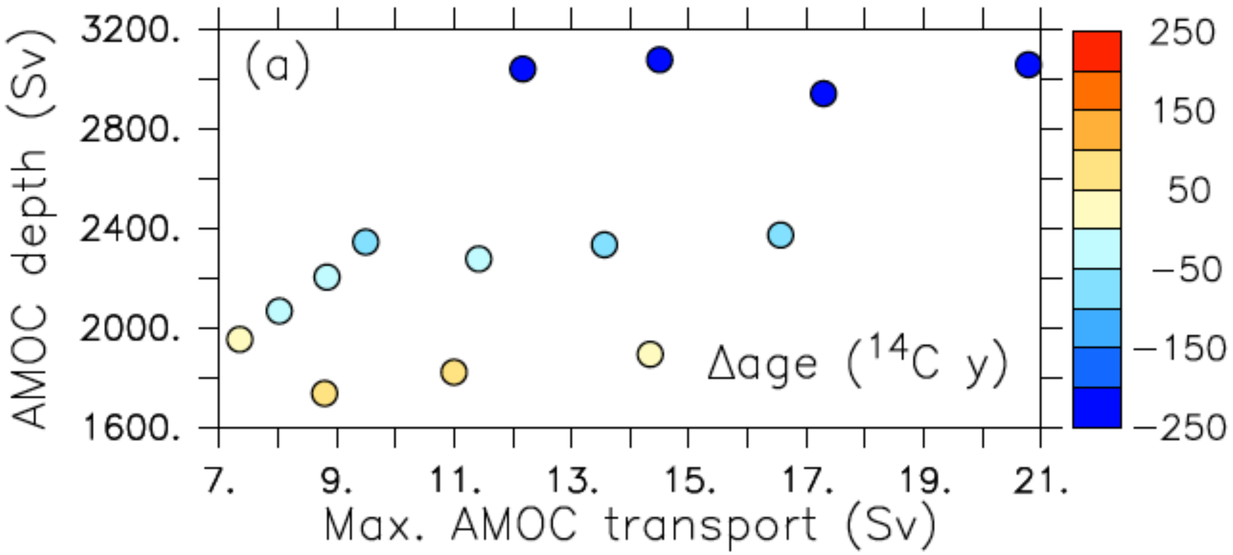


Root-Mean-Squared Error





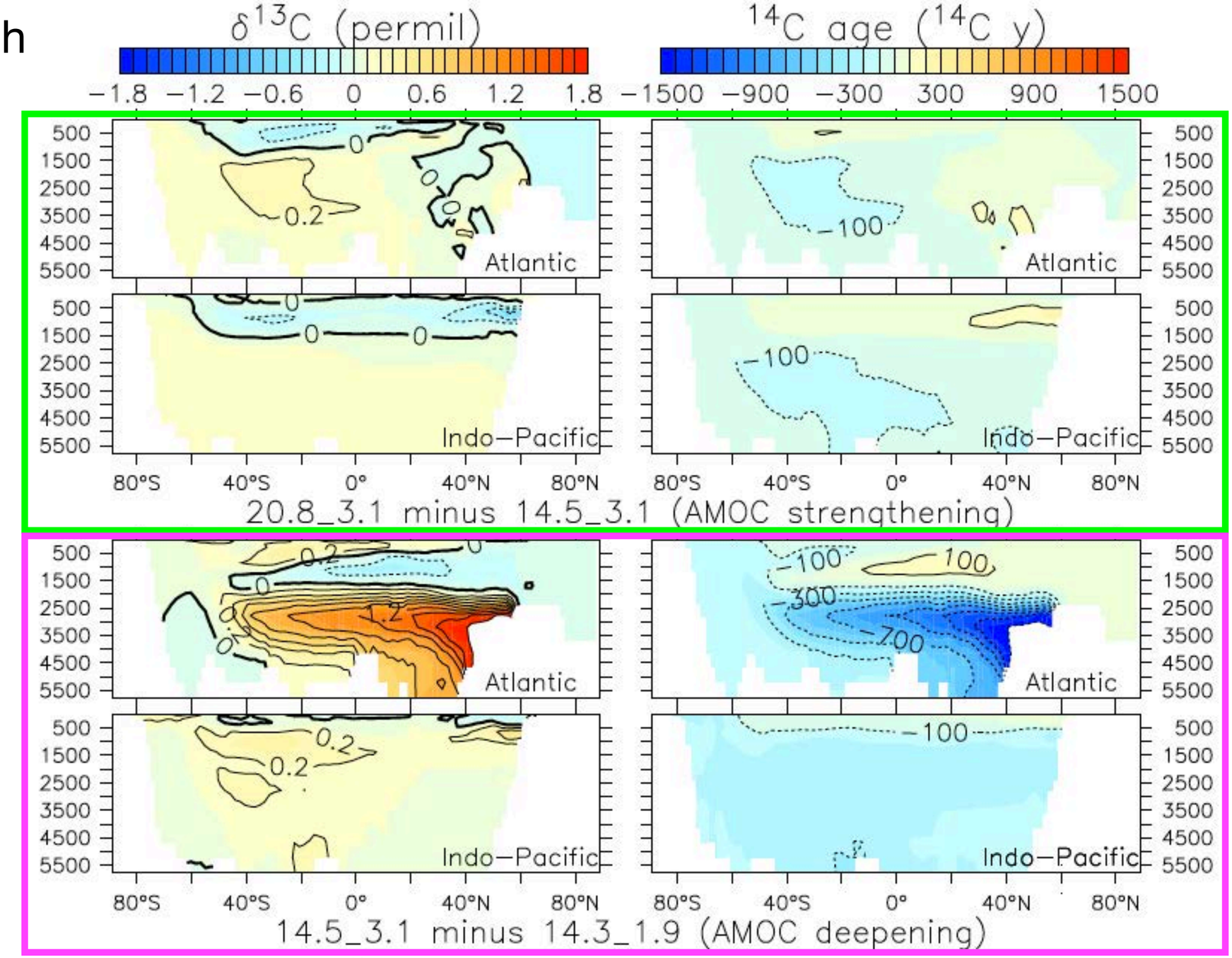
Whole Ocean ^{14}C Age
Model - Data



AMOC depth strongly affects Southern Ocean reservoir age!

Effects of AMOC Strength vs Depth on Isotope Distributions

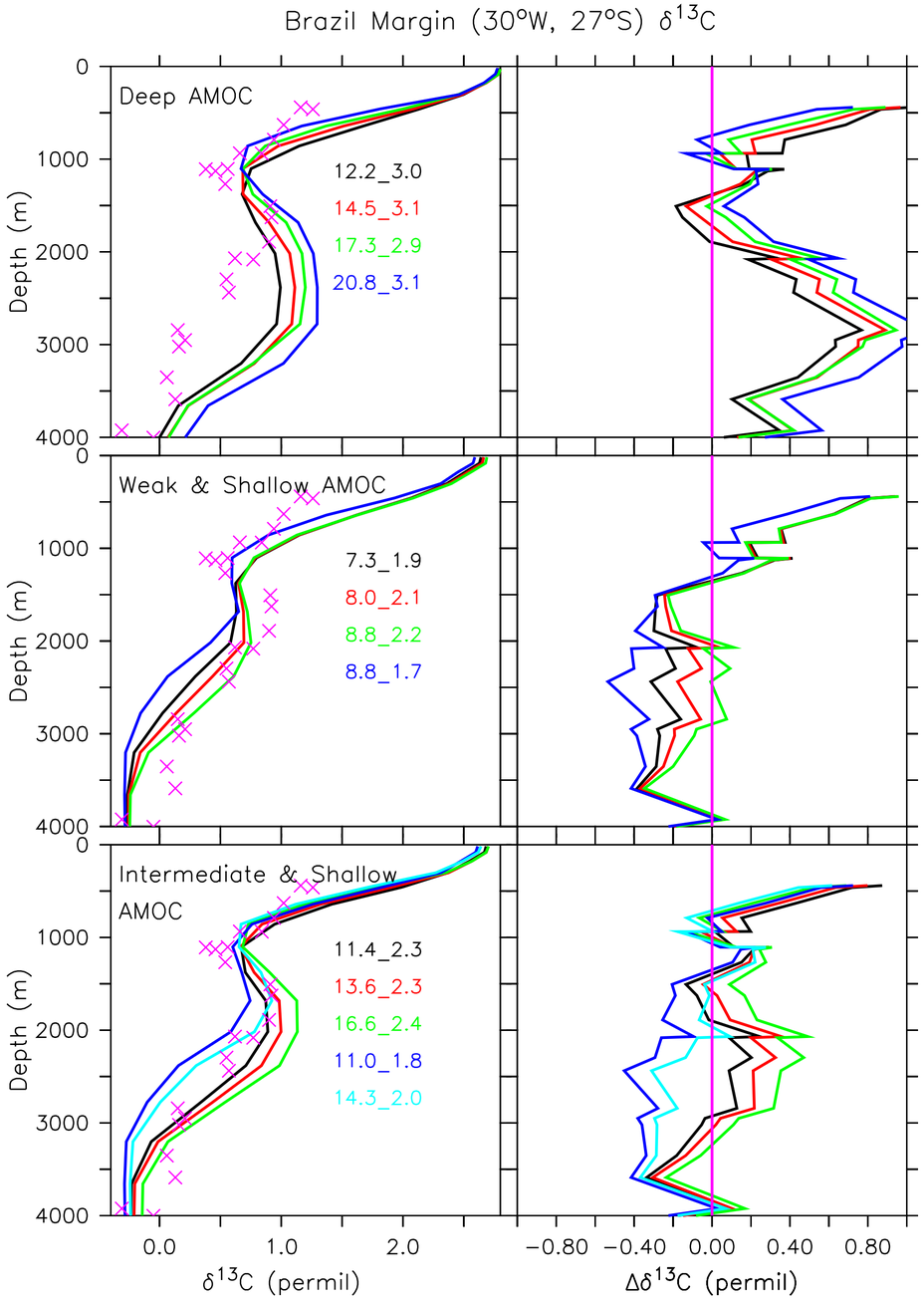
- AMOC strengthening has much less of an effect on both isotopes than AMOC deepening.
- Generally, $\delta^{13}C$ and radiocarbon response is anti-correlated. (Not a lot of independent information.)
- Deepening affects northern North Atlantic deep waters most.
- Strengthening doesn't affect North Atlantic, but maybe better constrained by South Atlantic data.
- Deepening decreases Southern Ocean surface reservoir ages, which propagate into the interior decreasing the whole ocean radiocarbon age

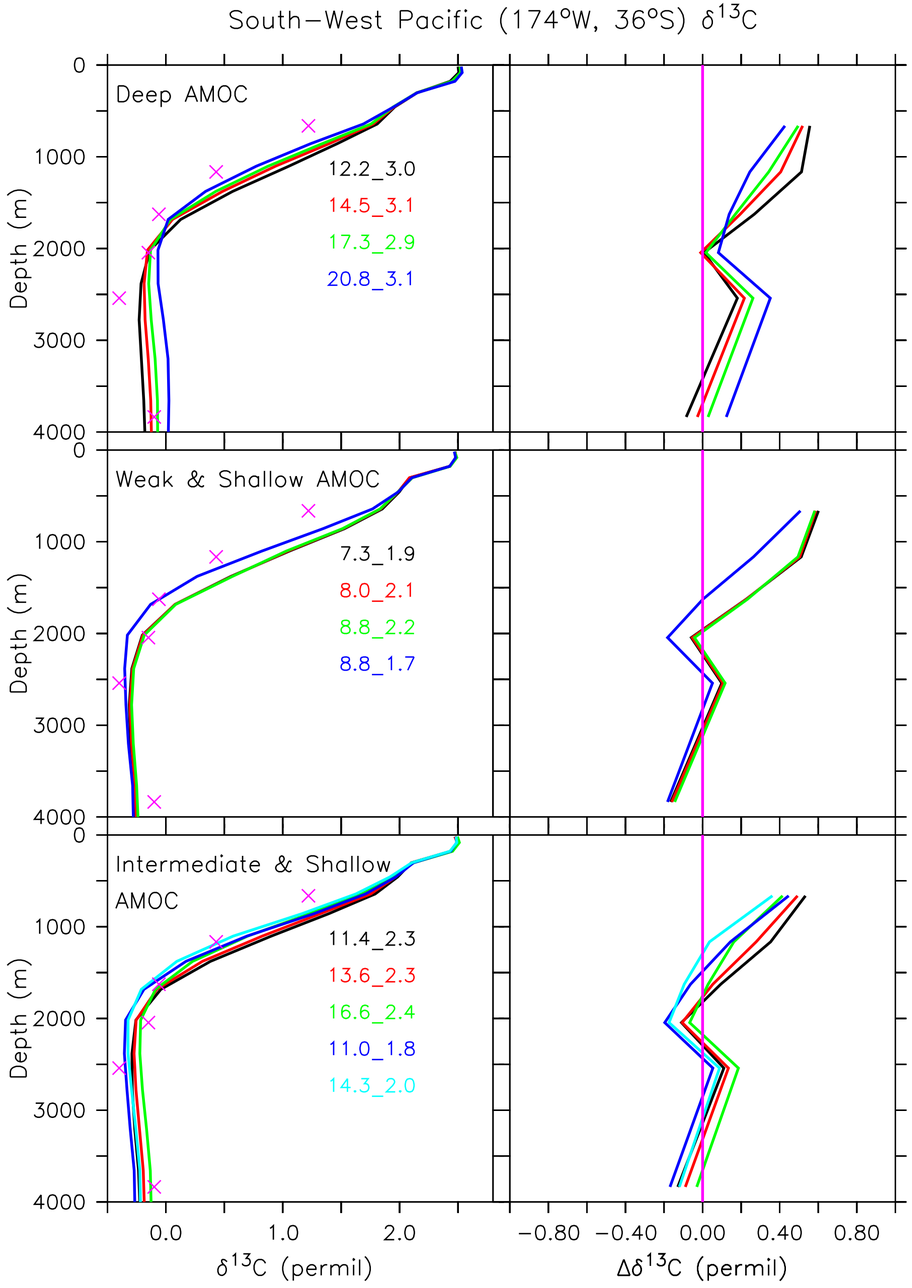


Conclusions

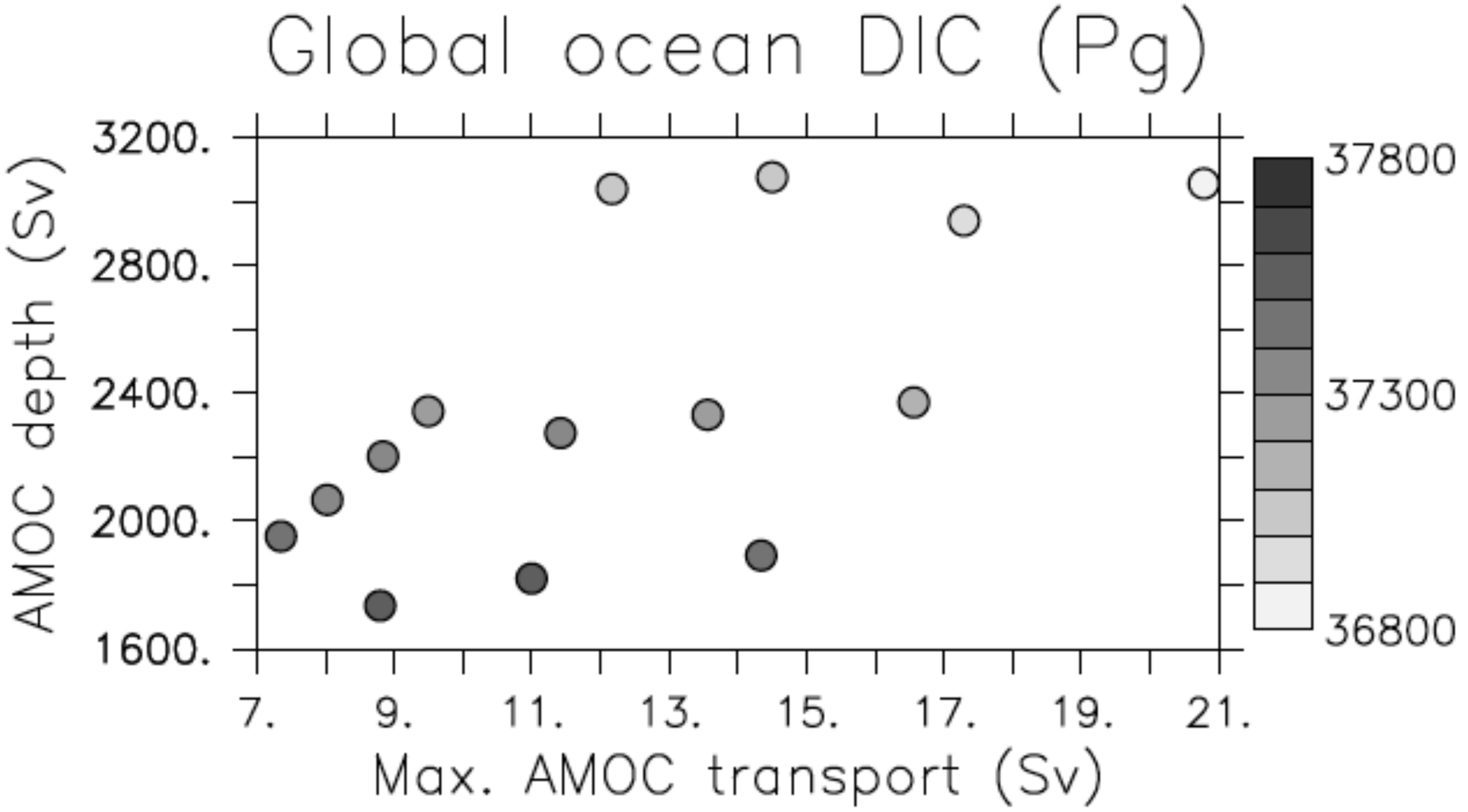
- Carbon isotopes provide strong constraints on AMOC depth, but not on AMOC strength
- LGM AMOC depth was 2,000-2,500 m (500-1,000 m shallower than today)
- LGM AMOC strengths between 8 and 17 Sv are all similarly consistent with the data
- These results are consistent with Gu et al. (2020) CESM study
- Future work: include additional paleo tracers such as Neodymium isotopes and Protactinium Thorium ratios, which may be more sensitive to AMOC strength changes

Thank You


Brazil Margin (30°W, 27°S) δ13C
Deep AMOC
12.2_3.0
14.5_3.1
17.3_2.9
20.8_3.1
Weak & Shallow AMOC
7.3_1.9
8.0_2.1
8.8_2.2
8.8_1.7
Intermediate & Shallow AMOC
11.4_2.3
13.6_2.3
16.6_2.4
11.0_1.8
14.3_2.0
Depth (m)
δ13C (permil)
Δδ13C (permil)


South−West Pacific (174°W, 36°S) δ13C
Deep AMOC
12.2_3.0
14.5_3.1
17.3_2.9
20.8_3.1
Weak & Shallow AMOC
7.3_1.9
8.0_2.1
8.8_2.2
8.8_1.7
Intermediate & Shallow AMOC
11.4_2.3
13.6_2.3
16.6_2.4
11.0_1.8
14.3_2.0
Depth (m)
δ13C (permil)
Δδ13C (permil)

Carbon Storage



More sensitive to AMOC depth than AMOC strength.