Topographic Effects on AMOC Variability and its Pathways

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Interannual variability at RAPID array at 26.5°N:
Three-layer wind-driven model:

Based on 2-layer model of Yang (2015);
Fully nonlinear and primitive equation model
Model domain: 20°S-80°N and 100°W-20°E;
Resolution: 0.25°
Minimum water depth $h_{\text{min}}=5$ m;
ERA5 wind stress forcing (1979-2020);
Realistic bathymetry (GEBCO);
\[ \beta V = \frac{1}{\rho_0} \text{curl} \vec{\tau} \quad \text{(where } \beta = \frac{df}{dy}) \]

**Model with realistic bathymetry**

\[ \beta T V = \frac{1}{\rho_0} \text{curl} \vec{\tau} \quad \text{(where } \beta_T = \left| H \nabla \left( \frac{f}{H} \right) \right|) \]

\( \beta \) is typically much smaller than \( \beta_T \), especially in high latitudes.
Detrended and de-seasonalized AMOC transport anomalies at RAPID array.

Thin lines: monthly anomalies

Thick lines: 3-month running mean
(a) Detrended and deseasonalized AMOC transport anomaly (Sv)

Transport (Sv)

Thin lines: monthly anomalies
Thick lines: 3-month running mean

(b) Middle-layer transport anomaly (Sv)

Transport (Sv)

(c) Lower-layer transport anomaly (Sv)

Transport (Sv)


RAPID Array at 26.5°N

Model Control Run
Model using a constant depth $H=5000m$
Additional experiments:
Comparison with ECCO4v4

Detrended and non-seasonal AMOC transport anomaly

- ECCO4
- 3-layer model

(a) RAPID (26.5N)
(b) 35N
(c) 45N
(d) OSNAP-East
Figure 7. The schematics of interactions between subtropical and subpolar gyres. (top) There is southward transport in the upper layer when either the Ekman pumping in the subtropics or Ekman suction in the subpolar basin intensifies. This would lead to a weakening of the mean AMOC. (bottom) Likewise, the AMOC would increase when either the Ekman pumping in the subtropics or suction in the subpolar basin weakens.
A potential topographic effect on barotropic component of AMOC:

\[
\begin{array}{c|c|c}
V_{wbc1} & V_1 & H_1=1000m \\
\hline
-Q_0 & Q_0 & \\\n\hline
V_{wbc2} & V_2 & H_2=3000m \\
\hline
-3Q_0 & 3Q_0 & \end{array}
\]

Net transport in layer 1: 0

Net transport in layer 2: 0

\[
\begin{array}{c|c|c}
V_{wbc1} & V_1 & H_1=1000m \\
\hline
-2Q_0 & Q_0 & \\\n\hline
V_{wbc2} & V_2 & H_2=3000m \\
\hline
-2Q_0 & 3Q_0 & \end{array}
\]

Net transport in layer 1: -Q_0

Net transport in layer 2: Q_0
Topographic effects AMOC variability pathways:
Topographic effects on mean transport pathways based on ECCO4 release 4:

Zhai et al. (2021, GRL)
Topographic effects on coastal sea-level variability:

(a) Sea-level anomaly south of Cape Hatteras (tide gauge stations)

(b) Sea-level anomaly between Cape Hatteras and New England

(c) Sea-level anomaly along New England
(a) Detrended monthly sea-level anomaly south of Cape Hatteras (504 months, Jan 1979 - Dec 2020)

Correlation Coefficient = 0.684

(b) Detrended monthly sea-level anomaly between Cape Hatteras and New England

Correlation Coefficient = 0.779

(c) Detrended sea-level anomaly along New England

Correlation Coefficient = 0.764

Model Control Run
(a) Detrended sea-level anomaly south of Cape Hatteras (12-month running mean)

Correlation Coefficient = 0.668

(b) Detrended sea-level anomaly between Cape Hatteras and New England

Correlation Coefficient = 0.688

(c) Detrended sea-level anomaly along New England

Correlation Coefficient = 0.762
Model using a constant depth H=5000m
Summary:

(1) Topography affects both the shapes and magnitudes of AMOC’s responses to wind-stress forcings;

(2) The amplified variability of the lower NADW layer transport at RAPID array is mainly due to topographic effects;

(3) Latitudinal communication of AMOC variability is mainly along geostrophic contours when topographic effects are included, which is different from the boundary wave mechanisms in classic models without topography;

(3) Topography strongly affects how AMOC variability influences the coastal sea level changes;