Comparing Simulated and Observed AMOC Transport Estimates

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This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

Background

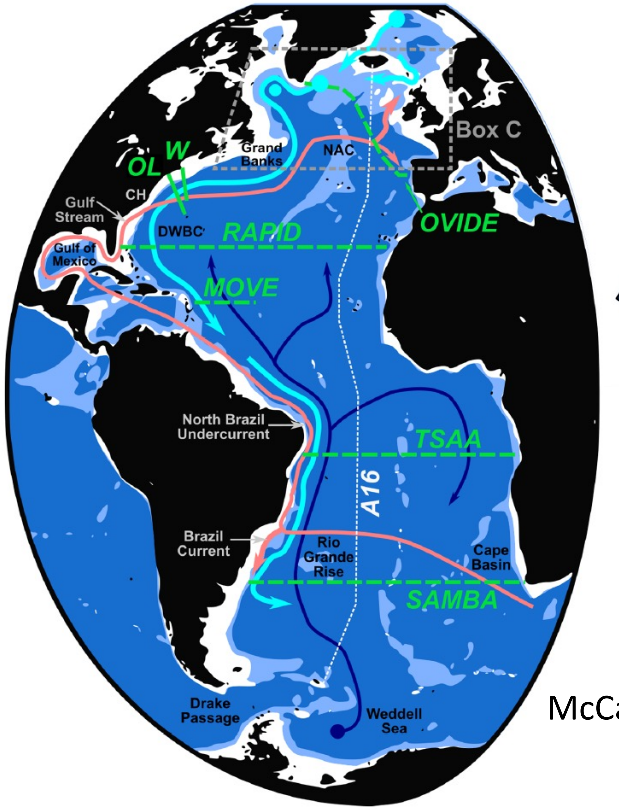
- Comparing model simulations of AMOC characteristics with those from available observations is essential for assessing the quality of our models and advancing their fidelity.
- This has been widely acknowledged within the AMOC community and the concept of a common framework into which both observations and models can be mapped and subsequently analyzed has emerged under the term *AMOC Metrics*.

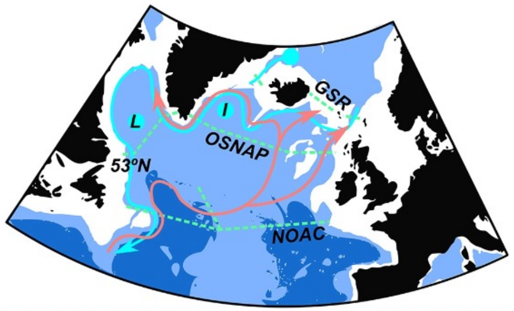
A python-based Meridional ovErTurning diagnostIC (METRIC) package is being developed. The package enables consistent calculations of AMOC estimates at several observational sites from ocean general circulation models and is freely available to the community at https://github.com/NCAR/metric.

Background

Reproducing transports from:

- RAPID Array at 26.5°N;
- MOVE Array at 16°N;
- SAMBA Array at 34.5°S;
- OSNAP Array in the Subpolar North Atlantic





McCarthy et al. (2020, *Rev. Geophys.*)

Revisiting underlying assumptions used to calculate their respective transports using model simulations

The Same / as-similar-as-possible observational methods as well as several alternative approaches are considered with particular attention to reference level details

Simulation

High-resolution Forced Ocean – Sea-Ice (FOSI) hindcast simulation for the 1958-2018 period where the horizontal resolution is 0.1° in the ocean and sea-ice models. The atmospheric datasets are based on the JRA-55 Japanese Reanalysis Product.

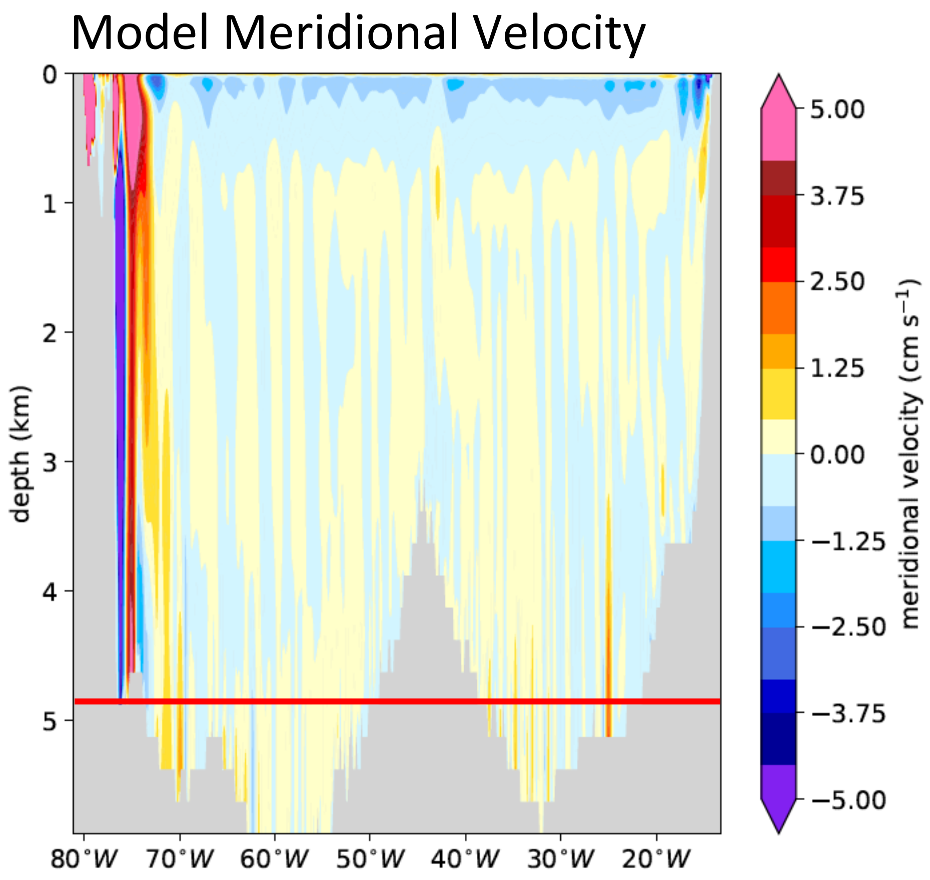
Danabasoglu, G., F. S. Castruccio, R. J. Small, R. Tomas, E. Frajka-Williams, and M. Lankhorst, 2021: Revisiting AMOC transport estimates from observations and models. *Geophys. Res. Lett.*, **48**, e2021GL093045, doi: 10.1029/2021GL093045.

RAPID Array

Transport is calculated as the sum of four components:

- Western Boundary Wedge,
- Florida Current,
- Wind-driven, near-surface Ekman, and
- Interior, mid-ocean geostrophic transport using a level of no motion at 4820 m.

As a final step, a barotropic compensation is applied to the geostrophic transport to insure zero net transport across the section (=> time varying deep reference velocity).

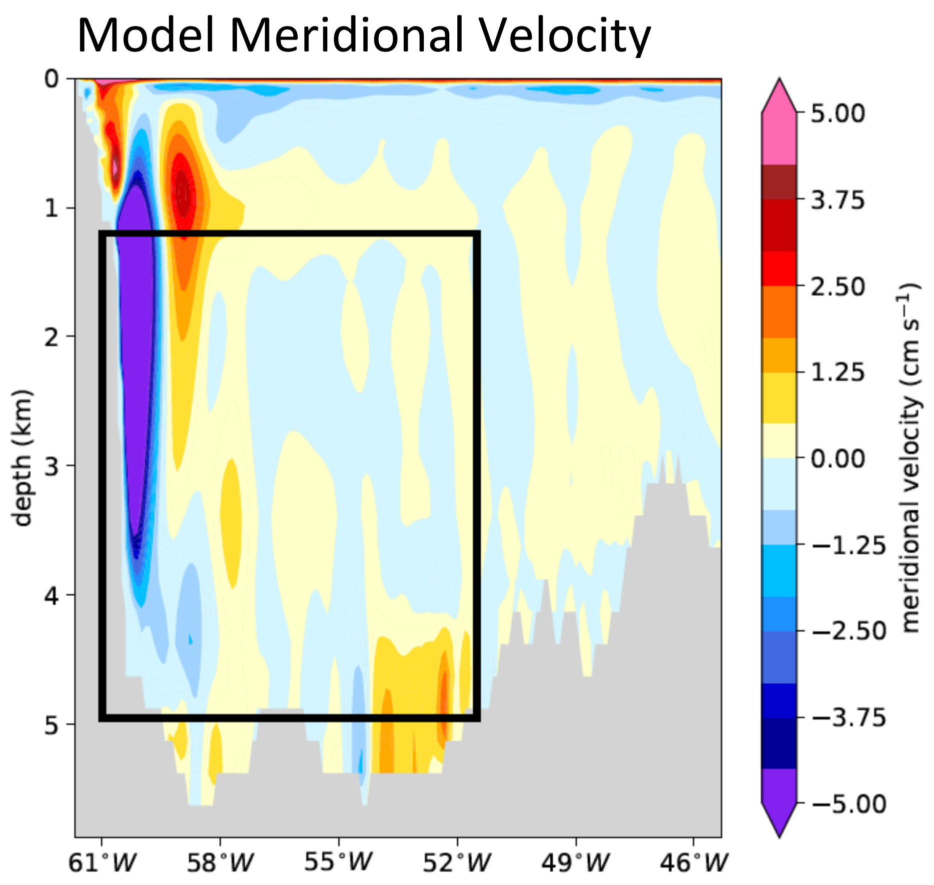


MOVE Array

Measures the southward volume transport associated with the deep North Atlantic Deep Water (NADW) below 1200-m depth between Guadeloupe to the west and the Mid-Atlantic Ridge to the east.

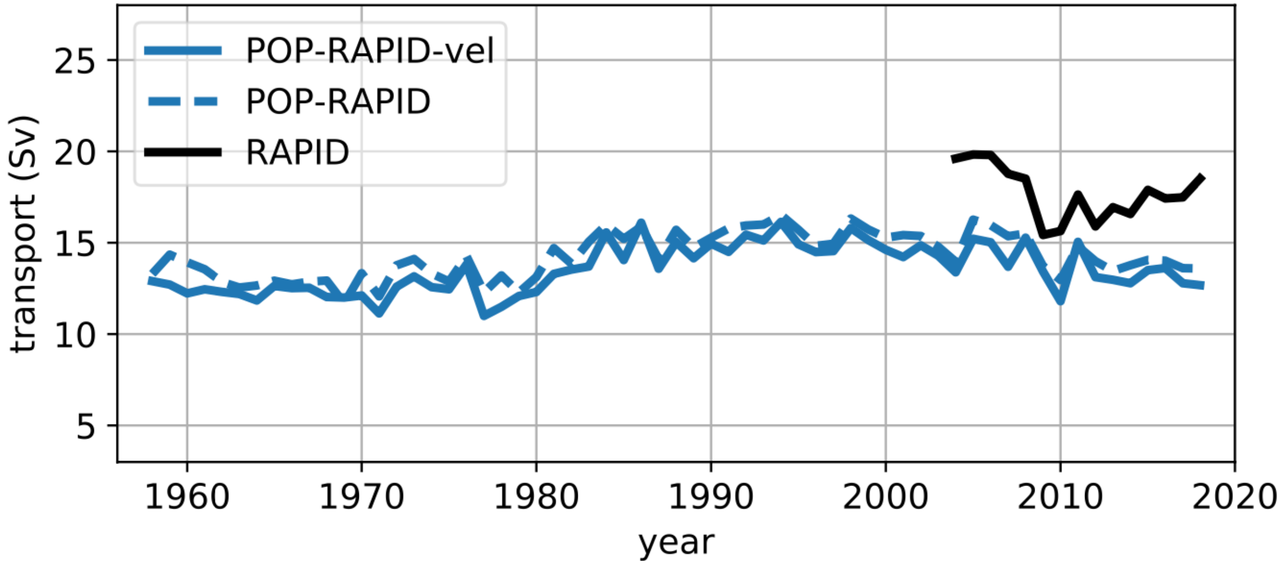
Transport is calculated as the sum of two components:

- Boundary component and
- Internal geostrophic component using a level of no motion at 4950 m.



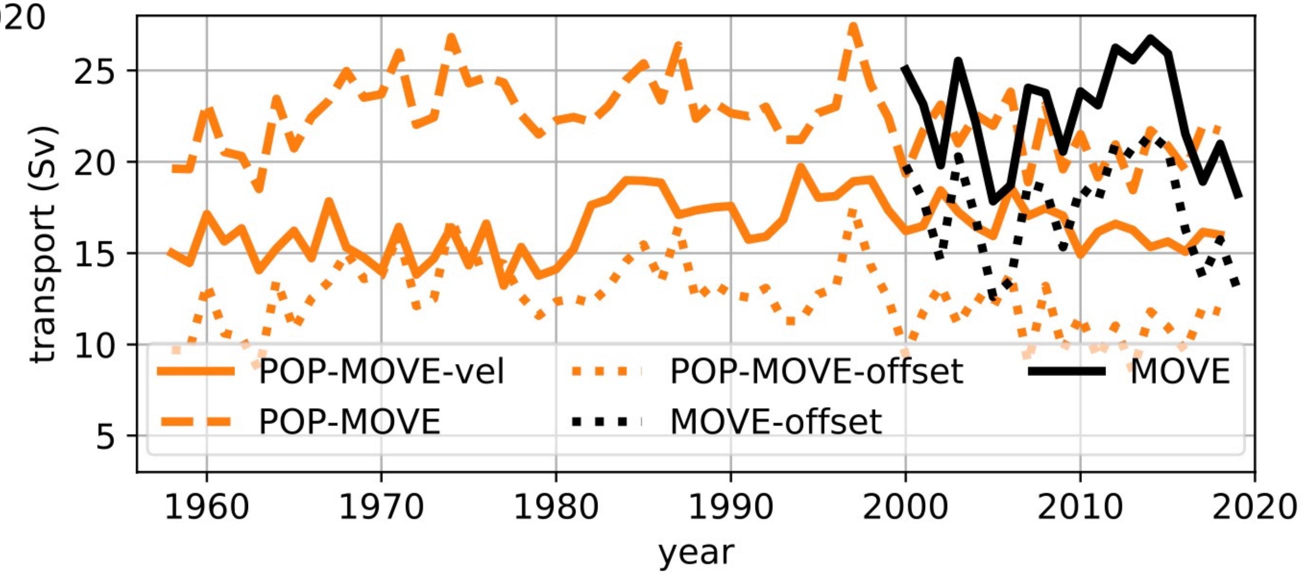
RAPID and MOVE Transport Comparisons

RAPID



Model estimates agree with each other, all showing lower transports than in observations.

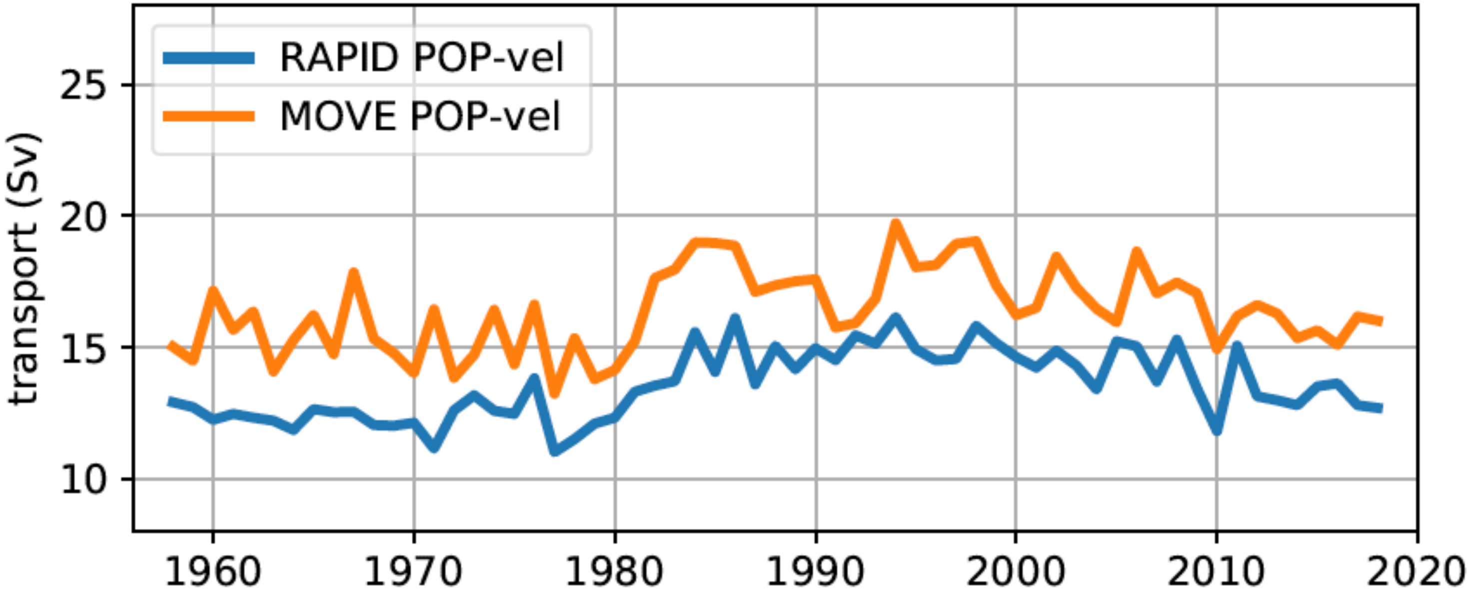
MOVE



There are large differences among the model estimates which also differ from the observational estimates.

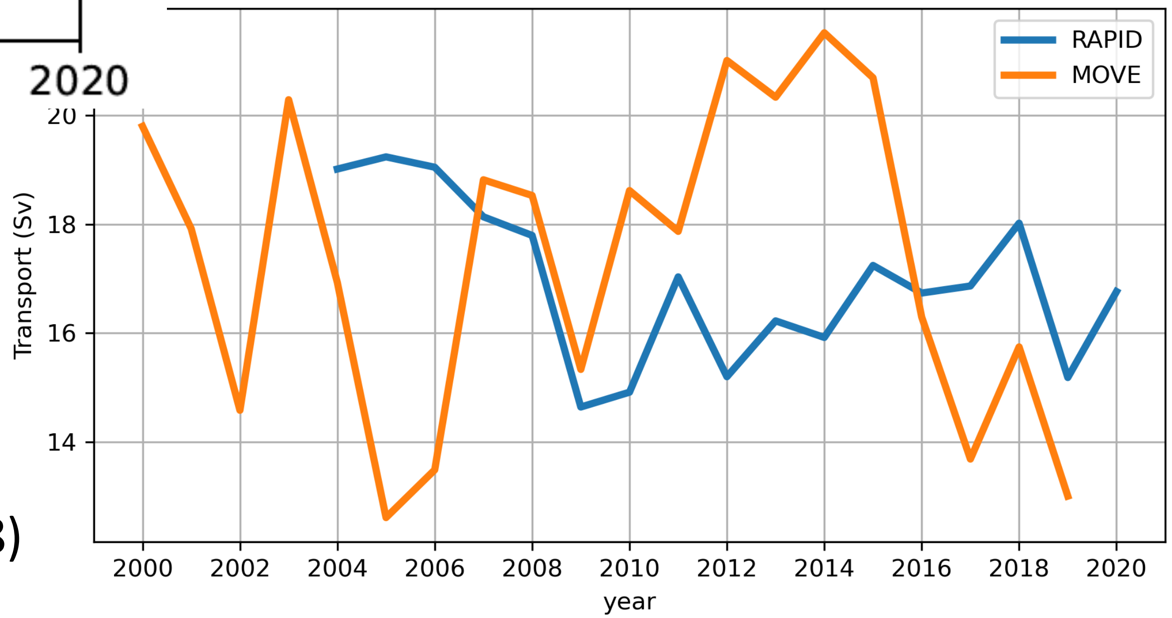
RAPID and MOVE Transport Comparisons

Model Truth



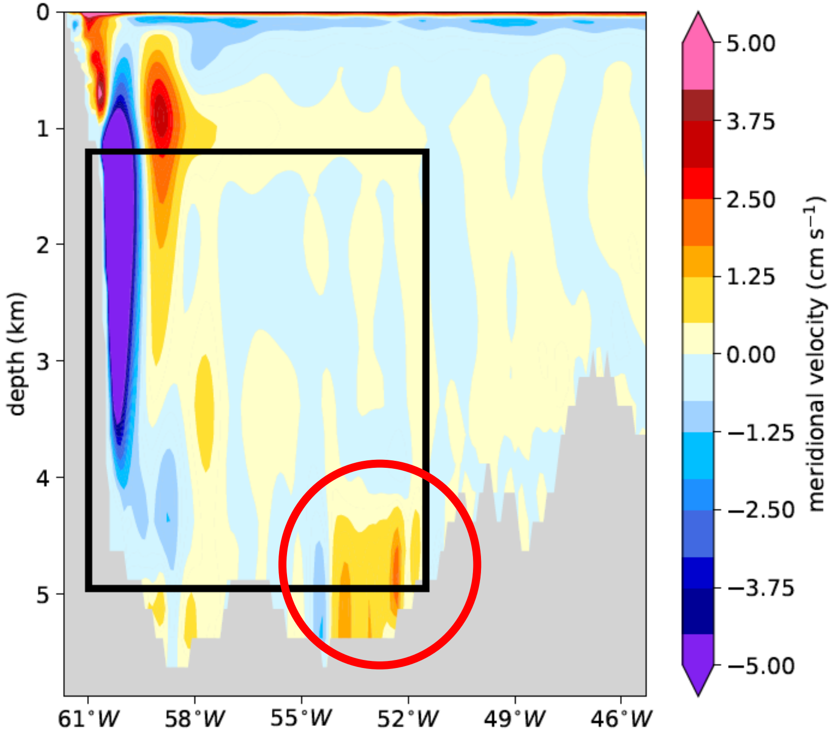
Correlation: +0.72 (1958-2018)
+0.56 (2004-2018)

Observations

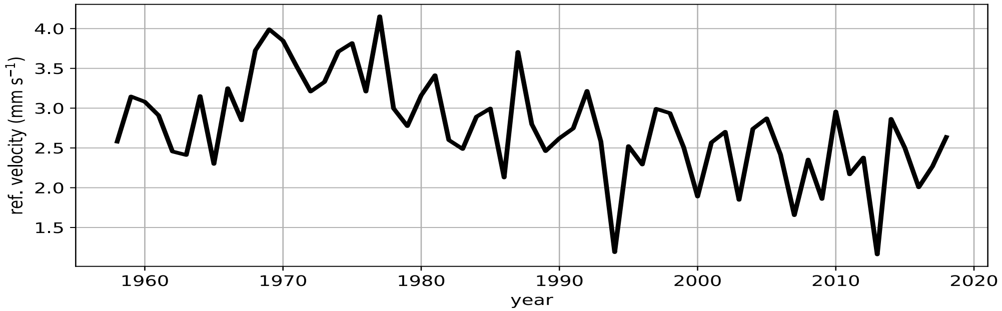


Correlation: -0.47 (2004-2018)

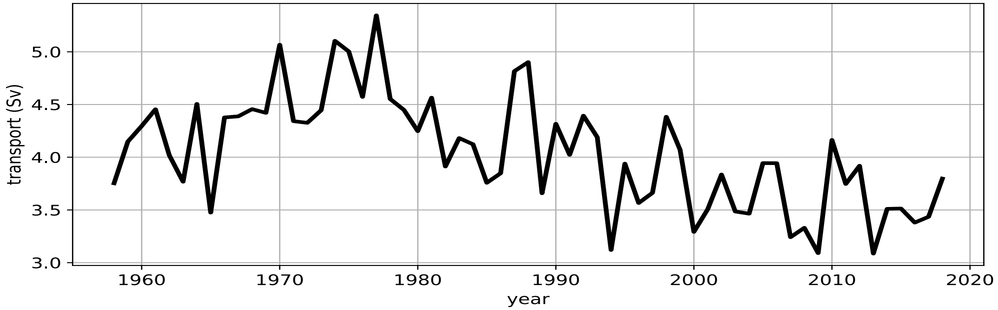
Model Level of No Motion at MOVE



- Antarctic Bottom Water (AABW) is flowing north along the MAR
- 4950 m is not a level of no motion
- Slow variability of the reference velocity at 4950 m => problematic for long term trends

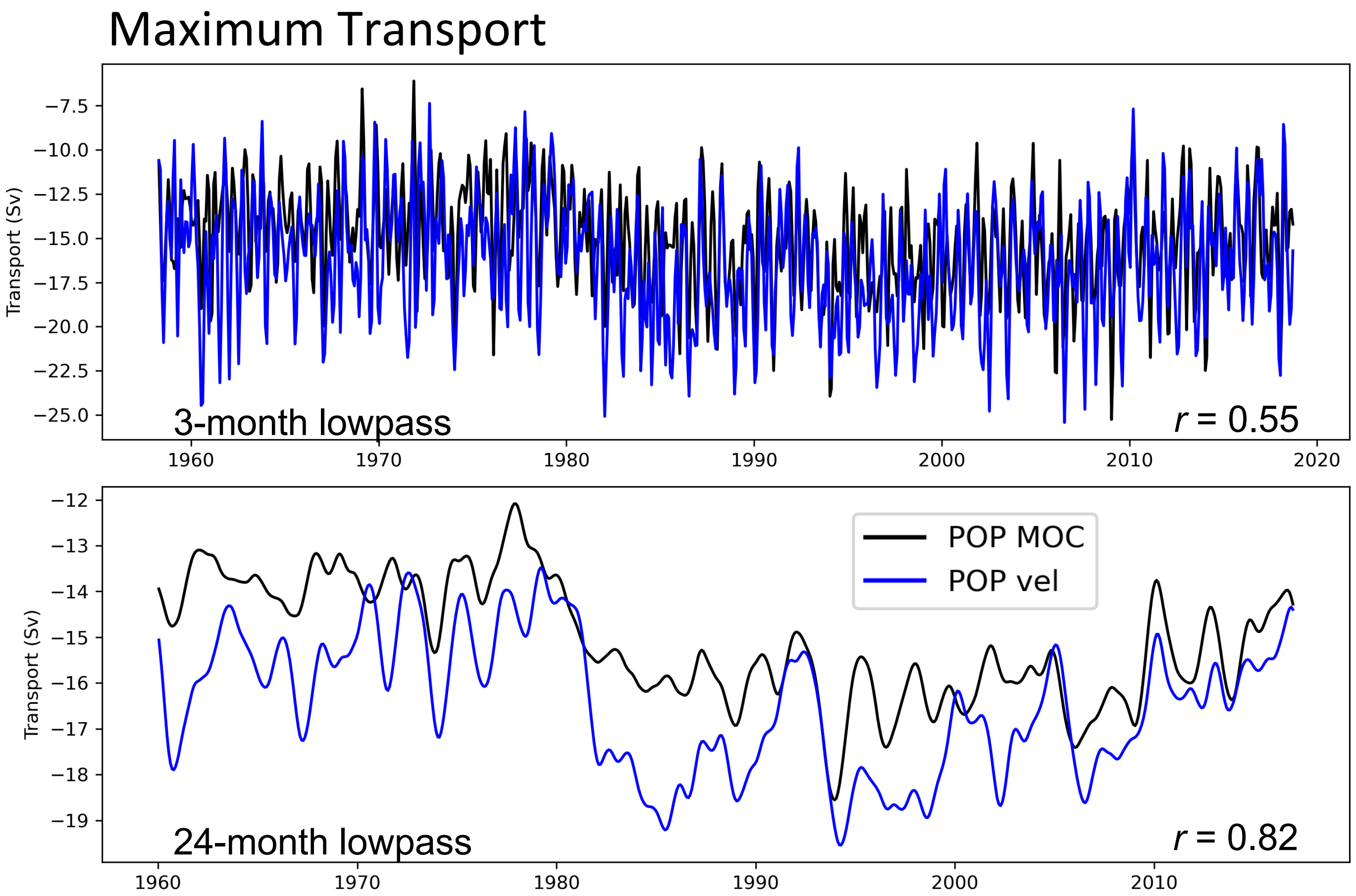


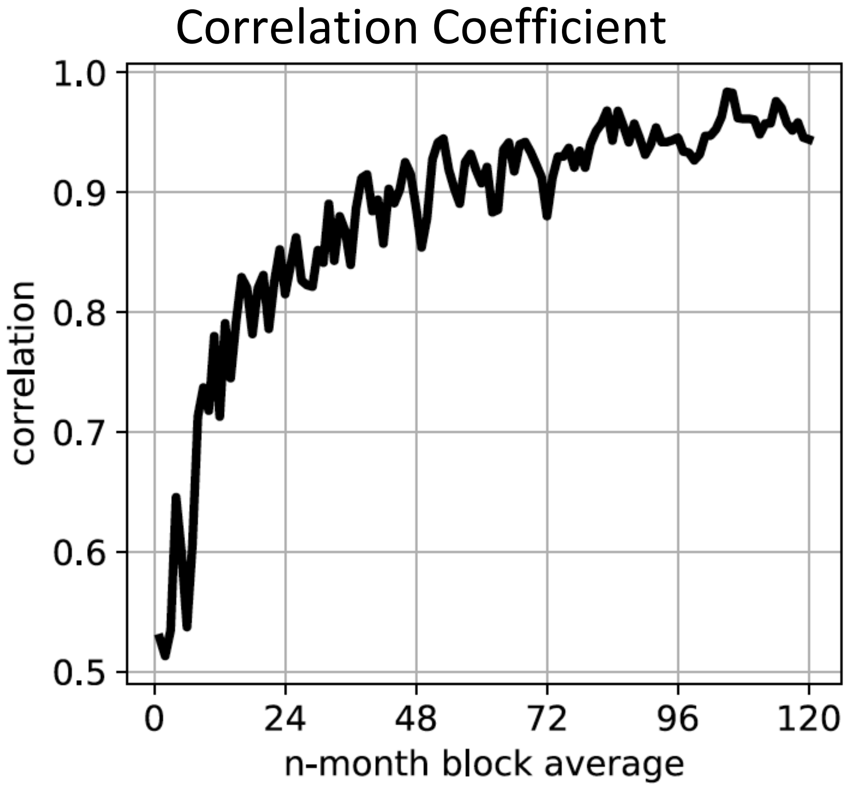
Model Reference Velocity @ 4950 m



AABW transport below 4500 m

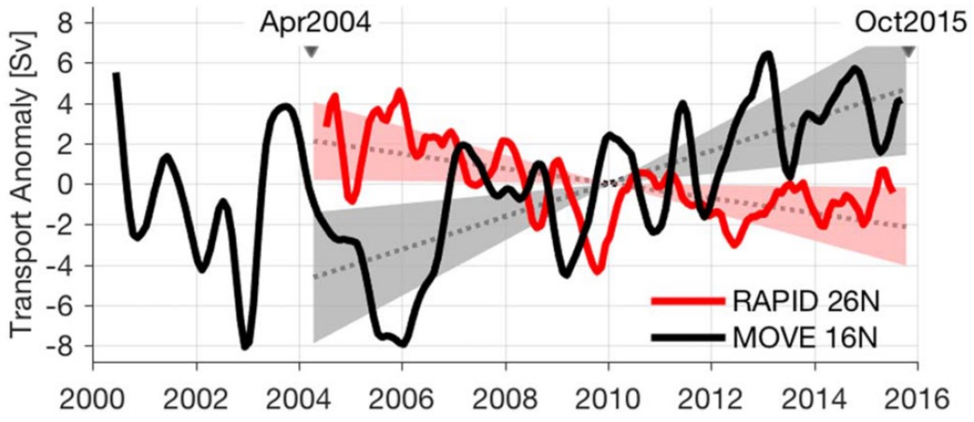
MOVE Array: Model DWBC vs AMOC transport





DWBC transport can only be used to estimate AMOC on longer time scales in the model.

Decadal Trends at MOVE and RAPID



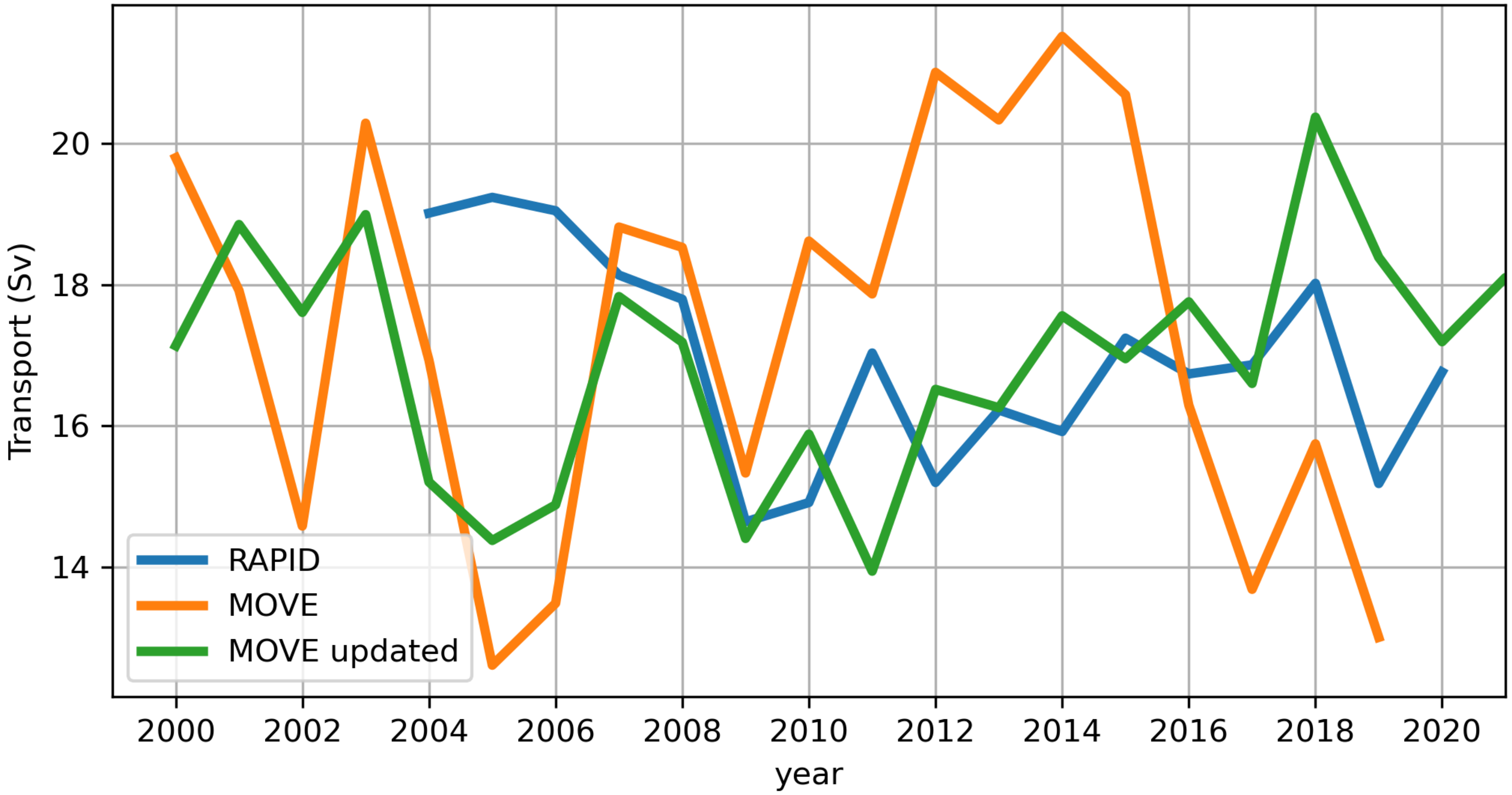
Sv decade^{-1}

Trend Period	POP-vel RAPID	POP-RAPID	POP-vel MOVE	POP-MOVE	POP-MOVE-ref	POP-MOVE-td
2004-2015	–1.4	–1.7	–1.4	–2.0	–1.2	–2.5

Frajka-Williams et al. (2018)
MOVE: +8.1 Sv decade^{-1}
RAPID: -3.7 Sv decade^{-1}

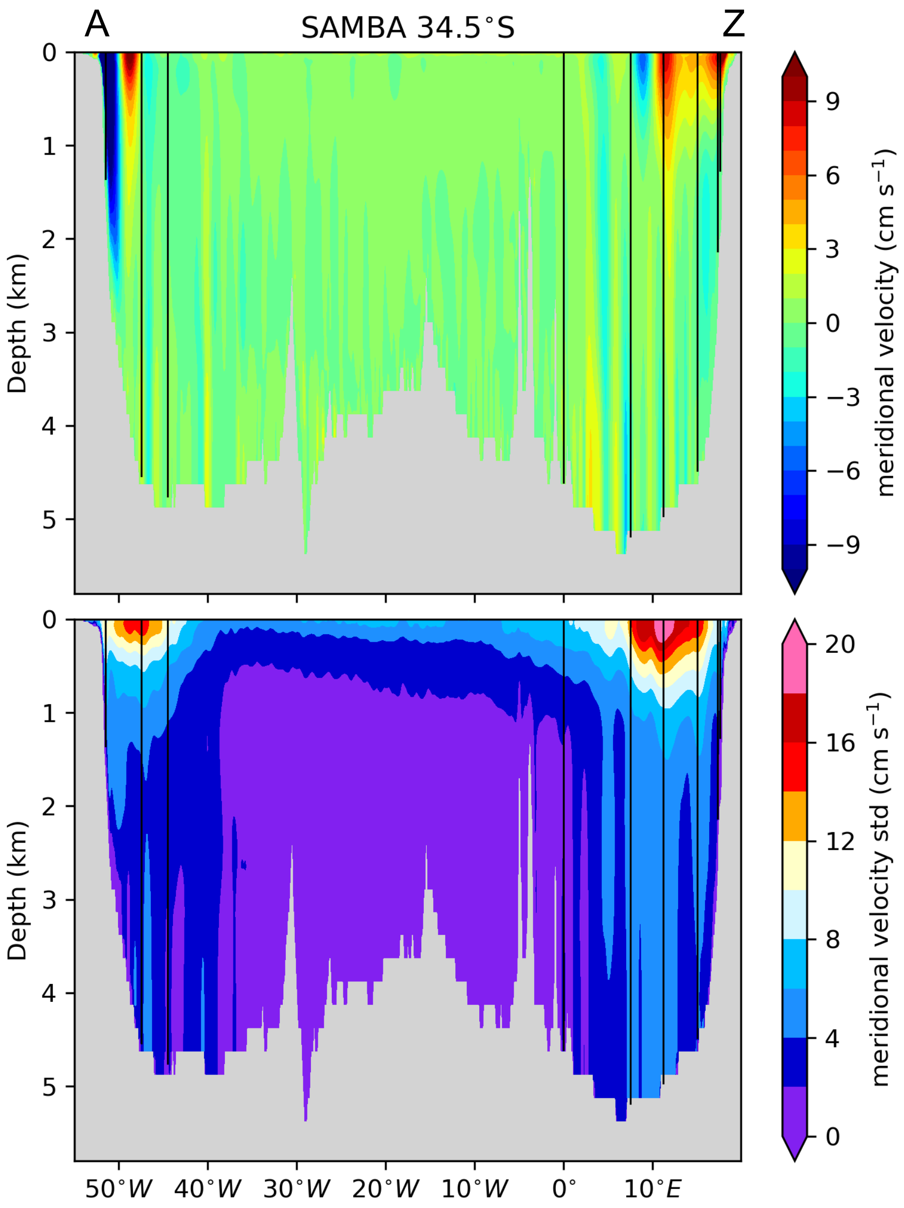
MOVE Array: Updated Transport Timeseries

(from Matthias Lankhorst)



The salinity data have been reprocessed to address spurious trends that likely arise from fouling inside the sensors that gets washed out during recovery.

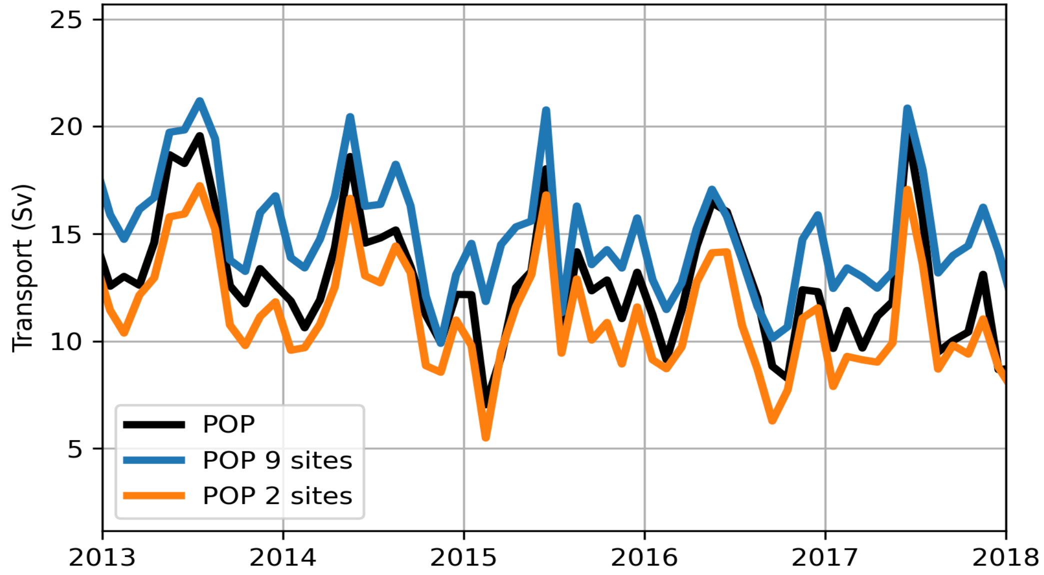
SAMBA Array

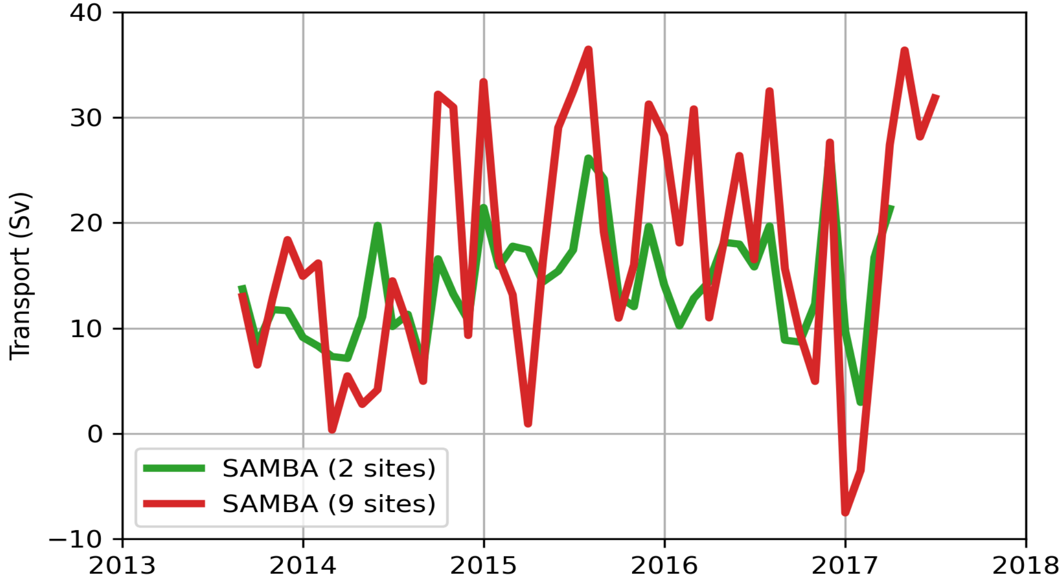


Transports are calculated as the sum of the Ekman and the geostrophic transport

- In-situ observations of ocean bottom pressure and acoustic round-trip travel times
- T&S profiles are estimated from travel times using the Gravest Empirical Mode (GEM) technique
- Zonal gradients of density profiles are used to obtain geostrophic velocity
- Zonal gradients in bottom-pressure provide the temporal variations of the absolute geostrophic velocity at the reference level
- The mean absolute geostrophic velocity comes from ECCO2 at a depth of 1200 m

SAMBA Array: 2- vs 9-site Computations



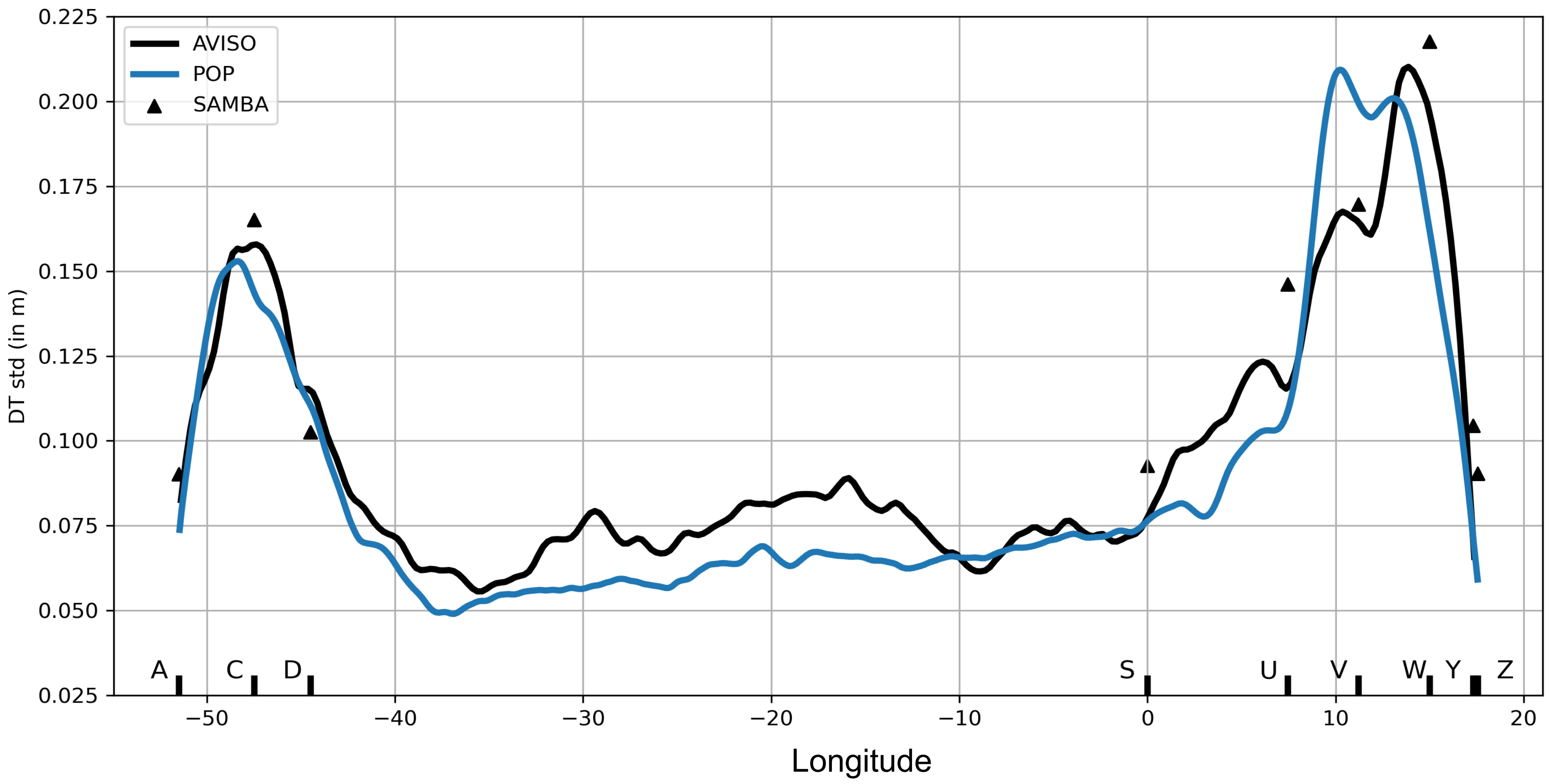


- Model AMOC can be reconstructed using the 2-site and 9-site computations
- Correlation between 2- vs 9-site AMOC time series is 0.95

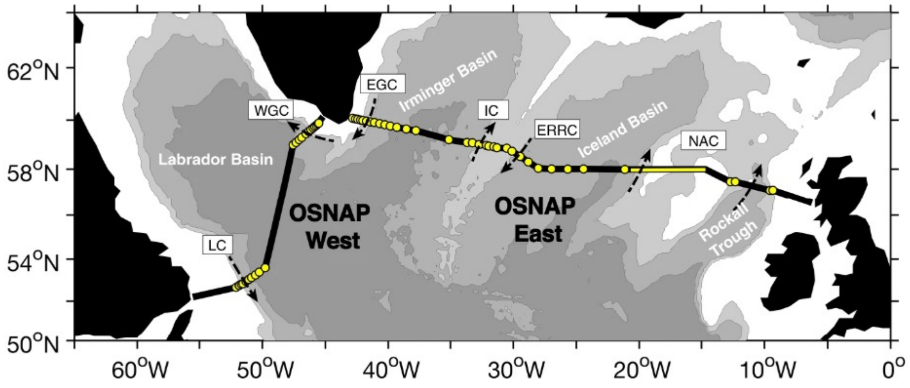
- This does not appear to be true for the observed AMOC
- Correlation is only 0.62 between the 2- vs 9-site estimates
- The magnitude of the variability is larger when considering 9 sites

SAMBA Array: Sea Level Variability

Both the SAMBA full-depth dynamic height and model sea level variability are in good agreement with AVISO

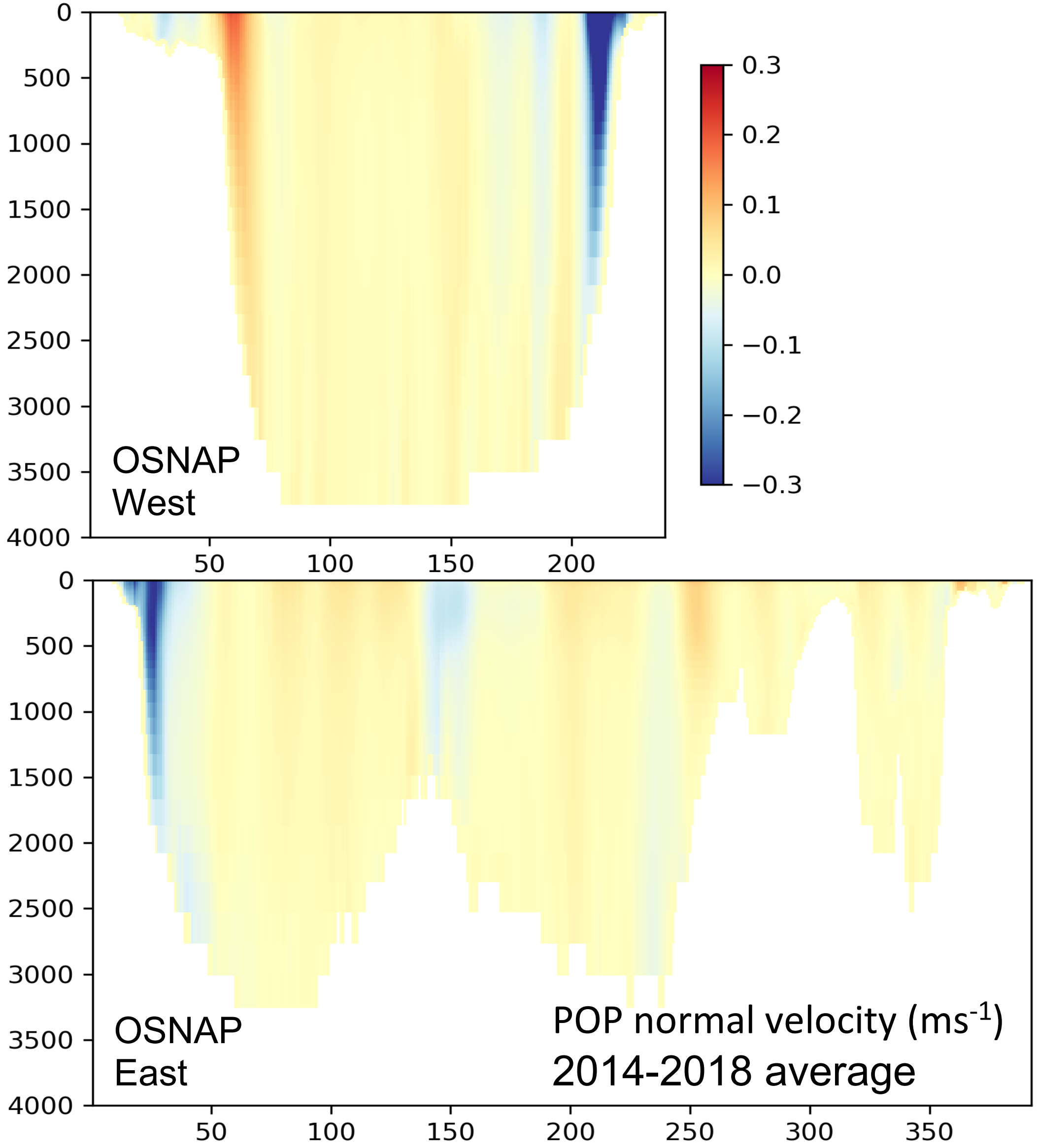


OSNAP Array

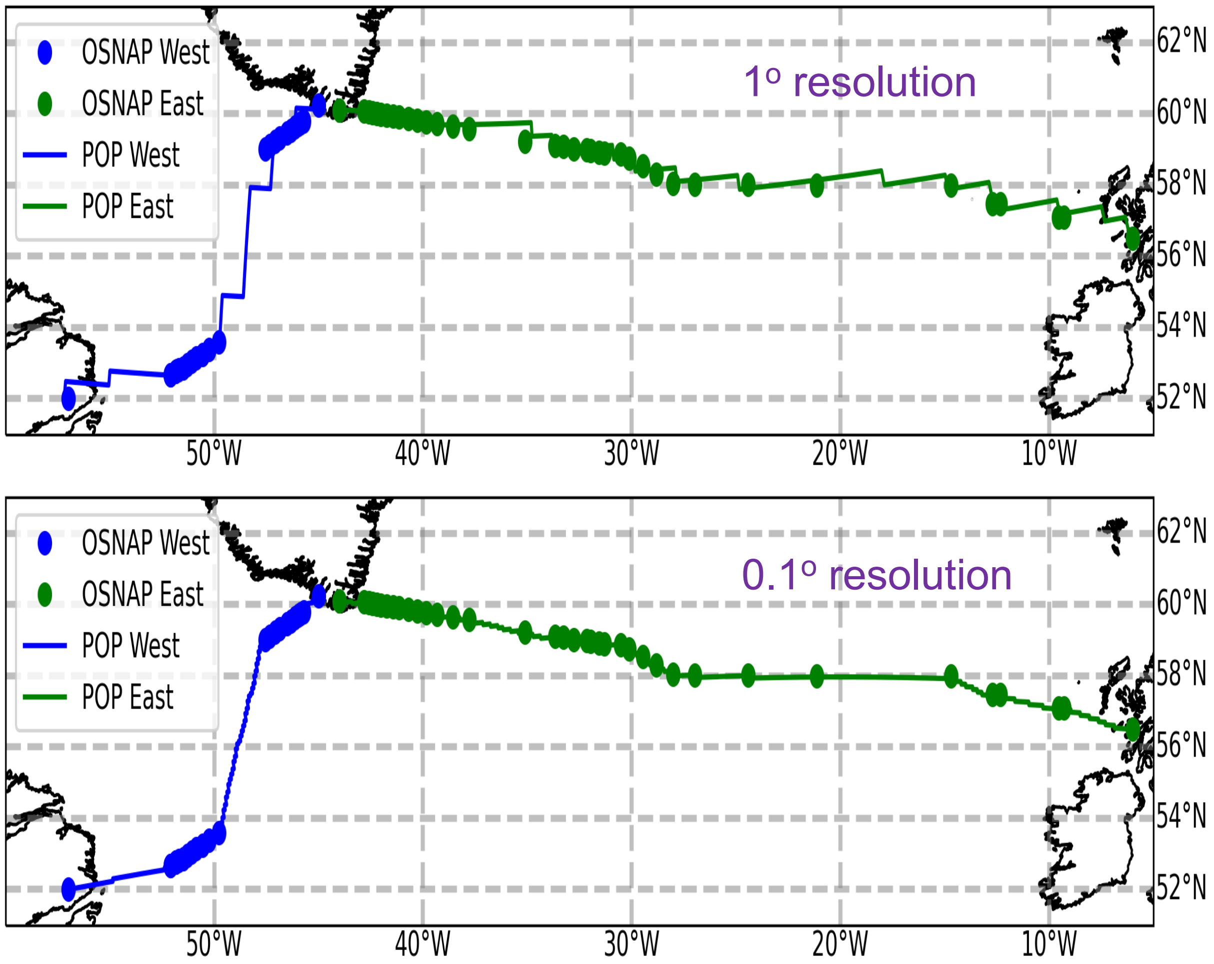


Locations of OSNAP moorings (Li et al. 2021)

- OSNAP is a trans-basin array comprised of 2 sections: OSNAP West and OSNAP East
- OSNAP uses a combination of fixed moorings at the continental boundaries providing direct measurement of the velocities and geostrophic and Ekman flows to infer MOC
- A spatially uniform velocity is applied to ensure no mass transport across the combined section



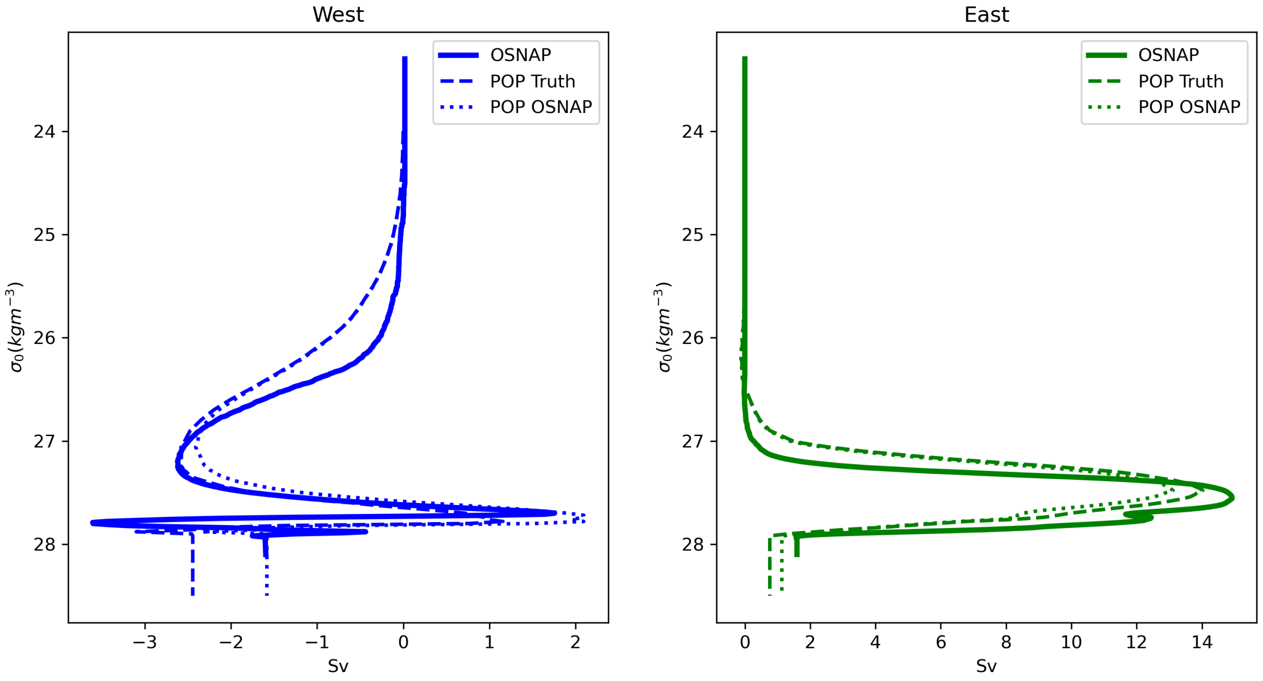
OSNAP Array



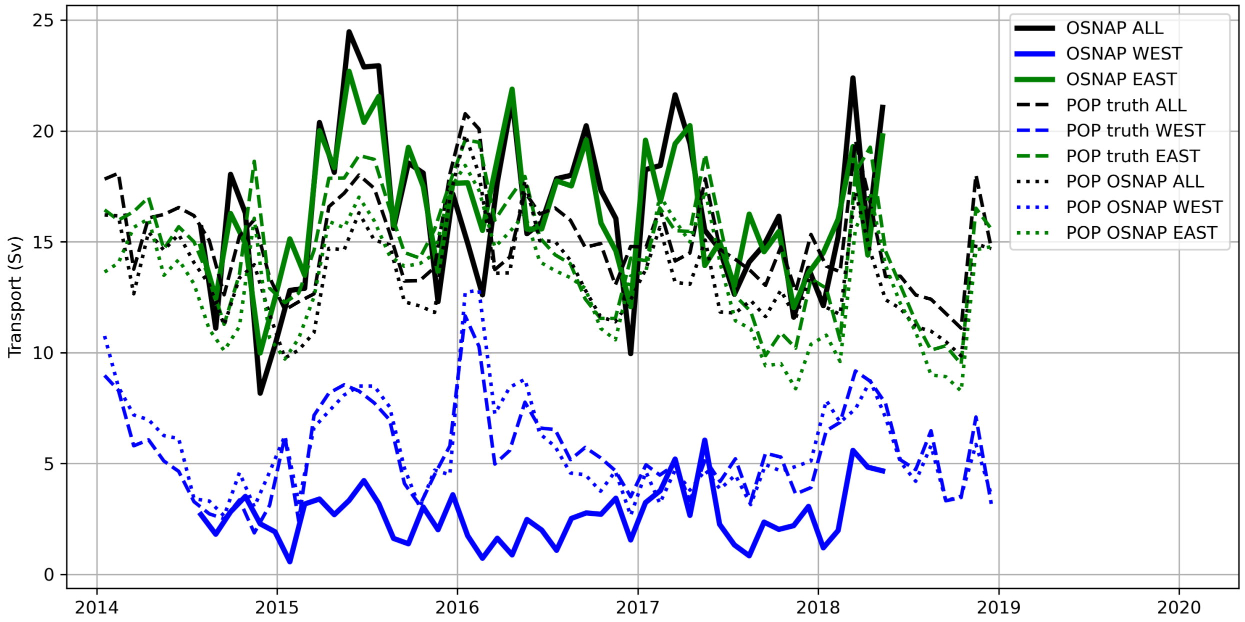
- A tool to extract the best broken grid line through a set of mooring locations has been developed
- The returned indices can be used to index a python xarray along the section
- The tool works across resolutions
- It is fast! Only a few seconds to extract the OSNAP sections on the global 0.1° grid
- Provide direct and accurate access to the simulated fields across the OSNAP sections. No interpolation.

OSNAP Array

Mean overturning streamfunction in σ_0



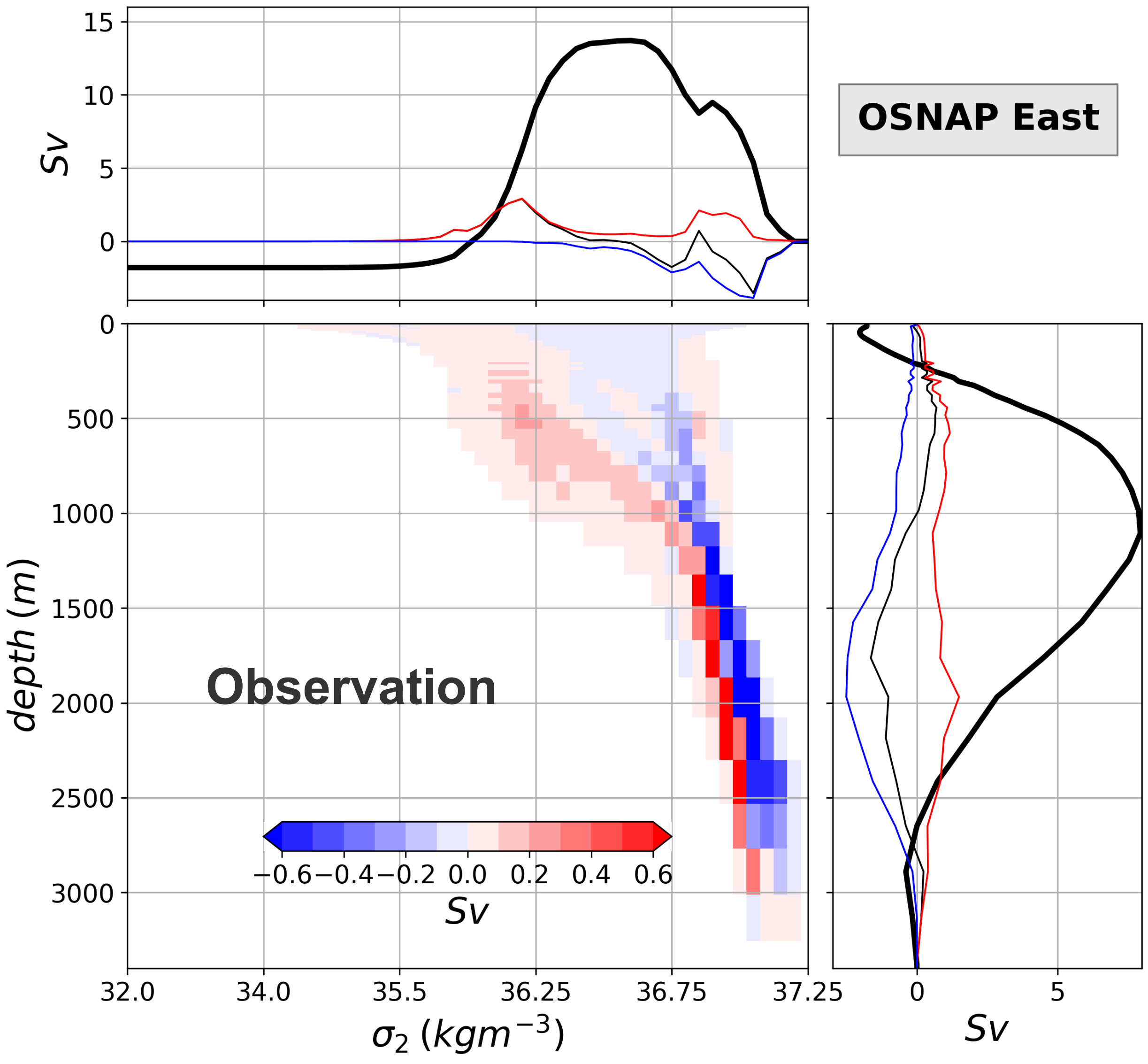
Preliminary results show good agreement between the model truth and the model observational equivalent



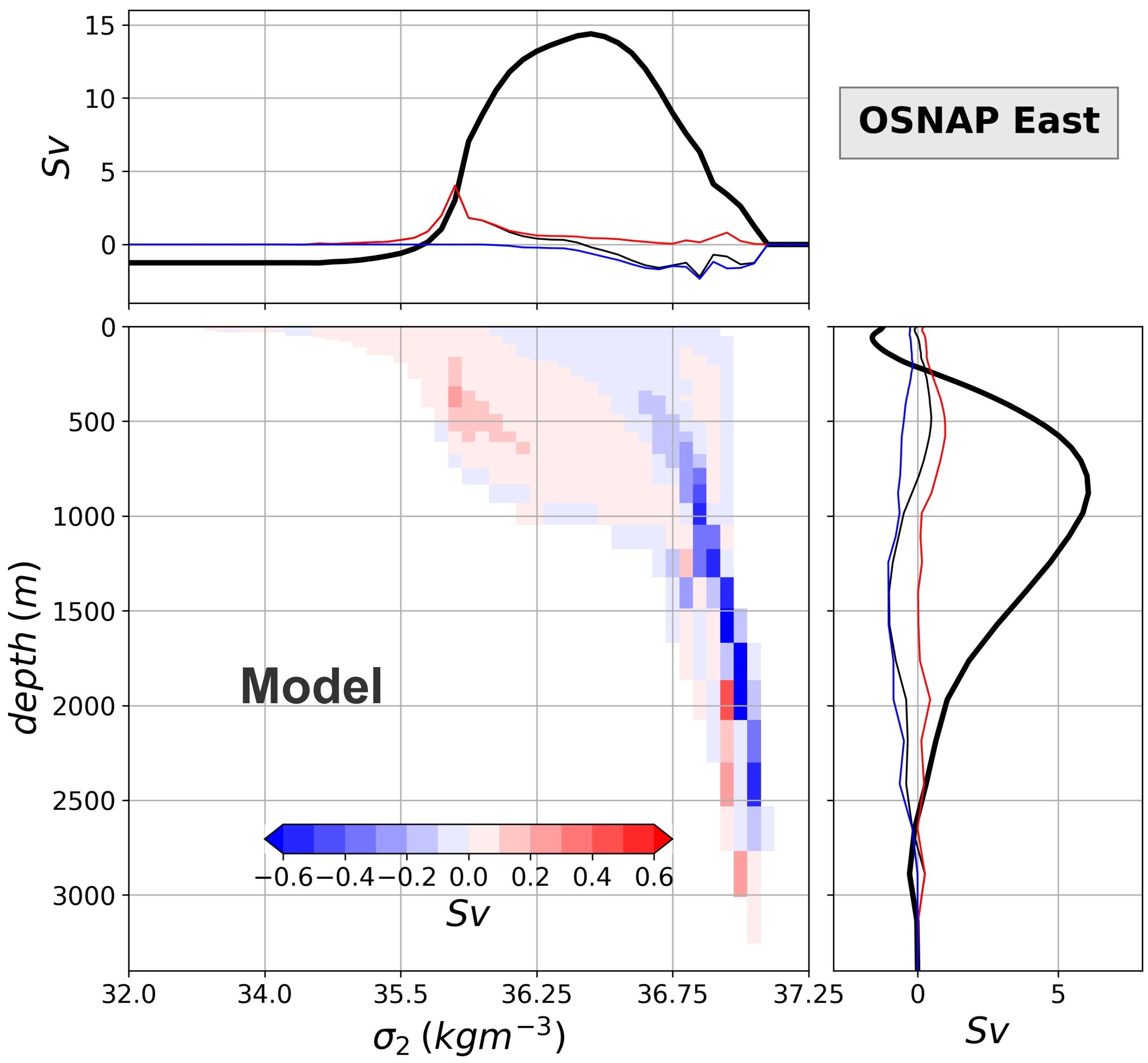
maximum of the overturning streamfunction in σ_0

Model realistically captures the relative strengths of overturning in the east and west

OSNAP Array

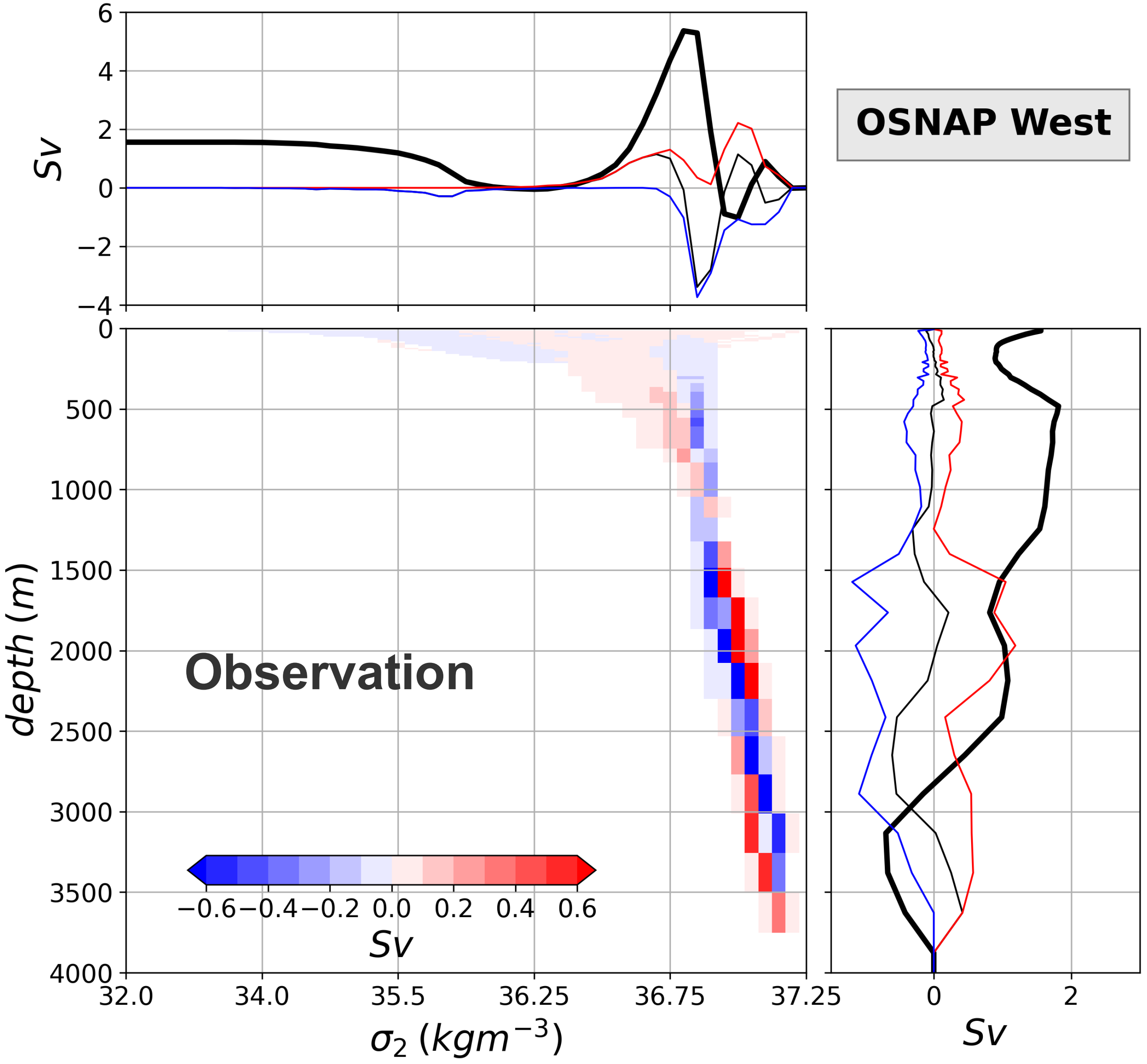


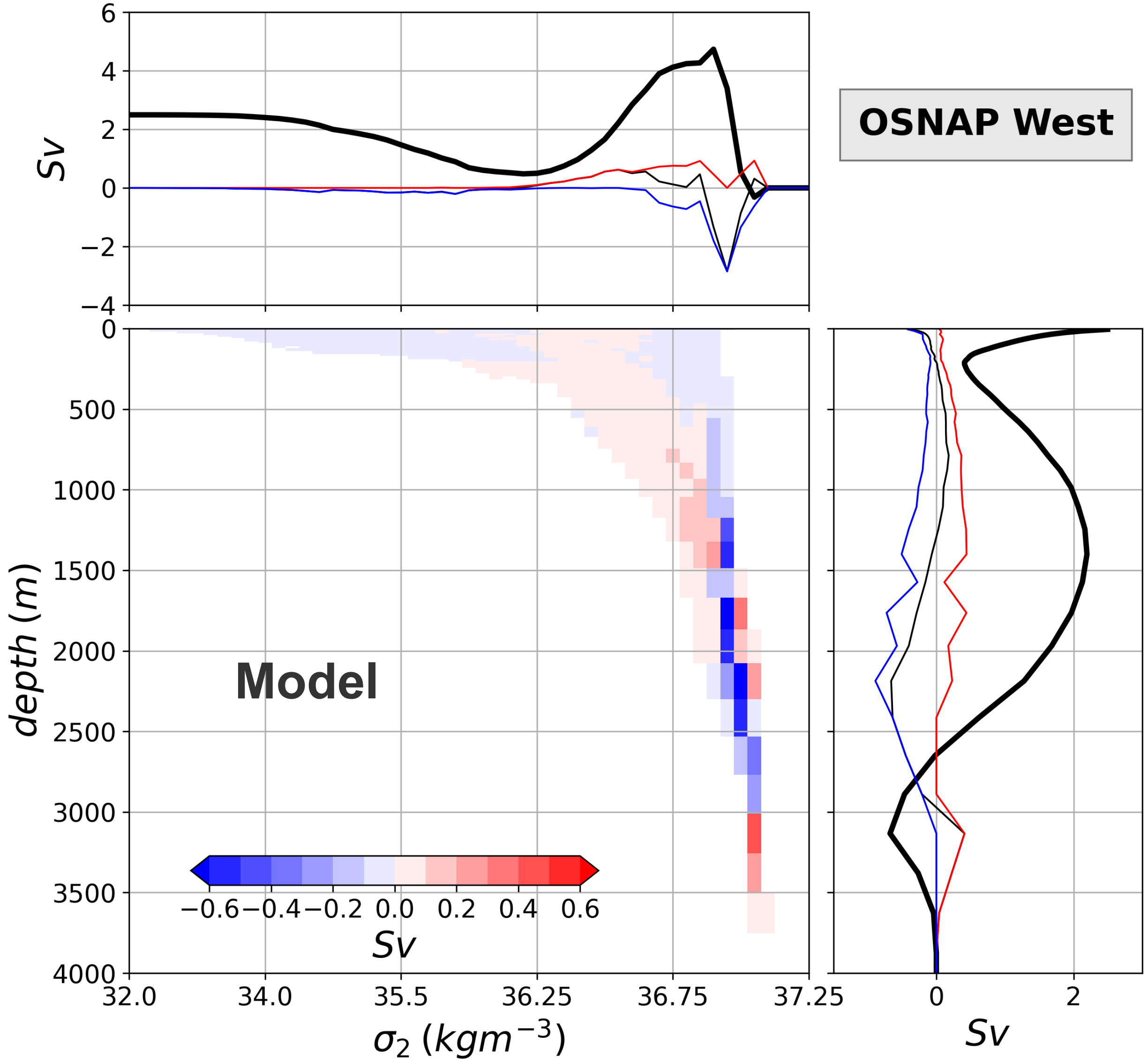
Sv
15
10
5
0
OSNAP East
0
500
1000
1500
2000
2500
3000
depth (m)
Observation
−0.6 −0.4 −0.2 0.0 0.2 0.4 0.6
Sv
32.0
34.0
35.5
36.25
36.75
37.25
σ2 (kgm−3)
0
5
Sv



Sv
15
10
5
0
OSNAP East
0
500
1000
1500
2000
2500
3000
depth (m)
Model
−0.6 −0.4 −0.2 0.0 0.2 0.4 0.6
Sv
32.0
34.0
35.5
36.25
36.75
37.25
σ2 (kgm−3)
0
5
Sv

OSNAP Array





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Summary and Conclusions

- The METRIC module enables consistent calculations of AMOC estimates at various observational sites from ocean models: https://github.com/NCAR/metric
- RAPID: Various model estimates of AMOC are consistent with the observational estimate, but they are also consistent among themselves
- MOVE: Model estimates differ from observations, and they show significant differences among themselves
- MOVE and RAPID transport variabilities and trends agree with each other in model simulations, but not in observations ….. Newly updated MOVE observational timeseries
- SAMBA: Variability estimated by the 9-site array is larger than the simulated variability, but also larger than that of the 2-site array
- OSNAP: Preliminary results indicate good agreement between the observations and model
- Reiterating the known challenges associated with treatments of reference depths / velocities in (observational) transport estimates
- Substantial cancellations in transports both in depth- and density-space; both should be used together