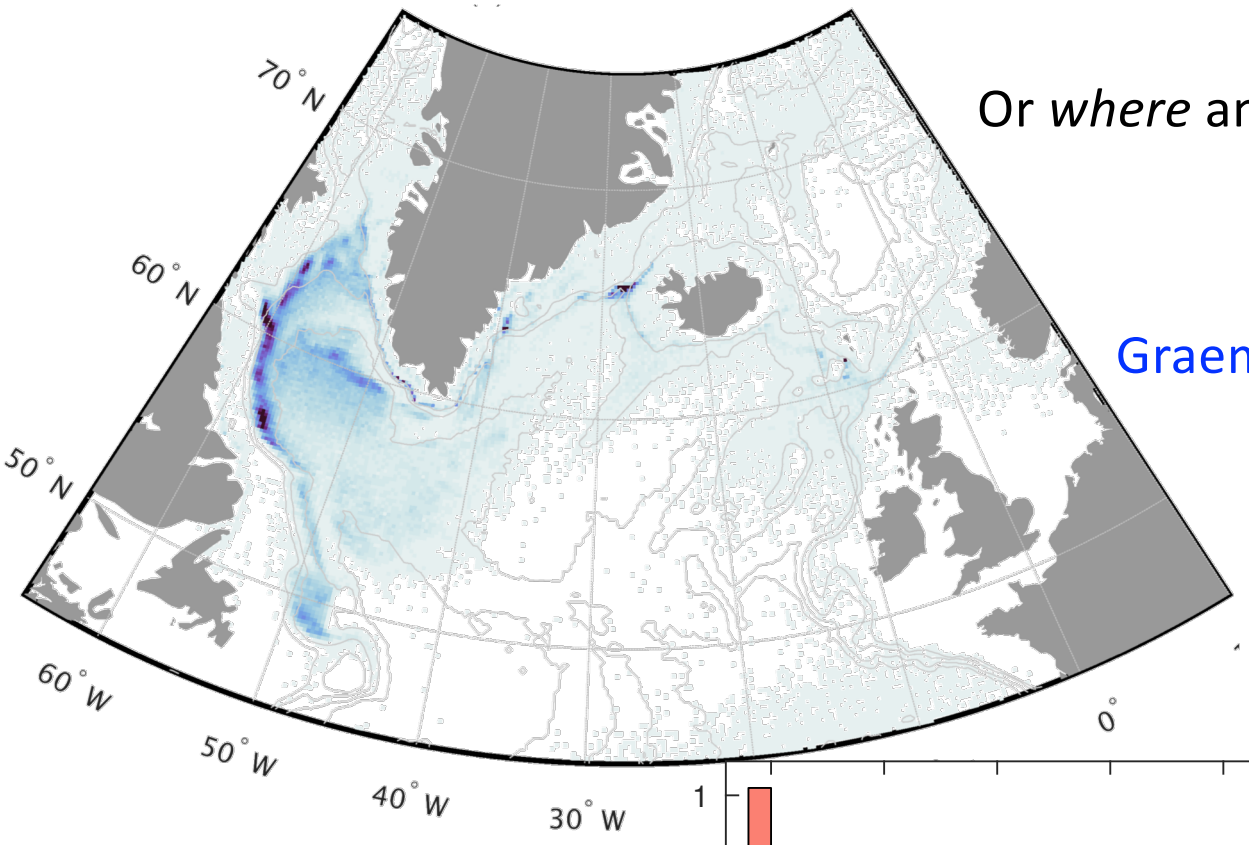
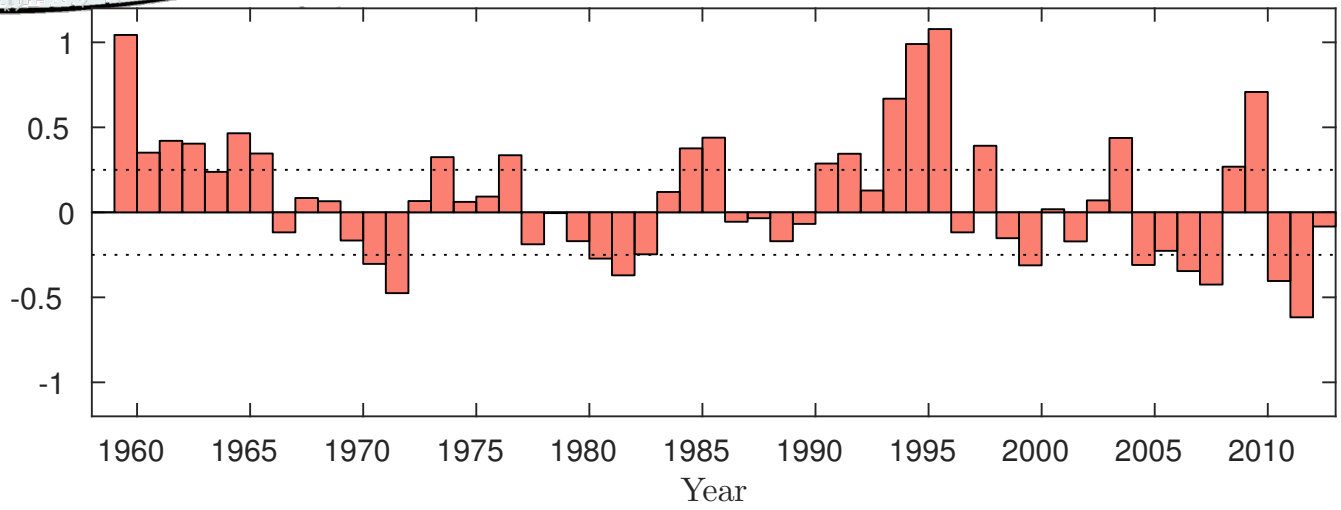
Characteristics and variability of ocean ventilation in the high-latitude North Atlantic in an eddy-permitting ocean model



Or *where* and *when* is NADW ventilated?!

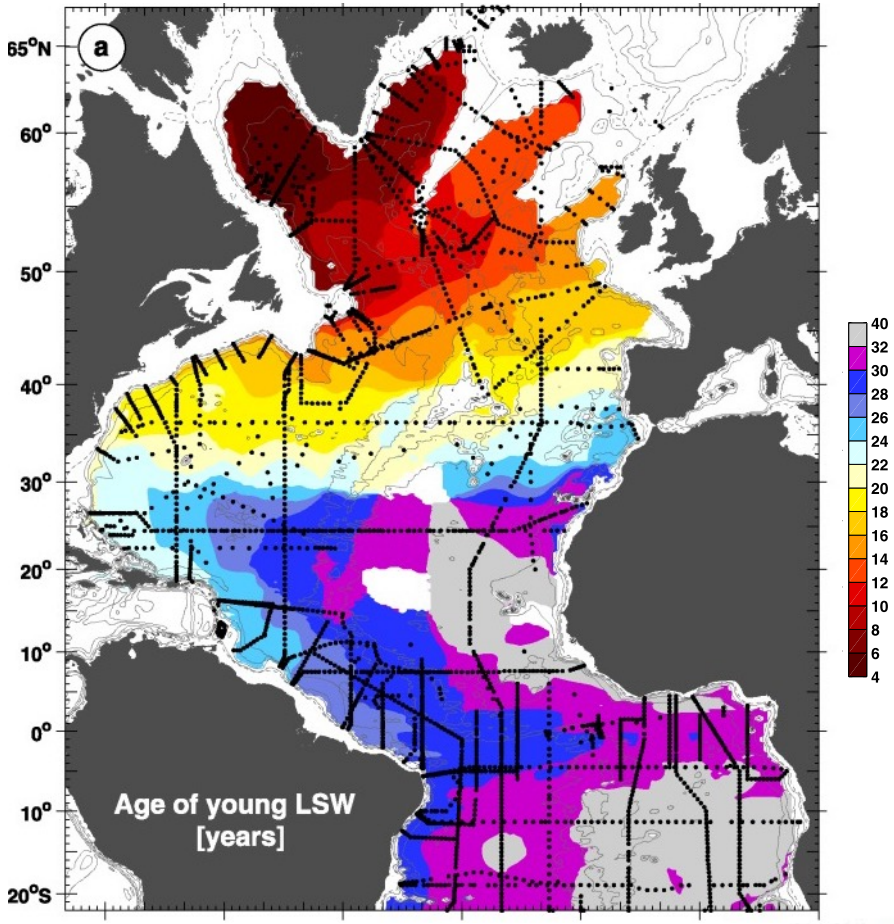
Graeme MacGilchrist, Helen Johnson and David Marshall



with input from Camille Lique, Matt Thomas, Laura Jackson and Richard Wood.

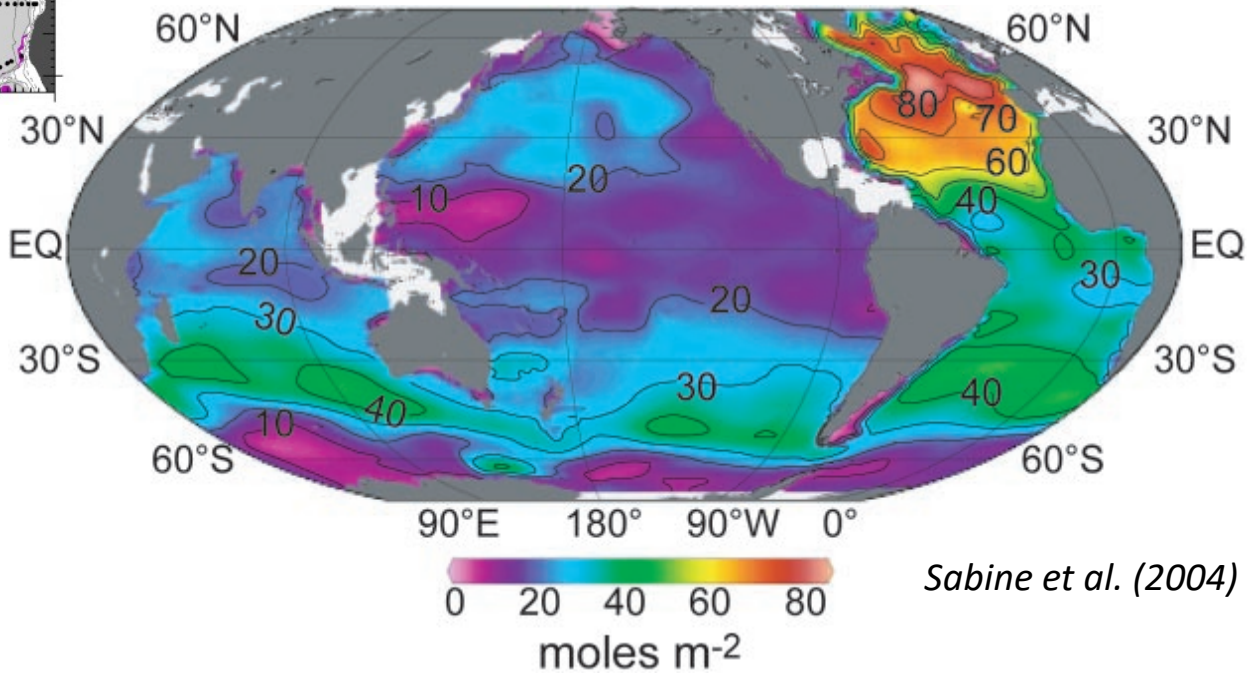
MacGilchrist et al. (2020), MacGilchrist et al. (2021)

North Atlantic ocean ventilation is important for mean climate and for the response to anthropogenic forcing



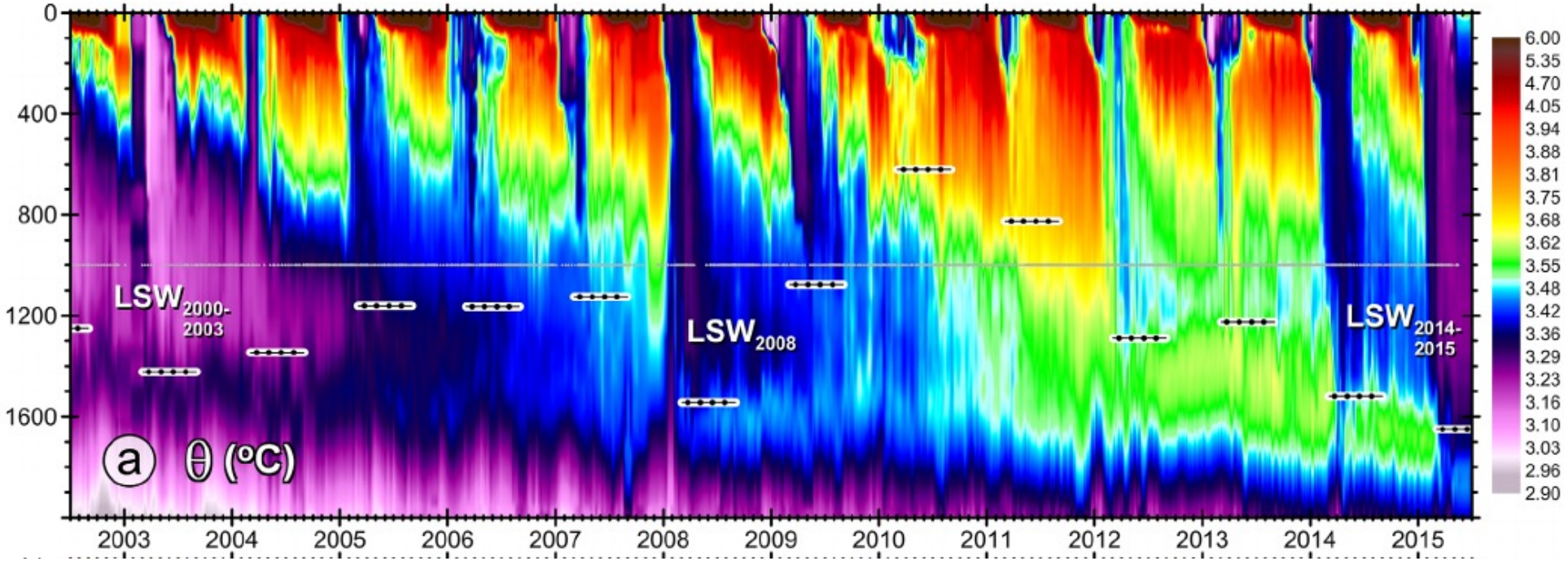
Rhein et al. (2015)

Column inventory of anthropogenic CO_2



Sabine et al. (2004)

Variability in atmospheric conditions affects the ocean surface mixed layer…



Yashayev and Loder et al. (2016)

…but how is this translated into the ocean interior?

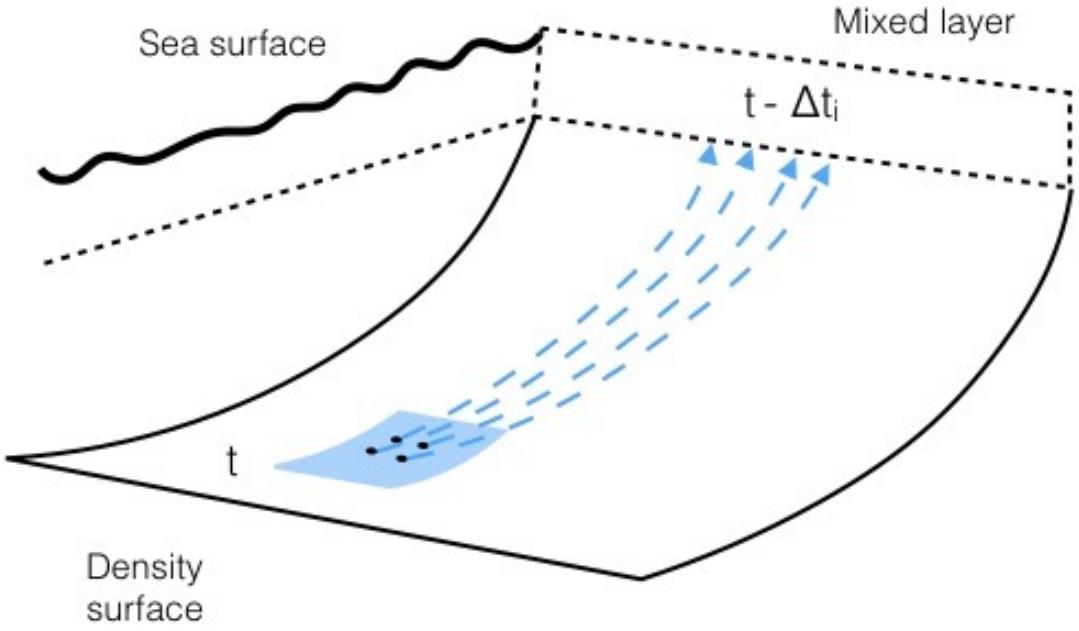
Questions

When, where and how does ventilation of North Atlantic Deep Water (NADW) happen?

How is variability in atmospheric forcing communicated into the ocean interior?

Approach

Backwards-in-time trajectories in an ocean model hindcast.
Determine where and when NADW was last in the surface mixed layer.



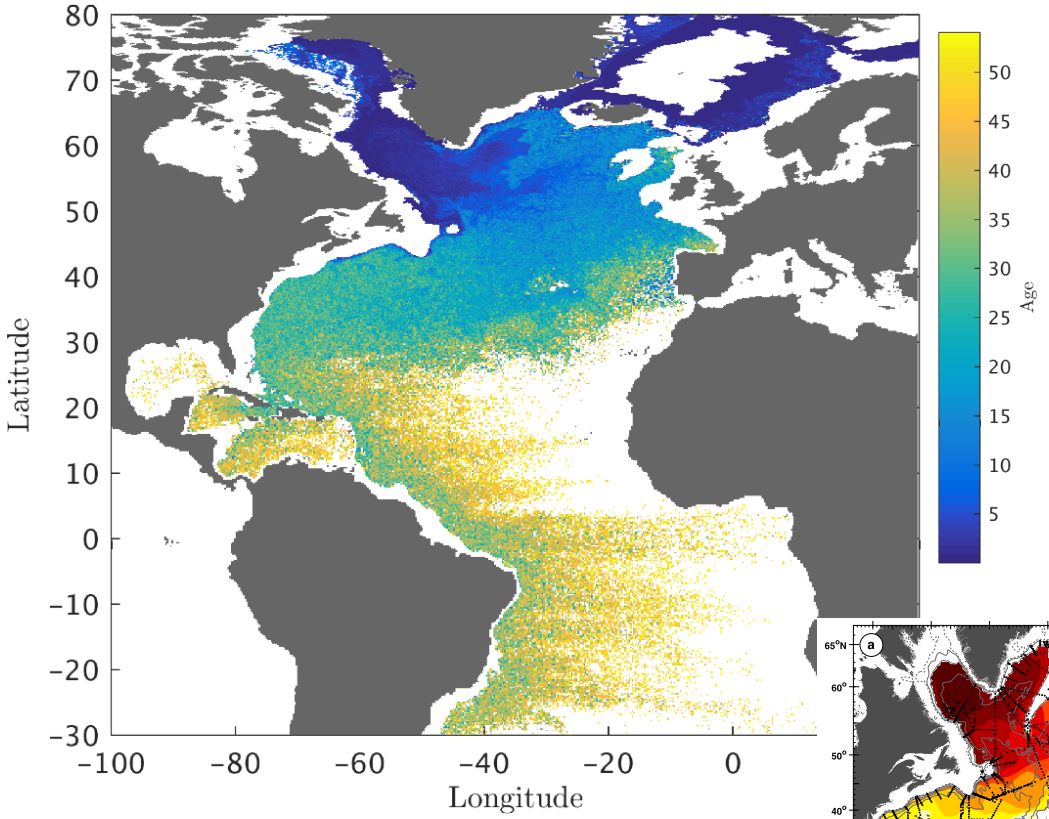
Model details

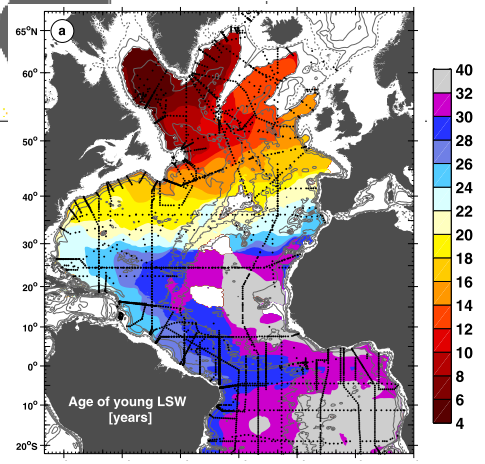
- NEMO, ORCA025, Drakkar simulation
- Ocean + sea-ice at 1/4°
- Forced by atmospheric reanalysis
- 57 year model run (1958-2015)
- Initialised from climatology
- Lagrangian trajectories using *Ariane* and 5-day-mean velocity fields
- model's NADW = $27.7 < \gamma_n < 28$ kg m^{-3}

Sanity check!

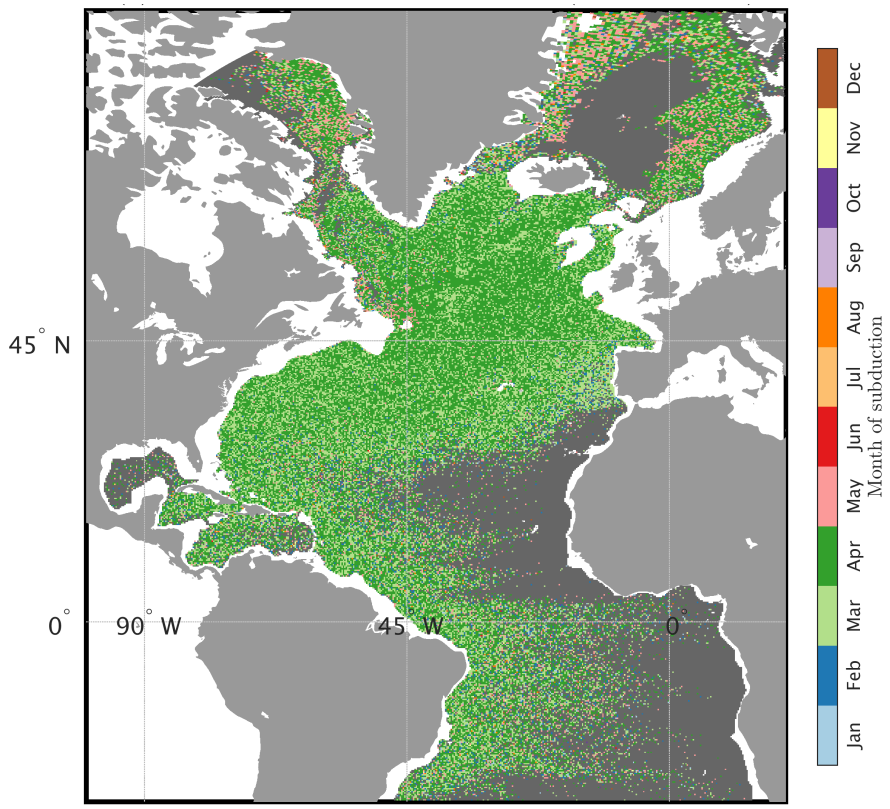
NADW age distribution agrees well with estimates from CFC measurements.

Depth averaged age-distribution for water in 2012





Depth median month of subduction



Most NADW in the interior left the mixed layer in March/April.

$27.7 < \gamma_n < 28$ kg m^{-3}

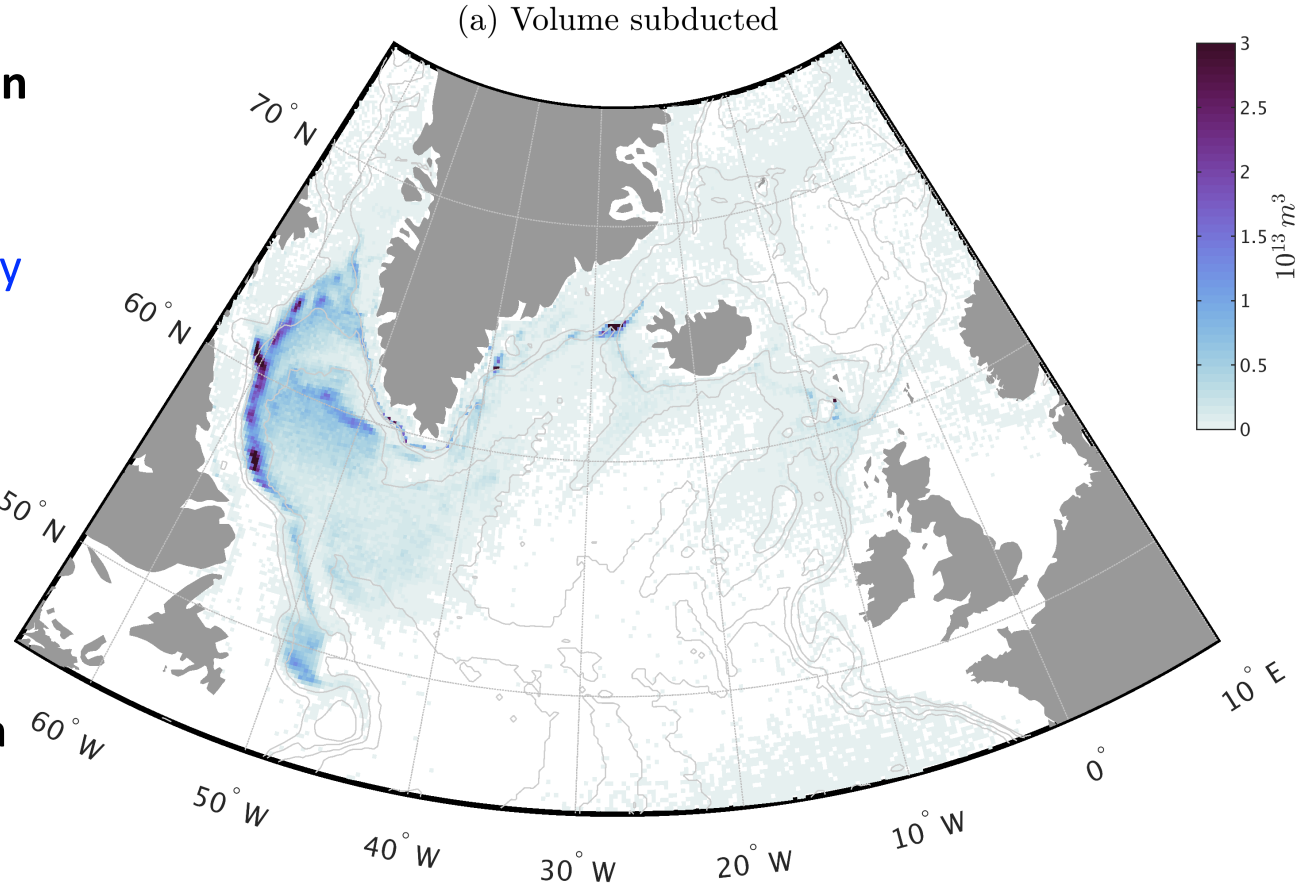
MacGilchrist et al. (2020)

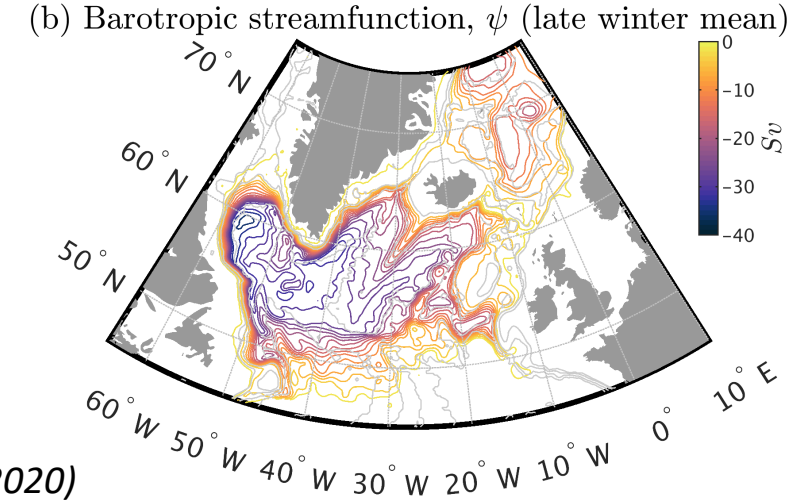
Location of subduction

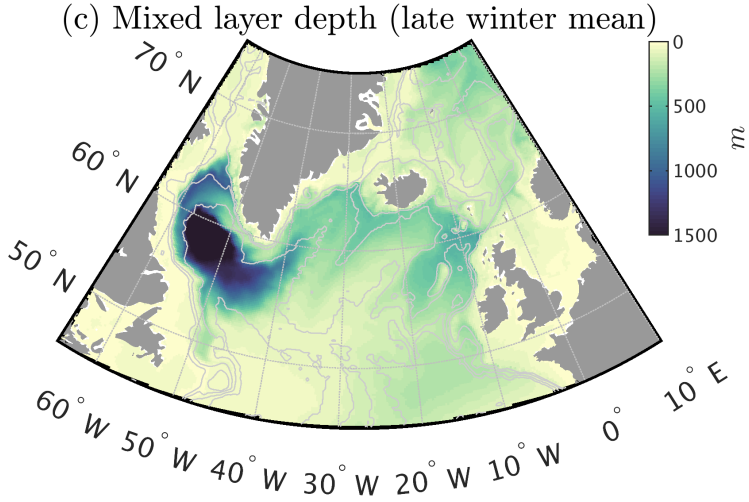
Labrador Sea boundary current dominates.

Lab Sea interior also plays a role.

Very little contribution from Nordic Seas

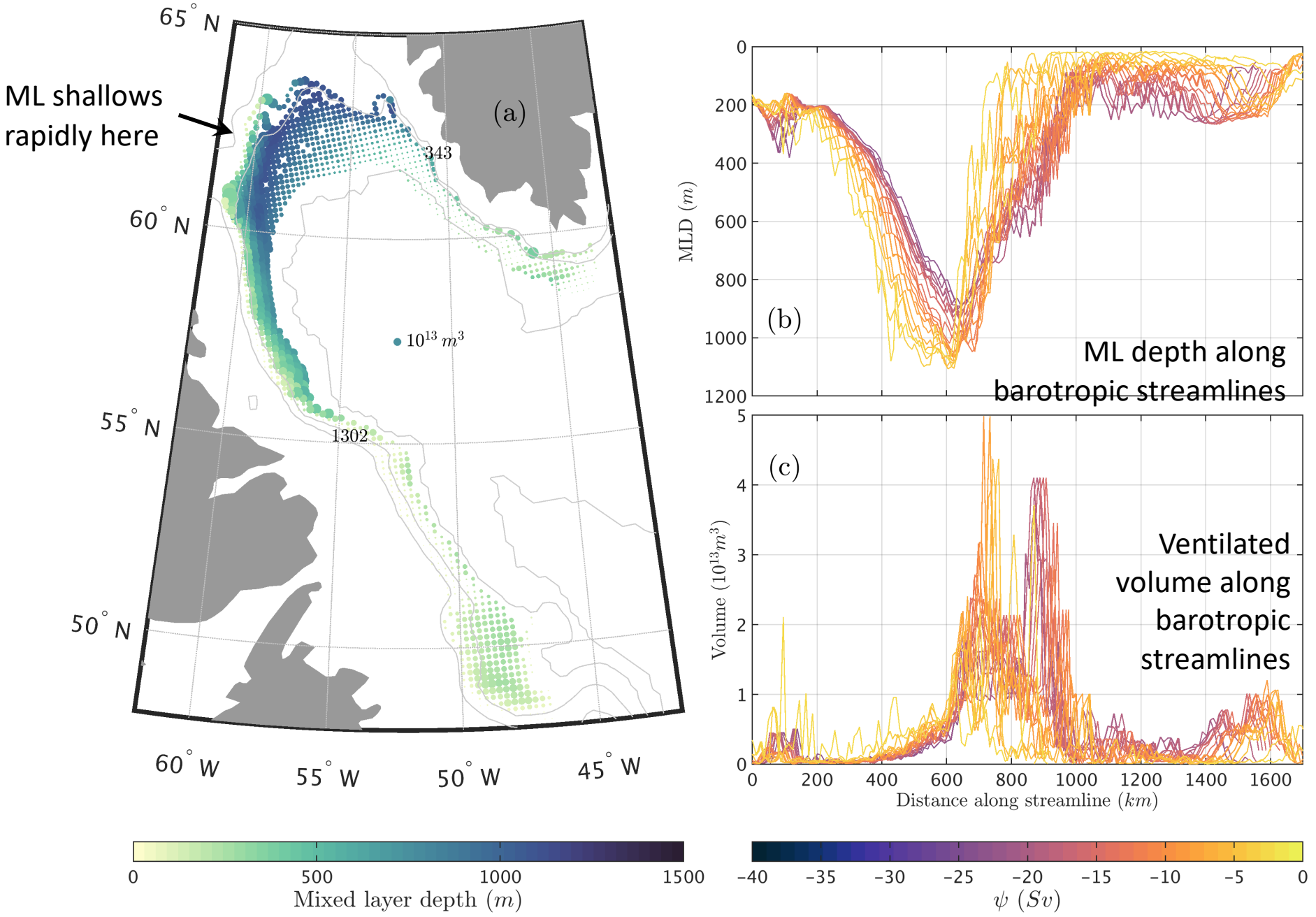






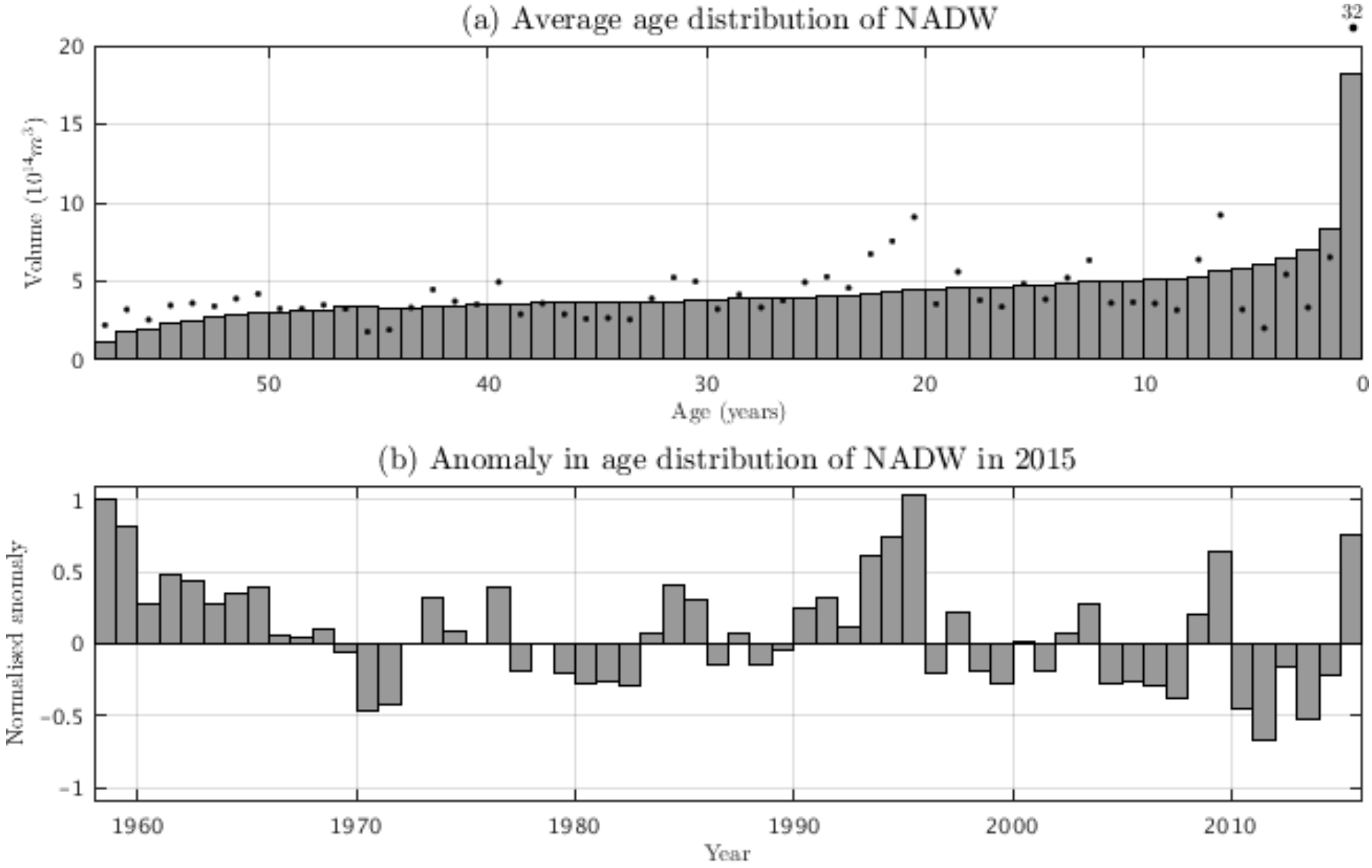
MacGilchrist et al. (2020)

Boundary current subduction occurs via lateral fluxes across the sloping late-winter ML base.

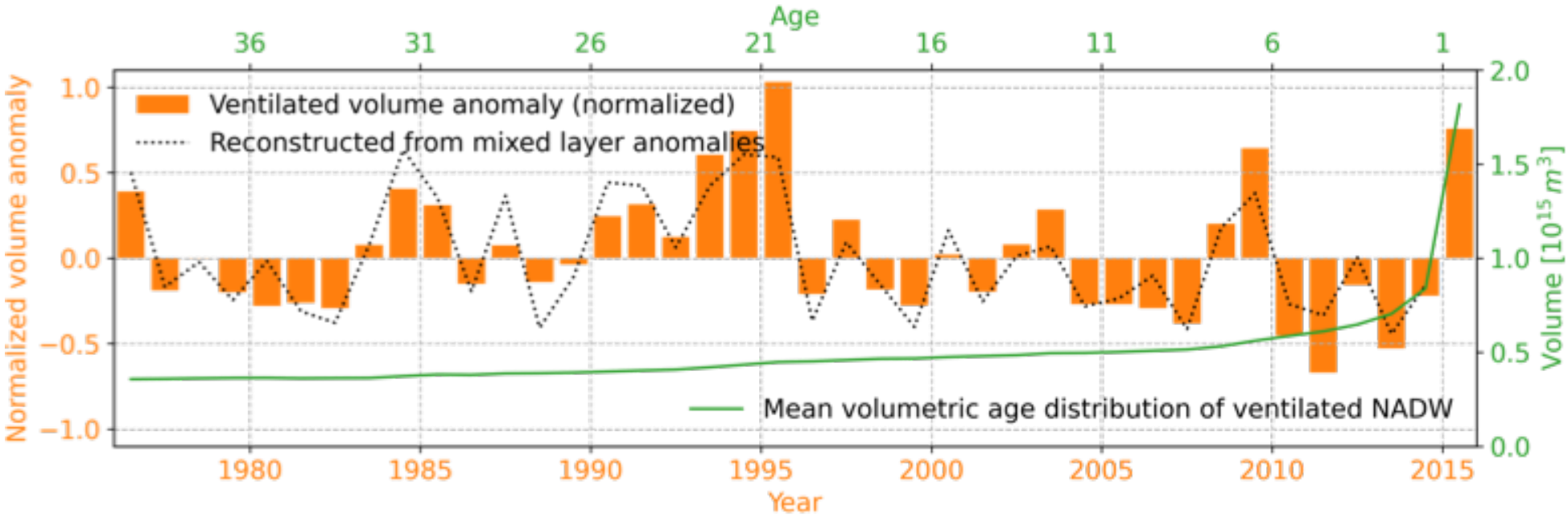


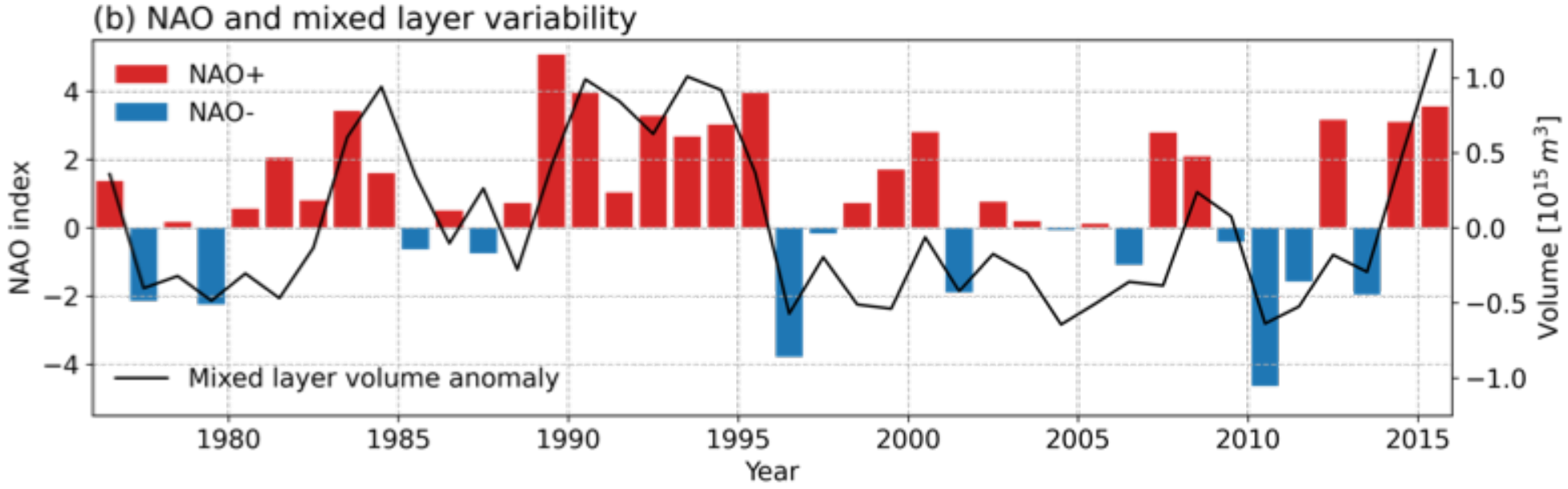
MacGilchrist et al. (2020)

Interannual variability in NADW ventilation



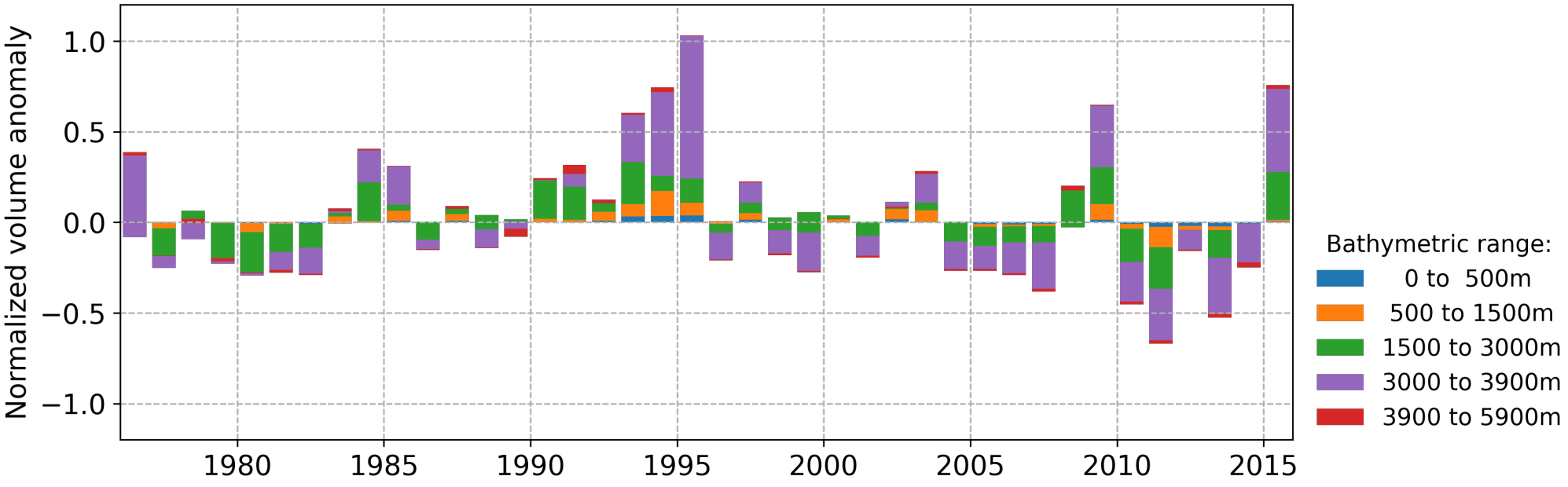
Ventilation variability compared with atmospheric forcing and ML response





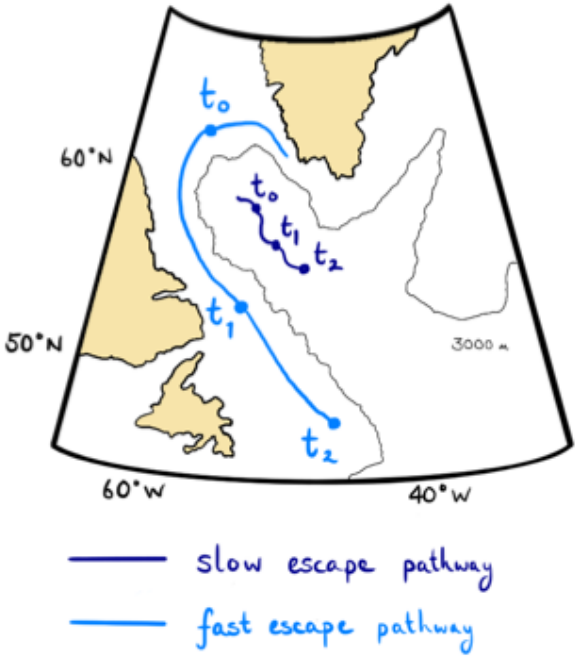
MacGilchrist et al. (2021)

Anomaly in ventilated volume for open ocean ( ) compared with boundary current ( ) subduction



Ventilation variability depends on variability in the sub-surface retention of newly ventilated water in addition to variability in the amount subducted each year.

Re-entrainment associated with Labrador Sea open ocean convection dominates the ventilation variability.



MacGilchrist et al. (2021)

Conclusions

Ocean ventilation is a fundamentally Lagrangian process, requiring subduction out of the surface mixed layer and subsurface retention. Mixed layer depth is not always a good proxy!

NADW ventilation in the model is predominantly due to subduction in the Labrador Sea boundary current.

Variability in ventilation is driven by atmospheric forcing changes related to the NAO, and is heavily influenced by year-to-year variations in subsurface retention in the Lab Sea interior. An interannual version of Stommel's Demon is at work!



MacGilchrist et al. (2020, Journal of Climate)
https://doi.org/10.1175/JCLI-D-20-0191.1

MacGilchrist et al. (2021, Geophysical Research Letters)
https://doi.org/10.1029/2020GL092340

Questions?
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