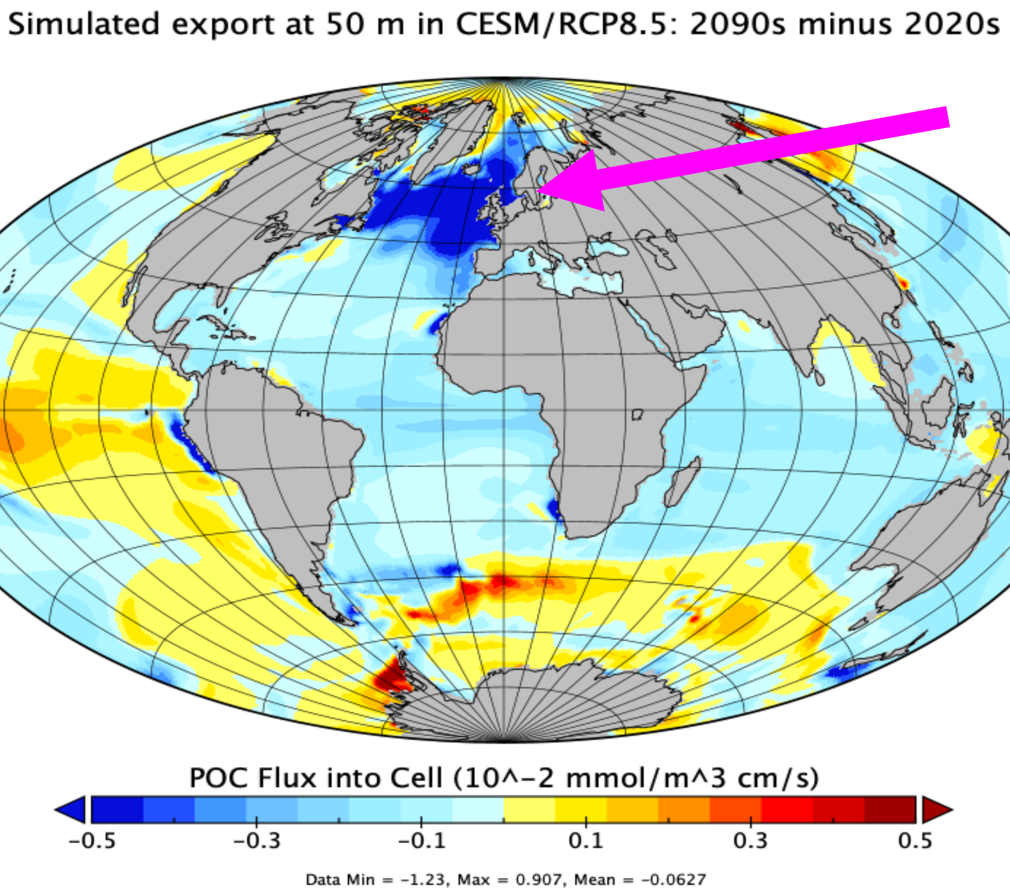
Elucidating the role of ocean circulation in changing North Atlantic nutrients and biological productivity

Funded by
NASA 2020 New Investigator Program in Earth Science
NASA Physical Oceanography Program

Earth system models show Subarctic Atlantic biological productivity especially vulnerable to global warming



Four papers … slower MOC reduces NAtl productivity

2019

4

On the Role of the Gulf Stream in the Changing Atlantic Nutrient Circulation During the 21st Century

Daniel B. Whitt

2020

Slower nutrient stream suppresses Subarctic Atlantic Ocean biological productivity in global warming

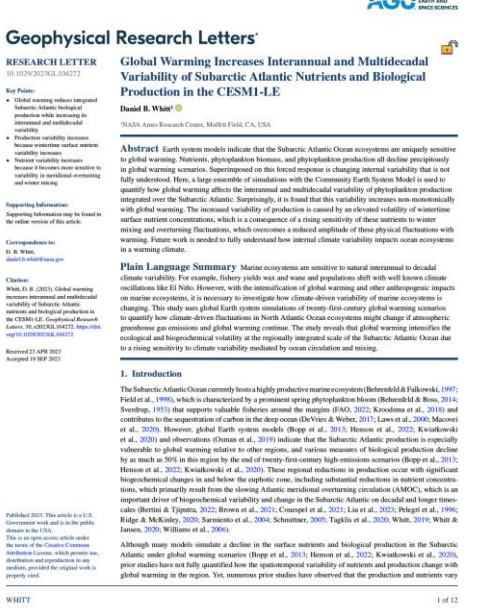
Daniel B. Whitt and Malte F. Jansen

2023

Global Biogeochemical Cycles

Submesoscale Effects on Changes to Export Production Under Global Warming

2023



Geophysical Research Letters

Global Warming Increases Interannual and Multidecadal Variability of Subarctic Atlantic Nutrients and Biological Production in the CESM1-LE

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SUBARCTIC ATLANTIC OCEAN

Seasonal cycle

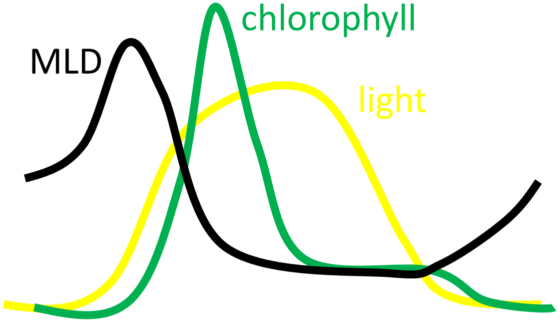
Phytoplankton require light and nutrients such as nitrate (NO_3^-) to grow.

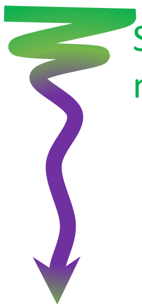
NO_3^- is low at the surface and replete at depth during summer.

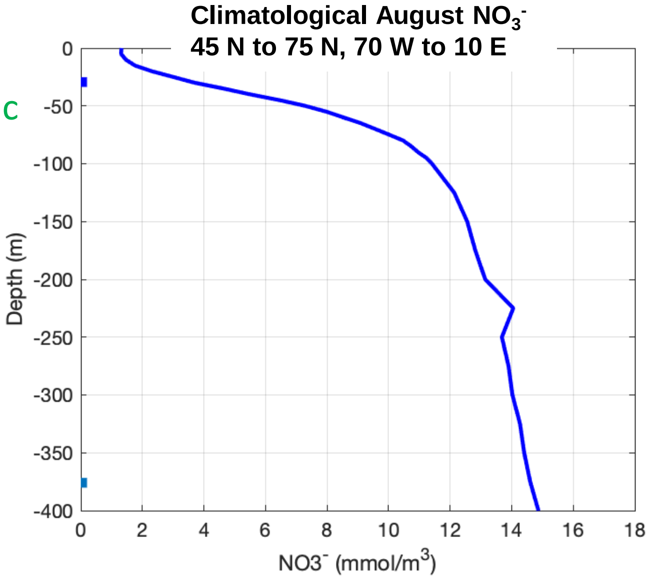
Wintertime vertical mixing replenishes NO_3^-

Spring solar radiation shoals the mixing layer, and phytoplankton draw down NO_3^-

Sinking detrital material is remineralized back to NO_3^- in the seasonal thermocline or deeper







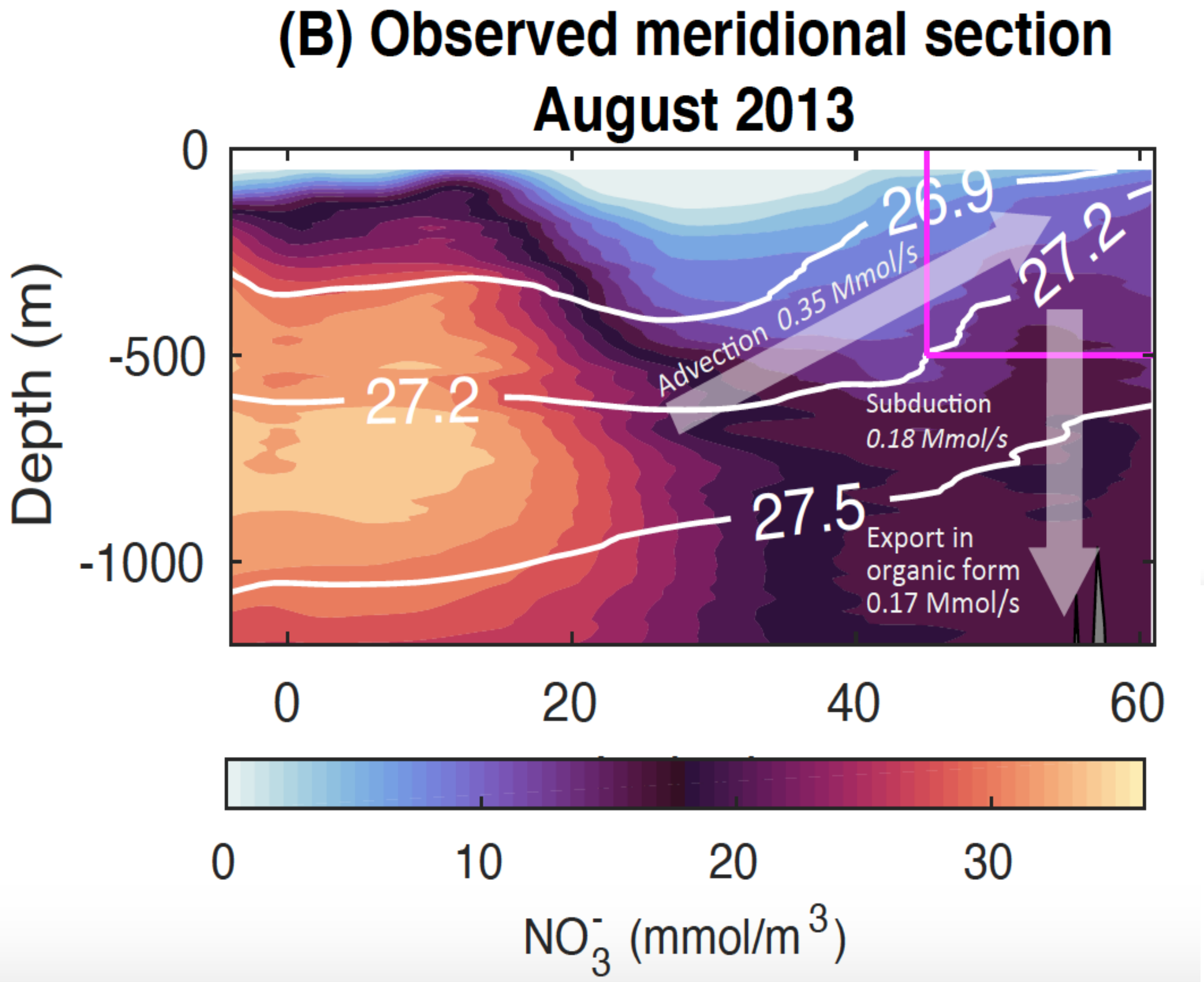
Dynamics are essentially local/vertical/1-D

Annual mean

Export & subduction to depths below the winter mixed layer is replenished by meridional circulation

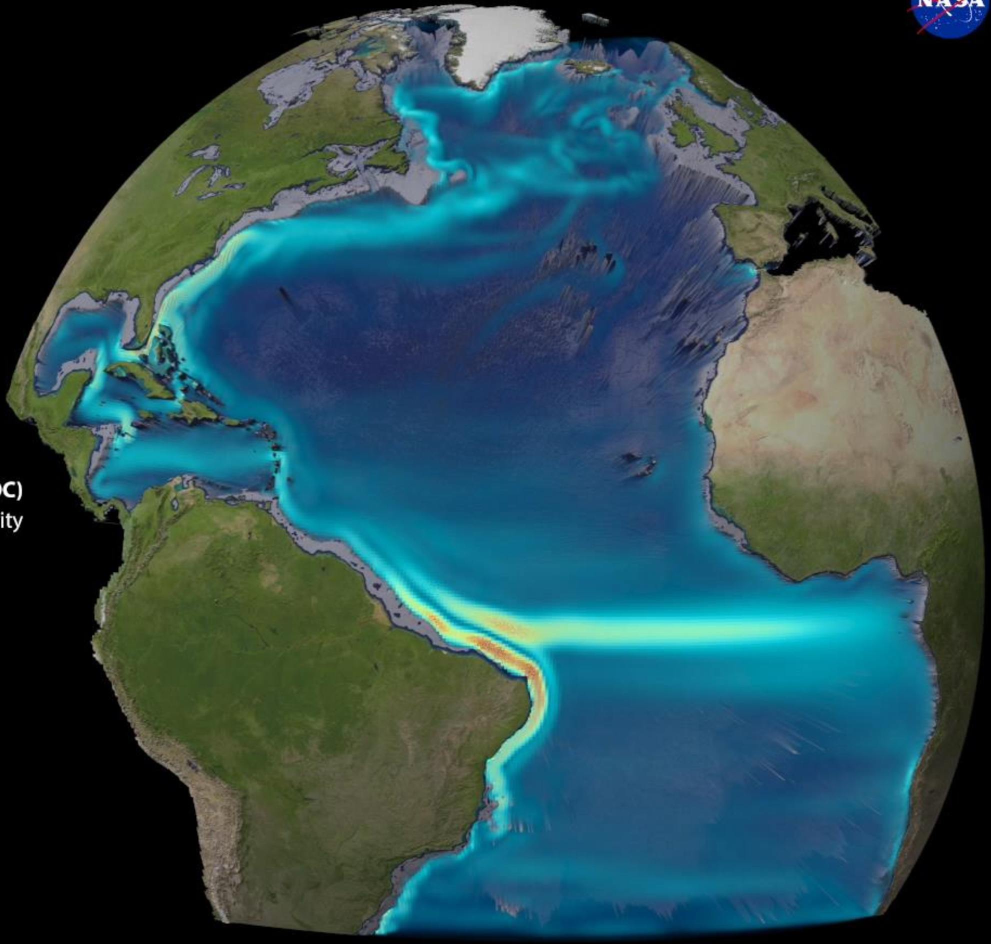
To put these numbers in perspective:
Global Anthropogenic N fixation ~ .475 Mmol/s (Fowler et al. 2013)

Advective replenishment timescale for Subpolar North Atlantic NO_3^- above 1 km: (200 Gmol) /(0.3 Mmol/s) ~ 20 years



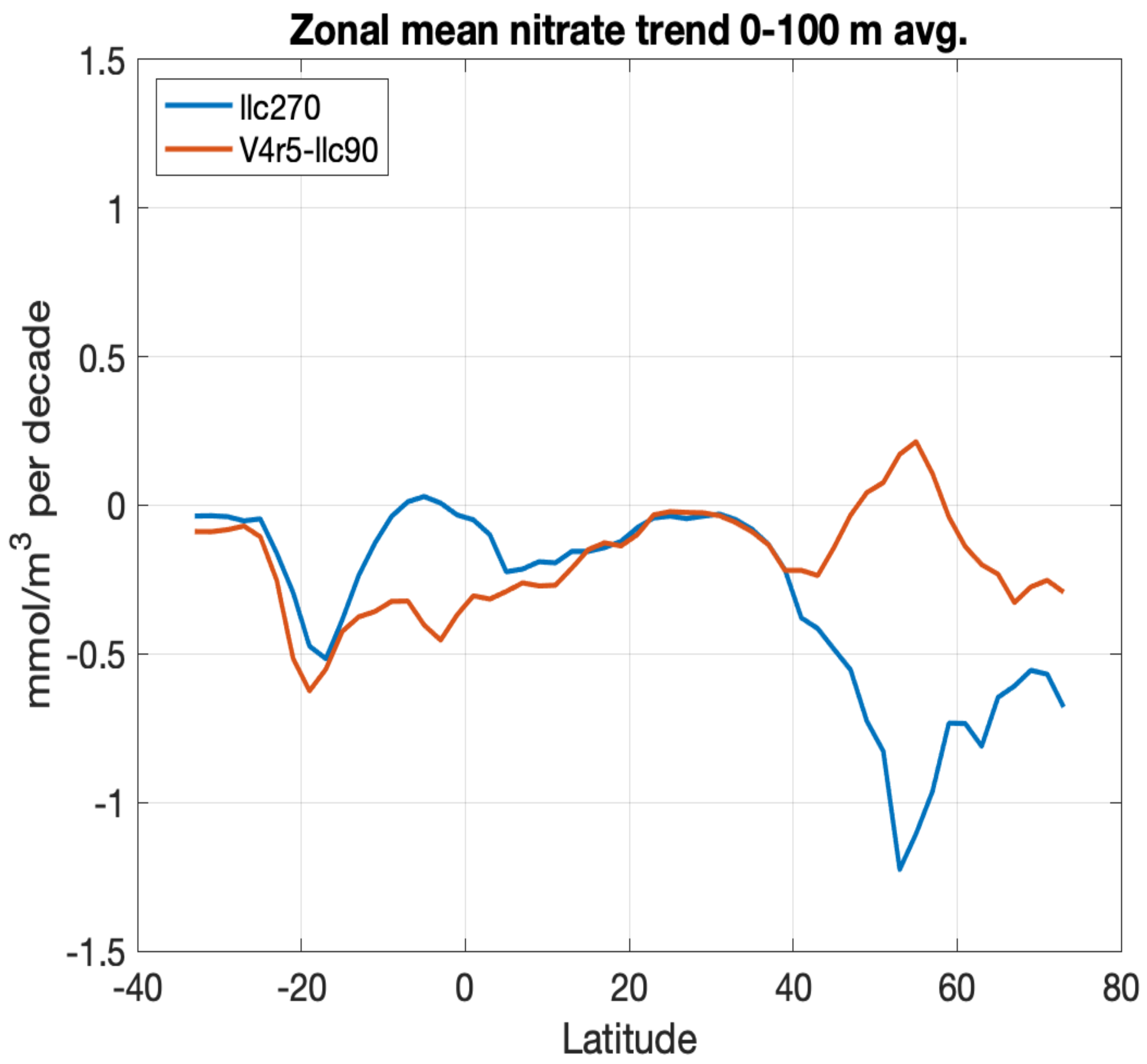
How ***does*** the MOC participate in North Atlantic biogeochemistry?

Nitrate transport by the Atlantic Meridional Overturning Circulation (AMOC)
a key governor of marine ecosystem productivity



Annual mean

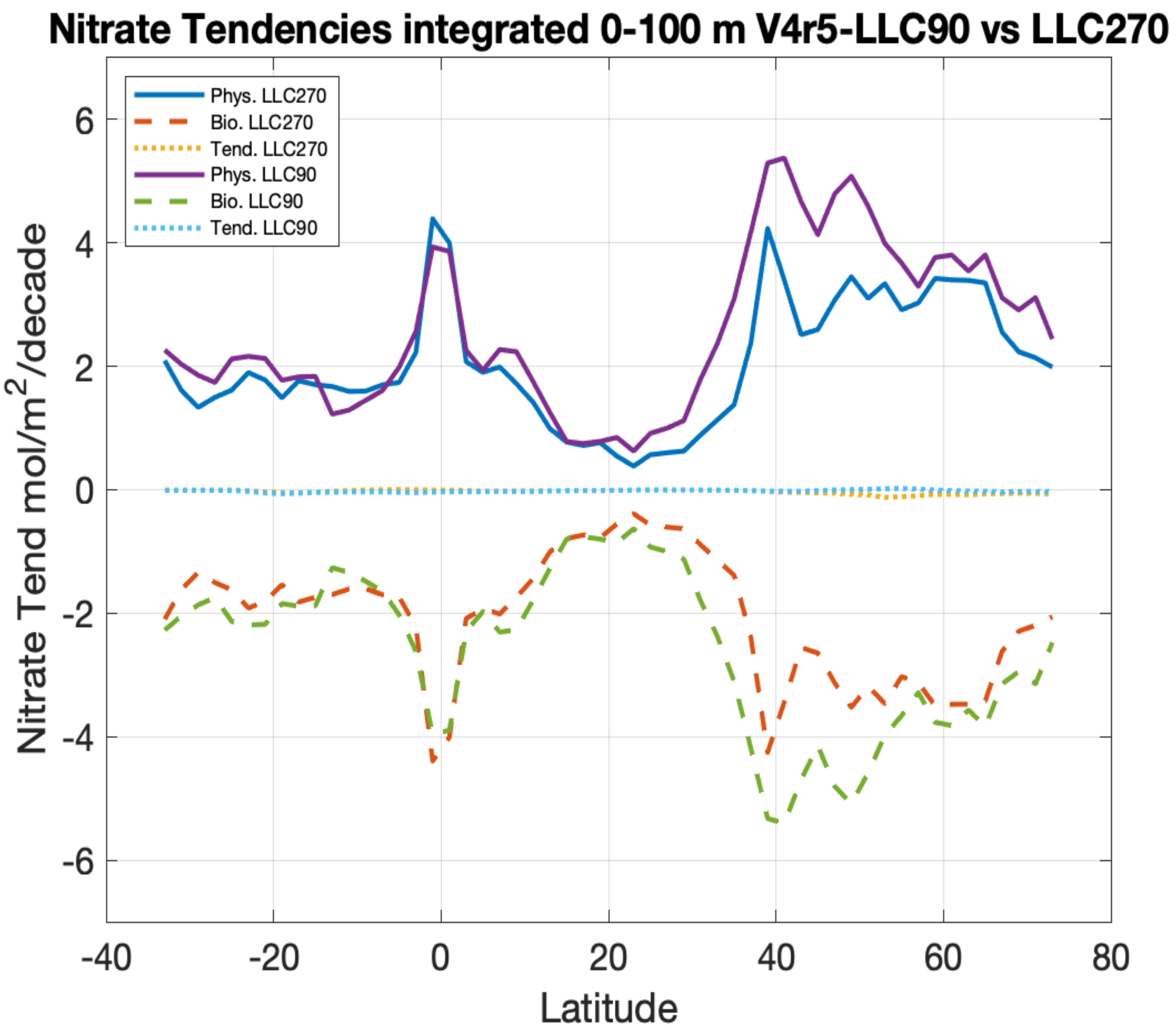
Patterns are qualitatively reasonable, but biases and trends are large relative to low background concentrations in the upper ocean.



Top 100 m

Physical transport supplies and biology consumes and exports nitrate in the top 100 m on a timescale ~ 1 year on average.

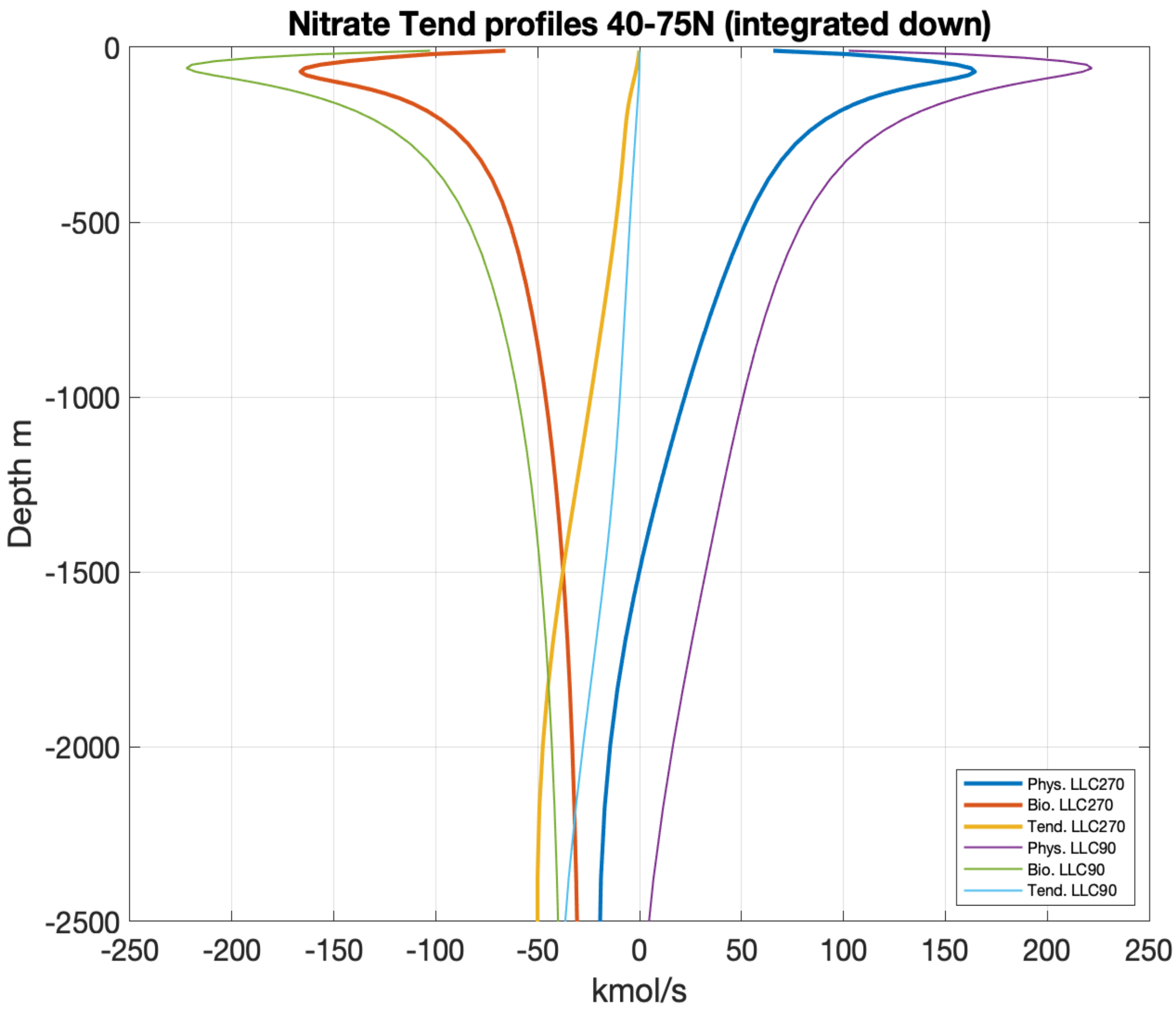
LLC270 has lower new production, weaker biological pump in the Subarctic Atlantic



Subarctic Atlantic Profile

Nitrate tendency of new productivity in the euphotic zone and remineralization at depth mirrors physical transport

The Subarctic Atlantic biological pump is 30-40% stronger in V4r5 than LLC270

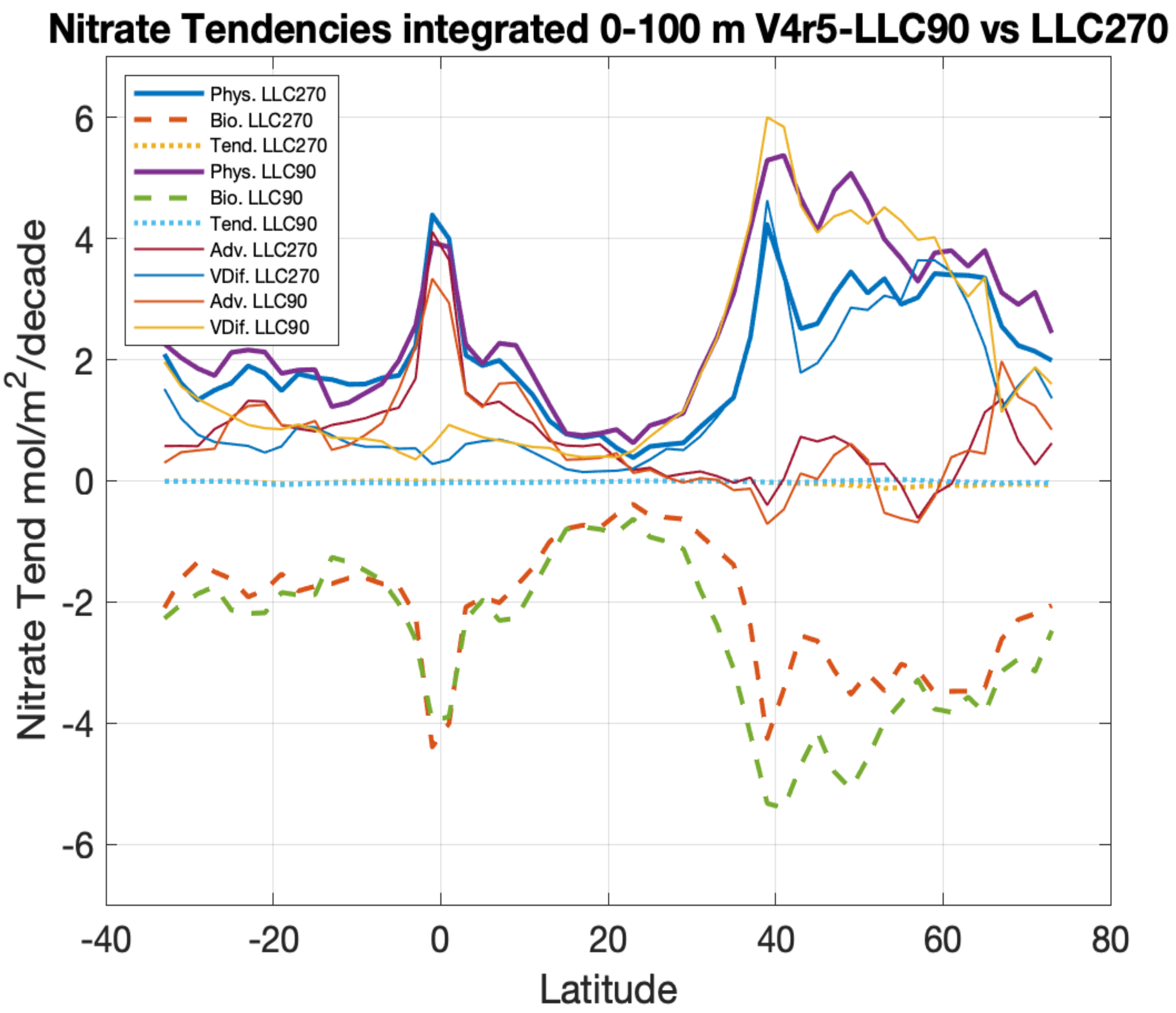


Dynamics of ECCO-Darwin
Zonal-mean Atlantic Nitrate

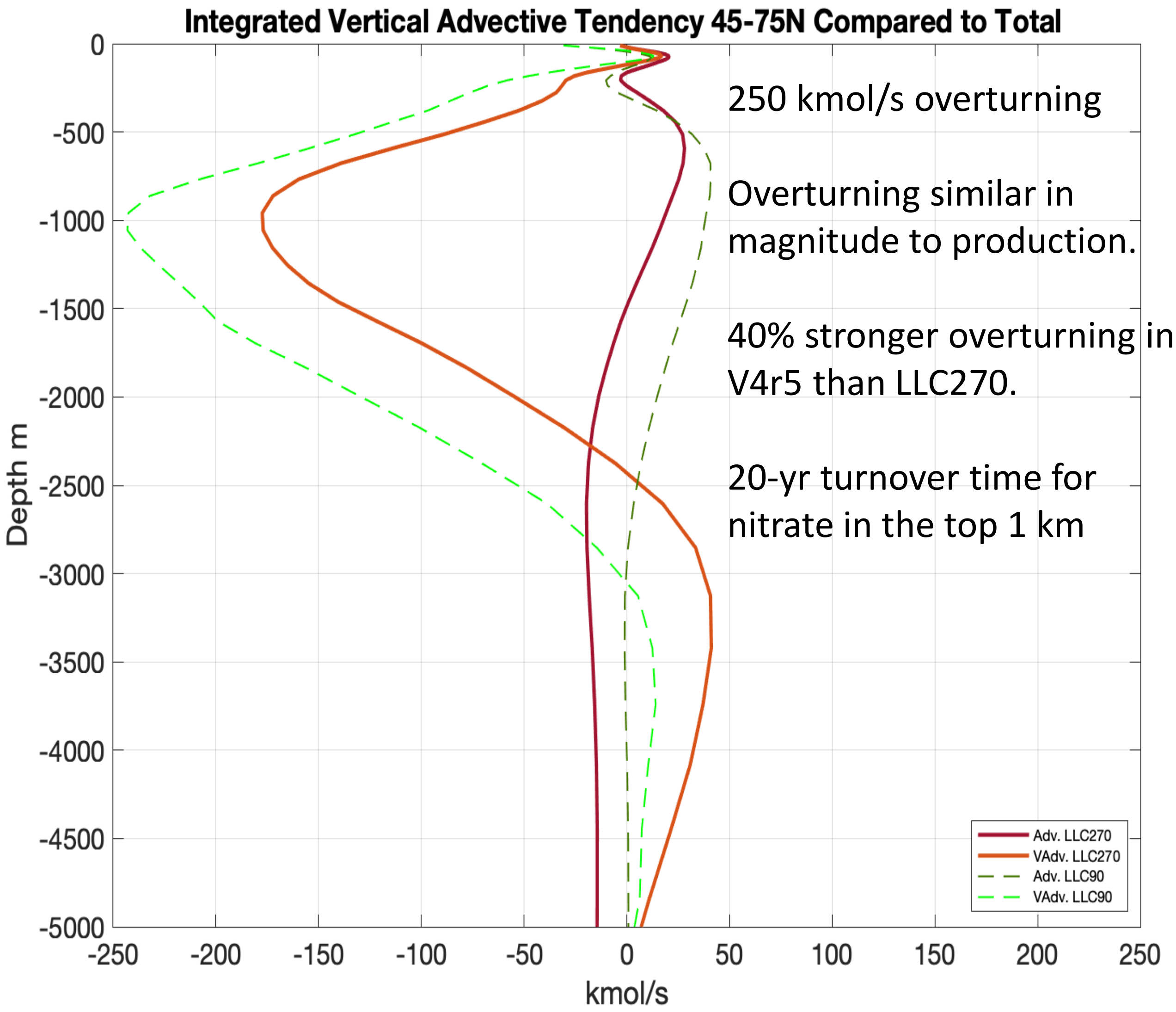
Separating Physical Contributions to New Production in the top 100 m

Vertical mixing dominates flux at 100 m poleward of 30º

Upwelling dominates flux at 100 m equatorward of 30º



Separating Physical Contributions to New Production in the Subarctic Atlantic Profile



250 kmol/s overturning

Overturning similar in magnitude to production.

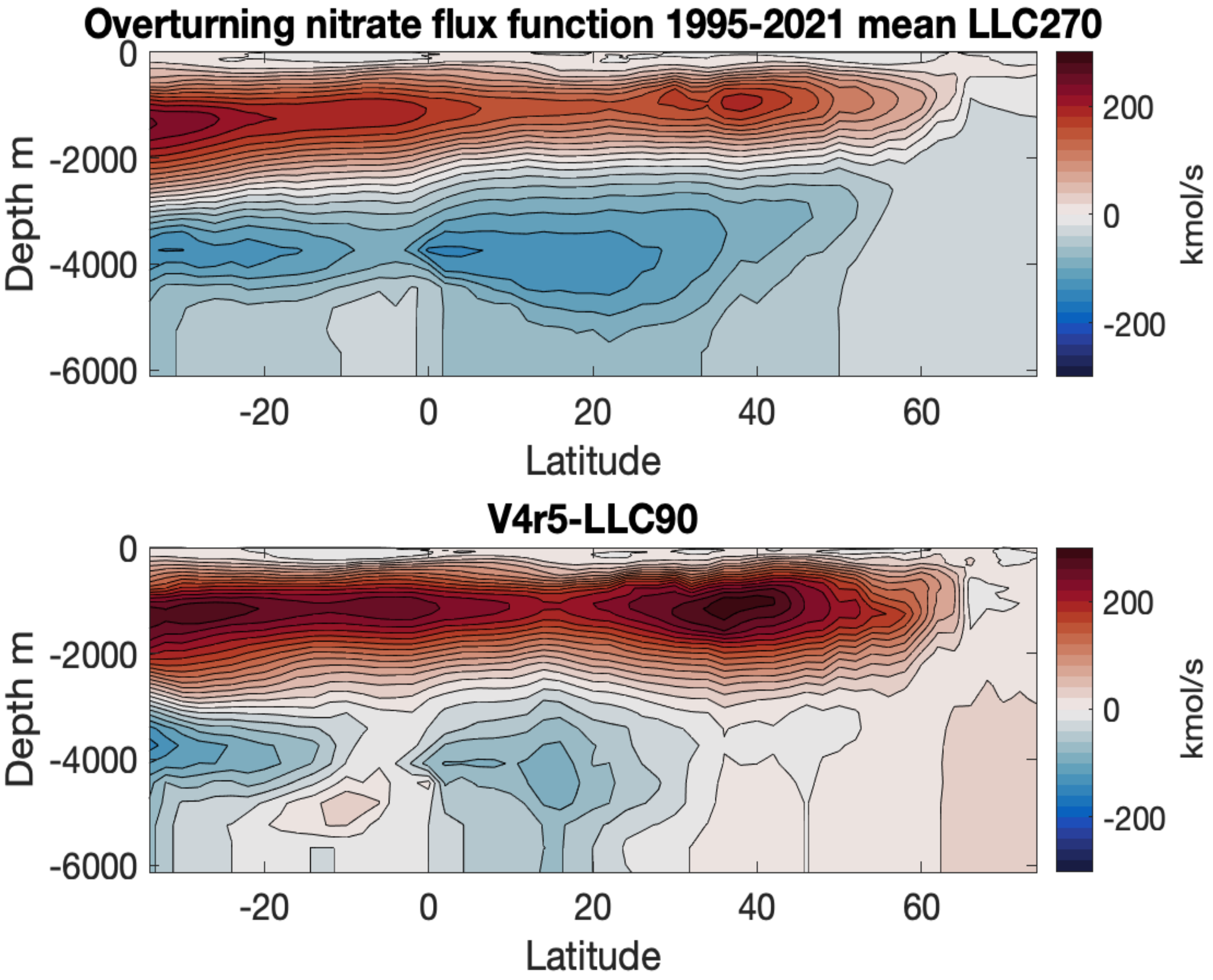
40% stronger overturning in V4r5 than LLC270.

20-yr turnover time for nitrate in the top 1 km

AMOC vertically integrated meridional fluxes

Overturning 50% stronger in V4r5 vs LLC270 and penetrates deeper in the N. Atl.

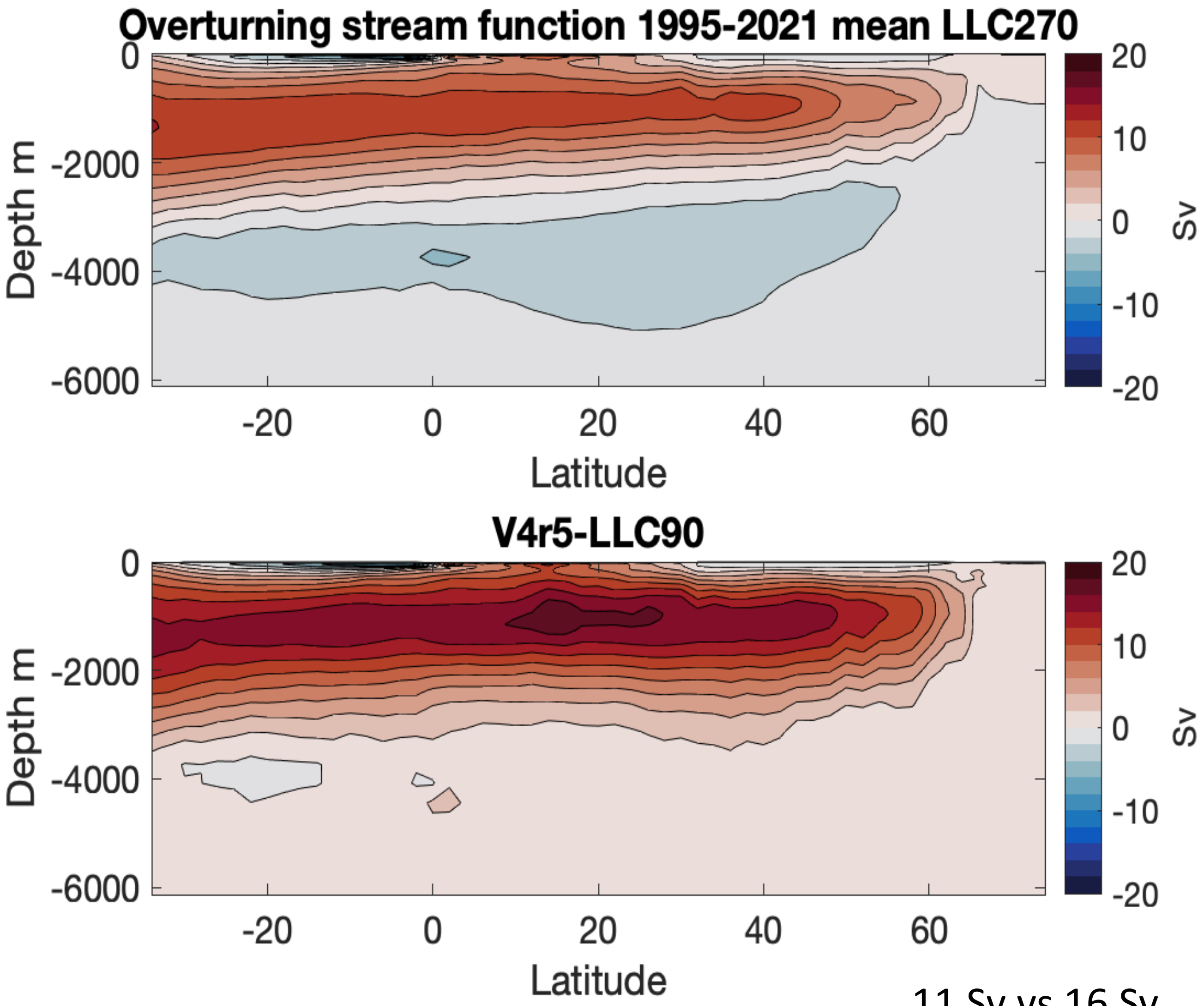
Overturning is stronger at all latitudes in V4r5



190 kmol/s vs 290 kmol/s

AMOC vertically integrated meridional fluxes

Virtually all of the difference between the nitrate transports between V4r5 and LLC270 is due to difference in volume transport



11 Sv vs 16 Sv

Overturning, vertical mixing, and biology/export interact to control the nutrient dynamics of the Subarctic North Atlantic

It remains challenging to simulate and thus quantify the nutrient dynamics of the Subarctic Atlantic and the role of MOC therein

Slower MOC likely explains low and declining Subarctic Atlantic nitrate in LLC270 and presumably impacts other biogeochemical tracers too

Thanks

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