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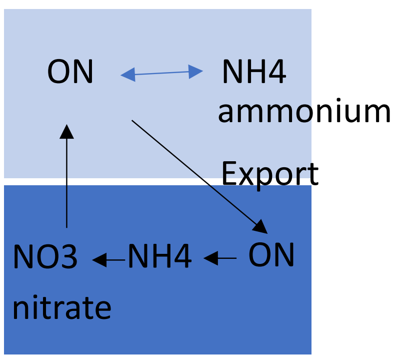
Elucidating the role of ocean circulation in changing North Atlantic nutrients and biological productivity

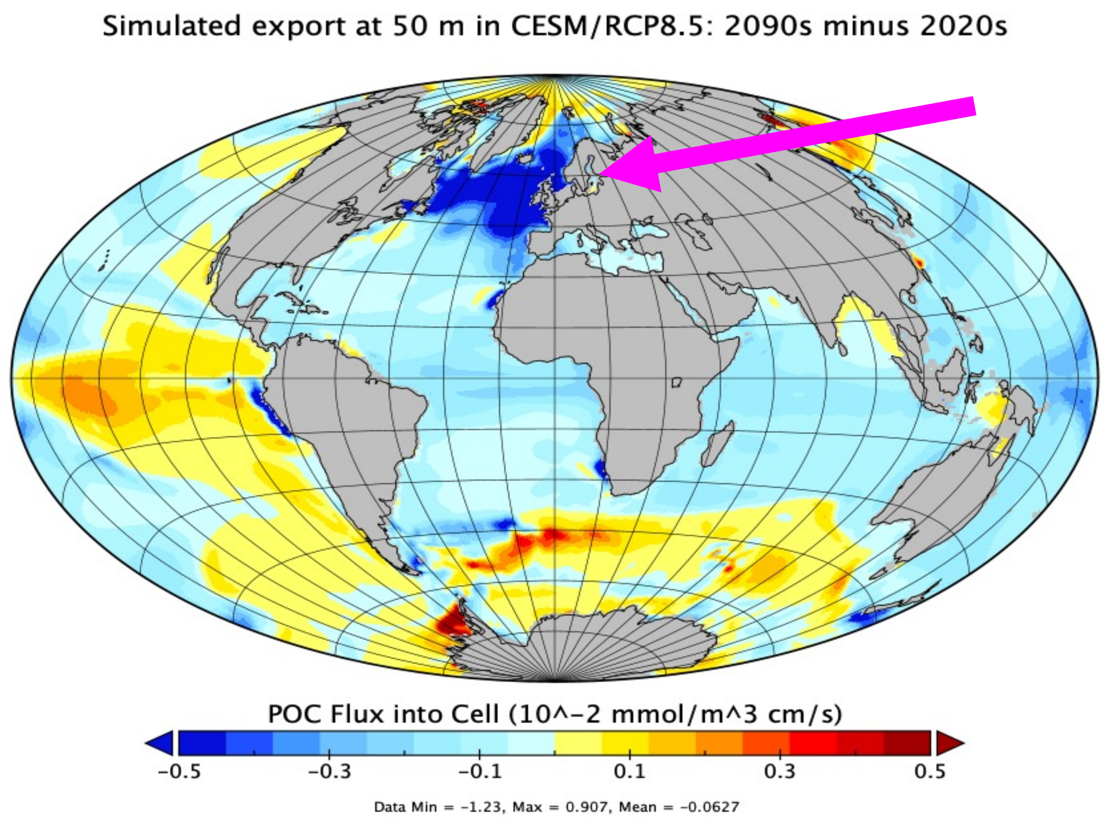
Funded by
NASA 2020 New Investigator Program in Earth Science
NASA Physical Oceanography Program

MOTIVATION

Earth system models indicate that the Subarctic Atlantic biological productivity is particularly sensitive to global warming

Schematic **part** of the N cycle





PRIOR CONTRIBUTIONS

Four papers…

2019

2020

2023

2023

Malte Jansen
UChicago

Jay Brett
JHU/APL

How will marine biogeochemistry and ecosystems evolve in a changing climate?

How does the ocean physics influence marine biogeochemistry and ecosystems?

SUBARCTIC ATLANTIC OCEAN

Seasonal cycle

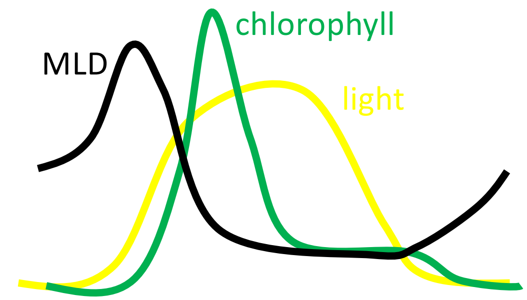
Phytoplankton require light and nutrients such as nitrate (NO_3^-) to grow.

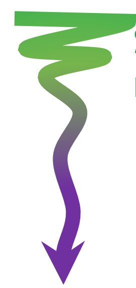
NO_3^- is low at the surface and replete at depth during summer.

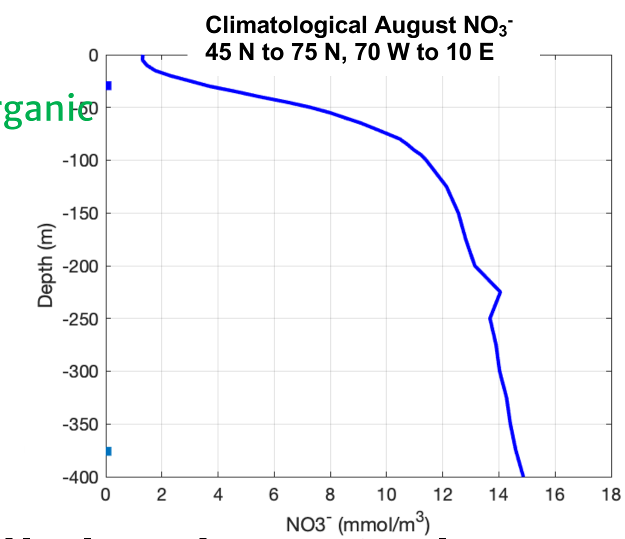
Wintertime vertical mixing replenishes NO_3^-

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

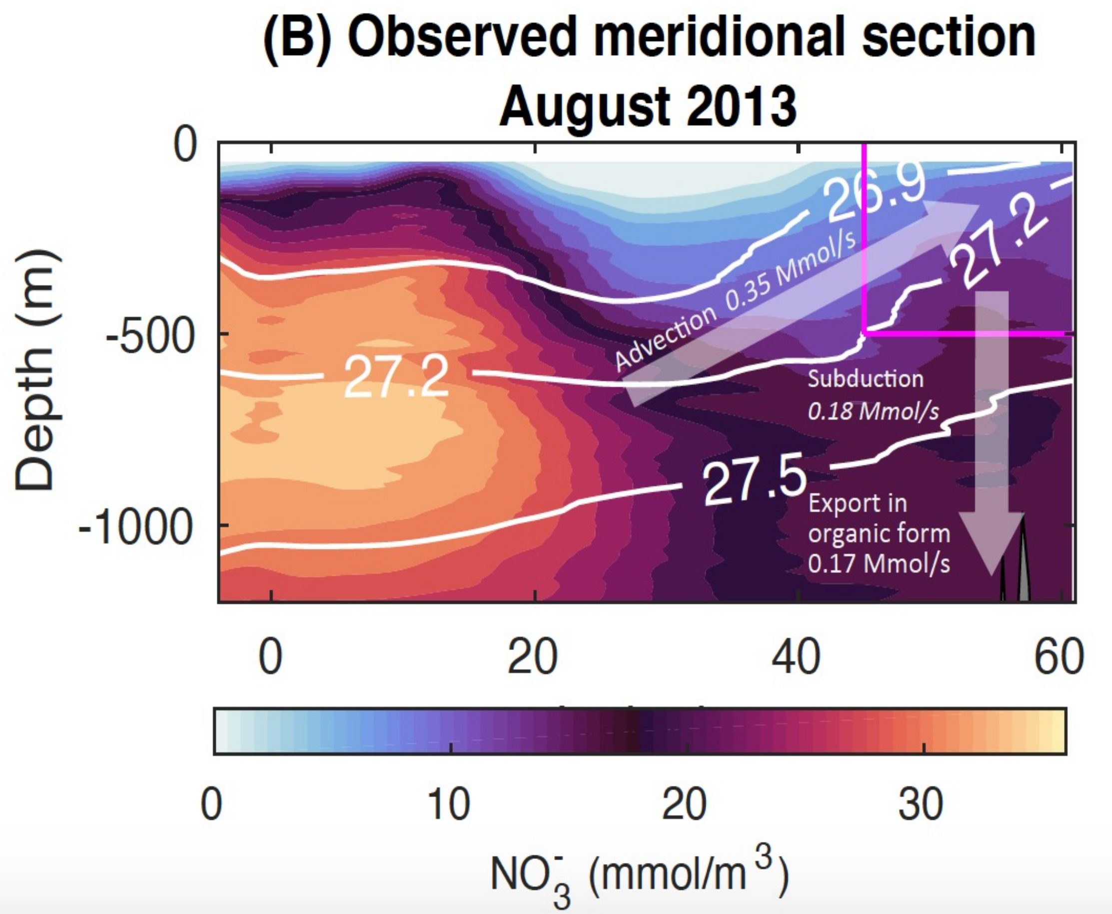
SUBARCTIC ATLANTIC OCEAN

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?

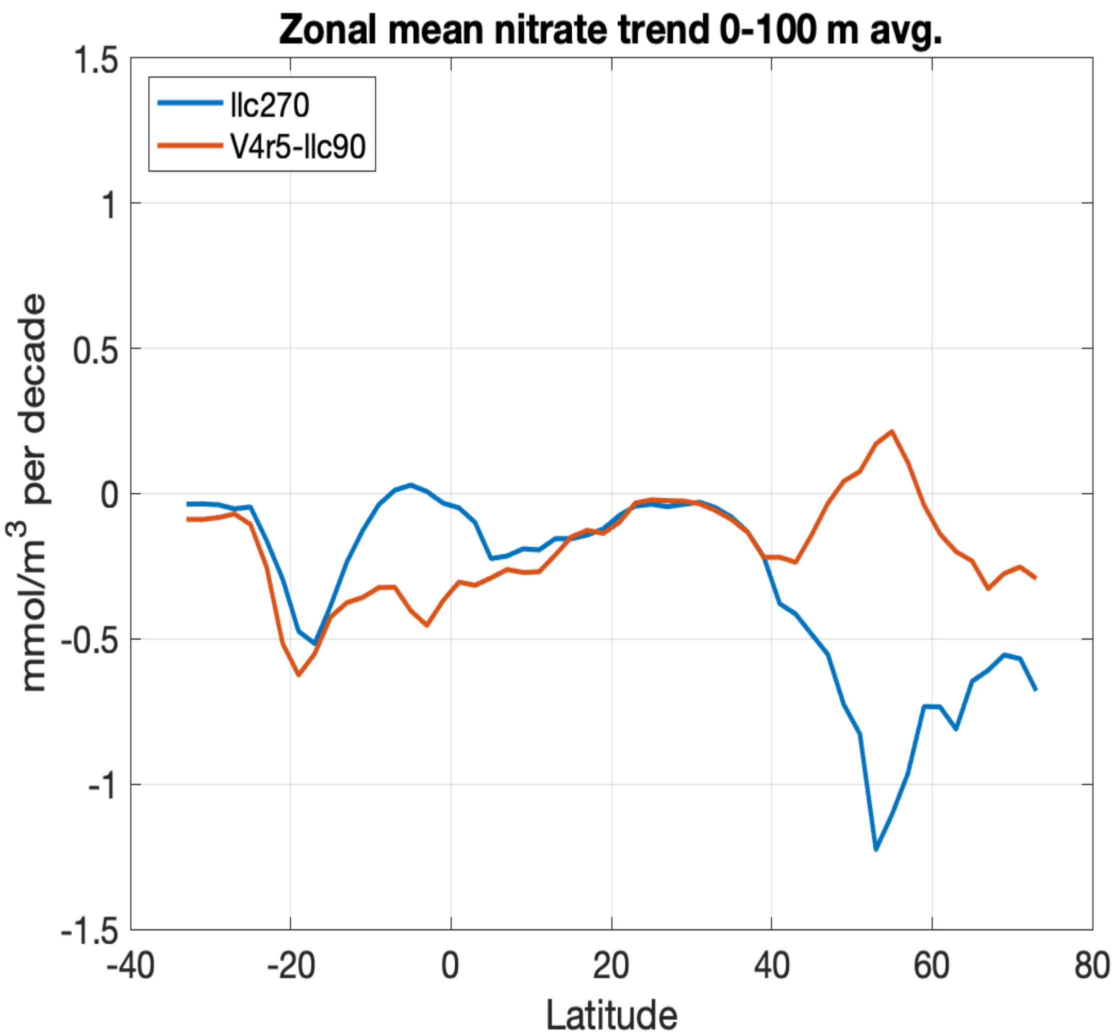
We can only understand it after we can model it.

Evaluation of ECCO-Darwin
Zonal-mean Atlantic Nitrate

Annual mean

Below 500 m:
Nitrate > 18 mmol/m^3
Trends ~0.1-1 mmol/m^3/decade
Biases ~1-3 mmol/m^3 are small

Patterns are qualitatively reasonable in the upper ocean, but exhibit large biases and trends compared to low reference concentrations.

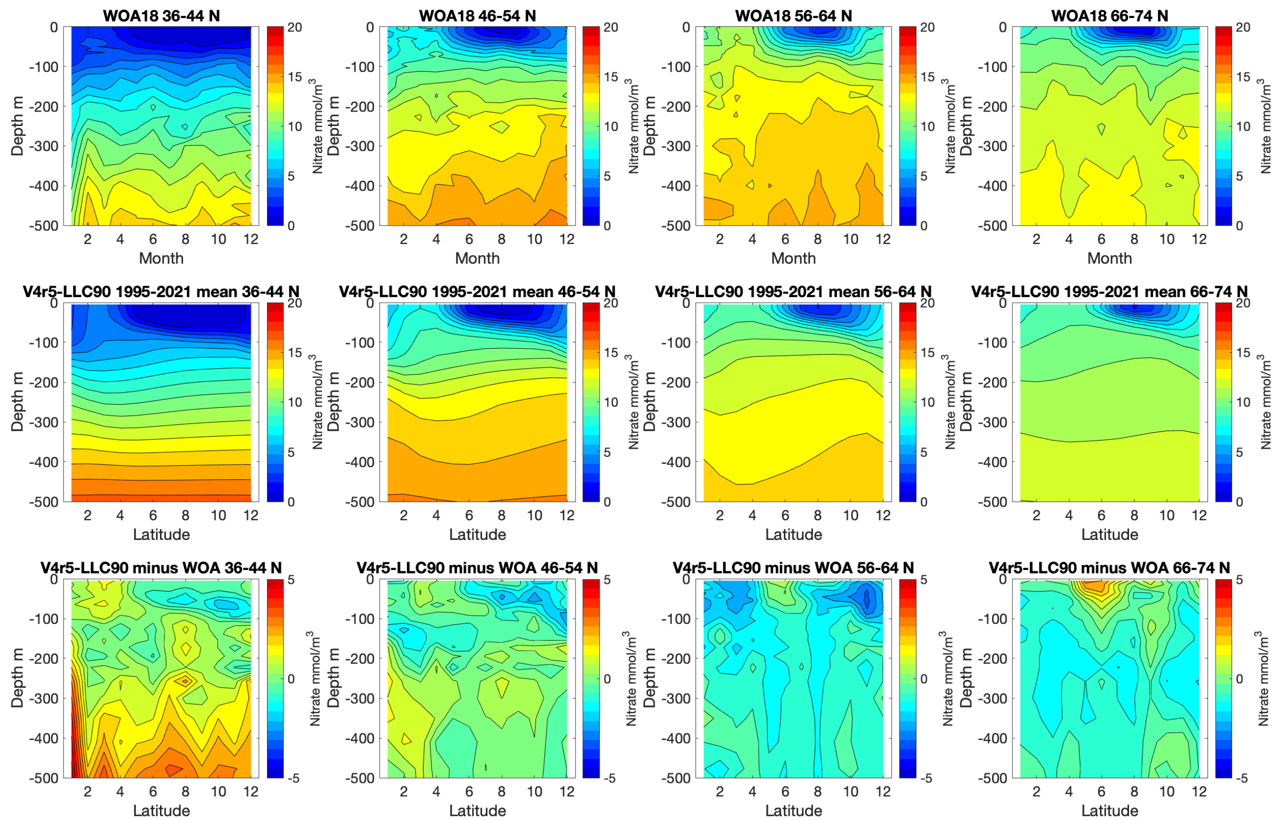


Evaluation of ECCO-Darwin
Zonal-mean Atlantic Nitrate

Seasonal cycle in the Subarctic Atlantic

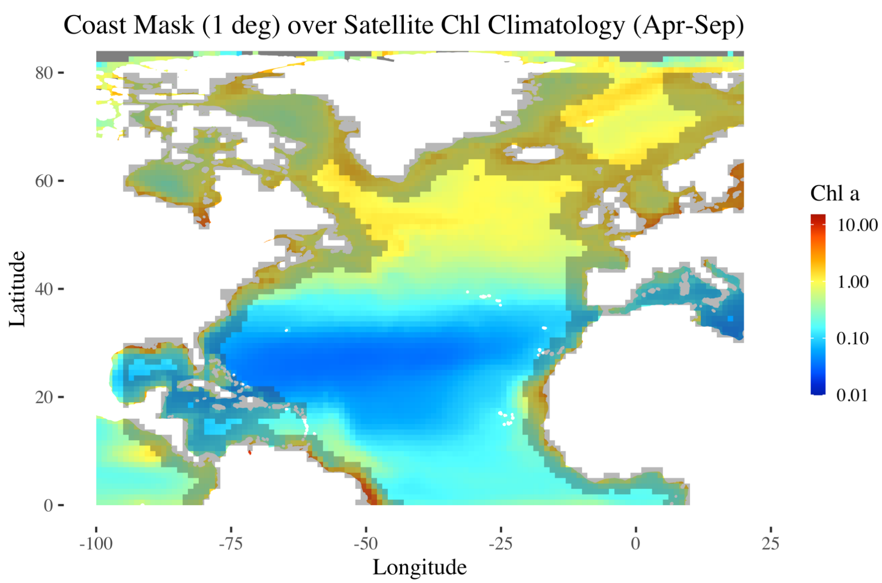
V4r5 is fairly realistic

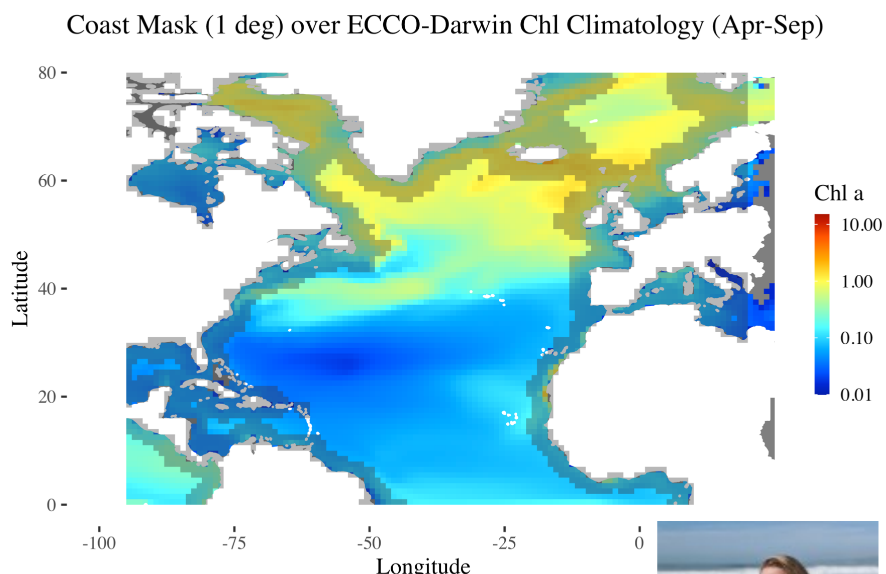
LLC270 (not shown) has low-bias that is most pronounced in winter, damped seasonal cycle



Evaluation of ECCO-Darwin
Zonal-mean Atlantic Nitrate

State estimates qualitatively capture climatological open-ocean chlorophyll





Low modeled growing season chlorophyll in LLC270 vs satellite qualitatively consistent with low-nutrient biases

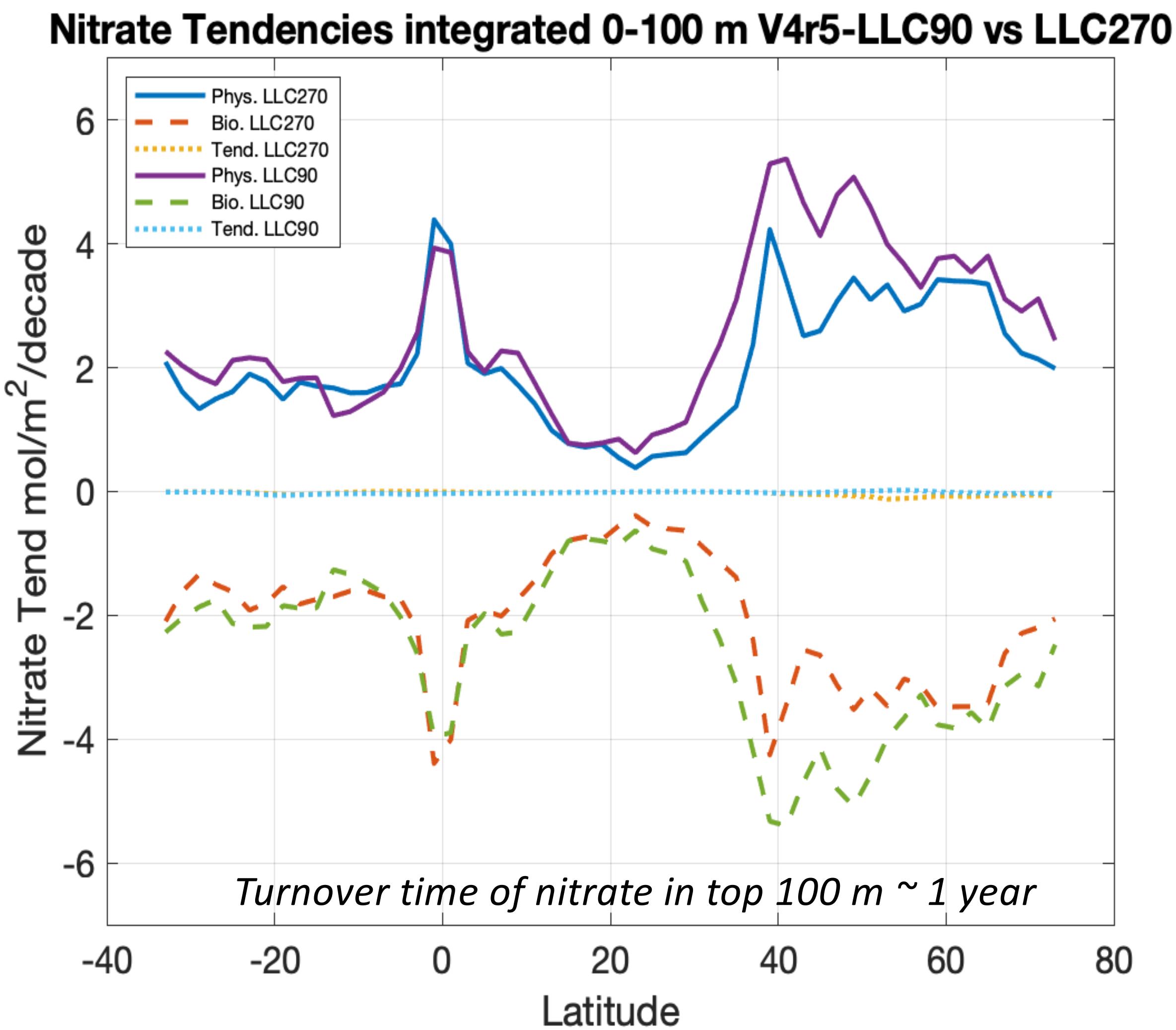
Post-doc Casey Schine
Now at Middlebury

Dynamics of ECCO-Darwin
Zonal-mean Atlantic Nitrate

Top 100 m

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

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

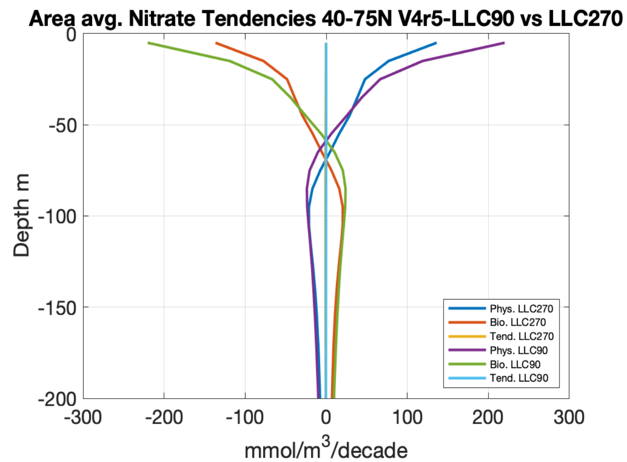


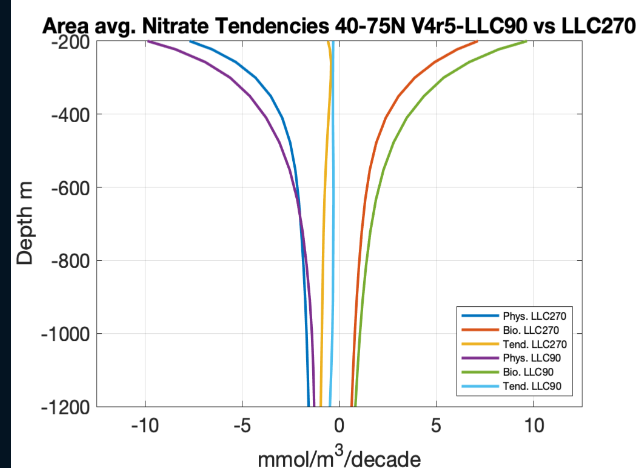
Dynamics of ECCO-Darwin
Zonal-mean Atlantic Nitrate

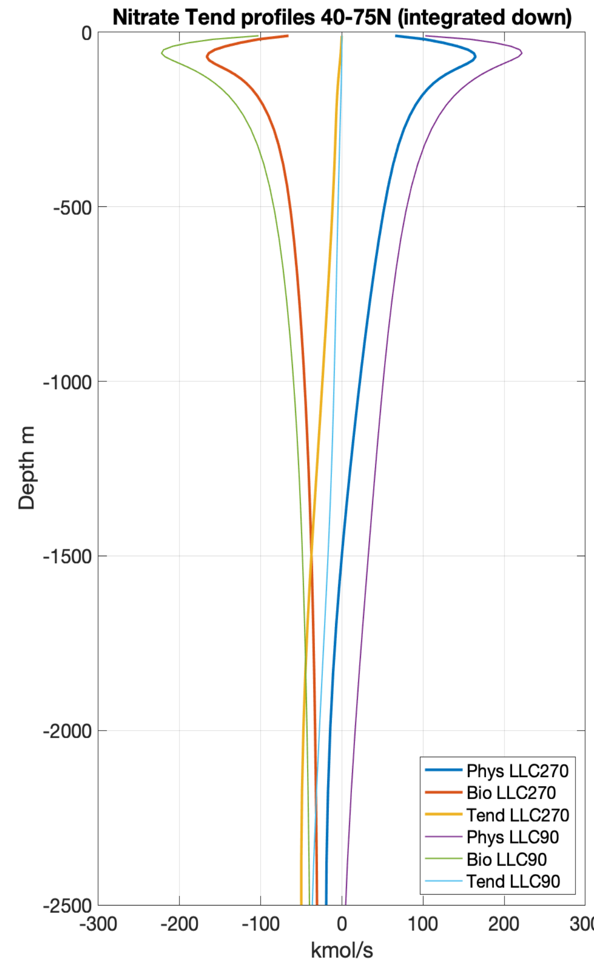
Subarctic Atlantic Profile

The nitrate tendency due to new productivity in the euphotic zone and remineralization at depth largely mirrors physical transport

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





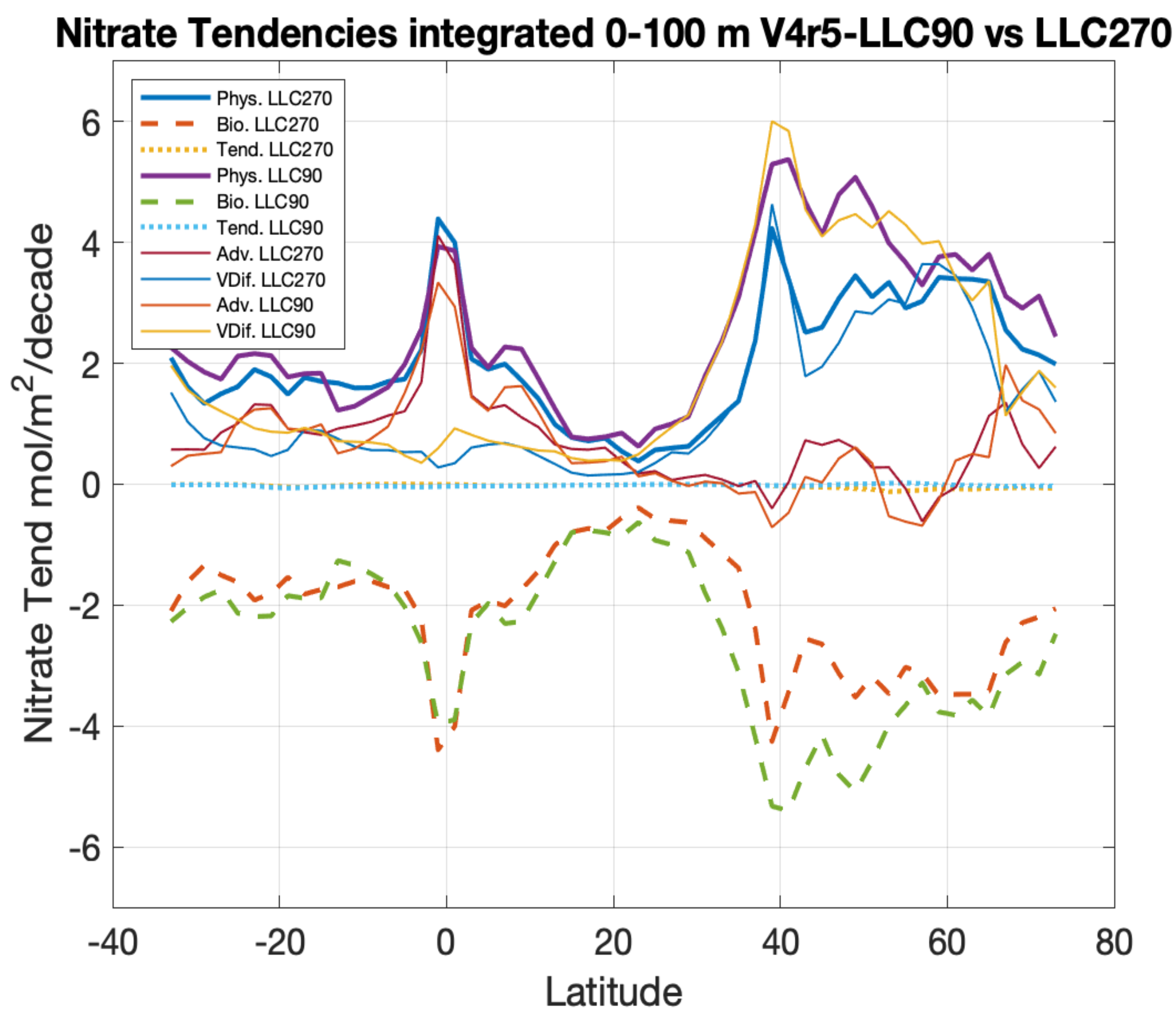


Dynamics of ECCO-Darwin
Zonal-mean Atlantic Nitrate

Separating Physical Contributions to New Production in the top 100 m

Vertical mixing dominates flux at 100 m poleward of 30°

Upwelling dominates flux at 100 m equatorward of 30°



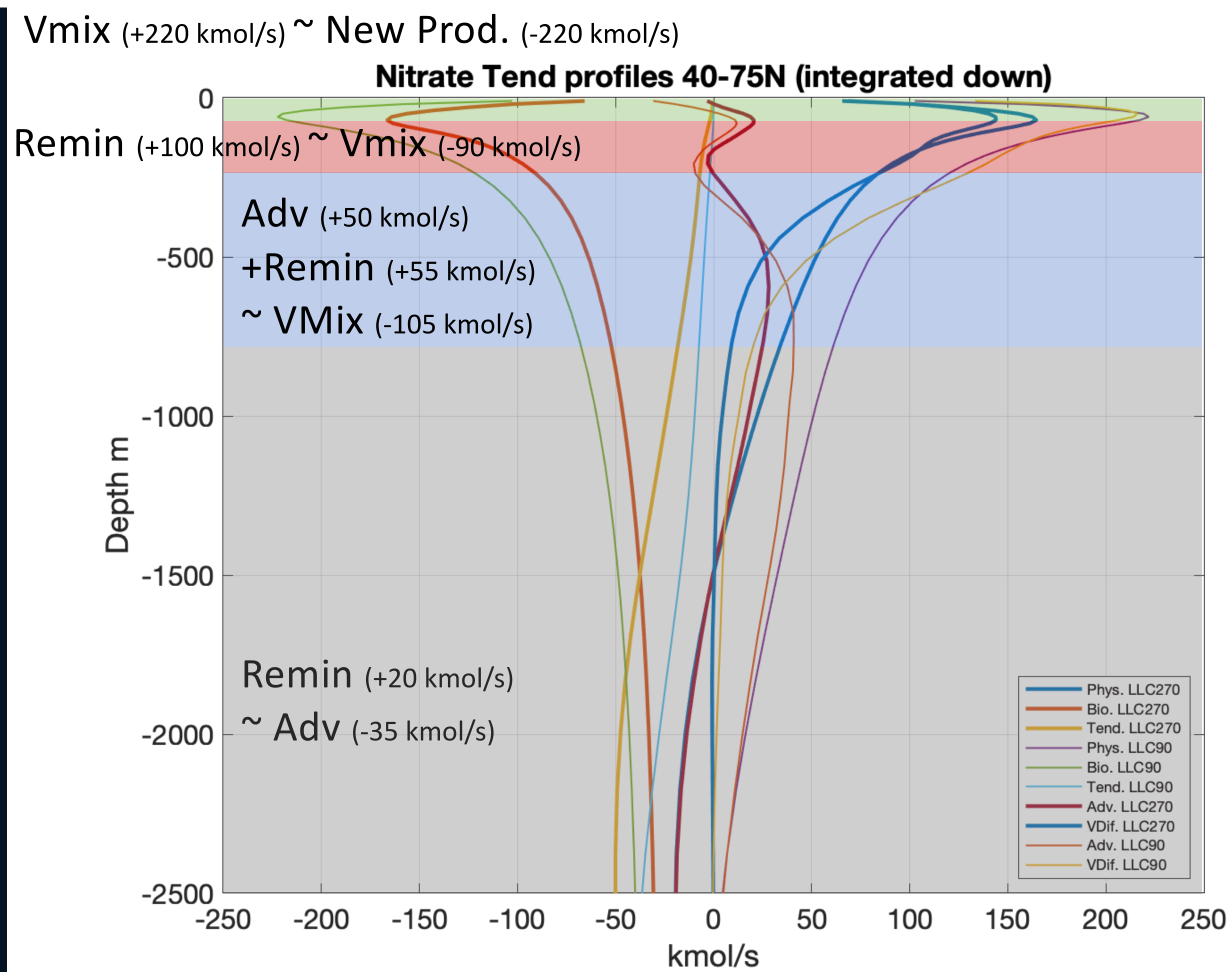
Dynamics of ECCO-Darwin
Zonal-mean Atlantic Nitrate

Separating Physical Contributions to New Production in the Subarctic Atlantic Profile

Mixing drives the shallow cycle

Advection drives the deep cycle

Dynamics are qualitatively similar in V4r5 and LLC90



Thanks

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