Connecting AMOC variability and biological cycling in two Earth System Models

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1. Motivating Questions

Large interannual variations seen in biological cycling in various parts of North Atlantic, occurring on similar time scales as SST variations (AMO Index)

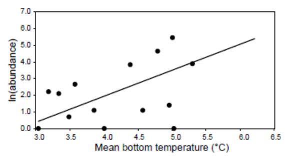


Fig. 17. Correlation of 0-group haddock (*Melanogrammus aeglefinus*) and mean bottom water temperatures off West Greenland, averaged over the number of haul- in the given year; data: 1989–2003; $r^2 = 0.40$, $p<0.0$

Example: haddock associated with warm bottom temperatures (Stein, 2007)

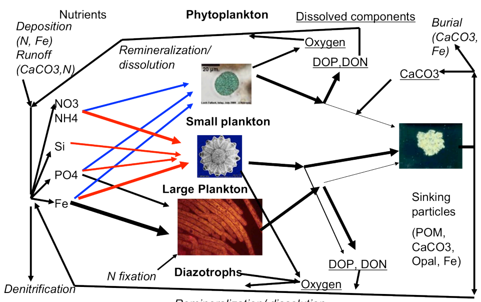
Do interannual changes in the AMOC drive changes in primary productivity big enough to explain such large variations?

Are such changes robust across physical models?

Is there any predictability of such changes?

2. Model description-common elements

Two Earth System Models with identical
- -Atmosphere
- -Land
- -Sea ice
- -Ocean biogeochemical cycling



Schematic of nutrient flows in biogeochemical model.
Key pieces of model to understand.
-North Atlantic either limited by nitrogen or light.
-Parameterized grazing results in a response to changes in limitation such that

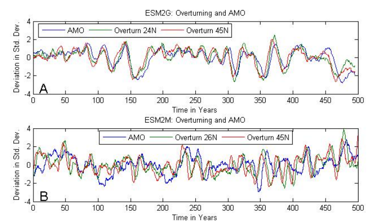
Doubling growth rate — Small phytoplankton double
— Large phytoplankton increase 8x (cubic in growth rate)

3. Model description- differences

Different ocean models

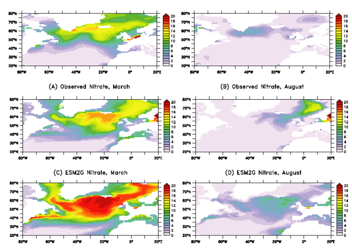
ESM2M: Level-coordinate B-grid ocean
-Resolves transition layer below mixed layer.
-Does not do a good job representing overflows, narrow straits, fine variations in MLD

ESM2G: Isopycnal coordinate C-grid ocean
-Strengths and weakness inverse of level coordinate model.



ESM2G: Close relationship between AMO Index and AMOC. AMOC leads by 4 years.

ESM2M, less close relationship. Peak lead correlation at about 4 years.



Observations: nitrate drawn down over summer.

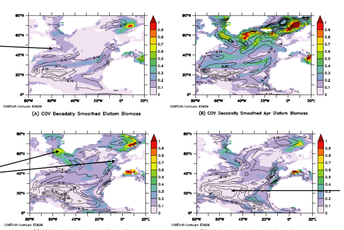
ESM2G qualitatively similar.

ESM2M retains nitrogen.

4. Biogeochemical variability

Interannual coefficient of variation of diatom (large phytoplankton) biomass.
Much more sensitive to changes in growth rate…

But still little variation in annual mean in ESM2G (colors) or ESM2M (contours)



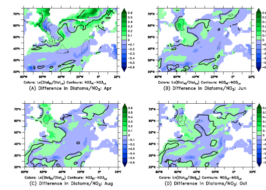
Larger variations when individual months are considered.

ESM2G has more variance at high latitudes.

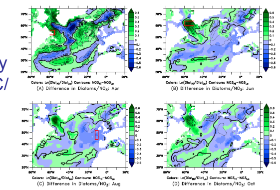
ESM2M has more variance at low latitudes, where biomass is low

5. Ecosystem variability in sync with AMOC

Ln(High AMOC conditions/Low AMOC Conditions) for diatom biomass (colors), nitrate (contours)



ESM2M: Variability weakly related to AMOC/ nutrients.



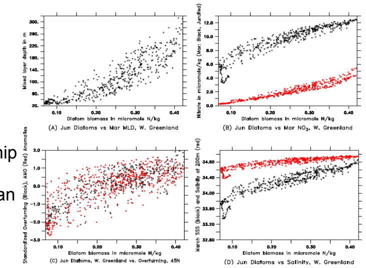
ESM2G: Variability strongly related to overturning. Significant differences in nitrate track differences in biomass.

Because ESM2G is more (realistically) nitrate-limited, it shows more response to changes in nitrate supply.

6. West Greenland variability in ESM2G

Biomass tracks Winter MLD

Better relationship with overturning (convection), than AMO



Deep winter MLD associated with higher nitrate persisting until summer

High biomass associated with low salinity stratification.

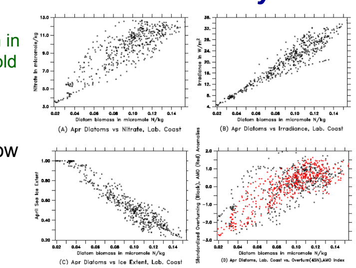
High (low) surface salinity
↓
Deep (shallow) convection
↓
Warm (cold) SSTs and High (low) surface nitrate
↓
High (low) diatom biomass. Variability over a factor of 5.

Variability consistent with Great Salinity Anomaly impacts on temperatures, fisheries. Some questions about whether amplitude of variability in ESM2G is realistic.

7. Labrador Coast variability in ESM2G

Sevenfold variation in biomass with fourfold variation in nitrate

High biomass= low sea ice extent.



Better correlation with light.

Better relationship with AMO index than overturning.

High overturning → Warmer SSTs → Earlier ice meltback/Spring bloom

8. Conclusions

One of GFDL's ESMs is capable of generating large variability in ecosystems in response to changes in AMOC.

Salinity anomalies lead the AMOC and may provide predictability…

But response are far from robust across models. Need to get both physics and factors limiting biology right.

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