Ocean ecosystems and AMOC variability

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Ecosystem variability plausibly tied to AMOC


Suggests changes in mixing might be involved, with linkage to Atlantic Multidecadal Oscillation (AMO).
Paradigmatic regime shift: North Pacific

- Regionally coherent
- Temporally closely spaced
- Results seen across multiple trophic levels.
  - Turtles
  - Salmon
  - Pacific halibut
  - CalCOFI zooplankton

Hare and Mantua, Progr. Oceanog. 2000
GFDL’s Ocean BGC model (TOPAZ)

- **Nutrients**
  - NO₃, NH₄, Si, PO₄, Fe

- **Phytoplankton**
  - Small plankton
  - Large Plankton

- **Dissolved components**
  - Oxygen
  - DOP, DON

- **Remineralization/dissolution**
  - Deposition (N, Fe)
  - Runoff (CaCO₃, N)

- **Diazotrophs**

- **Zooplankton** (parameterized)

- **Sinking particles** (POM, CaCO₃, Opal, Fe, Lith)

- **Burial** (CaCO₃, Fe)

- **Remineralization/dissolution**

- **Denitrification**

- **N fixation**

References:

Dunne et al., 2010, Dunne 2013.
West Greenland vs. Labrador

Higher biomass throughout spring/fall
Similar signal for overturning, AMOI.
Driven by higher nutrients associated with deep convection.

Higher biomass during spring
Similar signal for overturning, AMOI.
Driven by higher light associated with warming.

Gnanadesikan, Dunne and Msadek, J. Mar. Sys., 2014
What do observations show?

How are functional groups of phytoplankton changing over N. Atlantic?

Dataset- Continuous Plankton Recorder dataset

www.safhos.ac.uk
Seasonal Dependence

Different seasonal cycles match standard picture of North Atlantic bloom.

Overall magnitudes change… but at different times.
- Diatoms high at beginning, drop by 1970s.
- Dinos also drop but return in 1990s
- Copepods drop around 2000
- Forams increase around 2000
Probability of finding coccolithophores in the N. Atlantic increases by an order of magnitude!

Rivero-Calle et al., Science, 2015

Interdecadal variability of Trichodesmium in Bay of Biscay (high during the 1980s).

Rivero-Calle et al., GBC., 2016
Random forest

- Take a random subset of variables, data.
- Build a regression tree-subsetting data one variable at a time.
- Examine error in predicting points not included.
- Repeat over many trees.
- Aggregate results
Variable importance plots show how often a variable is included/how much error eliminating it from the analysis causes

Partial dependence plots show nonlinear relationship between predictor and predictand.
AMO partial dependence

High values often at high and low values of AMO
Conclusions

• Both models and observations link biological variability to the AMO… and thus implicitly to AMOC…
• But in some cases the key is convection, in others it’s temperature.
• Linkages are likely to be dependent on region and functional group.
• No evidence at presence for a “regime shift” as has been seen in the Pacific.
Carbon dioxide dependence

Trend is relatively robust.

Local CO2 is a top predictor.

Roughly a factor of 3 increase attributable to increase in CO2 over fifty years.
Compilation of laboratory datasets...

• Over pCO2 ranges seen in last 50 years over North Atlantic.

• A significant subset of laboratory measurements also show increase in growth
Trichodesmium Variability

- Found in North Atlantic in relatively cold waters.
- Big increase in 1980s in Bay of Biscay—usually towards end of the year.
- Doesn’t seem to correspond to changes in diatoms...
Rain in Sahel
Dust in Barbadoes
Trichodesmium in Bay of Biscay.
Speculation: Dust source + atmospheric pathway?

Evidence at present is circumstantial...

But if true would imply Trichodesmium in cold waters are sensitive to dust supply, while diatoms are not.

Does this imply nitrogen fixation (contrary to laboratory results)?