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ANALYSIS OF NUTRIENT BUDGETS AND CARBON EXPORT IN THE EASTERN AND WESTERN SUBTROPICAL NORTH ATLANTIC OCEAN

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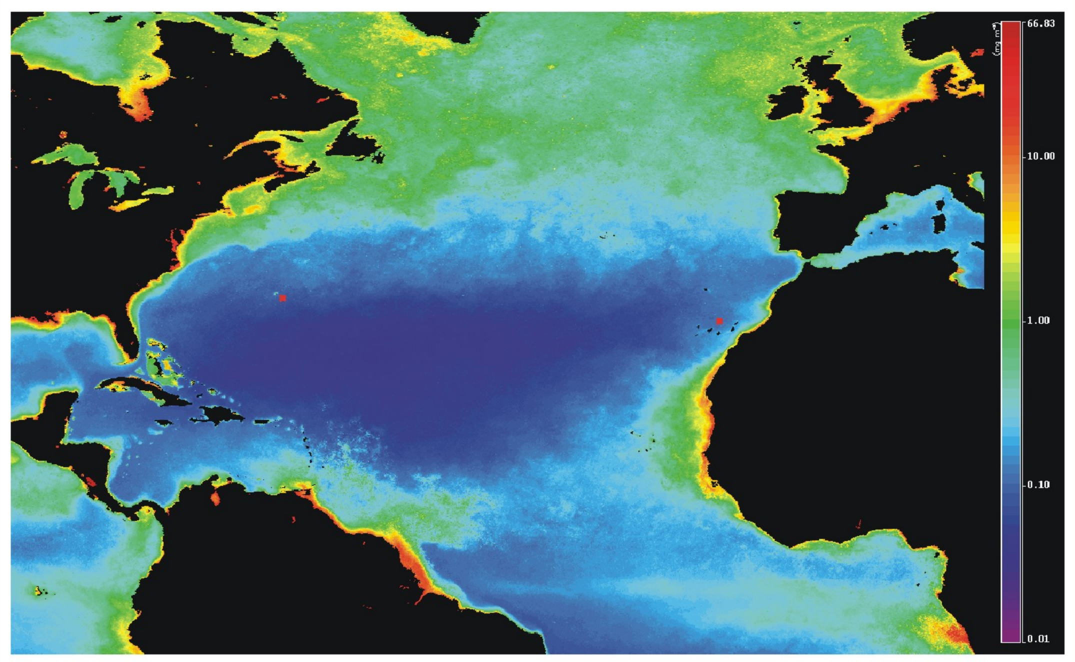
Project outline

Introduction

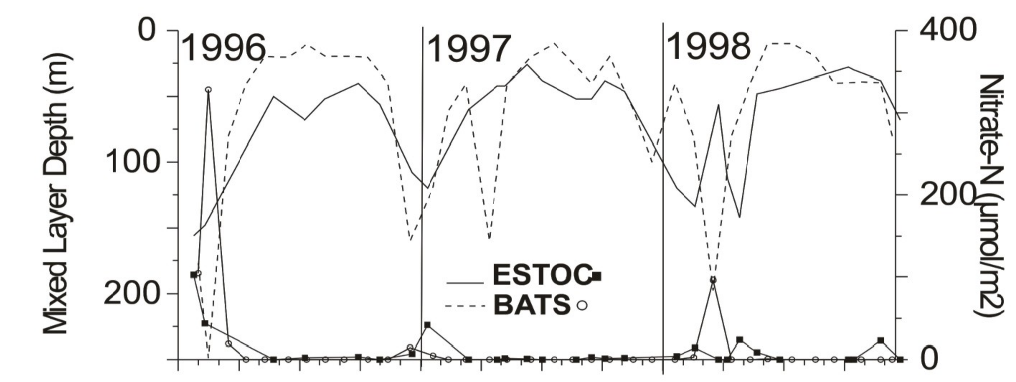
The comparison of the seemingly similar North Atlantic subtropical ocean sites shows that a lower input of new nutrients does not result in lower primary production and phytoplankton biomass *per se* but rather influences the removal efficiency (export ratio) of biologically produced carbon into the ocean's interior. The lower f-ratio found at ESTOC may be characteristic of the eastern basin of the subtropical North Atlantic as a whole, thus pointing to a dichotomy of biological carbon pump efficiency in the subtropical North Atlantic. In order to derive values of new production from satellite derived phytoplankton biomass and primary production we need to advance our understanding of the biological pump in the subtropical North Atlantic. The opportunity rendered by the data sets of the two time-series stations located on either side of the subtropical North Atlantic gyre is unprecedented, and much can be learned from a more thorough comparison of their carbon and nutrient budgets. We believe that the understanding gained at the two sites, which appear to be "end-members" with regard to nutrient supply and carbon export, will strongly constrain satellite algorithms for the marine carbon cycle in the subtropical North Atlantic Ocean.

Satellite data input: chl-a, PP, SSH, SST



e.g. SeaWiFS chl-a 2003 yearly mean. Positions for BATS and ESTOC (red stars).

In situ data:

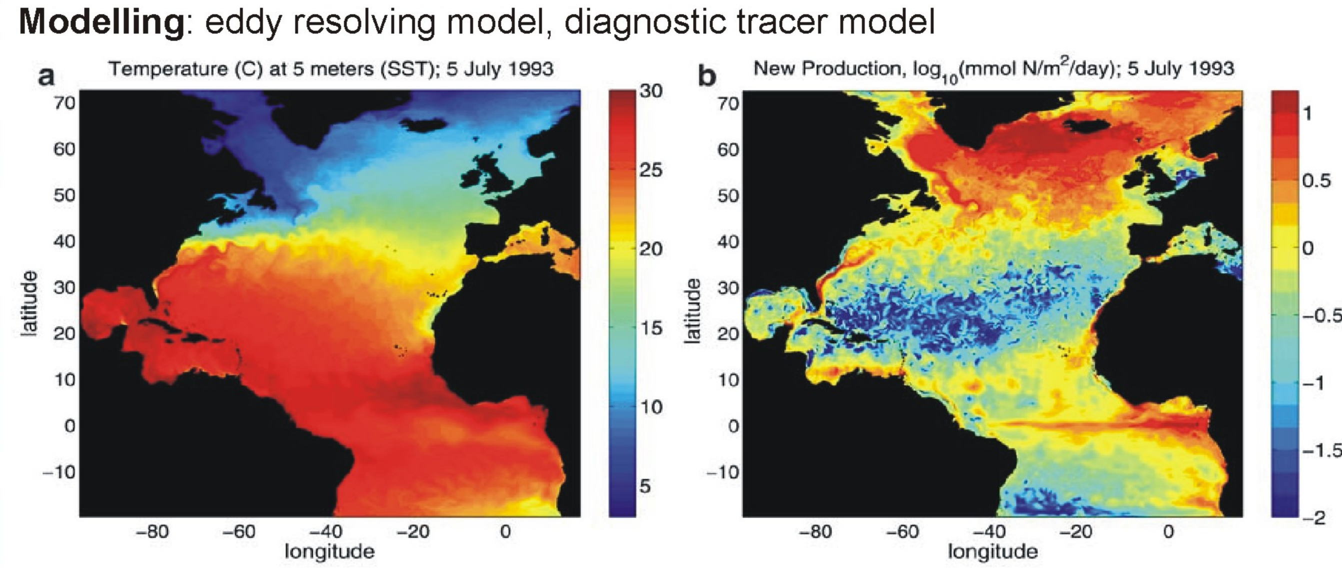


Comparison of mixed layer depth, the depth at which the potential density exceeds the surface value by 0.125 kg m^{-3} (upper curves) and mixed-layer integrated nitrate concentration (lower curves) for ESTOC and BATS (Neuer et al., 2002).

Goals:

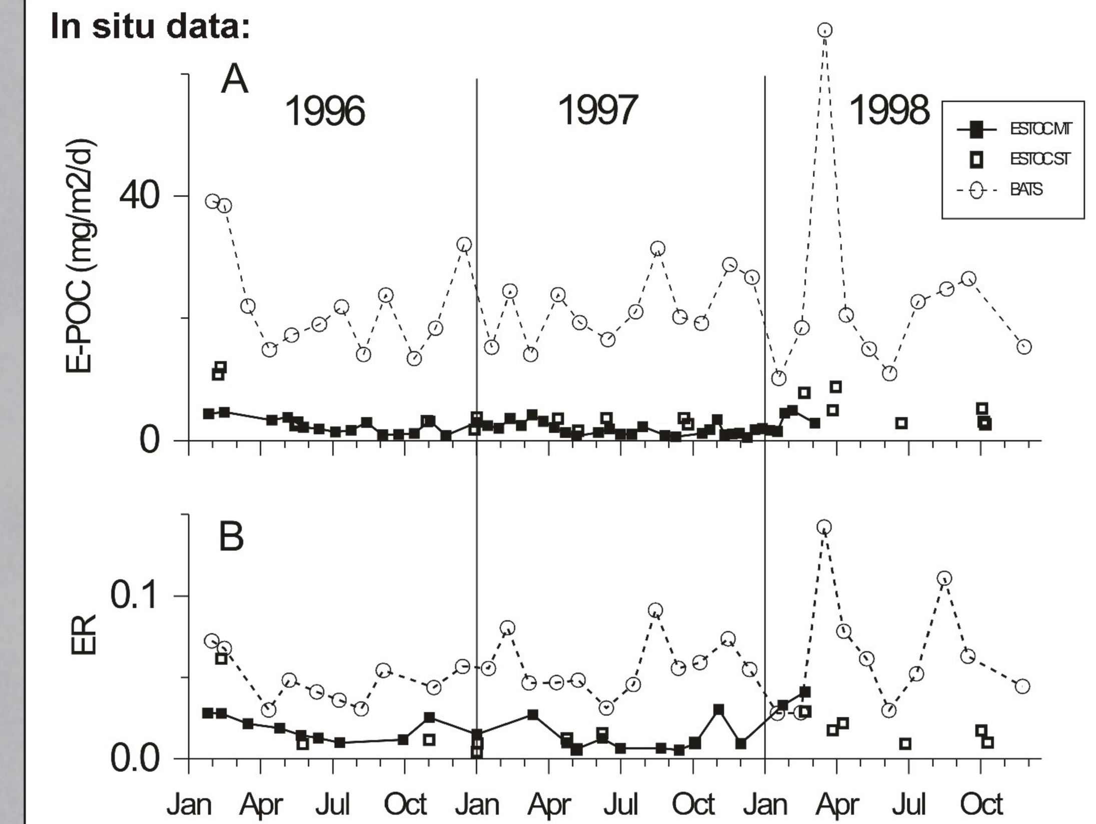
- Satellite ocean color, altimeter and temperature data at the two time-series stations will be analyzed to determine differences between the two sites in eddy-scale spatial and temporal variability of phytoplankton biomass and primary production.
- To conduct a synthesis and comparative analysis of in situ biogeochemical measurements at the two time-series stations.
- Development of a diagnostic model of tracer distributions at the two stations in order to infer carbon and nutrient sources and sinks.
- Analyze output of marine nutrient cycling models embedded in high resolution, eddy-resolving models of the North Atlantic in order to (a) evaluate their skill at simulating the BATS and ESTOC data and (b) suggest new biogeochemical parameterizations.
- Quantifying organic carbon export in the eastern and western part of the Northatlantic subtropical gyre.
- Evaluate existing f-ratio models and develop new ones if needed.

Modelling: eddy resolving model, diagnostic tracer model



e.g. eddy resolving model: Snapshots of (a) temperature and (b) new production in a 0.1deg simulation of the North Atlantic Ocean (McGillicuddy, 2003).

In situ data:

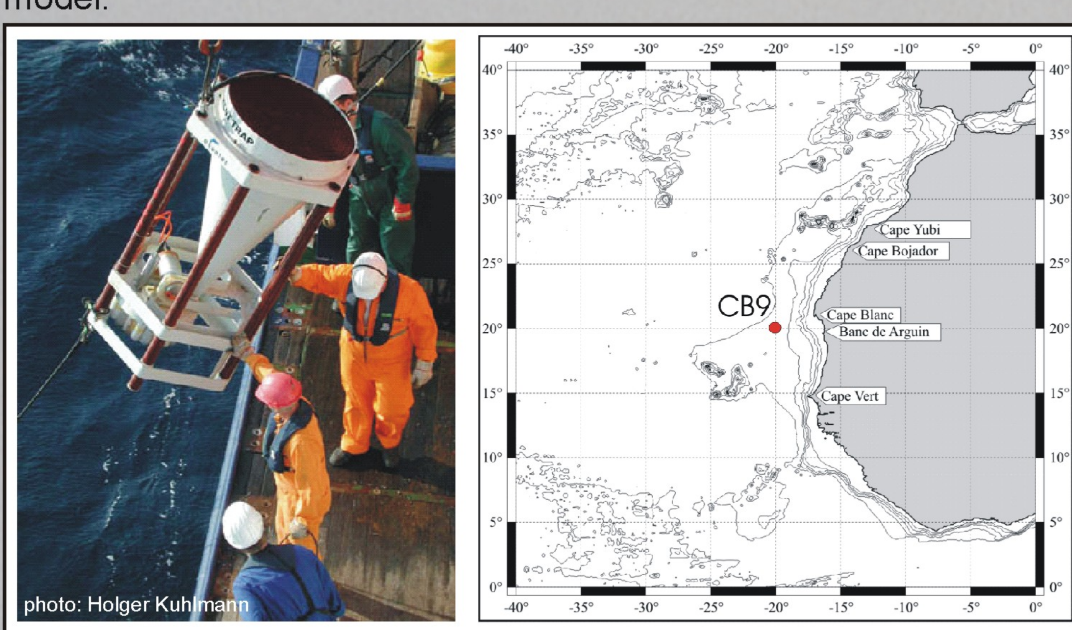


A. Seasonality of particulate organic carbon flux (POC) determined at the two time-series stations with surface tethered traps in 200 m (ST, BATS and ESTOC) for the three-year period 1996-1998. For ESTOC, flux is also shown for moored trap at 500 m depth (MT). B. Seasonality of export ratios (Neuer et al.,

Organic carbon export calculation

Method and previous work

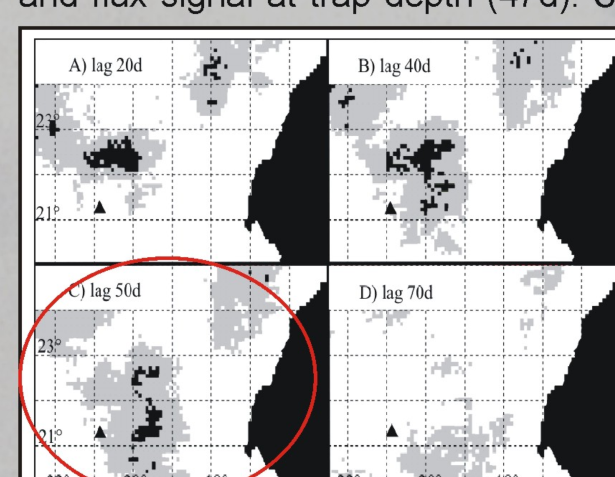
We combined the analysis of sediment trap data and satellite derived sea surface chlorophyll to quantify the amount of organic carbon export to the deep sea in the upwelling induced high production area off Northwest Africa. In contrast to the generally global or basin-wide adoption of export models, we used a regionally fitted empirical model.



Sediment trap deployment off NW Africa

Instead of the common selection of a rectangular box as the assumed source region for the sediment trap sample material we estimated the trap source region through correlation.

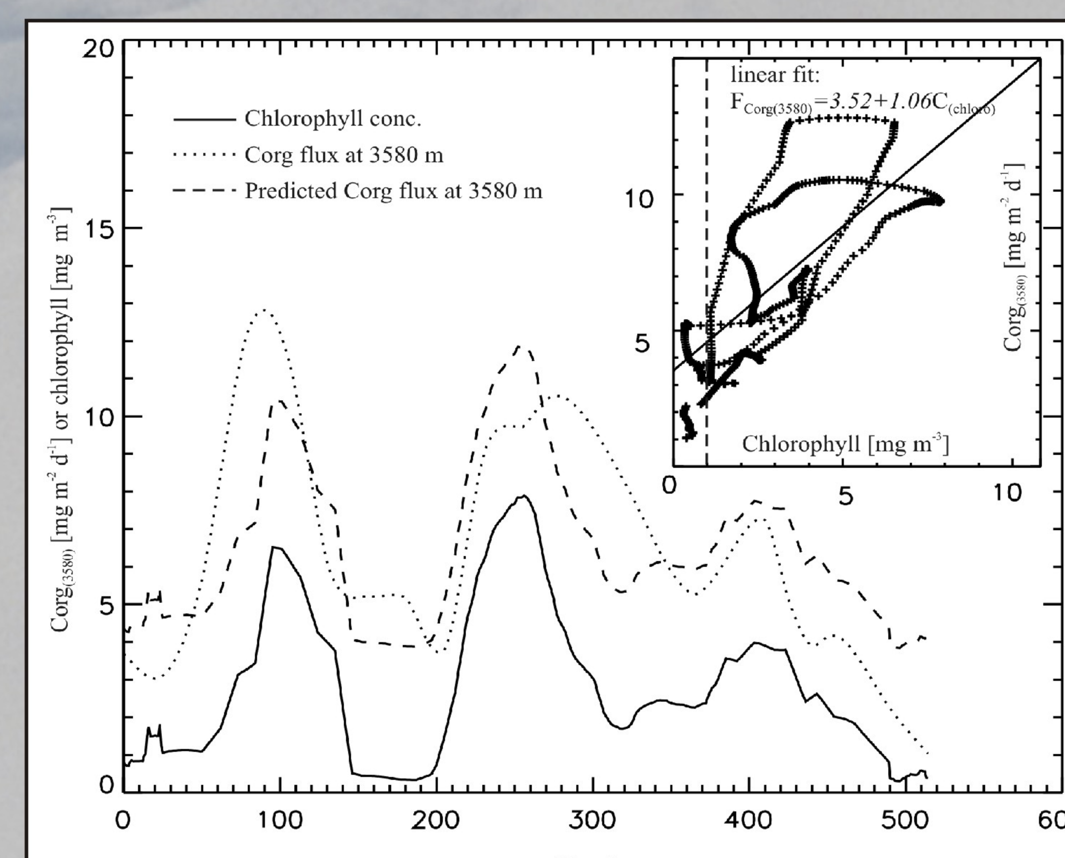
A time series of average chlorophyll data was extracted over an area of 99 km by 99 km to the east of the trap position as a first guess for the source region and to determine the average lag of surface chl-a signal and flux signal at trap depth (47d). Spatial correlations for different lags were calculated. The source region was then defined as the area of correlation r > 0.5 at a lag of 47 days. A linear regression of lagged chl-a and organic carbon (Corg) flux at trap depth was established to serve as a predicting model for regional Corg flux. As a preparation for the regression, the five main maxima of lagged chl-a and deep-sea Corg flux were matched to account for sinking velocity varying from average.



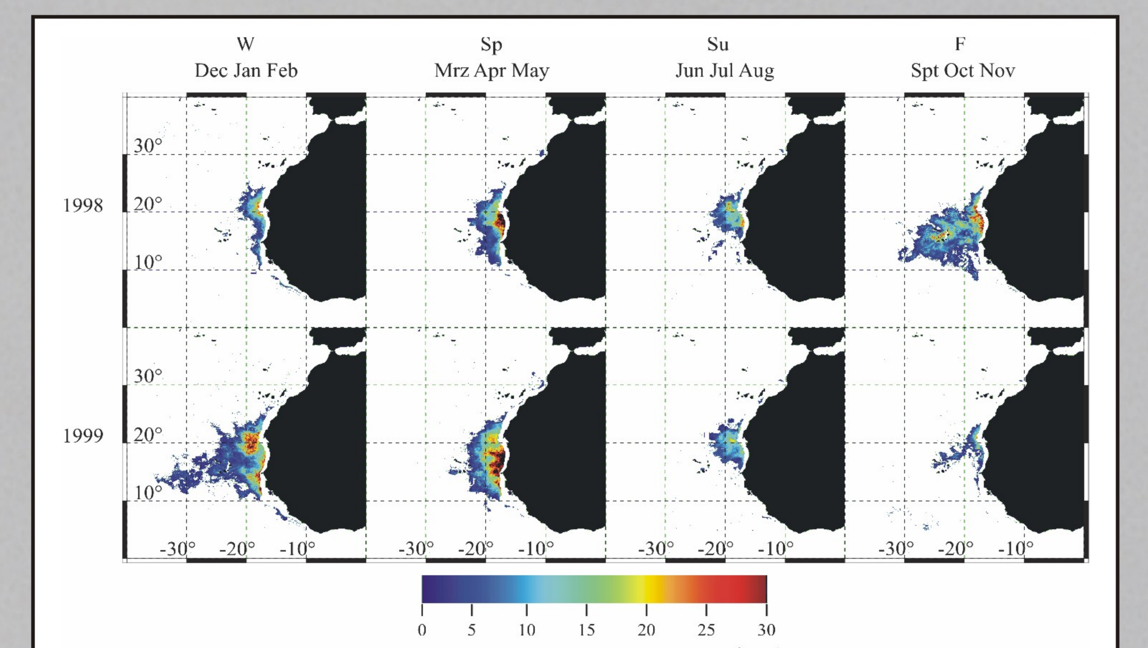
Correlation pattern between surface chlorophyll and sediment trap (triangle) Corg flux at lags of 20, 40, 50 and 70 days. Gray, r > 0.3; black, r > 0.5.

The derived regression function was then applied to the regional chl-a field to deduce Corg export out of the zone of high chl-a concentration (HCZ) associated with the NW African upwelling area. The HCZ was defined as C_{chl-a} > 1mg m^{-3} and evaluated on a daily basis to ensure the model was applied only to a region which resembles the productivity close to the trap location.

To yield an optimal parameterization, the regional function of Corg decomposition with depth has to be known, and it was not known at the Cape Blanc trap location.



Chlorophyll concentration in the source region (solid line), derived daily Corg flux at 3580 m (dotted line), predicted Corg flux at 3580 m (dashed line). The inlay shows the scattering of interpolated daily Corg flux at 3580 m against the 50d lagged surface chlorophyll concentration and the linear fit. The threshold for the export calculation is also shown (dashed line).



Seasonally averaged Corg export. A spring maximum is visible in all years; additional strong export with exceptionally far westward extension is evident from September 1998 to February 1999.

The availability of multi-depth sediment trap experiment data at both time-series stations, BATS and ESTOC, however, now enables us to apply this approach, with regional adaptation, to both compartments of the subtropical North Atlantic gyre, focusing on a advanced understanding of mechanisms controlling the organic pump.

McGillicuddy Jr., D. J., et al. (2003), Eddy-driven sources and sinks of nutrients in the upper ocean: Results from a 0.1° resolution model of the North Atlantic, *Global Biogeochem. Cycles*, *17*, 1035, doi: 10.1029/2002GB001987.
Neuer, S., et al. (2002), Differences in the biological carbon pump at three subtropical ocean sites, *Geophys. Res. Lett.*, *29*, 32-31-34, doi: 10.1029/2002GL015393.
Helmke, P., O. Romero, and G. Fischer (submitted), Northwest African upwelling and its effect on off-shore organic carbon export to the deep-sea.

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