Comparison of Productivity, Plankton Types and Carbon Export Mechanisms in two Different Regimes of Subtropical North Atlantic: a Modeling Study

MIDDLE EAST TECHNICAL UNIVERSITY
INSTITUTE OF MARINE SCIENCES

Yumruktepe, V. Çağlar and Salihoglu, B.

caglar@ims.metu.edu.tr

Middle East Technical University, Institute of Marine Sciences, TURKEY

TÜBİTAK

EURO-BASIN

Objectives

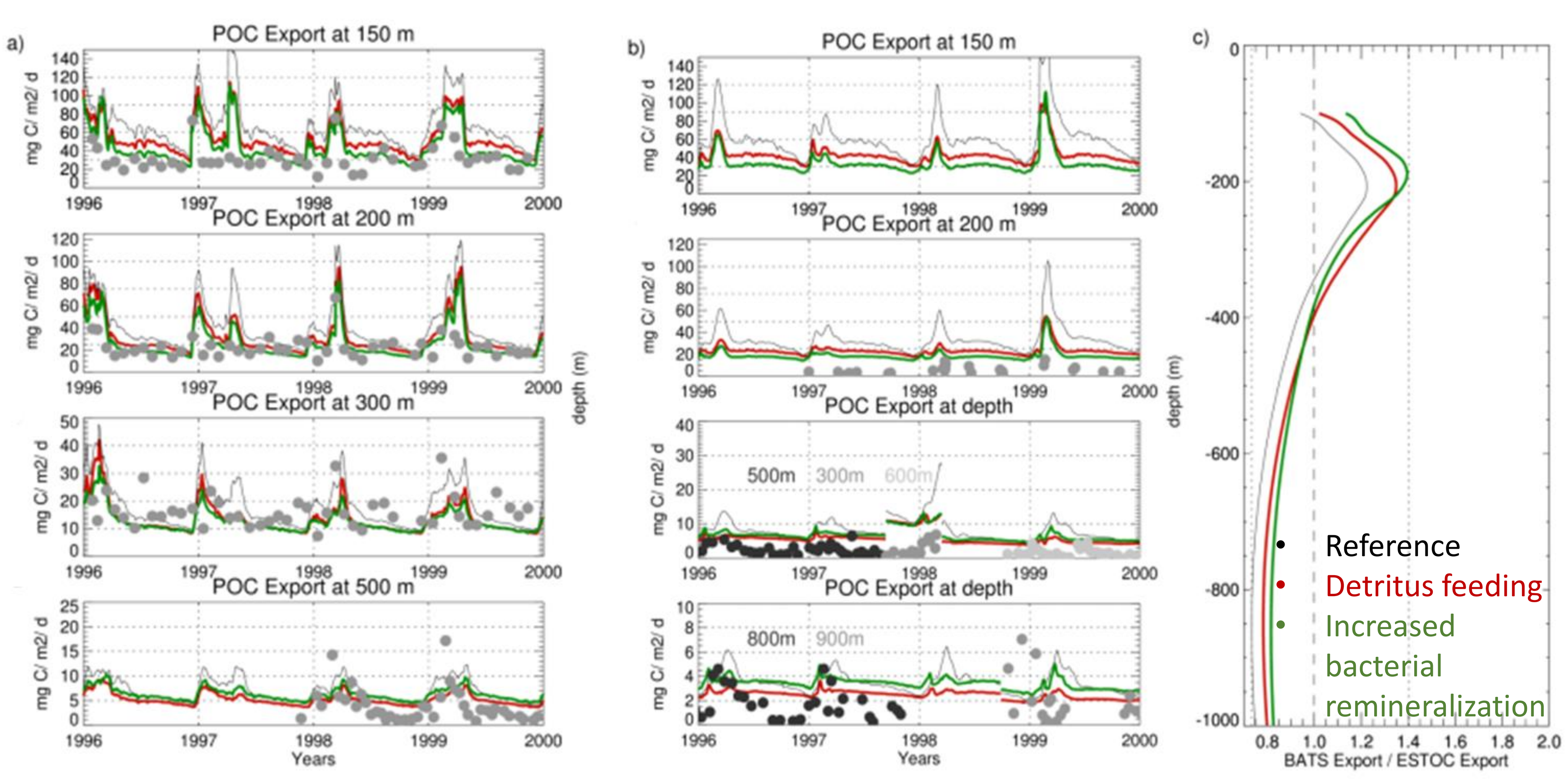
- We setup a 1D ecosystem model specifically designed to describe processes of biogeochemical cycling and primary production at **BATS and ESTOC**.
- The modeling tool presented here facilitates model algorithm testing and development, and ultimately the timely transfer of new algorithms derived from the latest observations into 3D coupled ecosystem models.
- The model is used to explore the drivers of similarities and dissimilarities in primary production and carbon export at BATS and ESTOC. In particular, the impact of variable remineralization rates and detritus consumption by zooplankton on carbon export rates are explored.

Through simulations and data comparison, each individual algorithm is evaluated and is used to answer the reasoning behind the realized carbon export at BATS and ESTOC. Successful set of algorithms are aimed to be included in global 3D models.

MODEL HIGHLIGHTS

- Export ratios decreased by 20% (BATS) and 25% (ESTOC) when detritus grazing added.
- Ratios decreased further by 48% (BATS) and 52% (ESTOC) when bacterial remineralization increased. These suggest that the sites are very sensitive to recycling.

- Longer retention times at ESTOC results in more effective recycling.
- BATS / ESTOC export increased from 7% to 13% with detritus feeding, and 17% with increased remineralization. Thus physics become a key element in defining export rates, and both sites show nonlinear response.



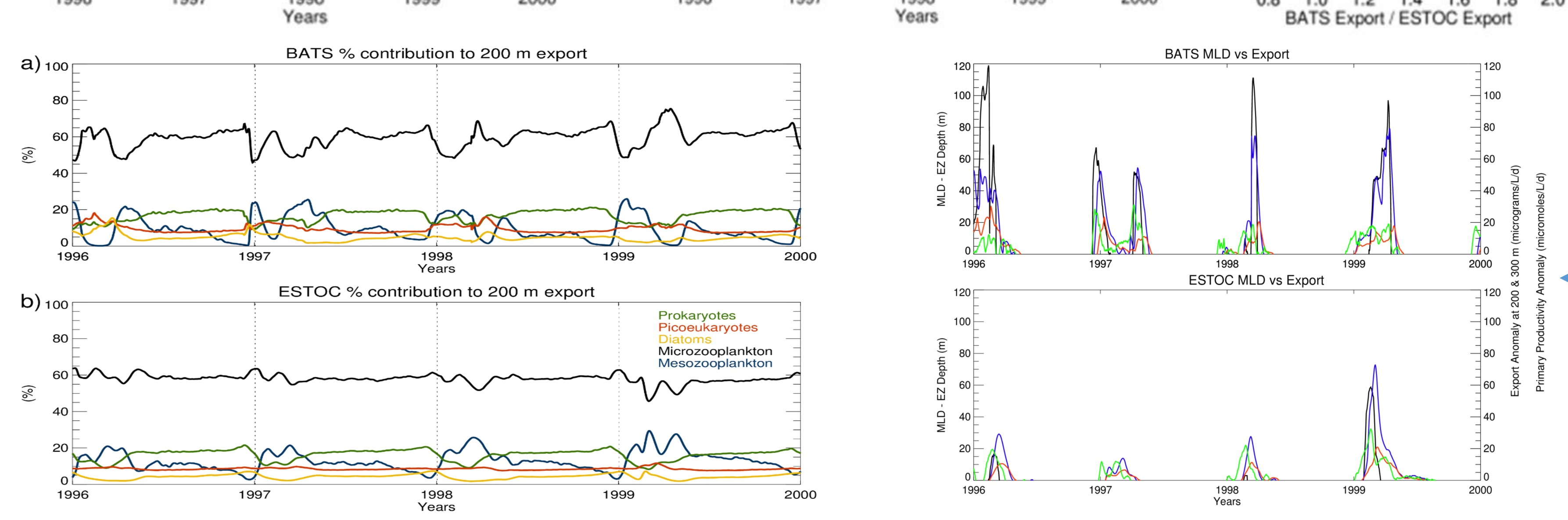
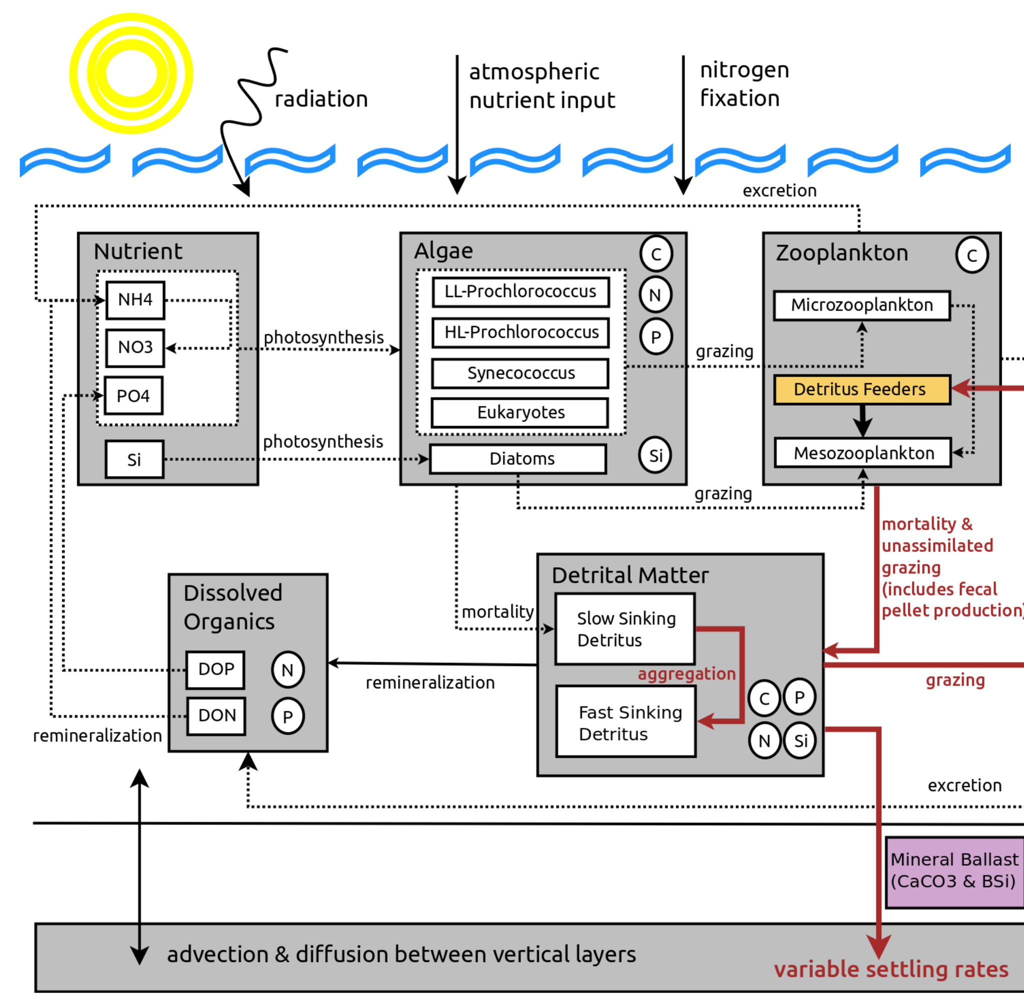
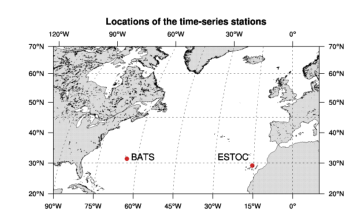


Figure 3) Simulated carbon export at **a)** BATS (mg C/ m2/ d) and at **b)** ESTOC at various depths. Grey dots indicate the observed exported carbon from the sediment traps. **c)** Ratio (BATS/ESTOC) of annually averaged export rates at depth. **d)** Simulated contribution (%) of individual plankton groups to total daily carbon export at 200 m depth. Prokaryotes indicate the total biomass of HL & LL Prochlorococcus and Synechococcus. **e)** MLD vs export and productivity rates. Black lines denote the MLD difference from the EZ depth (MLD - EZdepth). Blue lines denote the export rate positive anomalies (micrograms/L/day) at 200 m and red lines at 300 m. Green lines denote the integrated primary productivity positive anomalies (micromoles C/L/day).

- Magnitude and temporal variability of primary productivity and carbon export are closely modulated by the intensity and duration of the vertical mixing events.
- BATS, due to it's more dynamic physical environment, is characterized by pulses of enhanced and export. ESTOC is less dynamic but due to higher availability of inorganic nutrients, productivity in the euphotic zone has similar rates of production to BATS.

- Grazers are the main variables that channel POC to sinking detritus (70% of the total flux to sinking detritus, with micrograzers contribution of 60%).
- Phytoplankton channel POC through aggregation.
- Eukaryotes can provide deep sinking detritus as high as 20% in winter/spring.
- Prokaryotes can also reach 20% in summer.





Model Setup

Figure 1) a) Model state variables and currency flow **b)** Locations in the sub-tropical North Atlantic, the Bermuda Atlantic Time-series Study (BATS) and the European Station for Time series in the Ocean, Canary Islands (ESTOC). Colored boxes and arrows represent the algorithms tested over the reference simulations.

Sensitivity Analyses and Algorithm Evaluation

A reference simulation was run following the setup in Figure 1a, grey boxes (M-REF). Individual additions of detritus feeding (M-ZOO) and increased bacterial remineralization (M-REM) are evaluated.

Further algorithms under development include the topics:

- **Physical aggregation** (Differential settling & turbulence triggered coagulation)
- **Biological aggregation** (Fecal pellet production)
- **Mineral ballast effect** (Implicit CaCO3 and explicit BSi representation)
- **Diel vertical migration of mesozooplankton**

Model Validation

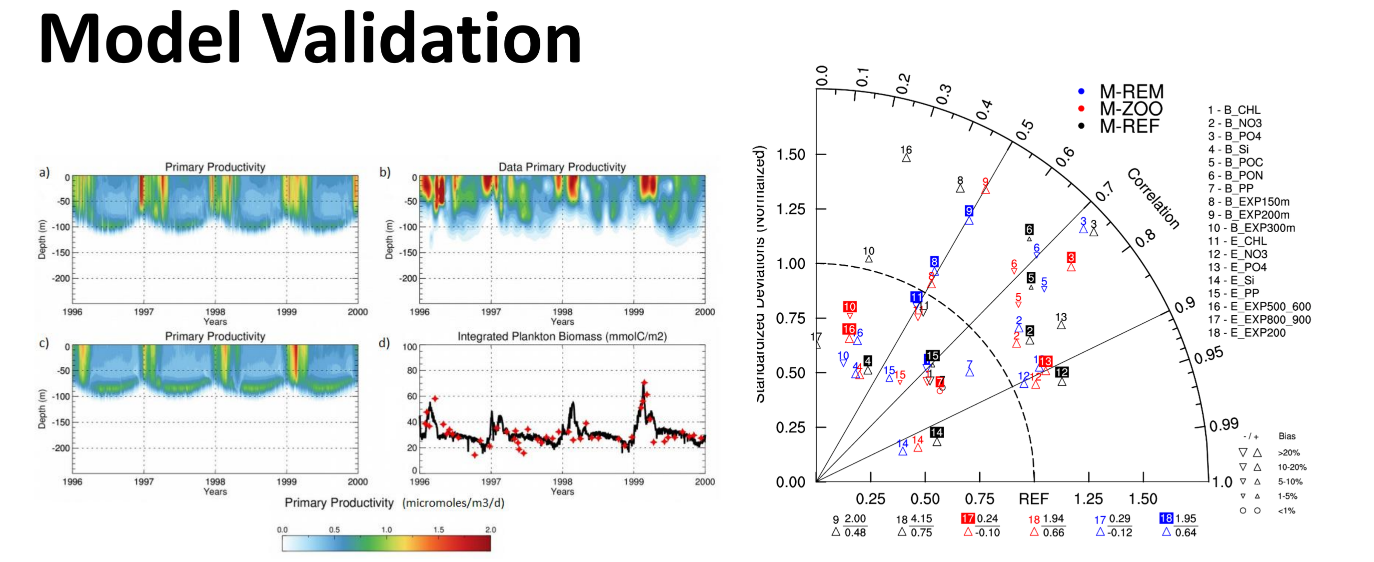


Figure 2) Hovmuller plots of simulated and observed primary productivities (micromoles C/m3/d), **a)** Simulated at BATS, **b)** Observed at BATS, **c)** Simulated at ESTOC and **d)** Observed depth integrated primary productivity at ESTOC station (mmol C/m2/d) . In (d), red stars indicate the satellite estimated integrated primary productivities (Neuer et al., 2007) and the black line indicate the depth integrated model primary productivity (mmol C/m2/d). **e)** Model statistics shown on a Taylor diagram Percent biases are also represented with triangles. Upper triangles indicate that model has a positive bias, and down triangles indicate negative bias. The percent intervals are represented with the triangle size. Model data standard deviations outside the x- and y-axis range are shown below the diagram. Black marks represent the M-REF, red marks represent the M-ZOO and blue marks represent the M-REM simulations.

Modelled depth integrated annual mean primary productivities of 13.12 molC/m2/y and 11.12 molC/m2/y at BATS and ESTOC respectively

Algorithms Under Development (initial results)

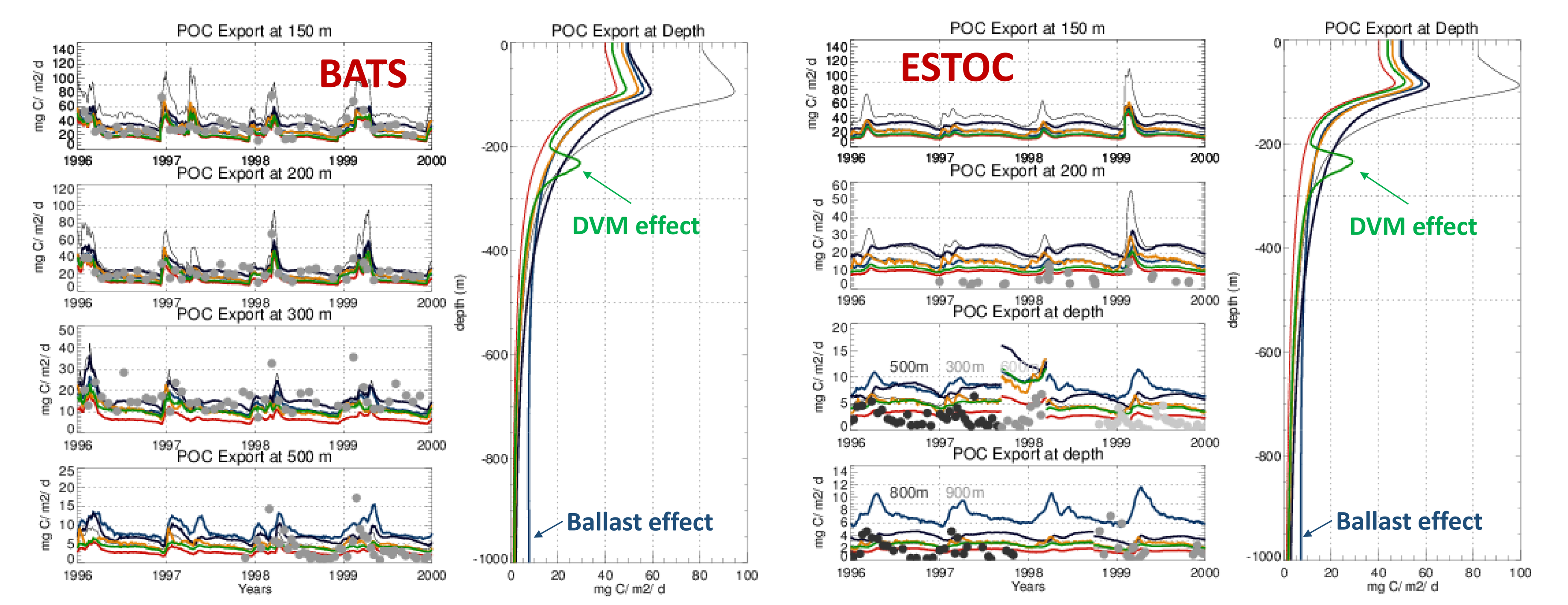


Figure 5) Simulated carbon export at depth vs observations **a)** BATS **b)** ESTOC. For BATS, observations are from 150, 200, 300 and 500m depths. For ESTOC, observed depths are 200, 300, 500, 600, 800 and 900m depths. Observed depths are grey color coded for ESTOC for various depths. Data taken from BATS website and Helmke et al., 2010. Results of each individual algorithms are represented solid lines, where continuous depth graphs are simulation averaged carbon export at depth. Black thin line is the M-ZOO simulation. Remaining algorithms all include differential settling rates. Red lines denote differential settling only, blue: ballast effect, green: DVM addition, orange: fecal pellet production, purple: turbulent aggregation.

Additional algorithms of physical & biological aggregation, mineral ballast effect and diel vertical migration are under development, and can further explain the missing reasons in the difference in export ratios at BATS and ESTOC.

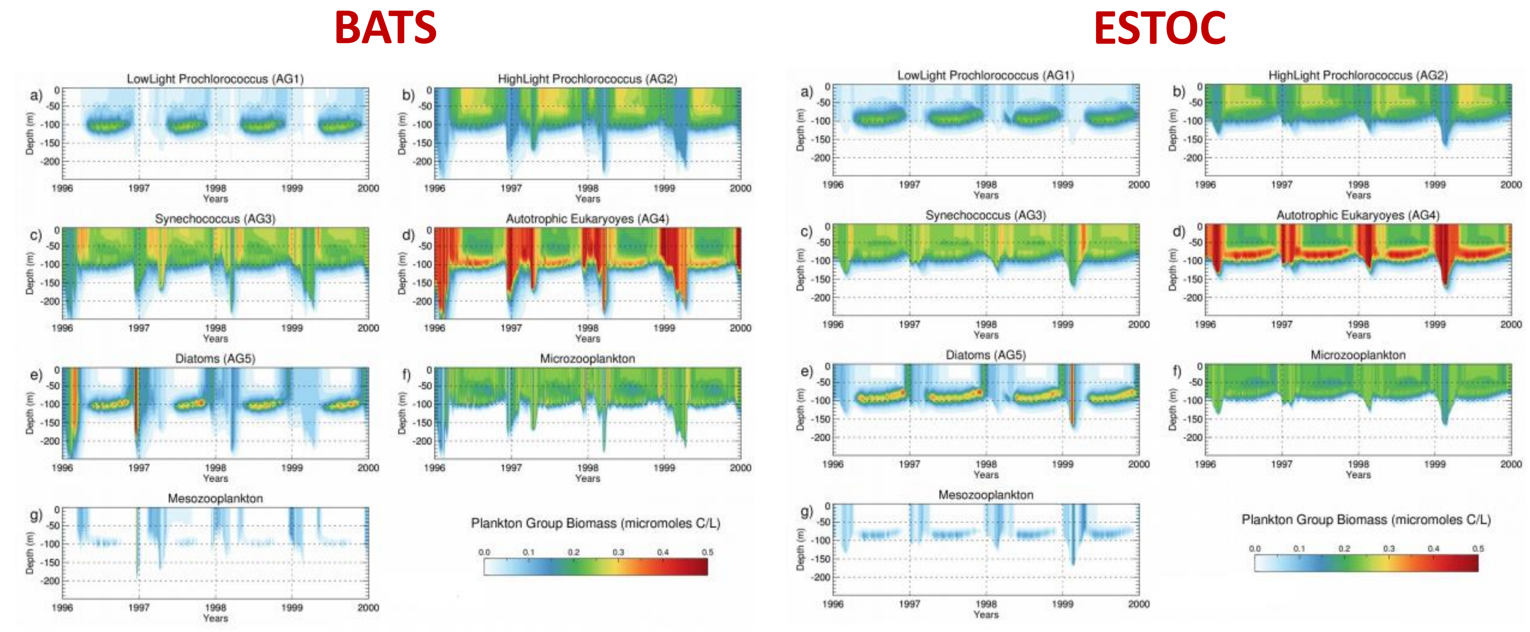


Figure 4) Simulated algal groups: HL and LL Prochlorococcus, Synechococcus, Autotrophic Eukaryotes, Diatoms, Micro-Mesozooplankton (mmolC/m3).