Estimating carbon export and sequestration in ocean at regional and global scales

Introduction
During the last decade, there has been a large increase in the number of satellite-derived marine biogeochemical products, which contributed to quantifying global biogeochemical cycles. Here, we propose a novel approach to derive, from surface chlorophyll imagery, carbon export (i.e. at the base of the euphotic zone: $Z_{eu}$) and sequestration (i.e. at the base of the mesopelagic layer, 1000 m deep) in the world's open oceans.

Why?
1) Only few data available (Mainly sediment traps)
2) The remineralization length scale ($b$ from the Martin curve) is usually presented with a unique value
3) Biogeochemical models need more data (global) for validation and/or parameterization

How?
1) We can derive relationships between surface chlorophyll a concentration from SeaWiFS and vertical chlorophyll a profiles associated with micro-, nano-, and picophytoplankton (Ulitz et al. 2006).
2) There is global relationship between the size structure of phytoplankton biomass in the euphotic zone and the mass flux of particles in the mesopelagic layer (Guidi et al. 2009).

By combining (1) and (2), the mass flux can be estimated on a global scale.

Method

- **Parameterization for stratified waters ($Z_{eu} > MLD$)**
  - Gaussian vertical profile of Chla for each phytoplankton group (PG) at depth $z$:
    \[ \text{Chla}_a(z) = f(z; C_0, s, C_{max}, \zeta_m, \Delta \zeta) \]
  - with $C_0$, $s$, $C_{max}$, $\zeta_m$, $\Delta \zeta$: For each phytoplankton group a set of 5 parameters which are functions of Chla$_{sat}$
  - Vertical profiles of Chla$_{sat}$ are obtained by extending surface Chla$_{sat}$ values in the water column

- **Parameterization for mixed waters ($Z_{eu} < MLD$)**
  - Contribution to Chla for each phytoplankton group (PG) at surface:
    \[ \text{Chla}_a(Z_{eu}) = \%_{PG} \times \text{Chla}_{sat} \]
  - with $\%_{PG}$: function of Chla$_{sat}$

- **SeaWFSo-derived surface Chla (Chla$_{sat}$)**

- **Depth of the euphotic zone ($Z_{eu}$)**

- **Mixed layer depth (MLD)**

- **Chla$_{sat}$ / MLD**

- **Multiple linear regressions**

- **Validation and correction using in-situ sediment traps**

Results

**Analysis of sediment traps fluxes (Mass vs POC) and comparison to SeaWiFS flux estimations**

- **Sediment traps flux ratio**
  - Mass flux / POC flux
    \[ (1^{st} \text{ quartile} < \text{median} < 3^{rd} \text{ quartile}) \]
  - $r^2 = 0.55$ $p<0.001$

- **The Organic Carbon flux is strongly correlated to the mass flux on a global scale ($n=1200$)**
  - No depth dependence
  - There is an inter-site variability (ex: BATS vs DYFAMED) that can be used for regionalization

- **Climatological annual mean**
  - Strong spatial variability
  - Global annual carbon export
    \[ 0.75 < 3.03 < 13.77 (GtC) \]
    - This range is function of the ratios (median and quartiles) calculated using sediment traps data
    - Estimations comparable to the literature (~12 GtC)
  - Global annual carbon sequestration
    \[ 0.15 < 0.61 < 2.78 (GtC) \]
    - This range is function of the ratios (median and quartiles) calculated using sediment traps data
    - Estimations comparable to the literature (~2 GtC)

**Carbon export at the base of $Z_{eu}$ (mg m$^{-2}$ d$^{-1}$)**

- **Strong spatial variability**
  - Large spatial variations (0.2 – 0.8)

- **Global mean annual $b$**
  - Inferior to the mean $b$ from Martin et al. 1987 ($b = 0.86$) but into its range (0.32-0.97)

**References**

- Final global flux estimation

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