Assimilating water column and satellite data for marine export production estimation

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Introduction

The ocean is one of the major carbon reservoirs in the Earth, containing about 50 times more than in the atmosphere. The strength of the carbon pump influences the surface ocean carbon concentration and therefore has an impact on the exchange of CO_2 with the atmosphere. Drawdown of surface carbon concentrations by the biological pump leads to an increased flux of CO_2 from the atmosphere, and the overall oceanic CO_2 uptake thus depends on the strength of the biological pump. Quantification of export flux and the strength of the biological pump therefore is an important objective.

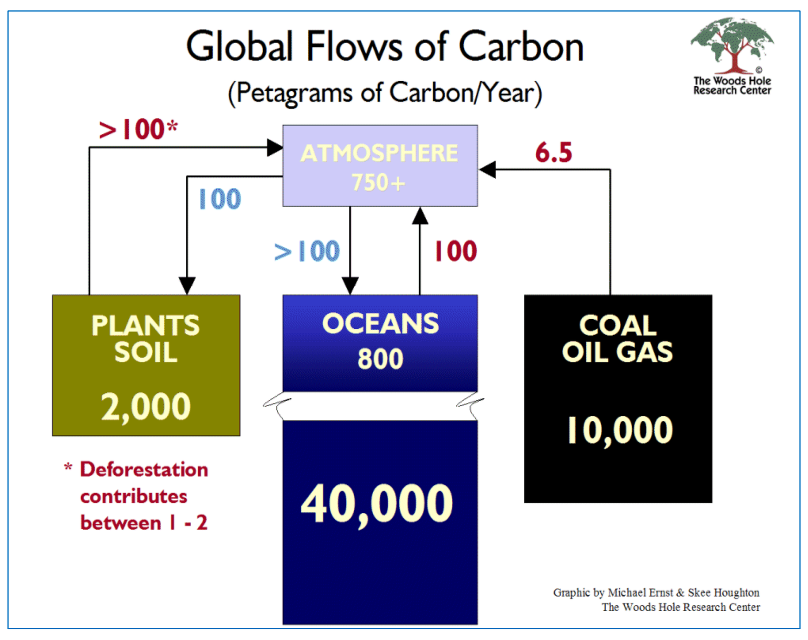

Fig.1 Global fluxes of Carbon. Ocean stores the largest amount of carbon in the earth carbon cycle system.

Data

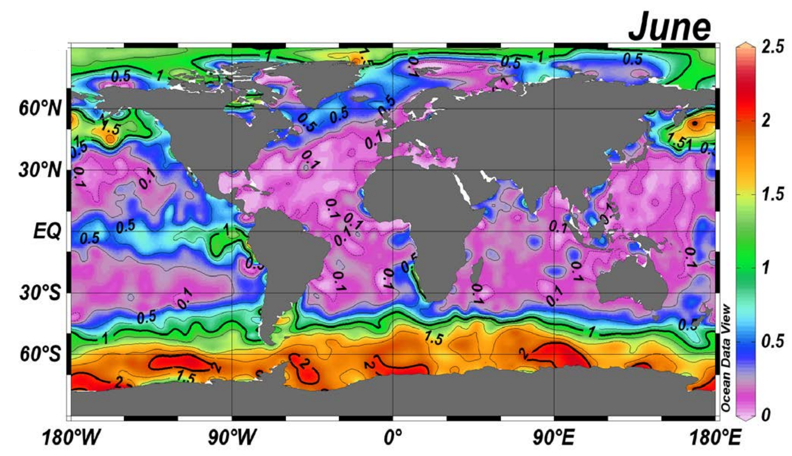

Fig.2 Phosphate concentration in June (µmol/kg) from WOA09.

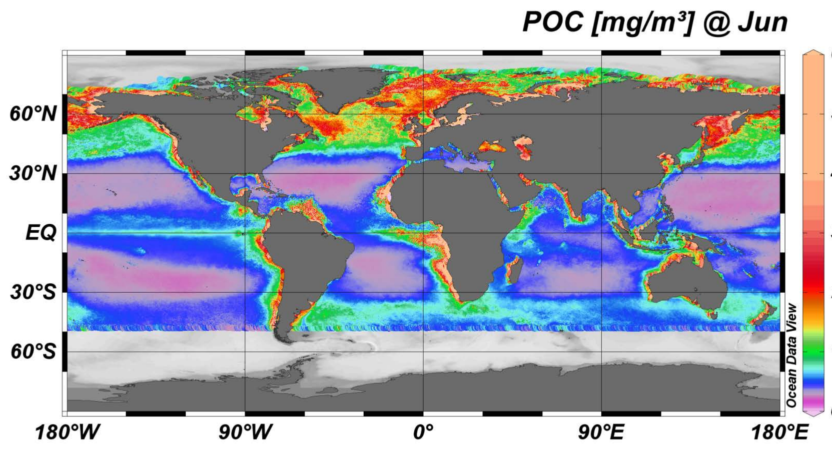

Fig.3 SeaWiFs monthly climatology POC of June.

The phosphate water column data cover the whole global ocean and have full depth coverage. The particulate data are derived from satellites which monitoring the ocean surface from space. They provide better temporal information, but only for the ocean surface.

Combining water column phosphate and satellite POC data in the adjoint model, allowing us to get better carbon export estimations on a monthly basis.

Model

Model description:

The model is global and has a non-uniform grid with horizontal resolution ranging between 1º×1º and 4º×5º . Finer resolution is realized near coastal regions while coarser resolution prevails in the open ocean. The model has 26 vertical layers.

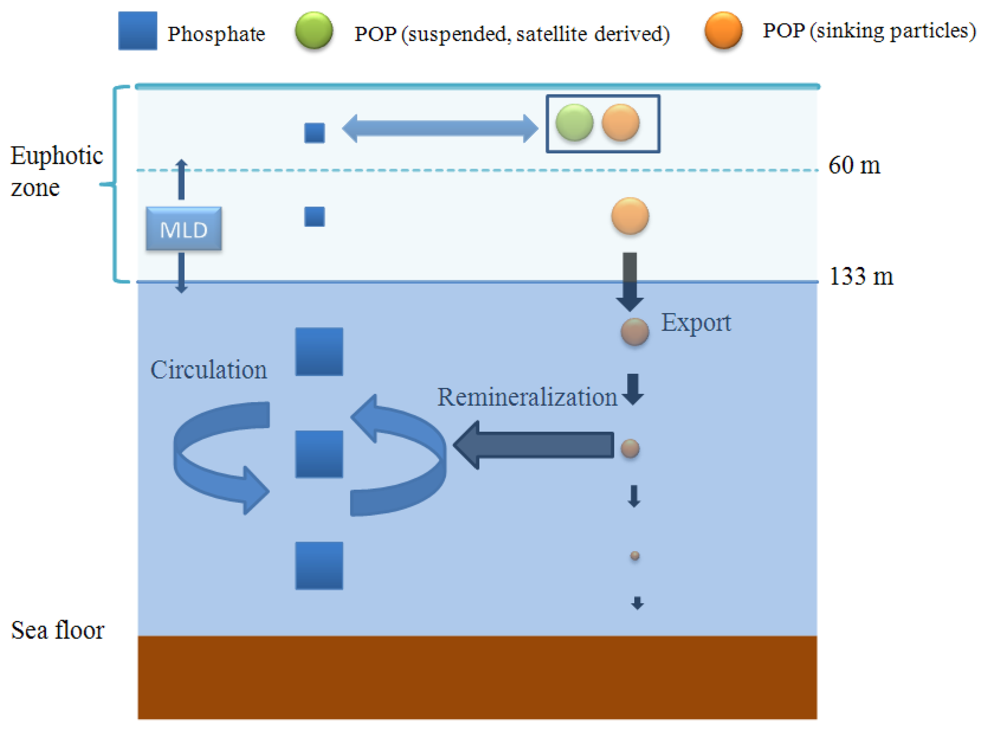

Fig. 4 Schematic of model processes.

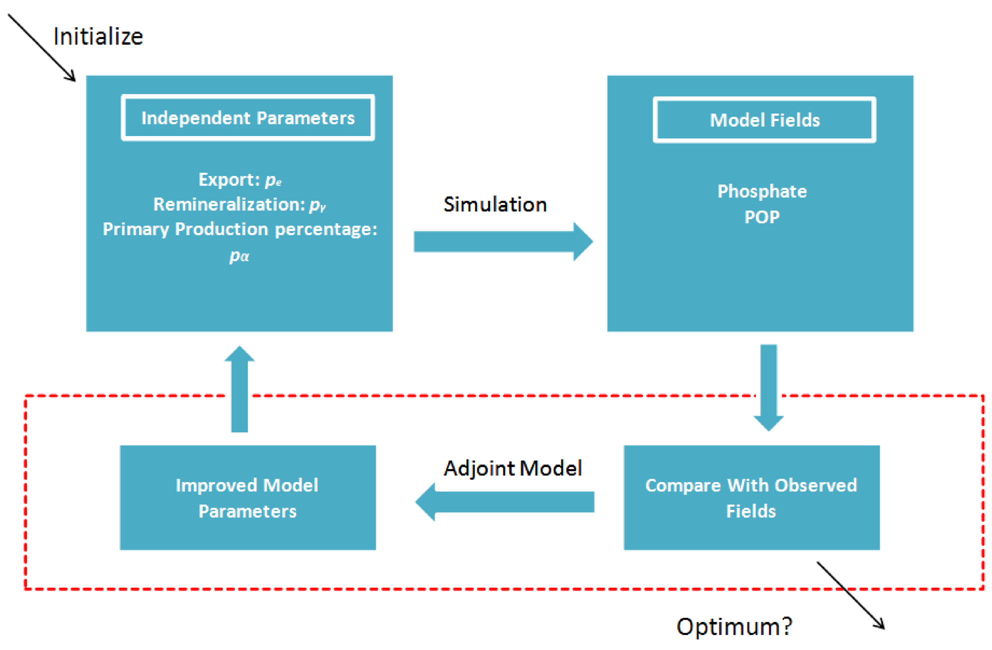

Fig.5 Schematic overview of model calculations.

Model budgets:

Phosphate

$$V\frac{dC_D}{dt}=\sum_i A_i(u_iC_{Di}-K_h\nabla C_{Di})+\sum_j A_j(v_jC_{Dj}-K_h\nabla C_{Dj})+\sum_k A_k(w_kC_{Dk}-K_v\nabla C_{Dk})-q_D-V\frac{dC_P}{dt}$$

POP

$$V\frac{dC_P}{dt}=q_P$$

$$V\frac{dC_P}{dt}=\alpha\cdot a-V\frac{C_P}{\tau}$$ Exp A

$$V\frac{dC_P}{dt}=\beta\cdot N_P\cdot A_i-V\cdot\gamma\cdot C_P$$ Exp B

Adjustable parameters

Both expriments contain the parameter p_e to adjust the strength of export production. In Exp B, it contains two additional parameters to adjust the POP production (β) and remineralization (γ).

The model calculation is divided into two parts (*Fig. 5*). The first part is a normal forward-run model solving the budget equations with initialized independent parameters and solving the C_D and C_P field. The other part of the model is the adjoint model, which compares the simulated C_D with the water column data C_{Pd} and the simulated C_P with the satellite data C_{Pd} by calculating their misfits. The knowledge on adjustable parameters' improvement is gained from these misfits in the adjoint model. This adjoint model guarantees that the next iteration simulation with improved model parameters will have better C_D and C_P, which means closer to the observations than previous simulation.
There are two experiment Exp A and Exp B, using different POP equations. In Exp A the production rate of POP is set to be proportional to export production EP and in Exp B the POP production rate is linked to primary production rates (NPP).

Model goal:

Export production

$$a=\alpha_0\cdot p_e^2(x,y)\cdot s(y,t)$$

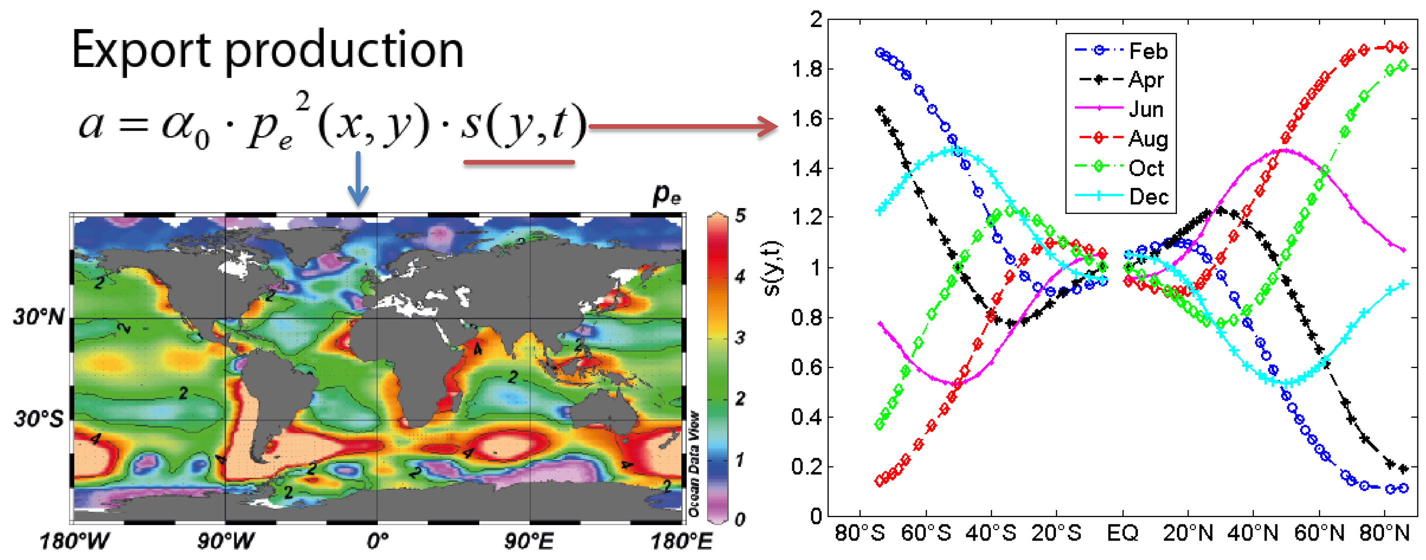

Fig.6 The form of export prudcution.

In the model the export production term contains: (1) an adjustable parameter p_e which varies geographically, and (2) a seasonal factor *s(y,t)* which varying with time and latitude.

Summary

The present study shows that in principle the adjoint method can be applied for determination of time varying export flux fields using satellite and water column data.
The existence of significant and systematic model/data misfits suggests that the treatment of POP budgets and the coupling with dissolved nutrients is overly simplistic and unrealistic.
The POP misfit analysis suggests that the POP budget equation should be refined by introducing a nonlinear production term.

Results

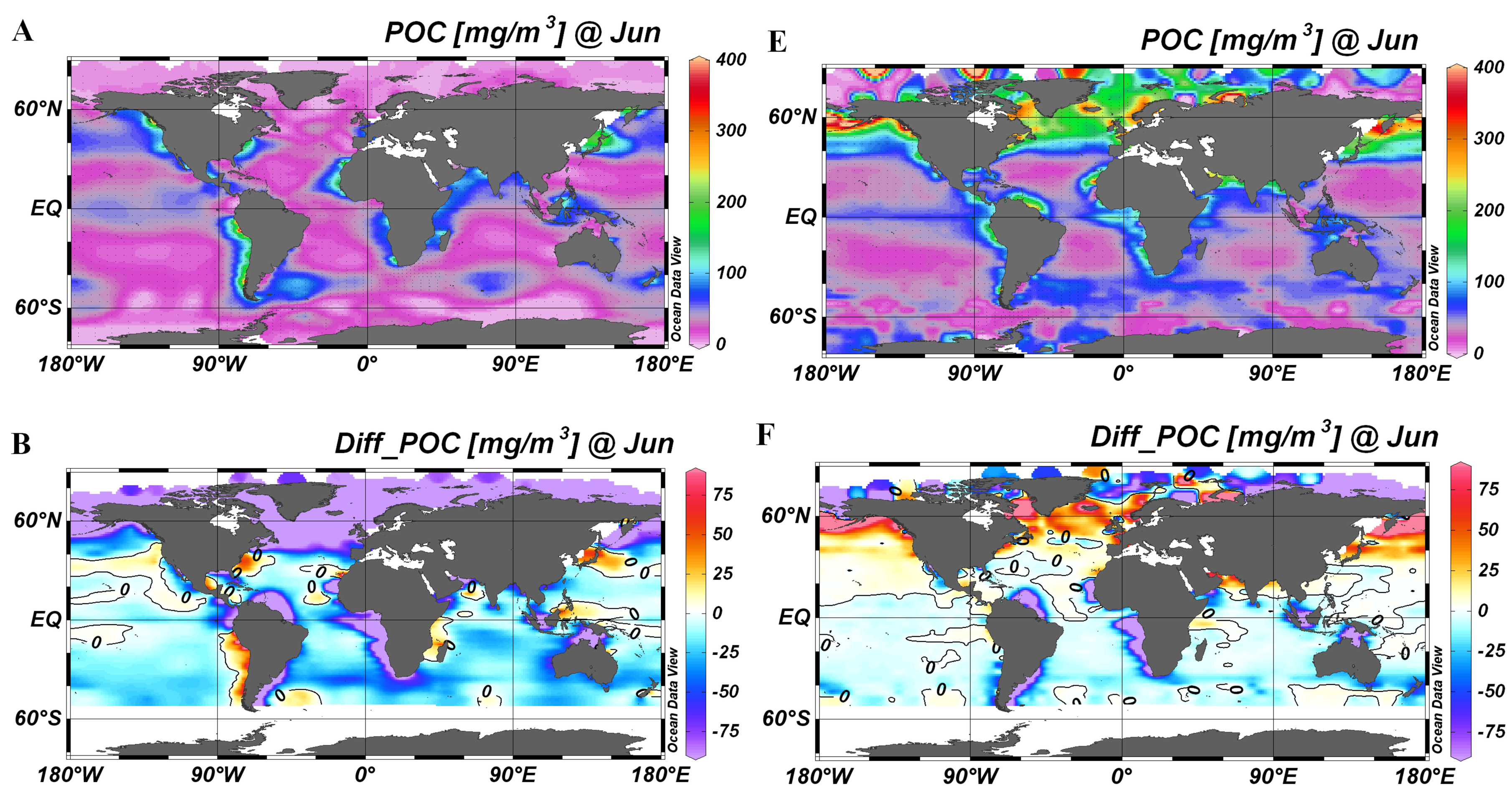

Fig. 7 Model-simulated POC field of June and December, comparison of Exp A (A-B) and Exp B (E-F). Diff_POC shows the difference between simulated and satellite POC, which is simulated POC minus satellite POC.

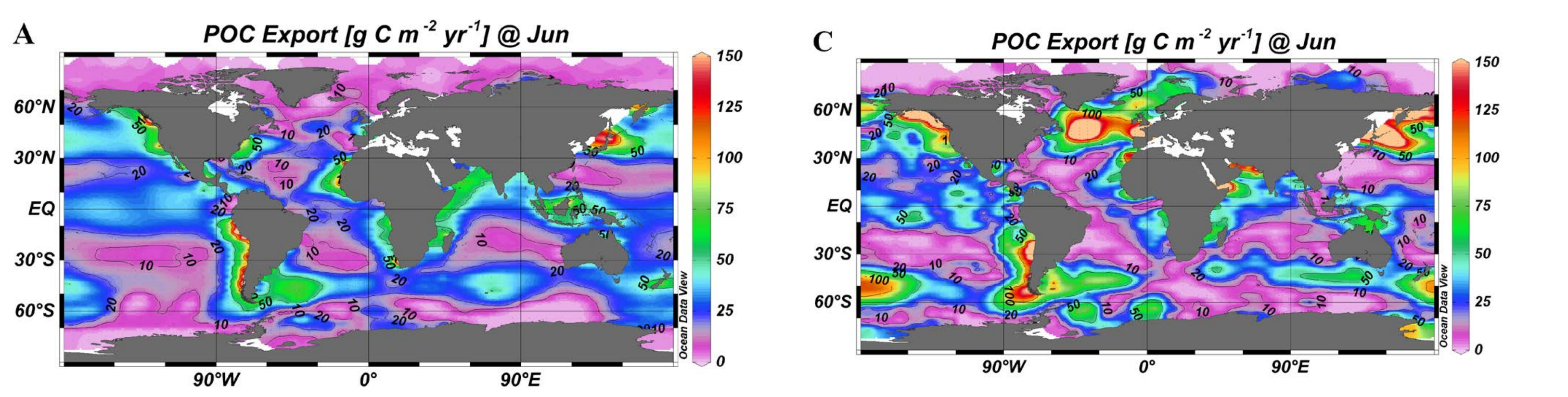

Fig.8 Global POC export of Jun , Exp A (A) and Exp B (C)

Global carbon export:

Exp A= 9.9 Gt C/yr
Exp B= 12.3 Gt C/yr.

Reference

Yao, X. and Schlitzer, R.: Assimilating water column and satellite data for marine export production estimation, Geosci. Model Dev. Discuss., 6, 2045-2085, doi:10.5194/gmdd-6-2045-2013, 2013.