Assessing the Value of BGC Argo Profile Observations for Ocean Biogeochemical Data Assimilation in a Model of the Gulf of Mexico (Paper Number: OB44C-0683)

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1. Introduction

Data assimilation (DA), i.e. the combination of observations and dynamical models, is essential for hindcasting and nowcasting past and present ocean states and for predicting future changes. Biogeochemical DA falls into two broad categories, parameter optimization and state estimation. Both approaches critically depend on appropriate observations. Although satellite data of ocean color have been the major source for biogeochemical DA to date, they are limited to the near-surface ocean and are an imperfect proxy of carbon biomass. BGC Argo profiles increasingly provide subsurface information of chlorophyll and other parameters. In this study, we analyze the value that profiling float observations can add by conducting 1) a parameter optimization to assess the role of subsurface measurements for determining poorly known biological parameters in a coupled physical-biogeochemical model, and 2) state estimation to evaluate how the sequential assimilation of satellite and float observations into the model can improve subsurface distributions.

Parameter Optimization

2. Methods:

3D model
- ROMS and Bio_Fennel (7-components N-based model)
- 2010-2015, first year as spin-up

1D model
- Same biogeochemical formulations as 3D model
- Simplified vertical mixing (turbulent surface layer and quiescent bottom layer)
- No advection considered
- Physics (i.e. temp, solar radiation) obtained from 3D model
- 2010

Observations
- Satellite estimates of Chlorophyll (Chl) from OC-CCI
- Profiles (derived Chl, phytoplankton, and POC) from six BGC Argo floats during 2011-2015 (see Figure 1)

Optimization Algorithm
- Evolutionary algorithm (stochastic exploration of optimal parameter set by minimizing misfit with observations)

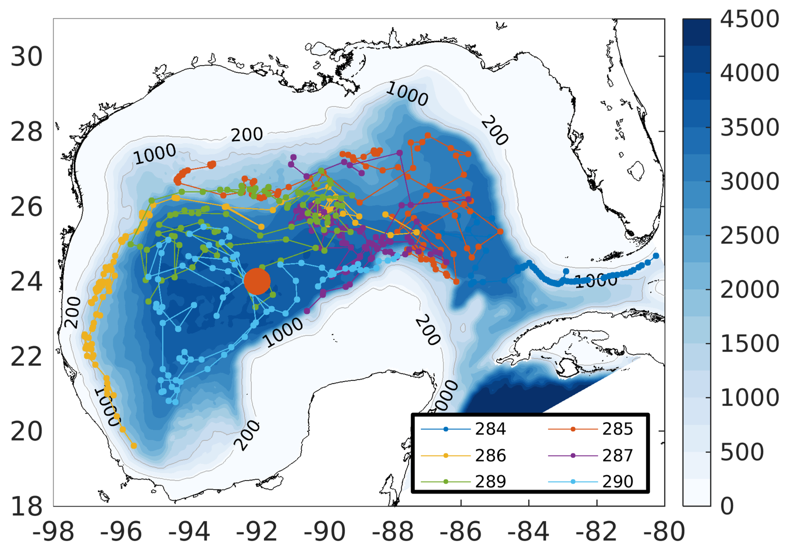


Figure 1. Bathymetric map of the Gulf of Mexico with trajectories of six BGC Argo floats. The location of 1D model is denoted by the orange solid cycle.

3. 1D models' results :

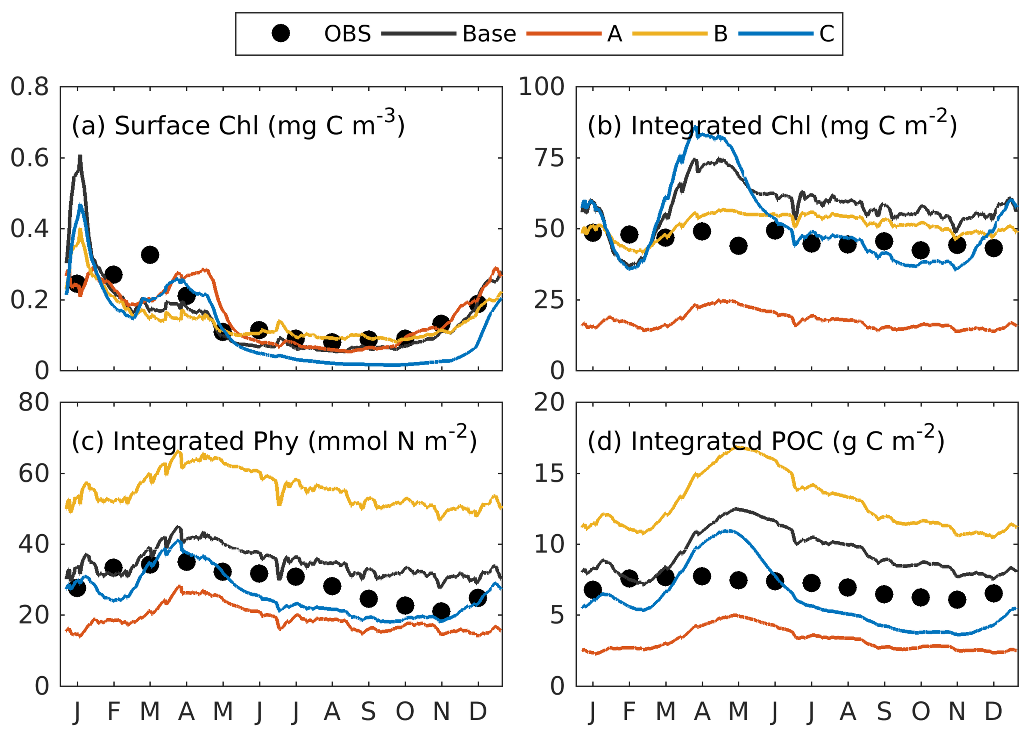


Figure 2. Observed and simulated annual cycle of surface chlorophyll (a) as well as vertically integrated chlorophyll (b), phytoplankton (c), and POC (d) over the top 200m.

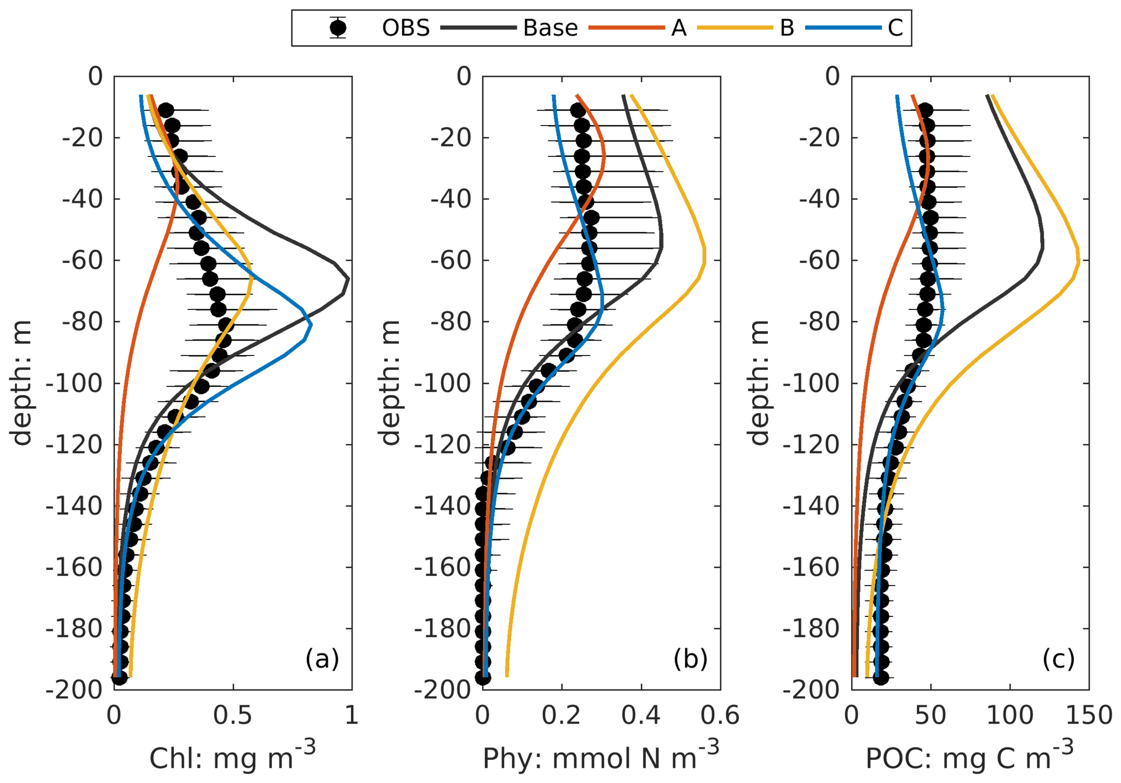


Figure 3. Observed and simulated vertical profiles of chlorophyll, phytoplankton, and POC.

➢ **Experiment A (assimilating satellite surface Chl)**

Experiment A improved simulation of surface chlorophyll but can't reproduce the vertical profiles, e.g. underestimation of deep chlorophyll maximum in terms of depth and intensity.

➢ **Experiment B (assimilating satellite surface Chl and profiles of Chl)**

Experiment B improved surface chlorophyll and vertical profiles of chlorophyll with the expense of deteriorations in phytoplankton and POC

➢ **Experiment C (assimilating satellite surface Chl and all profiles available, i.e. Chl, phytoplankton, and POC)**

Experiment C improved almost all aspects including the non-zero POC concentrations at 200m with dominant contributions from nonalgal detritus.

4. 3D models' results:

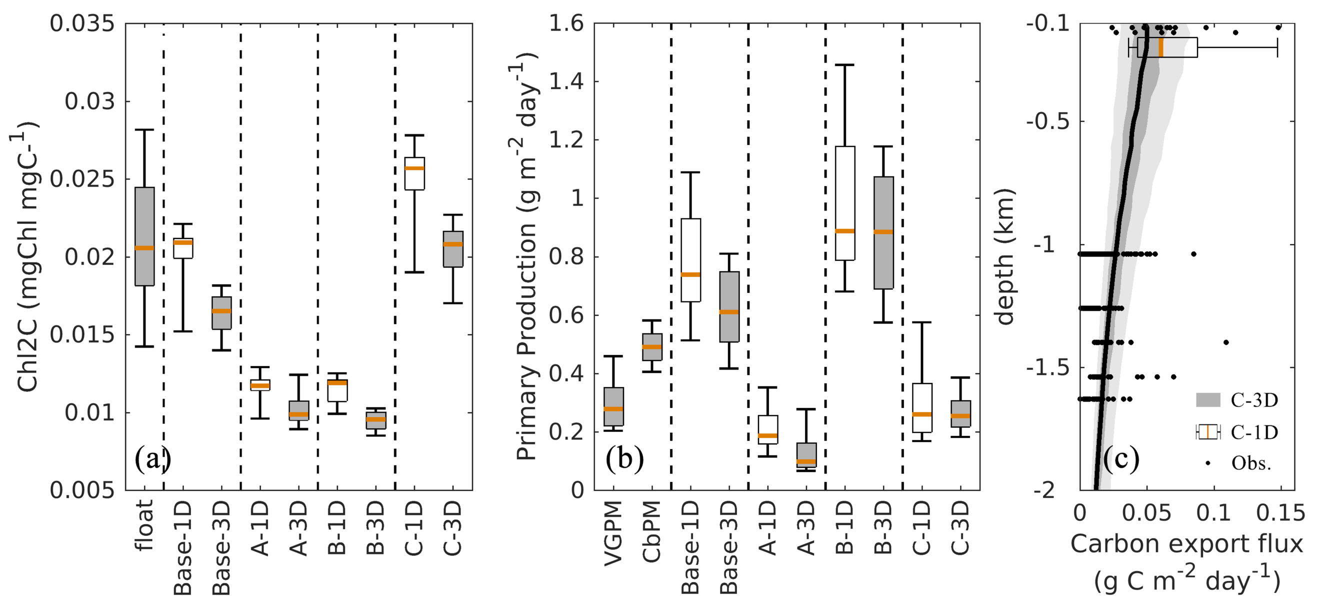


Figure 4. Comparisons of the chlorophyll to carbon ratio (a), primary production (b), and carbon export fluxes (c) between 1D and 3D models.

Resulting parameters from 1D models (2010) were used in 3D models (2010-2015), finding that:

➢ 1D and 3D model reproduced qualitatively similar results

➢ Only experiment C reproduced reasonable magnitude of chlorophyll-to-carbon ratio, primary production, and carbon export fluxes.

State updates

5. Methods

3D model
- ROMS and Bio_Fennel (7-components N-based model) (2015)

Observations to be assimilated
- Mapped SLA from AVISO + MDT (Mulet et al, 2013) (std of error 2cm)
- SST from GHRSST (std of error 0.3°C)
- Satellite estimates of Chl from OC-CCI (std of error 35%)

Independent observations
- Argo profiles (T&S) up to 2000m (792 profiles)
- BGC profiles (T&S, Chl, phytoplankton, and POC) up to 1000m (114 profiles)

DA Algorithm
- Deterministic Ensemble Kalman Filter (20 ensembles)
- Assimilating observations every 7 days

6. Relative improvement of physical component:

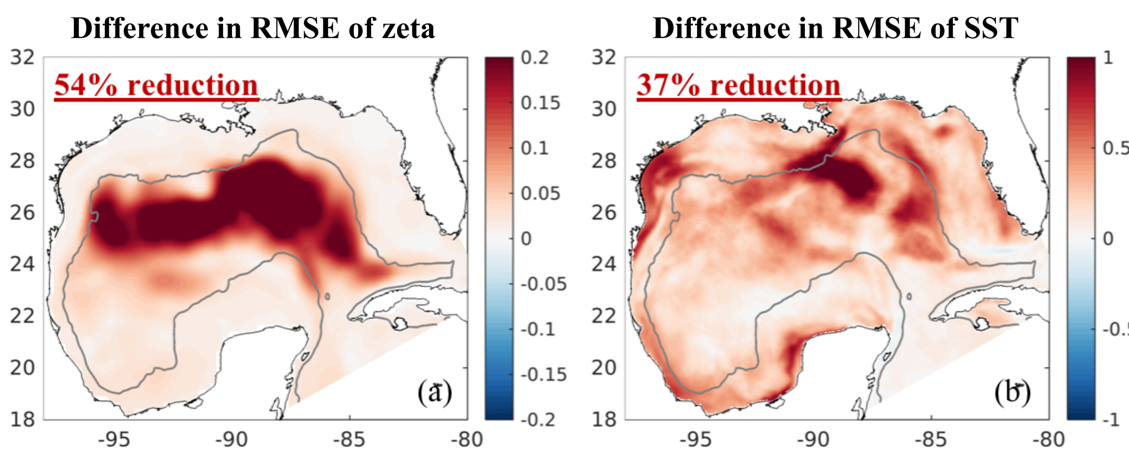


Figure 5 Differences in RMSE of zeta (a) and surface temperature (b) between the Cont run and DA run. Positive values (red color) represent RMSE reductions while negative values (blue color) represent RMSE increment in DA run.

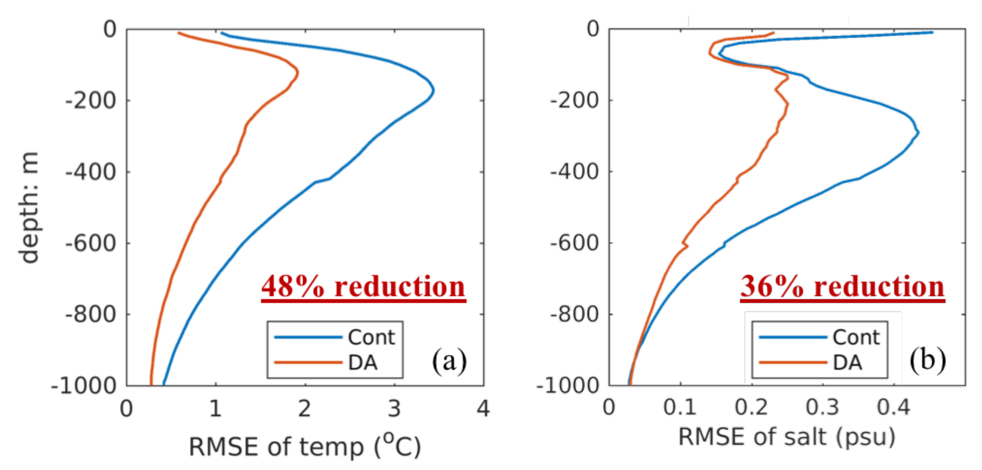


Figure 6 Vertical profiles of RMSE values for temperature (a) and salinity (b) with respect to Argo profile observations

7. Relative improvement of biological component:

7.1. Relative improvement in surface layer

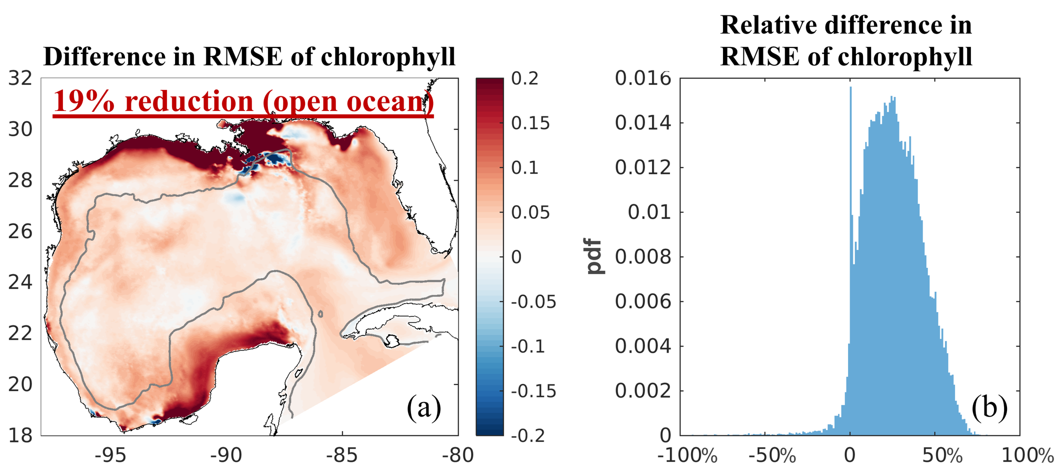


Figure 7 Differences in RMSE of chlorophyll (a) and histogram of relative differences (b) between the Cont run and DA run. Boundary of open ocean (depth>1000m) is marked by the gray line in figure 7a.

➢ DA improved surface chlorophyll in most of regions (97%) with the largest relative improvement as high as **80%**.

➢ Half of regions had relative improvement above **25%**.

➢ The overall improvement of surface chlorophyll in the open ocean (depth>1000m) is **19%**.

7.2. Relative improvement in surface layer

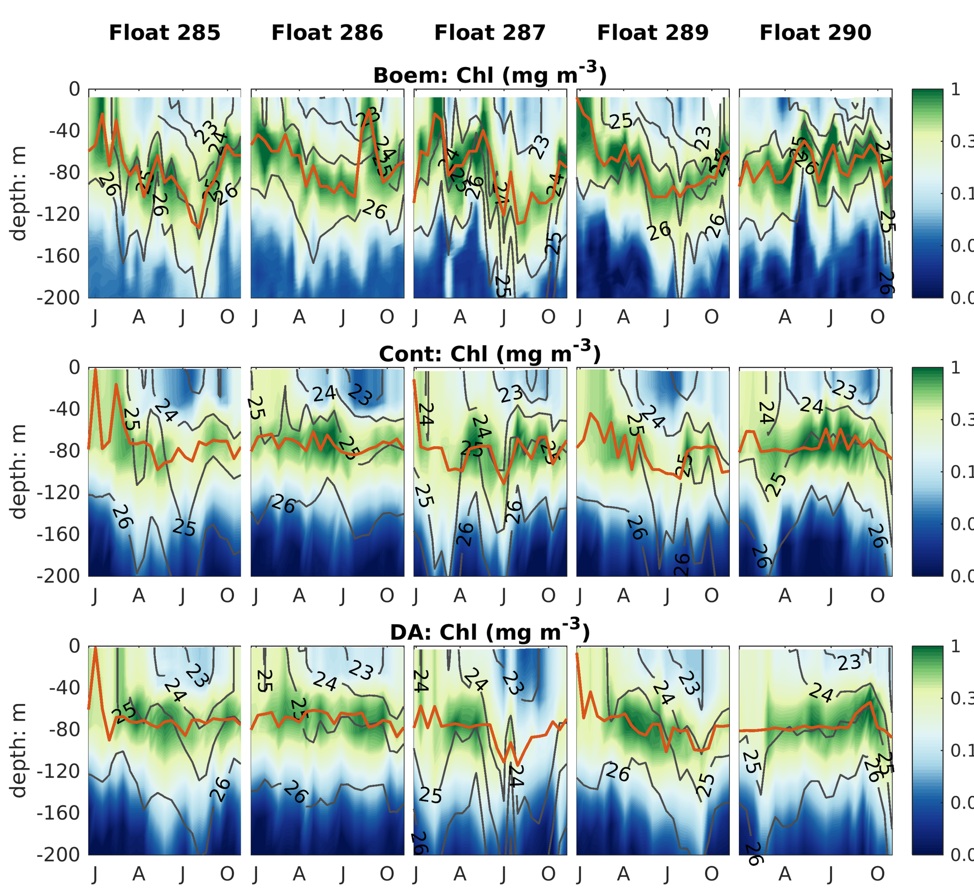


Figure 8 Vertical distributions of chlorophyll from Boem floats (upper panels), Cont run (middle panels), and DA run (bottom panels). Black lines represent isopycnic lines and red lines represent where the DCM is.

Table 1. RMSE of zeta, chlorophyll, and the depth of DCM with respect to each BGC float. The observed zeta is obtained from the matching record of Mapped SLA from AVISO added by MDT from Mulet et al (2013)

		285	286	287	289	290
zeta	Cont	0.15	0.07	0.45	0.21	0.08
	DA	0.11	0.04	0.11	0.09	0.08
Chl	Cont	0.17	0.19	0.17	0.18	0.18
	DA	0.16	0.18	0.18	0.17	0.15
DCM	Cont	26.89	22.07	35.56	23.01	14.91
	DA	26.89	24.77	21.14	16.36	12.56

➢ Both Cont run and DA run were insufficient to reproduce the temporal variabilities of subsurface chlorophyll and DCM

➢ The mesoscale features were an important factor controlling the variabilities of DCM with correlation coefficient being 0.60, 0.49, and 0.51 for observations, Cont run, and DA run, respectively.

➢ Modelled DCM was less sensitive to zeta than observed one.

➢ DA improved the depth of DCM by correcting mesoscale features especially along the float 287 when it passed though a newly-formed Loop Current eddy (anticyclone)

8. Summary and next steps

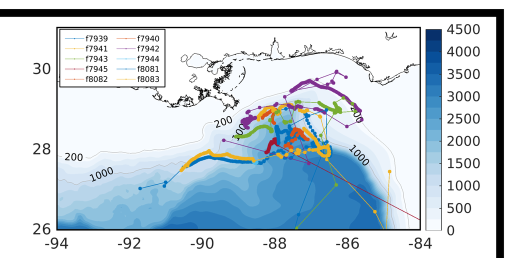
➢ Parameters optimized with respect to satellite data do not well reproduce subsurface distributions or carbon fluxes without profile observations (chlorophyll, phytoplankton, and POC).

➢ The state updates show a general improvement of surface chlorophyll on the basin-scale without deterioration in subsurface chlorophyll.

➢ The simultaneous assimilation of physical and biogeochemical data provides improvements in the vertical distribution of chlorophyll and DCM on local scales by correcting mesoscale features.

9. Next steps

Figure 9. Bathymetric map of the northern Gulf of Mexico with trajectories of ten BGC Argo floats.



➢ To assimilate BGC profiles (please see Figure 9) into the coupled physical-biological model.

Reference

Mulet, S., Rio, M. H., Greiner, E., Picot, N., and Pascual, A.: New global Mean Dynamic Topography from a GOCE geoid model, altimeter measurements and oceanographic in-situ data, OSTST Boulder USA 2013, available at: http://www.aviso.altimetry.fr/fileadmin/documents/OSTST/2013/oral/mulet_MDT_CNES_CLS13.pdf (last access: 31 August 2016), 2013.