Impact of BGC Argo data on state estimation by using the Estimated Ocean State for Climate Research (ESTOC)

Toshimasa Doi, Satoshi Osafune, Shinya Kouketsu, Shigeki Hosoda and Shuhei Masuda

Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Japan.

E-mail: doit@jamstec.go.jp

We are trying to estimate both physical and biogeochemical ocean states with integrating various observations including BGC Argo float array through a 4-dimensional variational data synthesis system.

Focused on the dissolved oxygen observation collected by BGC float.

Examined the effectiveness in ocean state estimation.

- ✓ The optimal model parameters are obtained for five basins (Atlantic, Pacific, Indian, Southern Ocean, and Arctic Ocean) with a Green’s function approach.
- ✓ Evaluate the BGC float observation impacts on our ocean state estimation.
  Comparing the results based on obtained optimized parameters between with and without BGC float observations.

Observation and model

Model

ESTOC >>> The data-set of ocean state estimate are published.
https://www.godac.jamstec.go.jp/estoc/e/

- The background dynamical ocean state :
  An ocean general circulation model (OGCM), the GFDL MOM3.
- The ocean data assimilation system :
  Based on a 4-dimensional variational (4D-VAR) data synthesis system.
- Resolution : 1° x 1° in horizontal and 45 + BBL vertical levels.
- Region : 75°S to 80°N and covering the full depth range.
- Period : From 1957 to 2014.

Ecosystem model : $\frac{\partial B}{\partial t} = ADV(B) + DIFF(B) + SMS(B)$

Observation

BGC ARGO from 2002 to 2020

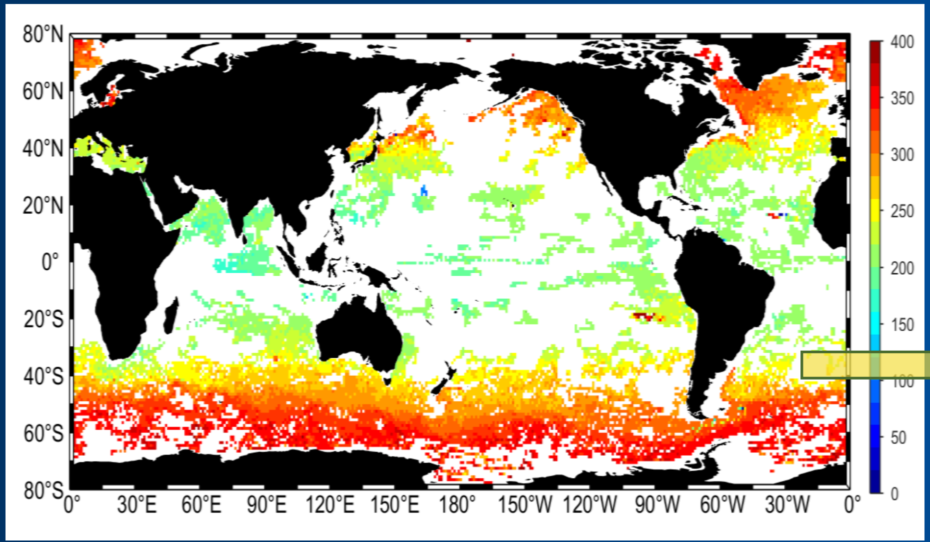

Figure 1: Position of dissolved oxygen profiles which observed by BGC Argo float from 2002 to 2020. Colors indicate dissolved oxygen concentrations (μmol/L).

Synthesis of observational data and model

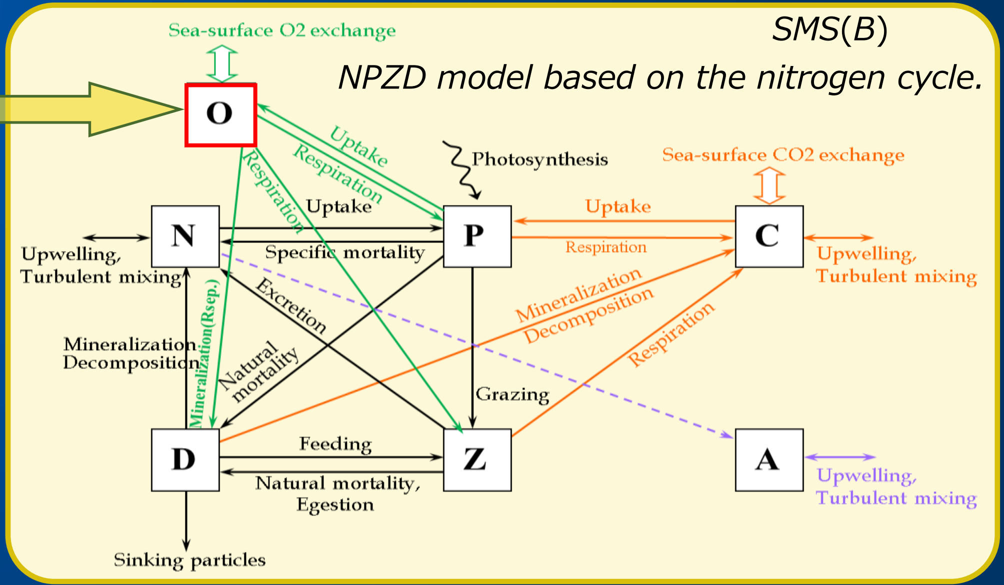

Figure 2: Schematic diagram of ecosystem part.

Synthesis of observational data and model

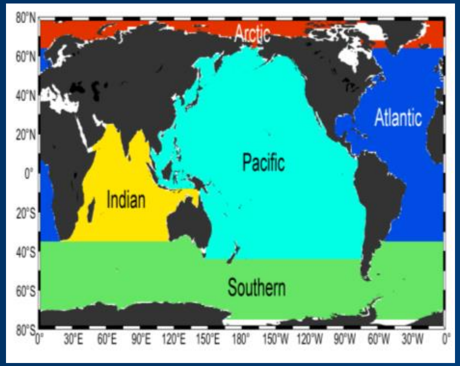

Figure 3: Five basin definition.

- The global ocean was divided into five basins .
- Optimize model parameters related to dissolved oxygen in each basin.
  - O/N ratio : The rate of oxygen consumption by biogeochemical activity.
  - O_2 gas transfer rate [m/day] : sea-surface exchange coefficient of oxygen.
- An optimal set of model parameters were searched through a Green's function approach (Menemenlis et al., 2005).
- The costs are dissolved oxygen concentration obtained by BGC float observation (Fig.1).

Optimized values for the control variables estimated by a Green's function approach

Parameter	First guess	Optimized values					
		Atlantic	Pacific	Southern	Indian	Arctic	Global
O/N ratio	8.63	9.29	9.26	8.90	9.29	8.43	
O2 gas transfer rate (m/day)	2.00	2.02	1.80	1.81	1.82	1.37	
Cost reduction rate (%)	-	-3.3	-5.0	-2.7	-6.9	-19.1	-4.1

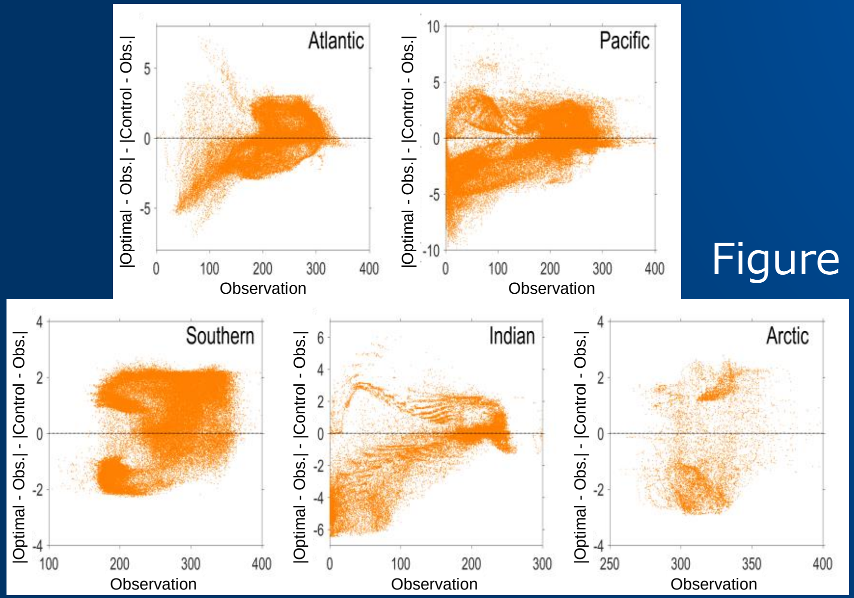

Figure 4: Scatter diagrams showing the correspondence with the observational data. The vertical axis indicates how much the difference from the observed value has changed by the optimization. Negative values represent that the difference from the observed values decreased. "Control run" was the result of execution with "First guess" parameters. Units are μmol/L.

Results of optimized model

The two optimal parameters resulted in the following changes from the model without dissolved oxygen assimilation.

- Concentrations were modified to have higher in the surface layers of the northern Atlantic, eastern Pacific, and southern oceans.
- Concentrations were lowered in the mid to deep layers, mainly in the low oxygen layer.

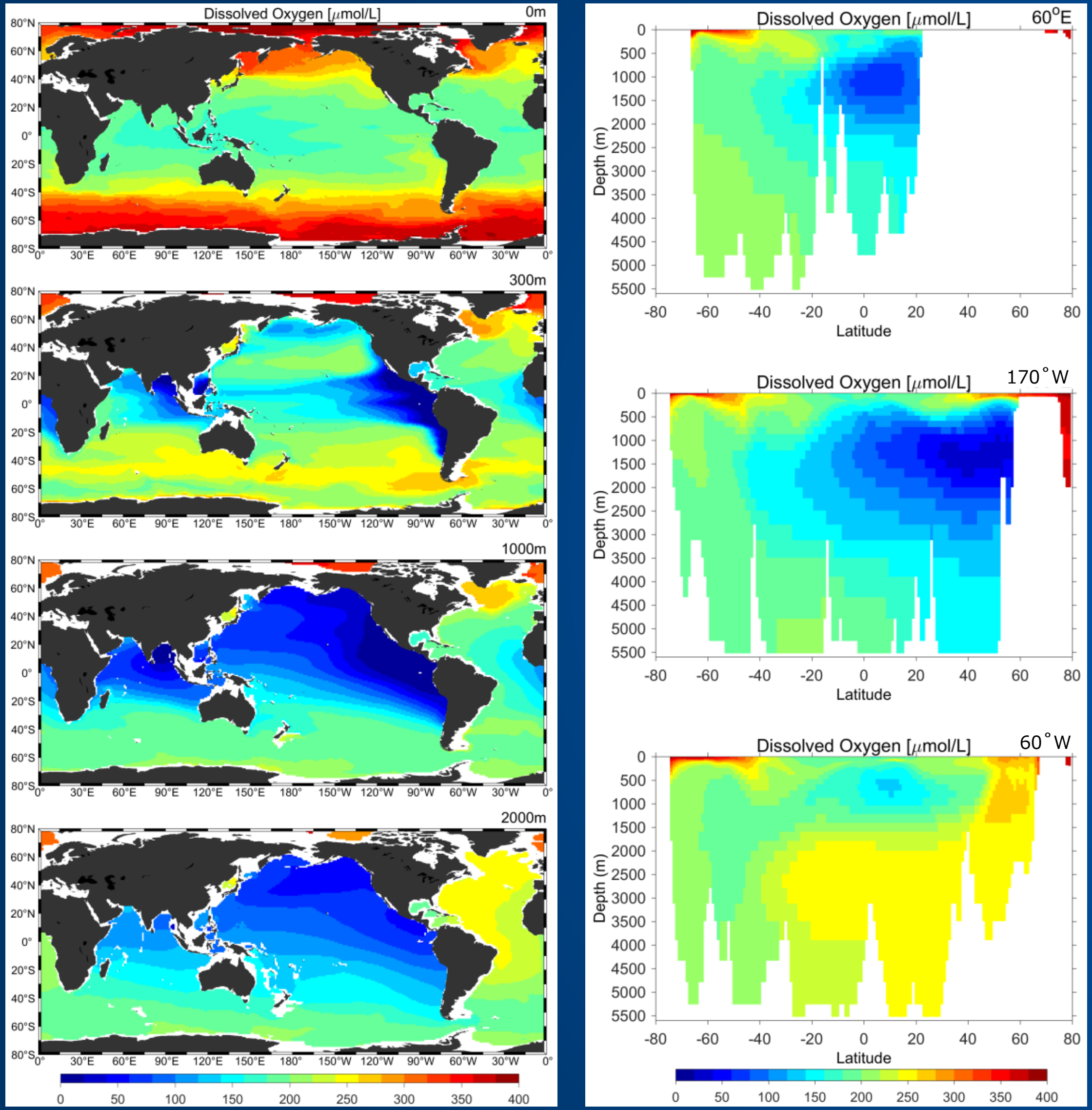

Figure 5: Dissolved oxygen distribution of the optimized model results.

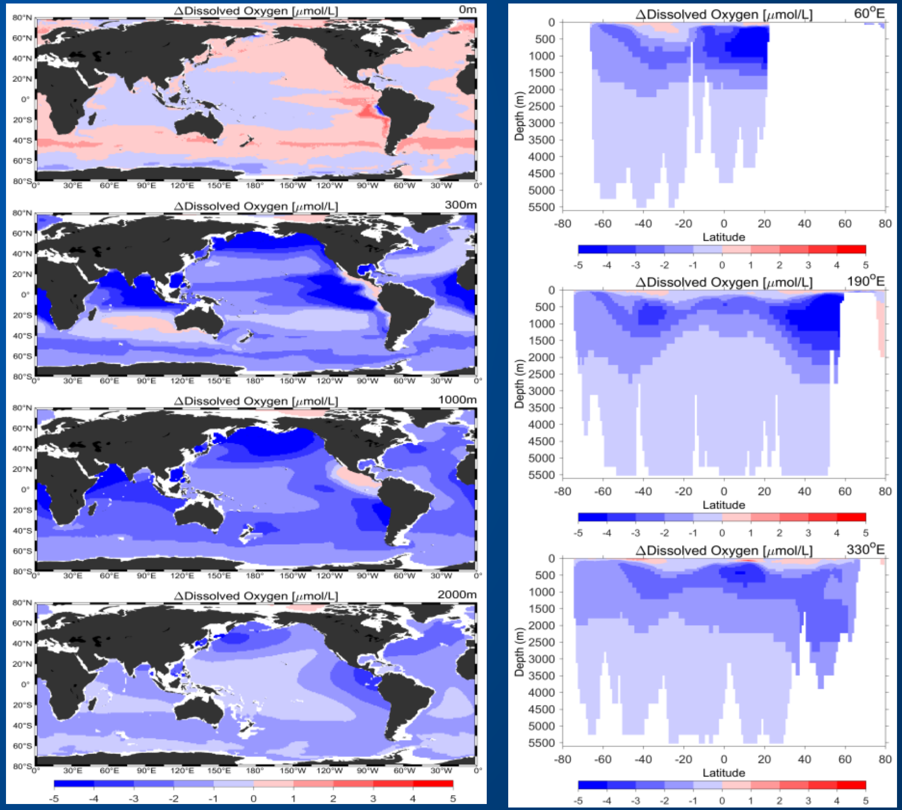

Figure 6: Dissolved oxygen difference from case without BGC float data.

Contribution of observational data to the model parameter optimization.

Method

- Investigate the difference between
  cost reduction rates from optimization using all observations
  and
  for each 10-degree rectangular region, the optimized cost reduction rate without considering its region's observation.

- The colors indicate
  in red : the basin cost increased.
  in blue : the basin cost decreased.
  in white : there were no observed profiles in that region at all.

- The black dots show the locations of BGC float profile.

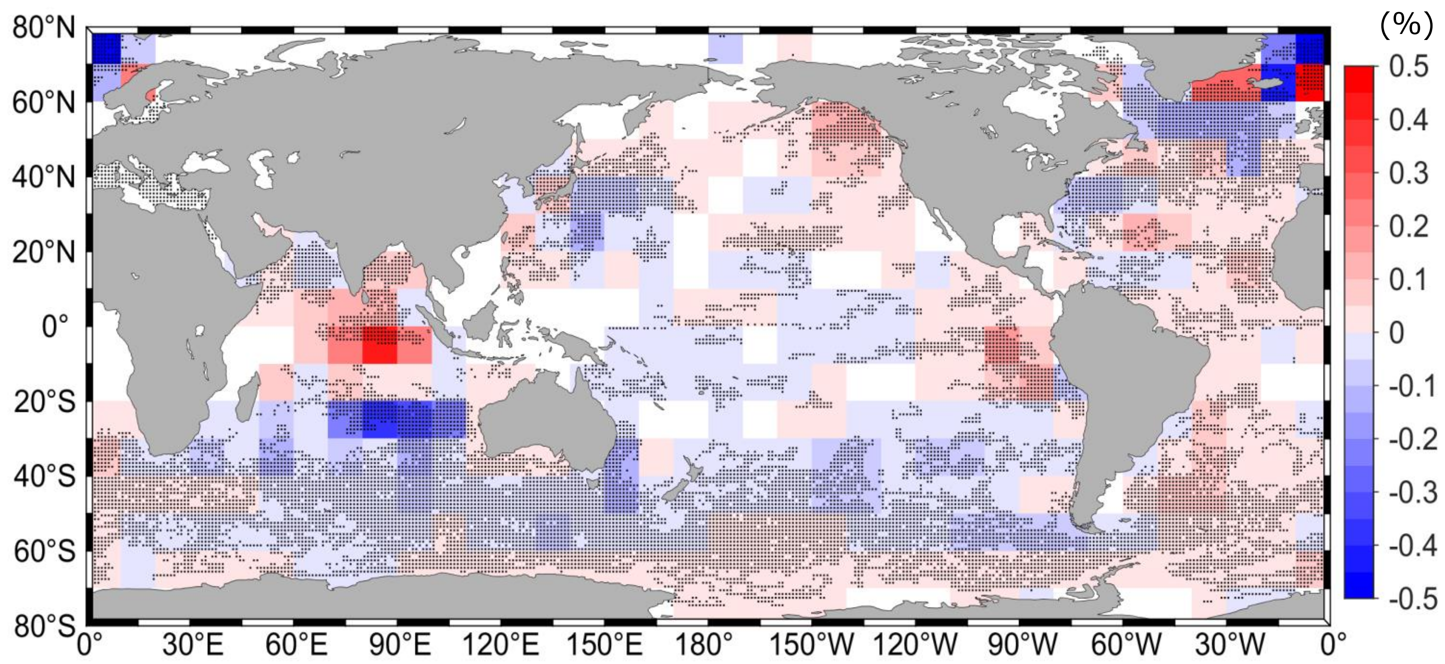

Figure 7: Map of differences in cost reduction rates.

Result

- Red areas show that the effect of optimization for the basin is estimated to become small.
- Blue areas indicate that the optimization of this basin is estimated to be better.

Pacific Ocean
Red areas are prominent in the eastern part of the basin.
It is suggested that the observations off Alaska and Peru play an important role.

Indian Ocean
Strong signals exist in the eastern equatorial region and the eastern of 20˚S.
It's suggests that observation in the equatorial region is effective and important for assimilation into the model.
The results around 20˚S suggest that there may still be problems with ESTOC modeling.
Red regions are slightly stronger in the Indian Ocean than in other basins.
→ More observation in the Indian Ocean is desired.

Arctic Ocean
Few observations.
The region where observations exist is limited.
→ Available or not of observations may have a significant impact.

Contribution of observational data to the model parameter optimization.

Conclusions

This analytical method is not yet a sufficient.

It is difficult at this stage to determine,
whether this is the result of model bias or is dependent on the evaluation methodology.

Impact of observation :
Note that we are not evaluating the regional impact, but rather the basin scale oxygen distribution.
Figure 7 indicates the regions that are effective in controlling the basin scale dissolved oxygen distribution reproduced by this system,
But
It does not mean that observation in the red region is important and in the blue region is not.

The results suggest that the stronger colored regions in each basin, the stronger the relative impact of the observations.

In this study, we controlled only dissolved oxygen concentration by two parameters for the data synthesis.

In the future work, the data synthesis will control the entire process of the lower trophic level ecosystem model, including oxygen and carbon, shown in Figure 2.

We will continue to improve the evaluation methodology and the model system.

Acknowledgements

This work was supported by JSPS KAKENHIs Grant Number JP22H05207 and JP18H04129.

The BGC Argo data used was obtained from GDAC.

Argo (2000). Argo float data and metadata from Global Data Assembly Centre (Argo GDAC). SEANOE. https://doi.org/10.17882/42182

Appendix

For more information on ESTOC, please refer to the following paper.

Osafune, S., S. Masuda, N. Sugiura, and T. Doi (2015), Evaluation of the applicability of the Estimated State of the Global Ocean for Climate Research (ESTOC) data set, Geophys. Res. Lett., 42, 4903–4911, doi:10.1002/2015GL064538.

Doi, T., S. Osafune, N. Sugiura, S. Kouketsu, A. Murata, S. Masuda, and T. Toyoda (2015), Multidecadal change in the dissolved inorganic carbon in a long-term ocean state estimation, J. Adv. Model. Earth Syst., 7, 1885–1900, doi:10.1002/2015MS000462.