Estimated State of Ocean for Climate Research by Using a 4 Dimensional Variatinal Approach (ESTOC)

Project Representative

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A 4-dimensional variational data assimilation system has been used to better define the 53-year global ocean state estimation for climate research. The synthesis of available observations and general circulation model with a pelagic ecosystem model based on nitrogen cycle yields a dynamically self-consistent dataset. Obtained ocean state estimation possibly has greater information than do models or data alone. We here present the properties of the analysis fields and some results of climate study by using this state estimation named ESTOC. This report implies that our synthesis scheme as a dynamical interpolation for sparse observations including bio-geochemical parameters is possibly promising and useful for climate researches.

Keywords: Ocean, Data assimilation, Hydrological cycle

1. Introduction

Ocean state estimation is a coherent picture of the global ocean circulation by synthesizing data from observational tools of a very wide diversity of type and is usually capable of being used for global-scale energy, heat, and water cycle budgets (*Wunsch and Heimbach, 2013*)[1]

It is getting widely recognized that dynamical state estimation is a promising tool for ocean climate change research (*e.g., Masuda et al., 2010*)[2].

In this study, we have conducted a global ocean synthesis on the basis of available ocean observations, satellite data and a global circulation model through a 4-dimensional variational (4D-VAR) data assimilation to obtain a comprehensive 4-dimensional integrated dataset. The dataset includes an estimate of the global biogeochemical variables toward an Integrated Earth System Analyses (*Rienecker et al., 2010*)[3].

2. Model

The background dynamical ocean state is derived from ocean data assimilation system, based on ocean general circulation model (OGCM); version 3 of the GFDL Modular Ocean Model (MOM) (*Pacanowski and Griffies, 1999*)[4] with major physical parameter values determined through a variational optimization procedure (*Menemenlis et al., 2005*)[5]. The horizontal resolution is 1 degree in both latitude and longitude, and there are 46 vertical levels for the global ocean basin.

Biogeochemical model we used is a NPDZC-model. This model is the pelagic ecosystem model based on nitrogen cycle and is optimized for the Earth Simulator. Our system is summarized in Fig. 1.

3. Optimization

In our 4D-VAR approach, optimized 4-dimensional analysis fields are sought by minimizing a cost function on the basis of adjoint method for physical parameters (*e.g., Sasaki 1970*)[6] and Green's function approach (*Menemenlis et al., 2005*)[5] for biogeochemical ones. The assimilated elements are temperature and salinity based on EN3 dataset provided by Met Office Hadley Centre, sea surface height anomaly form AVISO, nitrate from WOA05, and chlorophyll-a from WOA98 and SeaWiFS. We carried out a data synthesis experiment on the Earth Simulator, which covers 53-year period for 1957-2009.

OGCM:
GFDL MOM3, quasi-global 75°S-80°N
horizontal res: 1°x1°, vertical res:45 levels

Spinup:
1. 3000-year with a climatological forcing (accelerated method)
2. 120-year as climatological seasonal march.
3. 10-year with interannual forcings from NCEP/DOE.

Biogeochemical model:
NPDZC model (Off Line)

Data synthesis for physical parameters:
method: strong constraint 4D-VAR adjoint.
adjoint coding: by TAMC with some modifications.
assimilation window: 53 years (1957-2009)
control variables: initial T, S, 10-daily surface fluxes
first guess: executed form the last of Spinup 3
assimilated elements: OISST, T, S (Ensembles ver.3 inclusive of Argo float data + Mirai RV independent dataset),AVISO SSH anomaly.

Data synthesis for biogeochemical parameters:
method: 4D-VAR without adjoint (Green's function)
control variables: model parameters
assimilated elements: Nitrate (WOA climatology), Phytoplankton (SeaWiFS)
Chl-a (WOA climatology as Detritas)

Fig. 1 Overview of the ocean data synthesis system.

4. Results

The obtained synthesis results were compared with Grid Point Value of the Monthly Objective Analysis using the Argo data (MOAA GPV) (WOCE Hydrographic Program) (*Hosoda et al., 2008*)[7]. Figures 2 show the distribution of temperature and salinity at 1000-m depth. These panels illustrate the synoptic patterns in ESTOC are by and large consistent with observations.

Figure 3 shows salinity anomaly for 2003-2007 above 100-m depth. It is implied that positive (negative) anomalies tend to appear in the high (low) salinity regions. This result is in basic agreement with *Hosoda et al*., (*2009*)[8]. Some positive anomalies are caused by change in the surface fresh water flux (not shown), which support the hydrological cycle intensification hypothesis made by *Hosoda et al*., (*2009*)[8].

5. Concluding Remarks

Our ocean data synthesis system is a powerful tool to better understand ocean climate change and will possibly contribute to the resolution of scientific issues, for instance, on global hydrological cycle in conjunction with global warming. This report implies that further work along these lines may enable us to obtain new scientific findings and also identify the optimal requirements for measurement instruments to be deployed in the future.

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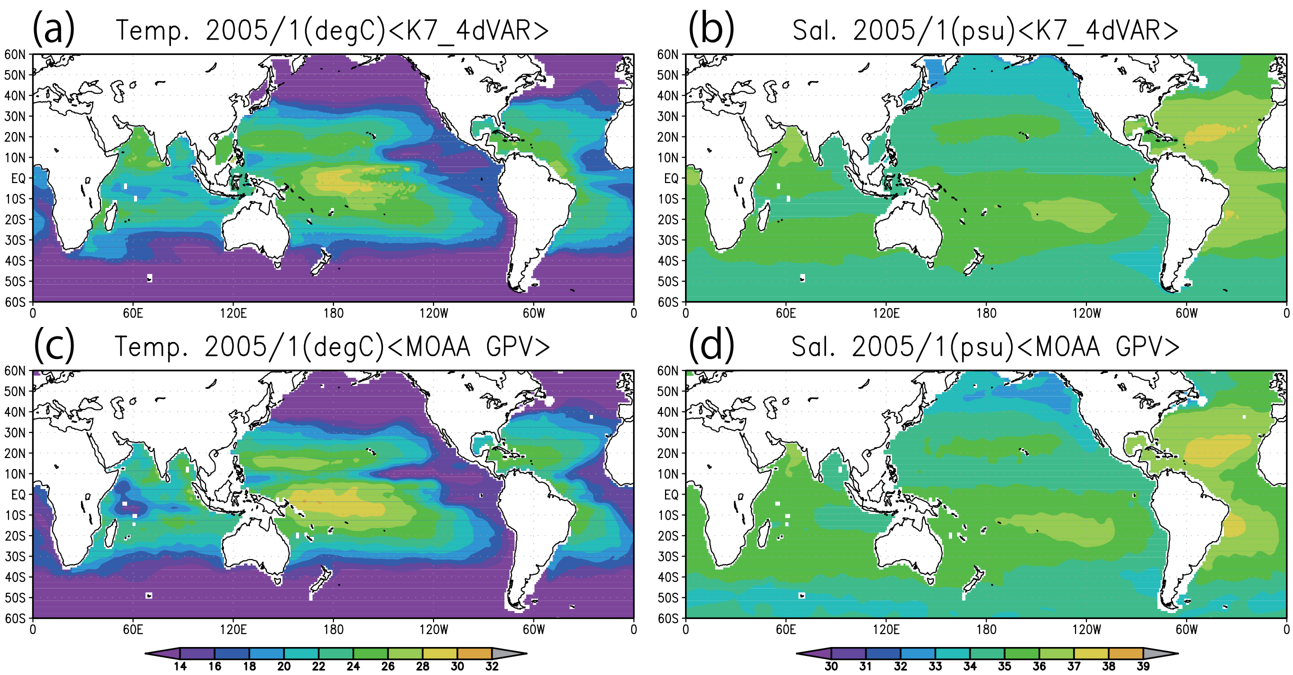

Fig. 2 (a), (b) Temperature and salinity distribution at the depth of 1000 m in ESTOC. (c), (d) The same as (a) and (b) but for MOAA GPV.

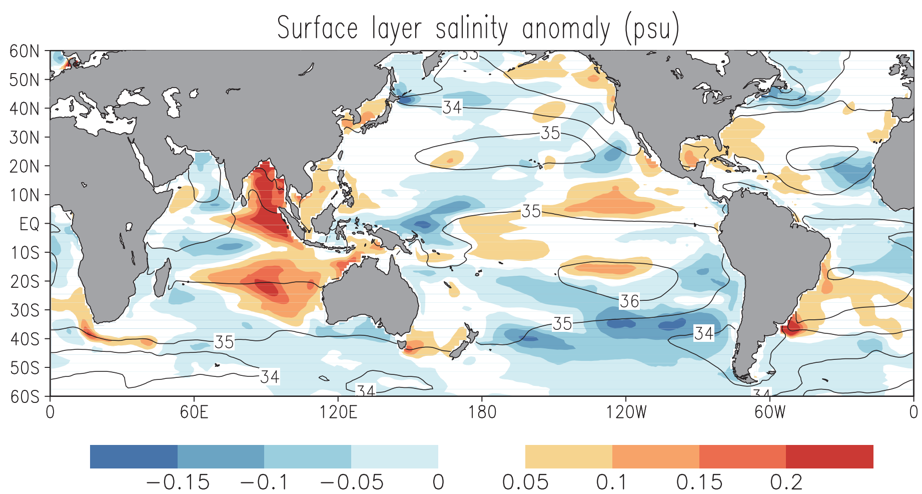

Fig. 3 Surface-layer salinity anomaly (color shade) with climatological salinity (contour).

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四次元変分法を用いた海洋環境再現
(Estimated State of Ocean for Climate Research: ESTOC)

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数年から数十年の時間スケールを持つ気候変動現象の包括的な理解を深めるためには海洋の状態を正確に把握することが重要である。そのための手段として海洋観測と数値シミュレーション結果を力学的整合性を保持しながら統合する海洋環境再現が注目されている。(独) 海洋研究開発機構では水温、塩分などの物理データ、溶存化学物質、植物プランクトン色素などの生物化学データ等、異なる時空間スケールを持つ様々な海洋観測データを数値モデルを活用して時空間的に矛盾なく統合したデータセット (Estimated State of Ocean for Climate Research: ESTOC) を作成した。本研究ではESTOC の概要とそれを用いた海盆規模での淡水循環変動研究への応用可能性を示す。

キーワード : 海洋, データ同化, 淡水循環