

## 4D-VAR Ocean State Estimation

April 10, 2019

### ■ Name of data set and the abbreviated name

**Name:** Estimated state of ocean for climate research

**Abbreviation:** ESTOC

### ■ Data Overview

This version of dataset is an updated version of dataset shown by Osafune et al. (2015) (see them for more details). Our four-dimensional variational (4D-VAR) data synthesis system, which consists of an ocean circulation model, its adjoint and an optimization system, is based on a system developed as a part of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC)-Kyoto University collaborative program (known as "the K7 consortium"). The Ocean General Circulation Model (OGCM) is version 3 of the GFDL Modular Ocean Model (MOM3) [1], which is equipped with several sophisticated schemes; e.g., Noh scheme for mixed layer physics[2], the Gent and McWilliams (GM) scheme for isopycnal mixing [3], and quicker advection scheme. Major physical parameter values are determined through a variational optimization procedure [4]. The horizontal resolution is  $1^\circ$  in both latitude and longitude, with 46 vertical levels spaced from 10 m near the sea surface to 400 m at the bottom. This model is better able to reproduce ocean circulation processes and is expected to form a platform suitable for the use of the 4D-VAR adjoint model.

Physical parameters:

4D-VAR adjoint data assimilation approach is applied [5,6]. The adjoint codes of the OGCM were obtained using the Tangent linear and Adjoint Model Compiler (TAMC) [7] and the Transformation of Algorithms in Fortran (TAF) [8]. In the 4D-VAR approach, optimized 4-dimensional datasets are sought by minimizing a cost function [9,10].

The assimilated elements in this study are subsurface temperature and salinity, Sea-surface Temperature (SST), Sea-surface height anomaly (SSHA) and Global Mean Sea Level (GMSL). The subsurface data is from EN4 dataset which was quality controlled using a comprehensive set of objective checks developed at the Hadley Centre of the UK Meteorological Office [11]. This dataset is largely composed of observations from the World Ocean Database 2009 [12] and supplemented by data from the GTSP (Global Temperature and Salinity Profile Program) and Argo autonomous profiling floats [13]. The SST data is from Reynolds and OISST, and SSHA data is derived from high-precision multi-satellite altimetry products distributed by Copernicus Marine Service. The GMSL data is monthly data until 2013, which is reconstructed based on Church and White (2011) and published by Ocean and Atmosphere unit in the Commonwealth Scientific and Industrial Research Organisation (CSIRO) ([http://www.cmar.csiro.au/sealevel/sl\\_data\\_cmar.html](http://www.cmar.csiro.au/sealevel/sl_data_cmar.html)). All observational data except for GMSL were averaged onto  $1^\circ$  by  $1^\circ$  bins and then compiled as series of 10-day means for the SST and SSHA data and monthly means for the subsurface and GMSL data. The control variables are surface fluxes (for net-heat, fresh water, and momentum) and oceanic initial conditions. The assimilation window is 58 years during 1957-2014.

Biogeochemical parameters:

The synthesis of available observations and a pelagic ecosystem model based on nitrogen cycle produces a dynamically self-consistent dataset. Optimized 4-dimensional datasets are sought by minimizing a cost function on the basis of Green's function approach [4]. The assimilated elements are the climatological monthly mean nitrate from WOA05, monthly mean ocean color data from SeaWiFS, and annual mean chlorophyll-a from WOA98 as detritus.

- [1] R. C. Pacanowski, S. M. Griffies, The MOM 3 Manual, Geophysical Fluid Dynamics Laboratory/NOAA, Princeton, USA, p.680 (1999).
- [2] P. R. Gent, J. C. McWilliams, J. Phys. Oceanogr., 20, 150 (1990).
- [3] Y. Noh, Geophys. Res. Lett., 31, L23305 (2004).
- [4] D. Menemenlis et al., Mon. Weath. Rev., 133, 1224 (2005).
- [5] Y. Sasaki, Mon. Weather Rev., 98, 875(1970)
- [6] C. Wunsch, The Ocean Circulation Inverse Problem, Cambridge Univ. Press, New York, 442 pp (1996).
- [7] R. Giering, T. Kaminski, Recipes for Adjoint Code Construction, ACM Trans. On Math. Software, 24 (4), 437 (1998).
- [8] R. Giering, T. Kaminski, Applying TAF to generate efficient derivative code of Fortran 77-95 programs, Proceedings in Applied Mathematics and Mechanics, 2 (1), 54 (2003).
- [9] J. Marotzke et al., J. Geophys. Res., 104, c12, 29529 (1999).
- [10] D. Stammer et al., J. Geophys. Res., 107, C9, 3118 (2002).
- [11] B. Ingleby, M. Huddleston, J. Mar. Sys., 65, 158 (2007).
- [12] Boyer et al., World Ocean Database 2005, NOAA Atlas NESDIS 60, US Gov. Print. Off., Washington DC, (2006).
- [13] Gould, Deep Sea Res., II, 52, 529 (2005)

■ **Dataset release date**

May 14, 2019

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#### ■ References to be cited

Please cite as follows:

Osafune, S., S. Masuda, N. Sugiura, 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, 12, 4903–4911.

Doi, T., S. Osafune, N. Sugiura, S. Kouketsu, A. Murata, S. Masuda, and T. Toyoda (2015) Multi-decadal change in the dissolved inorganic carbon in a long-term ocean state estimation, *Journal of Advances in Modeling Earth Systems*, 7, 4, 1885–1990

#### ■ Available Products

Variables, abbreviations	Potential temperature [°C], Salinity [PSU], Horizontal velocity u[m/s] v[m/s], Surface heat flux [cal/m <sup>2</sup> /s], Surface freshwater flux [m/s], Wind stress $\tau_x$ [N/m <sup>2</sup> ] $\tau_y$ [N/m <sup>2</sup> ], Nitrate [ $\mu$ mol/L], Phytoplankton [ $\mu$ mol/L], Detritus [ $\mu$ mol/L], Zooplankton [ $\mu$ mol/L], Dissolved inorganic carbon [ $\mu$ mol/kg], Dissolved Oxygen [ $\mu$ mol/L],	tmp sal vel shf sff tau no3 pht det zoo dic oxy
Region	Quasi-global (75°S-80°N)	
Resolution	Horizontal 1°x1°, Vertical 46 levels	
Period	1957-2014 (Ver. 03b)	
File format	Monthly data in netcdf format: “k7oda_[XXX]_[YYYY][MM]00_[VVV].nc” where “[XXX]” is model variable, “[YYYY]” year, “[MM]” month, and “[VVV]”version, respectively.	

■ **Reference URL**

- K7 Database  
<http://www.jamstec.go.jp/frcgc/k7-dbase2/eng/index.html>
- K7 Ocean State Estimate based on 4D-VAR Ocean Data Assimilation  
[http://www.jamstec.go.jp/frcgc/k7-dbase2/eng/datadoc/k7ra\\_ocean.html](http://www.jamstec.go.jp/frcgc/k7-dbase2/eng/datadoc/k7ra_ocean.html)
- Data and Sample Research System for Whole Cruise Information in JAMSTEC (DARWIN)  
<http://www.godac.jamstec.go.jp/darwin/e>
- Japan Argo Delayed-mode Data base\_  
[http://www.jamstec.go.jp/ARGO/argo\\_web/argo/?lang=en](http://www.jamstec.go.jp/ARGO/argo_web/argo/?lang=en)