CESM Large Ensemble with Increased Access for Ocean Biogeochemistry

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Overview

Large ensemble (LENS) of comprehensive Earth System Model allows scientists to identify and separate anthropogenic effects from the natural variability. Open sharing of the LENS datasets can lead to groundbreaking research. However, the analysis of model output can be challenging due to its massive data volume. A compressed version of LENS dataset is assembled in order to significantly reduce the data volume while retaining major features of the original output. The objective of this poster is to introduce the compressed outputs of CESM-LENS (Kay et al., 2015) for selected variables relevant to ocean biogeochemistry. A resolution of 2°x2° longitude-latitude grid with 33 vertical z-levels is chosen to balance the integrity of large-scale fields. The reduction in both temporal and spatial resolution causes the loss of information, and its effect is assessed. Initial assessments suggest that the benefit of compact dataset can outweigh minor errors due to the resolution reduction. This project is supported by NSF OCE Grant 1737188, 1737282 and 1737158.

A compact CESM Large Ensemble

CESM LENS (Kay et al., 2015)

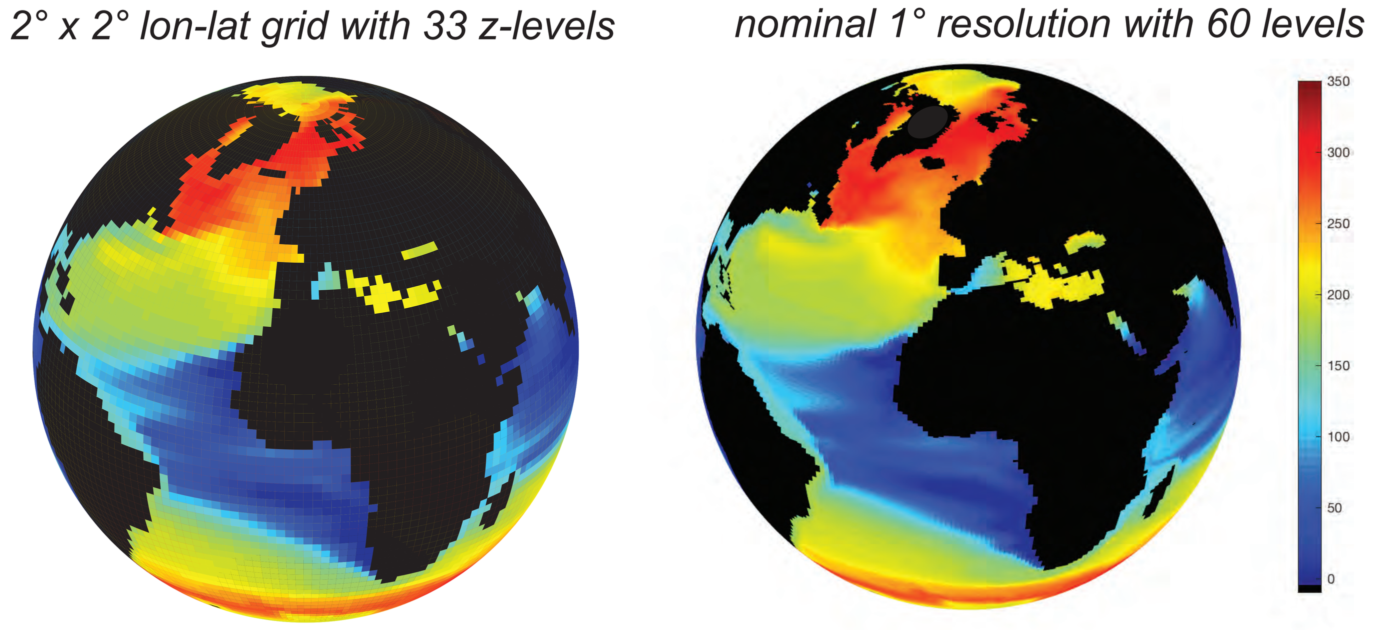
Ensemble simulations are performed with a fully coupled earth system model, CESM1, from 1920 to 2100. Each member is forced by identical historical and RCP8.5 radiative forcing, but is initialized by slightly different atmospheric initial condition. 34 ensemble members include the ocean biogeochemistry component. At the native resolution, monthly output of a single ocean variable (3D) takes 37GB of data from 1920 to 2100, and the full output is on the order of 25TB.

Re-gridding

Bilinear interpolation is performed using cdo (climate data operators) to reduce the resolution. Annual means of monthly means are calculated and recorded.

O_2 at 200m

2° x 2° lon-lat grid with 33 z-levels *Native grid (f09_g16) nominal 1° resolution with 60 levels*



What's included?

4D fields (lon,lat,depth,time) of potential temperature, salinity, potential density, oxygen, phosphate, DIC, total alkalinity, ideal age, OUR, and current speed.

3D fields (lon,lat,time) of air-sea CO2 flux, air-sea O2 flux, air-sea heat flux, air-sea freshwater flux, fractional ice cover, maximum mixed layer depth (annual maximum of monthly maximum).

All variables from a single ensemble member can fit within one netCDF file of **7.3GB** combining historical and RCP8.5 scenario (1920-2100).

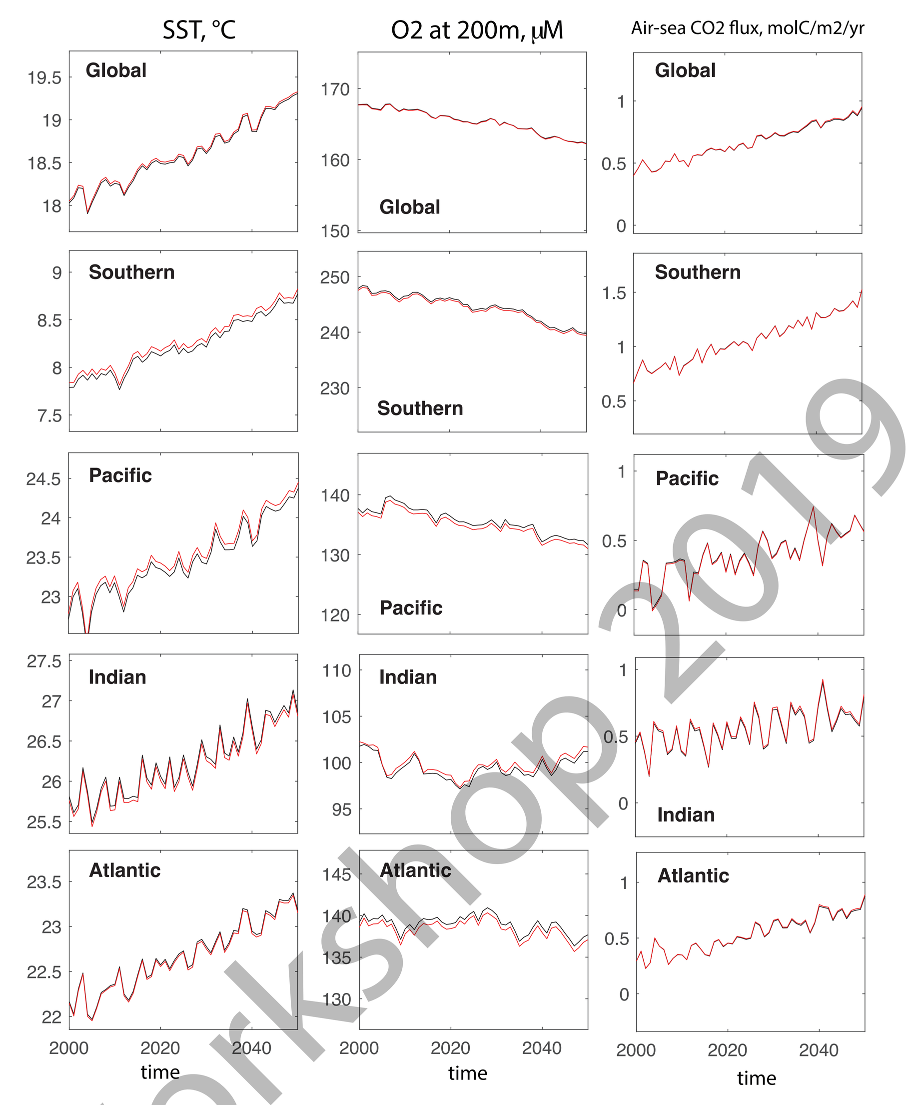
Pre-industrial control is also provided, and the total data volume is about **310GB** which can be downloaded over less than one day using broadband connection, and can fit on a small hard drive.

It is publicly available (registration required) at http://rda.ucar.edu/datasets/ds645.0

Benchmark: single member

How is a single member affected by the re-gridding?

Basin-scale averages of a single member (001) are calculated for a few selected variables and compared to the original CESM- LENS output. They closely follow the original data.



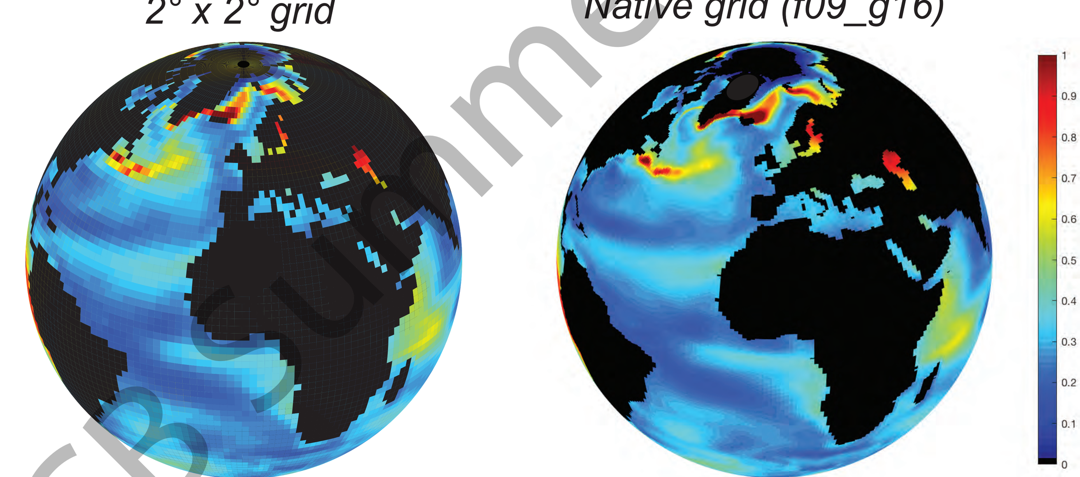
Here, we examined area-weighted averages of (left) SST, (middle) O_2 at 200m, and (right) air-sea CO_2 flux. Black lines reflect the values directly calculated from the original data, and the red lines are based on the re-gridded (2° x 2°) data.

The square of correlation coefficient (R^2) are greater than 0.99 for all basins and for all variables. Generally, errors tend to occur near the coastlines. For the basin-scale averages, it is expected that smaller basins have larger errors.

Benchmark: ensemble statistics

Standard deviation of SST

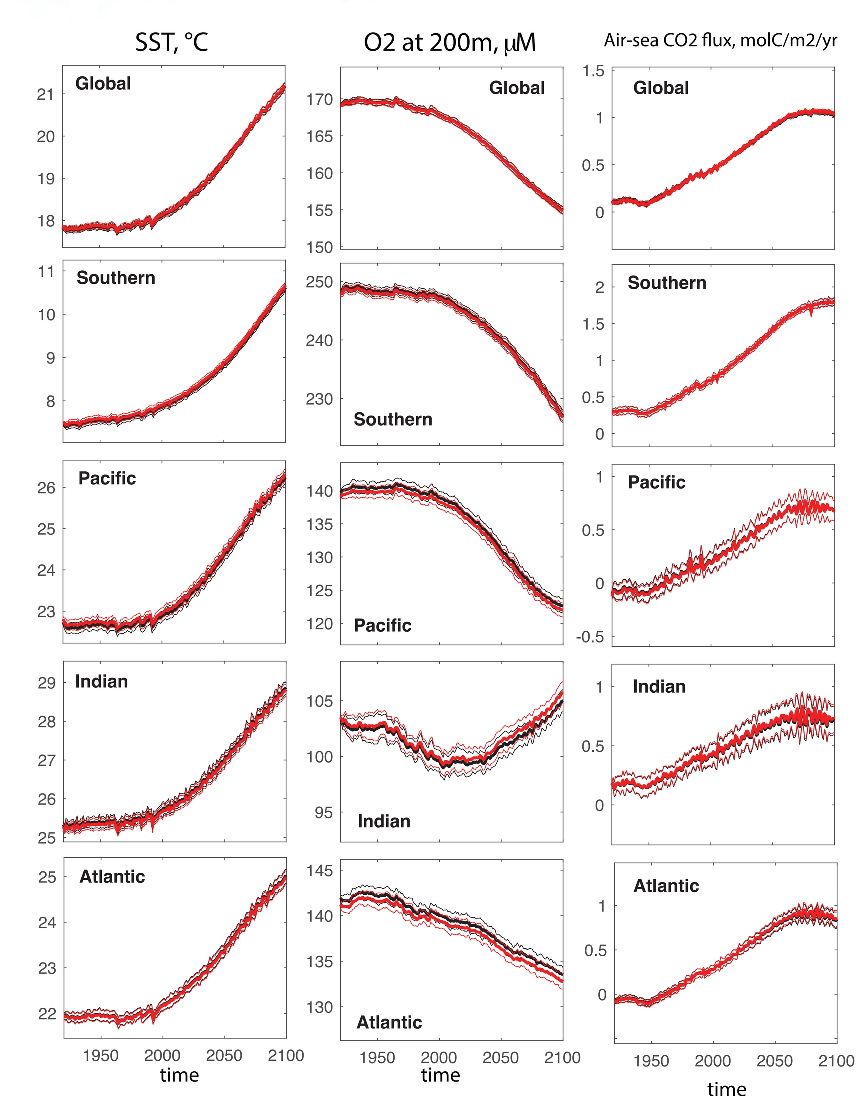
2° x 2° grid *Native grid (f09_g16)*



Standard deviation among ensemble members can quantify the magnitude of natural variability. Its spatial pattern is generally well captured.

How are the ensemble statsitics affected by the re-gridding?

Ensemble mean and standard deivation are calculated for a few selected variables and compared to the original CESM-LENS output. They capture the statistics of the original data well.



The thick lines are the ensemble me, and the thin lines are ±1 STD. The 2° product generally follows the original data closely.

For the basin-scale means, the mean biases are less than 0.07°C for SST, 0.7 μM for O2 at 200m, and 0.03 molC $m^{-2}yr^{-1}$ for air-sea CO2 fluxes.

The 2° product captures the large-scale averages very well. Also it captures the spatial patterns of variability. These assessments suggest that the benefit of compact dataset can outweigh minor errors, especially for large-scale analyses.

Application: Time of Emergence

Example: The Time of Emergence (ToE) for hypoxic depth

Hypoxic depth is defined as the depth at which the O_2 level goes below a threshold. Low-O_2 water can be harmful to marine organisms, and the hypoxic depth is expected to rise under global warming.

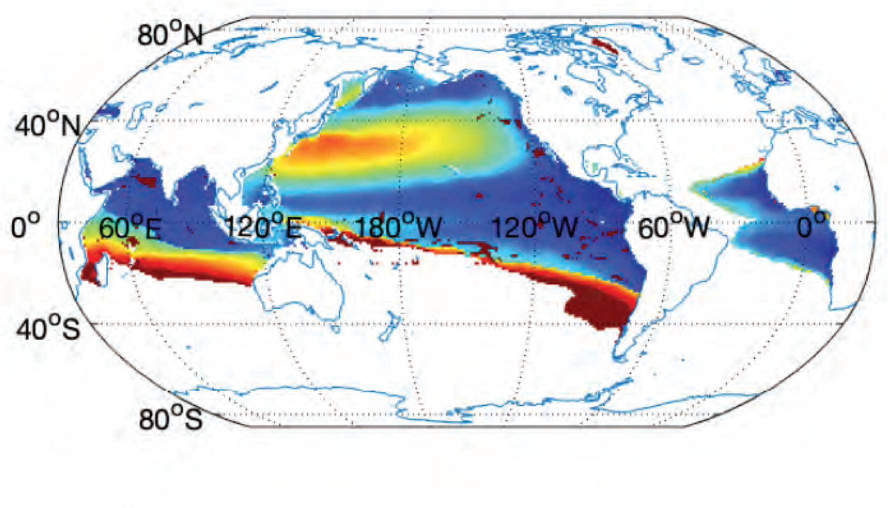
(top) Oxygen climatology from the World Ocean Atlas 2013v2 is used to assemble the climatological hypoxic depth for the 40μM surface.

(bottom) CESM-Large Ensemble at 2° resolution. Encouraged by the ability of the model to reproduce the overall patterns of the observations, ToE of the 40μM depth is calculated.

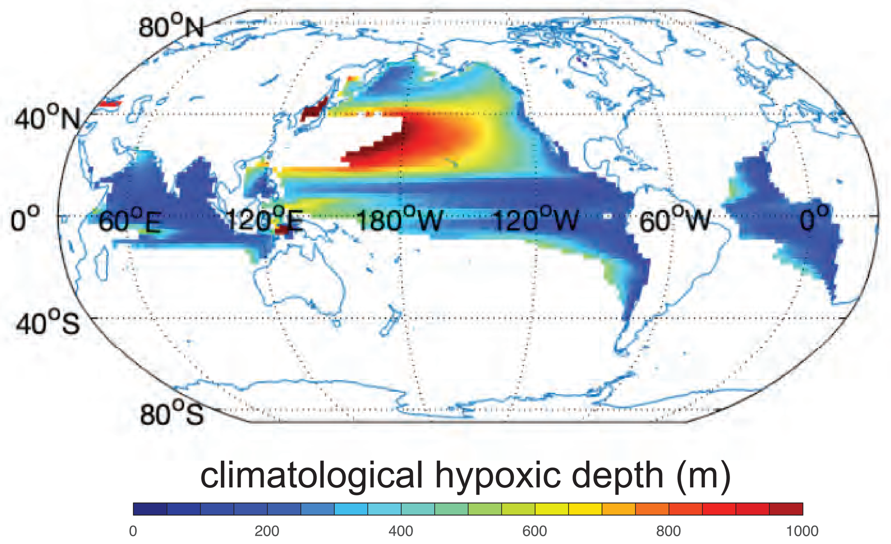
Time of Emergence is defined as the time when the forced response (signal) exceeds the range of natural variability (noise). ToE can be calculated based on the anomalies of state variables (Santer et al. 1994; Long et al. 2016).

First, the global mean hypoxic depth is plotted on the right with (blue) each members and (white) ensemble mean. The baseline period is set to 1970-1990 with a mean of 328m and the standard deviation of 2.8m. ToE is detected when hypoxic depth remains outside of two times the standard deviation below the baseline value. Excluding one outlier, the ToE covers the range of 2021 to 2059 with the

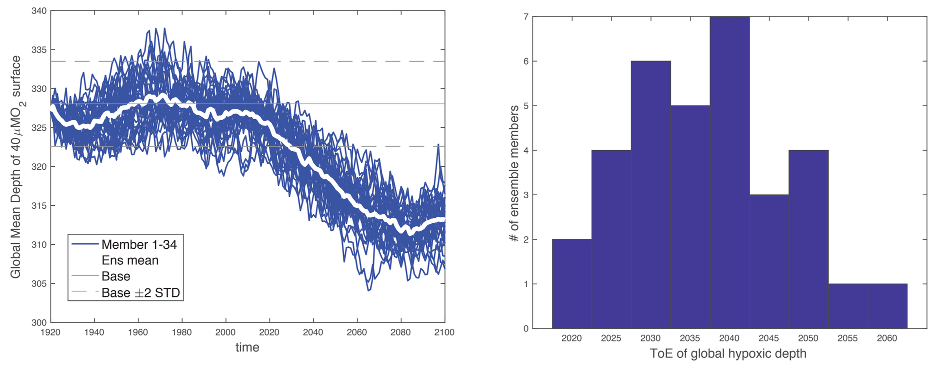
World Ocean Atlas 2013v2



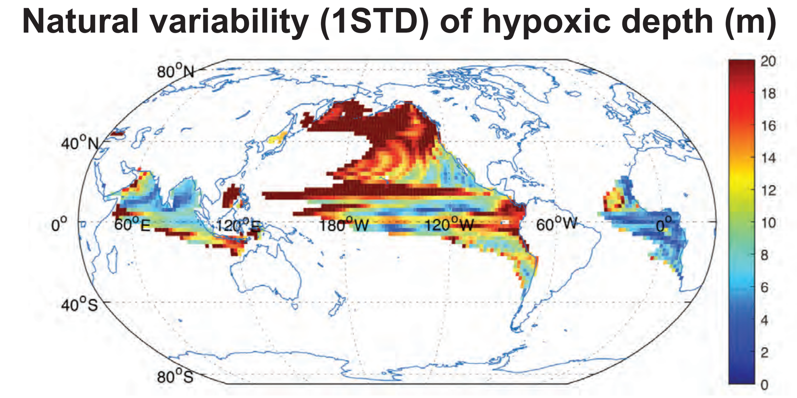
CESM-LEIA



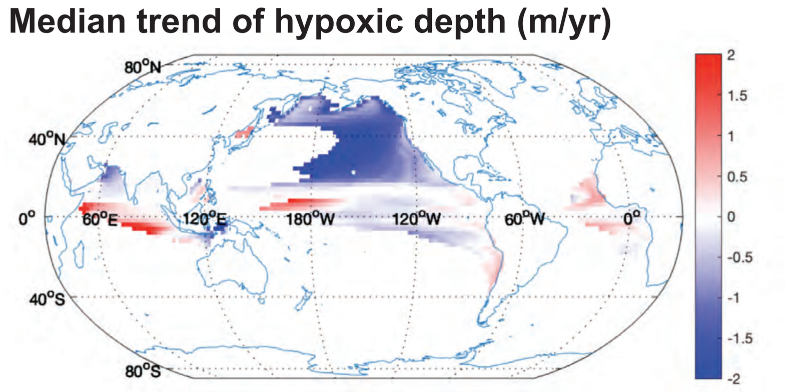
Analysis of global mean hypoxic depth



Natural variability (1STD) of hypoxic depth (m)

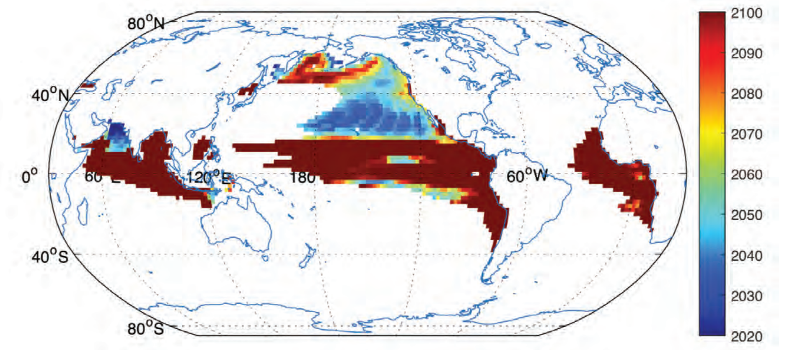


Median trend of hypoxic depth (m/yr)



To determine the spatial map of ToE, the natural variability (noise) is first estimated from all ensemble members during 1970-1990 (upper left). For each grid cells, ToE is detected when hypoxic depth remains outside of two times the STD below the baseline value (lower right). ToE does not occur in most of tropics because the hypoxic depth does not have a significant shoaling trend.

Median ToE of hypoxic depth (Year)



This data product is freely available from https://doi.org/10.5065/Y5K4-6D48.
We welcome collaborations/suggestions for scientific applications, inter-comparison with other ESM-LENS dataset(s), or selection of variables for future refinement of this dataset.

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