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Creating an Eight-Member Ocean Reanalysis Ensemble for Use by the Climate Modeling Community

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Abstract

NASA Goddard Space Flight Center's Collaborative REAnalysis Technical Environment (CREATE) team and the Climate Variability and Predictability (CLIVAR) Global Synthesis and Observations Panel (GSOP) collaborated to develop ensemble average and standard deviation (spread) products for potential temperature, salinity, and zonal and meridional velocities from eight ocean reanalyses:

1. NCEP/CFSR (National Centers for Environmental Prediction Climate Forecast System Reanalysis)
2. CMCC/C-GLORSv5 (Centro Euro-Mediterraneo per i Cambiamenti Climatici) Global Ocean Physical Reanalysis System v5 C-GLORSv5)
3. ECMWF/ORA-S4 (European Centre for Medium-Range Weather Forecasts Ocean ReAnalysis System 4)
4. ECMWF/ORAP5.0 (European Centre for Medium-Range Weather Forecasts Ocean ReAnalysis Pilot 5.0)
5. University of Hamburg/GECCO2 (University of Hamburg German Estimating the Circulation and Climate of the Ocean)
6. GFDL/ECDA (Geophysical Fluid Dynamics Laboratory Ensemble Coupled Data Assimilation v3.1)
7. NOAA/GODAS (National Oceanic and Atmospheric Administration Global Ocean Data Assimilation System)
8. MOVE/MRI.COM-G2i (Multivariate Ocean Variational Estimation Meteorological Research Institute Community Ocean Model)

Ocean Reanalysis Products

Native Grid at Native Depths for Each Member Reanalysis

The variables are potential temperature, salinity, and zonal and meridional velocities, in the native grid and native depths of the source, for the time range 1980–2010. The files are modified:

1

- Source files require minimum formatting to use Climate Data Operators (CDO) and NetCDF Operators (NCO) and publish in THREDDS and the Earth System Grid Federation (ESGF).
- NetCDF is required; GODAS GRIB and MRI binary are converted.
- The global attribute *regridding: native* indicates source data.
- Informational metadata furnished by science teams added.
- Time axis indicates 12 monthly timesteps in each yearly file.
- CMIP5 variables *(salinity, vosaline -> so)* facilitate ESGF search.

WOA09 1°x1° Grid at 33 Depths for Each Member Reanalysis

The individual member variables of potential temperature, salinity, and zonal and meridional velocities, in WOA09 1°x1° grid and interpolated to 33 depths from 5 to 5750 meters, for the time range 1980–2010. The first product files are modified to create the second product:

2

- Data is regridded using tools specific to the grid type, model and data producer's advice (see **Ensemble Member Source Grids** and **Regridding Methods**).
- Data is interpolated to 33 depths from 5 to 5750 meters (see **Vertical Interpolation**).
- Output is processed through a NASA Center for Climate Simulation (NCCS) custom Python wrapper to configure inputs to the Climate Model Output Rewriter (CMOR); output is ESGF- and CF-compliant NetCDF.

WOA09 1°x1° Grid at 33 Depths Monthly Mean and Standard Deviation of the Multi-model Ensemble

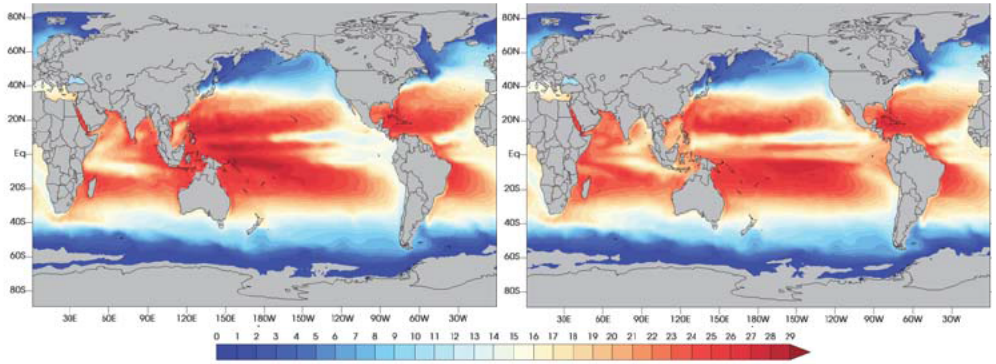
Monthly mean and standard deviation multi-model ensemble of potential temperature, salinity, and zonal and meridional velocities, in WOA09 1°x1° grid and 33 depths from 5 to 5750 meters, for the time range 1980–2010. The second product files are used:

3

- The Python script calculates the ensemble average and standard deviation.
- The ensemble is processed with the NCCS custom Python wrapper to format files and ESGF paths, and post-processed to add metadata on the statistic method and ensemble members and CREATE project source.

Ensemble Sneak Peak

January 1998 (left) Warmer Eastern Equatorial Pacific than January 1999 (right)



Note the differences in potential temperature, with the January 1998 ensemble average at 112.5 meter depth °C (left) showing a significantly warmer eastern equatorial Pacific during the peak of the warming associated with the 1997-98 El Niño than the January 1999 ensemble average at 112.5 meter depth °C (right) during the subsequent La Niña cold event.

Ensemble Member Source Grids

	CFSR	CMCC	GECCO2	GFDL/ECDA	GODAS	MOVE MR .COM-G2i	ORAP5.0	ORA-S4
Grid type	rectilinear equatorial refinement	curvilinear tripolar	rectilinear equatorial refinement	curvilinear tripolar, equatorial refinement	rectilinear quasi global, equatorial refinement	curvilinear tripolar, quasi global	curvilinear tripolar	rectilinear equatorial refinement
Resolution	Latitude 0 25 0 5° Longitude 0 5° 720 x 360 x 40	Latitude 0 25° Longitude 0 25° 1442 x 1021 x 50	Latitude 0 3 1° Longitude 1° 360 x 180 x 50	Latitude 0 3 1° Longitude 1° 360 x 200 x 50	Latitude 0 3 1° Longitude 1° 360 x 418 x 40	Latitude 0 3 1° Longitude 1° 364 x 394 x 53	Latitude 0 25° Longitude 0 25° 1442 x 1021 x 75	Latitude 0 3 1° Longitude 1° 360 x 180 x42
Ocean model	MOM4	NEMOv3 1 + LIM2	MITgcm	ECDA	MOMv3	MRI COMv3	NEMOv3 4 1	NEMOv3
Format, pre processing	NetCDF	NetCDF (ncrename depth, time) (cdo setreftime, settaxis)	NetCDF (cdo setlonlat from generic grid) (ncrename depth)	NetCDF (ncrename depth, lat/lon)	GRIB (cdo copy) (cdo enlargegrid)	Binary (GrADS) (cdo enlargegrid)	NetCDF (ncrename time, depth, lat/lon)	NetCDF no preprocessing
Horizontal regridding method and tool	Nearest neighbor (cdo remapnn)	SOSIE (*Only a Surface nterpolation Environment*), bilinear	Nearest neighbor (cdo remapnn)	Ferret v7, using function CURVE_TO_RECT	Nearest neighbor (cdo remapnn)	Nearest neighbor (cdo remapnn)	Nearest neighbor (cdo remapnn)	Nearest neighbor (cdo remapnn)

* Equatorial refinement is present in source data but not in the version furnished for these products.

About CREATE

The Collaborative REAnalysis Technical Environment (CREATE) is a NASA Center for Climate Simulation (NCCS) project to collect and format all available global reanalysis data into one centralized location providing standardizing data formats, improved access to data download, and web-based visualization and analytics.

NCCS hosts an ESGF node focused on supporting NASA climate model datasets (CMIP5), NASA observation datasets (obs4MIPs), reanalysis datasets (CREATE and ana4MIPs), and downscaled data (NEX). Data is also available through a THREDDS Server (TDS), the Web Mapping Service (WMS) and a web-based visualization and comparison tool, CREATE-V.

About CLIVAR/GSOP

CLIVAR is a component of the World Climate Research Programme. Its purpose is to identify the physical processes responsible for climate change and develop modeling and predictive capabilities for climate modeling.

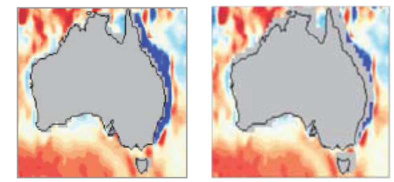
GSOP is a CLIVAR scientific steering group whose primary roles include developing and implementing strategies for observation- and model-based synthesis of global ocean observations, and evaluating and promoting ocean and coupled synthesis products for ocean and climate research and climate prediction.

Ongoing activities include Global Ocean Synthesis/ReAnalysis Intercomparison Project (ORA-IP) and the realtime extension of ORA-IP using ensemble operational ocean analysis products.

Regridding Methods

The common horizontal grid for ensemble member output is the World Ocean Atlas 2009 (WOA09) 1 degree horizontal resolution. The grid coordinates (as reported by *cdo sinfon*) are *longitude: 0.5 to 359.5 by 1 degrees_east circular and latitude: -89.5 to 89.5 by 1 degrees_north.*

The source reanalyses use a variety of rectilinear and tripolar grids (see **Ensemble Member Source Grids**), with differing global coverage, equatorial adjustments and zonal and meridional velocity representations. For two of the curvilinear datasets, CMCC and GFDL, we used the software and methods used by the data producers, SOSIE and Ferret respectively. We regridded the remaining five reanalyses evaluating both bilinear and nearest neighbor and plotted each.



These are plots of CFSR VO January 1980 at 5 meter depth, 1x1 horizontally regrid from .5 x .5. The side-by-side plots show that the nearest neighbor method (left) creates greater detail in the coastal areas than the bilinear method (right); this detail was consistent in the plots of all variables.

Vertical Interpolation

The custom Python script vertically interpolates the reanalysis data along World Ocean Atlas 2009 (WOA09) 33 standard levels (depths). The center depths of target levels range from 5 meters to 5750 meters. Linear interpolation is applied to remap physical variables from 40 to 75 meter levels in the source data to the target 33 levels.

The script retrieves physical variables from NetCDF files. For each target level, all source levels that overlap with the target levels are taken into consideration. A weighted average is calculated across these source levels, and the weight coefficients are inversely related to the distance between the centers of source and target levels. Interpolated results and associated attributes are stored in NetCDF4 format with default compression and vertical dimension information updated accordingly.

Why Ensembles?

Research shows that ensemble-averaged ocean reanalyses generally outperform individual ocean reanalysis products. Early single-model ensembles (mid-1990s) found the spread of the ensemble too small to be a benefit. Subsequent approaches (circa 2000) included independent models, and these better accounted for model uncertainties. Newer ensembles take advantage of higher-resolution, coupled, and better-tuned models. Ensembles:

- Provide robust estimation (ensemble mean).
- Expose structural uncertainty (ensemble spread).
- Cancel model-dependent errors (through ensemble average).
- Uncover differences among models (ensemble means and spread).

Get the Data

The monthly mean average and standard deviation multi-model ensemble, member reanalysis native grid at 33 depths, and member reanalysis native grid at native depths data can be found here:

ESGF: esgf.nccs.nasa.gov
TDS/WMS: dataserver.nccs.nasa.gov
CREATE-V: cds-cv.nccs.nasa.gov/CREATE-V

We would like to gratefully acknowledge the data producers listed in this poster. Use the QR code to find the link and companion NCCS poster information.

References

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3. FERRET: The authors wish to acknowledge use of the Ferret program for analysis and graphics in this paper. Ferret is a product of NOAA's Pacific Marine Environmental Laboratory. (Information is available at ferret.pmel.noaa.gov/Ferret/)
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6. SOSIE: sosie.sourceforge.net/
7. UVCDAT: uvcdat.llnl.gov/index.html
8. Panoply: http://www.giss.nasa.gov/tools/panoply/