

## ***GMAO global ocean data assimilation system***

Michele Rienecker, Christian Keppenne, and Jossy Jacob  
*Global Modeling and Assimilation Office (GMAO)*  
*NASA/Goddard Space Flight Center, Greenbelt, MD, U.S.A.*

Ocean data assimilation efforts of the Global Modeling and Assimilation Office (GMAO) at NASA/Goddard Space Flight Center are directed towards ocean initialization for seasonal-to-interannual climate prediction using our coupled ocean-atmosphere-land surface general circulation model. The GMAO has developed two near-global ocean analysis systems, one based on optimal interpolation and one with an Ensemble Kalman Filter. Estimates from the former are available at 3-day intervals from January 1993 to present and are extended in time regularly every month. Monthly-mean estimates are accessible via the Live Access Server at <http://nsipp.gsfc.nasa.gov/las/servlets/dataset> and from a link on the USGODAE web site: <http://ferret.pmel.noaa.gov/GODAE/servlets/dataset>. For this CLIVAR-GODAE GSOP inter-comparison we provide a 13-year long reanalysis from 1993 to 2005.

GMAO activities and progress in ocean data assimilation are documented at <http://gmao.gsfc.nasa.gov/research/ocean>.

### ***The Ocean Model***

GMAO uses the Poseidon V4 quasi-isopycnal ocean model (Schopf and Loughe, 1995; Borovikov et al., 2001). The model is a finite-difference, reduced-gravity ocean model which uses a generalized vertical coordinate designed to represent turbulent, well-mixed surface layers and nearly isopycnal deeper layers. The prognostic variables are layer thickness, temperature, salinity, and current components. The sea surface height (SSH) field is diagnostic. Vertical mixing is parameterized through a Richardson number-dependent mixing scheme (Pacanowski and Philander, 1981) implemented implicitly. An explicit mixed layer is embedded within the surface layers following Sterl and Kattenberg (1994). For layers within the mixed layer, the vertical mixing and diffusion are enhanced to mix the layer properties through the depth of the diagnosed mixed layer. A time-splitting integration scheme is used whereby the hydrodynamics are done with a short time step (15 minutes), but the vertical diffusion, convective adjustment and filtering are done with coarser time resolution (half-daily). The model is run quasi-globally from Antarctica to 70°N with a resolution of 1/3° meridionally and 5/8° zonally with 27 vertical coordinate surfaces. There is a buffer zone at the northern boundary, with relaxation to Levitus and Boyer (1994) climatology.

The model is forced by daily surface wind stress from near real-time surface wind analyses based on SSM/I and QuikSCAT (e.g., Atlas et al., 1996), monthly-mean surface heat flux from the NCEP CDAS, and monthly-mean GPCP precipitation (Adler et al., 2003). Freshwater fluxes are implemented by changing the model's freshwater volume. Model sea surface temperature (SST) and sea surface salinity (SSS) are additionally relaxed toward the NCEP (Reynolds) weekly SST analysis and the climatological mean SSS of Levitus and Boyer (1994), respectively. SSS is relaxed with a time-scale of 2 years, whereas SST is relaxed using a spatially and seasonally varying time-scale, typically between 1-2 months, based on the Comprehensive Ocean-Atmosphere Data Set (COADS) (da Silva et al., 1994).

### ***The Assimilation System***

The analyses contributed to the GSOP inter-comparison use a Univariate Optimal

Interpolation (UOI) to assimilate temperature profiles. A separate salinity analysis is generated using Argo salinity profiles and synthetic salinity profiles derived for each XBT temperature profile from Levitus and Boyer (1994) T-S climatology. The forecast temperature and salinity error covariances are Gaussian. In the equatorial region, the decorrelation scales for temperature are 20° in the zonal direction and 4° in the meridional direction. The vertical decorrelation scale is 100 m. For salinity assimilation, the decorrelation scales are 8° in the zonal direction and 3° in the meridional direction. The vertical decorrelation scale is 40 m. Away from the equator the horizontal scales become more isotropic. The standard deviation of observational error for temperature is taken to be 0.5°C for all instrument types so as to include representation error. The standard deviation of the forecast temperature error is 0.7°C. For salinity, the standard deviation of observational error from Argo profiles is taken to be 10% of the forecast error, and the synthetic profiles are assumed to have twice the standard deviation of the forecast error. Salinity is not updated within the mixed layer. Observation errors are assumed to be white in time and to have a decorrelation scale of 1500 km.

The assimilation window is 10 days, with data up to 5 days before and 5 days after included with a temporal decay of 20 days applied to the innovations, similar to that of Alves et al. (2004). The assimilation is performed every 5 days. The performance of the assimilation system in the tropical Pacific has been diagnosed in Sun et al. (2006).

### **Data**

Real-time data are from the Global Telecommunication System (GTS) and historical data are from the NODC. Data consist of temperature profiles from XBTs, Argo, TAO moorings, and CTDs, quality controlled by D. Behringer at NOAA/NCEP. Profiles from the moorings and Argo are extracted from this data set and replaced with the quality-controlled data from web servers. Temperature profiles from TAO/TRITON/PIRATA mooring are downloaded from the TAO project website. Argo temperature and salinity data are downloaded from the Argo GDAC on the GODAE/Monterey server and are then subjected to additional quality-control checks.

### **Ongoing Advancements**

The three major advancements underway are: upgrading the model to Poseidon V5 which is a complete primitive equation model with prognostic sea surface height and including the effects of bottom topography; generalizing the analysis code so that it may be applied to other models (with the goal of undertaking assimilation with the Modular Ocean Model MOM4, Griffies et al, 2003) or to a disparate ensemble of ocean models; and undertaking a re-analysis with the Ensemble Kalman Filter of Keppenne et al. (2005) for improved error covariance modeling. With the introduction of Poseidon V5, we are migrating to the GEOS-5 implementation where the model and analysis are coupled using the Earth System Modeling Framework (e.g., Collins et al., 2005).

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