ECCO Near Real-Time Ocean Analysis

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The ECCO Near Real-Time Analysis provides near-global data assimilated estimates of the ocean on a regular basis. The analysis provides a means to monitor the state of the ocean and to analyze the nature of its evolution. Estimates are available at 10-day intervals (12-hour intervals for sea level and bottom pressure) from January 1993 to present and are extended in time regularly every month. All estimates are accessible for analysis and application at http://ecco.jpl.nasa.gov/external or via the Live Access Server at http://ecco.jpl.nasa.gov/las.

Model: The analysis is based on the Massachusetts Institute of Technology general circulation model (MITgcm; Marshall et al. 1997). The model is configured in a near-global domain (72.5°S~72.5°N) with a uniform zonal grid spacing of 1° longitude. The meridional grid spacing is 0.3° latitude in the tropics (within 10° of the Equator) that gradually increases to 1° in the extratropics (poleward of 22° latitude). The total horizontal grid dimension is 360 zonally and 224 meridionally. There are 46 vertical levels with 10 m spacing within 150 m of the surface, gradually increasing to 400 m spacing at depth. The model bathymetry is based on ETOPO5 (NGDC, 1988) by bin-averaging the 5-minute latitude and longitude ocean bathymetry to within model resolution closest to one of the 46 levels.

The model employs a free-slip boundary condition, an implicit free surface, and is forced by 12-hourly surface wind stress and daily heat and freshwater fluxes. The fluxes are based on the reanalysis products of the National Centers for Environmental Prediction and the National Center for Atmospheric Research (NCEP-NCAR) (Kalnay et al., 1996) (approximately 2° spatial resolution), except the time-means are adjusted combining climatological products of the Comprehensive Ocean-Atmosphere Data Set (COADS) (da Silva et al., 1994) and satellite scatterometer winds (Menemenlis et al., 2005). Freshwater fluxes (evaporation, precipitation, river runoff) are implemented as a virtual salt flux in which surface salinity is modified in accordance to the freshwater forcing as opposed to changing the model's freshwater volume. Model sea surface temperature (SST) and sea surface salinity (SSS) are additionally relaxed toward NCEP's SST analysis and the climatological mean SSS of Boyer and Levitus (1998), respectively. SSS is relaxed with a time-scale of 60-days, whereas SST is relaxed using a spatially varying time-scale, typically between 1-2 months, based on the method of Barnier et al. (1995).

Assimilation: The near real-time assimilation employs an approximate Kalman filter and Rauch-Tung-Striebel (RTS) smoother. The approximations, consisting of a time-asymptotic approximation (Fukumori et al., 1993), state reduction (Fukumori et al., 1995), and partitioning (Fukumori, 2002), are designed to reduce the estimation's computational requirements associated with the derivation and utilization of the model's state error covariance matrix. The present analysis estimates and corrects model errors (control) associated with time-variable uncertainties in model wind forcing. (Model process noise is assumed to be uncorrelated in time.) The corresponding state reduction is comprised vertically of a normal dynamic mode decomposition of horizontal velocity and vertical displacement that includes the first five baroclinic modes and the barotropic mode. Horizontally, the estimation employs regional partitioning that consists of seven overlapping regions for baroclinic components and a global domain for barotropic elements. Within each partition, the estimate further employs a reduction based on a coarse horizontal grid on which large-scale errors are estimated. These consist of 5° zonal by 3° meridional grids for baroclinic elements and a 6° by 6° grid for barotropic components.

Data: The analysis assimilates sea level from satellite altimeters and vertical temperature profiles from in situ measurements. Sea level observations consist of those of TOPEX/POSEIDON and Jason along the satellites' ground tracks. Temperature profiles are from the Global Telecommunication System (GTS) and consist of measurements from XBTs, Argo, TAO moorings, and CTDs, quality controlled by NCEP (D.Behringer, personal communication). Temporal anomalies are assimilated in correspondence to the assimilation method that estimates time-dependent errors; data are referenced to their respective time-means and compared with the model with respect to it's time-mean equivalent to the data mean. Data errors and corresponding model process noise (wind error) are determined based on covariance matching (Fu et al., 1995). For simplicity, data errors are assumed to be uncorrelated in both space and time. Accordingly, the data are decimated prior to assimilation for consistency. Altimetric measurements are averaged along satellite ground tracks in latitudinal bins ranging from 2° to 6°, commensurate with model resolution. In situ temperature measurements are averaged in 10-day and 3° bins prior to assimilation. The assimilation is conducted every 6-hours, assuming available data within three hours of the assimilation instant are coincident.

Products, Applications, and Ongoing Advancements: The model state (velocity, temperature, salinity, sea level, bottom pressure) is available for analysis and application as 10-day averages. In addition, instantaneous values of sea level and bottom pressure are saved at 12-hour intervals to better resolve their high-frequency fluctuations. Independent components of model tendencies are also saved as thirty-day integrals to diagnose temperature and salinity budgets over arbitrary regions of the model domain (Lee et al., 2004).. Estimates from reference simulation, Kalman filter, and RTS smoother are separately available at http://ecco.jpl.nasa.gov/las. Furthermore, the model adjoint is available to quantify the sensitivity of the model estimate to various controls and, thereby, to deduce mechanisms of the circulation.

The modeling and assimilation system and their estimates are being employed in studies of ocean circulation as well as in various applications beyond oceanography per se, including climate analysis and forecasting, biogeochemical studies, and geodetic analyses. Some of these examples include Lee et al. (2002), Dickey et al. (2002), Lee and Fukumori (2003), Gross et al. (2004), Fukumori et al. (2004), Wang et al. (2004), Kim et al. (2004), Fukumori et al. (2006), and Yulaeva et al. (2006).

The MITgcm-based analysis is currently being transitioned to a second generation system based on the Modular Ocean Model (MOM4, Griffies et al, 2003) that is utilized in operational seasonal-to-interannual climate forecasting at NCEP. Additional filters and smoothers that estimate other sources of model error have also been developed and are being implemented in conjunction with the present estimation system. The additional estimates include time-variable surface diabatic flux errors (heat and freshwater fluxes) and time-mean biases in surface forcing. The supplementary filters and smoothers correspond to additional partitions and will further resolve the information content of the observations not yet utilized and permit exploitation of additional measurements, including satellite sea surface temperature and in situ salinity observations.

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