MONITORING SEA LEVEL VARIATIONS IN THE NORTH ATLANTIC OCEAN

J. Carton (University of Maryland, USA) and
L. Miller (NOAA/Laboratory for satellite oceanography, USA)

We have developed a multi-decadal retrospective analysis of temperature, salinity, velocity, and sea level (currently 1950-1996). The analysis is global, but our focus is on variations in the Atlantic. We present a brief overview of the model and assimilation. This discussion is followed by some comparisons to independent tide gauge and altimeter sea level time series. More complete details will be available in Carton et al. [1998a,b].

The analysis described here relies on an ocean model based on Geophysical Fluid Dynamics Laboratory Modular Ocean Model 2.2 software. The model horizontal resolution is 2.5 x0.5° in the tropics, expanding to a uniform 2.5 x1.5° degree resolution at midlatitudes. The basin domain extends from 70°S to 60°N for a total of 146 x91° horizontal grid points. The model vertical resolution is 15 m in the upper ocean for a total of 20 levels. The time step is 1 hour. At each time step the background fields of temperature and velocity are updated using a continuous updating scheme that maintains a near-geostrophic relationship between mass and momentum. The model is forced by COADS historical winds [da Silva et al, 1994] and climatological heat flux. The updating procedure is based on the Optimum Interpolation equations. The major data sets used to force the model include SST , MBTs, XBTs, bottle data, CTDs, and altimetry.

We use historic tide gauge sea level time series to provide independent assessment of the accuracy of the analysis. One of the most interesting and well-documented sea level records is at Bermuda [Roemmich, 1990; Joyce and Robbins, 1996]. At Bermuda low frequency thermal anomalies are well correlated to sea level. In order to use Bermuda sea level as an independent data set we have removed hydrography from nearby Ocean Station S from our updating data set. When fluctuations shorter than 5 years are removed, the analysis sea level has a 0.72 correlation with Bermuda. The second station we examine is San Juan, Puerto Rico where the correlation is 0.34. The third is La Coruna, Spain (0.31).

Although the sea level time series comparisons discussed above provide information about interannual to decadal variability, they have limited spatial coverage and have only indirect information about currents. In order to make the comparison to altimeter sea level independent we introduce a new experiment in which altimeter sea level information has been excluded from the updating procedure. We limit our discussion here to a comparison to the TOPEX/POSEIDON altimetry because of its low observation error.

The error in observed monthly-averaged TOPEX/POSEIDON altimeter sea level has been estimated to be in the neighborhood of 2 cm in the tropical Pacific [Cheney, et al, 1994; Mitchum, 1994]. The root-mean-square (RMS) difference between observed and analysis sea level when the altimetry is not assimilated exceeds the observation error by 2-4 cm (Figure 1a). The difference is lowest in the tropics, and somewhat lower on the eastern side of the basin than the western side.

When altimeter sea level is used as a constraint on the analysis temperature and salinity fields (but not pressure since pressure is not a prognostic model variable), the RMS difference is reduced by 1-2 cm (Figure 1b). In the tropical Atlantic and Pacific the differences lie in the range 2-3 cm. The average for the full tropical belt becomes 3.1 cm. In the mesoscale eddy production regions of the midlatitudes the RMS difference again increases due to limitations in model physics and poorer error statistics. We are currently using these analyses to investigate the causes of sea level variations in the subtropical and tropical Atlantic Ocean and their relation to climate fluctuations during 1996-1997.

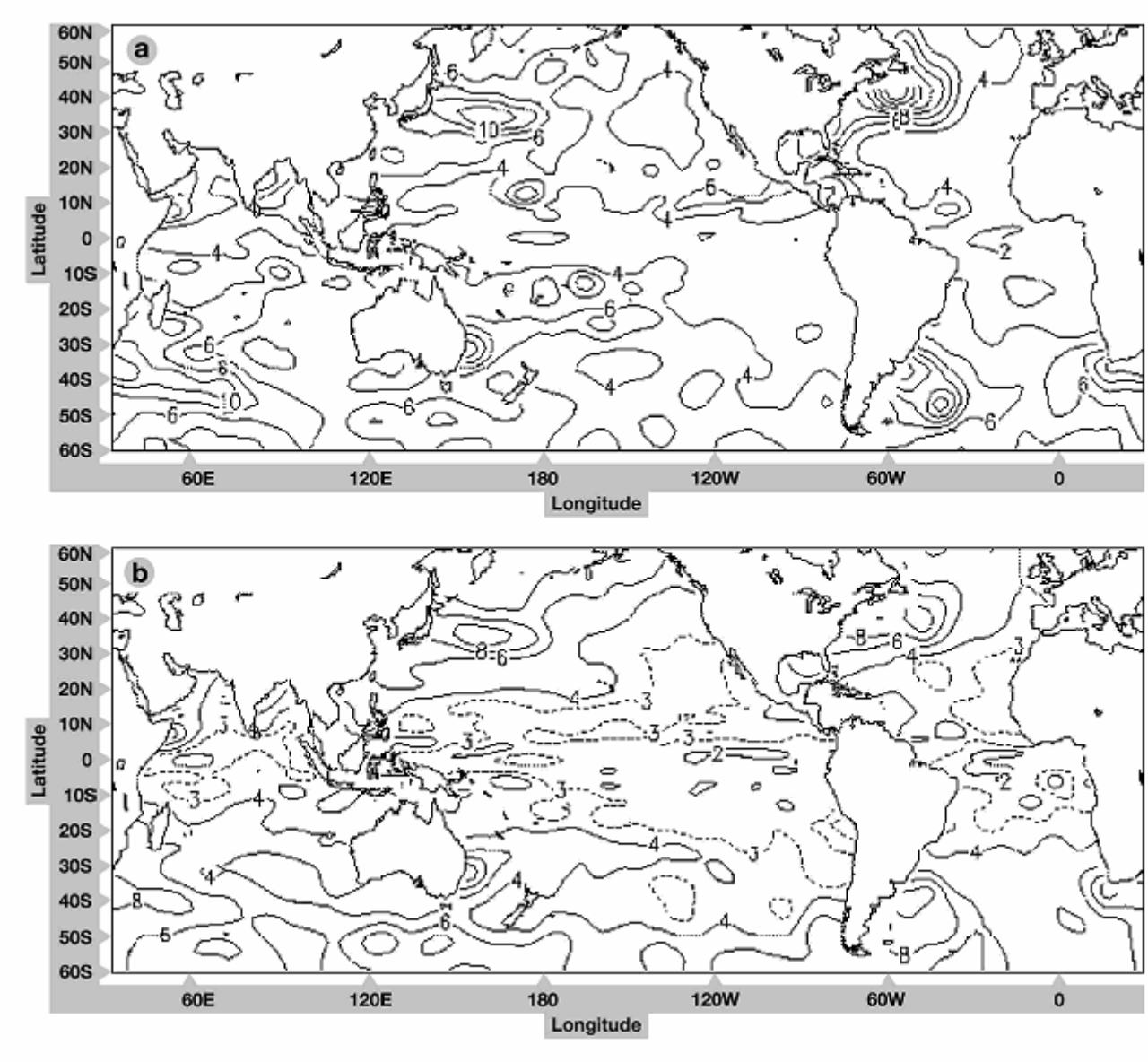

Figure 1

Sea level error estimated using three years of TOPEX/POSEIDON altimetry.
(a) Root-mean-square (RMS) difference (in cm) between altimeter and the experimental analysis sea level in which altimeter sea level observations have been excluded from the analysis.
(b) Root-mean-square (RMS) difference (in cm) between altimeter and the analysis sea level in which temperature and salinity are constrained by altimeter observations as well as direct observations.

References :

- Carton, J.A., G. Chepurin, X. Cao, and B.S. Giese, 1998a: A Simple Ocean Data Assimilation analysis of the global ocean, 1950-1995 (submitted).
- Carton, J.A. , G. Chepurin, and X. Cao, 1998b: A retrospective analysis of the global ocean 1950-1995 and its comparison to observations (submitted).

- Cheney, R.E., L. Miller, and J. Lillibridge, 1994: TOPEX/POSEIDON, the 2 cm solution, *J. Geophys. Res., 99*, 24,555.
- da Silva, A. M., C. C. Young and S. Levitus, 1994: Atlas of Surface Marine Data 1994, Volume 1: Algorithms and Procedures. *NOAA Atlas NESDIS 6*, U.S. Department of Commerce, NOAA, NESDIS.
- Joyce, T., and P. Robbins, 1996: The long-term hydrographic record at Bermuda, *J. Clim., 9*, 3121-3131.
- Mitchum, G., 1994: Comparison of TOPEX sea surface heights and tide gauge sea levels, *J. Geophys. Res., 99*, 24, 541.
- Roemmich, D., 1990: Sea level and the thermal variability of the ocean. "Sea-Level change", Geophysics study committee, Commission of Physical Sciences, Mathematics and Resources, National Research Council, *National Academy Press*, 208-217.