Interannual sea level change at global and regional scales using Jason-1 altimetry

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With the launch of Jason-1, the extension of the nearly decade-long altimetry data set collected by TOPEX/POSEIDON will allow studies of interannual sea level change, and possibly detection of the climatic signal associated with global change. Our contribution to the Jason-1 mission will consist in (1) validating Jason-1 sea level data using tide gauge data, (2) determining interannual fluctuations and trends in sea level at global and regional scales, and (3) quantifying the respective contributions to the observed changes, in particular the steric component and water mass exchanges with the continents.

Determination of present-day sea level changes is a subject of considerable interest in the context of the present debate on global climate change. This is so because all components of the climate system contribute to sea level change through various effects: change of the ocean volume in response to variations in sea water temperature and salinity at all depths, and change of the ocean mass as a result of exchanges of water with the other surface reservoirs (atmosphere, continental waters, glaciers and ice sheets). Modeling these effects is difficult because it involves complex physical processes that are still poorly understood. On the other hand, measuring the temporal and spatial characteristics of sea level change, at various time scales, is an important goal since this can provide boundary conditions for the models. Over the past few decades, long-term sea level change has been estimated from tide gauge measurements. From these observations, it has been deduced that the global mean sea level has risen by about two millimetres per year since the beginning of the 20th century [see for example Douglas et al., 2001, for a review]. However, tide gauges have two drawbacks: (1) their geographical distribution provides very poor sampling of the ocean basins, especially when studying the climatic signal over the past century, and (2) they measure sea level relative to the land, hence recording vertical crustal motions that may be of the same order of magnitude as the sea level variation. High-precision satellite altimetry, in particular the TOPEX/POSEIDON mission, has demonstrated its capability to monitor sea level variations, with great accuracy, high spatio-temporal resolution, global coverage of the oceans, and absolute sea level measurements in a terrestrial reference frame tied to the Earth's center of mass [see Fu and Cazenave, 2001, for a review]. Analyses of TOPEX/POSEIDON altimetry data indicate that, in terms of global mean, sea level has risen by about two millimetres per year since early 1993 [e.g., Nerem and Mitchum, 2001a, b; Cabanes et al., 2001; see also figure 1]. Satellite altimetry also enables us to map the spatial characteristics of the observed rate of change (figure 2). Both geographical distribution and global averages show that altimetry-derived sea level trends and sea surface temperature trends are highly correlated, which suggests that, at least in part, the observed sea level change has a steric (thermal) origin [Nerem and Mitchum, 2001a, b; Cabanes et al., 2001]. Recent investigations based on temperature and salinity time series from Levitus et al. [2000] show that the TOPEX/POSEIDON-derived interannual mean sea level is dominated by the steric component [Cabanes et al., in preparation; see also Chambers et al., 2000].

At the level of the millimetre per year, which is the order of magnitude of the present-day sea level rise, several factors due to instrumental drifts or non-modeled effects in the altimetric system may still affect mean sea level estimates. Comparisons between TOPEX/POSEIDON and tide-gauge-based sea level determinations have highlighted instrument drifts and bias of the TOPEX/POSEIDON altimetry system, and demonstrated the value of tide gauge measurements for calibrating altimetry missions [Mitchum, 1998, 2000, Cazenave et al., 1999].

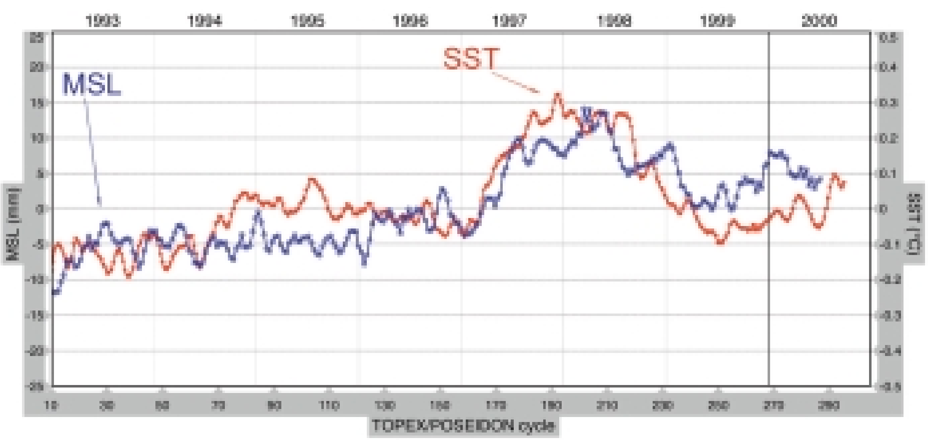

Figure 1: Global mean sea level variation (in mm) from January 1993 to October 2000 computed from TOPEX/POSEIDON altimetry (blue curve). Global mean sea surface temperature (in °C) is superimposed (red curve).

Our contribution to the Jason-1 mission aims to:
(1) participate in the calibration/validation of the Jason-1 mission by comparing Jason-1-derived sea level data with tide gauge measurements, using the approach developed in Cazenave et al. [1999]; for that purpose, we will pay special attention to correcting tide-gauge sea level measurements from vertical crustal motion using space geodesy techniques (DORIS and GPS);
(2) extend the TOPEX/POSEIDON time series (global mean sea level as well as geographical sea level maps) using Jason-1 data to determine interannual sea level variations and trends since the early 1990s; determine the steric contribution to the observed sea level change using global temperature and salinity fields recently provided to us by S. Levitus and J.I. Antonov; estimate the water mass exchanges between oceans and continental waters using global fields of soil moisture and snow depths over the time span of analysis; and lastly, attempt to deduce from the residuals of the above three contributions (observed sea level by TOPEX/POSEIDON and Jason-1, steric sea level, continental water mass change), the contribution from the Greenland and Antarctic ice sheets, using the approach developed in Cazenave et al. [2000] for the seasonal sea level,
(3) extend with Jason-1 data the regional studies undertaken with the TOPEX/POSEIDON data: Mediterranean sea [Cazenave et al., 2001a, b], the Austral Ocean [Cabanes et al., 2001].

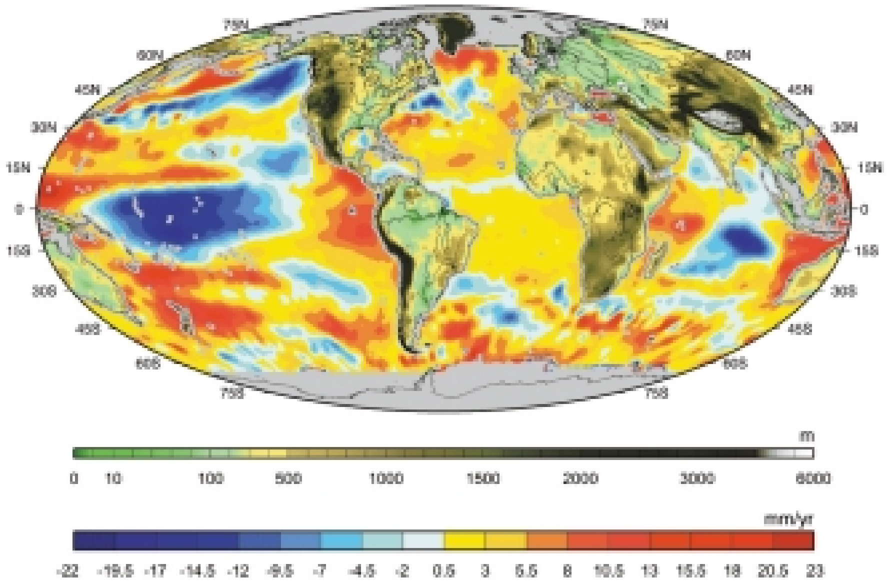

Figure 2: Geographical distribution of sea level trends (in mm/yr) computed from TOPEX/POSEIDON altimetry between January 1993 and December 1999. Yellow and red colors correspond to sea level rise, while blue color corresponds to sea level drop.

References

Cabanes C., A. Cazenave, C. Le Provost, 2001: Sea level changes from TOPEX/POSEIDON Altimetry for 1993-1999, and warming of the southern oceans, *Geophys. Res. Lett.*, 28, 9-12.

Cazenave A., K. Dominh, L. Soudarin, F. Ponchaut and C. Le Provost, 1999: Sea level changes from TOPEX/POSEIDON altimetry and tide gauges, and vertical crustal motions from DORIS, *Geophys. Res. Lett.*, 26, 2077-2080.

Cazenave A., F. Remy, K. Dominh and H. Douville, 2000: Global ocean mass variation, continental hydrology and the mass balance of the Antarctica ice sheet at the seasonal time scale, Geophys. Res. Lett., 27, 3755-3758.

Cazenave A., P. Bonnefond, K. Dominh and F. Mercier, 2001: Sea level changes in the Mediterranean and Black seas from satellite altimetry, *Global and Planetary Change* (in press).

Cazenave A., C. Cabanes, K. Dominh and S. Mangiarotti, 2001: Recent sea level change in the Mediterranean sea revealed by satellite altimetry, *Geophys. Res. Lett.*, (in press).

Chambers D.P., J. Chen, R.S. Nerem and B.D. Tapley, 2000: Interannual mean sea level change and the Earth's water mass budget, *Geophys. Res. Lett.*, 27, 3073-3076.

Douglas B.C., M.S. Kearney and S.P. Leartherman, 2001: Sea Level Rise, History and Consequences, *International Geophysics Series*, vol. 75, Academic Press, San Diego.

Fu L.L. and A. Cazenave, 2001: Satellite Altimetry and Earth Sciences, A Handbook of Techniques and Applications, *International Geophysics Series*, vol. 69, Academic Press, San Diego.

Levitus S., J.I. Antonov, T.P. Boyer and C. Stephens, 2000: Warming of the world ocean, *Sciences*, 287, 2225-2229.

Mitchum G.T., 1998: Monitoring the stability of satellite altimeters with tide gauges, *J. Atmos. Oceanic. Tech.*, 15, 721-730.

Mitchum G.T., 2000: An improved calibration of satellite altimetric heights using tide gauge sea levels with adjustment for land motion, Marine Geodesy, 23, 145-166.

Nerem R.S. and G.T. Mitchum, 2001: Observation of sea level change from satellite altimetry, in Sea Level Rise, Douglas et al. Ed., Academic Press, San Diego.

Nerem R.S. and G.T. Mitchum, 2001: Sea Level Change, in *Satellite Altimetry Earth Sciences*, Fu and Cazenave Ed., Academic Press, San Diego.

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