THE ANNUAL CYCLE OF SEA LEVEL IN THE WESTERN MEDITERRANEAN SEA

Catherine Bouzinac [1], Jordi Font [2] *, Johnny Johannessen [3]

[1] ESA-ESTEC, Postbus 299, 2200-AG Noordwijk ZH, The Netherlands - catherine.bouzinac@esa.int
[2] Institut de Ciències del Mar CSIC, Passeig Maritim 37-49, 08003 Barcelona, Spain - * jfont@icm.csic.es
[3] Nansen Environmental and Remote Sensing Centre, Edv. Griegsvei 3a, 5059 Bergen, Norway - johnny.johannessen@nersc.no

Abstract

An estimation of the annual sea level variations in the different basins of the western Mediterranean has been addressed using sea level anomalies derived from satellite altimeters and sea surface temperatures from infrared imagery. Empirical orthogonal function analysis on SLA allows estimating the seasonal dynamic height and the steric effect. The remaining signal is used to examine the annual cycles of sea level due to water mass budget variations, mesoscale oceanic variability and atmospheric forcing.

Keywords: Sea level variations, altimetry, SST, EOF

Satellite altimetry has become a powerful tool to understand the dynamics of the surface circulation in the Mediterranean Sea (1). At any location, the sea surface height is the sum of various components: geoid, astrophysical tides, mean dynamic topography, atmospheric forcing, steric effect, water mass budget and circulation variations. Annual cycles in sea level can be expected because the primary driving forces of ocean circulation, momentum and surface fluxes, have strong seasonal changes. As shown with altimetric data (2), the annual cycle of the Mediterranean Sea level has an amplitude of about 10 cm. The sea level variability in the Algerian basin is in 80 % due to the annual cycle, while standard deviations of 5 cm correspond to high mesoscale activity (3). The steric effect seems to play a significant role in the seasonal variation of the surface circulation between the Tyrrhenian and Ligurian basins (4).

This study aims at separating and evaluating the annual cycles of the western Mediterranean sea level variability due to the steric effect and seasonal dynamic height variations. The data used are sea level anomaly maps (SLA) derived from TOPEX/POSEIDON and ERS-1/2 altimeters (5) and sea surface temperatures (SST) from NOAA/AVHRR (6), obtained between 1992 and 1998. The annual variability in SLA and SST has been extracted with empirical orthogonal function (EOF) analyses. The EOF results and the combination of SST and climatological hydrology allow an estimation of the steric effect, taking into account the temporal and spatial variations of the temperature in the mixed layer despite a few uncertainties on the mixed layer thickness.

The time response of the steric effect is about 40 days and the contribution of the intermediate and deep layers is not significant except in some particular areas. The choice of the mixed layer thickness is an important parameter for the estimation of the steric effect. A better knowledge of the mixed layer, whose temporal and spatial evolution depends mainly on sea surface fluxes and local turbulent mixing, is clearly necessary. The use of thermocline depth values from a mixed layer model should give more reliable estimations than the parameterisation used here.

The largest dynamic height annual variation and steric effect (> 6 cm) are found in the Catalan and Tyrrhenian seas while the lowest amplitudes (< 3 cm) occur on the path of the Atlantic Water (AW) circulation, where the steric effect is expected to be weaker due to the smaller annual temperature variability. The annual cycles in the Alboran sea appear to be more complex than in the rest of the western Mediterranean. The large annual sea level variation observed there is likely due to other forcing effects such winds and AW inflow, inducing circulation variability, which could be only partially sampled by the seasonal climatology used.

After removing the dynamic height annual variation and the steric effect in the mixed layer, the remaining annual signal still represents about 50% of the residual sea level variability. The EOF analysis shows that one part of this signal is spatially homogeneous (3.5 cm) and can therefore be associated with the annual variation of water mass budget and some remaining annual steric and dynamic signal not correctly removed because of the too simple parameterisation of the mixed layer. The other part of the signal is mainly observed along the north African coast and could be associated with the annual variation of winds and fluxes at the Straits of Gibraltar and Sicily, and their impact on the regional mesoscale activity. To improve these results the mean sea level used to get the SLA should be computed on a time scale longer than 3 years to avoid any local persistent anomalies due to long-lasting eddies.

An extended version of this study has been published in *Journal of Geophysical Research* (7).

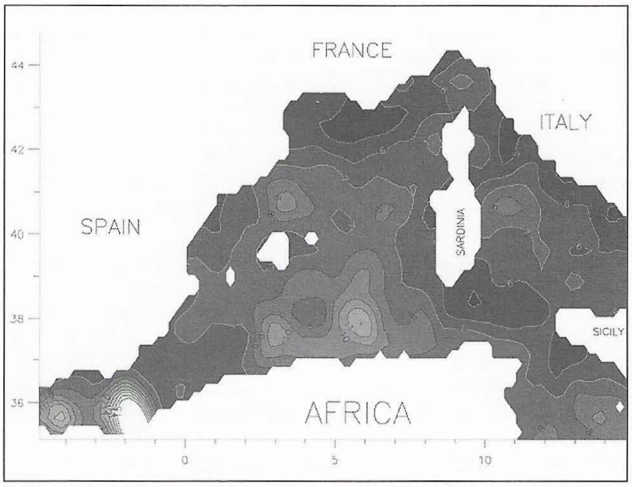

Fig. Western Mediterranean sea level anomaly standard deviation between 22 October 1992 and 30 December 1998 with a contour interval of 1 cm.

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