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A Mean Dynamic Topography of the Mediterranean Sea computed from altimetric data, in-situ measurements and a general circulation model

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Abstract

In the Mediterranean Sea, where the mean circulation is largely unknown and characterized by smaller scales and less intensity than in the open ocean, the interpretation of altimetric Sea Level Anomalies (SLA) is rather difficult. In the context of operational systems such as MFS (Mediterranean Forecasting System) or MERCATOR, that assimilate the altimetric information, the estimation of a realistic Mean Dynamic Topography (MDT) consistent with altimetric SLA to be used to reconstruct absolute sea level is a crucial issue. A method is developed here to estimate the required MDT combining oceanic observations as altimetric and in-situ measurements and outputs from an ocean general circulation model (OGCM).

In a first step, the average over the 1993–1999 period of dynamic topography outputs from MFS OGCM provides a first guess for the computation of the MDT. Then, in a second step, drifting buoy velocities and altimetric data are combined using a synthetic method to obtain local estimates of the mean geostrophic circulation which are then used to improve the first guess through an inverse technique and map the MDT field (hereafter the Synthetic Mean Dynamic Topography or SMDT) on a 1/8° resolution grid.

Many interesting current patterns and cyclonic/anticyclonic structures are visible on the SMDT obtained. The main Mediterranean coastal currents are well marked (as the Algerian Current or the Liguro–Provenço–Catalan Current). East of the Sicily channel, the Atlantic Ionian Stream divides into several main branches crossing the Ionian Sea at various latitudes before joining at 19°E into a unique Mid-Mediterranean Jet. Also, strong signatures of the main Mediterranean eddies are obtained (as for instance the Alboran gyre, the Pelops, Ierapetra, Mersa-Matruh or Shikmona anticyclones and the Cretan, Rhodes or West Cyprius cyclones). Independent in-situ measurements from Sea Campaigns NORBAL in the North Balearic Sea and the North Tyrrhenian Sea and SYMPLEX in the Sicily channel are used to validate locally the SMDT: deduced absolute altimetric dynamic topography compares well with in-situ observations. Finally, the SMDT is used to compute absolute altimetric maps in the Alboran Sea and the Algerian Current. The use of absolute altimetric signal allows to accurately follow the formation and propagation of cyclonic and anticyclonic eddies in both areas.

Keywords: Mediterranean Sea; Altimetry; Mean Dynamic Topography

1. Introduction

In the last decade, the use of altimetric measurements from TOPEX/POSEIDON and ERS1,2 led to an

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improved understanding of the Mediterranean sea level variability (Larnicol et al., 1995; Ayoub et al., 1998; Iudicone et al., 1998; Larnicol et al., 2002). This is despite the difficulty to capture the full mesoscale variability of the Mediterranean circulation due to its small dimensions (30–100 km) compared to the resolution permitted by the use of altimetric data. Furthermore, the lack of an accurate knowledge of the Mediterranean Mean Dynamic Topography (MDT) makes the variability as measured by altimetry particularly difficult to interpret. A positive anomaly detected by altimetry can indifferently be interpreted as the creation of an anticyclonic eddy, the strengthen (resp. the decay) of a quasi-permanent anticyclonic (resp. cyclonic) eddy or meander, the meandering or the spatial shift of a current. The Mediterranean circulation is characterized by numerous structures which were first identified punctually during in-situ measurements campaigns and whose permanent, recurrent or transient nature is, for some of them, still poorly known. An exhaustive inventory of the main Mediterranean features from basin scale to mesoscale, mainly based on the analysis of Sea Surface Temperature (SST) images, is given in Millot (1999) for the western Mediterranean basin and in Hamad et al. (2005) for the eastern basin. Despite the fact that a correlation exists between the dynamic height and the surface temperature, such images are not always easy to interpret as they only contain surface information and therefore do not reflect the ocean dynamic. The accurate knowledge of the Mediterranean MDT should help to correctly interpret the altimetric measurements and therefore to remove many remaining ambiguities on the Mediterranean variability. Moreover, the use of an accurate MDT was shown to contribute to major improvements in data assimilating forecasting systems (Le Provost et al., 1999; Le Traon et al., 2002). In the framework of operational systems as MERCATOR (France) and MFS (Mediterranean Forecasting System, Italy), which assimilate altimetric data into a general circulation model, the need of an accurate Mediterranean MDT becomes even more crucial. The scope of this study is to produce a tool allowing to compute the absolute sea level of the Mediterranean Sea (and the corresponding absolute geostrophic circulation) from altimetric measurements. The time period that has to be covered by the Mean Dynamic Topography thus shall correspond exactly to the time period used to compute Sea Level Anomalies from altimetric measurements using the conventional repeat track analysis. In order to be consistent with the SLA distributed by AVISO, which are computed at CLS relative to a seven year (1993–1999) mean profile, we compute here the Mediterranean Mean Dynamic Topography for the period 1993–1999. Section 2 describes the method and data used for the computation of the MDT. The core idea is the combination of altimetric anomalies and in-situ drifting buoy velocity measurements through a so called "synthetic method", in order to obtain "synthetic estimates" of the MDT. This was already done globally by Niiler et al. (2003) and Rio and Hernandez (2004). The computation of a Mediterranean dataset of synthetic estimates of the MDT is done in Section 3. In Section 4, the Mediterranean MDT is mapped on a global 1/8th degree regular grid. (We will call Synthetic Mean Dynamic Topography, or SMDT, the MDT obtained through the synthetic method). The mean fields (dynamic height and geostrophic circulation) are first described qualitatively and a quantitative validation is successively done in three different areas where independent in-situ measurements are available. Before drawing the main conclusions of this work (Section 4), Section 5 presents some illustrations of using the Mediterranean SMDT to better follow the formation and propagation of eddies from altimetry in the Alboran Sea and along the Algerian Current path.

2. Methods and data

2.1. Method

The method used to compute a global Synthetic Mean Dynamic Topography of the Mediterranean Sea was already described and applied for the global ocean in Rio and Hernandez (2004). The main steps are explained briefly hereafter: the method is first based on a synthetic technique which consists in subtracting the oceanic variability as measured by altimetry to in-situ measurements of the absolute oceanographic signal in order to compute local estimates of the Mediterranean Mean Dynamic Topography (that we will refer to hereafter as 'synthetic estimates' of the MDT). The oceanographic signal can be the dynamic topography h but also any variable linearly related to it (as the geostrophic velocity (u_g,v_g)). Subtracting the altimetric Sea Level Anomaly h'_a (resp. the altimetric geostrophic velocity anomaly u'_a,v'_a), a synthetic estimate of the Mean Dynamic Topography $<h>_s$ (resp. of the mean geostrophic circulation $<u>_s$,$<v>_s$) is obtained (Eqs. (1.1)–(1.3)).

$$<h>_s = h - h'_a \tag{1.1}$$

$$<u>_s = u_g - u'_a \tag{1.2}$$

$$<v>_s = v_g - v'_a \tag{1.3}$$

This technique allows to get rid of the temporal variability contained in the in-situ observations. To