ARTICLE IN PRESS

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ScienceDirect

Advances in Space Research xxx (2016) xxx–xxx

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

www.elsevier.com/locate/asr

Impacts of reprocessed altimetry on the surface circulation and variability of the Western Alboran Gyre

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Received 29 January 2016; received in revised form 9 May 2016; accepted 13 May 2016

Abstract

New altimetry products in semi-enclosed seas are of major interest given the importance of the coastal-open ocean interactions. This study shows how reprocessed altimetry products in the Mediterranean Sea from Archiving, Validation and Interpolation of Satellite Oceanographic data (AVISO) have improved the representation of the surface circulation over the 1993–2012 period. We focus on the Alboran Sea, which is the highest mesoscale activity area of the western Mediterranean. The respective impacts of the new mean dynamic topography (MDT) and mapped sea level anomaly (MSLA) on the description of the Western Alboran Gyre (WAG) are quantitatively evaluated. The temporal mean and variability of the total kinetic energy have been significantly increased in the WAG considering both the new MDT and MSLA (by more than 50%). The new MDT has added 39% to the mean kinetic energy, while the new MSLA has increased the eddy kinetic energy mean (standard deviation) by 53% (30%). The new MSLA has yielded higher variability of total (eddy) kinetic energy, especially in the annual frequency band by a factor of 2 (3). The MDT reprocessing has particularly increased the low-frequency variability of the total kinetic energy by a factor of 2. Geostrophic velocities derived from the altimetry products have also been compared with drifter data. Both reprocessed MDT and MSLA products intensify the velocities of the WAG making them closer to the *in situ* estimations, reducing the root mean square differences and increasing the correlation for the zonal and meridional components. The results obtained using refined coastal processing of altimetry products and new observational data are very encouraging to better understand the ocean circulation variability and coastal-open ocean interactions, and for potential improvements in other sub-basins, marginal seas and coastal global ocean.

Keywords: Satellite altimetry; Sea level anomaly; Mean dynamic topography; Kinetic energy; Mediterranean Sea; Western Alboran Gyre

1. Introduction

Satellite altimetry has revolutionized our vision and knowledge of ocean dynamics, providing continuous monitoring of the sea level variability and the associated changes of the large scale surface circulation in the global ocean since the early 90s (Le Traon, 2013). Mesoscale structures are highly energetic features of the ocean circulation that interact and modify the large scale circulation at regional and local scales. The description of mesoscale variability has been enhanced with the merging of multi-mission satellites (Pascual et al., 2007). The important role of oceanic eddy dynamics in the ocean circulation, heat and salt transports, and their interactions with atmosphere and

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http://dx.doi.org/10.1016/j.asr.2016.05.026
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Please cite this article in press as: Juza, M., et al. Impacts of reprocessed altimetry on the surface circulation and variability of the Western Alboran Gyre. Adv. Space Res. (2016), http://dx.doi.org/10.1016/j.asr.2016.05.026

biology is now established and better understood (Morrow and Le Traon, 2012; McGillicuddy, 2016). Altimetry is also an extremely valuable tool to assess the realism of eddy permitting or resolving ocean model circulation and variability from mesoscale to interannual scale (Penduff et al., 2010; Juza et al., 2015) and to constrain ocean models through data assimilation (Mourre et al., 2006; Oke and Schiller, 2007; Bell et al., 2015). Altimetry products strongly support the operational oceanography by improving the performance of ocean modeling and forecasting systems (Le Traon et al., 2003; Haines et al., 2011; Le Traon, 2013). Better estimations and forecasts of ocean surface currents have direct applications for the pollution monitoring, marine safety, national security, marine transport, as well as coastal area and fishery managements (Tintoré et al., 2013). Additionally, altimetry has a significant impact on climate applications providing long-term series of data for the monitoring of climate signals and addressing climate variability, and also providing initial fields for coupled ocean–atmosphere models.

As a consequence of these societal and scientific applications, maximum accuracy and confidence are required in these products in both the open and coastal oceans. The continuous improvement of altimetry data corrections and processing is crucial to provide a better representation of the mesoscale variability in the global and regional oceans (Pascual et al., 2009). In recent years, the altimetry community has continued its efforts to improve the products for the global ocean and the marginal seas, both the sea level anomaly (SLA) and the mean dynamic topography (MDT), upgrading instrumental and geophysical corrections, improving interpolation methods (in particular in coastal areas; Dussurget et al., 2011; Escudier et al., 2013), calibration, satellite constellation, and geoid (e.g. exploiting data from GRACE and GOCE space gravity missions). Recent improvements in coastal altimetry have also been made (Cipollini et al., 2010; Vignudelli et al., 2011; Birol and Niño, 2015; Troupin et al., 2015). The mapped SLA (MSLA) product for the global ocean, produced and delivered by Archiving, Validation and Interpretation of Satellite Oceanographic data (AVISO, http://www.aviso.altimetry.fr), has been updated in 2014 (Pujol et al., 2016). Capet et al. (2014) have shown that this product improves the description of mesoscale activity in Eastern Boundary Upwelling Systems, returns higher eddy kinetic energy levels within a 300 km coastal band than the previous version (Dibarboure et al., 2011), and shows improved geostrophic velocities in coastal regions through statistical comparisons with drifter observations. Dedicated regional products have also been built and improved, such as for the Mediterranean Sea, which is a challenging area for both science and society. In this oceanic basin, the first Rossby deformation radius characterizing the minimum length of mesoscale features is around 10–15 km, four times smaller than typical values found in the world ocean (Robinson et al., 2001). The Mediterranean Sea is also a place of socio-economic and environmental concerns related to the considerable human pressures in coastal areas and the impacts of climate change (e.g. sea level rise, marine ecosystem variations). The AVISO MSLA products for the Mediterranean Sea have also been reprocessed in 2014. Marcos et al. (2015) have evaluated the updated and previous products locally in regions close to coastal area, considering the MSLA grid points which are the closest and most correlated with the coastal tide gauge records. The comparisons with monthly values from tide gauge time series have shown that the new MSLA captures more variability, has a higher correlation in most of the selected sites, and improves the linear trends over 1993–2012.

In the western Mediterranean Sea, the Alboran Sea is particularly challenging and of great interest for the altimetry at both global and regional scales. Indeed, this region exhibits the highest energy and mesoscale activity in the basin (Pascual et al., 2014). The Atlantic Jet (AJ) enters the Alboran Sea through the Strait of Gibraltar bringing Atlantic Water into the Mediterranean Sea (Viúdez et al., 1998). The AJ modulates the main hydrographic and circulation features in this sub-basin (Baldacci et al., 2001), forming the quasi-permanent Western Alboran Gyre (WAG), the intermittent Eastern Alboran Gyre (EAG), and the strong Almeria-Oran density front, between Spain and Africa (Tintoré et al., 1988; Renault et al., 2012). The Alboran Sea is also characterized by an upwelling of nutrient rich waters along the Spanish coast north to the WAG. The fluctuations of the AJ intensity, driven by meteorological conditions, induce strong variability in these circulation features (Tintoré et al., 1991; Viúdez et al., 1998; Flexas et al., 2006). Mesoscale structures strongly affect biological processes in this sub-basin (Baldacci et al., 2001). The northern shelf region has also been shown to be a suitable area for the spawning of small pelagic fish (e.g. European anchovy or sardine; Macías et al., 2011; Ruiz et al., 2013). The high biological productivity along the Spanish coast has been found to be related to the WAG position and strength, and to enhanced lateral and vertical nutrient fluxes, declining towards the interior of the WAG (Macías et al., 2008; Oguz et al., 2014).

In this study, the new satellite absolute dynamic topography products released by AVISO are evaluated in the Alboran Sea. More precisely, we quantify the impact of both the reprocessed MDT and MSLA on the representation and variability (from weekly to interannual scales) of the WAG, which constitutes the strongest dynamical feature of the western Mediterranean mean circulation and whose position and variations directly impact the biological activity in the north-western Alboran Sea. Note that this study evaluates and quantifies the contributions of both MDT and MSLA while the previous studies assessed one of the two products. The previous and updated satellite altimetry products are compared between themselves through kinetic energy approach to evaluate the respective impacts of the MDT and MSLA updates on the mean flow and eddy variability. Additionally, the realism of the associated geostrophic velocities from altimetry is assessed

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