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Improved satellite altimeter mapped sea level anomalies in the Mediterranean Sea: A comparison with tide gauges

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Abstract

The new gridded Mediterranean sea level anomaly product recently released by AVISO (DT14) is evaluated and compared with the earlier version (DT10) at which it is aimed to substitute. Differences between the two products are found along coastal regions, where the new version captures more variability (up to 10% more) and trends locally differ by up to 1 mm/yr for the altimetric period. Coastal tide gauge observations have therefore been used as the basis for quantifying changes in DT14. Correlation and variance reduction in available monthly tide gauge time series are improved in more than 80% of the selected sites by up to 0.2 and 5 cm^2, respectively. This resulted in an overall higher skill to recover coastal low frequency (with periods larger than a few months) sea level signals. Results for higher/lower order percentiles were also explored and showed different performances depending on the site, although with a slight overall improvement. A comparison with tide gauges on a daily basis using wavelet analysis reveals that altimetry gridded products are not capable of recovering higher frequency (a few days) coastal sea level signals despite some advances have been achieved thanks to the daily temporal sampling of DT14.

Keywords: Mediterranean Sea; Sea level; Satellite altimetry; Tide gauges

1. Introduction

Since the early nineties, satellite altimetry has become an essential tool in oceanographic research, with applications in sea level changes, mesoscale variability or propagating ocean Rossby waves, among others (Cazenave and Llovel, 2010; Le Traon, 2013; Cipollini et al., 2010; Calafat and Marcos, 2012). During the last 20 years, many efforts have been devoted to data processing and development of geophysical corrections that allowed reaching the current maturity of the sea surface height observations with 1–2 cm accuracy. The use of multiple satellites has furthermore permitted merging sea level measurements into interpolated products, thus facilitating the investigation of ocean mesoscale variability (Ducet et al., 2000; Pascual et al., 2009). Regional altimetric gridded sea surface height products deserve special attention, as they have been developed using processing adapted to areas of particular oceanographic interest with higher spatial resolution than the global products. This is the case of the Mediterranean Sea, where products are developed with a resolution of 1/8 of degree and that is considered a reduced scale ocean laboratory, where processes can be studied at smaller scales than in other oceanic regions (Internal Rossby Radius is 10–15 km) including deep convection, shelf-slope exchanges, thermohaline circulation, water mass interaction and mesoscale and sub- mesoscale dynamics (Robinson et al., 2001; Herrmann et al., 2009; Bouffard et al., 2012).

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Dedicated altimetric gridded fields for the Mediterranean Sea produced and delivered by the Archiving, Validation and Interpretation of Satellite Oceanographic Data (AVISO) have provided access to realistic sea surface circulation variability (e.g. Larnicol et al., 2002; Pujol and Larnicol, 2005; Pascual et al., 2007; Mason and Pascual, 2013). It must be remarked though that, as evidenced by previous in situ experiments (e.g., Nencioli et al., 2011; Escudier et al., 2013), altimetric maps have limited capabilities in detecting small and coastal features (~10–100 km). Indeed, Nencioli et al. (2011) showed that in comparison with in situ experiments the altimetry maps for the Mediterranean Sea lack the resolution required to detect small and coastal features. In this context, Escudier et al. (2013) has developed innovative strategies to attempt to improve existing satellite altimetry products to better resolve mesoscale eddies. It is shown that this improvement is possible but at the cost of the homogeneity of the fields; the resolution can only be improved at times and locations where altimetric observations are densely distributed.

The objective of the present work is to assess the changes and quantify the improvements in the new gridded Mediterranean sea level anomalies product recently released by AVISO. New reprocessing and updated geophysical corrections have been developed within the framework of MyOcean Project (User Handbook Ssalto/Duacs, 2014). This assessment will be based on comparisons with tide gauge data.

2. Data and methods

2.1. Sea level anomalies from altimetry

Two different satellite altimetric regional products on the Mediterranean Sea have been compared. Both consist of gridded Sea Level Anomaly (SLA) observations generated by AVISO and available at its web site (http://www.aviso.altimetry.fr/). The first product, hereinafter referred to as DT10, corresponds to the former altimeter gridded fields, i.e. SLA interpolated onto a 1/8° × 1/8° regular grid and weekly sampling, using satellite observations available since October 1992 (User Handbook Ssalto/Duacs, 2014).

The second product, hereinafter refer to as DT14 and released by AVISO in April 2014, correspond to SLA spanning the period 1993–2012, interpolated with the same spatial resolution (for the specific product of the Mediterranean Sea) and with daily temporal sampling. The process is the same as for DT10 products except that some parameters were adjusted (see below for details) and that a map is produced for every day instead of one map per week as for the DT10 product. The daily maps in DT14 are obtained by optimal interpolation (OI) as are the weekly maps in DT10. In both the datasets, each map produced use data selected in a temporal window of ±49 days. This windows is larger than the temporal correlation scale considered (10 days in the Mediterranean Sea) in order to allow an optimal correction of the long-wavelength errors that need to be accounted for (i.e. reduction of large scale bias between the different altimeter tracks). The main differences between DT14 and DT10 are induced by the use of:

- A new reference field and SLA bias convention: the SLA DT10 were referenced to the mean sea surface MSS_CNES_CLS_2001 (or equivalent precise mean profile for repetitive missions), representative of the 7-year (1993, 1999) period. The SLA DT14 are referenced to the MSS_CNES_CLS_2011 2001 (or equivalent precise mean profile for repetitive missions) corrected to be representative of the 20-year (1993, 2012) period. Mean SLA over year 1993 are fixed to 0 by convention.
- Updated sensor-specific standards for geophysical and atmospheric corrections, and a new ocean tidal component. The details of the standards used in DT14 are given in User Handbook Ssalto/Duacs (2014).
- Revised inter-calibration (reduction of the bias Between the missions): in DT14, Jason-2 is used as reference. The previous missions Topex/Poseidon and Jason-1 were corrected from a global and regional bias is order to ensure the consistency of the mean sea level over all the altimeter period. In DT10 this calibration was done using Topex-Poseidon as reference.
- Improved error budget: The variance characteristic of the uncorrelated noise measurement and long wavelength correlated errors, that are involved in the covariance matrix definition (OI process) were reviewed taking into account the characteristics the different altimeters that can impact the measurement errors (i.e. no radiometer; mono-frequency measurements, non repetitive orbit).
- The inclusion of Cryosat since 2011 in DT14.

We refer to CNES (2014) for further details. Additionally the use of new mean profiles (precise mean sea surface height along the tracks of the different altimeters required to derive SLA) has enabled a gain of measurements in coastal areas, compared to previous mean profiles. Another change consists in the extension of the gridded product up to 6°W, improving the representation of the Alboran Sea. The contribution of the atmospheric pressure and wind forcing is removed in both DT10 and DT14 datasets using a dynamic atmospheric correction applied to the along-track data prior to the objective analysis. This correction combines the high frequencies output of the barotropic ocean model MOG2D (Modèle d'Onde de Gravité à 2 Dimensions) forced by pressure and wind from the European Centre for Medium-Range Weather Forecasts (ECMWF) analysis with the low frequencies of the inverted barometer (IB) correction (Carrère and Lyard, 2003; Pascual et al., 2009). It has been shown that using this correction rather than the static IB improves the representation of the high frequency atmospheric forcing on sea level (Volkov et al., 2007; Pascual et al., 2008).