GLOBAL SURFACE GEOSTROPHIC CURRENTS FROM SATELLITE ALTIMETRY AND GOCE

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ABSTRACT

We present a first result for the global mean geostrophic currents derived from a merged solution of altimetric satellites (T/P, Jason 1/2, ERS-1/2, GEOSAT) and the geoid estimated from the first 61-day cycle of the GOCE mission. This result is compared with that obtained based on a GRACE-induced mean geoid, as well as with mean circulation patterns estimated from ocean in-situ data from drifters and from model simulated data by the Global Circulation Model ECCO. The results show that with only one cycle (the first release)of GOCE data, the resolution of the geostrophic currents from a satellite only Mean Dynamic Topography (MDT) is remarkably improved, reaching amplitudes much closer to in-situ data than those coming from a GRACE-induced MDT, and from ECCO model.

1. INTRODUCTION

First results from the GOCE (Gravity and steady-state Ocean Circulation Explorer) satellite mission are available since July 2010. One of the products is a 61-day cycle of geoid height solution of the Earth with an unprecedented accuracy of 1 cm on spatial scales shorter than 100 km [1], enabling the estimation of a Mean Dynamic Topography (MDT) with such spatial resolution. In this study we present the global surface geostrophic currents estimated using only satellite data, from a GOCE geoid and a GRACE geoid. While both estimations reflect the mayor patterns of circulation, we show how with a GOCE-derived geoid the resolution is highly improved over those using a GRACE-derived geiod. We pay more attention to well-known currents where such improvement can be more clearly appreciated. As a validation of the only space data estimation, results are compared with in-situ observations from drifter buoys, as well as with model simulations from ECCO model.

2. DATA USED AND PROCESSING

We use a geoid height (N) from the first 61-day cycle of GOCE combined with a 16-year Mean Sea Surface (MSS) from a mixed solution from satellite altimetry. The MSS is estimated for the period from 1993/10/14 to 2010/03/31 as an extension of the CLS01-MSS with the Sea Level Anomalies (SLA) provided by AVISO (http://www.aviso.oceanobs.com, version 03 May 2010). Both data sets were combined in the spectral domain (with complete spherical harmonics up to degree and order 240) where a Gaussian smoothing was applied in order to exclude the spatial scales shorter than ~83 km from the MSS. Both kind of data, MSS and N, have been carefully rendered coherent before their combination with usual corrections applied to both of them (for details see, e.g., [2],[3],[4],[5]). In particular they are combined with the MSS field to obtain the MDT field according to [6].

Then, the surface geostrophic currents were computed as the gradient of the MDT:

$$u_s = -\frac{g}{f}\frac{\partial MDT}{\partial y} \quad (1)$$

$$v_s = \frac{g}{f}\frac{\partial MDT}{\partial x} \quad (2)$$

Where g is the gravitational acceleration; f is the Coriolis parameter and (x, y) denotes the horizontal coordinates: East and North. Geostrophic currents at the equator band [5S, 5N] are omitted in these first results; we are working on an algorithm to smooth the transition between hemispheres.

In order to compare the results and have a better appreciation of the improvement in resolution made possible by GOCE, the geostrophic currents were also estimated from a MDT using a GRACE-derived geoid. In this case, we used a time averaged set of spherical harmonic complete up to degree and order 60 (space scales longer than 333 km) from 100 months of GRACE data (provided by CSR: podaac.jpl.nasa.gov/grace).

These satellite-induced surface geostrophic currents are compared with velocities from in-situ data and outputs from anocean model. Here we use an annual climatology for the near-surface geostrophic currents from drifter buoys estimated by [7] and provided by the Global Drifter Program (www.aoml.noaa.gov). A more detailed description of such data can be found in [8] and [9]. For a comparison as a function of actual time we use the near-surface geostrophic velocities components from the ECCO model [10] which is based on the Massachusetts Institute of Technology general circulation model (MITgcm, ecco.jpl.nasa.gov). Both two data sets are given at grids of 1 degree.

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3. RESULTS AND DISCUSSION

In Fig. 1 it is depict the mean global surface geostrophic currents from the GOCE-induced MDT. Figure 1 a,b are the eastward and northward velocity components, while Figure 1c,d show the corresponding module and angleof the velocity vectors. Similar results from a GRACE-induced MDT are shown in Fig. 2.

At first glance both reproduce the well-known general ocean circulation pattern. The geostrophic currents derived from the GOCE induced MDT with much higher resolution than those derived from a GRACE-induced MDT. This is better appreciated if we zoom-in at areas corresponding to well known currents asisthe case of the North Atlantic Gulf Stream (GS), the North Pacific Kuroshio Current (KC), or the Antarctica Circumpolar Current (ACC). Fig.3-5 show azoom-in for these areas of interest. It can be observed that the general pattern of each current system is shared by all four data set results. Nevertheless, because GOCE captures shorter space scales than GRACE, some differences in amplitude and space definition can be clearly observed between the only-satellite-induced geostrophic currents (Fig. 3-5 a,b). The GOCE-derived currents are remarkably close to the in-situ observations given by drifters (Fig.3-5 a,d).

The high resolution of GOCE-derived geoid makes feasible studies at regional scales and for enclosed areas, e.g., the Mediterranean Sea (Fig.6). Due to the continental leakage and the limited spatial resolution of the GRACE products, till now it has not been possible to provide an estimate of the mean geostrophic currents from only-satellite data for this kind of enclosed or semi-enclosed basins. This suppose a new age for oceanographic and operational applications.

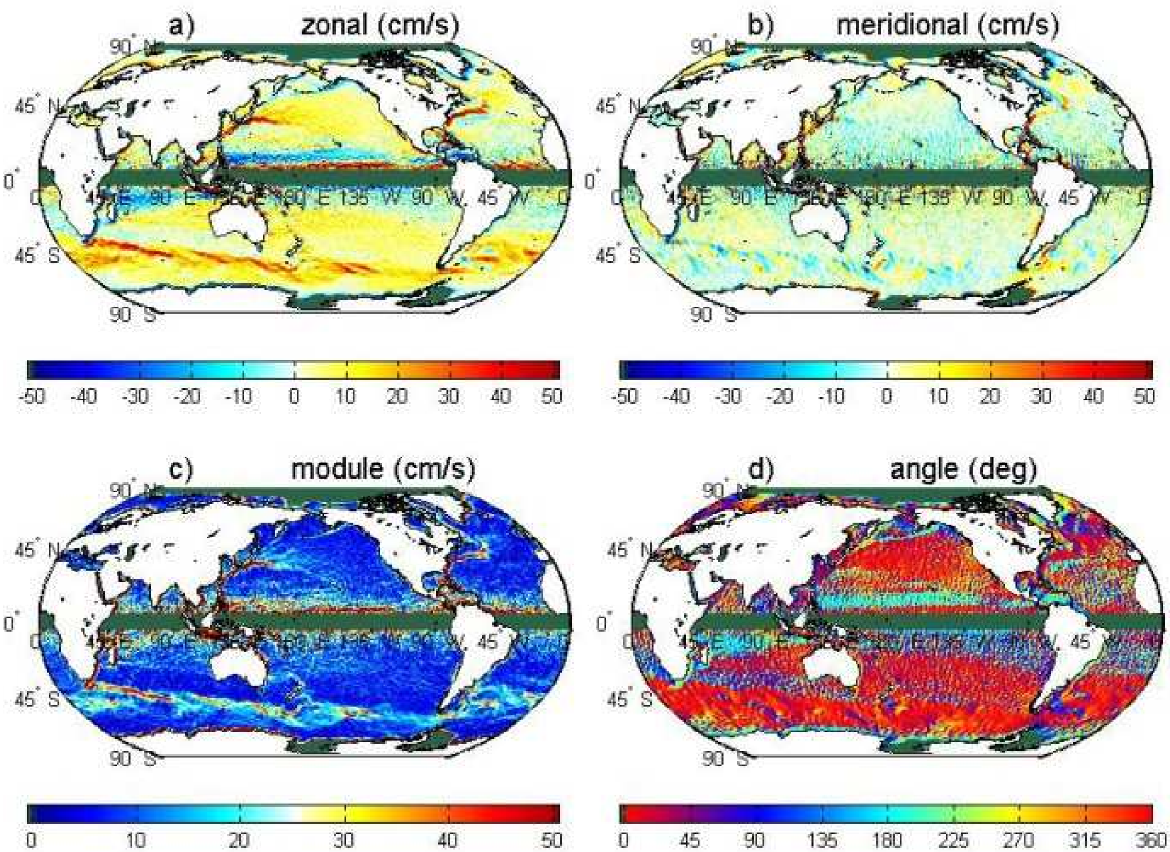

Figure 1. (a) zonal component, (b) meridional component, (c) module and (d) direction of the surface geostrophic currents estimated using a GOCE-induced geoid.

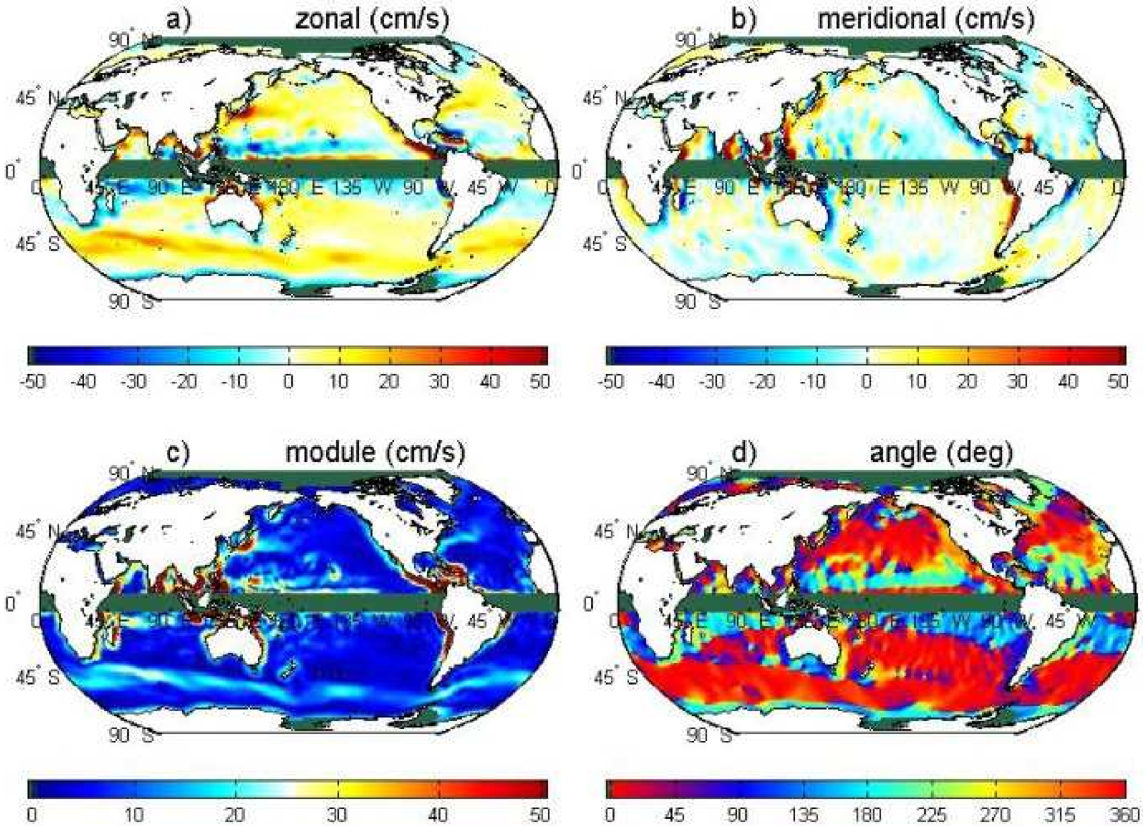

Figure 2. Same as Figure 1 but from a MDT estimated using a GRACE-derived geoid

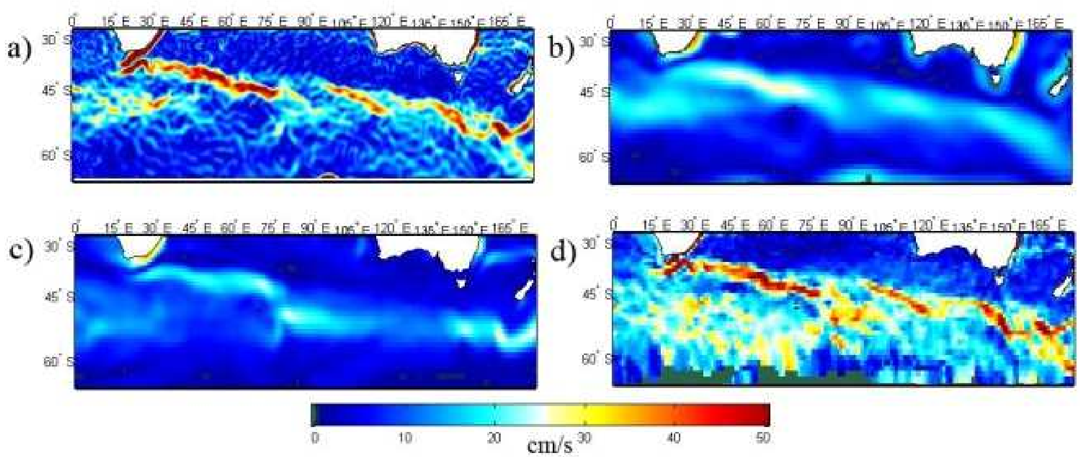

Figure 3. Zoom-in of the velocities amplitude (module) map at the Antarctica Circumpolar Current from the (a) GOCE-induced MDT, (b) GRACE-induced MDT, (c) ECCO outputs and (d) drifter buoys.

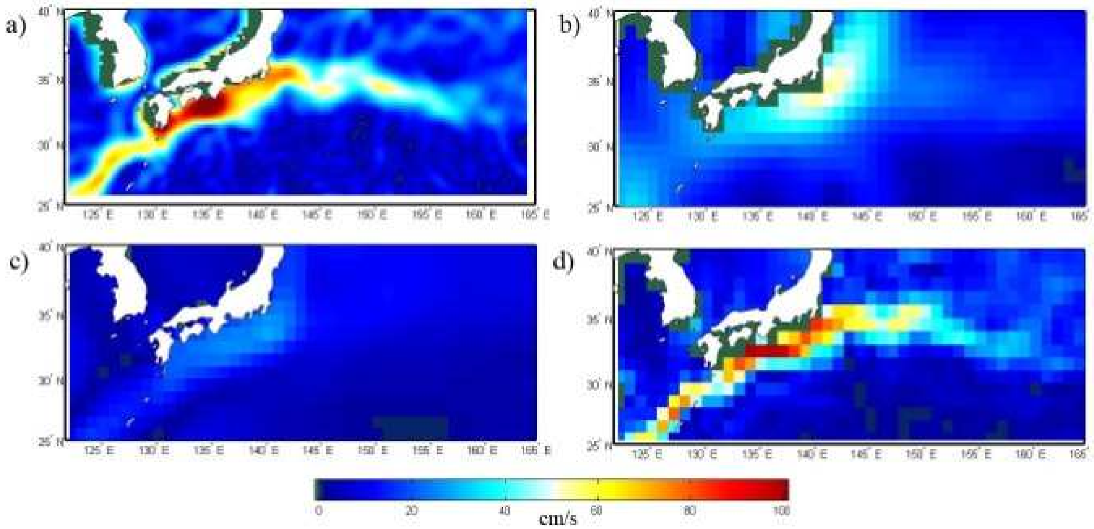

Figure 4. Same as figure 3 but at the Kuroshio Current area.

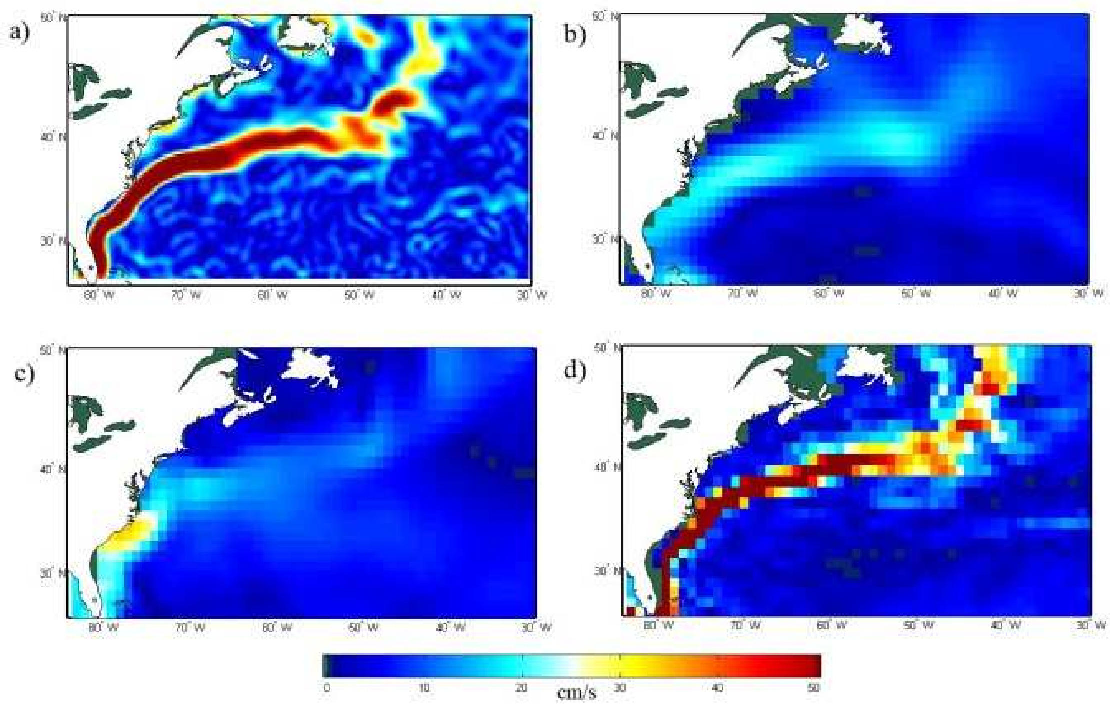

Figure 5. Same as figure 3 but at the Gulf Stream area.

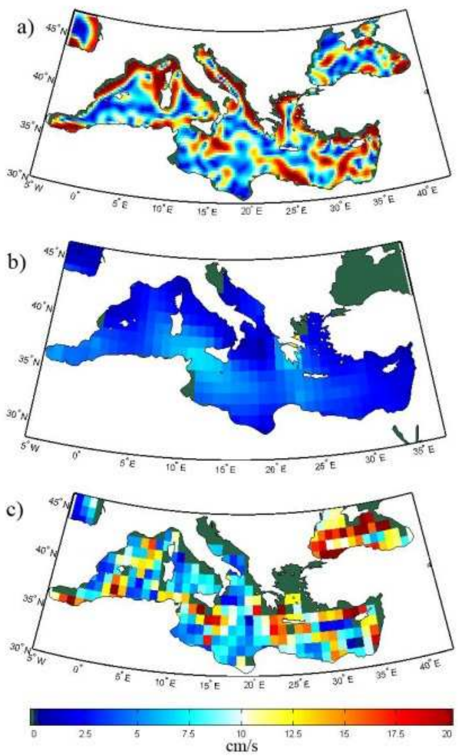

Figure 6. Velocities amplitude (module) map of the Mediterranean Sea from the (a) GOCE-induced MDT, (b) ECCO model and (c) drifter buoys.

From a close look at the ACC, KC and GS (Fig. 3-5) it is amazing how well the GOCE derived currents reproduce the in situ observations (from drifters), all main streams of these currentscan be appreciated and not only with the same spatial patterns but the GOCE space only approach also provides very close values for the amplitudes of the velocities with respect to the in-situ data.

The case of the Mediterranean see (Fig. 6), is a good example where we can appreciate problems along the coast. In this first approach, continental leakage was reduced using the geoid over the land areas, nevertheless, as can be observed in Fig. 6, but further studies are needed in order to get an optimum filtering for coastal areas.

CONCLUSIONS

From the early results presented here it can be observed how the resolution of the only space derived geostrophic currents is drastically improved with GOCE with respect to GRACE-induced MDT. The derived GOCE geostrophic currents reproduce the main currents at a level of detail till now unimaginable, reproducing even the smaller features captured by in-situ data and increasing in magnitude providing values muchcloserto the ones provided by drifters. As expected, GOCE resolution allows the study of geostrophic currents for enclosed basins (as Mediterranean Sea), though the spectral consistency between satellite altimetry and the GOCE geoid constitute a new challenge in order to reduce the coastal problems.

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