Validation of altimetry-derived Ocean Dynamic Topography by in-situ measurements of ocean currents

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Introduction

Satellite altimetry measurements together with high-precision Earth gravity field models can be used to estimate the ocean topography by subtracting the geopotential reference surface from the sea surface. We developed a "profile-approach" which allows the estimation of so-called instantaneous dynamic ocean topography (iDOT) profiles along individual altimeter ground tracks . In contrast to other methods using a long-term mean sea surface and estimating a mean topography (MDT) our approach provides temporal variations of almost meso-scale structures. The iDOT profiles can be gridded and converted to surface velocities by applying the geostrophic equations.

A complete independent method for measuring the ocean surface velocities are in-situ observations of ARGO floats and surface drifters. After correcting these measurements for wind and Ekman drift they provide an independent data set for comparison and validation of our altimetry-derived surface velocities.

iDOT-profiles and derived geostrophic velocities

iDOT-profiles generated by the "profile-approach" (*Bosch & Savcenko 2010*) are available for nearly all individual passes of all satellite altimeters operated since 1992 (*Bosch et al. 2013*). For this study iDOTs from Jason-1/2 and Envisat are used.

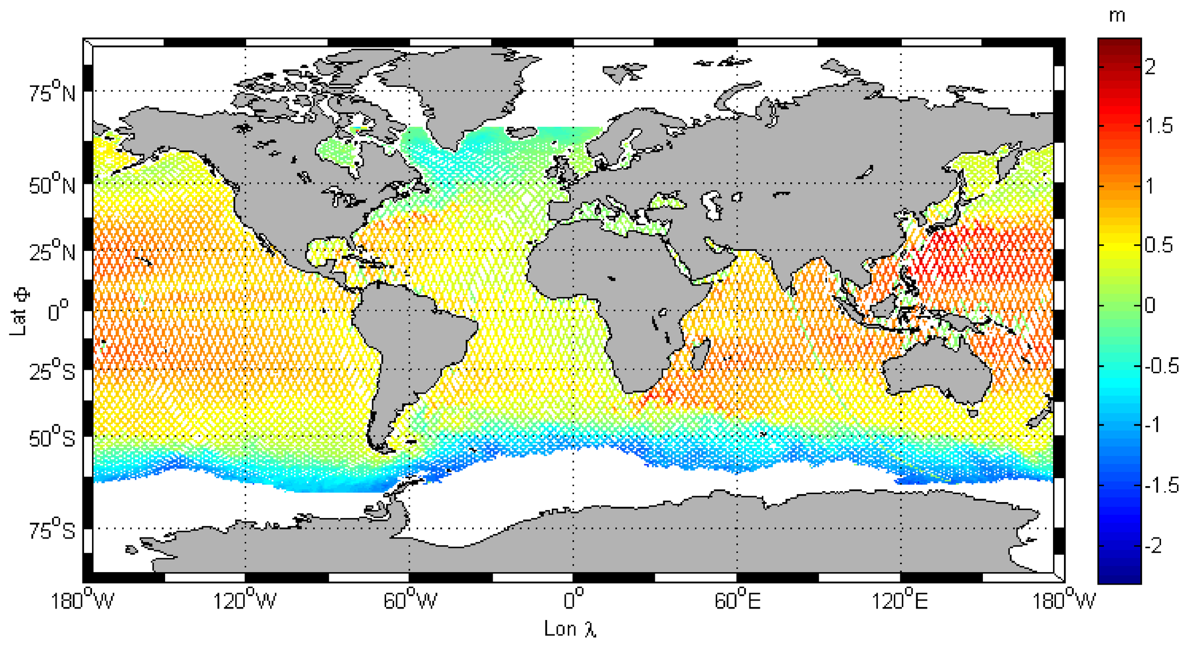


Fig. 1: The global iDOT profiles on the ground tracks of Jason-2 (Cycle 8, September 2008)

The interpolation of the iDOT-profiles to the location of in-situ observations are performed in a common step together with the conversion to geostrophic velocities. For this purpose a least-squares fit of a slant plane to the location of the in-situ data with weights set by Gauss functions of the distance and the time-lag between DOT and in-situ data is used. The slopes of the plane correspond to the u- and v-components of the geostrophic current.

ARGO floats and surface drifter

As in-situ data the combination of ARGO floats (Lebedev et al. 2007) and surface drifters recently reprocessed by Lumpkin et al. (2013) are taken. A maximum of ARGO float data was observed within period 2007 – 2010, which is taken for comparison.

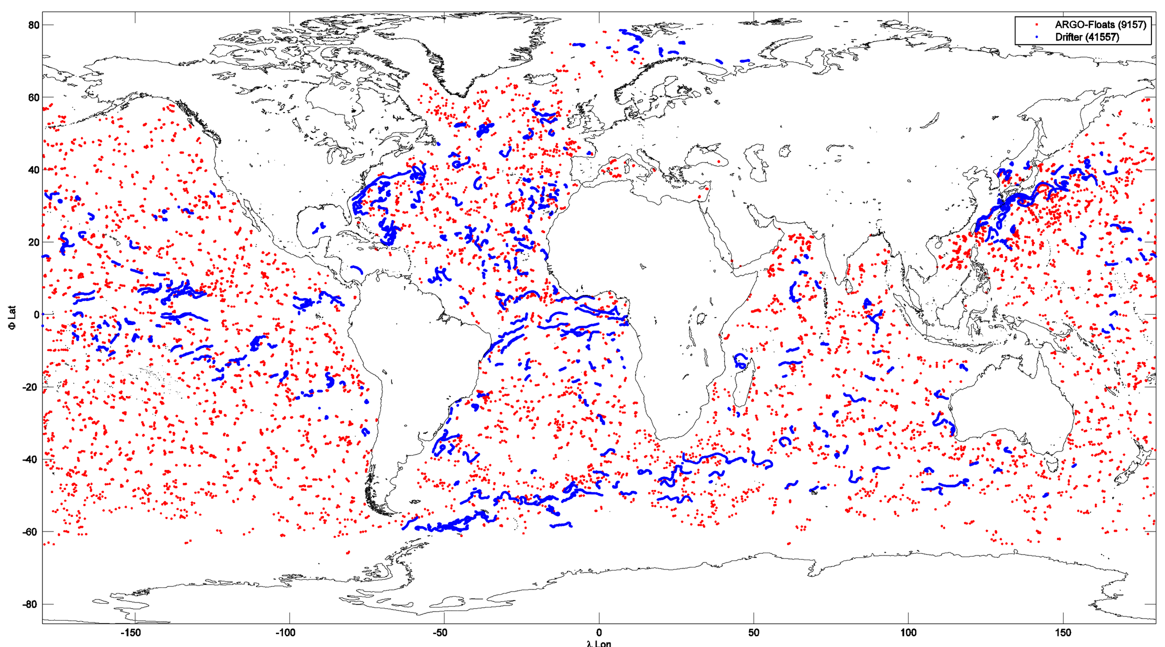


Fig. 2: Common distribution of ARGO floats (red) and surface drifters (blue) for a one month period.

As the in-situ data is affected by wind we correct the observed velocities for the Ekman drift, following the approach of *Lagerloef et al. (1999)*. Monthly wind field and the wind stress are taken from NOAA's NCDC (http://www.ncdc.noaa.gov/oa/rsad/air-sea/seawinds.html). Drifters are taken only if no loss of the wind sack was flagged or if correction for defect sensors are applied according to *Lumpkin et al. (2013, 2014)*.

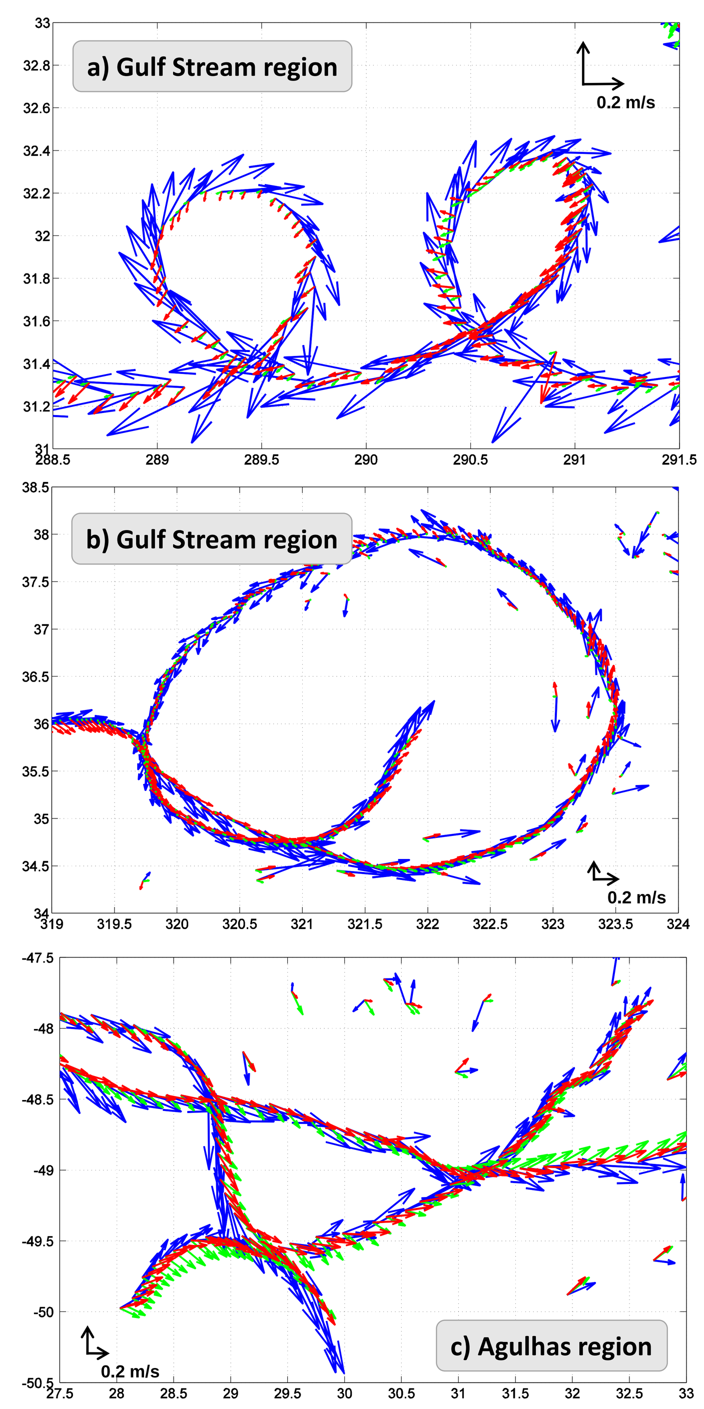
Comparison of geostrophic velocities

The altimetry-derived geostrophic velocities are compared with the in-situ velocities for each in-situ observation. For interpretation purposes, the differences are grouped in 3-month periods and analyzed for six different areas (each expanding 60° in longitude and 30° in latitude): Malvinas, Gulf Stream, Kuroshio, and Agulhas, representing all major western boundary currents as well as two calmer regions, Tasmanian Sea and North-West Pacific.

In addition, CNES-MDT13 (*Rio et al, 2014*) is used to demonstrate the advantages of the instantaneous iDOTs over classical MDTs. CNES-MDT13 already provides gridded geostrophic velocities in u- und v-direction. For its computation not only altimetry and GOCE data were used but also in-situ observations from drifters and ARGO-flats. The interpolation is handled exactly in the same way as the interpolation of iDOTs.

Point-wise Comparisons

The iDOTs are able to represent the main ocean currents as well as smaller structures such as eddies. However, for some cases the direction my differ significantly and the velocities are underestimated by factor 1-2 due to the smoothing within the interpolation process. iDOT-based velocities normally outperform MDT results.



The (unscaled) difference between in-situ and iDOT-derived geostrophic velocities varies around zero with standard deviation between 0.2 and 0.3 m/s (c.f. Tab.1). 90% of the differences are smaller than 0.3 m/s for the Tasmanian Sea and 0.4 m/s for the Kuroshio (c.f. Fig.3). The u-components are slightly more accurate than the v-components.

	Tas. Sea	NW Pacific	Malvinas	Gulf	Kuroshio	Agulhas
Mean std du [m/s]	0.18	0.22	0.19	0.21	0.27	0.23
Mean std dv [m/s]	0.18	0.35	0.19	0.21	0.31	0.27

Tab. 1: Mean standard deviation of differences between in-situ and iDOT-derived velocities.

Fig. 4: Percentage of differences below a certain threshold for two of the six areas (best and worst).

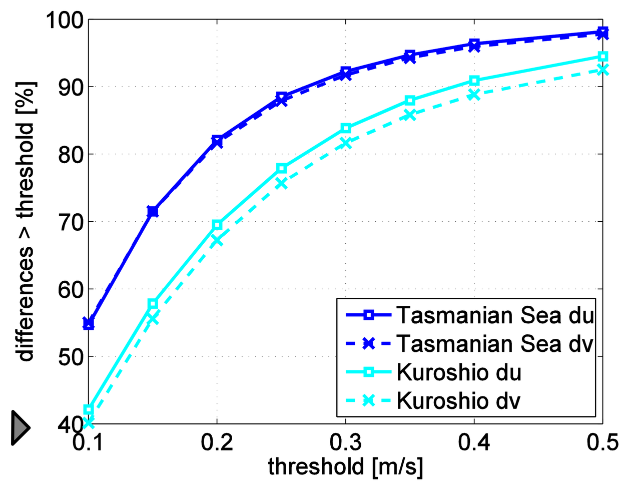
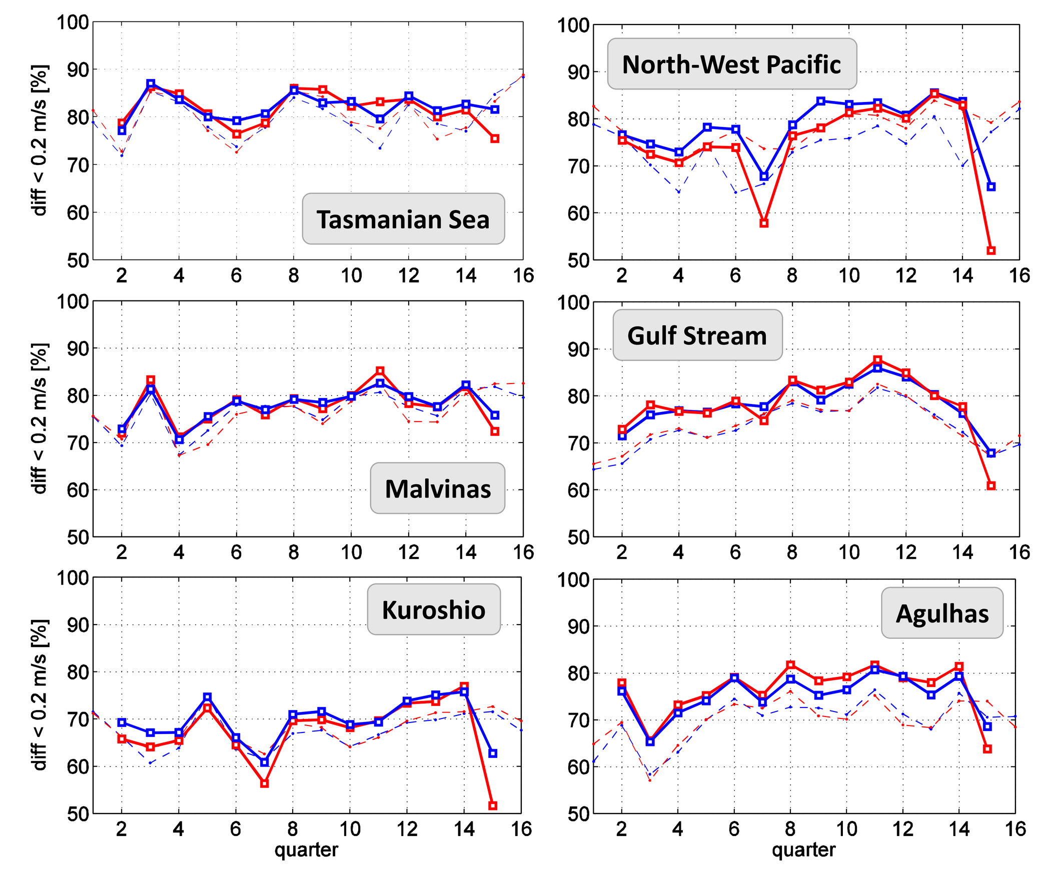


Fig. 3: Geostrophic velocities for three different examples in Gulf stream region, April-June 2009 (a+b) and Agulhas, Oct.-Dec. 2009 (c). Blue arrows represent the in-situ velocities, red arrows are derived from iDOTs and green ones from MDT.

Temporal behavior of differences

Analyzing the differences between in-situ velocities and altimetry-derived velocities within 3-month time periods reveals only moderate temporal variations (Fig. 5). There seems to be an annual signal for the Tasmanian Sea but for the other areas no significant time-dependency is visible.



The MDT differences perform worse than the iDOT differences but also show no significant variation with time.

Fig. 5: Percentage of differences (in-situ – altimetry) less than 0.2 m/s for 16 3-month periods (2007-2010), separately for u-component (blue) and v-component (red). The bold lines illustrate the iDOT differences, thin dotted lines the MDT differences for 6 different areas.

iDOTs show a significant improvement over MDT for the Gulf Stream region and the Agulhas region. For the other four regions only moderate difference between the two solutions are visible.

Tab. 2: Percentage of differences between in-situ and iDOT-derived velocities below 0.2 m/s. The values in brackets give the differences to MDT-based velocities (positive numbers indicate better performance of iDOTs)

	du < 0.2 m/s [%]	dv < 0.2 m/s [%]
Tasmanian Sea	82.1 (2.8)	81.7 (2.0)
North-West Pacific	78.0 (5.1)	74.5 (-2.8)
Malvinas	78.0 (1.2)	77.7 (1.4)
Gulf Stream	78.3 (4.1)	78.3 (3.9)
Kuroshio	69.5 (2.6)	67.3 (-0.7)
Agulhas	75.2 (5.0)	76.4 (6.1)

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Conclusions

It can be shown that in-situ and iDOT velocity fields agree well with differences smaller than 0.2 m/s on average. Within the pointwise comparison, the altimetry-derived velocities show the same pattern as the in-situ data. However, they are smaller by a factor of almost two due to the inevitable smoothing of the iDOT-profiles within the interpolation process.

Compared to CNES-MDT13 velocities improvements can be seen in the area of Gulf Stream and Agulhas current (even though in-situ observations were used to compute the MDT).
The temporal behavior of differences from iDOT and MDT show no significant information.

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