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

Introduction

Satellite altimeter 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 & Savovexen 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 to a spline grid is used with 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.

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 (Rie 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- and v-direction. For its computation not only altimetry and GOCE data were used but also in-situ observations from drifters and ARGO-flots. 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.

ARGO floats and surface drifter

As in-situ 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.

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/sea-air-seawinds.html). Drifters are taken only if no wind the sun was flagged or if correction for defect sensors are applied according to Lumpkin et al. (2013, 2014).

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.

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

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.

References:

Bosch W., B. K. H. S. H., N. Yoshitani, N. A. Masunov, and P. W. Hackett. (2014) MDT-2013_Velosity data assessed from trajectories of Argo floats at parking level and at the sea surface. IPRC Technical Note No. 42
Lumpkin R. (2014) personal communication

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

Fig. 3: Geostrophic velocities for three different examples in Gulf Stream, North-West Pacific, and Agulhas region. Oct.-Dec. 2009 (c). Blue arrows represent the in-situ velocities, red arrows are derived from IDOTs and green ones from MDT.

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

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 indicate the IDOT differences, the dotted lines the MDT differences for 6 different areas.

Table 1: Mean standard deviation of differences between in-situ and IDOT-derived velocities.

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