Pointwise comparison of geostrophic currents of altimetry-derived instantaneous Ocean Dynamic Topography with in-situ measurements

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Introduction

The time-variable dynamic ocean topography (DOT) along individual ground tracks of altimeter missions (iDOT-profiles) allows to study temporal variations of the DOT. By using the so-called "profile-approach" (Bosch & Savcenko, 2010; Bosch et al, 2013) in a multi-mission scenario a monitoring of meso-scale eddies is possible.

Our aim is to validate the iDOT-profiles with geostrophic velocities derived from surface drifters and ARGO floats. We perform a pointwise comparison by interpolating the iDOT profiles to the positions of the in-situ measurements and converting them to geostrophic velocity vectors.

Recent studies have shown, that the interpolation method causes a smoothing of the iDOT data and yields about two-times smaller geostrophic velocities than the in-situ measurements. In the present investigation we conduct a sensitivity analysis quantifying the impact of the smoothing to the scale factors. Results are presented for the Gulf Stream area and for different periods.

iDOT-profiles and in-situ measurements

The multi-mission dataset containing all iDOT profiles between 2007 and 2010 of Envisat and Jason1/2 altimeter missions is taken from the Open Altimeter Data Base (OpenADB) of the DGFI-TUM. They have been generated based on the profile approach. The new satellite-only gravity field model GOCO05S (Mayer-Gürr T., et al. 2015) has been used as reference.

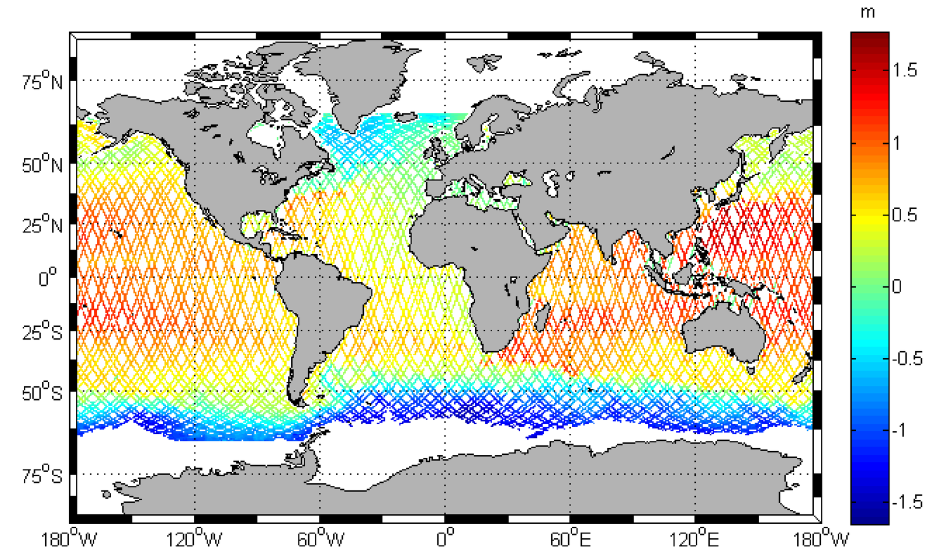

Fig. 1: The global iDOT profiles on the ground tracks of Cycle 36 from Jason-2 in June 2009.

The global in-situ data set consists of ARGO floats (Lebedev et al, 2007) and surface drifters (Lumpkin et al, 2013). In order to compare the in-situ observations with geostrophic velocities from the iDOT-profiles a correction for wind and Ekman drifts is necessary. For this purpose, the approach of Lagerloef et al (1999) is used. Daily wind and wind-stress fields are taken from NOAA'S NCDC. Additionally, a one day moving average is applied in order to reduce noise in the drifter data.

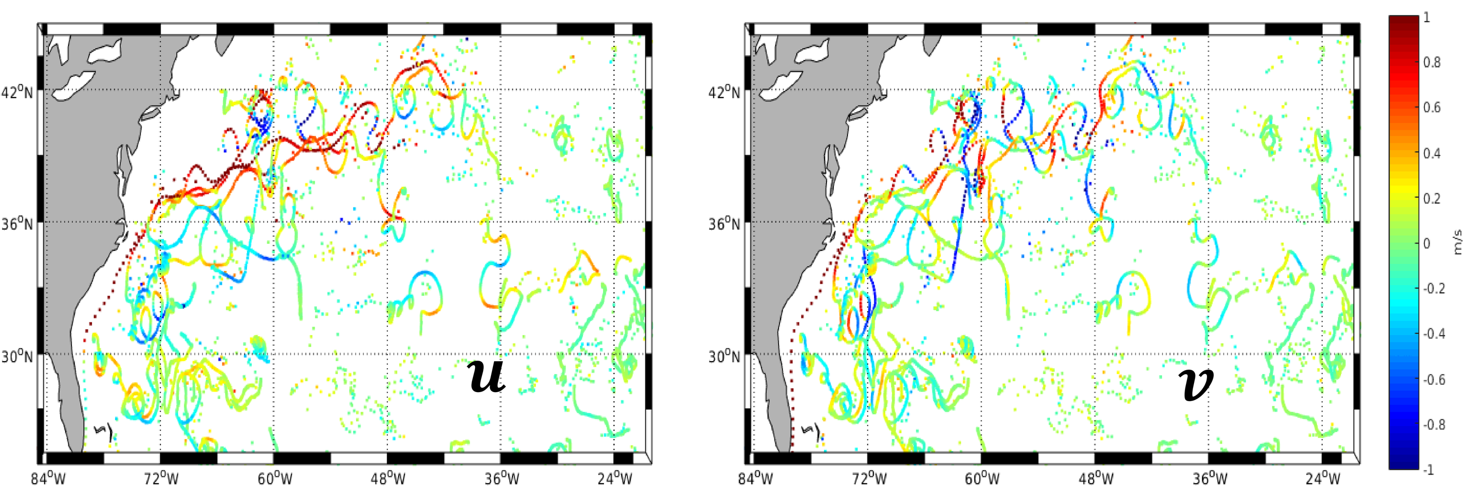

Fig. 2: In-situ surface velocity components for the Gulf Stream of between July and September 2009 (corrected for wind and Ekman drift).

References:

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Bosch W., R. Savcenko, D. Dettmering, and C. Schwatke (2013) A Two-decade Time Series Of Eddy-resolving Dynamic Ocean Topography (iDOT), ESA SP-710 (CD-ROM), ISBN 978-92-9221-274-2, ESA/ESTEC

Lebedev K., H. Yoshinari, N. A. Maximenko, and P. W. Hacker (2007). YoMaHa'07: Velocity data assessed from trajectories of Argo floats at parking level and at the sea surface, IPRC Technical Note No. 4(2)

Lagerloef G.S.E., G. Mitchum, R.B. Lukas, and P.P. Niiler (1999) Tropical Pacific near-surface currents estimated from altimeter, wind, and drifter data. J.Geophys.Res., 104(C10), 23,313-23,326

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Methodology: Pointwise Comparison

We model the iDOT heights h_{DOT} by an inclined plane with respect to a local Cartesian coordinate system x,y centered in the location in each in-situ observations.

$$h_{DOT}(x,y) = c_0 + c_1 x + c_2 y$$

All iDOT values near the in-situ observation are used to estimate by least squares the coefficients c_i. The c_1 and c_2 coefficients representing the inclination in meridional and zonal direction. The selections of the iDOT data used for interpolation is done by a circular cap with a certain interpolation radius R and within a maximum temporal spacing T around each in-situ observation. These interpolation parameters have a significant impact on the smoothing of iDOT profiles.

In order to get geostrophic velocity vectors we apply the geostrophic equations and derive the geostrophic components

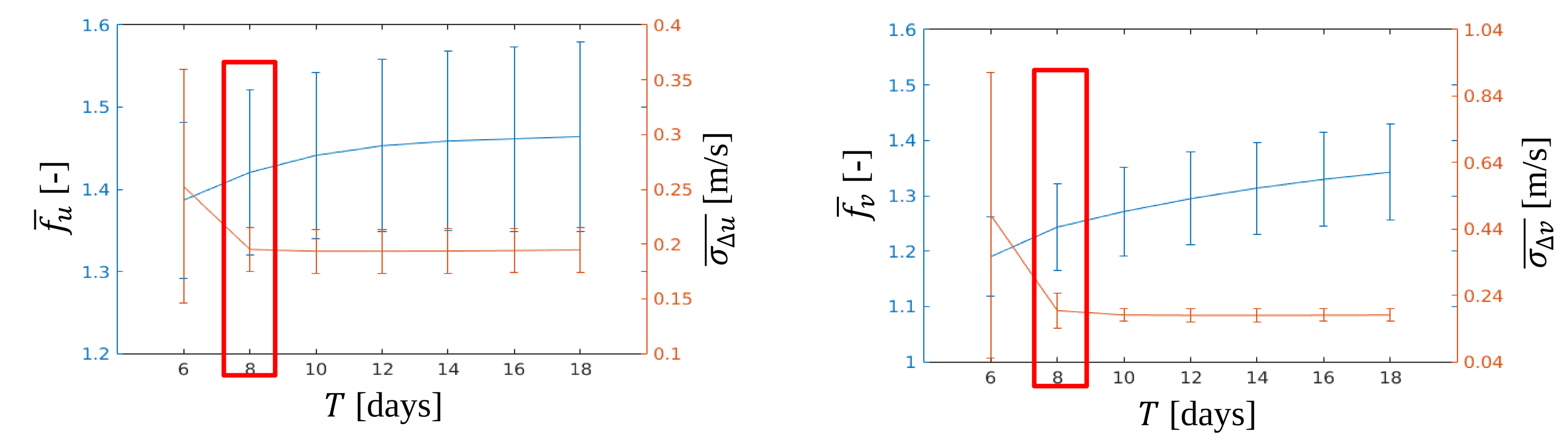
$$u = -\frac{g}{f} c_2 \quad \text{and} \quad v = \frac{g}{f} c_1.$$

f: *Coriolis paramter* $(2\Omega \sin(\phi))$ g: gravity acceleration

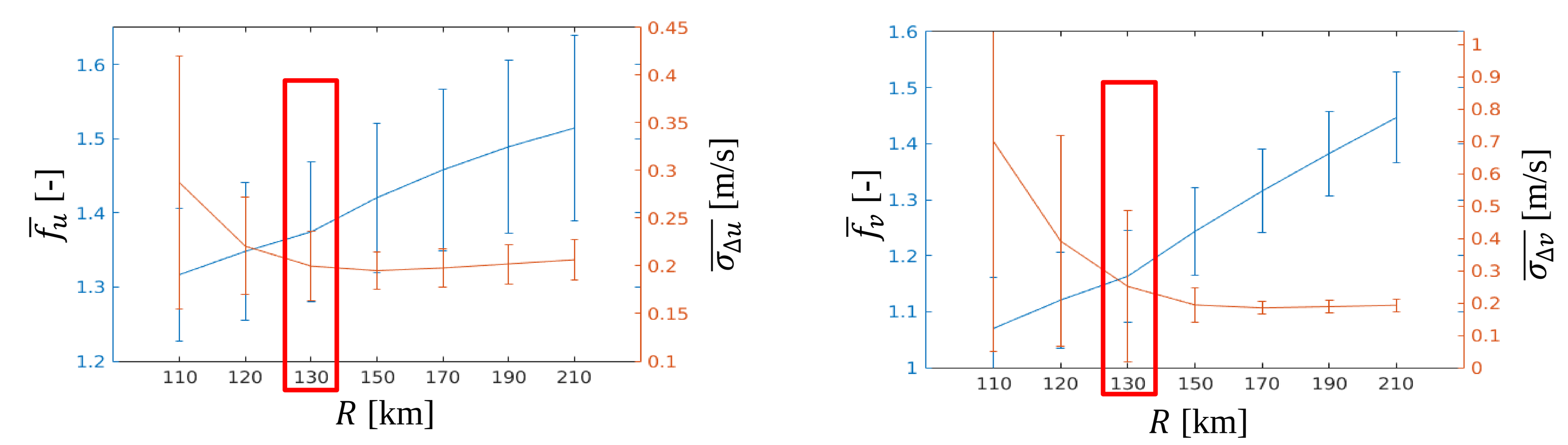
In the present investigation we use a 2D function W for the weighting of the input data. Each iDOT height is weighted based on its spatial r and temporal dt distance to the corresponding in-situ measurement.

$$W(r,dt) = e^{-\sigma_1 r^2} e^{-\sigma_2 dt^2} \text{ with } \sigma_1 = \left(\frac{\ln(2)R}{3}\right)^{-2} \text{and } \sigma_2 = \left(\frac{\ln(2)T}{3}\right)^{-2}$$

In order to define optimized interpolations parameters R, T and to minimize the degree of smoothing with enough input data we vary the parameters and analyze resulting scaling factors (in-situ divided by iDOT) and the standard deviation of the differences.



▲▼ Fig. 3: Mean scaling factor (blue), mean standard deviation of the differences (orange) and its formal error as a function of empirical chosen temporal (top) and spatial resolutions (bottom) for both components in the Gulf Stream area. The best fitting compromise between an increasing scaling factor and a decreasing standard deviation is highlighted (red).



First the interpolation is done for different maximum temporal spacing T and a fixed R (150 km). Afterwards the maximum spatial resolution R is varied with T = ±8 days. This sensitivity analysis implies, that growing interpolation parameters cause an increasing scaling factor and a decreasing mean standard deviation because of a more intense smoothing.

The interpolation parameters are considered optimal where the decay of the mean standard deviations is significant, while the increase of the mean scaling factors remains moderate.

Results: Pointwise Comparison

With T= ±8 days and R=130 km we can improve the results in both components. However, a scaling factor of 1.37 in u and 1.16 in v is still present. The data distribution of the iDOT-profiles in time and space depicts a limiting factor.

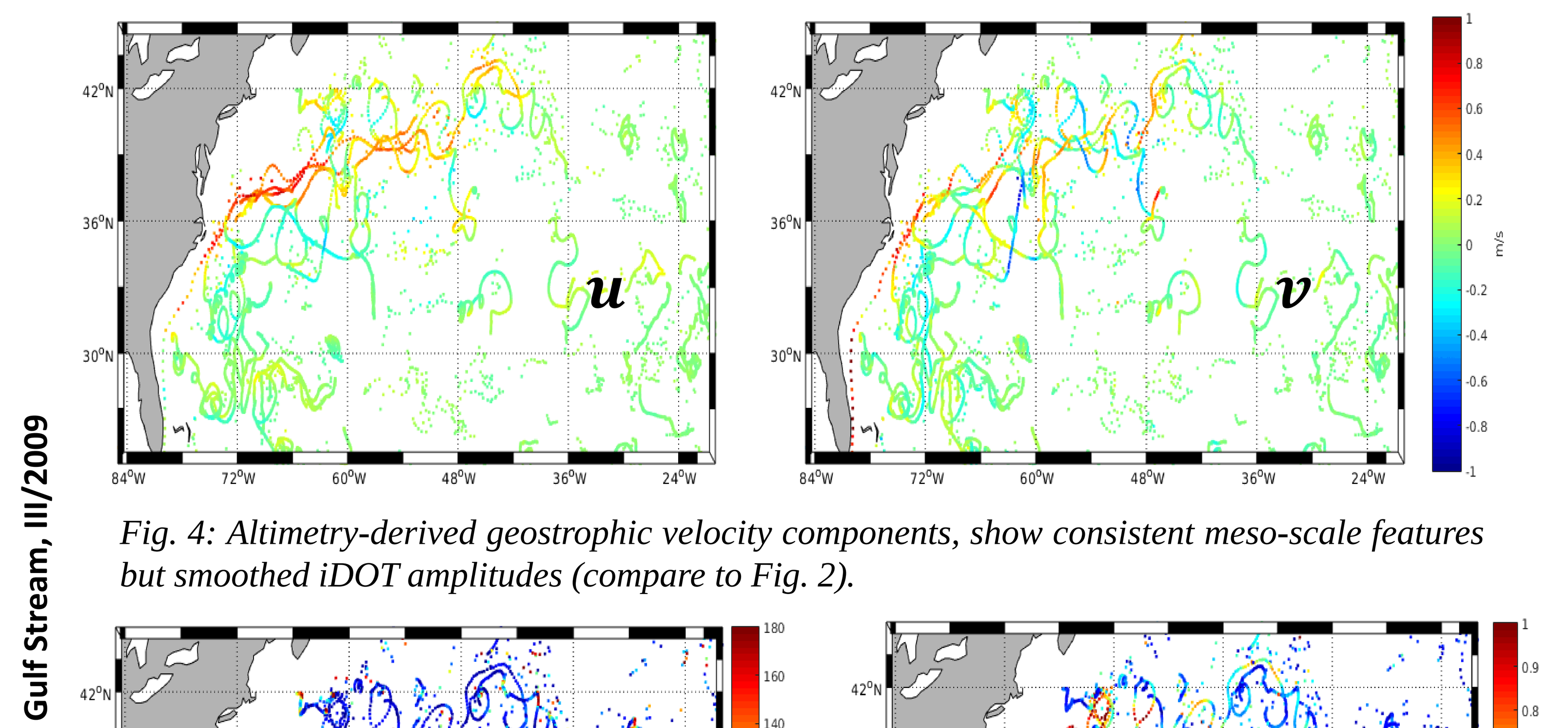


Fig. 4: Altimetry-derived geostrophic velocity components, show consistent meso-scale features but smoothed iDOT amplitudes (compare to Fig. 2).

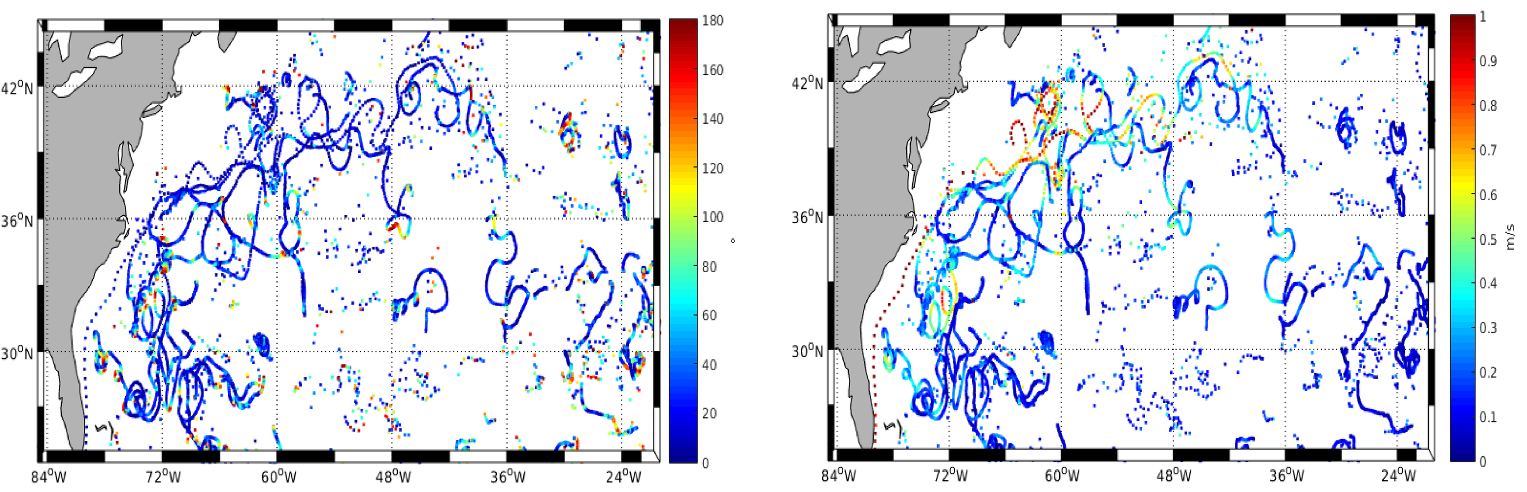


Fig. 5: Phase (left) and amplitude (right) differences (in-situ – iDOT) between the geostrophic velocity fields, show few residues in the central area of the Gulf Stream.

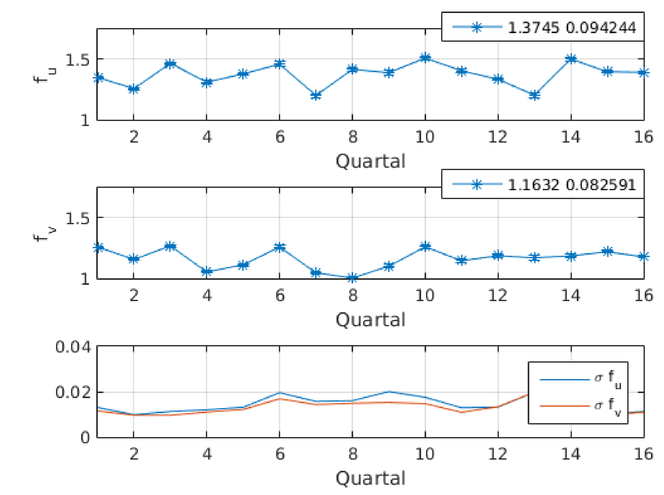


Fig. 6: Least-squares estimates of scaling factors (iDOT divided by iDOT) for both components and their formal errors as a function of the quarter III/2009.

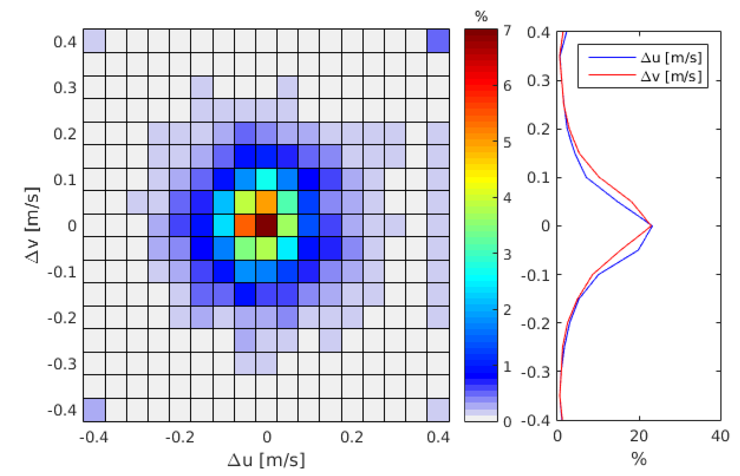


Fig. 7: Scatter plot of the differences (in-situ – iDOT) showing an unbiased 2D distribution with most differences inside the interval ±0.10 m/s in III/2009.

Conclusions

- Due to the spatio-temporal sampling of altimetry with repeat orbits the smoothing of DOT-derived geostrophic velocities is unavoidable and manifests itself by scaling factors.
- A sensitivity analysis yields optimal interpolation parameters.
- The optimal choice of the interpolation parameters depends on the altimetry missions and their temporal and spatial resolution.
- In areas with western boundary currents the altimetry-derived geostrophic velocities are less sensitive to strong meandering flow.
- The differences between in-situ and DOT-currents exhibit an almost normal distribution with zero mean and most differences located inside the interval ± 0.10 m/s
- The altimetry-derived geostrophic currents mirror in-situ existing current patterns in direction and amplitude quite well.

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