A REGIONAL CHARACTERIZATION OF THE GLOBCURRENT OCEAN SURFACE CURRENT ANALYSIS

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ABSTRACT

Observations of extreme conditions, characterized by high heat flux, rapidly changing surface salinity, or strong ocean current, are rare. Although analyses provide estimates of these conditions, because there are few observations to begin with, it is difficult to separately characterize (in terms of calibration and validation) extreme and typical conditions using independent observations. This requirement of independence may not be so dire, however, if we acknowledge that the impact of observations on an analysis is generally local, as is the propagation of errors in space and time.

We propose that temporal extrapolation from outside a typical analysis window permits a calibration and validation by triple collocation (e.g., using only an analysis and available in situ observations; cf. Stoffelen 1998). We seek evidence of analysis performance improvement (as expected) using the calibrations that can be derived. We also seek to validate the GlobCurrent ocean current analysis across an entire current speed range, including at both the low (0.1ms^{-1}) and high (1ms^{-1}) ends.

ERROR MODEL

Four metrics of analysis calibration and performance are given in the triple collocation method that we apply below, following Stoffelen (1998) and McColl et al. (2014). These include an affine transformation (bias and slope), along with estimates of RMSE and correlation with an idealized target (or true) analysis. These four metrics can be obtained from the following error model

$$\begin{array}{rrcl}
\text{drogued drifter (calibrated)} & x & = & t + \delta_x \\
\text{analysis extrapolation from before} & y & = & \alpha_y + \beta_y t + \delta_y \\
\text{analysis extrapolation from after} & z & = & \alpha_z + \beta_z t + \delta_z
\end{array}$$

where α, β, t, and δ are bias, slope, truth, and error, respectively, and drifter velocity is taken to be well calibrated. The drifters are taken from Sep. 2012 to Dec. 2014 and were not employed in the analysis. Extrapolation provides the other two independent data values, based on data from outside a typical analysis data window (cf. Rio et al. 2014). As the GlobCurrent analysis is a linear combination of the Ekman and geostrophic components, extrapolations from two different window lengths (6 h and 5 days) are combined (Fig. 1).

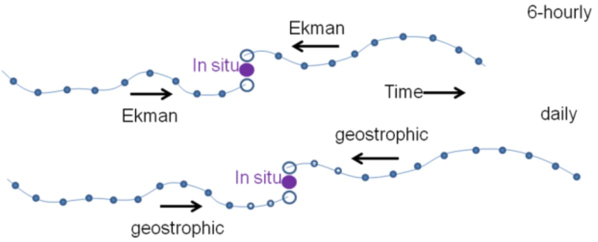

Figure 1. Illustration of forward and backward extrapolation (large open circles) from two independent nine-day analysis timeseries to the time of an in situ observation (purple circle). The Ekman and geostrophic timeseries are 6-hourly and daily, respectively, and geostrophic extrapolation excludes the two days nearest the target day (small open circles).

IDENTIFICATION OF COLLOCATIONS

Well over a million velocity estimates (Fig. 2a) are available from drifters that likely retained their drogues (Rio et al. 2012). Two independent groups of the most complete timeseries of more than 10 observations at 2° resolution (Fig. 2b,d) are taken from this set.

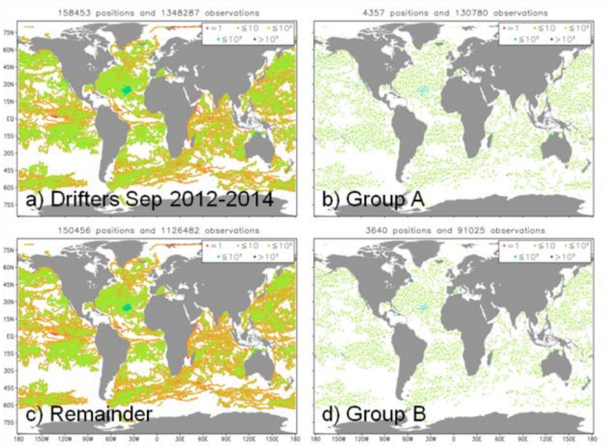

Figure 2. Number of surface drifter velocity observations between September 2012 and December 2014 (order of magnitude in colour) with drogues attached. Shown are values at the ¼° resolution of the GlobCurrent grid. The best temporal coverage during this period is defined by a subset of b) 4357 velocity positions (i.e., the most complete timeseries of

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more than 10 observations at 2^{o} resolution) taken from the total set (a). The same selection procedure is applied after excluding (b), which yields a separate group of d) 3640 velocity positions, with the remainder shown in (c).

CURRENT COMPONENT EXTRAPOLATION

Our use of three sources of current information, but with only two distinct resolutions (drifter and analysis) avoids the main challenge of the triple collocation method: correlations not captured by the lowest resolution information source are not well known, require iteration in general, and may fail to converge (Vogelzang et al. 2011, Vogelzang and Stoffelen 2012).

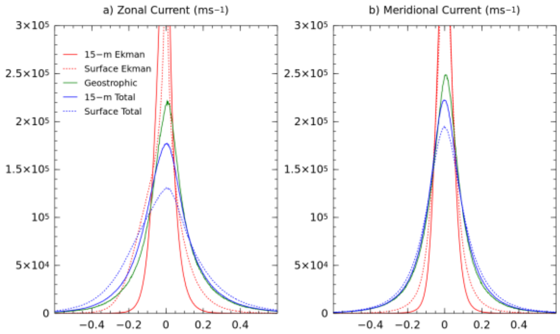
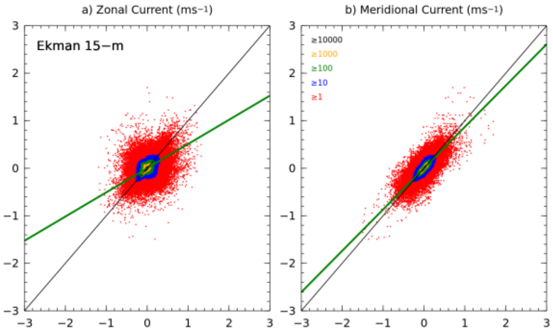


Figure 3. Histograms of the GlobCurrent a) zonal and b) meridional Ekman (red), geostrophic (green), and total (blue) current components at the surface (dashed) and 15-m depth (solid) for all Group A and B collocations (Fig. 2b,d).

As for ocean surface wind components, the zonal and meridional current components (Fig. 3) appear to be more consistent with a Gaussian characterization of errors (as given by the model above) than current speed and direction. This facilitates an interpretation of triple collocation performance metrics (McColl et al. 2014) in the next section.

Fig. 4 depicts the 15-m Ekman (above) and geostrophic (below) current component extrapolations (ordinate) as a function of the values being estimated (abscissa). Extrapolation is well conditioned for the meridional component and for strong zonal flow; less so for weak zonal flow.



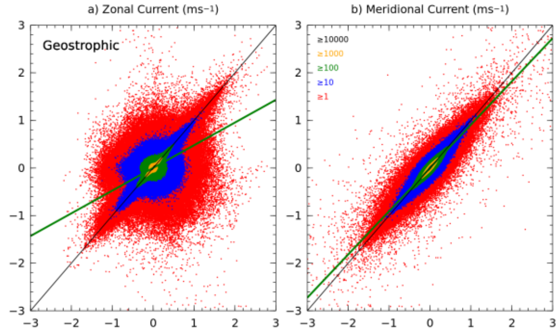


Figure 4. Two dimensional histograms of the extrapolated GlobCurrent 15-m Ekman (top) and geostrophic (bottom) current components for all Group A and B collocations. The abscissa of each panel is the unextrapolated target value at collocation time (as in Fig. 3) and the ordinate is the corresponding extrapolation using nine points before or after. Zonal and meridional components are on the left and right, respectively.

CALIBRATION AND VALIDATION

Consistency between the affine error model and (extrapolated) current component PDFs can be exploited in an investigation of GlobCurrent analysis calibration. Performance metrics (Tab.1) are calculated for the O[10^{5}] collocations of Groups A and B (separately for zonal and meridional current).

	Bias	**Slope**	RMSE	Corr
No Calibration				
Grp-A U	**0.003**	**1.456**	0.054	0.891
Grp-A V	**0.001**	**1.486**	0.059	0.827
Grp-B U	**0.004**	**1.308**	0.052	0.907
Grp-B V	**0.001**	**1.327**	0.057	0.850

Table 1. Triple collocation calibration and validation metrics for the GlobCurrent Group A and B zonal and meridional current components.

The GlobCurrent components are found to be relatively unbiased, except with respect to the unknown target current (*t*), and thus the drifter velocity, with a slope parameter that is 30%-50% too large. In order to test a recalibration, the α and β parameters from Group A are applied to the Group B GlobCurrent collocations, and vice versa. Performance is rechecked and RMSE is reduced (Tab. 2), as should be expected.

	Bias	Slope	**RMSE**	Corr
Calibration independent of Current Speed				
Grp-A U	-0.001	1.113	**0.041**	0.891
Grp-A V	-0.001	1.120	**0.044**	0.827
Grp-B U	0.001	0.898	**0.036**	0.907
Grp-B V	0.001	0.893	**0.039**	0.850

Table 2. As in Table 1, but following a global recalibration of the GlobCurrent extrapolations.

Instead of a global recalibration that employs all collocations, however, we also experiment with the nearest 200 collocations to current speed at intervals of 0.1m/s. These are used to obtain the functional dependence of the performance metrics. A different story is revealed by Fig. 5.

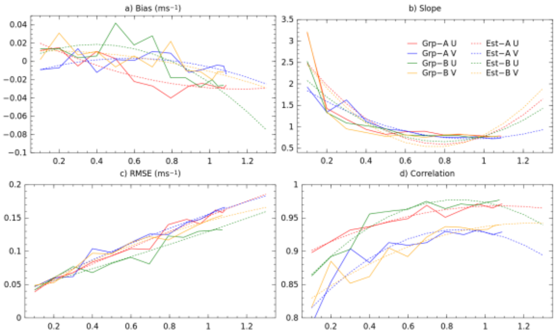


Figure 5. Triple collocation validation and performance metrics a) bias, b) slope, c) RMSE, and d) correlation to a hypothetical target current analysis as a function of the nearest 200 GlobCurrent 15-m total current speed at target speeds between 0.1m/s and 1.2 m/s.

It is only the far more typical weak currents (Fig. 3) that are associated with a slope parameter greater than one, whereas the strongest currents appear to be too weak. At low current speed, the slope parameter is well above one.

	Bias	Slope	**RMSE**	Corr
Calibration with dependence on Current Speed				
Grp-A U	-0.002	0.930	**0.032**	0.902
Grp-A V	-0.005	0.827	**0.033**	0.828
Grp-B U	-0.002	0.815	**0.029**	0.921
Grp-B V	0.005	0.862	**0.038**	0.851

Table 3. As in Table 1, but following a current-speed dependent recalibration of the GlobCurrent extrapolations.

Allowing for a functional dependence of the calibration parameters α and β (e.g., on current speed in this experiment) is a degree of freedom that can also be tested. Table 3 reveals a further drop in RMSE, which suggests that the functional dependence is relevant. In turn, such dependencies permits local mapping (in space and time) of these four metrics, because the current speed itself varies accordingly.

CONCLUSIONS

Best estimates of observational and analysis quality are often sought, even under severe constraints of limited observational diversity and coverage, which impose complementary limits on accessible resolution and level of sophistication in geophysical retrieval. An accommodation of such constraints, and specifically the existence of errors in all types of observations, motivates our application of the triple collocation method (Stoffelen 1998), which has provided robust statistical estimates of quality for a number of satellite derived geophysical quantities (McColl et al. 2014). The method provides a simultaneous calibration and validation using three independent datasets and seeks to avoid pseudobias when the signal-to-noise ratio of the observations is small. Its application to a large number of observation-based analyses is novel, as is a local application in space and time.

We find the GlobCurrent 15-m current components to be well suited for experimenting with a local characterization in terms of triple collocation performance metrics. The component PDFs are well behaved (in a Gaussian sense) as is extrapolation in time from outside the expected influence radius of the mainly altimetric and wind analysis observations that were employed.

The tentative conclusion is that relative to the drifter velocity, which is assumed to be well calibrated, the GlobCurrent weak current (less than about 0.3 m/s) is too strong by at least half and that the strong current components (greater than perhaps 0.6 m/s) are too weak.

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