A regional and Lagrangian characterization of GlobCurrent ocean surface current analyses

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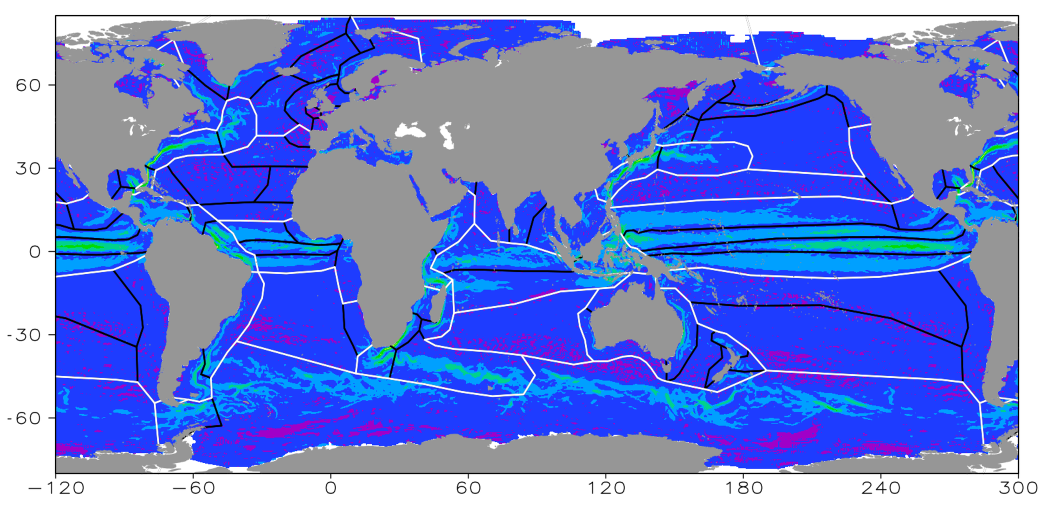
Validation Approach

A consensus exists that most applications of ocean surface current information (just like other oceanic and atmospheric state estimates) require useful measures of confidence. A challenging aspect is to provide measures of confidence that are as local as possible, whether in space or in time. Regional characterizations of a combined geostrophic and Ekman surface current estimate at 15-m depth, as given by ESA's GlobCurrent analyses (2010-2014), are provided at a spatial resolution defined by numerous regions covering the global oceans. This work provides the context for hypotheses to explain the skill variations found within and between regions.

Identification of Regions

- Divisions of the global oceans are available for many purposes (e.g., www.marineregions.org provides economic and scientific divisions) but a division by surface current regime is not widely available. On the other hand, climatological ocean surface currents are generally well documented (e.g., at oceancurrents.rsmas.miami.edu and on wikipedia), but without proposing corresponding limits.

- We propose a division of the global ocean that is informed by documented sources (in particular the RSMAS website) and whose limits follow the CNES-CLS2013 climatology (i.e., a two-decade mean geostrophic current derived from a combined satellite and in situ mean dynamic topography) described by Rio et al. (2014).



- The large-scale divisions that are relevant are shown by white lines, while a division that is more consistent with documented sources (and probably more generally relevant) includes the black lines.

Simulated Drift

- Drifters that have been identified as likely having retained their drogues for the full lifetime of their drift are distinguished from those that may have lost their drogues (Rio et al. 2012).

- Only the drogue-on drifters are considered here. The six hourly position of each real drifter defines the launch position for a simulated drifter.

- Simulations of passive drift are performed following the GlobCurrent geostrophic and Ekman current at 15-m depth. As these current analyses at 0.1-degree resolution, further interpolation in space is omitted and the nearest 0.1 degree velocity is employed.

- Positions are updated at 15-minute intervals by linearly interpolating in time between the three-hourly GlobCurrent analyses; positions are stored every six hours for comparison. Numerous examples of individual trajectories are given at ftp://ftp.nersc.no/pub/rick/trajectories/

Metrics of Comparison

- A basic measure of difference between actual and simulated drifters is the Lagrangian separation distance. As noted by Liu and Weisberg (2011) and Liu et al. (2014), comparisons between slow and fast current regimes require a normalization by current speed (or distance travelled). They propose a measure of skill defined as

$$Skill = 1 - c/n \text{ for } c \le n \quad (1)$$

where c is the sum of Lagrangian distance and n is the cumulative sum of distance along the trajectory. Both sums are calculated over three days and skill is zero where $c > n$.

- Rather than normalize by actual cumulative distance here, we take n to be the average of actual and simulated cumulative distance. (Although a normalization by actual and simulated trajectories *in equal measure* is no doubt inaccurate, normalizing *in part* by the simulated trajectory recognizes that the actual trajectory resolves scales that even the most skillful simulation would not represent.)

- For both Lagrangian separation and skill metrics, we restrict ourselves to simulated and real trajectories that have data available for all 25 days (to facilitate comparisons at different times). Note that each region usually contains many real drifters, each of which has many simulated drifters. Thus, to facilitate comparisons between regions, we reduce the number of simulated trajectories in each group to about 2000 by random subsampling. (Each plot identifies the number of real and simulated trajectories that are employed.)

References

Liu, Y., and R. H. Weisberg (2011), Evaluation of trajectory modeling in different dynamic regions using normalized cumulative Lagrangian separation, J. Geophys. Res., 116, C09013, doi:10.1029/2010JC006837.

Liu, Y., R. H. Weisberg, S. Vignudelli, and G. T. Mitchum (2014), Evaluation of altimetry-derived surface current products using Lagrangian drifter trajectories in the eastern Gulf of Mexico, J. Geophys. Res. Oceans, 119, 2827–2842, doi:10.1002/2013JC009710.

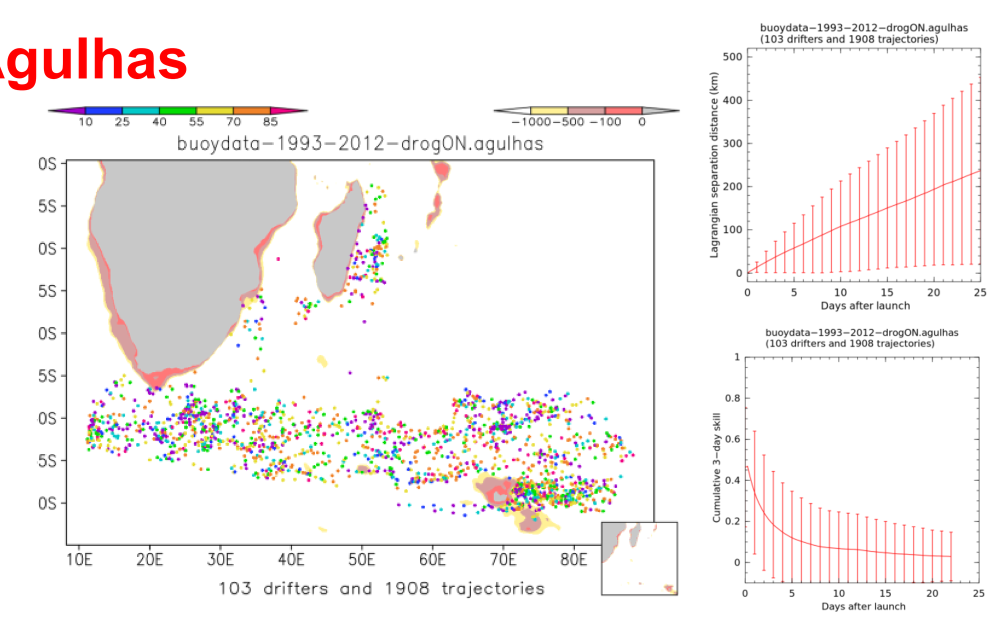
Rio, M.-H. (2012), Use of Altimeter and Wind Data to Detect the Anomalous Loss of SVP-Type Drifter's Drogue, J. Atmos. Ocean Tech., 29, 1663-1674, doi:10.1175/JTECH-D-12-00008.1.

Rio, M.-H., S. Mulet, and N. Picot (2014), Beyond GOCE for the ocean circulation estimate: Synergetic use of altimetry, gravimetry, and in situ data provides new insight into geostrophic and Ekman currents, Geophys. Res. Lett., 41, doi:10.1002/2014GL061773.

Regional Comparisons

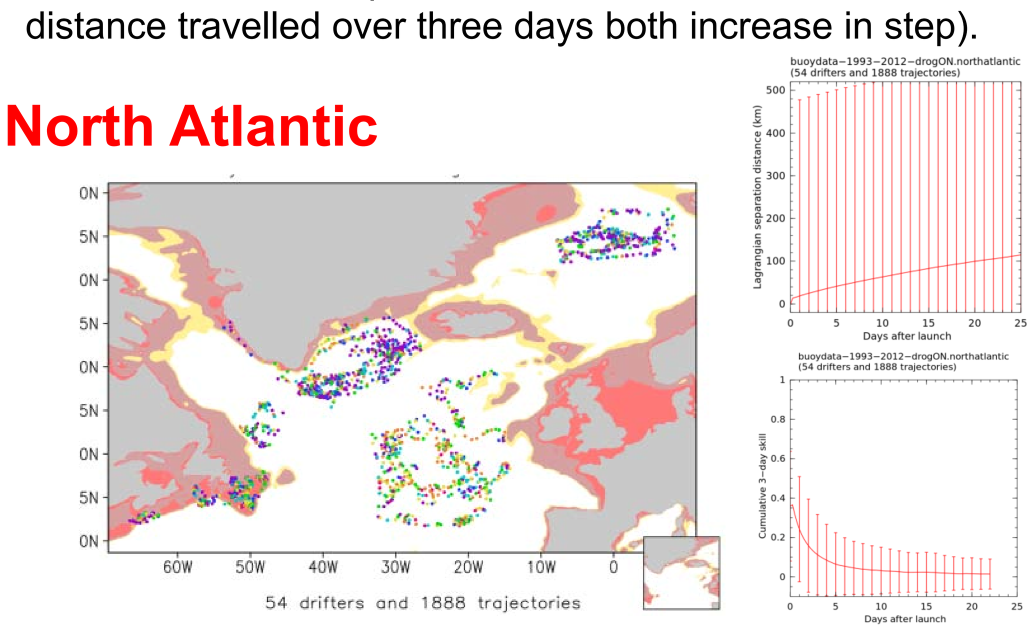
The following are depictions of skill over three days. Left panel is initial skill (in colour) at the position of launch, with shallow bathymetry (shaded). Upper and lower panels are the 25-day and 22-day evolution of Lagrangian separation distance and normalized skill, respectively, shown as a mean for all trajectories plus and minus one standard deviation (where skill is associated with the beginning of its three-day interval).

Agulhas



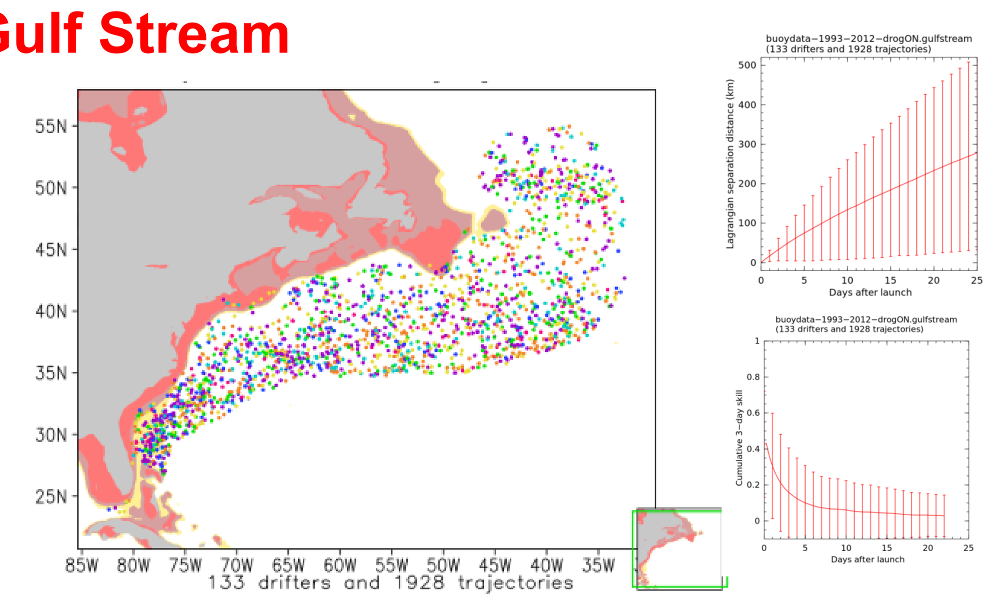
- Skill is similar across all regions with large variations within each domain. Normalized skill falls from about 0.5 to a minimum value within about 10 days. (This minimum skill is nonzero because separation distance and cumulative distance travelled over three days both increase in step).

North Atlantic



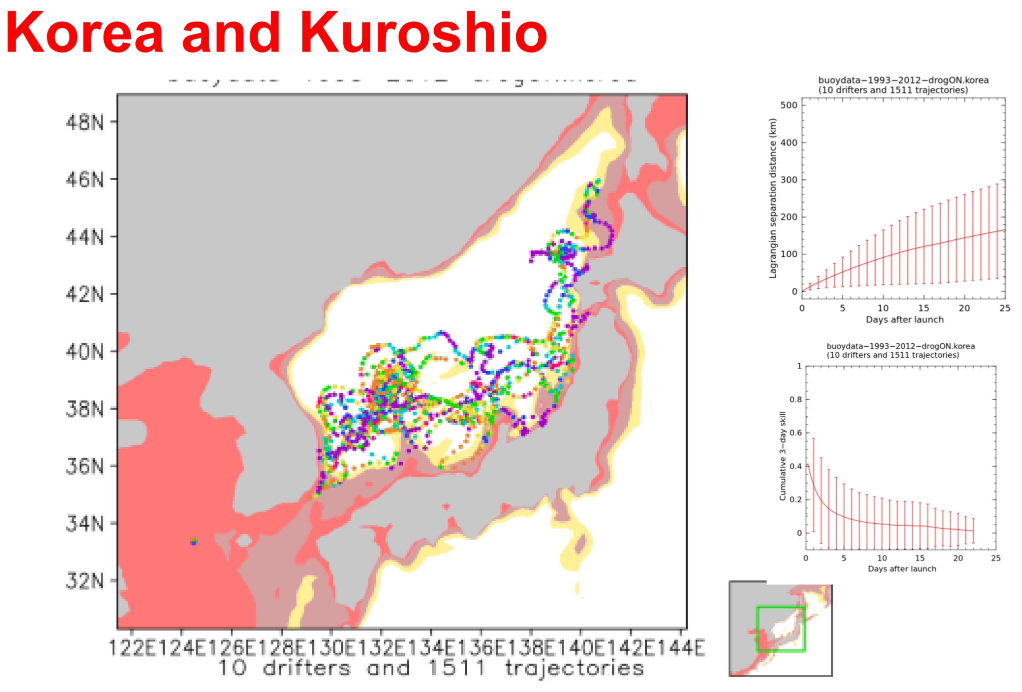
- Unlike elsewhere, local distinctions in initial skill seem evident in the North Atlantic, with higher skill in the North Atlantic drift and smaller skill in the Norwegian Sea and East Greenland current. The average skill is slightly smaller here than in any other region shown in this report, but evidently this is owing partly to the pockets of low skill at higher latitudes.

Gulf Stream

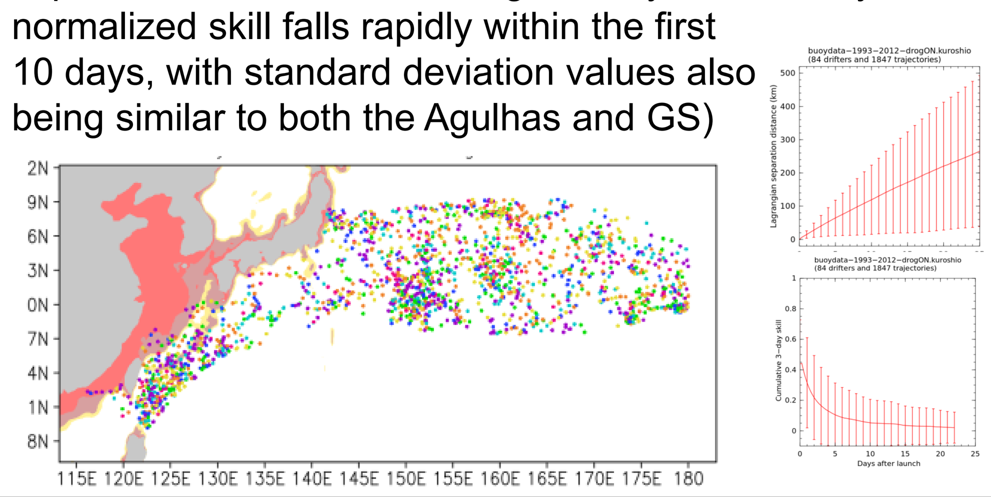


- Lagrangian separation at the end of the 25-day trajectory simulations is slightly larger in the Gulf Stream than in other regions, but the time evolution of average skill appears quite comparable across all the western boundary currents. As expected, the mean and standard deviation of Lagrangian separation distance increases steadily over 25 days.

Korea and Kuroshio

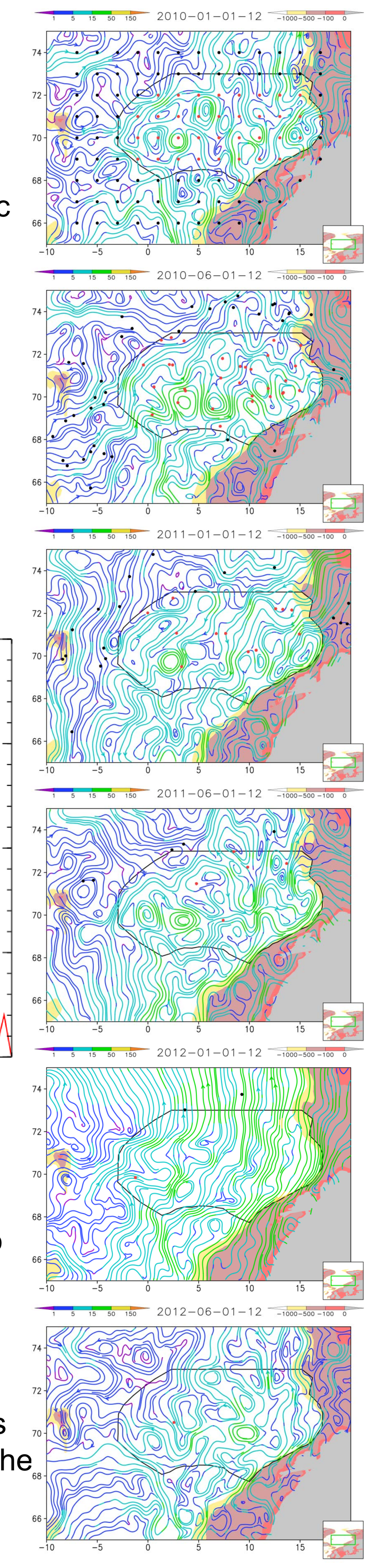


- Low skill is suggested in shallow regions of Yellow Sea (cf. Liu et al. 2014) and the Kuroshio seems consistent with other western boundary current regions (average Lagrangian separation distance increasing steadily over 25 days and normalized skill falls rapidly within the first 10 days, with standard deviation values also being similar to both the Agulhas and GS)



Lofoten Basin Simulation

An integrated characterization of the first three years of GlobCurrent's 15-m combined (geostrophic and Ekman) currents is possible by comparison with the tracking of cyclonic and anticyclonic eddies in the Lofoten Basin of the Norwegian Sea. Raj et al. ("Quantifying mesoscale eddies in the Lofoten Basin", submitted 2015) employ altimeter-derived trajectories of these eddies to reveal that less than 1% of the eddies that form upstream of the southern boundary of the Lofoten Basin propagate into the basin, and similarly, less than 1% of the eddies forming within the Lofoten Basin propagate downstream out of the basin.

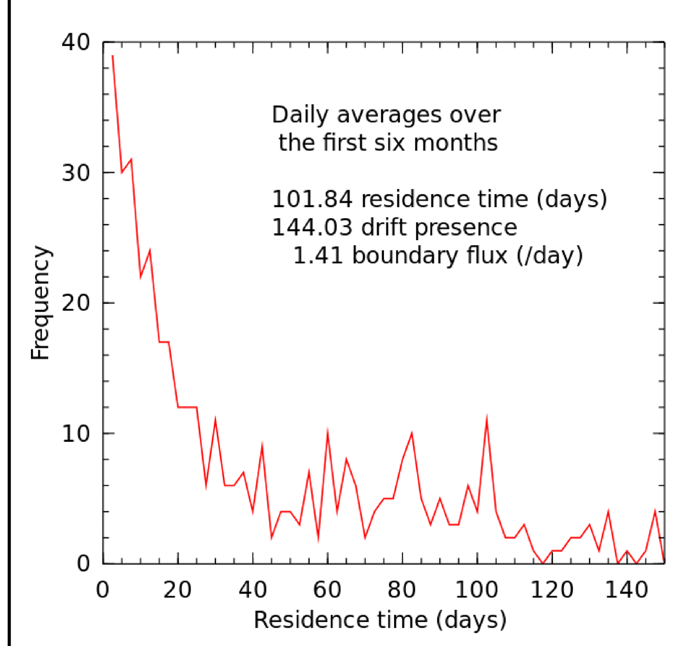


Experimental Design

- An idealized regular distribution of simulated bouys is advected passively in the Norwegian Sea following the combined (geostrophic and Ekman) flow, shown as streamlines.

- Tracking of the buoys (red) that pass into and out of the Lofoten Basin (black line), as well as the total number in the basin, is monitored.

Residence Time



- During the first six months of the simulation, the existing simulated buoys continue to be advected into the Lofoten Basin from upstream and the flux can be considered in steady state.

- A residence time calculation is thus made for this six months, dividing the number of simulated buoys by the average flux (including in and out).

- This residence time confirms the altimetric eddy tracking estimate of about 1% flux through the Lofoten Basin compared to density within. Also of interest is that one drifter lasted almost three years.

- Should the GlobCurrent-based trajectories be "leakier" (i.e., expecting 5-10% flux or so)? Perhaps, the eddy trapping in the basin is either resolved by GlobCurrent (despite strong wind-generated Ekman "purging events", as on the second last panel above), or residence time is simply a macroscopic measure of the flow and current components that are not included (Stokes, tidal, and inertial) have little not impact (or a bit of both).

Conclusions

- The global oceans have been divided according to well documented climatological ocean surface current regimes, as depicted in the CNES-CLS2013 mean dynamic topography (Rio et al. 2014).

- The resulting regions have been examined for 2010-2012 in terms of Lagrangian separation distance and a normalized skill score (Liu et al. 2014). The spatial distribution of skill in reproducing actual drifter trajectories by following the GlobCurrent 15-m combined current appears to depend little on the broad regions shown in this initial examination.

- Although it may be possible to reproduce a tendency for lower skill in shallow regions (e.g., Liu and Weisberg 2011), this is but one working hypothesis to explain skill variations (e.g., transient divergent conditions are another; cf Korosov poster).

- The North Atlantic region is associated with the lowest overall skill, and while not significantly lower, this seems to be associated with two high latitude positions in the east Greenland current and Norwegian Sea. Separate examinations of ocean currents in such high latitude subregions thus seems appropriate (e.g., using the slightly finer resolution given in the proposed new division).

- An integrated test of the passive advective properties of the GlobCurrent combined current reveal good consistency with observations of eddy movement through the Norwegian Sea and support the idea (Raj et al. 2015) that the Lofoten Basin supports a local development of many of the eddies that form there.

Acknowledgement

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