QUANTIFYING THE IMPACT OF ASSIMILATING ALTIMETRY AND LIMTED DRIFTER DATA ON OCEAN CURRENT FORECASTING IN THE ANGOLA BASIN

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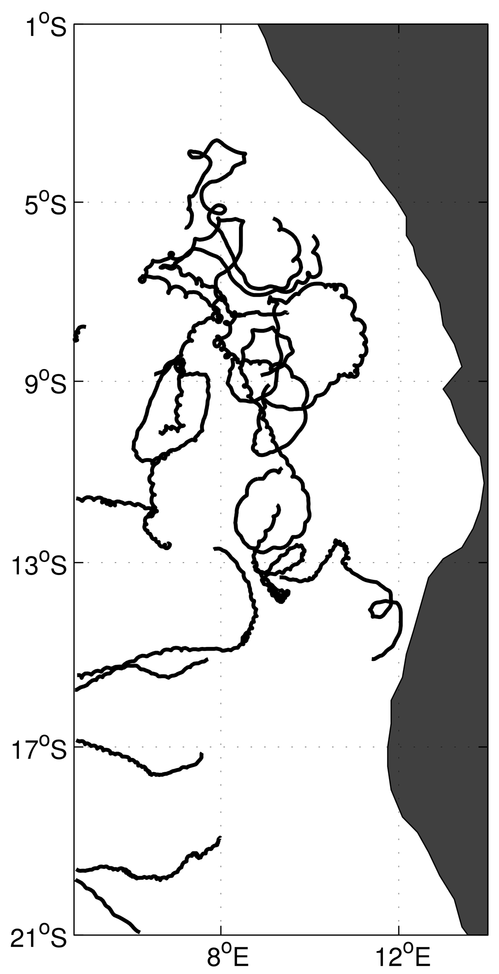
INTRODUCTION

Accurately forecasting ocean currents for short-term predictions is of great importance for a number of applications such as tracking marine pollution. Muscarella et al. (2015) has previously shown drifter inferred velocity assimilation improves Lagrangian predictability in the Gulf of Mexico and recently Carrier et al. (2016) showed qualitatively that assimilating the combination of altimetry and drifters improves upon solely altimetry assimilation. This study expands on this work by formally quantifying the relative importance of assimilating altimetry and a limited amount of drifter data (more typical of general ocean coverage) both separately and combined.

Figure 1: Location of all drifters used throughout the study.



Experiment Label	DRIFT	SSHG	SST	TS
TS-SST (B)	N	N	Y	Y
B-SSHG	N	Y	Y	Y
B-DRIFT	Y	N	Y	Y
B-SSHG-DRIFT	Y	Y	Y	Y

Table 1 (left): The study OSE. DRIFT refers to the drifter inferred velocity, SSHG refers to altimetry measuring sea surface height, SST refers to satellite sea surface temperature and TS represents profile measurements of temperature and salinity. B refers to the baseline observational data set.

Metric	Equation
Average Separation Distance $D(t)$	$\sqrt{[x_{obs}(t) - x_{ROMS}(t)]^2 + [y_{obs}(t) - y_{ROMS}(t)]^2}$
Average Growth Rate of Separation Distance $D_{Linear}(t_0..t_{end})$	$\hat{D}(t_0..t_{end})/(t_0..t_{end})$
Angular Difference $AD(t)$	$ang_{obs}(t) - ang_{ROMS}(t)$
Cumulative Distance Difference Skill Score $S(t)$	$S = \begin{cases} 1-c, (c<1) \\ 0, (c>1) \end{cases}$ $c(t) = \sum D(t)/\sum D_0(t)$ $D_0(t) = \sqrt{[x_{obs}(t) - x_{obs}(t-1)]^2 + [y_{obs}(t) - y_{obs}(t-1)]^2}$

Table 2 (left): Summary of Lagrangian metrics used within the study. Average separation distance between the drifters and ROMS simulated floats, average growth rate of separation distances (linear fit applied to the average separation distances over the entire 4 day forecast), average angular difference and a normalized cumulative distance difference skill score Liu and Weisberg (2011).

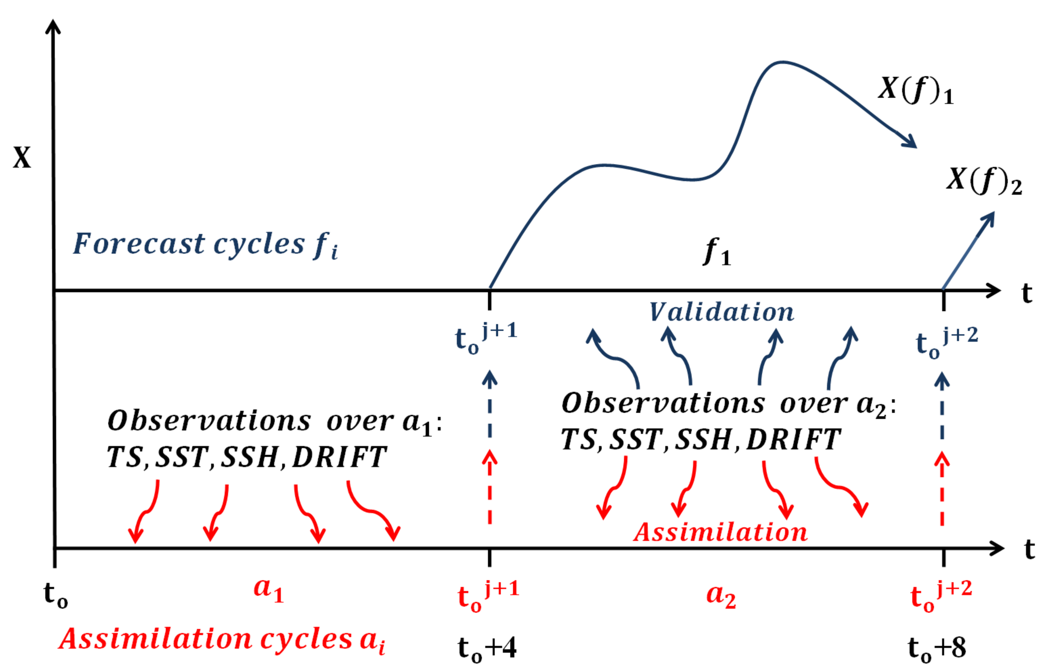
METHOD

The Regional Ocean Modelling System (ROMS) IS4D-Var scheme was run sequentially in four day cycles from 1st January to 13th March 2013. Four experiments were assessed consisting of differing observation sets (Table 1). Four day forecasts (Non-Linear ROMS without any assimilation) were produced at the end of each cycle (Figure 2).

After validating the assimilation system (Figure 3) the ocean current forecast skill was assessed using two frameworks;

1. Eulerian ocean current skill using OSCAR as gridded observations (domain wide and near- drifter).
2. Lagrangian ocean current skill using 4 Lagrangian metrics (Table 2) computed by comparisons of simulated ROMS floats and the drifter data outside of assimilation cycles.

Figure 2 (right): Schematic of experiment setup



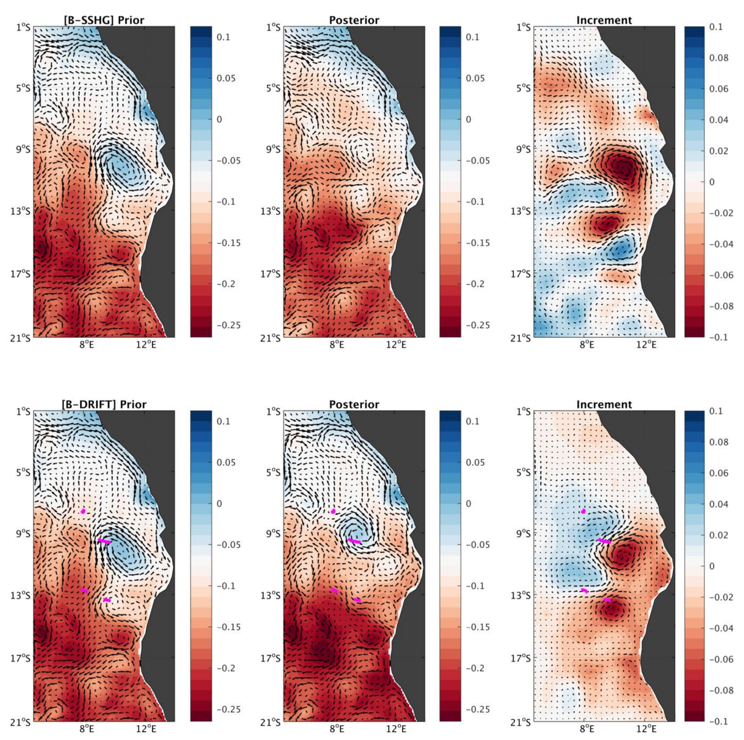


Figure 3 (left):Column left to right: Prior (background forecast), posterior (updated forecast from the assimilation system) and increments (prior minus posterior) for the end of first assimilation cycle, 5th January. Top to bottom: The B-SSGH experiment and B-DRIFT experiment.

RESULTS

- The assimilation of solely altimetry (B-SSHG) produces the closest domain-wide forecast comparisons to OSCAR. Near-drifter forecast comparisons shows the drifter velocity assimilation (B-DRIFT) improvements are closer to that of solely altimetry assimilation as expected (Figure 4).

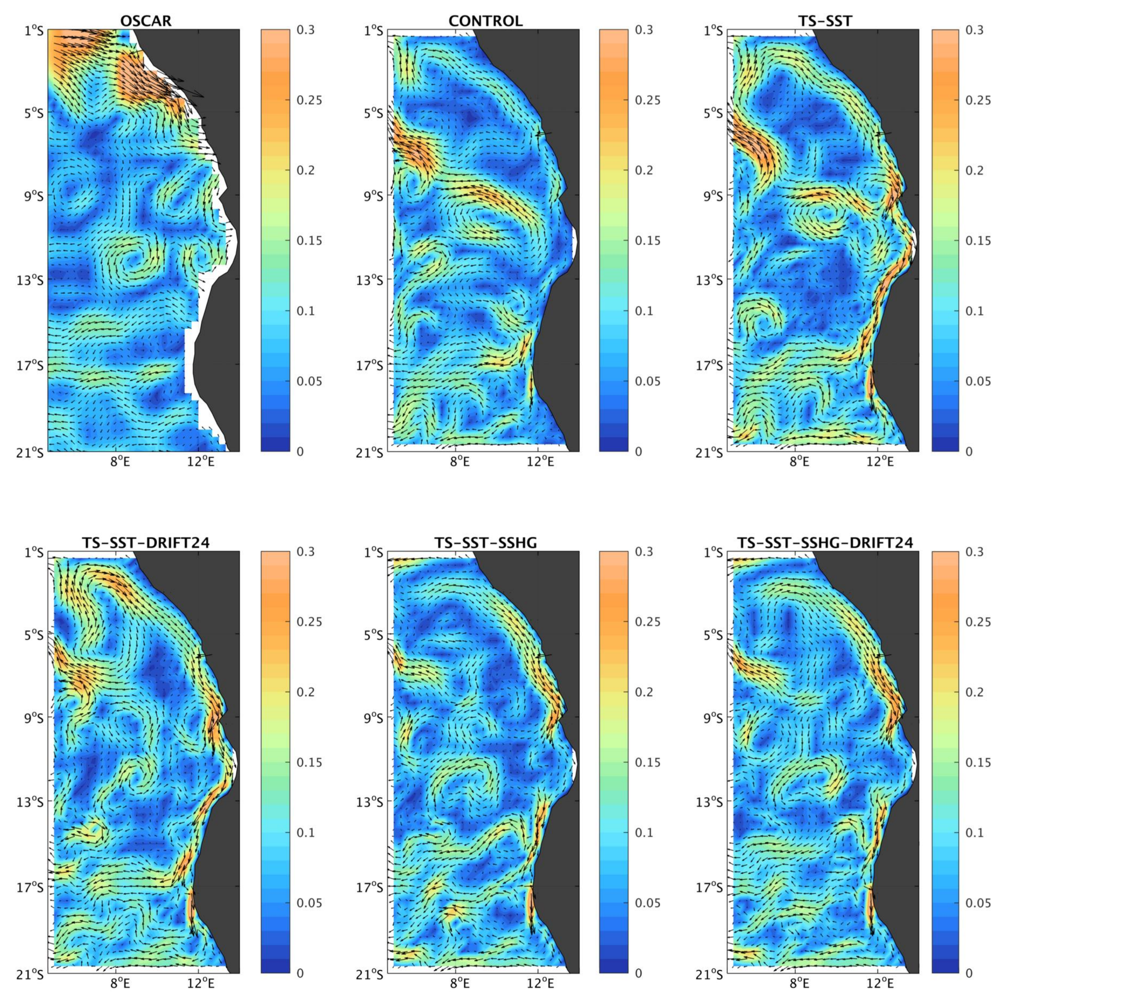


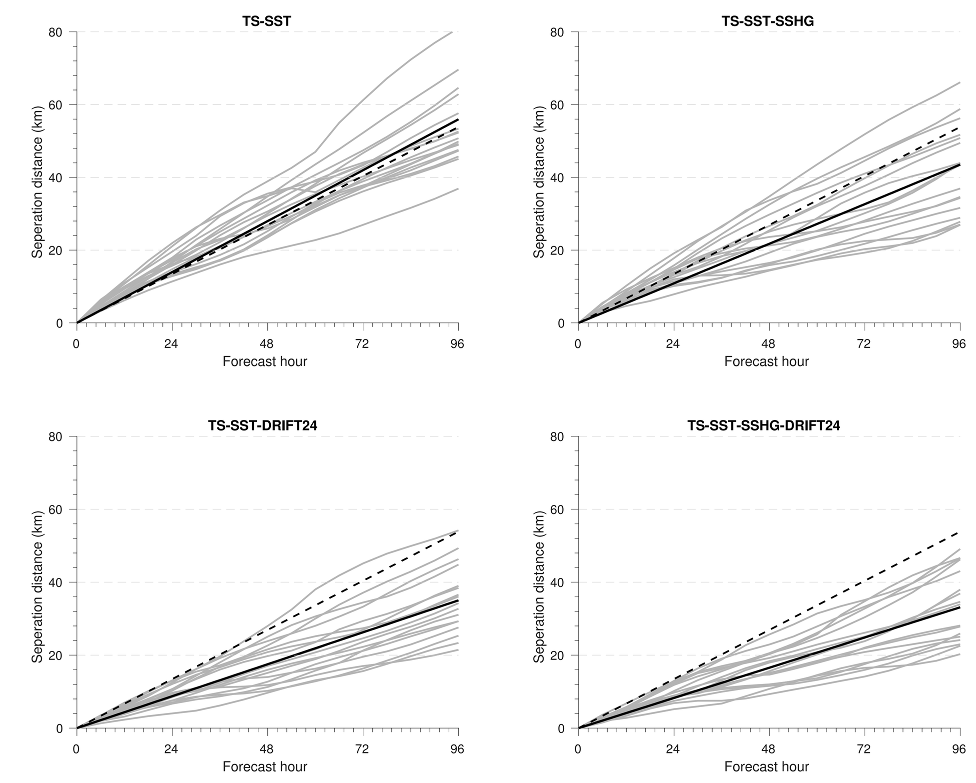
Figure 4 (right): Ocean current speeds (m/s) and velocity vectors averaged over all forecast cycles (5th January-13th March) and over the top 30 meters depth for top left OSCAR analysis, top middle: Control (free run with no assimilation), top right: TS-SST (B), bottom left: B-DRIFT, bottom middle: B-SSHG and bottom right: B-SSHG-DRIFT.

Table 3 (below): Summary of Lagrangian metric statistics.

Metric	CTL	TS-SST (B)	B-SSHG	B-DRIFT	B-SSHG-DRIFT
$\hat{D}(24)$ (km)	15.3 ± 8.4	16.3 ± 8.9	13.4 ± 7.8	9.5 ± 6.3	9.5 ± 6.4
$D_{Linear}(0..96)$ (km/day)	13.5 ± 7.7	14.1 ± 7.9	10.9 ± 7.0	8.7 ± 6.1	8.3 ± 5.2
$AD(24)(degrees)$	76 ± 50	81 ± 51	65 ± 52	42 ± 35	47 ± 43
$S(72), n=1$	0.16 [45%]	0.13 [44%]	0.24 [58%]	0.35 [77%]	0.35 [75%]
$S(72), n=2$	0.42 [79%]	0.41 [81%]	0.51 [87%]	0.61 [93%]	0.62 [93%]

- The addition of **drifter velocities** was shown on average to **significantly improve** the Lagrangian forecast skill in all four metrics as compared to the baseline assimilation, B (35-40%) and solely altimetry assimilation, B-SSHG (18-20%) in line with previous studies (Table 3, Figure 5).
- The assimilation of the **combination of altimetry and drifter velocities,** B-SSHG-DRIFT may either **improve** or even **degrade** the Lagrangian forecast skill over **solely assimilating drifter velocities,** B-DRIFT (Table 3, Figures 5 & 6). The average difference between these two distributions of all computed Lagrangian metrics in Table 3 is not in significance.

Figure 5 (right): The average and spread of the growth rate in separation per day (km /day) for top left: TS-SST (B), top right: B-SHH, bottom left: B-DRIFT and bottom right: B-SSHG-DRIFT. Each grey line represents the average separation for each drifter over the entire domain within one forecast cycle. The black line represents the average over all drifters and forecasts. The dashed line shows the CONTROL (free run without assimilation) average over all drifters and forecasts for comparison.



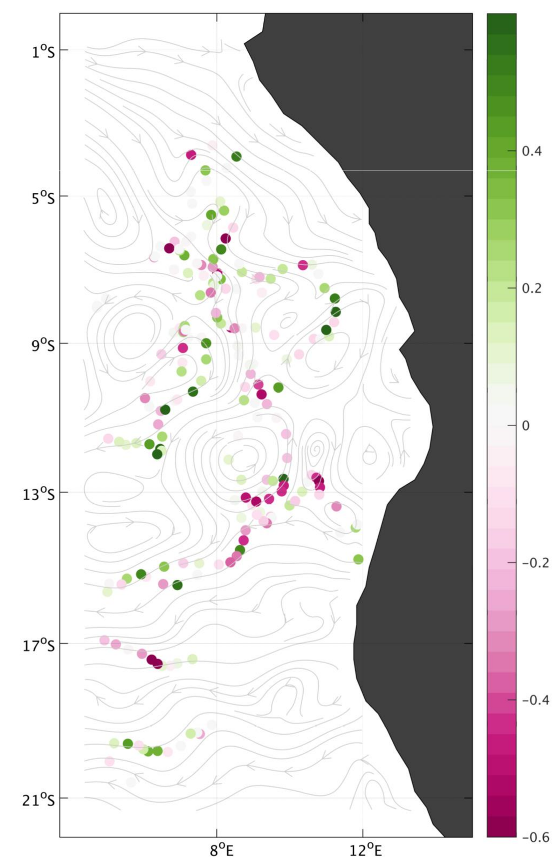


Figure 6 (left): The spatial distribution of the cumulative skill score metric, S differences between B-SSHG-DRIFT and B-DRIFT. Positive values (green) indicate where B-SSHG-DRIFT is having a more positive impact on the skill score than B-DRIFT. Negative values (magenta) indicate where B-DRIFT is having a more positive impact on the skill score than B-SSHG-DRIFT. Overlaid in light grey is the OSCAR current streamlines averaged over the entire study period.

CONCLUSION

Here, for the first time, we quantify the relative importance of assimilating altimetry and drifter observations for ocean current forecast skill. By directly comparing the addition of either solely altimetry, solely drifter inferred velocities and a combination of the two to a set of baseline observations assimilated into the ROMS 4D-Var system. We find drifters are essential for large local improvements and the subsequent addition of altimetry may either improve or degrade the trajectory forecast skill.

REFERENCES

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