Evaluation and application of operational altimeter-derived ocean surface current datasets on the NW Atlantic shelf

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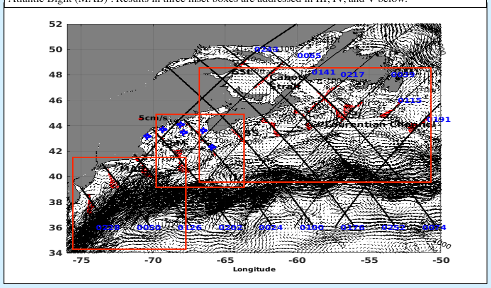
I. Introduction

The satellite altimeter record now extends for decades and can support examination of the mean state of ocean circulation dynamics in coastal regions such as the shelf of the Northwestern Atlantic (NWA) including the semi-enclosed marginal sea Gulf of Maine (GoM) and Mid-Atlantic Bight (MAB). This technical study evaluates the strengths and weaknesses of the global altimeter-derived gridded ocean current products (e.g. GlobCurrent) in their application to coastal process studies using the NWA shelf as a test case. Specific **objectives** are:

- to evaluate the quality of GlobCurrent products (www.globcurrent.org) against *in situ* current measurements from the US Integrated Ocean Observing System (US-IOOS): including the Gulf of Maine (GoM) moored buoy network with ADCP current time series from Northeast Regional Association of Coastal Ocean Observing Systems (NERACOOS) and a MAB HF Radar (CODAR) network from the Mid-Atlantic Regional Coastal Ocean Observing System (MARACOOS)
- to explore its application to a known topic- how subsurface Gulf hydrography relates to upstream (remotely-forced) advection

Fig 1 Regional map with mean GlobCurrent surface current vectors on the NWA shelf. Some key locations include the Gulf of St. Lawrence (GSL), Scotian Shelf (SS) , Gulf of Maine. (GoM) and Mid Atlantic Bight (MAB) . Results in three inset boxes are addressed in III, IV, and V below.



II. Data and Methods

Altimeter-derived gridded surface current products (GlobCurrent, V3) from 1993-2015 produced using an optimal interpolation of multiple altimeters, with both east and north components of:

- Surface total geostrophic current $\mathbf{U}_{geo}$ on a 1/4 degree (~25 km) grid with daily time resolution
- Total current U_{total} at depth of significant wave height and as the sum of surface geostrophic $\mathbf{U}_{geo}$ and Ekman currents $\mathbf{U}_{ek}$ on a 1/4 deg grid with a 3-hour resolution <u>Note the effective resolution of U_{geo} and U_{ek} is of the order of 5-10 days & 50-100 km</u>

In situ buoy measurements: (US-IOOS-NERACOOS)

- ADCP-measured ocean currents at six GoM buoys (Fig. 2) are used for Globcurrent validation(2001-2015).
- Hydrographic measurements at these buoys (depths of 1, 20, and 50 m) used for water mass advection analyses
- HF radar (CODAR) surface current measurements in MAB (2006-2017)
- All in-situ current measurements are de-tided and low-pass filtered for analysis

Low-passed time series: formed by applying a 70 day running mean low pass filter to remove higher frequency aliasing but preserve seasonal to interannual signals.

III. GlobCurrent product : Buoy Validation in GoM

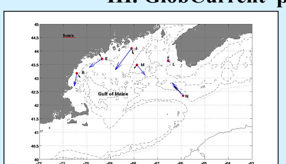


Fig. 2 The climatological mean surface current vectors from GlobCurrent geostrophic current (**Black**) and buoy-measured upper ocean (average over 5-50m) currents (**Blue**) at six GoM buoy stations.

Table 1. Statistics - (R) correlation coefficient, RMSE (cm/s), Bias (cm/s) and (N) # of matchup observations of GlobCurrent and buoy-measured current for eastward (U) and northward (V) components at buoys N,L,M,I,E and B (Fig. 2) at 5–50m depth-average (70-day moving average low-pass filtered)

Buoy ID	U R	U RMSE	U Bias	V R	V RMSE	V Bias	N
Geostrophic $\mathbf{U}_{geo}$							
N	**0.68**	**3.24**	**1.06**	**0.54**	**4.08**	**-0.82**	3653
L	-0.20	4.25	0.20	0.03	5.37	2.72	1769
M	0.23	4.04	-4.53	-0.01	4.86	2.37	1874
I	**0.39**	**3.85**	**7.57**	**0.32**	**3.89**	**5.54**	4832
E	0.31	3.39	3.86	-0.09	3.76	5.55	4932
B	0.15	2.18	2.67	-0.20	4.82	2.37	4846
$\mathbf{U}_{total}$ = Geostrophic $\mathbf{U}_{geo}$ + Ekman currents $\mathbf{U}_{ek}$							
N	**0.74**	**3.02**	**3.29**	**0.70**	**3.79**	**-2.91**	7306
L	-0.08	4.15	2.30	0.21	5.31	0.85	3536
M	0.13	4.92	-2.22	0.17	4.14	0.41	3752
I	**0.53**	**3.38**	**9.55**	**0.01**	**4.31**	**3.56**	9655
E	0.49	3.16	5.51	0.29	3.90	3.74	9862
B	0.31	2.41	4.30	-0.25	4.81	0.49	9689

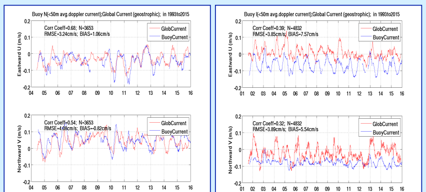


Fig 3 . Globcurrent surface geostrophic current (U_{geo}, RED) vs. buoy current (BLUE) at station N (left) and I (right). The upper /lower panels show U and V current components.

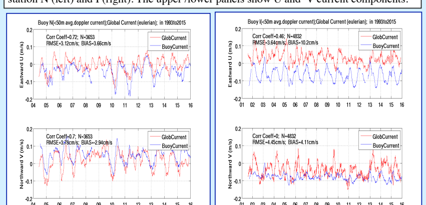


Fig 4. GlobCurrent U_{total}=U_{geo}(surface geostrophic) + U_{ek} (surface Ekman) (**RED**) vs. buoy (**BLUE**) current at station N(left) and I (right). The upper /lower panels show U and V current components

GlobalCurrent shows excellent agreement with Buoy N in the shelf break, but inside GoM its accuracy degrades variably, showing relatively better performance in the east coast (Buoy I) than in the west (Buoys E, B). The Ucomponent accuracy is higher than the V component. This is likely because of strength in U, aligned with the shelf as well as V in altimeter track orientation. The addition of the Ekman estimate does not yield significant improvement and depends somewhat on site locations.

IV. GlobCurrent product : HF Radar Validation in MAB

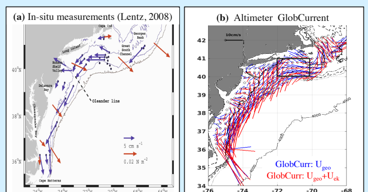
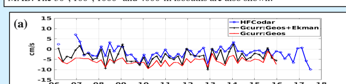


Fig 4. **(a)** in situ mean depth-averaged current vectors (**BLUE**)**,** and mean wind stress vectors (**RED**) (from Lentz, 2008) ; (**b**) Altimeter-based GlobCurrent mean geostrophic current U_{geo} (**BLUE**) and Geostrophic +Ekman U_{geo} +U_{geo}(**RED**) in MAB. The 50-, 100-, 1000- and 4000-m isobaths are also shown.



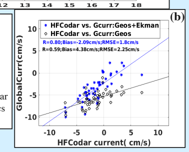


Fig 5. **a)** Low passed (70-day bin average) time series of mean alongshore surface current from in situ HF Codar (**BLUE**), GlobCurrent U_{total}=U_{geo}(geostrophic) + U_{ek} (Ekman) (**BLACK**), and U_{geo} (**RED**) in MAB (inbox in Fig.4b). **b)** Scatter plots of GlobCurrent U_{total} and U_{geo} against HF Codar alongshore surface current, with the statistics of correlation, Bias and RMSE shown.

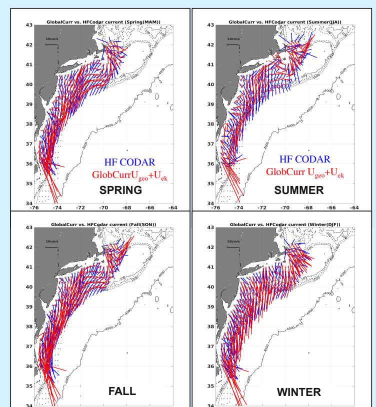


Fig 6. Comparisons of **seasonal mean surface current vectors in i**nsitu HF Codar measurements (**BLUE**) and altimeter-based GlobCurrent U_{total}=U_{geo}(geostrophic) + U_{ek} (Ekman) (RED), The 100-, 1000- and 4000-m isobaths are also shown.

Fig 4. shows GlobCurrent geostrophic flow U_{geo} but not U_{total} = U_{geo}+ U_{ek} matches in situ mean currents matches very well, and Fig. 5 shows that GC U_{total} matches HF Codar measured current much better GC U_{geo} in MAB

Fig 6 shows that GlobCurrent U_{total} = U_{geo}+ U_{ek} matches HF Codar measured surface flow well in most areas. There is a best match in winter when downwelling wind is dominantly in the same direction as mean flow.

V. GoM subsurface salinity variability tied to southwest Scotian Shelf inflow and its potential remote controls

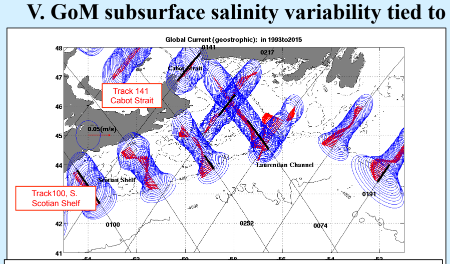


Fig. 7 Climatological mean surface geostrophic current vectors (red arrows) and ellipses (blue) from GlobCurrent (1993-2015) on the Scotian Shelf, in the Gulf of St. Lawrance, and along shelf-slope domain. Long-term altimeter (Topex and Jason) repeat ground tracks are shown in black. In particular, data near six tracks (#100, 252, 074,191, 217, and 141) are selected for analysis, with focus on shelf sections as indicated with dark black dots. Along-shelf geostrophic current V_g for these tracks are estimated by projecting the vector currents normal to the local isobath

A recent study (Feng et al, 2016) found that interior GoM subsurface salinity (and thus biochemistry) variability at 90-360 day time scales is closely tied to Scotian Shelf inflow that is, in turn, correlated with V_g change measured on track 100. The study showed that satellite altimeter data allow monitoring/ prediction of remote forcing of GoM hydrography due to this upstream advection. We examine GlobCurrent data to further explore potential sources of control on this variable advection process.

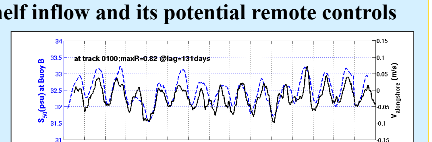


Fig. 8. Filtered time series of GoM salinity and Scotian shelf currents. Blue curve is 70-day moving average of Buoy B measured subsurface salinity at 50m depth and black is the lagged alongshelf altimeter-based (GlobCurrent) current V_g near track 100 on the Scotian shelf. The 130 day time lag represents the offset for maximum correlation (R=0.8) between salinity and Vg100. Positive lag indicates Vg100 leads. Also note that negative Vg100 corresponds to downstream flow. This result is consistent with that reported by Feng et al.(2016) using dedicated altimeter processing of along-track data including near coast corrections.

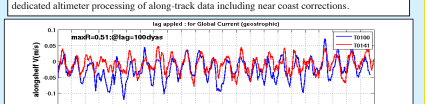


Fig. 9. Time series (70 day moving average) of alongshelf altimeter-based (GlobCurrent) current Vg across track 100 on the Scotian shelf and for track 141 along the Cabot Strait. Time lag and max correlation are indicated. Positive lag indicates Vg141 leads. Negative alongshelf currents are downstream flow. The estimated advection time from Cabot Strait (track 141) to the southwest SS (track 100) is ~100 day, consistent with modeling and observation studies

First conclusions related to use of GlobCurrent for coastal advection studies in NWA

- •Preliminary results show similar correlation levels to that using coastally-processed data
- •New GlobCurrent results indicate added insight into remote control of key regional dynamics

Overall Conclusions

- On the NWA shelf, GlobCurrent data show excellent agreement with Buoy N in both mean and variation, but inside GoM, its accuracy degrades and is more variable, with better performance in the east (Buoy I) than in the west (Buoys E, B). The U component accuracy is higher than the V component. It is likely because of strength in U, aligned with shelf as well as NS altimeter track orienta-tion. Moreover, there is a higher bias inside GoM, clearly indicating that the local mean dynamic topography for GlobCurrent data is incorrect (Figs.2-3, Table 1)
- In MAB, GlobCurrent U_{geo}matches in situ well (Fig.4, Lentz, 2008); to accord with HF Codar currents, one needs to use GlobCurrent U_{total} = U_{geo}+ U_{ek} (Figs 5-6)
- GlobCurrent data (section V) indicate added insight into remote controlled advection in key regional dynamics

Future steps

- Develop a similar evaluation of the NOAA OSCAR surface current product
- Provide quantitative detail on the strengths and weaknesses of these altimeter current products in the region
- Assess value of gridded vs. alongtrack current data for ocean dynamics studies on the NWA shelf as well as in NRT ROMS data assimilation ongoing at Rutgers Univ.

References

• Feng, H., D. Vandemark, and J. Wilkin (2016), Gulf of Maine salinity variation and its correlation with upstream Scotian Shelf currents at seasonal and interannual time scales, JGR..Oceans, 121.

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