Pelagic *Sargassum* Blooms and Marine Connectivity of the North Tropical Atlantic

Sargassum Pelagico Floraciones y Conectividad Marina del Atlántico Tropical Norte

Sargassum Pélagiques Fleurissent et la Connectivité Marine de l'Atlantique Tropical Nord

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EXTENDED ABSTRACT

Introduction

Satellite identification and interpretation of a new *Sargassum* source region off Brazil (Gower et al. 2013) together with numerical model-based studies of marine connectivity (Wang et al. 2019) have produced a limited picture of pelagic *Sargassum* distribution in the north Tropical Atlantic. Cloud cover and satellite resolution have inhibited detection in much of the North Equatorial Recirculation Region (NERR; Johnson et al. 2013), leading to an interpretation that it is 'blooming' off Brazil in the North Brazil Current Retroflection (NBCR) area and spreading to West Africa via the North Equatorial Counter Current (NECC) and to the Caribbean via the North Brazil Current (NBC) and Guiana Current (GC). Distribution within the southern half of the NERR has not been recognized although historical surface currents suggest that this is an important component of the distribution (Franks et al. 2012 Johnson et al. 2013, Franks et al. 2016a; Franks et al. 2016b). Ocean surface transport patterns and *Sargassum* events along the coasts of West Africa from Sierra Leone to the Gulf of Guinea and Brazil from the Amazon River to Fernando de Noronha, indicate that there is a much larger distribution with substantial *Sargassum* in the southern half of the NERR. Confirmation is seen in high resolution satellite images using Sentinel-2, Sentinel-3 and MODIS-Aqua (www.cls.fr).

Part of the difficulty with the new source region interpretation is that model backtracking from the NBCR area using archived Hycom currents have shown little connection with the equatorial Atlantic (Wang et al. 2019). In this study, the question of marine connectivity between the northern half of the NERR and its southern half is reexamined. Establishing this connectivity is important for a variety of reasons including accurate prediction of coastal events, determination of annual and inter-annual event cycles and impacts on *Sargassum*-connected tropical Atlantic fisheries, as well as global issues of carbon sequestration.

Results

Model tracking-current validations were composed of vector correlations with the drogue-less drifter data set together with skill in forward and backward tracking against a single drogue-less drifter that had traveled the entire area of interest. Vector correlation between model currents and the set of drifter currents that had lost their drogues yielded very encouraging results. Correlations were done between the drogue-less drifter set and Hycom GOFS 3.0, Hycom GOFS 3.1, and Oscar. The mean speed of the drogue-less drifter set was 0.308 ms^{-1}. This was the target to match. Each of the models had wind addition of between 0 and 2% of wind speed.

The best statistical outcomes were with Hycom GOFS 3.1 at 1.07% wind speed: $R = 0.72$, $\theta = 0.15^o$ and $S = 0.308\ ms^{-1}$, where R=correlation amplitude, θ=deflection angle and S=mean speed, and with Oscar at 1.75% wind speed: $R=0.85$, $\theta = 1.1^o$ and $S = 0.308$. Early studies (Pazan and Niiler 2001) of drogue-less drifter wind slippage gave global results at 1% ± 0.5% of wind speed. If pelagic *Sargassum* follows the water without wind slippage, then Hycom GOFS 3.1 surface currents should track it exactly without wind and Oscar should have a 0.75% wind addition. This is reasonable since Hycom calculates a level at the surface and the wind layer including the surface is well defined. Oscar is tuned to mixed layer depth (15 m) and should require a wind addition to bring it to the surface.

This excellent result, however, is mitigated by tracking results against drifter 118523 which had lost its drogue. Figure 1 shows forward and back tracking validation efforts using Hycom GOFS 3.1 with 1.07% wind addition. It also shows forward and back tracking using the drifter gridded current set. The drifter current data set with 0.5% wind addition shows remarkable skill in replicating tracks both forward and backward. Hycom tracks, however, immediately veer off the drifter path in both the forward and backward tests. Tests with Oscar (not shown) were marginally better although with similar results in boundary areas. Additional tests starting at intermediate positions along the drifter track showed poor results on both eastern and western boundaries and in the equatorial channel.

Surface currents (Vo) can be separated into an Ekman component (Ve, wind driven) and a geostrophic component (Vg, sea surface height gradient balanced by Coriolis). Ve and Vg are connected at the base of the mixed-layer and at coastal boundaries. Hycom and Oscar are very well tuned to Ve but appear to have difficulties at boundaries (including the equator) in low latitudes, and hence have inadequate descriptions of Vg. Additional difficulties with simulating mass balance adjustments in the presence of equatorial Rossby and Kelvin waves are likely to impact modeling in the NERR.

Conclusions

Model based tracking (Hycom and Oscar) in the NERR is highly sensitive over the long distances needed for marine connectivity and, at present, does not validate well with observations. Drifter gridded current climatology, however, does provide a reasonable alternative. These latter currents suggest good marine connectivity across the NERR with no need to invoke a greater *Sargassum* 'loop' between the Sargasso Sea and the NERR. This is important for causation and maintenance of masses of *Sargassum* in the north Tropical Atlantic. The Franks et al. 2016b hypothesis, using both drifters and model, indicate the presence of a western consolidation area off Brazil and a broad eastern recirculation area off West Africa with seasonally varying connections between the two and initialization in the eastern area by historical current patterns along the coast of Africa. Although drifter-based currents answer some foundational questions, this data set needs improvements for marine connectivity and prediction of events. Both drifter and *Sargassum* windage is not well addressed in the NERR, and likely varies over a wide range of parameters such as mixed layer depth, wind speed and fetch, and wave height.

KEYWORDS: *Sargassum*, NERR, connectivity, drifters, ocean current models

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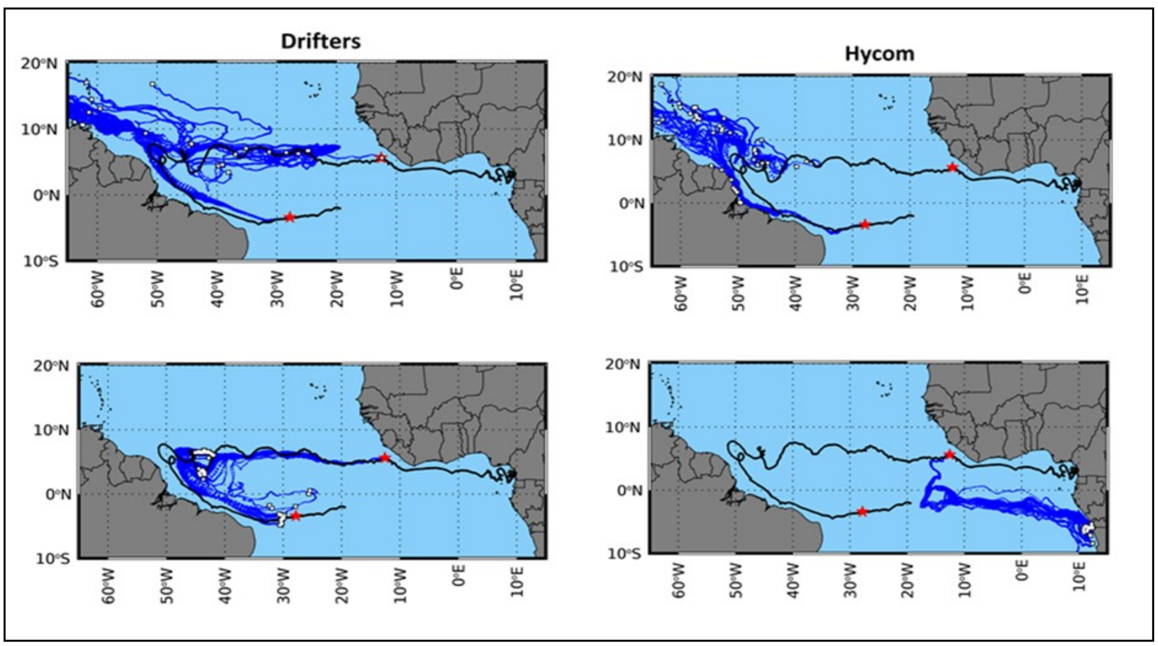

Figure 1. Drifter 118523 tracks (black). Red stars indicate loss of drogue near equator off Brazil and arrival off West Africa. Model simulated forward (upper) and back tracks (lower). 100 parcels released at each red star. White points are end of simulated tracks. Gridded drifter current simulations in left column and Hycom GOFS 3.1 simulations on right.