Preliminary analysis report on the variables associated with the growth and arrival of pelagic sargassum in the eastern Caribbean using the HYCOM model

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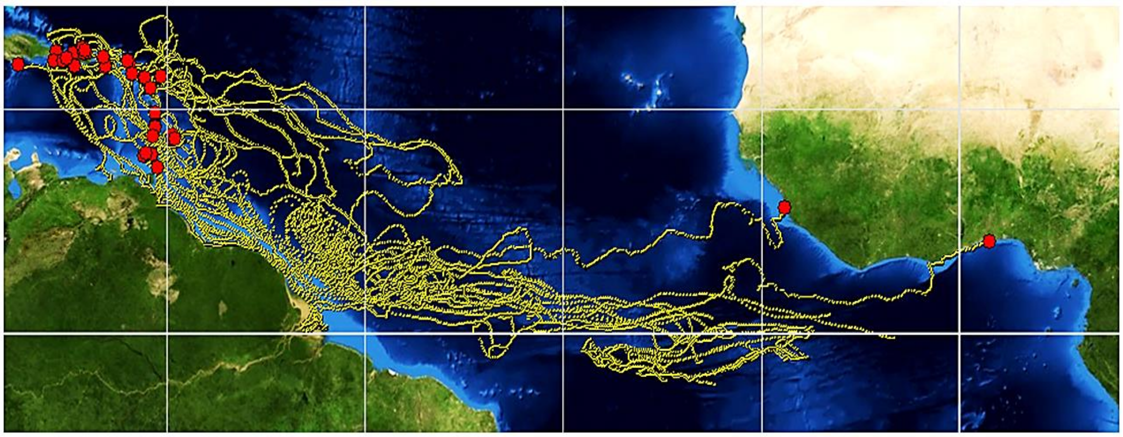

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Cover photograph: Illustration of Pelagic sargassum back traced for one year. Courtesy of the authors

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Abstract

Movements of pelagic sargassum in the Eastern Caribbean inundation events were backtracked for a period of several years to possible source regions in the sub-equatorial region using archived surface currents from the global Hybrid Coordinate Ocean Model (HYCOM). It is expected that prolonged time spent in recirculation within the higher nutrient, warmer North Equatorial Recirculation Region (NERR) of the equatorial Atlantic can significantly increase the biomass of pelagic sargassum. Modeling pelagic sargassum blooms and transport in the NERR will require knowledge of a number of variables (presently unknown) associated with pelagic sargassum growth rates, mortality rates, and genetic factors of the plant, and finding the balance between recycling in the NERR and export from the NERR, e.g., into the Eastern Caribbean. Having greater knowledge of recirculation/consolidation dynamics in the NERR and sargassum transport pathways is critical to understanding timing of sargassum bloom, coastal invasion and modelling efforts.

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Introduction

We formulated a Hypothesis that the pelagic sargassum bloom is occurring in north Atlantic equatorial regions due, in part, to alterations in ocean/atmospheric transport dynamics combined with increased water temperatures and strong nutrient enhancement. This *Hypothesis* necessitates additional study and investigation to further test its criteria.

Within this large scale seasonal circulation, there are areas which can confine and consolidate pelagic sargassum for multiple seasons, i.e., 1) an extensive eastern area which includes the Gulf of Guinea and much of the central North Equatorial Recirculation Region (NERR), and 2) a western area of the tropical Atlantic including the North Brazil Current Retroflection and the western North Equatorial Counter Current. Our tracking of water parcels using ocean models (HYCOM) together with satellite tracked mixed-layer drifter observations tended to confirm the existence of these two areas and the connections between them.

Our contention is that recirculation of pelagic sargassum in the NERR for multiple seasons, coupled with high nutrient input, allowed time for mass growth and consolidation of pelagic sargassum. Linkage of eastern and western retention and consolidation areas of the NERR along with increasing water temperatures and high nutrient availability appear to be at the core of pelagic sargassum proliferation in the tropical Atlantic regions and the recent influx events in the Eastern Caribbean.

A number of studies have shown that the atmospheric tropical belt has widened (Seidel et al. 2008, Lu et al. 2009) due to global warming and related factors. The 2010/2011 anomalous oceanic circulation patterns appear to be directly involved in the intensive pelagic sargassum bloom that occurred at that time, and it seems reasonable that future blooms and inundations may result from the changing atmospheric-oceanic coupling that drives equatorial dynamics.

Testing our hypothesis

Movements of pelagic sargassum in the Eastern Caribbean inundation events were backtracked for a period of several years, including 2014/2015, from reported stranding sites in the Eastern Caribbean, as well as Brazil and West Africa, to possible source regions using archived surface currents from the open source, global Hybrid Coordinate Ocean Model (HYCOM; www.hycom.org). The model has 1/12° longitude/latitude resolution and complete coverage of the tropical Atlantic domain of interest, is updated daily and archived. The HYCOM model uses hybrid vertical coordinates consisting of sigma—coordinates in the upper layer and z—coordinates in the lower layer. Surface boundary conditions (wind stress, heat flux, and salt flux) are supplied by the Navy Operational Global Atmospheric Prediction System (NOGAPS), and climatological river input is included for major rivers. In addition, data assimilation of satellite derived sea surface height and sea surface temperature through the Navy Coupled Ocean Data Assimilation (NCODA) system tends to phase lock the HYCOM model into real events.

Reverse-time trajectory tracking (a.k.a. back-tracing, back-tracking, hind-casting) is a process executed with a field of finite-difference modeled currents by calculating successive positions of a parcel of water over small time increments:

$$\delta x(t+\delta t) = U(x+\delta x/2, t+\delta t/2)\, \delta t$$

where:
x and t are the initial position and time,
U is the current vector located midway in space and time,
dt is the time step,
dx is the distance traced by the parcel during the time step.

The equation for dx was solved explicitly by iteration, and Akima cubic spline (Akima 1970) was used to interpolate gridded model currents to the time and location. The time step was set to 15 min. To accommodate the effects of sub-grid scale motion, 5 parcels were released at each position with a Gaussian (mean of zero, 1SD) addition of 1 km/d to the current vector and center-of-mass averaged for a new position. By example, the first application of the model was continued for 365 days from reported locations of sargassum strandings on Caribbean islands in 2011 (Figure 1A); the same procedure was conducted for landings in 2014 (Figure 1B).

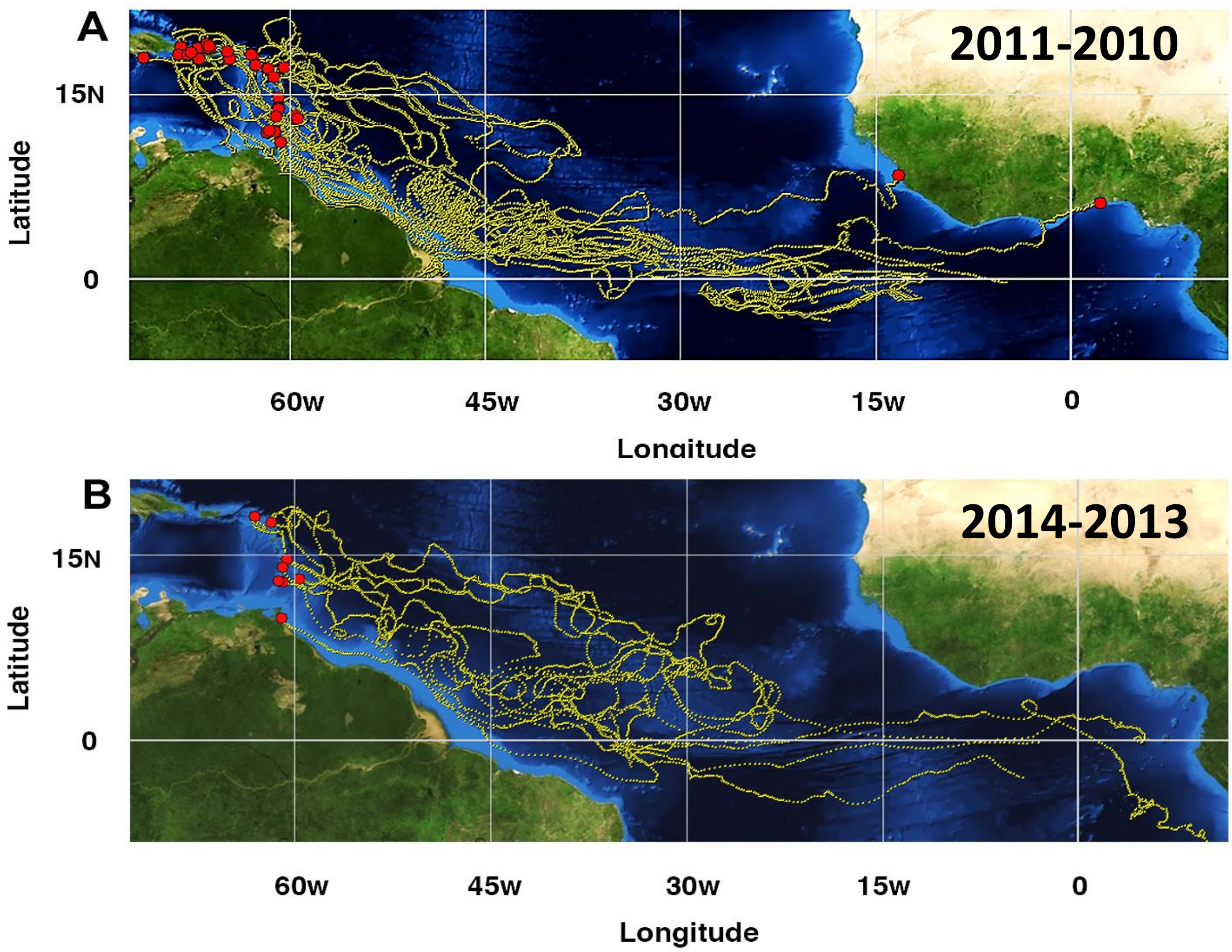

Figure 1. Pelagic sargassum back-traced for one year from reported stranding locations (red dots) on Eastern Caribbean islands and West Africa, showing tracks leading back to the equatorial region with no apparent connection northward to the Sargasso Sea. A - shows back-traces from 2011-2010, and illustrates a consolidation off NE Brazil prior to influx into the Caribbean in 2011. It also illustrates that West Africa strandings show a westward connection with the equatorial region. B - shows back-traces from 2014-2013, and that back-traces from the Eastern Caribben lead to the equatorial region and far eastward to the Gulf of Guinea, West Africa.

Identified data gaps

It is expected that prolonged time spent in recirculation within the higher nutrient, warmer North Equatorial Recirculation Region (NERR) of the equatorial Atlantic (Franks et al. 2015, 2016) can significantly increase the biomass of pelagic sargassum. Modeling pelagic sargassum blooms and transport in the NERR will require knowledge of variables associated with pelagic sargassum growth rates, mortality rates, and genetic factors of the plant, and understanding dynamics between recycling within and export from the NERR into the Eastern Caribbean. For example, we lack any knowledge of how fall-out of mineral/nutrient-rich African dust being swept across the equatorial Atlantic affects pelagic sargassum growth or how low salinity Amazon water affects mortality. Furthermore, a greater understanding of climate changes in tropical ecosystems, including equatorial ocean dynamics, which would enable massive broad-scale pelagic sargassum bloom and regional consolidations to occur is essential. Lastly, having greater knowledge of recirculation/consolidation dynamics in the NERR and sargassum transport pathways is critical to understanding timing of sargassum bloom, coastal inundation and modeling efforts. We suggest that stronger than normal currents and higher sea surface temperatures can be expected as the earth warms, with likely enhanced retention of pelagic sargassum in the NERR producing growth for subsequent blooms.

Next steps

We will work to advance our fundamental understanding of recent blooms and incursions through (1) Continuing our efforts to identify factors critical to understanding bloom events, and (2) An examination of temporal change over time in the sargassum consolidation regions of the NERR with regard to areas of mass accumulations of sargassum and the dynamics of the original bloom. The results of this work is expected to contribute to the on-going development of prediction capabilities (seasonal and annual) applicable to Eastern Caribbean and other tropical Atlantic nations in support of risk assessments and emergency response strategies, the tourism industry, resource management and protection, and scientific studies.

References

Akima, H. 1970. A new method of interpolation and smooth curve fitting based on local procedures. *Journal of the Association for Computing Machinery* 17:589-602.

Bleck, R. 2002. An oceanic general circulation model framed in hybrid isopycnic-Cartesian coordinates. *Ocean Modelling* 37:55-88. doi: 10.1145/321607.321609

Franks, J.S., D.R. Johnson, and D.S. Ko. 2015. Mass strandings of pelagic *Sargassum* along Caribbean and West Africa Coastlines: Understanding and prediction. *Proceedings of the Gulf and Caribbean Fisheries Institute* 68:402-408.

Franks, J.S., D.R. Johnson and D.S. Ko. 2016. Pelagic *Sargassum* in the Tropical North Atlantic. *Gulf and Caribbean Research*. SC6-SC11. doi:10.18785/gcr.2701.08

Lu, J., C. Deser, and T. Reichler. 2009. Cause of the widening of the tropical belt since 1958. *Geophysical Research Letters* 36:L03803, 1-5.

Seidel, D.J., Q. Fu, W.J. Randel, and T.J. Reichler. 2008. Widening of the tropical belt in a changing climate. *Nature Geoscience* **1**:21–24. doi: 10.1038/ngeo.2007.38