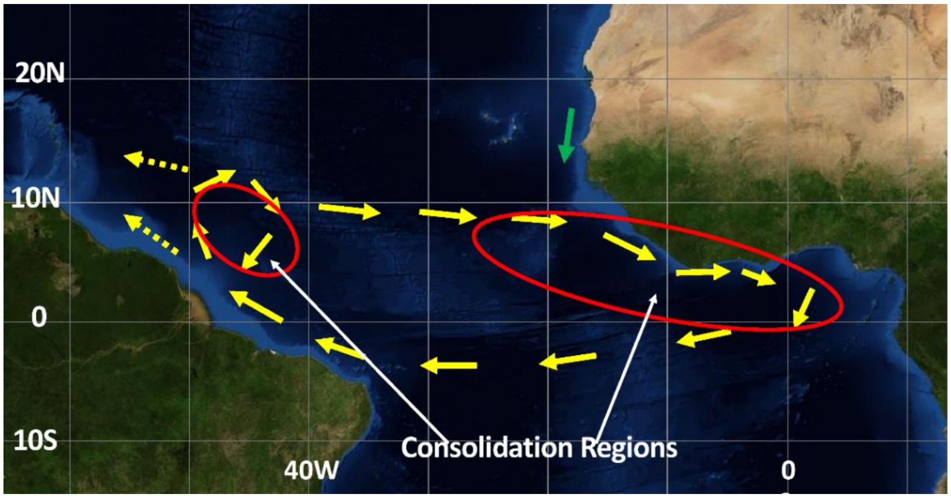
Summary report describing pelagic sargassum seaweed growth, abundance and mass transport within the North Equatorial Recirculation Region (NERR) and Eastern Caribbean for 2014 and 2015

J. S. Franks and D. J. Johnson



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Center for Fisheries Research and Development (CFRD)
The University of Southern Mississippi
School of Ocean Science and Engineering
Gulf Coast Research Laboratory (GCRL)
Ocean Springs, Mississippi, USA

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Cover photograph: Illustration of the NEER developed by the Authors.

Abstract

Since 2011, unprecedented quantities of pelagic sargassum have inundated coastal waters and shorelines of Eastern Caribbean countries, the first such known mass intrusions into the region. The quantity of the sargassum in the invasion events and the frequency of event occurrence created immense problems for fisheries and the tourism industry and presented unknown consequences for marine ecosystems. Results of modelled back-traces of landings events, including years 2014 and 2015, using landing dates and locations in ocean circulation models, supported by findings of experiments conducted to simulate pelagic sargassum transport pathways derived from archived satellite tracked mixed-layer drifting buoy data, indicated that the sargassum arrived from the North Atlantic sub-equatorial region rather than directly from the Sargasso Sea. Several North Atlantic climate indices with decadal-scale oscillations reached historical maxima/minima prior to-during the initial incursion (2010-2011). A *Hypothesis* was developed suggesting that climate related circulation changes in the equatorial Atlantic created conditions for increased pelagic sargassum retention, while warm, nutrient-rich environments aided sargassum bloom conditions. Identified needs to enable a greater understanding of the dynamics of inundation events include growth and mortality rates of pelagic sargassum.

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Contents

Introduction

Since 2011, unprecedented quantities of pelagic sargassum have inundated coastal waters and shorelines of Eastern Caribbean countries, the first such known mass intrusions of the 'weed' into the region. The quantity of the sargassum in the inundation events and the frequency of event occurrence have created immense problems for fisheries, the tourism industry and livelihoods (World Economic Forum 2015, Ramlogan et al. 2017, Caribbean News Service 2018) and presented unknown consequences for marine ecosystems (CRFM 2014, Oxenford and Franks 2015, but see van Tussenbroek et al. 2017). The sargassum has been identified as two species (*Sargassum natans* and *S. fluitans*) (Fig. 1). Both species are commonly found in the Gulf of Mexico and North Atlantic (Sargasso Sea), but typically in low quantities in north equatorial regions and the Caribbean. Simultaneous with the Caribbean sargassum influx, mass strandings of pelagic sargassum were also reported over a broad area of the tropical North Atlantic from Brazil to the Caribbean Sea (Gower et al. 2013, Smetacek and Zingone 2013).

Figure 1. *Sargassum natans* (left) and *S. fluitans* (right).
Photo: J. Franks

Since at the time of the event there were no documented reports of pelagic sargassum being transported in large quantities on currents from the North Atlantic Gyre into the tropical Atlantic, and lacking evidence to the contrary from either *in situ* observations or satellite imagery, indications were strong that the pelagic sargassum bloomed in an area we identified (and termed) as the North Equatorial Recirculation Region (NERR; Franks et al. 2011) (Fig. 2), inclusive of its Eastern and Western Atlantic consolidation regions (i.e., isolated circulation patterns). The NERR lies between the South Equatorial Current and the North Equatorial Counter Current, and is bounded on the west by the North Brazil Current and the North Brazil Current Retroflection and on the east by the Guinea Current (Gulf of Guinea). The NERR is substantially larger than any area where coastal eutrophication could be expected to produce pelagic sargassum blooms.

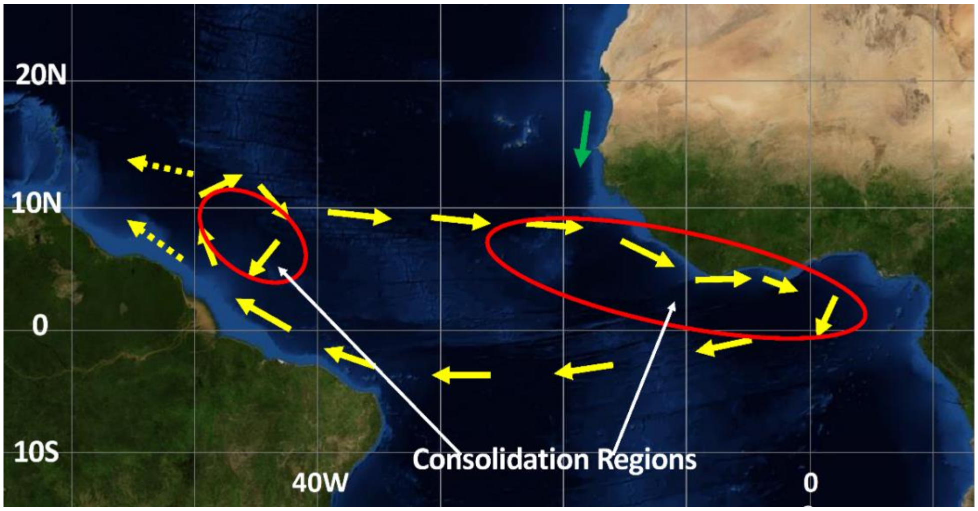

Figure 2. The North Equatorial Recirculation Region (NERR) showing eastern and western consolidation regions.

In an effort to understand the timing of the bloom and its coastal incursions, as well as the source and transport pathways associated with the event, we used modeled back traces (i.e., hind casts from reported pelagic sargassum stranding locations and dates submitted to the University of Southern Mississippi - Gulf Coast Research Laboratory Caribbean Pelagic Sargassum Reporting Website (http://www.usm.edu/gcrl/sargassum/sargassum.observation.form.php). This suggested the likelihood of a sub-equatorial origin for the bloom (Franks et al. 2011, Johnson et al. 2012), with no connection to the Sargasso Sea. Furthermore, results of modelled back traces of landings events in subsequent years, including 2014 and 2015, supported by findings of experiments we conducted to simulate pelagic sargassum transport pathways derived from archived satellite tracked mixed-layer drifting buoy data provided at www.aoml.noaa.gov/phod/dac/index.php), provided strong support for our *Hypothesis* that climate related variations in equatorial Atlantic circulation in association with nutrient enrichment resulted in conditions supportive of vigorous pelagic sargassum growth, mass blooming, consolidation, and transport into the Caribbean, as outlined in Franks et al. (2016).

Working hypothesis

Our basic *Hypothesis* for circulation in the NERR as it pertains to the variation in recent pelagic sargassum events in the Eastern Caribbean is as follows: spring events are sourced from sargassum arrivals along the coast of NE Brazil in late winter. The southern Lesser Antilles are especially vulnerable to these early arrivals. As spring and summer progress, the Amazon River outflow increases, forcing coastal flows offshore where they are partly trapped in the North Brazil Current Retroflection (NBCR). From the NBCR, pelagic sargassum escapes by eddy motions or by 'breaking down' of the NBCR loop which then ultimately impacts the Lesser Antilles. But the NBCR also deflects much of the sargassum back into the NERR through the North Equatorial Counter Current (NECC) with arrivals off West Africa in late summer and fall. The deflected sargassum which is left in mid-Atlantic when the NECC breaks down in winter, is then pushed westward for possible late arrivals in the upper Lesser Antilles in winter and early spring. This *Hypothesis* considers two consolidation/growth regions in the NERR, one off the coast of NE Brazil and one off West Africa (see Introduction, Figure 2). We strongly emphasize that understanding connections between the two pelagic sargassum consolidation/growth regions and sargassum 'leakage' into the Eastern Caribbean is of major importance in future development of long-range prediction capability and requires further study.

This complex system is principally driven by the large scale winds, not only by wind amplitude but also in latitudinal distribution. It is modified on the scale of the Lesser Antilles by Amazon outflow and by sea surface heating (location and intensity of the Intertropical Convergence Zone (ITCZ)). Preliminary studies of ocean dynamics of the two consolidation regions have shown that the eastern region is trending toward increasing consolidation potential while the western region is not. The important parameters to be studied are the wind strength and distribution, and Amazon outflow dynamics, but these are global issues tied to changes in sea surface temperature, wind distribution on a large-scale, and equatorial rainfall. How these changes fit into the pelagic sargassum events is primary to any prediction scheme.

As an example of building capacity to understand recent historic levels of pelagic sargassum incursions at Eastern Caribbean islands, we used monthly composites of sargassum coverage seen in processed satellite images of the Western Atlantic (University of South Florida Optical Oceanography Laboratory (http://optics.marine.usf.edu/cgi-in/optics_data?roi=C_ATLANTIC&current=1), by enumerating sargassum pixes, to construct a time-series for a one degree square region directly to the east of Barbados (Fig. 3). The time series runs from January 2010 (year before the sargassum events began) to December 2015. Using these data, it suggests that the first sargassum influx events surrounding Barbados occurred with a minor peak in March 2011, followed by a major peak in August/September of 2011. This pattern continued through 2012 and 2013 with diminishing peaks in the summer major event of each year. In 2014/2015, the pattern changed, with a major event occurring in June 2014, but lasting until November 2014, followed by a major inundation event in March 2015 that continued throughout the summer. In contrast to diminishing summer peaks as in 2012-2013, the summer peaks increased between 2014 and 2015. Application of this tool will serve as a local metric for comparisons of temporal occurrence and intensity of pelagic sargassum with local (island specific) fisheries landings data.

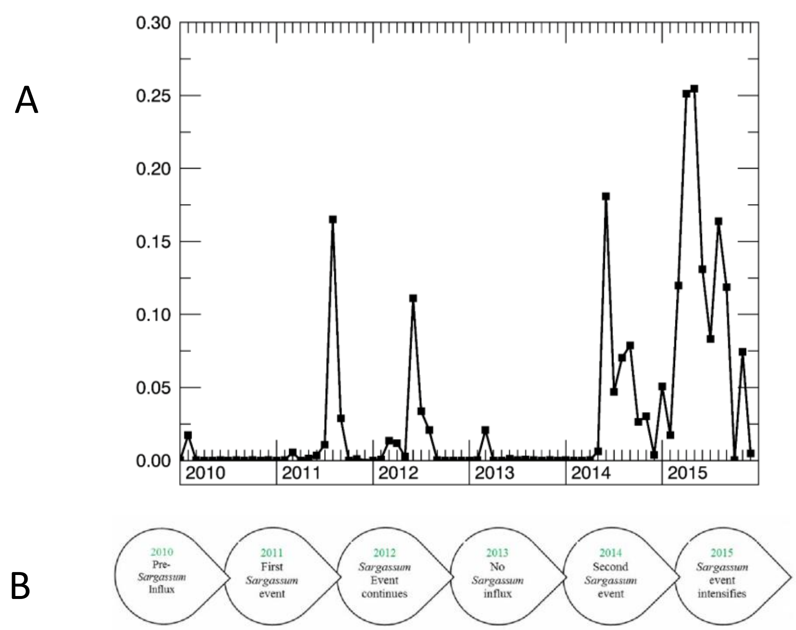

Figure 3. A -Time-series plot of pelagic sargassum incursion events at Barbados, years 2010 -2015. Y axis value = index of relative ocean surface coverage by sargassum; x axis value = years shown by month (season). B – Sargassum events as reported by fishers in Barbados (from Ramlogan et al. 2017).

This analysis appears to have good potential given the very close match between the recorded extent of sargassum obtained from satellite images and the sargassum events reported by fishers in Barbados (Ramlogan et al. 2017) (Fig. 3)

Identified needs

Growth and mortality of pelagic sargassum are of major importance in understanding the inundation events and, in fact, the overall dynamics of the events. Our experimental use of growth rates reported in previous studies in our transport models showed little relationship to reality. Growth and mortality are presumed not constant for all regions of the Atlantic and must vary, depending on oceanographic, biological and chemical (nutrient input) factors. Studies on variables associated with growth and mortality are seriously needed. At present, we are relying on satellite imagery and conjecture to estimate abundance.

Additionally, among unknowns critical to studies of pelagic sargassum bloom genesis and influx into the Eastern Caribbean are:

1. Is a critical mass of pelagic s*argassum* required to initiate an immense bloom?
2. What sources/patterns of nutrient input fuel the blooms?
3. What is the distribution and biomass of pelagic *Sargassum* within the NERR at any given time?
4. What is the long-term prognosis for bloom events?

Research addressing gaps in knowledge will support building a fundamental understanding of bloom and inundation events and facilitate development of prediction capabilities important for resource management and protection, livelihoods, food security in tropical Atlantic countries.

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