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# Influence of climatic factors on *Sargassum* arrivals to the coasts of the Dominican Republic

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**Since 2011, the coasts of North America, Mexico, and the Caribbean have experienced an unusual increase in the arrival of *Sargassum*. A large amount of *Sargassum* has caused significant economic losses in the tourism sector of the Dominican Republic as well as the entire Caribbean region. The present article discusses the possible factors contributing toward this unusual increase. Large *Sargassum* masses are generated in the Sargasso Sea. In this region, several current systems converge with the North Atlantic Subtropical Anticyclone (NASH), which has an area of displacement extending from Brazil to Africa. *Sargassum* is transported toward Africa, where it meets the Northern Equatorial Recirculation Region (NERR) before recirculating back toward the Caribbean in a clockwise pattern (Putman et al., 2018; Wang, 2007). Upon returning to the Caribbean and Gulf of Mexico, Sargasso grows flowers and distributes across the region. The effect of the North Atlantic Oscillation (NAO) is also analyzed as well as the possible influence of Sahara dust, which acts as a source of nutrients for the growth and development of *Sargassum*. In the Dominican Republic, the species found in the current study included *Sargassum fluitans* and *Sargassum natans*. As for the species *Sargassum polyceratium var. ovatum*, the variety *ovatum* has not been reported before on the coasts of the Dominican Republic.**

**Key words:** *Sargassum* arrival, Caribbean, Dominican Republic, Azore High.

## INTRODUCTION

The arrival of Sargassum is a natural phenomenon caused by the detachment of aggregations of algae from the Sargasso Sea (Figure 1). Since 2011, there has been an unusual increase in the occurrence of this phenomenon. The coasts and beaches of the Caribbean region have been engulfed with large amounts of Sargassum, causing significant economic losses, especially in the tourism sector, in addition to affecting marine fauna. The arrival of Sargassum since 2009 has negatively impacted the biodiversity, tourism and

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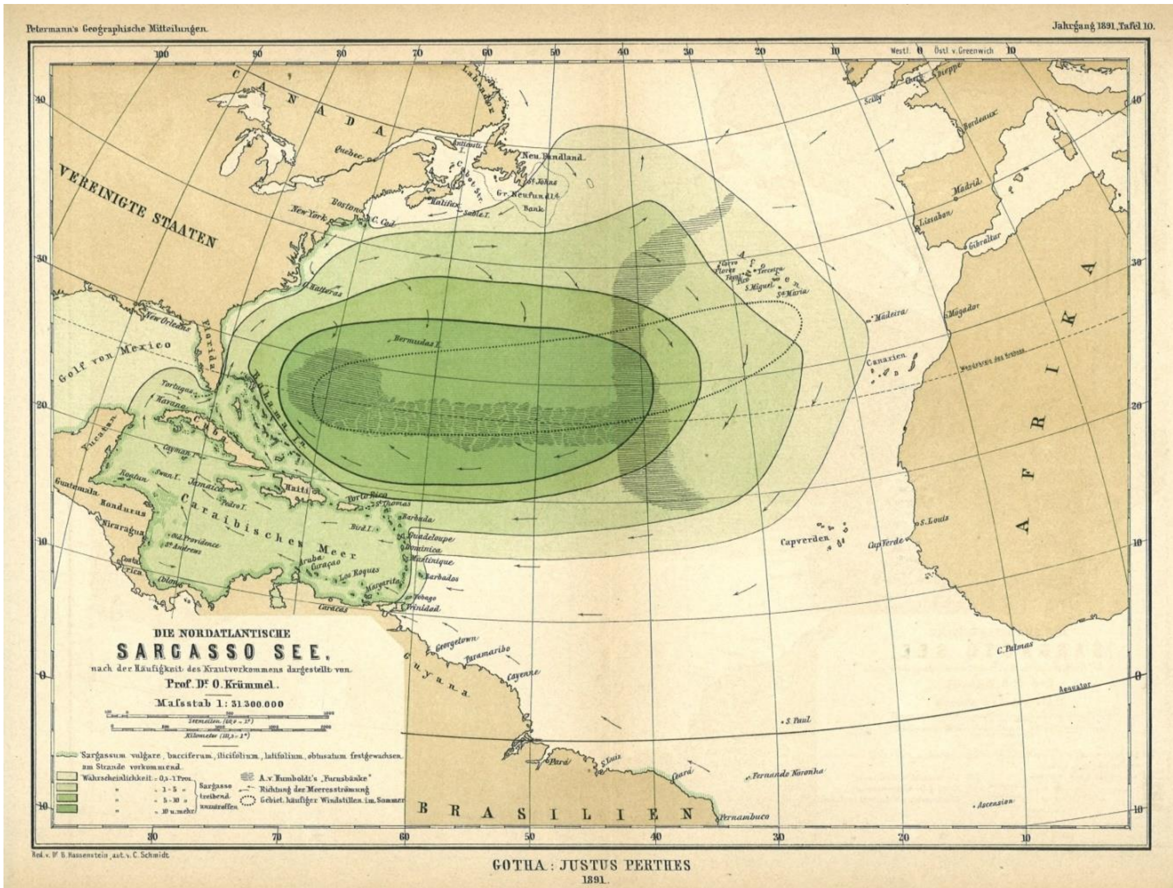


**Figure 1.** Map of the Sargasso Sea and Northern Atlantic Ocean Sample. The Sargasso Sea is the only sea unbounded by land and entirely located in the Atlantic Ocean.
Source: https://noaateacheratsea.blog/tag/north-atlantic/

livelihoods of coastal communities in Ghana, West Africa (Addico and de Graft-Johnson, 2016)

Since the conquest of the Americas, *Sargassum* has been reported in the Atlantic. Farlow (1914) first described this phenomenon, which was assumed to be natural. However, in the latter decade (2010-2019), the amounts of *Sargassum* arriving at coastlines throughout the Caribbean are alarming, causing enormous economic and ecological impacts. On the other hand, *Sargassum* does play an essential role in the productivity and stability of beaches and coasts (Critchley et al., 1983). Plants that grow in the dunes obtain nutrients from *Sargassum*, and seabirds depend on the marine life transported by *Sargassum* for food. However, excess amounts can cause problems, including during the decomposition process, which emits an unpleasant smell and attracts insects.

In 2011 on the eastern coast of Dominican Republic (DR), massive amounts of pelagic *Sargassum* began to appear according to the accounts of tour operators, fishermen, journalists, and vendors. Since then, similar annual events of increasing magnitude have occurred, mostly from May to September. In particular, a significant event in 2015 extensively affected aquatic resources, fishing, coastal water quality, beaches, and tourism. In 2016, *Sargassum* similarly appeared but was exceeded by the events of 2015 and 2017.

Hurricanes Irma and María in September 2017, produced large waves that affected the beaches of the eastern region of the Dominican Republic, eliminating the algae stored on the beaches. In May of 2018, *Sargassum* once again began to reach the coast, especially in the summer months of June to August until autumn, when the levels of accumulated *Sargassum* began to decline due to the action of storm waves in the Caribbean (Wang et al., 2019). Currently, in the summer of 2019, significant arrivals are also expected in the DR according to satellite images (https://optics.marine.usf.edu/projects/SaWS.html).

It is not known with certainty whether this phenomenon will continue to occur every year. However, the scientific community has made efforts to predict outbreaks or develop early warning systems to help answer this question and take measures to mitigate impacts. Overall,

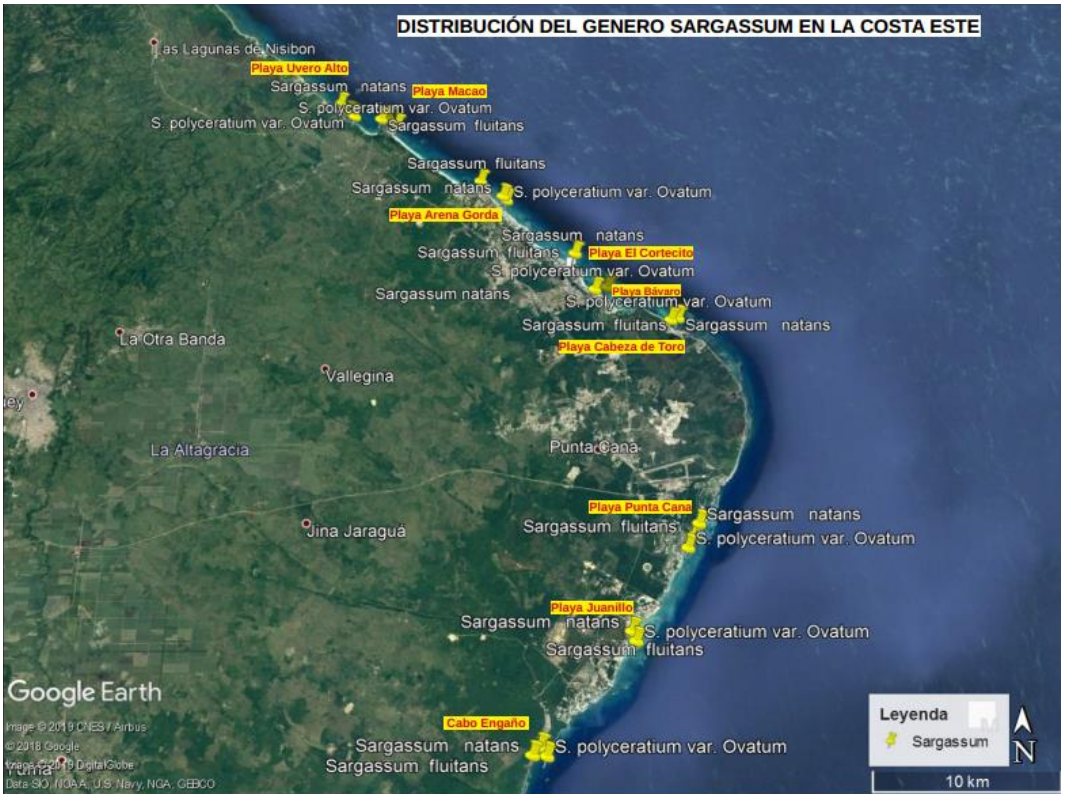


**Figure 2.** Map of the study region and distribution of *Sargassum* in the Dominican Republic from Uvero Alto Beach to Cabo Engaño.

the scientific community has predicted that *Sargassum* arrivals will continue to periodically occur in the Caribbean region. Also, it has been concluded that *Sargassum* does not affect all areas of the Caribbean with the same intensity. Some scientists associate this behavior with higher than usual temperatures and low winds, which influence ocean currents and may be related to climate change. Chien et al. (2016), Jickells et al. (2005) and Tagliablue et al. (2017) related the increase in *Sargassum* with the oil spills by British Petroleum in the Gulf of Mexico in 2010. Other researchers have mentioned the role of nutrients generated by the deposition of more significant amounts of dust from the Sahara on the ocean surface (Fingas, 2008; Peterson et al., 2012; Torralba et al., 2017).

This article tries to explain the climatic oceanographic factors that contribute to the arrival of *Sargassum* on the Caribbean coast, in particular, the coasts of the DR; in addition, the arrival of a new species of *Sargassum* is reported to the coasts of the DR.

## METHODOLOGY

Three excursions were made to nine beaches in Higüey, RD. Two kilograms of samples were collected at different points on each beach and then mixed in plastic Ziploc bags. The samples were immediately placed in a refrigerator and subsequently stored in the freezer until processing. Then, the samples were cleaned and separated under running water, removing all observed impurities in the laboratory. The classification was made using a BA310 digital microscope model, Motic brand to look for morphological characteristics in the samples to identify each species, following the guidelines of Littler et al. 1989; Littler and Littler 2000), Taylor (1960), and Núñez and Soler (2002).

### Study site

*Sargassum* species were found on all of the beaches along the northeastern and eastern coast of the province of Higüey, where the tourism center of Punta Cana, Dominican Republic, is also located (Figure 2). Geographically, this province borders the Atlantic Ocean in the north, the Mona Canal (Atlantic Ocean) in the east, and the Caribbean Sea in the south. To the west, the provinces of La Romana and El Seibo are located. The nine beaches from Uvero Alto to Cabo Engaño were sampled.

## RESULTS AND DISCUSSION

### Classification and description of *Sargassum* spp. on the coast of the Dominican Republic

On the southern and eastern coasts of Hispaniola, two dominant species of *Sargassum* were found: *Sargassum*

**Figure 3.** Morphological characteristics of *Sargassum fluitans* (Boergesen).

*natans* and *Sargassum fluitans*. These two species are pelagic, float freely in the sea, and never adhere to the bottom. Also, a small amount of *Sargassum polyceratium* var. *ovatum* (Collins) was found (Rosado, 2019).

The genus *Sargassum* belongs to the Phaeophyta group of algae. The term "Phaeophyta" is derived from the Greek word "phaios," which means "brown." The species forming this genus are almost exclusively marine. In tropical waters, the species *S. fluitans* and *S. natans* are dominant. These were both named by Portuguese sailors in the fifteenth century, who thought that the air bladders of these algae resembled a kind of grape. Drift lines of *S. fluitans* and *S. natans* can often be seen on the surface of the ocean, and both species are frequently found in the drift lines along beaches. The brown color of these algae is determined by the brown pigment fucoxanthin. Yet, these algae may range in color from pale beige to almost black. In tropical seas, *Sargassum* spp. vary in size from microscopic filaments to several meters in length (Littler et al., 1989; Littler and Littler 2000; Moreira and Cabrera, 2007; Suarez and Martínez-Daranas, 2018).

### *S. fluitans* (Boergesen 1914a: 66)

*S. fluitans,* known as the gulf weed, seems more robust than *S. natans* (Figure 3). This species strictly floats in open ocean waters and is often found in large groups or rafts at the surface. Round floats or air bladders along a smooth thallus. Individual algae up to 1 m in length. "Fronds" or "leaves" golden brown, numerous, and thin. Cylindrical branches widely extended. Thin, flat blades with a short thallus and prominent central ribs with well-marked, finely serrated margins. Cryptostomas absent, scattered, small, dark dots visible in the light.

*S. fluitans* (Figure 3), is distributed throughout Florida, the Bahamas, the Greater and the Lesser Antilles, the South Caribbean, the Western Caribbean, and the Gulf of Mexico (Littler et al., 1989; Moreira and Cabrera, 2007; Suarez and Martínez-Daranas, 2018).

The characteristics of the species *S. fluitans* (Taylor, 1960) are identified as follows:

(1) Floats or air bladders develop at the base of leaves
(2) Cross-section of leaves show a thickened central rib

### *S. natans* (Linnaeus) Gaillon

*S. natans,* brown pelagic alga found floating alone or in small groups up to 50 cm in diameter (Figure 4). Color pale to dark brown with thin, wavy, smooth axes, lacking a dominant axis. Leaves elongated, narrow, 1-4 mm wide, and 2-10 cm long, with narrow toothed margins. Numerous bladders/spherical air floats, 3-6 mm in diameter, smooth, with alternate ramifications from the main thallus or twigs at the base of the leaf ending in small spines. Projection of the leaf-shaped thallus ending in a spine thallus 3-5 (-10) mm long. Gripping point and absent cryptostomas. Non-fixed thalli.

*S. natans* (Figure 4), is distributed throughout the region of the Bahamas, Greater Antilles, Lesser Antilles, South Caribbean, Western Caribbean, and Gulf of Mexico.

The characteristics of the species *S. natans* (Taylor, 1975) are identified as follows:

(1) Terminal part of frond has mature leaves and thick teeth.
(2) Ends of fronds have air bladders/floats ending in small spines.
(3) Immature leaves

### *S. polyceratium var. ovatum* (Collins, 1928: 12; Taylor, 1928)

*S. polyceratium var. ovatum* is not common in the Caribbean (Figure 5). The present study represents the first report of this species for the Dominican Republic. Numerous thalli, erect, hard, leathery, and densely

**Figure 4.** Morphological characteristics of *Sargassum natans* (Linnaeus) (Gaillon, 1928: 355; Taylor, 1928).

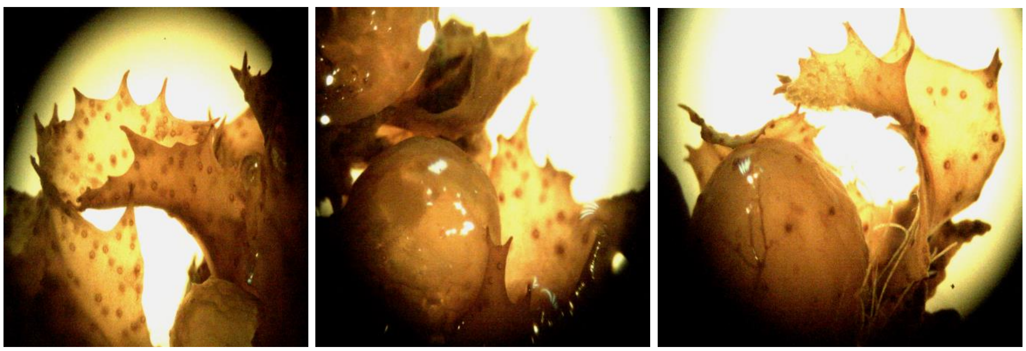

**Figure 5.** Morphological characteristics of *Sargassum polyceratium* var. *ovatum* (Collins) (Taylor, 1928: 129).

branched. Length 1 m, with several main axes. Color brown, rough when young and covered by small spines. Numerous closed sheets 3-8 mm wide and 1.5-2.0 cm long. Asymmetric base, absent stipe, rounded apices. Dense and often deeply jagged margins. Different ribs. Numerous spherical air floats 3-5 mm in diameter close to the base of leaves. Short thallus 2-mm long at maximum with firmly fixed leaves in the shape of a disc. Cryptostomas appear as small, dark spots, scattered and abundant on leaves and as hairs on-air floats. Irregular fertile branches, rounded and short, generally less than a 1/3 of the length of adjacent leaves. Branches full of extremely harsh concepts.

The characteristics of the species *S. polyceratium var. ovatum* are identified as:

(1) Thallus has many cryptostomes with spherical leaves and floats.
(2) Fertile branches with many concepts.
(3) Mature concepts with two oogonia

## Climatic factors influencing *Sargassum* arrival in the Dominican Republic

The Caribbean climate is greatly influenced by the so-called Caribbean Climate Regulatory Centers (CRCCs) (Méndez-Tejeda et al., 2016), including the Azores Anticyclone or North Atlantic subtropical high (NASH), Atlantic Multidecadal Oscillation (AMO), Atlantic Warm Pool (AWP), Caribbean Low-Level Jet (CLLJ), El Niño Phenomenon, and trade winds. Of these, the most important phenomena influencing *Sargassum* movement to the Caribbean are the trade winds, and NASH, there is a significant contribution from the Brazilian Current as well as the NERR. Oyesiku and Egunyomi (2104) observes the displacement of the algae *S. natans* and *S. fluitans* seaweed from the Brazilian coast to new areas along the West African coast. This effect shows the influence of NERR on the transport of *Sargassum* to the Caribbean region.

## Trade winds

The arrival of Christopher Columbus to the Americas would not have been possible without the help of the trade winds. The term in Spanish "vientos alisios" comes from the Latin language: ventus, in English the correct terms is trade winds. These winds are characterized by air currents moving from the southeast to the northwest in the southern hemisphere and from the northeast to the

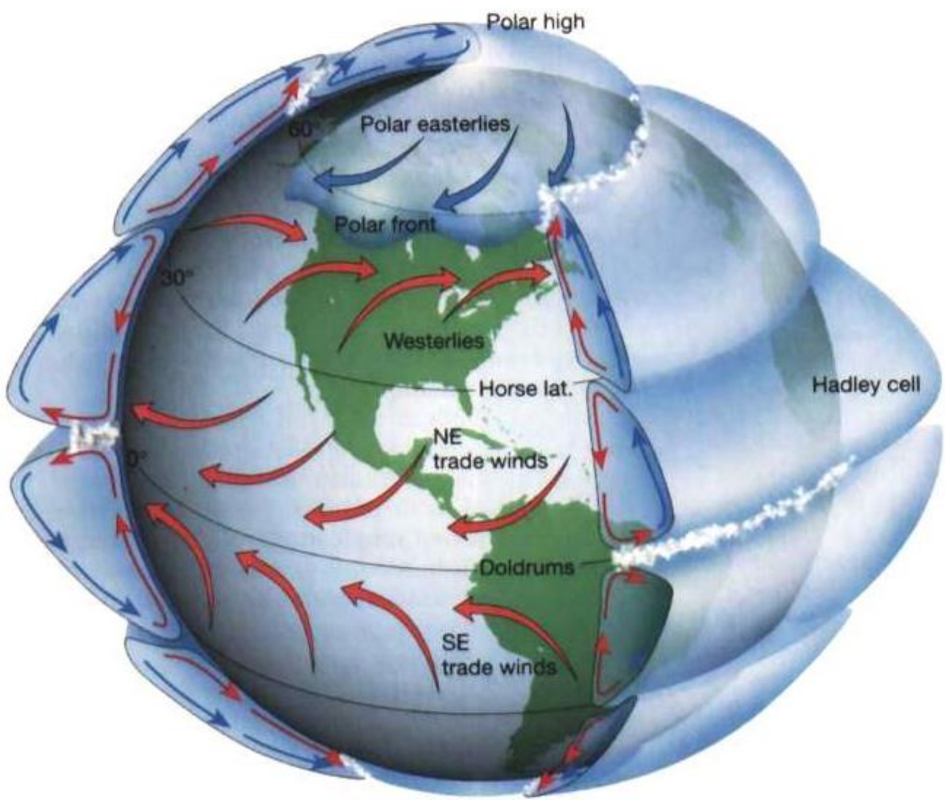


**Figure 6.** Behaviour of the trade winds in the tropical region.
Source: University of Michigan-Ann Arbor.

southwest in the northern hemisphere. These winds tend to be stronger during the summer but are generally constant in the tropics (Kerry, 2005).

Trade winds also play an important role in the transport of dust from the Sahara Desert to the Caribbean. Particulate matter travels over the tropical Atlantic Ocean in the so-called Saharan Air Layer, a very dry and hot air mass that extends from 1500 m to about 6000 m (6 km) in the atmosphere (Prospero et al., 2013; Evan et al., 2016). This dust takes approximately seven days to cross the Atlantic, from its departure in the desert to its arrival in the Caribbean, traveling around 5,000 km. This dust absorbs moisture and contributes to episodes of drought in the Caribbean, as it reduces cloud formation. Also, it can serve as a source of nutrients in the Atlantic Ocean and may contribute to an increase in the abundance of *Sargassum* (Clifford et al., 2017).

## Azores Anticyclone or North Atlantic Subtropical High (NASH)

NASH is a permanent center of high atmospheric pressure in which winds circulate clockwise in the northern hemisphere and counterclockwise in the southern hemisphere. The best known is the Azores Anticyclone. This anticyclone is dynamic and usually located in the center of the North Atlantic at the height of the Portuguese Islands of Azores (Sánchez-Rubio et al., 2018).

This anticyclone, also known as the Bermuda Anticyclone or Azores High, contributes to the flow of winds in the Caribbean region, affecting the direction of the trade winds and, therefore, the movement of *Sargassum* to this region as well as the Atlantic coasts of Mexico and the United States. In Figure 7, it can be seen that storms born on Cape Verde Island move toward the Caribbean. So, depending on the intensity of the anticyclone, it can influence the direction and arrival of winds, which in turn affect marine currents and *Sargassum* movement.

The pressure system of NASH (Figure 8) controls the direction of winds, causing them to travel tangent to the isobars (lines outlining fields of similar atmospheric pressure). In particular, this pressure system interacts with the wind regime of the trade winds that travel across the Atlantic to the Caribbean Sea and similarly influences the displacement of surface currents (Wang, 2007).

Meanwhile, the arrows in Figure 9 show the typical patterns of the surface currents in the Atlantic region above Brazil (Lumpkin and Garzoli, 2005). It can be seen that the wind direction is tangent to the isobars. At the

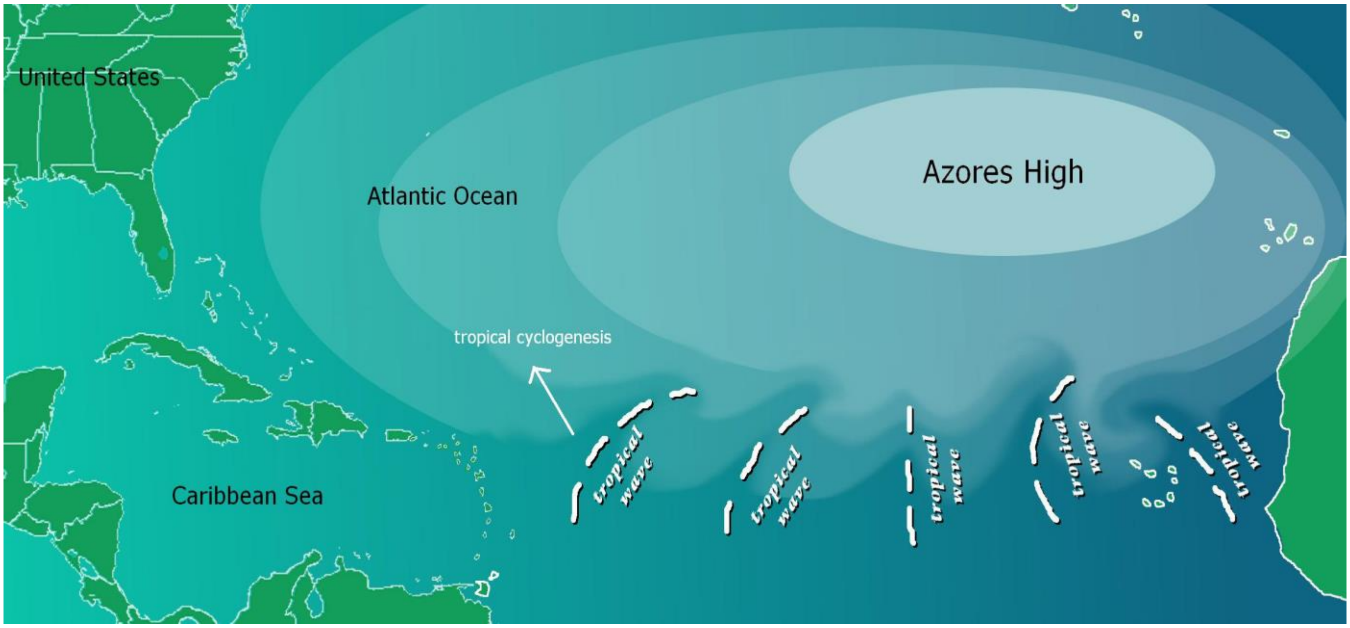


**Figure 7.** Azores Anticyclone in a fortified state shown covering a vast expanse of the North Atlantic.
Source: NOAA; Retrieved July 20, 2019.

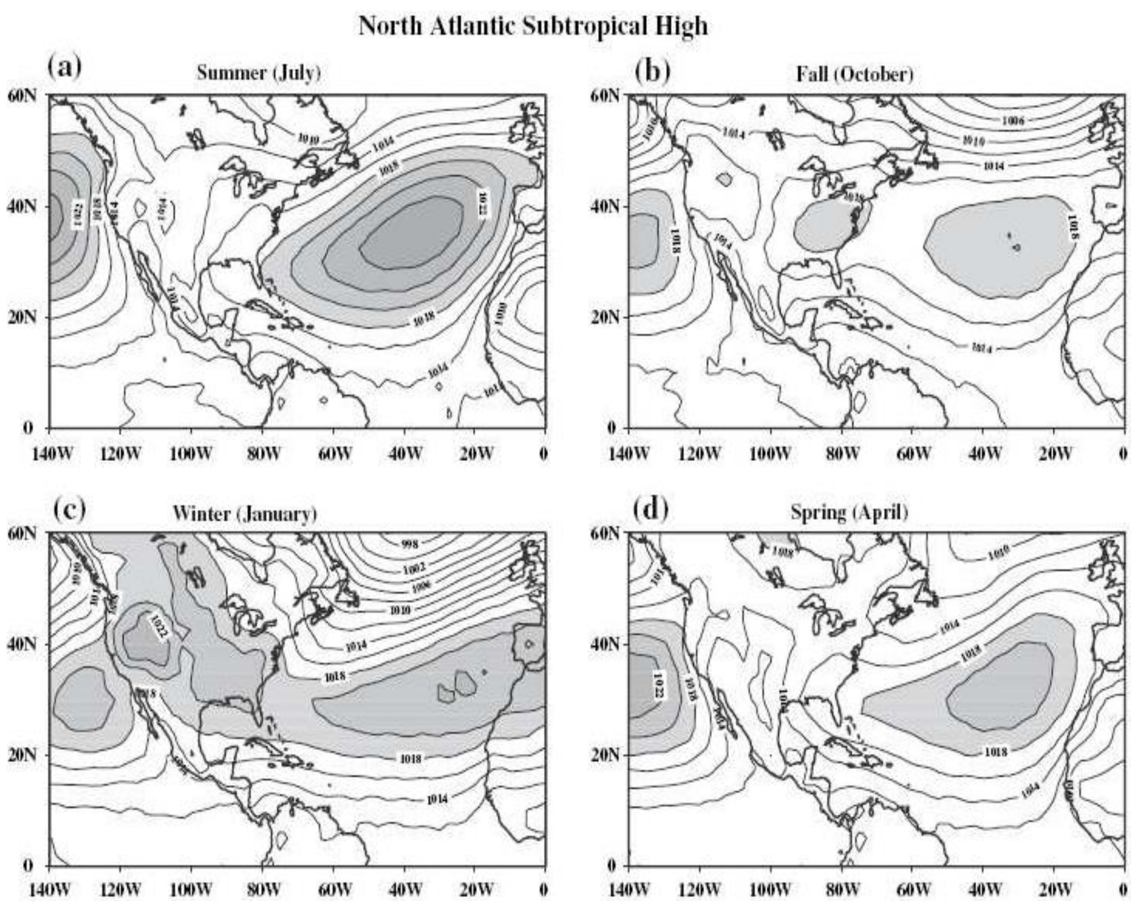


**Figure 8.** Behaviour of the Azores Anticyclone during the year.
Source: Wang (2007).

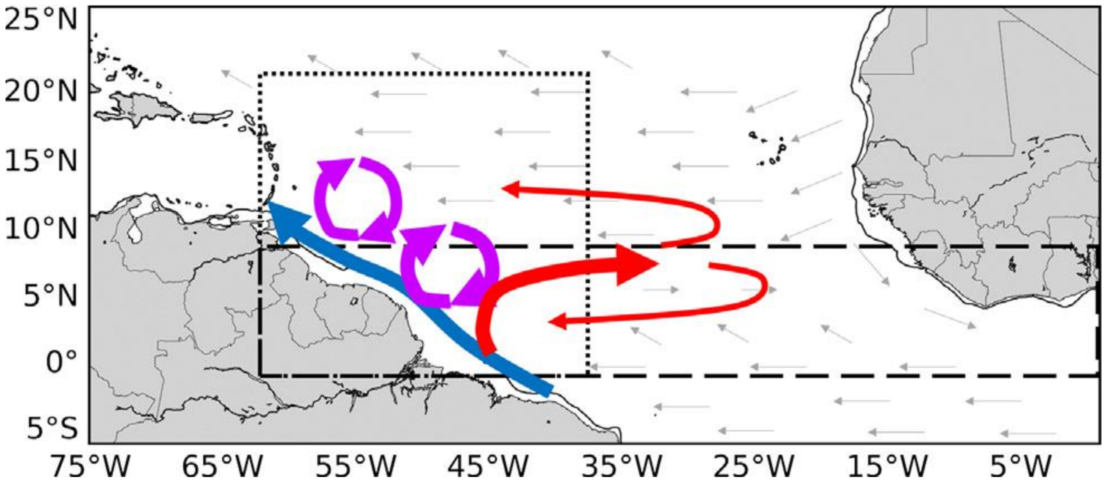


**Figure 9.** General surface circulation scheme relevant for the movement of pelagic *Sargassum* from the equatorial Atlantic to the Caribbean Sea. Grey arrows show typical surface current directions across the region, colored arrows represent the ocean circulation patterns of the North Brazil Current System.
Source: Putman et al. (2018), Lumpkin and Garzoli (2005), https://optics.marine.usf.edu/projects/SaWS.html.

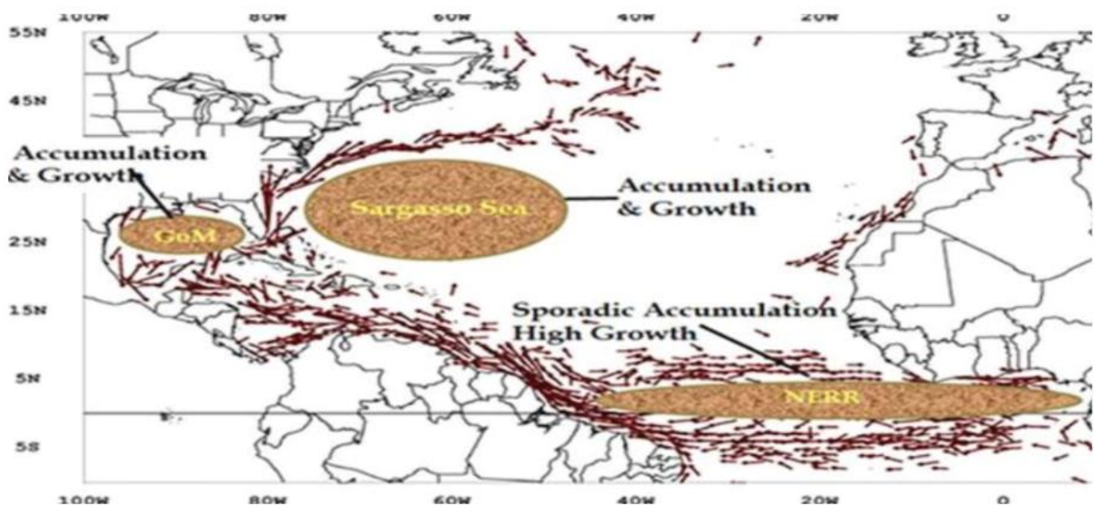


**Figure 10.** Growth and accumulation of *Sargassum* in the Atlantic region.
Source: Johnson et al. (2013).

beginning of spring, the dominant wind direction strengthens the currents heading toward the south of Cuba, Jamaica, and the Dominican Republic. For this reason, the first arrivals of *Sargassum* occur in the south of Hispaniola (near Haiti). Then, in the summer, *Sargassum* spreads throughout the southeastern and eastern Dominican Republic (Putman et al., 2013; Putman et al., 2018).

The Azores Anticyclone, which moves in a counterclockwise direction, distributes *Sargassum* to the Canary Islands and Northern Africa. *Sargassum* is then integrated to the NERR current. This warm water current moves from east to west until arriving in the Caribbean region. Part of the *Sargassum* carried by this current integrates with the Brazilian current and then mixes with the waters of the South American Amazon and Orinoco Rivers (Figures 10 and 11).

## Impact of *Sargassum* arrival on the Dominican Republic

The arrival of *Sargassum* is associated with the increasing temperatures of the ocean caused by climate change (Wang et al., 2016) and higher amounts of nutrients in water due to, for example, increasing

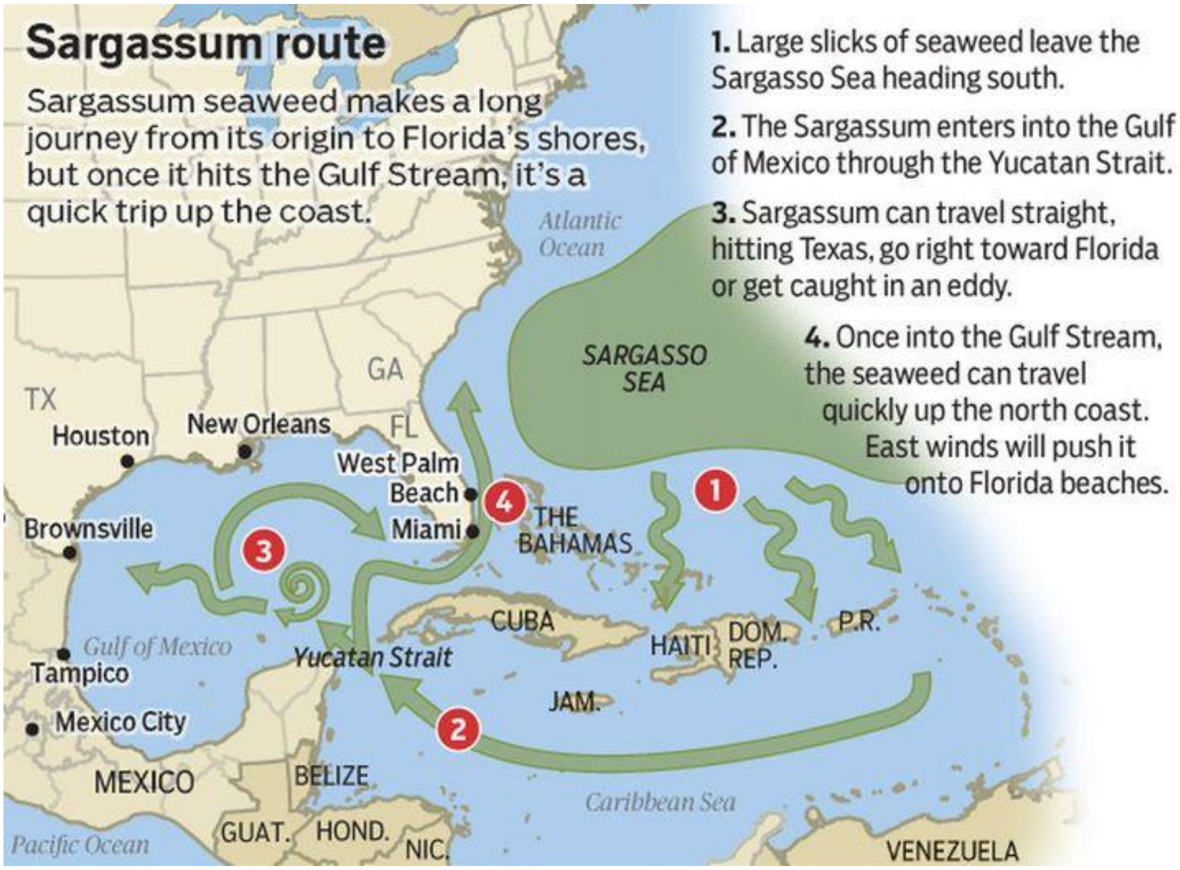


**Figure 11.** Step-by-step behavior of *Sargassum* in the Atlantic Ocean and its arrival to the Caribbean or, "*Sargassum"* Route in the Atlantic Ocean.
Source: Texas A&M University, Galveston. Robert Calzada/Staff.

quantities of Saharan dust. In this regard, authors such as Tagliabue et al. (2017), Chien et al. (2016) and Serebryakova et al. (2018) have reported that what is currently happening in the Caribbean is related to an event occurring several thousand kilometers away (in the Sahara). The iron and phosphate contents of dust from the Sahara promote the growth of algae in the Atlantic Ocean and the Caribbean Sea along with the behaviour of the positive-phase NAO. Furthermore, the nutrient discharges of the great South American Rivers (Amazon and Orinoco) along with the North Equatorial Current and the Brazilian Current favour the growth of the algae (Figure 9) (Condie, 1991; Putman et al., 2018).

The negative impacts of *Sargassum* are compounded when *Sargassum* accumulates and decomposes in large quantities along the coastline, leading to the smell of rotten eggs as a result of the hydrogen sulfide gas emitted during natural decomposition and also request a bad aesthetic show for the tourist. The Occupational Safety and Health Administration of the United States established that prolonged exposure to "more offensive" smells (3-5 parts per million) can cause effects such as nausea, tearing of eyes, headaches, and loss of sleep. Asthma sufferers may also experience respiratory problems and skin conditions (https://www.osha.gov/SLTC/hydrogensulfide/hazards.html). Also, it has been reported in some areas that *Sargassum* causes the corrosion of metal infrastructure and boats, which is likely associated with the effects of hydrogen sulfide. These effects dissipate as exposure decreases.

## Conclusions

Large masses of *Sargassum* originate in the Sargasso Sea. Due to the NASH (Figure 8), *Sargassum* is first displaced toward Brazil and Africa, where the North Equatorial Recirculation Region (NERR) is located and currents from the Caribbean, Gulf of Mexico, and Africa converge. In this region, *Sargassum* grows, flowers, and distributes across the Caribbean region with the help of the trade winds and the Brazilian Current (Figures 9, 10, and 11).

Satellite images, such as Landsat 8 and MODIS/TERRA images, can be used to predict the arrival


**Figure 12.** *Sargassum* accumulation on Cabeza del Toro beach (left), Punta Cana (right), Dominican Republic, in 2015.

**Figure 13.** Accumulation of *Sargassum* on Bavaro Beach (left), Cortesito (right), Dominican Republic, in 2016. Note that the effect of erosion on the coast can also be observed.

of *Sargassum* and distinguish it from the chlorophyll contributed to the Atlantic by South American rivers (Wang et al., 2016).

According to the Florida Oceanographic Observatory, the month of February 2019 showed a total Sargasso coverage of 356 km$^2$ compared to the historical average of 33 km$^2$ between 2011 and 2017 in the area defined by 8-23°N and 89-58°W. Previously, in January 2018, an unusually high amount of Sargasso was captured on satellite images in both the Caribbean and the Central-Western Atlantic. As has been established since the beginning of this article, the Sargasso has been increasing since 2011 and 2012, with a significant decrease in 2013. From 2014 to 2019, the increase has continued with notable peaks in 2018 and 2019, which can be classified as historical (Wang et al., 2017, 2019).

It is not desirable to clean beaches, as many are already facing a critical amount of erosion, recreation areas, as blowing of sand by wind can similarly increase or worsen erosion.

The disposal of Sargasso should be to and from the designated areas. Disposal teams must use the same route to and from the beach to avoid damaging dunes and destroying vegetation or turtle and bird nests.

It is essential to establish clear policies on where, when, and how to clean beaches to avoid harmful impacts, such as the intensification of erosion due to the use of machinery for beach cleaning.

## ACKNOWLEDGEMENTS

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## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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