

NASA DEVELOP National Program

Summer 2016 Project Proposal

NASA Ames Research Center Caribbean Oceans II

Utilizing NASA Earth Observations to Detect, Assess, and Monitor Floating *Sargassum* Mats in the Caribbean Sea

Project Overview

Objective: To analyze environmental change and model oceanic variables affecting floating *Sargassum* mats and *Sargassum* inundation events in the Caribbean Sea

Community Concern: *Sargassum* is a complex of several species of brown holopelagic seaweeds. Although floating *Sargassum* mats provide critical ecosystem services, large influxes pose serious threats to coastal communities and tourist industries. The first notable influx of *Sargassum* in the Caribbean at this unprecedented scale occurred in 2011 and again in 2015. *Sargassum* concentrations in the Caribbean increased significantly, affecting the ecology and economy in most Caribbean islands and continental coasts. As it washes ashore, these seaweeds decompose, leaving a fetid smell that negatively impacts coastal tourism, forcing many industries to remove this macro alga by way of heavy machinery or tools. Irresponsible removal methods can further impact coastal biodiversity and beaches through erosion, as well as compression of sea turtle nesting grounds. Finally, thick *Sargassum* mats can occlude light on the surface of the water, leading to reduced photosynthesis in benthic communities, including coral reefs and seagrass beds. As *Sargassum* concentrations continue to proliferate along the Caribbean coast, there becomes an increased need for detection, assessment, and monitoring of this macro alga in the Caribbean Sea.

National Application Area Addressed: Oceans

Study Location: Caribbean Sea with particular emphasis on coastal Quintana Roo (Mexico), Bermuda, Barbados, Puerto Rico, and Guadeloupe.

Study Period: January 2003 – December 2015

Advisor: Juan Torres-Pérez (Bay Area Environmental Research Institute)

Source of Project Idea: Dr. Porfirio Álvarez, project partner of the DEVELOP Summer 2015 Mexico Water Resources project at the NASA Ames Research Center, requested that this project be conducted. This project idea was virtually presented at the Latin America and Caribbean Sea Large Marine Ecosystems Symposium in September of 2015 in Cancún, Mexico, and was very well received.

Partner Overview

Partner Organizations:

Organization	POC (Name, Position/Title)	Partner Type	Boundary Org?
Consorcio de Instituciones de Investigación Marina del Golfo de México y del Caribe (CiiMar-GoMC)	Dr. Porfirio Álvarez Torres, Executive Secretary	End-User	Yes
Centro Interdisciplinario de Ciencias Marinas: Instituto	Dr. Francisco Arreguín-Sánchez, Researcher, Dr. Norma Patricia	End-User	Yes

Politécnico Nacional (CICIMAR-IPN)	Muñoz, Secretary of Postgraduate Research, Dr. Mariana Elvira Callejas Jiménez, Research Scientist		
University of Puerto Rico, Department of Marine Sciences	Dr. Roy A. Armstrong, Bio-optical Oceanography Laboratory	Collaborator	Yes
Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO)	Dr. Sergio Cerdeira, Marine Monitoring Coordinator	Collaborator	No

End-User Overview

End-User's Current Decision Making Process:

Currently, end-users in Mexico (CiiMar-GoMC and CICIMAR-IPN) have not made any management or policy decisions based on the proliferation of *Sargassum* in the Mexican Caribbean. However, tourist industries within affected coastal areas are utilizing live webcams to monitor shores for *Sargassum* occurrences. The Mexican government and others have released regulation standards about how to remove *Sargassum* on beaches, which usually requires heavy machinery. This method can kill marine species or significantly stir the sand, thereby disrupting coastal environments. Other methods include removal of *Sargassum* by hand, which is time-consuming and costly. Caribbean governments rely mostly on reports from local fishermen and other coastal community members, and are not currently using remote sensing to address this issue.

End-User's NASA Earth Observations Capacity:

CiiMar-GoMC – Dr. Álvarez has benefited from the results derived in the Mexico Water Resources project from the summer of 2015, and the Caribbean Oceans I project from the spring of 2016. Therefore, he already has exposure to the incredible capability of NASA Earth observations, and is familiar with the types of variables that can be detected using satellite imagery. However, the lack of advanced computational facilities in the institutions with whom he collaborates is a major problem and he would “very much appreciate NASA's involvement.” This project will investigate the environmental and oceanic variables that make the most significant contributions to *Sargassum* inundation events. The findings will allow Dr. Álvarez and other Caribbean end-users to focus their limited resources on tracking these variables via NASA Earth observations.

CICIMAR-IPN – The scientists affiliated with CICIMAR-IPN are experts in marine biology, but have not had much experience with, or exposure to, NASA Earth observations. Due to the expansive spatial extent of this project, these end-users can greatly benefit from understanding the capacity of remote sensing in their marine monitoring positions. The Caribbean-wide results can later be refocused to their specific study regions.

Collaborator & Boundary Organization Overview

Collaborator Support:

CONABIO- Dr. Sergio Cerdeira is eager to address the '*Sargassum* issue' in Mexico and the wider Caribbean. His insight in marine biology helped guide the first term of the project, and his expertise connects the ARC DEVELOP team to the broader *Sargassum* community. His research has included the use of remote sensing, but he is interested in continuing to understand the applications of NASA Earth observations for *Sargassum* monitoring and detection, as well as its applications in other marine sciences.

CiiMar-GoMC - Dr. Porfirio Álvarez will support this project by disseminating results at upcoming marine and oceanographic symposiums, which are hosted by CiiMar-GoMC several times a year. Additionally, Dr. Álvarez has been very helpful in facilitating conversations with other researchers in this region who are observing *Sargassum* measurements on Caribbean shores. The DEVELOP Ames Research Center team may be able to use these data to compare to satellite measurements.

University of Puerto Rico – Dr. Roy Armstrong conducts regular field trips to permanent water quality stations along the Puerto Rico’s southwestern coast. GPS positions will be added and collected during those field trips to pinpoint the location of *Sargassum* mats in near shore areas. Additionally, Dr. Armstrong has agreed to collect *in situ* data (spectral samples obtained with a GER-1500 hand-held field spectroradiometer) during some of these trips to provide validation of satellite imagery and a better identification method of the floating *Sargassum* mats.

Boundary Organization Dissemination:

The results from this project will be disseminated at upcoming ocean-related symposiums as a direct handoff to the end-users, who simultaneously act as Boundary Organizations (CiiMar-GoMC and CICIMAR-IPN). These organizations have been sponsoring climate- and ocean-related meetings, such as the Latin American and Caribbean Larger Marine Ecosystems Symposium, for the past several years. The ARC DEVELOP team has virtually presented their findings from previous DEVELOP projects to these symposiums in the past, and this has proven to be a successful way to communicate end results, as well as request additional *in situ* data.

CiiMar-GoMC – this organization will disseminate project results to officials in the Mexican government and to other Caribbean nations to inform them of *Sargassum* detection and prediction mechanisms. This will help promote regionally coherent policy regulations on *Sargassum*, including mitigation efforts and beach cleanup strategies.

CICIMAR-IPN - this organization will disseminate project results to officials in the Mexican government and to other Caribbean nations to inform them of *Sargassum* detection and prediction mechanisms. This will help promote regionally coherent policy regulations on *Sargassum*, including mitigation efforts and beach cleanup strategies.

University of Puerto Rico - Dr. Armstrong in Puerto Rico will disseminate results to professors and colleagues within the Caribbean islands and nations, as well as the local government entities in Puerto Rico.

Project Communication & Transition Overview

In-Term Communication Plan:

CiiMar-GoMC and CICIMAR-IPN will communicate with the team about three times throughout the summer term via Skype. Chippie Kislik, the current Center Lead of ARC DEVELOP, will serve as the main POC for this communication, as she has been facilitating conversations with Dr. Álvarez and other partners for the past several months.

Transition Approach:

Results from the modeled *Sargassum* movement will be provided to the end-users through a cloud environment (such as Google Drive), and all reports, tutorials, and documents will be shared via email. As stated previously, the ARC DEVELOP team will also give a presentation during a meeting or symposium that is hosted by CiiMar-GoMC and CICIMAR-IPN. Software

release will not be necessary, as the team will be providing only model outputs (as opposed to Python scripts).

Letter of Support: CiiMar-GoMC: Dr. Porfirio Álvarez, Executive Secretary

Earth Observations Overview

Earth Observations:

Platform & Sensor	Parameter(s)	Use
Landsat 8 OLI	Near-Infrared / Red Band Ratio (Near-IR/R)	Floating Algal Index (FAI), Normalized Difference Vegetation Index (NDVI)
Aqua/Terra MODIS & ASTER	Chlorophyll A (Chl-a), Remote Sensing Reflectance (Rrs), Sea Surface Temperature (SST), Photosynthetically Available Radiation (PAR), Colored Dissolved Organic Matter (CDOM)	Identify <i>Sargassum</i> and measure variance of oceanic variables
Suomi NPP VIIRS	Sea surface temperature (SST), Ocean color, Chlorophyll A (Chl-a)	Identify <i>Sargassum</i> and measure oceanic variables

Ancillary Datasets:

NOAA National Buoy Center- wind speed, air temperature, sea temperature, wind gust- Inputs to Model

Caribbean Coastal Ocean Observing System (CariCOOS)- Wind, wave, current modeled data - Inputs to Model

GNOME Online Oceanographic Data Server (GOODS)- real-time ocean forecast system, measured currents, winds, base maps - Inputs to Model

Sea Education Association Cruise Tow Datasets – *Sargassum* sightings – validation of satellite imagery

Models:

GNOME (POC: Michael Bender, DEVELOP)

Multiple Endmember Spectral Mixture Analysis (MESMA) (POC: Tom Bell, University of California Santa Barbara)

TerrSet's Earth Trends Modeler (POC: James Toledano, Clark Labs/ Clark University)

Decision Support Tool & End-Product Overview

End Products:

End Products	Partner Use	Datasets & Analyses	Software Release Category
<i>Sargassum</i> Long Term Forecast	This model will help end-users estimate the source and likelihood of recurring	This model will be based on NASA EO and NOAA oceanic variable dataset	1

	<i>Sargassum</i> inundation events in the Caribbean Sea. This will assist in mitigating the long term effects of <i>Sargassum</i> influxes.	that will be analyzed over a 13 year study period to contextualize <i>Sargassum</i> inundation in the Caribbean Sea.	
<i>Sargassum</i> growth and proliferation model	This report and manual of how to run the model will assist decision-makers and the tourist industry in understanding the ideal environmental conditions for <i>Sargassum</i> inundation events. This will help Caribbean governments ascertain when and where <i>Sargassum</i> may appear on shore in a timely enough fashion to take preventative action.	This report will be based on the environmental context and use Terrest Earth Trends Modeler to assess the most significant environmental contributions to <i>Sargassum</i> inundation events.	1

End-User Benefit:

These end products will assist the end-user in understanding the environmental context and source of recent *Sargassum* proliferations in the Gulf of Mexico and Caribbean. These results can be used in collaboration with a French company (CLS)'s MOBIDRIFT model to better gauge prediction mechanisms in the short and long term. This will help the Caribbean governments understand how to proceed in sustainable clean-up tactics, and assist the tourist industry in maintaining the most time-efficient and cost-effective mitigation techniques.

Project Timeline & Previous Related Work

Project Timeline: 2 Terms: 2016 Spring (Start) to 2016 Summer (Completion)

Multi-Term Objectives:

- **Term 1:** 2016 Spring (ARC) – Caribbean Oceans I
 - This term focused on assessing which index and which imagery could be used to most accurately detect *Sargassum*, and also investigated the origin of the most recent *Sargassum* proliferation events along the Caribbean shorelines. Additionally, this term considered the environmental variables that may have contributed to the mass growth of *Sargassum* in the study region. The Floating Algal Index was used to detect *Sargassum*, and environmental variables (SST and PAR) were statistically analyzed in TerrSet. Findings and progress were communicated to project partners several times throughout the term, culminating in a final presentation via Skype.
- **Term 2 (Proposed Term):** Summer 2016 (ARC) – Caribbean Oceans II
 - The summer 2016 term will focus on expanding upon the explanatory power of the oceanic variables studied in the first term, and further investigating the significance of a changing Caribbean Sea environment for influx reoccurrence. This will aid in the prediction of *Sargassum* arrival on Caribbean shores. These predictions will be compared to live webcams from local hotels that point toward the shores and show whether or not *Sargassum* is present at the time of prediction. The model and long term forecast report will be handed off during this term via a Skype presentation, and through email communication.

Related DEVELOP Work:

Summer 2015 (ARC) – Mexico Water Resources

Fall 2013 and Spring 2014 (Stennis Space Center) – Texas Oceans: Enhancing Remote Sensing Capabilities of the *Sargassum* Early Advisory Systems (SEAS) Through the Use of NASA EOS and Open Source GIS

Summer 2013 (LaRC) – South Pacific Oceans: Predicting the Movement of Pumice Rafts for Enhanced Navigational Warnings

Project Needs/Requests

Participants Requested: 3

Software & Scripting:

TerrSet's Earth Trends Modeler – Seasonal Trend Analysis of *Sargassum* in the Caribbean Sea

ENVI – Classification of *Sargassum* presence (also ArcGIS)

Environmental Data Connector (EDC) – Data access software

MatLab – Statistical analysis of Floating Algal Index as predicted by oceanic variables

Notes & References:

Notes: End-users have requested this project in an effort to understand the implications of the *Sargassum* issue on coastal environments in the Caribbean; it poses a true challenge to the beach habitat and tourist industries of affected areas. Additionally, the idea for this project was pitched at the Latin America and Caribbean Sea Large Marine Ecosystems Symposium, which occurred in September of 2015 in Cancún, Mexico. This virtual presentation occurred during a Special Working Group Session to analyze the presence of *Sargassum* in coastal areas of the wider Caribbean region, and was received with high enthusiasm by fellow scientists and lead environmentalists who were present at the symposium.

References:

- NOAA Historical Natural Data Buoy Center summaries: Continuous winds, Ocean Current Data, Oceanographic Data: http://www.ndbc.noaa.gov/historical_data.shtml#adcp
- NOAA buoy locations: wind speed, air temperature, sea temperature, air-sea temperature, sea level pressure, wind gust: <http://www.ndbc.noaa.gov/obs.shtml?lat=25&lon=-50&zoom=3&type=h&status=r&pgm=&op=&ls=false>
- NOAA CoastWatch: Oceanic variables (sea surface temperature, primary productivity, chlorophyll-a, salinity, photosynthetically available radiation): <http://coastwatch.pfeg.noaa.gov/erddap/index.html>