NASA DEVELOP National Program
Spring 2016 Project Proposal

NASA Ames Research Center
Caribbean Oceans
Utilizing NASA Earth Observations to Detect, Assess, and Monitor *Sargassum* in the Caribbean Sea

Project Overview

Objective: This project (Spring 2016) has two objectives: (1) To assess the historical trends of *Sargassum* blooms and compare these blooms to trends in sea surface temperature, chlorophyll-a concentrations, photosynthetically available radiation, and current El Niño trends, and (2) to detect where the majority of the current concentrations are coming from and understand the movement of this macro algae to the Caribbean coast from wind and ocean current data.

The objective of the summer term (Summer 2016) is to model the movement of Sargassum toward the Caribbean, and predict its arrival on these shores using a basic transport model and species distribution model in TerrSet.

Community Concern: *Sargassum* is a floating brown macro alga that naturally occurs in shallow, tropical waters. Although this is a natural phenomenon, excess amounts of *Sargassum* pose threats to coastal communities and tourist industries. This year (2015), *Sargassum* concentrations in the Caribbean are higher than local observers have witnessed before (Alvarez, personal communication, 20 Aug. 2015). As it washes ashore, *Sargassum* begins to 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. Such activities also represent an impact to coastal biodiversity and beaches by significantly stirring the sand and turtle nesting grounds. Finally, thick *Sargassum* mats can occlude light on the surface of the water, which can lead to reduced photosynthesis in benthic communities, including coral reefs and seagrass beds. As *Sargassum* concentrations continue to proliferate along the Caribbean coast, there becomes a need for detection, assessment, and monitoring of this macro alga in the Caribbean Sea.

National Application Area Addressed: Oceans

Study Location: Caribbean Sea and Sargasso Sea, with particular emphasis on coastal Quintana Roo (Mexico), Bermuda, the British Virgin Islands, Barbados, Puerto Rico, Jamaica, and Tobago.

Study Period: March 2000 – January 2016

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

Source of Project Idea: Dr. Porfirio Alvarez, 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 Cancun, Mexico, and was very well received.

Partner Overview

Partner Organizations:

Consorcio de Instituciones de Investigación Marina del Golfo de México y del Caribe (CiiMarGoMC) (End-User, POC: Dr. Porfirio Alvarez Torres, Executive Secretary)
Centro Interdisciplinario de Ciencias Marinas: Instituto Politécnico Nacional (CICIMAR-IPN) (End-User, POC: Dr. Francisco Arreguin, Researcher, Dr. Norma Patricia Muñoz, Secretary of Postgraduate Research, Dr. Mariana Elvira Callejas Jiménez, Research Scientist)
Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) (Collaborator, POC: Dr. Sergio Cerdeira, Marine Monitoring Coordinator)
El Colegio de la Frontera Sur (ECOSUR) (Collaborator, POC: Dr. Laura Carillo, Oceanographer)
Universidad Autónoma de Baja California (UABC) (Collaborator, POC: Dr. Eduardo Santamaria del Angel, Professor and Researcher)
University of Puerto Rico, Department of Marine Sciences (Collaborator, POC: Dr. Roy A. Armstrong, Bio-optical Oceanography Laboratory)

End-User Current Decision Making Process:

Currently, the tourist industries within affected coastal areas are utilizing live webcams to monitor shores for *Sargassum* occurrences. The Mexican government has 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 sightings reports from local fishermen and other coastal communities' members and are not currently using remote sensing to mitigate this issue, and would benefit greatly from understanding the historical, current, and future implications of *Sargassum* concentrations on their shores. Additionally, understanding the historical and current context of *Sargassum* in this region will provide precautionary evidence for future monitoring of *Sargassum* occurrences when wind and ocean current data are incorporated into the analysis. The results from this project will be disseminated at upcoming ocean-related symposiums as a direct handoff to the end-user; these symposiums are organized by the Consortium of Marine Research Institutions of the Gulf of Mexico and the Caribbean and the National Polytechnic Institute (IPN).

NASA Earth Observations Capacity:

Consorcio de Instituciones de Investigación Marina del Golfo de México y del Caribe (CiiMar-GoMC): Dr. Alvarez has benefited from the results derived in the Mexico Water Resources project that was conducted at Ames Research Center in the summer of 2015. Therefore, he 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" (Alvarez, personal communication, 23 Sept. 2015).

Centro Interdisciplinario de Ciencias Marinas: Instituto Politécnico Nacional (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.

Collaborator & Boundary Organization Support:

CiiMar-GoMC: Dr. Porfirio Alvarez will support this project by disseminating results at upcoming marine and oceanographic symposiums, which ware hosted by CiiMar-GoMC several times a year. Additionally, Dr. Alvarez has been very helpful in facilitating conversations with other researchers in this region who are observing Sargassum measurements on

Caribbean shores. The Ames Research Center DEVELOP 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 nearshore areas.

Communication Plan & Transition Approach:
Communication lines have been established during the Summer 2015 term, and are very strong. Communication will continue biweekly via Skype and email during the Spring 2016 term. These meetings will allow team members to assess the needs of CiiMar-GoMC, CICIMAR-PIN, as well as other end-users, and incorporate end-user requests into the project. The hand-off will occur via email and a Cloud storage device such as Google Drive or Dropbox. Tutorials, results, and documentation booklets will be sent to the end-users upon completion of the project. End-users will then utilize these results in their own decision-making processes related to *Sargassum* mitigation along the Mexican coast, and communicate these findings to their Caribbean counterparts at conferences, workshops, and symposiums.

End-User Benefit:
The benefits of this project to the end-user include assisted management of coastal areas, and supplying a historical and current understanding of *Sargassum* presence in the Caribbean Sea to better inform future mitigation techniques. Incorporating remote sensing will help inform governmental policies for their regulation standards of *Sargassum* removal, which will, in turn, save time and money for cleanup efforts. Additionally, creating a *Sargassum* transport model will provide an early advisory system for when it can be expected to arrive on Caribbean shores. This will help inform the Mexican government in establishing regulations for *Sargassum* removal.

Earth Observations Overview

Earth Observations:

Platform	Sensor	Geophysical Parameter
Landsat 5	Thematic Mapper (TM)	Floating Algal Index (FAI), Normalized Difference Vegetation Index (NDVI), Near-Infrared / Red Band Ratio (Near-IR/R)
Landsat 7	Enhanced Thematic Mapper Plus (ETM+)	Floating Algal Index (FAI), Normalized Difference Vegetation Index (NDVI), Near-Infrared / Red Band Ratio (Near-IR/R)
Landsat 8	Operational Land Imager (OLI)	Floating Algal Index (FAI), Normalized Difference Vegetation Index (NDVI), Near-Infrared / Red Band Ratio (Near-IR/R)
Aqua/Terra	Moderate Resolution Imaging Spectroradiometer (MODIS), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)	Chlorophyll A (Chl-a), Remote Sensing Reflectance (Rrs), Sea Surface Temperature (SST), Photosynthetically Available

		Radiation (PAR), colored dissolved organic matter (CDOM)
Suomi NPP	Visible Infrared Imaging Radiometer Suite (VIIRS)	Sea surface temperature (SST), Ocean color, Chlorophyll A (Chl-a)
OSTM/Jason 2	Poseidon-3	Altimetry, Ocean Topography
EnviSat	MEdium Resolution Imaging Spectrometer (MERIS)	Chlorophyll (Maximum Chlorophyll Index)

NASA Earth Observations Use:
Landsat 5 will be used to derive FAI, NDVI, and a Near Infrared / Red Band Ratio for the study region.

Landsat 7 will be used to derive FAI, NDVI, and a Near Infrared / Red Band Ratio for the study region.

Landsat 8 will be used to derive FAI, NDVI, and a Near Infrared / Red Band Ratio for the study region.

Aqua and Terra will be used to detect chl-a, Rrs, SST, CDOM, and PAR.

Suomi NPP will be used for SST, chl-a, and ocean color.

OSTM/Jason 2 will provide information regarding water levels and topography.

Ancillary Datasets:
Chl-a, Rrs, SST, PAR- Sea-viewing Wide Field-of-view Sensor (SeaWiFs);
PAR, Chl-a - SeaBASS;
Wind speed, air temperature, sea temperature, wind gust- NOAA National Data Buoy Center;
Wind, wave, current modeled data- Caribbean Coastal Ocean Observing System (CariCOOS)

Models:
TerrSet-Earth Trends Modeler (POC: James Toledano, Clark Labs/ Clark University)

Decision Support Tool & End-Product Overview

Proposed End Products	Decision to be Impacted	Current Partner Tool/Method
Time Series of Floating Algal Index (FAI), Normalized Difference Vegetation Index (NDVI), and Near-IR / Red Band Ratio, (2000-2015)	Assess which method is most successful in detecting *Sargassum* (affect management decisions related to current *Sargassum* detection systems)	N/A
Statistical analysis of *Sargassum* presence	Understand the possible implications of SST, chl-a, and PAR and their connections with *Sargassum* presence	N/A

compared to SST, chl-a, PAR, (2010-2015)	(assist with management decisions related to warming ocean temperatures)	
Sargassum Transport Model	Estimate the rate and direction of *Sargassum* movement to the Caribbean shores	Sargassum Early Advisory System (SEAS)
Report on *Sargassum* movements toward the Caribbean Coast, (2010-2015)	Assist decision-makers and the tourist industry in understanding rate/direction of *Sargassum* movement, ascertain when *Sargassum* may appear ashore	Sargassum Early Advisory System (SEAS)

Time Series of FAI, NDVI, Near-IR/Red Band Ratio – This time series will identify which method (FAI, NDVI, Near-IR/Red Band Ratio) is the most accurate in detecting *Sargassum* presence. This will also provide a historical timeline of *Sargassum* presence in the Caribbean Sea since 2000, which will help decision-makers understand how severe the problem is now compared to previous occurrences.

Statistical Analysis of Sargassum and SST, Chl, PAR- Using TerrSet Earth Trends Modeler, this statistical analysis will compare sea surface temperature, chlorophyl-a, and photosynthetically available radiation with *Sargassum* presence to determine if they are related. This will assist decision-makers in understanding a potential cause of the recent *Sargassum* proliferation.

Sargassum Transport Model – This simple model will estimate the rate and direction of *Sargassum* movement toward the Caribbean Coast using Landsat imagery. This will assist Caribbean governments in understanding the proliferation of this macro algae along their coastal habitats, and will better inform these governmental agencies of how to advise the public and tourist industry of removal procedures and frequency.

Report on Sargassum Movement Toward the Caribbean Coast- This report will outline specific case studies of mass *Sargassum* movements toward the Caribbean islands, and identify the rate of movement of *Sargassum* to reach specific coastlines (given wind speed and ocean currents). This will provide insight into how long it may take future *Sargassum* mats to reach specific countries in the upcoming months. This will assist decision-makers in providing more accurate regulation standards for the removal of *Sargassum* on their beaches.

Project Timeline & Previous Related Work

Project Timeline: 2 Terms: Spring 2016 to Summer 2016

Multi-Term Objectives:

- **Term 1** – This term will focus on assessing the most accurate *Sarassum* detection mechanism and via which type of index and imagery, and investigating the origin of the most recent Sargassum proliferation along the Caribbean shorelines. This term will also consider the environmental variables that may contribute to the mass growth of Sargassum in the study region. Indices used to detect *Sargassum* will be applied in Google Earth Engine, and environmental variables will be statistically analyzed in TerrSet.

- **Term 2** – The Summer 2016 term will focus on creating the particle transport simulation, using a basic particle transport model and species distribution model in TerrSet. This will aid

in the prediction of when Sargassum will arrive 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.

Previous Related DEVELOP Work:

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

Project Needs/Requests

Participants Requested: 4

Software & Scripting:

TerrSet Earth Trends Modeler – Seasonal Trend Analysis of *Sargassum* in the Caribbean Sea
ENVI – Classification of *Sargassum* presence (also ArcGIS)

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 has been pitched at the Latin America and Caribbean Sea Large Marine Ecosystems Symposium, which occurred in September of 2015 in Cancun, 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 very well 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