**Belize & Honduras Water Resources II**

*Developing a Google Earth Engine Dashboard for Assessing Coastal Water Quality in the Belize and Honduras Barrier Reefs to Identify Adequate Waste Control and Inform Coastal Resource Monitoring and Management*

**VPS Title:** Coastal Coding: Using Google Earth Engine to Remotely Monitor Coastal Water Quality in Belize and Honduras

**Project Team**

***Project Team:***

Hayley Pippin (Project Lead)

Arbyn Olarte

Roxana Pilot

Vanessa Valenti

***Advisors & Mentors:***

Dr. Christine Lee (NASA Jet Propulsion Laboratory, California Institute of Technology)

Dr. Juan Torres-Perez (Bay Area Environmental Research Institute, NASA Ames Research Center)

Dr. Emil Cherrington (University of Alabama in Huntsville)

Dr. Deepak Mishra (University of Georgia)

Benjamin Page (University of Minnesota, Water Resources Center)

***Past or Other Contributors:***

Charlie Devine

Alana Higgins

Alice Lin

Sophia Skoglund

**Project Overview**

***Project Synopsis:*** Heightened economic development endangers the minimally protected coral ecosystem that runs along the eastern Caribbean coastline of Belize and Honduras. To help safeguard this ecosystem, the NASA DEVELOP Belize & Honduras Water Resources II team continued to build on a Google Earth Engine dashboard that monitors water quality parameters along the coastal reefs of Belize and Honduras. The tool provides partners with time-series analyses of metrics such as colored dissolved organic matter and chlorophyll-a, which will inform coastal land-use management practices and protected area designation. These spatiotemporal assessments will assist current efforts to protect the Mesoamerican reef system.

***Abstract:***

The Mesoamerican reef is a biodiverse ecosystem that stretches more than 600 miles along four Central American coasts and is the longest barrier reef in the western hemisphere. The national economies of Belize and Honduras heavily depend on the commercial, recreational, and subsistence fishing services the reef supplies. While the reef has benefitted from sustainable collaborative management practices, ecosystem stress resulting from the destruction of coastal habitats and overfishing threatens its diverse communities and ecological functions. The Belize & Honduras Water Resources II team at NASA Jet Propulsion Laboratory partnered with the Secretaría de Recursos Naturales y Ambiente (Honduras), the Comisión Centroamericana de Ambiente y Desarrollo, the Coastal Zone Management Authority and Institute (Belize), and the Wildlife Conservation Society to continue developing the Optical Reef and Coastal Area Assessment (ORCAA) tool in Google Earth Engine to monitor and evaluate water quality changes and advise coastal management decisions. The tool incorporates Earth observations from Landsat 8 Operational Land Imager (OLI), Sentinel-2 Multispectral Instrument (MSI), and Aqua and Terra Moderate Resolution Imaging Spectroradiometer (MODIS). ORCAA outputs maps and time series graphs of turbidity, sea surface temperature, chlorophyll-a, and colored dissolved organic matter concentrations from 2013 onward, which our partners will use to identify reef degradation, pass coastal resource regulations, and establish protected zones along the reef. These maps will better enable our partners to address declining water quality conditions through policy initiatives and maintain the environmental and economic health of the region.

***Keywords:***

turbidity, CDOM, chlorophyll-a, Landsat 8 OLI, Sentinel-2 MSI, MODIS, remote sensing, Google Earth Engine

***National Application Area Addressed:*** Water Resources

***Study Location:*** Coastal Belize, Belize Barrier Reef Reserve System; Coastal Honduras, Honduras Barrier Reef System

***Study Period:*** January 2013 to October 2019

***Community Concerns:***

* The Mesoamerican reef serves as a foundational support for coastal economies by advancing recreational and tourist industries, supplying fisheries, and bolstering food production for local and regional communities.
* More than one million people depend on the reef system for their livelihoods. Coastal water quality degradation generates significant costs to marine environments and poses serious threats to human welfare.
* The effects of human disturbances, such as nutrient enrichment and excess sedimentation, compounded with the effects of natural disturbances, put marine ecosystems and coastal populations at risk.
* A comprehensive spatial and temporal monitoring system is necessary to defend stakeholder interests and pass policies to control coastal waste and resource management.

***Project Objectives:***

* Incorporate an atmospheric correction algorithm into the Google Earth Engine (GEE) Optical Reef and Coastal Area Assessment (ORCAA) tool to permit the use of Level 1C Sentinel-2 Multispectral Instrument (MSI) data instead of the Level 2A Surface Reflectance data
* Determine the feasibility of assessing colored dissolved organic matter (CDOM) concentrations using Landsat 8 Operational Land Imager (OLI), Sentinel-2 MSI, and Aqua and Terra Moderate Resolution Imaging Spectroradiometer (MODIS) data
* Produce water quality parameter maps and time series graphs to help partners identify land-use areas that need greater regulation and guide coastal zone management activities

***Previous Term:*** 2019 Summer (JPL & ARC) – Belize Water Resources: A Google Earth Engine Dashboard for Assessing Coastal Water Quality in Belize’s Coral Reefs to Identify Sustainable Development Goals for Achieving Sustainable Use of Natural Resources

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC** | **Partner Type** | **Boundary Org?** |
| **Secretaría de Recursos Naturales y Ambiente (Honduras)** | Rosibel Martinez Arriaga, Director of External Cooperation and Resource Mobilization  Fausto Díaz, Special Cooperation Technician | End User | No |
| **Coastal Zone Management Authority and Institute (Belize)** | Chantalle Clark-Samuels, Chief Executive Officer;  Arlene Young, Director;  Andria Rosado, Data Analyst;  Samir Rosado, Coastal Planner | End User | No |
| Sistema de la Integración Centroamericana, Comisión Centroamericana de Ambiente y Desarrollo | Luis Castellanos, Monitoring Specialist, Manejo Integrado de la Cuenca al Arrecife del Sistema Arrecifal Mesoamericano (MAR2R) | Collaborator | No |
| **Wildlife Conservation Society** | Alexander Tewfik, Marine Conservation Scientist;  Myles Phillips, Technical Coordinator | Collaborator | Yes |

***Decision-Making Practices & Policies:***

The Secretaría de Recursos Naturales y Ambiente (MiAmbiente Honduras) has partnered with Convenio de Cartagena to establish a baseline for analyzing resource management data and monitoring water quality conditions in coastal Honduras. Convenio de Cartegena will assist Honduras in adopting measures to prevent, reduce, and control water contamination at the regional level with cooperation from the Comisión Centroamericana de Ambiente y Desarrollo (CCAD) and maritime, port, and regional authorities to properly monitor and evaluate coastal water conditions. The Coastal Zone Management Authority and Institute (CZMAI) designed the National Integrated Coastal Zone Management plan (ICZM) to provide guidance on future investments and developments to governmental and non-governmental agencies in Belizean ministries, in addition to recommending conservation practices to ensure sustainability of coastal resources. The ICZM helps facilitate the management of coastal resources by preparing guidelines for government approval, revising the plan every four years, and implementing the Informed Management Zoning Scheme that will enable collaborative decision-making processes to help balance environmental conservation and economic development in Belize.

***Project Benefit to End User:***

This project will help build the partners’ capacity for using NASA Earth observations and European Space Agency satellites for coastal water management. The partners will gain a more comprehensive understanding of current and changing water quality conditions by using remotely sensed data to monitor marine health parameters in coastal Belize and Honduras. The ORCAA tool in GEE will help partners identify coastal contaminants from land run-off and sewage and locate areas in need of more stringent conservation practices. The tool will be a valuable addition to the partners’ efforts to manage coastal watersheds and observe turbidity, chlorophyll-a, and CDOM levels to maintain the health of the Mesoamerican Barrier Reef System that extends across both countries.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Turbidity | Landsat 8 reflectance bands were used to derive turbidity measurements in Formazin Nephelometric units (FNUs) of ocean water at 30 m resolution between 2013 and 2019. Landsat 8 was not utilized to acquire the normalized difference chlorophyll index (NDCI) values because of the lack of a band centered around 708 nm. |
| **Sentinel-2 MSI** | NDCI, chlorophyll-a, CDOM | Sentinel-2 MSI reflectance bands were utilized to extract the NDCI values and chlorophyll-a and CDOM concentrations at 10 and 20 m resolution between 2015 and 2019. |
| **Aqua MODIS** | Chlorophyll-a, sea surface temperature (SST) | MODIS was utilized for the high temporal resolution of 1-2 days. Aqua satellite data was used to acquire metrics for chlorophyll-a and SST at a resolution of 1 km from 2013 to 2019. |
| **Terra MODIS** | Chlorophyll-a, SST | MODIS was utilized for the high temporal resolution of 1-2 days. Terra satellite data was employed to measure chlorophyll-a and SST at a resolution of 1 km from 2013 to 2019. |

***Ancillary Datasets:***

* United Nations Environment World Conservation Monitoring Centre Protected Areas Shapefile – Provided selectable regions of interest in Belize in the GEE dashboard
* Flanders Marine Institute Maritime Boundaries and Exclusive Economic Zones Shapefile – Provided marine protected and economic exclusive zones of Honduras
* NOAA Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN) – Provided daily precipitation data that is incorporated into the time series figures within our GEE dashboard

***Software & Scripting:***

* Google Earth Engine API – User-facing dashboard developed in GEE that extracts water quality measurements (SST, turbidity, chlorophyll-a, and CDOM) from satellite reflectance bands including Landsat 8 OLI, Sentinel-2 MSI, Aqua MODIS, and Terra MODIS
* ACOLITE Python 20190326.0 – Atmospheric correction of imagery and extraction of water quality parameters for validation of derived data in GEE
* ESRI ArcGIS 10.6 – Raster manipulation, data visualization
* R 3.5.0 – Statistical computation, data processing, chart and graph generation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Turbidity, Chlorophyll-a, SST, and CDOM Maps and Time Series Graphs** | Landsat 8 OLI  Sentinel-2 MSI  Aqua MODIS  Terra MODIS | Maps and time series graphs of water quality parameters allow partners to identify previous oceanic trends and visualize water quality and organic matter distribution, which will improve end users’ ability to focus management and conservation practices. | I |
| **Optical Reef and Coastal Area Assessment (ORCAA) GEE Tool** | Landsat 8 OLI  Sentinel-2 MSI  Aqua MODIS  Terra MODIS | This cloud-based computing tool allows our partners to run analyses and monitor water quality efficiently and effectively. End users can use the tool to spatially and temporally evaluate trends in ocean water quality to aid them in future coastal protection policy decision-making. | IV |
| **ORCAA Tool Tutorial** | N/A | This video tutorial will instruct our partners how to use and apply the tool to their future work. | N/A |

**Project Handoff Package**

***Transition Plan:*** Using NASA Large File Transfer, the team passed off the end products, excluding ORCAA, to MiAmbiente Honduras, CCAD, CZMAI, and the Wildlife Conservation Society at the end of the project term. A video conference via WebEx with the partners also took place, where the team explained all maps, analyses, and ORCAA, which will be released after undergoing the NASA Software Release process.

***Software Release Plan:*** The video conference allowed partners to receive an overview of ORCAA and its outputs prior to the tool’s release. Since the tool was not immediately available at the end of the term, the team included a tutorial video of the tool’s graphical user interface (GUI) in both English and Spanish for the partners to reference in the future. We also included a README document in the release package that details the application and instructions for its use. Finally, the ORCAA GUI is hosted as a web-based application that allows partners with a wide range of scripting and remote sensing capabilities to easily employ the tool.

***Team POC:*** Hayley Pippin, habpippin@berkeley.edu

***Software Release POC:*** Vanessa Valenti, vvalenti@ucla.edu

***Partner POC:*** Rosibel Martinez Arriaga, rmarriaga.miambiente@gmail.com

Arlene Young, director@coastalzonebelize.org

Myles Phillips, mphillips@wcs.org

Benjamin Page, pagex135@umn.edu

***Handoff Package:***

* Poster (in both English and Spanish)
* Project Video (in both English and Spanish)
* Technical Paper (in both English and Spanish)
* Turbidity, Chlorophyll-a, SST and CDOM Maps and Time Series Graphs
* ORCAA Tool Tutorial (in both English and Spanish)

**References**

Coastal Zone Management Authority and Institute. (2016). *Belize integrated coastal zone management plan.* Belize City, CZMAI. Retrieved from https://www.coastalzonebelize.org/wp-content/uploads/2015/08/BELIZE-Integrated-Coastal-Zone-Management-Plan.pdf

McField, M. & Kramer, P. (2007). Healthy reefs for healthy people: A guide to indicators of reef health and social well-being in the Mesoamerican reef region.  *Healthy Reefs Initiative.* Washington, D.C.: The Smithsonian Institute. Retrieved from https://www.researchgate.net/publication/228627962\_Healthy\_Reefs\_for\_Healthy\_People\_A\_Guide\_to\_Indicators\_of\_Reef\_Health\_and\_Social\_Well-being\_in\_the\_Mesoamerican\_Reef\_Region

McField, M., Kramer, P., Alvarez-Filip, L., Drysdale, I., Flores, M.R., Petersen, A.G., & Soto, M. (2018). Mesoamerican reef report card. *Healthy Reefs Initiative.* doi:10.13140/RG.2.2.19679.36005

Sistema de la Integración Centroamericana. (2019). *Comisión Centroamericana de Ambiente y Desarrollo* – *CCAD.* Retrieved from https://www.sica.int/ccad/breve.aspx