**Project Summary**

**ORCAA Water Resources**

*Updating and Expanding the Optical Reef and Coastal Area Assessment (ORCAA) Tool*

**Project Team:**

Tasos Tentoglou (Project Lead)

Eleda Fernald

Adam Weingram

David Carrasco Rivera

**Advisors & Mentors:**

Dr. Juan Torres-Pérez (NASA Ames Research Center)

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

Benjamin Holt (NASA Jet Propulsion Laboratory)

Dr. Emil Cherrington (NASA Marshall Spaceflight Center)

Dr. Kelly Luis (NASA Jet Propulsion Laboratory)

William Hernandez (University of Puerto Rico)

Roy Armstrong (University of Puerto Rico)

Britnay Beaudry (Science Systems and Applications, Inc., NASA Ames Research Center)

Hayley Pippin (Science Systems and Applications, Inc., NASA Ames Research Center)

**Past or Other Contributors:**

*2019 Summer (JPL/ARC) – Belize Water Resources I*

Alice Lin

Charles Devine
Sophia Skoglund

Alana Higgins

*2019 Fall (JPL) – Belize & Honduras Water Resources II*

Hayley Pippin

Vanessa Valenti

Arbyn Olarte

Roxana Pilot

***Team Contact:*** Tasos Tentoglou, ttentoglou@gmail.com

***Software Release Contact:*** Adam Weingram, nasadevelop@adamweingram.com

**Project Objectives:**

* Integrate water quality indices and validate the tool’s outputs with *in-situ* bio-optical data provided by project partners
* Extend the tool’s temporal range via the addition of remotely-sensed imagery from Landsat 5 TM and 7 ETM+
* Add a temporal trend analysis component and create a pluggable interface to ease the integration of additional datasets
* Restructure codebase into modules with documented application program interfaces

**Abstract:**

Initially developed by the Belize & Honduras Water Resources I/II teams, the Optical Reef and Coastal Area Assessment tool (ORCAA) is a Google Earth Engine application that allows stakeholders to effectively monitor coastal water quality within the Mesoamerican Reef. Utilizing 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 imagery and time series of turbidity, color dissolved organic matter (CDOM), chlorophyll-a (Chl-a), and sea surface temperature (SST) at a temporal range from 2013 to present. These outputs have enabled partners to better address declining water quality conditions by informing policy initiatives to maintain the region’s environmental and economic health. The ORCAA 2.0 update includes additional Chl-a and aquatic vegetation monitoring indices and an extended temporal range from 1984 to present through the addition of Landsat 5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+) imagery inputs. The team performed validation studies on the tool's outputs by comparing the processed imagery and time series data against ground truth bio-optical data at several shallow coastal locations around Earth. The updated tool's restructured codebase and broadened temporal and spatial capabilities enable improved water quality monitoring in coastal areas.

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

**Partner Organization:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **University of Puerto Rico,****Department of Marine Sciences,****Bio-optical Oceanography****Laboratory** | Dr. Roy Armstrong, Professor andDirector; Dr. William Hernández,Researcher | Collaborator | No |

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 5 TM** | Normalized Difference Chlorophyll Index (NDCI), Normalized Difference Turbidity Index (NDTI), Color Dissolved Organic Matter (CDOM), Normalized Difference Aquatic Vegetation Index (NDAVI) | Landsat 5 reflectance bands were used to derive turbidity, chlorophyll-a, and aquatic vegetation indices at 30 m resolution between 1984 and 2012. Landsat 5 was not utilized to acquire the NDCI values because of the lack of a band centered around 708 nm. |
| **Landsat 7 ETM+** | NDCI, NDTI, CDOM, NDAVI | Landsat 7 reflectance bands were used to derive turbidity, chlorophyll-a, and aquatic vegetation indices at 30 m resolution between 2012 and 2013. Landsat 7 was not utilized to acquire the NDCI values because of the lack of a band centered around 708 nm. |
| **Landsat 8 OLI** | NDCI, NDTI, CDOM, NDAVI | Landsat 8 reflectance bands were used to derive turbidity measurements in Formazin Nephelometric Units (FNUs) of ocean water, chlorophyll-a, and aquatic vegetation indices at 30 m resolution between 2013 and 2022. Landsat 8 was not utilized to acquire the NDCI values because of the lack of a band centered around 708 nm. |
| **Sentinel-2 MSI** | NDCI, NDTI, 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 2022. |
| **Terra MODIS** | Sea Surface Temperature (SST) | MODIS data were utilized for the high temporal resolution of 1-2 days. Terra satellite data were used to acquire metrics for SST at a resolution of 1 km from 2000 to 2022. |
| **Aqua MODIS** | SST | MODIS data were utilized for the high temporal resolution of 1-2 days. Aqua satellite data were used to acquire metrics for SST at a resolution of 1 km from 2000 to 2022. |

***Software & Scripting:***

* Google Earth Engine JavaScript API, Google Earth Engine App View – Primary application user interface, data processing backend
* Esri ArcGIS Pro 2.9.2 – Map creation for documentation
* Python 3.10 – Data pre-processing, validation, analysis, and reproducibility

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Benefit & Use** | **Software Release Category** |
| **Optical Reef and Coastal Area Assessment (ORCAA) 2.0 Google Earth Engine (GEE) Tool** | Landsat 5 TMLandsat 7 ETM+Landsat 8 OLISentinel-2 MSITerra MODISAqua MODIS | This tool allows project partners, researchers, and other stakeholders to expand the water quality monitoring and analysis efforts provided by the first version of ORCAA. They can evaluate trends for more water quality indices over a higher temporal resolution to include in their coastal protection policy decision-making. The tool is available to users globally and future DEVELOP teams. | IV |
| **ORCAA 2.0 User Guide** | N/A | This guide is a comprehensive tutorial instructing users how to run the tool and apply it to their work. It includes screenshots, architecture diagrams, and external links. | N/A |
| **ORCAA 2.0 Video Tutorial** | N/A | This video tutorial will instruct users how to run the tool with multiple case scenarios. | N/A |

**Project Reflections**

**Does the team consider this project to be successful?**

The team considers the project to be successful. The team was able to incorporate additional sensors that allowed for the expansion of the temporal range and additional geometries for the expansion of the spatial applicability of the tool, as well as add two new functionalities to the tool and an additional water quality parameter. The team performed validation analysis for the tool’s chlorophyll-a and turbidity outputs and found low correlation with the *in-situ* data. In discussion with the team, advisors noted that bottom albedo affects the signal, creating higher pixel values. The team identified the need for more *in-situ* data from multiple locations for improved tool validation.

**If you had the opportunity to do this project again, what would you do differently?**

The team would focus on conducting validation early in the term. This would allow for proper identification of what needed to be fixed in the existing tool to make the outputs more accurate and meaningful to the user. The team would also make the necessary changes to the GUI earlier, allowing us to expand the tool’s applicability even further.

**Do you have any recommendations for future teams pursuing a similar project to consider?**

1. Add more templates with preexisting geometries, allowing the user to have more options for given geometries and expand global applicability.
2. Validate the tool’s NDAVI, SST, CDOM, and land/water outputs for existing and additional templates, and validate chlorophyll-a and turbidity for additional regions.
3. Incorporate bottom albedo, sun glint, and non-obfuscated atmospheric corrections for the tool’s outputs.

**NASA Earth Observation Data**

*Landsat 8 OLI* (<https://doi.org/10.5066/f78s4mzj>)
*Landsat 7 ETM+* ([https://doi.org/10.5066/f7wh2pg](https://doi.org/10.5066/F7WH2P8G))

*Landsat 5 TM+* (<https://doi.org/10.5066/f7n015tq>)

* **Source**: Earth observations were obtained from the Google Earth Engine Cloud Database and were directly imported into the code.
* **General Overview**: We had no major issues accessing or incorporating Landsat 5, Landsat 7, or Landsat 8 imagery; there was readily available documentation for integrating these datasets into Google Earth Engine.
* **Acquisition**: The acquisition of the data from the sensors we added was very simple. The directions were clear, and having the preexisting tool as a template made it easier to incorporate them into the tool and keep the tool’s functionality.
* **Processing/Analysis**: We had no major issues with the processing or analysis of the data we incorporated. We were familiar with the data and the processes.

**Partner Engagement**

*University of Puerto Rico (Collaborator)*

* **Involvement**: They were very engaging and showed excitement about the project throughout the term. They also understood the complexity of the tool and the standards for what was being asked from the team. Respectively, they did provide insightful feedback and advice when needed.
* **Responsiveness**: The partners did attend the meetings to the best of their abilities. They were also very quick at responding to emails and getting back to us with any questions. We did need to remind them a couple of times about data they would provide, but they did offer it alongside appropriate context and advice on how to utilize it best.
* **Capacity Built**: Some of the team members had little experience with coding and/or remote sensing data acquisition, processing, and analysis, so they were able to develop this skill as a tool to incorporate sciences and remote sensing data. Additionally, some members had a more technical background and learned the project's science components, helping them integrate their technical knowledge into applied sciences. Combining these skills will allow all team members to integrate valuable scientific knowledge and remote sensing techniques into strategies to improve coastal water quality and coastal ecosystems management.
* **Further Collaboration**: The science advisors from the University of Puerto Rico were fully engaged and continuously showed excitement about the tool and the team’s efforts. They also provide detailed feedback and advice and a large number of resources to facilitate the accomplishment of the term’s goals.

**Culminating Research Questions Generated**

**Team-Identified Future Work:**

* The addition of more regions to the UI would improve spatial applicability of the tool, allowing the user to choose from more preexisting geometries (e.g., The Mediterranean Sea, The Great Barrier Reef, etc.). Additionally, though we did perform some validation, further validation of the parameters for the existing regions would improve the quality of the tool’s outputs. This validation could also be implemented into the additional geographic regions.
1. Add more templates from which users may choose preexisting geometries.
2. Validate the tool’s NDAVI, SST, turbidity, and land/water outputs for Caribbean and California regions.
3. Validate all of the tool’s outputs (Chlorophyll-a, CDOM, NDAVI, SST, turbidity, and land/water) for more regions.
4. Correct for bottom albedo and sun glint.
5. Incorporate atmospheric correction code that is not obfuscated.

**Partner-Identified Follow-On Research Questions:**

* Sun glint and bottom albedo corrections were topics of major interest across the partners. These seem to be areas that the scientific advisors would like for future teams to focus on as they improve the tool’s outputs.