**NASA DEVELOP National Program**

**2019 Summer Project Proposal**

**California – Ames and California – JPL**

**Belize Water Resources**

*A Google Earth Engine Dashboard for Assessing Coastal Water Quality in Belize’s Coral Reefs to Identify Sustainable Development Goals (SDGs) for Achieving Sustainable Use of Natural Resources*

**Project Overview**

***Project Synopsis*:** The NASA DEVELOP Belize Water Resources team will partner with the Wildlife Conservation Society (WCS) and Coastal Zone Management Authority and Institute (CZMAI) in Belize to evaluate water quality conditions, such as turbidity and chlorophyll-a, near the Belize Barrier Reef Reserve System and help them make informed and improved coral reef management decisions. In this project, we will develop a user-friendly tool utilizing Google Earth Engine (GEE) to produce a time series of water quality measurements taken from Landsat 8 OLI, Sentinel-2 MSI, and Sentinel-3 OLCI to assess potential impacts on the coral reefs by quantifying extent, duration or other indicators. Coral reef ecosystems are critical to communities living around and dependent upon them, particularly by providing ecosystem services through aquatic biodiversity, fisheries, recreation, and touristic value. This project will help partners identify areas of reef that are most threatened by land-based sources of nutrient and sedimentation. Improved watershed management will support overall conservation efforts on threatened coral reefs.

***Community Concern:*** The Belize Barrier Reef, located to the east of Belize coastline in the Caribbean Sea, is the longest coral reef system in the western hemisphere. The reef ecosystems are home to unique and diverse aquatic species and provide essential ecosystem services such as aquatic biodiversity, fisheries, shoreline protection, recreation purposes, touristic values, and is estimated to be responsible for 12-15% of Belize GDP. CZMAI, other Belizean government agencies and environmental NGOs (e.g. WCS) are seeking to better understand the linkages between natural disturbances and human activities and improve stewardship of marine ecosystems and the coastal zone and connected watersheds. Belize and other countries in Central America face great challenges in implementing monitoring approaches that can be maintained over time and, as a by-product, ensuring sustainable management of these vast and disparate environments. The results of the Belize Water Resources project will allow partners to better monitor water quality changes over time for future sustainable use of natural resources, planning of coral reef conservation practices, and environmental capital.

***Source of Project Idea:*** JPL Center Lead Erika Higa contacted JPL science advisor Christine Lee to see if there were project ideas that Christine would like to put into consideration. Christine Lee and her colleagues proposed this project that is similar to another NASA-funded project, but wanted to extend the project goals with NASA DEVELOP to provide work that is not a duplicate of their current project. Christine proposed to include a development of a GEE based tool to hand-off to the end-users to help them monitor coral reef ecosystems. The Wildlife Conservation Society sees the importance in having this tool since it would allow interested stakeholders to easily access and observe water quality conditions with an easy to use platform.

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

***Study Location:*** Coastal Belize and Belize Barrier Reef Reserve System, Belize

***Study Period:*** January 2013 – May 2019

***Advisors:*** Dr. Juan Torres-Pérez (Bay Area Environmental Research Institute, NASA Ames Research Center), Dr. Christine Lee (NASA Jet Propulsion Laboratory, California Institute of Technology)

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Wildlife Conservation Society** | Alexander Tewfik, Marine Conservation Scientist | End User | Yes |
| **Coastal Zone Management Authority and Institute (CZMAI)** | Chantalle Clarke-Samuels, Chief Executive Officer;  Andria Rosado, Data Analyst | End User | No |

***End-User Overview***

***End User’s Current Decision-Making Process:***As a government agency, CZMAI developed an Integrated Coastal Zone Management Plan (ICZMP) that is updated every five years, which is used as the basis to provide guidance for permitting and coastal zone activities by other agencies in Belizean ministries. It is also the basis for reviewing reference conditions for determining how much potential land or coastal repercussions might occur for a proposed project. CZMAI will review these proposals and provide a letter or objection (or acceptance) depending on what their assessment of potential impacts.  These letters are delivered to an advisory council to implement in granting a particular action. WCS mainly practices fishery management, but is beginning to consider reef management to save a number of species pertinent to Belize's ecosystem.

***End User’s Capacity to Use NASA Earth Observations:***

*Wildlife Conservation Society –* This partner is somewhat familiar with NASA Earth observations. This partner collects some geospatial data in relation to empirical surveys of critical habitats, marine biodiversity, and fisheries.

*Coastal Zone Management Authority and Institute –* CZMAI is familiar with some aspects of remote sensing or NASA Earth observations. Co-investigator Emil Cherrington used to work there and utilized NASA EO to evaluate land use changes and identify areas and extent deforestation. Most recently CZMAI has collected drone imagery (visible) to outline buildings, development and encroachment into vulnerable coastal areas. They do not yet work with Earth observations based water quality information, so this project will help build their capacity in the area.

***Collaborator & Boundary Organization Overview***

***Dissemination by Boundary Organizations*:**

*Wildlife Conservation Society –* Wildlife Conservation Society may help this project achieve dissemination. We anticipate including relevant outcomes in future dissemination efforts organized by WCS or others. Another key elements may include the public university (University of Belize) and an initiative to build the nation’s spatial data infrastructure (National Spatial Data Infrastructure).

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** During the term, the team will have biweekly teleconferences with partners to provide updates on project methodologies and analyses. The Project Co-Leads at the California - JPL and California - Ames Nodes will be the primary points of contact for in-term communications with project partners.

***Transition Plan*:** A formal handoff will take in place at the end of the project term in the form of a video conference via WebEx. Project end users will receive access to the Google Earth Engine app, including access to datasets and code after software release is approved. End products and deliverables will be sent to partners via NASA Large File Transfer (LFT) within two weeks after the project ends. This project will require NASA Software Release process.

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Chlorophyll-a, turbidity | Landsat 8 OLI reflectance bands will be used to derive turbidity (FNU) and chlorophyll-a concentrations from ACOLITE software and will be reproduced in GEE. It will be used to visualize environmental conditions, and through time series, including key impact events (such as discharge of sediment from Belize River and extent of that plume or algal blooms) |
| **Sentinel-2 MSI** | Chlorophyll-a, turbidity | Sentinel-2 MSI reflectance bands will be used to derive turbidity (FNU) and chlorophyll-a concentrations from ACOLITE software and will be reproduced in GEE. It will be used to visualize environmental conditions, and through time series, including key impact events (such as discharge of sediment from Belize River and extent of that plume or algal blooms) |
| **Sentinel-3 OLCI** | Chlorophyll-a, turbidity, CDOM | Sentinel-3 OLCI reflectance bands will be used to derive colored dissolved organic matter (CDOM), per algorithms described in literature (Matsuoka et al.) |

***Software & Scripting:***

Esri ArcGIS – raster manipulation and analysis, image enhancement, and map creation for reports

ACOLITE – atmospheric correction and processing for Landsat 8 OLI and Sentinel-2 MSI

R – data processing, statistical comparisons, figure generation

Python – data processing, statistical comparisons

Google Earth Engine API – derive turbidity and chlorophyll-a from Landsat 8 OLI and Sentinel-2 MSI

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Turbidity and Chlorophyll-a Maps** | This will be used to allow partners to monitor and see where there are abnormal or high levels turbidity and chlorophyll-a patterns. This product will help partners prioritize areas for coastal monitoring and understand the prevailing water quality conditions that impact coral reef health. | COLITE will be used to process Landsat 8 OLI and Sentinel-2 MSI to derive turbidity and chlorophyll-a maps using algorithms (t\_dogliotti, chl\_oc3, chl\_re\_moses3b) provided by the software. The same parameters will be processed on Sentinel-3 OLCI data. | I |
| **Water Quality GEE Monitoring Tool** | A water quality GEE monitoring tool will aid the partners to visualize turbidity and chlorophyll-a extent in vulnerable areas and coral reefs. The tool will help partners create up-to-date maps quickly without downloading and processing the maps themselves. This tool will aid partners in their effort to monitor water conditions affecting the barrier reef. | The algorithms used in ACOLITE will be translated over to Google Earth Engine to create turbidity and chlorophyll-a outputs from Landsat 8 OLI and Sentinel-2 MSI. The goal is for the GEE tool to have near-similar outputs with those maps outputted from ACOLITE. | IV |
| **Water Quality GEE Monitoring Tool Tutorial** | This document will help the partners understand how to use the GEE tool so they can run the tool themselves to visualize and output turbidity and chlorophyll-a maps. | This tool will be run on GEE that takes Landsat 8 OLI and Sentinel-2 MSI input data. | N/A |

***End-User Benefit*:** The partners are not familiar with NASA Earth observations in their decision-making processes, so this project will help build its capacity and provide methods of using remotely sensed data in coastal management. This project will use high resolution and temporal imagery from Landsat 8 OLI and Sentinel-2 MSI to map water quality in coastal Belize and will create a tool for partners to visualize turbidity and chlorophyll-a. The proposed end products will help partners identify regions that will need future conservation efforts and better water management practices. This project will also introduce the idea of using a water quality remote sensing GEE tool to begin evaluating more current information alongside the ICZMP.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 2 Terms: 2019 Summer to 2019 Fall

***Multi-Term Objectives:***

* **Term 1 (Proposed Term):** 2019 Summer (California - Ames & California - JPL) – Belize Water Resources
  + The first term will focus on utilizing GEE to produce, evaluate, and baseline water quality conditions in Coastal Belize. The team will produce turbidity and chlorophyll-a maps from ACOLITE software and replicate the same process using GEE on Landsat 8 OLI and Sentinel-2 MSI imagery. Time willing, the team will also work on Sentinel-3 OLCI data. The goal will be to produce a working GEE tool that outputs the water quality parameters for a time period the user chooses to study. The tool development will be the main focus for this term, and the team will make observations where water quality was poor for further study in the following term. Software release is anticipated to start at this term.
* **Term 2:**  2019 Fall (California - JPL) – Belize Water Resources II
  + The second term objective is to further make adjustments to the tool as necessary to work in other barrier reefs in addition to the Belize Barrier Reef System. The goal will be to expand to other study areas and to observe additional water quality parameters such as colored organic matter. Sentinel-3 OLCI EFR and Terra/Aqua MODIS will be additional datasets used to look at the ocean conditions near the reefs. Software release is expected to be near-complete and it is hoped that the tool is ready to be shared with the partners by this term to demonstrate its functionalities.

***Related DEVELOP Work:***

2018 Fall (Georgia - Athens ) – Osa Peninsula Water Resources III: Evaluating Potential Sites for Coral Reef Restoration in the Golfo Dulce, Costa Rica Based on Turbidity and Sea Surface Temperature

2018 Summer (California - Ames) – US Virgin Islands Water Resources: Analyzing Hurricane Influences on Coastal Water Quality and their Impact to Marine Ecosystems

2014 Summer (California - Ames) – American Samoa Oceans: Evaluating a Watershed Modeling Approach for Water Quality on Near-Shore Coral Reef Ecosystems in American Samoa Using NASA Earth Observations

**Notes & References:**

***Notes*:** Anything else you deem relevant and that supports the proposal.

* With time permitting the team may look at other water quality and ocean parameters such as sea surface temperature.
* This project will support in identifying Sustainable Development Goals (SDG) targets for achieving sustainable use of natural resources and environmental capital.
* The team will look at turbidity, chlorophyll-a, an CDOM  algorithms from Dogliotti et al., Nechad et al., Moses et al., Matsuoka et al., and Mishra et al.
* There will be continuing efforts to have partners from SICA involved in this project, including the Ministry of Natural Resources and the Environment Comisión Centroamericano de Ambiente y Desarrollo (CCAD) and Organización del Sector Pesquero y Acuícola de Istmo Centroamericano (OSPESCA).

***References:***

Almada-Villela, Mcfield, M., Kramer, P., Kramer, P. R., & Arias-Gonzalez, E. (n.d.). Main Publications: Status of Coral Reefs of Mesoamerica - Mexico, Belize, Guatemala, Honduras, Nicaragua, and El Salvador. Retrieved from http://www.reefbase.org/resource\_center/publication/main.aspx?refid=13888

Dogliotti, A. I., Ruddick, K. G., Nechad, B., Doxaran, D., & Knaeps, E. (2015). A single algorithm to retrieve turbidity from remotely-sensed data in all coastal and estuarine waters. *Remote Sensing of Environment*, *156*, 157-168.

Matsuoka, A., Hooker, B., Bricaud, A., Gentili, B., & Babin, M. (2013). Estimating absorption coefficients of colored dissolved organic matter (CDOM) using a semi-analytical algorithm for southern Beaufort Sea waters: application to deriving concentrations of dissolved organic carbon from space. *Biogeosciences*, *10*(2), 917-927.

Mishra, S., & Mishra, D. R. (2012). Normalized difference chlorophyll index: A novel model for remote estimation of chlorophyll-a concentration in turbid productive waters. *Remote Sensing of Environment*, *117*, 394-406.

Moses, W. J., Gitelson, A. A., Perk, R. L., Gurlin, D., Rundquist, D. C., Leavitt, B. C., ... & Brakhage, P. (2012). Estimation of chlorophyll-a concentration in turbid productive waters using airborne hyperspectral data. *Water research*, *46*(4), 993-1004.

Nechad, B., Ruddick, K. G., & Park, Y. (2010). Calibration and validation of a generic multisensor algorithm for mapping of total suspended matter in turbid waters. *Remote Sensing of Environment*, *114*(4), 854-866.