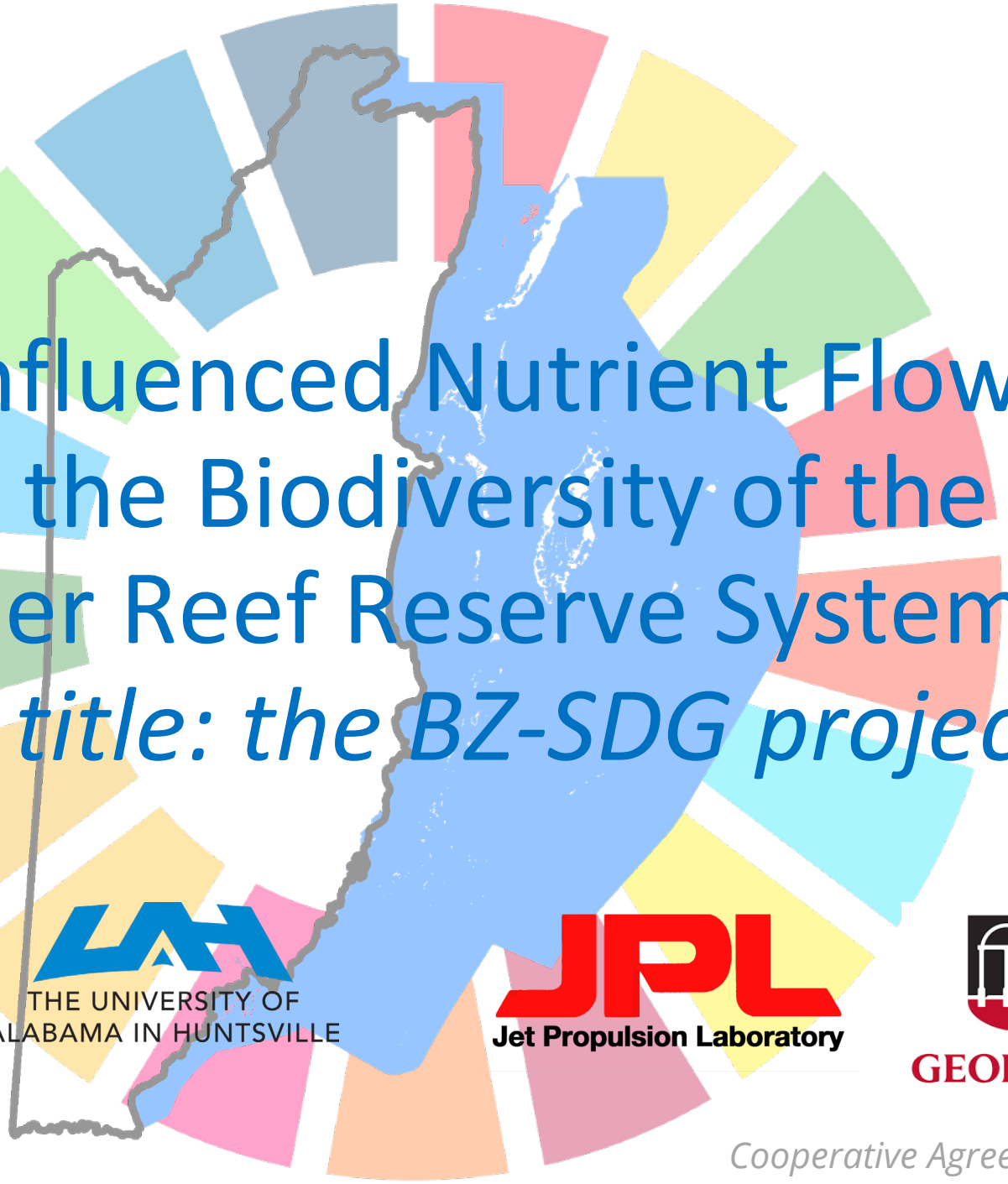
Climate-influenced Nutrient Flows and Threats to the Biodiversity of the Belize Barrier Reef Reserve System

(*short title: the BZ-SDG project*)



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THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Jet Propulsion Laboratory

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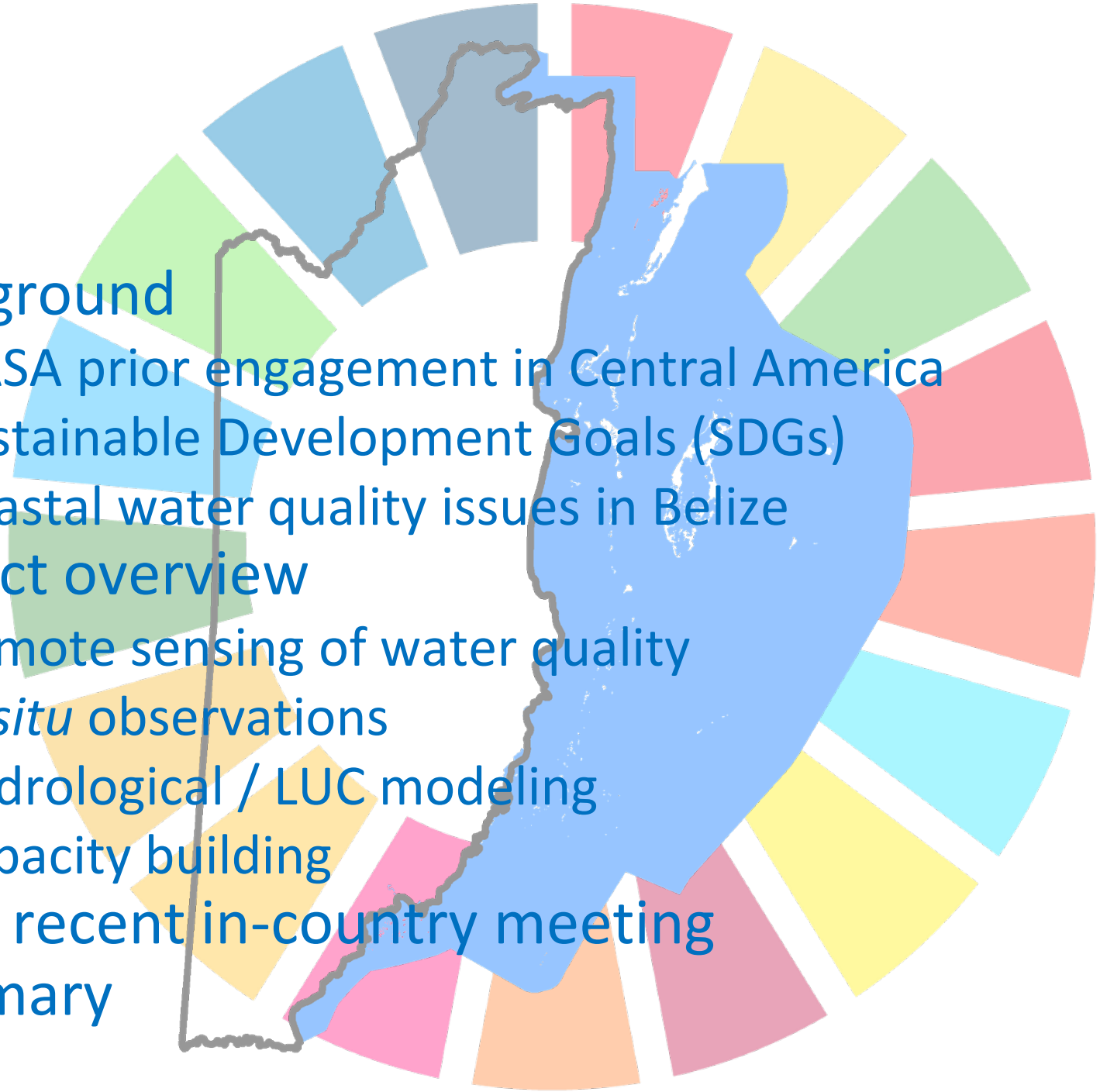
20.09.22

Cooperative Agreement no. #80NSSC19K0200

Outline

1. Background
   - NASA prior engagement in Central America
   - Sustainable Development Goals (SDGs)
   - Coastal water quality issues in Belize
2. Project overview
   - Remote sensing of water quality
   - *In situ* observations
   - Hydrological / LUC modeling
   - Capacity building
3. Most recent in-country meeting
4. Summary



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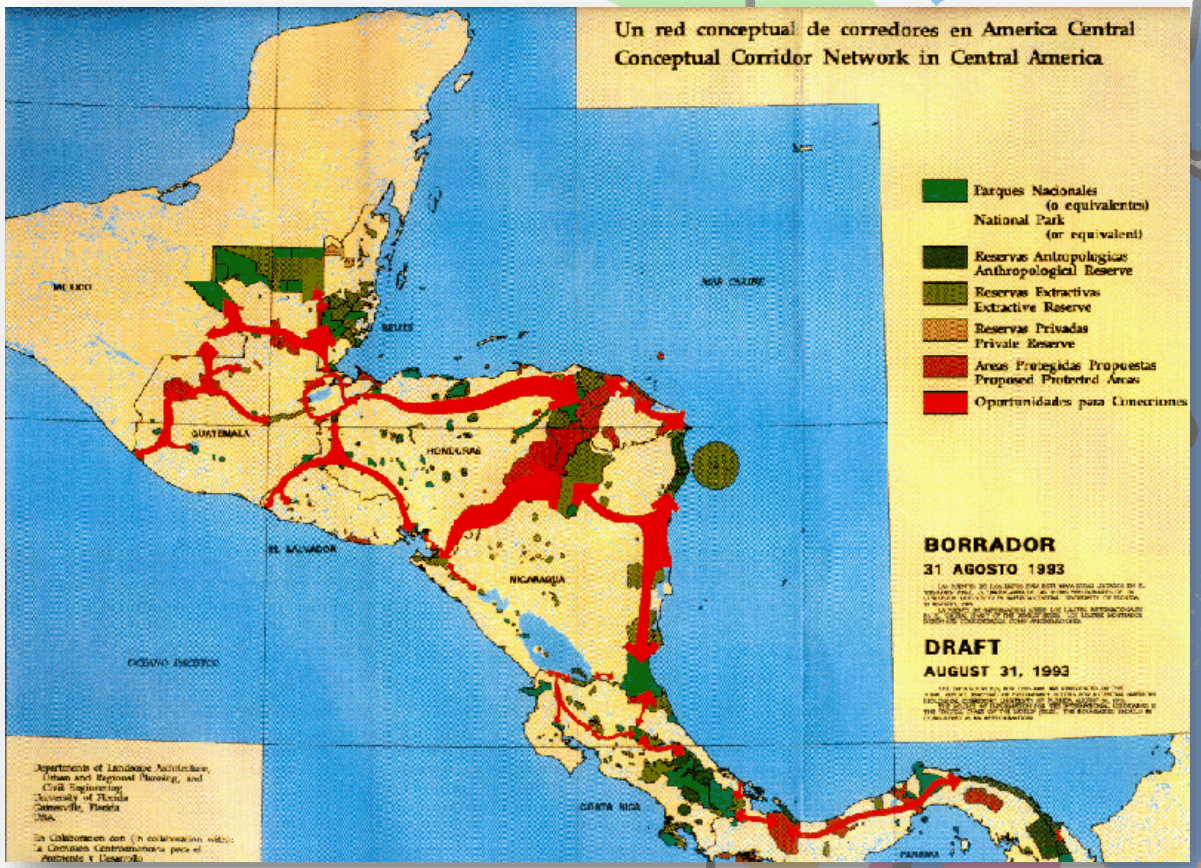
NASA

March 2019: Signing of Joint Statement between NASA and SICA in Costa Rica

April 2019: High-level NASA-SICA meeting at NASA Headquarters

BZ-SDG = First ever Belize-specific NASA research project



Paseo de la Pantera, developed by WCS in 1990s (now the Mesoamerican Biological Corridor)

SERVIR-Mesoamerica

14 LIFE BELOW WATER — CONSERVE AND SUSTAINABLY USE THE OCEANS, SEA AND MARINE RESOURCES FOR SUSTAINABLE DEVELOPMENT

TARGETS		INDICATORS	
14.1	By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	14.1.1	Index of coastal eutrophication and floating plastic debris density
14.2	By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	14.2.1	Proportion of national exclusive economic zones managed using ecosystem-based approaches
14.3	Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	14.3.1	Average marine acidity (pH) measured at agreed suite of representative sampling stations
14.4	By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics	14.4.1	Proportion of fish stocks within biologically sustainable levels
14.5	By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information	14.5.1	Coverage of protected areas in relation to marine areas
14.6	By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation	14.6.1	Progress by countries in the degree of implementation of international instruments aiming to combat illegal, unreported and unregulated fishing
14.7	By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism	14.7.1	Sustainable fisheries as a percentage of GDP in small island developing States, least developed countries and all countries
14.A	Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed	14.A.1	Proportion of total research budget allocated to research in the field of marine technology

15 LIFE ON LAND — PROTECT, RESTORE AND PROMOTE SUSTAINABLE USE OF TERRESTRIAL ECOSYSTEMS, SUSTAINABLY MANAGE FORESTS, COMBAT DESERTIFICATION, AND HALT AND REVERSE LAND DEGRADATION AND HALT BIODIVERSITY LOSS

TARGETS		INDICATORS	
15.1	By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	15.1.1	Forest area as a proportion of total land area
		15.1.2	Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type
15.2	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	15.2.1	Progress towards sustainable forest management
15.3	By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	15.3.1	Proportion of land that is degraded over total land area
15.4	By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development	15.4.1	Coverage by protected areas of important sites for mountain biodiversity
		15.4.2	Mountain Green Cover Index
15.5	Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	15.5.1	Red List Index
15.6	Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed	15.6.1	Number of countries that have adopted legislative, administrative and policy frameworks to ensure fair and equitable sharing of benefits
15.7	Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products	15.7.1	Proportion of traded wildlife that was poached or illicitly trafficked
15.8	By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species	15.8.1	Proportion of countries adopting relevant national legislation and adequately resourcing the prevention or control of invasive alien species
15.9	By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts	15.9.1	Progress towards national targets established in accordance with Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011-2020

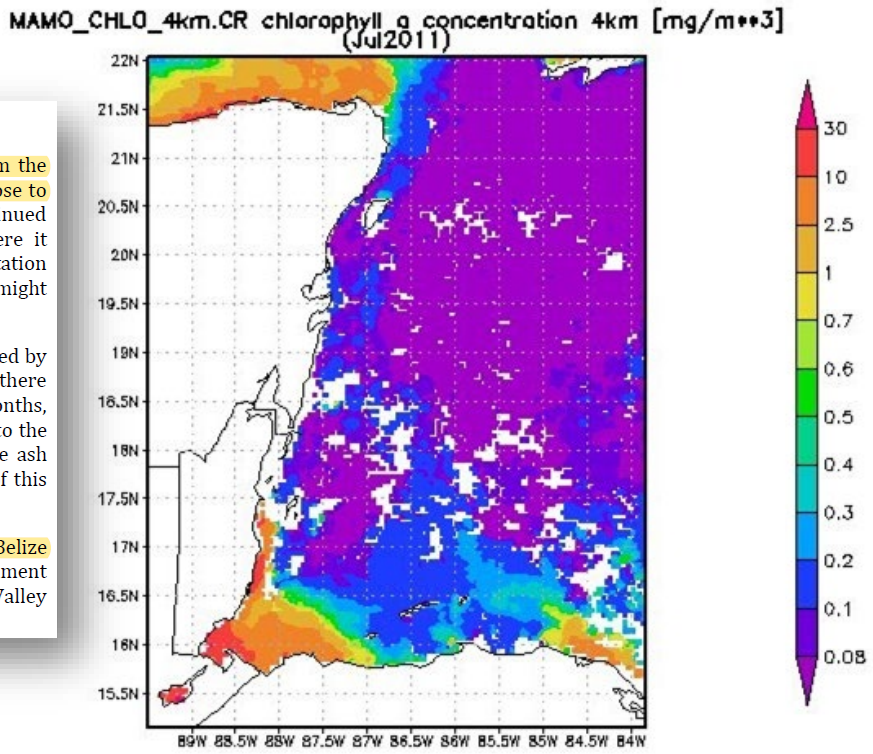
Terrestrial events with potential impact on the marine environment

One such event was in August 2009, when BECOL released large amounts of sediment from the bottom of the Chalillo hydro lake[1]. As a result, the turbidity in the Macal and Belize Rivers rose to such an extent that both rivers turned to the colour of chocolate milk. This release of silt continued for a couple of weeks and the resulting plume of silt eventually reached the sea, where it discoloured the water of the coast in front of the Buttonwood Bay area. The effects of the siltation on the riverine environment were never assessed, neither was it investigated whether there might have been an impact on, for example, the sea grass beds in front of Belize City.

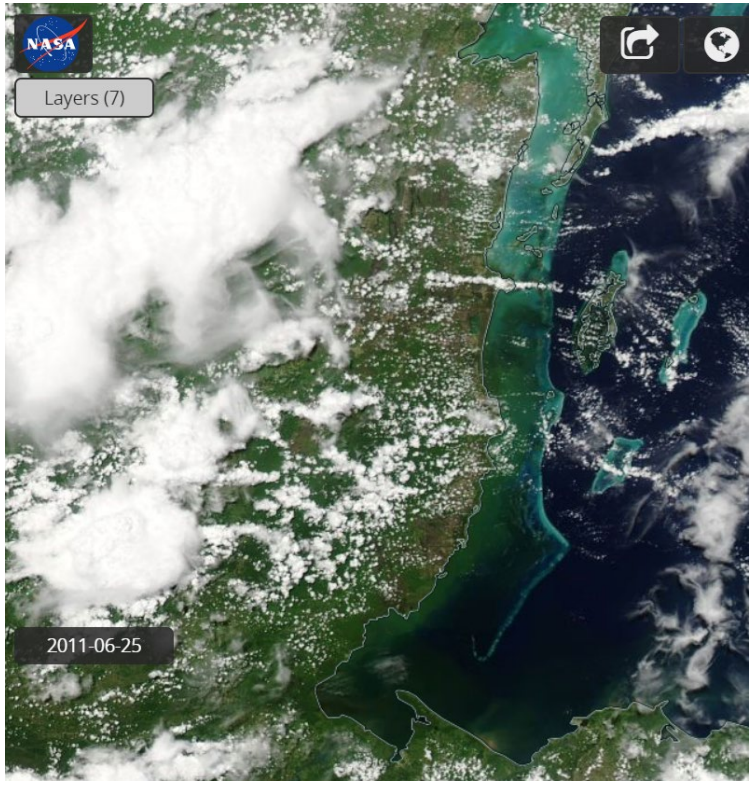
A similar event took place in April and May of 2011 when, as the result of forest damage caused by Hurricane Richard in October 2010 and in combination with an unusually strong dry season, there developed a large number of wildfires in Central Belize. These fires raged for nearly two months, affecting approximately 86,400 ha / 213,500 acres of broadleaf forest, this being in addition to the "usual" savannah and pine forest fires[2] (Fig. 1). Once the rainy season started, much of the ash washed away and with the bulk of the fires being centred in the Belize River Valley, much of this nutrient rich ash must have been washed into the Belize River.

In May of the same year, reports started to appear of a large algae bloom in Southern Belize waters[3]. Algae blooms are typically a result of sudden nutrient inputs in the marine environment and some people suggested that the nutrient input caused by the fires in the Belize River Valley might have been to blame, but the actual link was never investigated.

source: State of the Coast (2014)



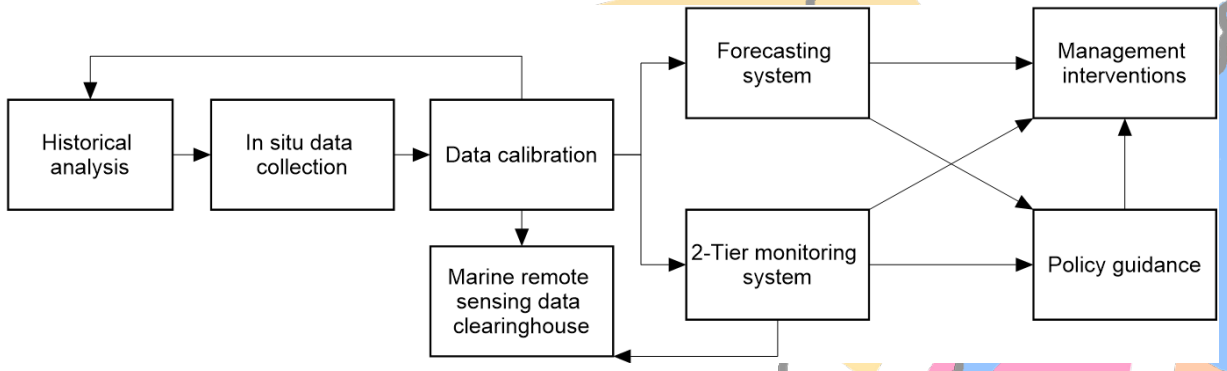
source: NASA Giovanni



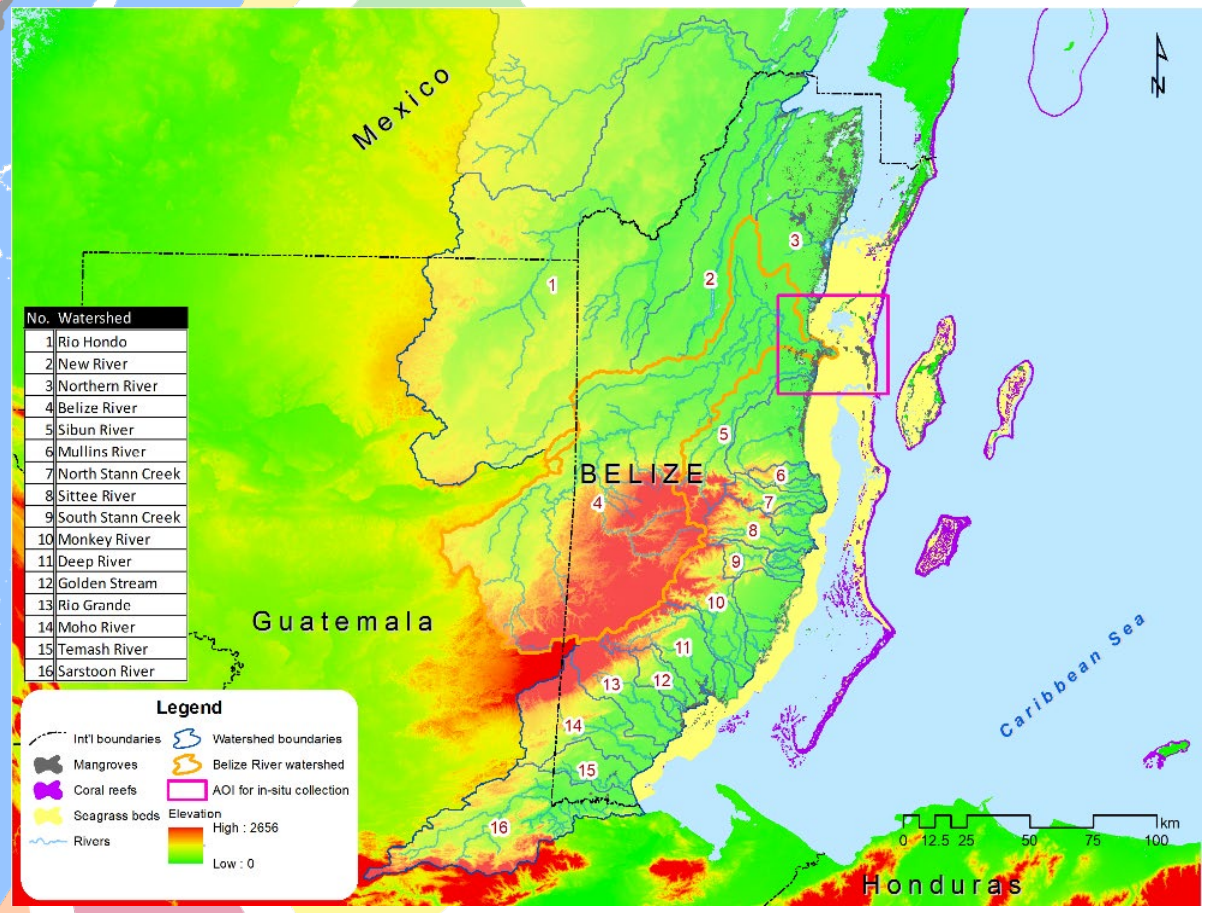
NASA MODIS Aqua image of summer 2011 algal bloom

Project overview (1)

- **Specific objectives:**
  - i. Utilize NASA, ESA data for assessing **land impacts** on **marine environment**
  - ii. Develop national monitoring + forecasting capabilities for marine pollution
  - iii. Transfer scientific + technical capacities to GOB entities [+ NGOs]
  - iv. Develop policy recommendations re: SDG 14, 15 targets



project activities

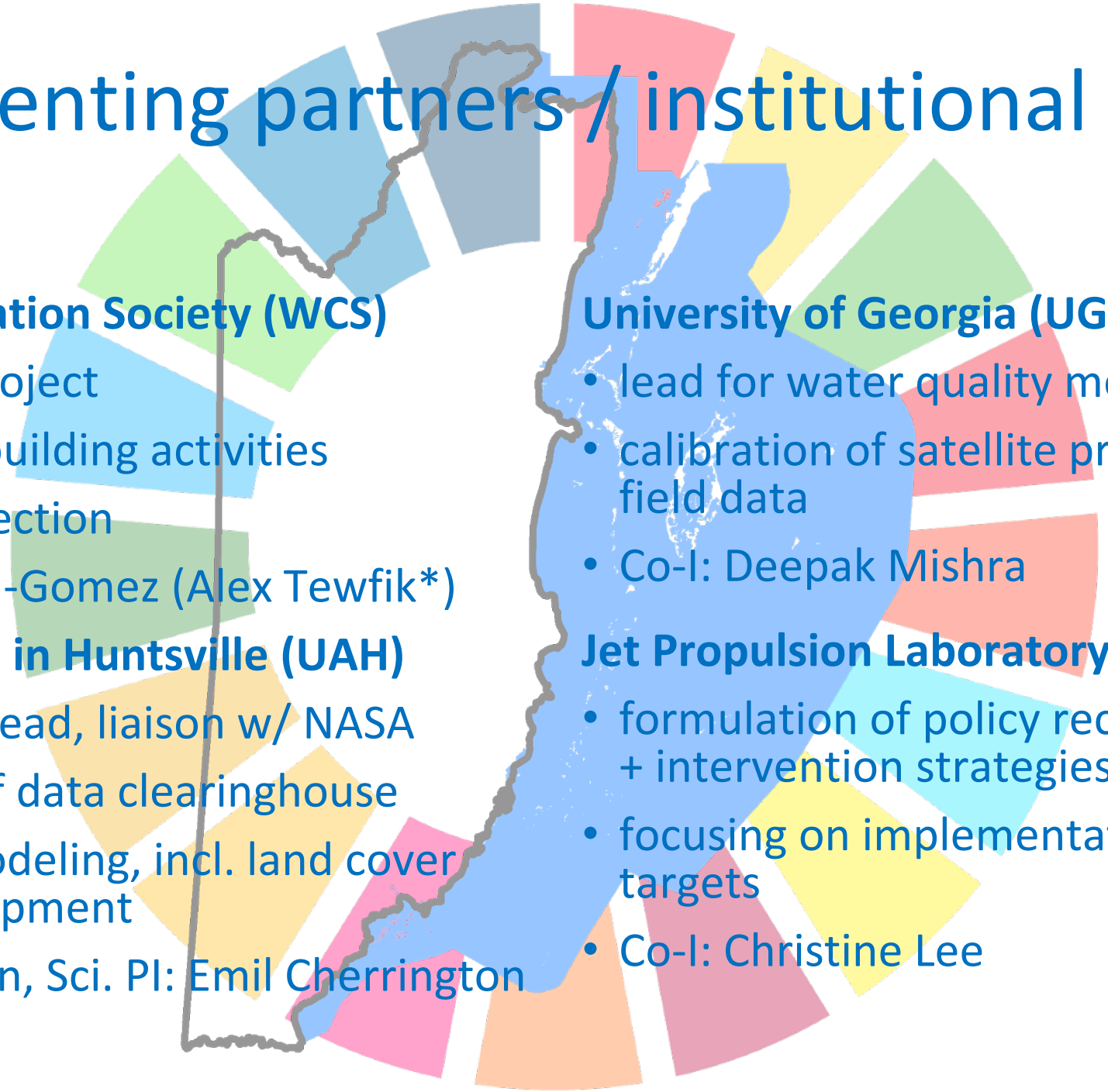


geographic domain

Project overview (2)

- **Geographic focus:** Belize Barrier Reef Lagoon (marine segment), Belize River Watershed (terrestrial segment)
- **Focus areas:** monitoring of sediments, algal blooms across BBR lagoon
- **Potential local stakeholder organizations:** CZMAI, Dept. of the Environment, Fisheries Dept., National Met. Service, broader GOB
- **Linkages w/ international efforts:**
  - Group on Earth Observations (GEO): GEO Marine Biodiversity Observation Network (MBON), Americas Group on Earth Observations (AmeriGEO)
  - United Nations Sustainable Development Goals (SDGs)

Implementing partners / institutional roles



Wildlife Conservation Society (WCS)

- local lead for project
- leads capacity building activities
- in situ data collection
- Co-I: Nicole Auil-Gomez (Alex Tewfik*)

Univ. of Alabama in Huntsville (UAH)

- overall project lead, liaison w/ NASA
- development of data clearinghouse
- hydrological modeling, incl. land cover scenario development
- PI: Robert Griffin, Sci. PI: Emil Cherrington

University of Georgia (UGA)

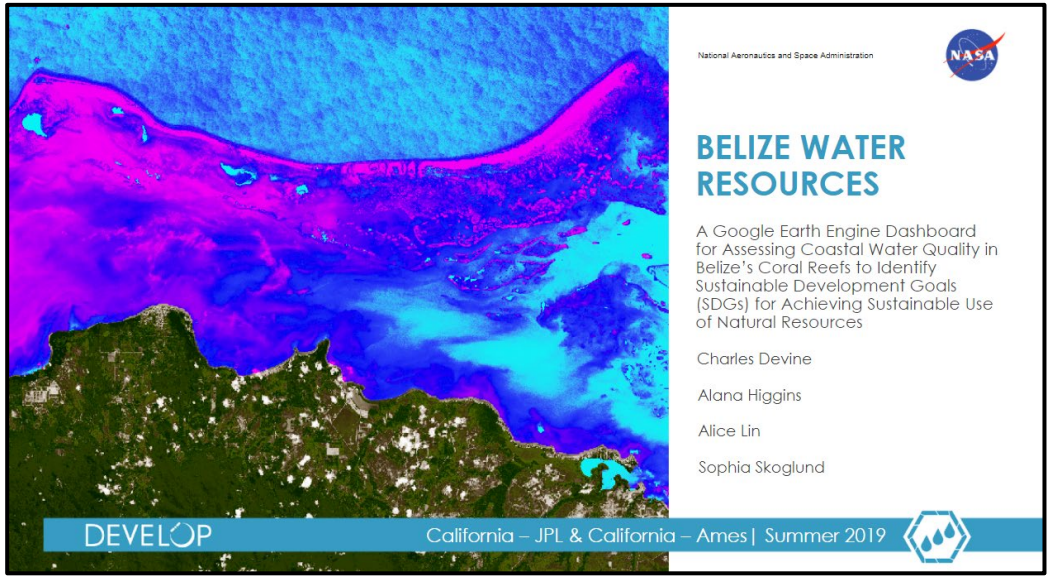
- lead for water quality modeling
- calibration of satellite products using field data
- Co-I: Deepak Mishra

Jet Propulsion Laboratory (JPL)

- formulation of policy recommendations + intervention strategies
- focusing on implementation of SDG 14 targets
- Co-I: Christine Lee

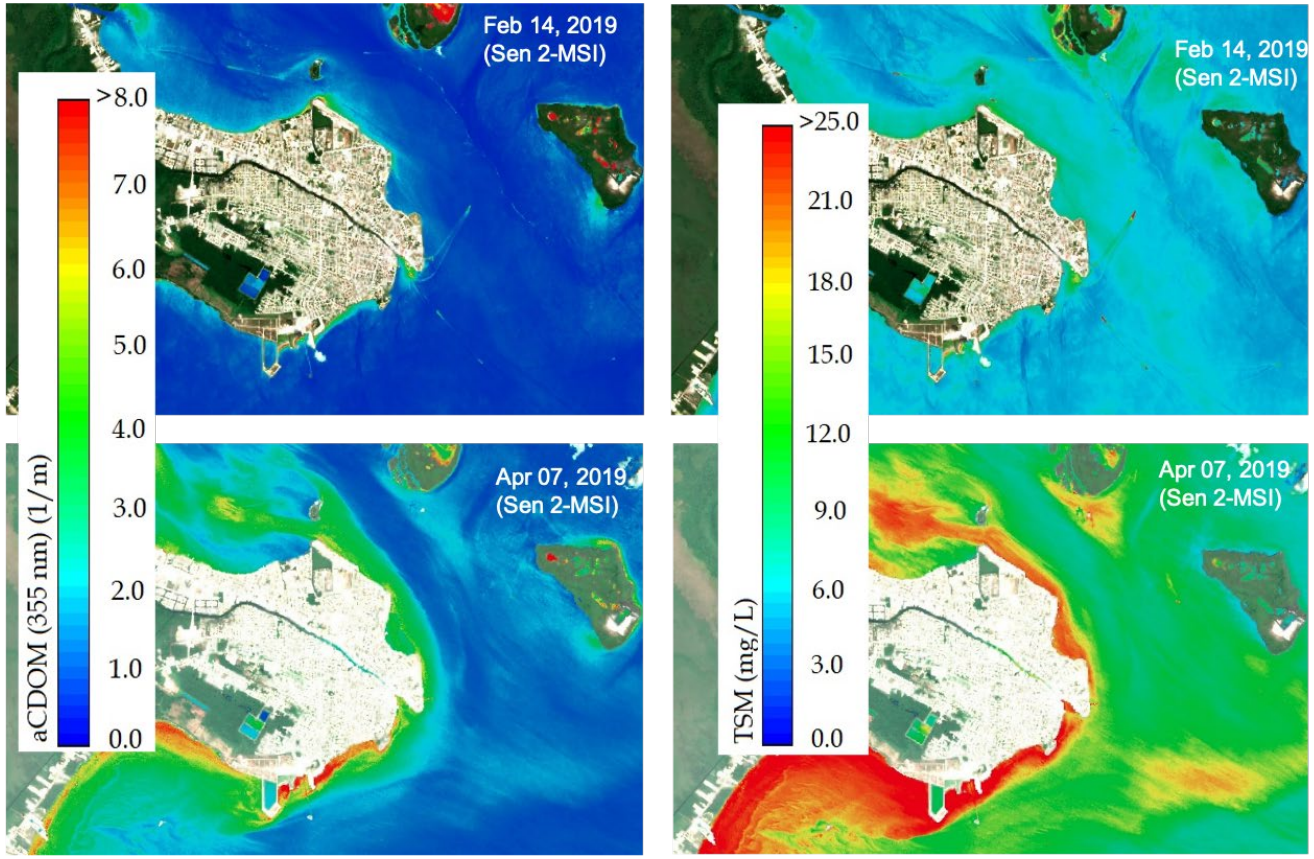
Water Quality Remote Sensing

(D. Mishra, C. Lee, I. Callejas, M. Rudresh)



NASA DEVELOP

Optical Reef and Coastal Area Assessment (ORCAA) tool estimates chlorophyll-a concentration and water turbidity from Sentinel-2 imagery



Remote Sensing Observed Parameters: CDOM (left), TSM (right), T, RGB

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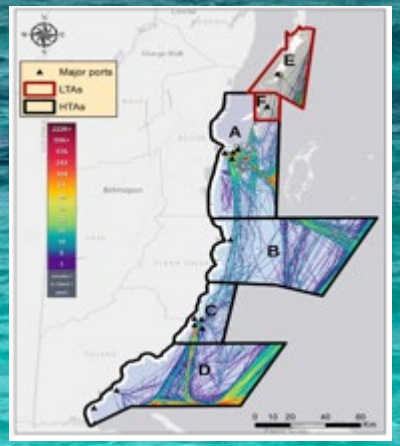
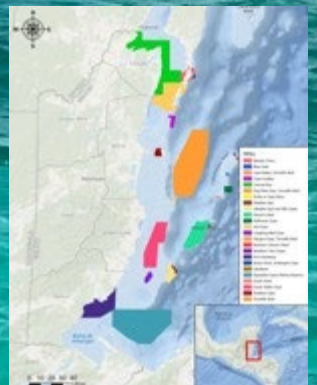
This investigation is funded by the NASA Biological Diversity and Ecological Forecasting Program and the Rapid Response and Novel Research in Earth Science Program; Grants #80NSSC19K0200 and #80NSSC20K1746

Utilizing Remote Sensing for SDG-14 Applications in Belize

Marine traffic and water quality



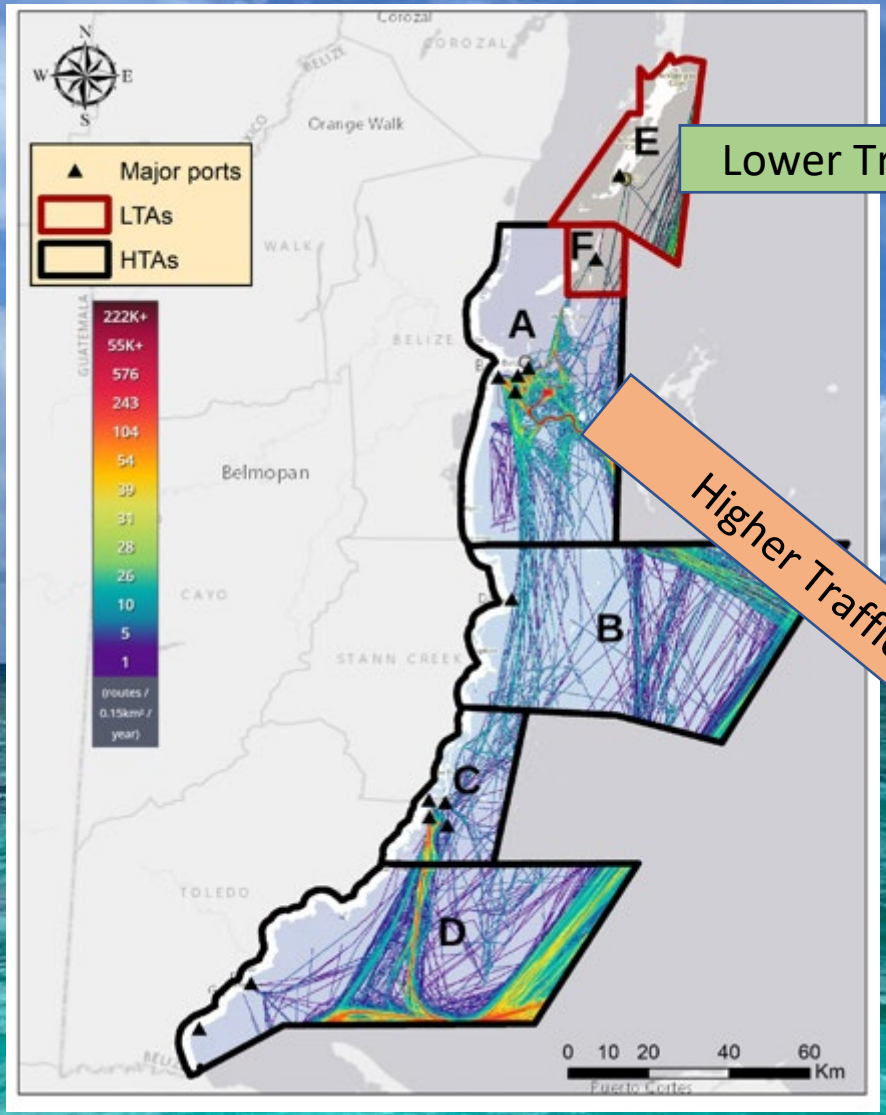
Coral stressors in Marine Protected Areas



Linking stressors with bleaching extent

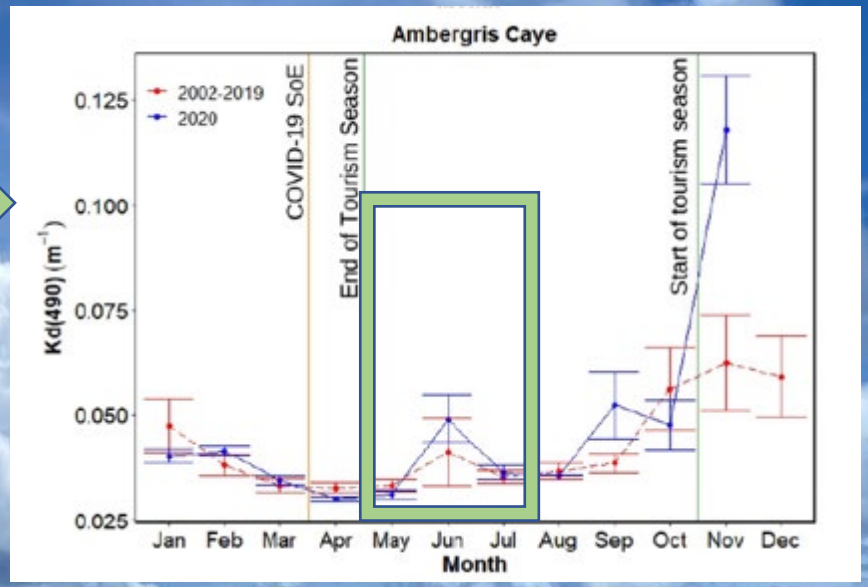
credits: Christine Lee / NASA JPL

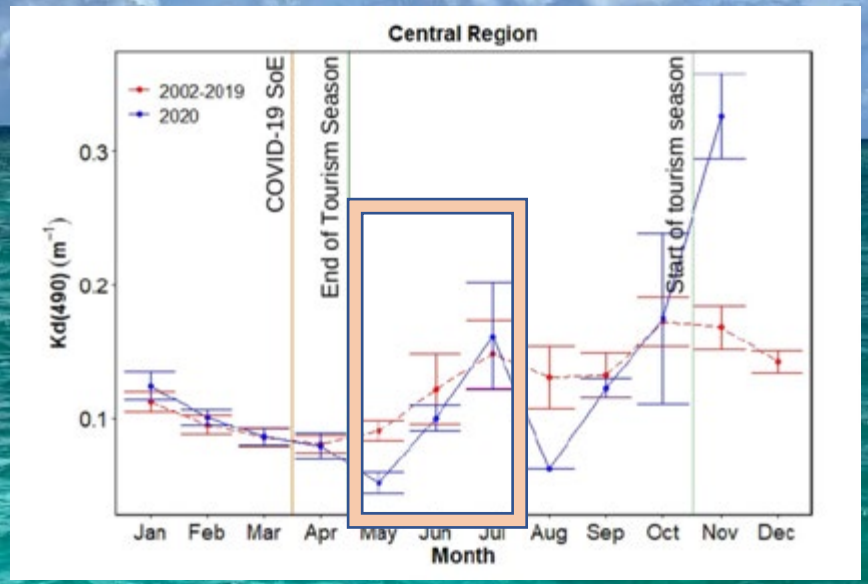
Departures from long term water clarity baseline during covid shutdown



Lower Traffic

Higher Traffic





https://doi.org/10.3389/fmars.2021.648522 Joint publication with CZMAI, Callejas et al 2021

credits: Christine Lee / NASA JPL

Utilizing Remote Sensing for SDG-14 Applications in Belize

Questions for discussion today:

- **Ideas Supporting the ICZMP process and plan - inclusion of 3-4 case studies (2-3 water quality, 1 watershed)**
- **Other ideas**
  - **Harmful algal blooms**
  - **Resilient Reefs Initiative**
  - **Other**

2016 Belize Integrated Coastal Zone Management Plan

Coastal Research and Monitoring Actions/Goals

1. Develop a centralized **data repository** for Belize on ecosystem health and human use activities within the coastal zone
2. Facilitate data accessibility among government agencies and non-governmental organizations for **monitoring ecosystem health** and **human use impacts on the coastal area**
3. Establish a national **water quality monitoring** programme for Belize
4. Develop a long-term national strategy for **the scientific monitoring of the health of critical habitats,** including but not limited to reef, seagrass, mangroves, and coastline dynamics
5. Prepare annual State of the Coast Report to **analyze trends** and **changes in the coastal zone**

credits: Christine Lee / NASA JPL

In Situ Observations

(N. Auil Gomez, M. Phillips, D. Mishra)

M. Phillips & K. Gale, YSI data collection 2021

M. Rudresh, C. Wheelock, 2021

NH3, (NO2+NO3), TOC, TN, TSS (mg/L), Secchi (cm), pH, temperature (C), salinity (ppt), DO (%, mg/L)

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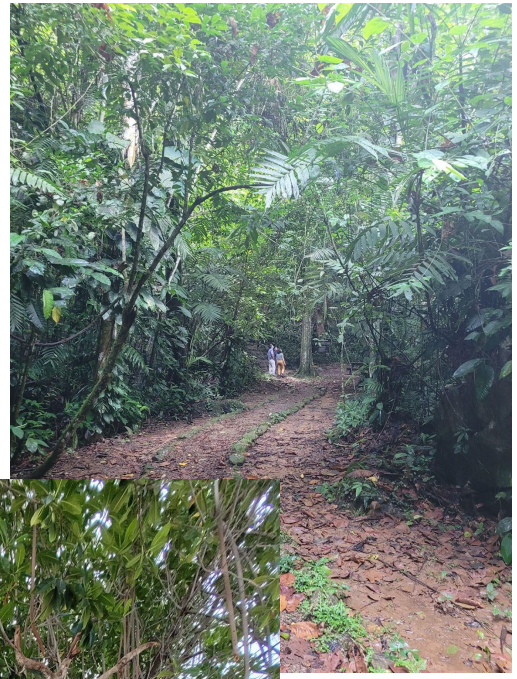
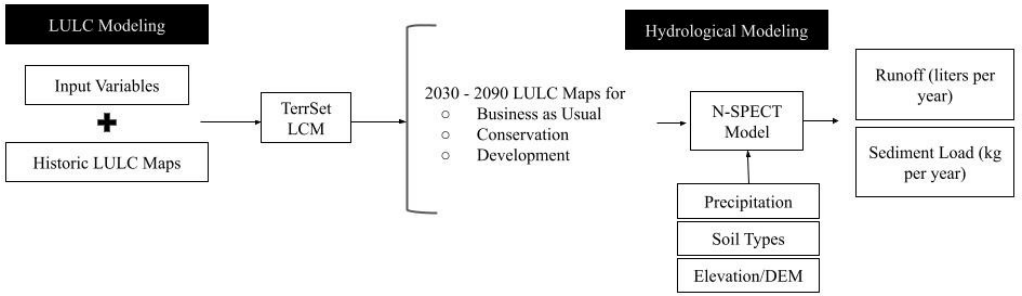
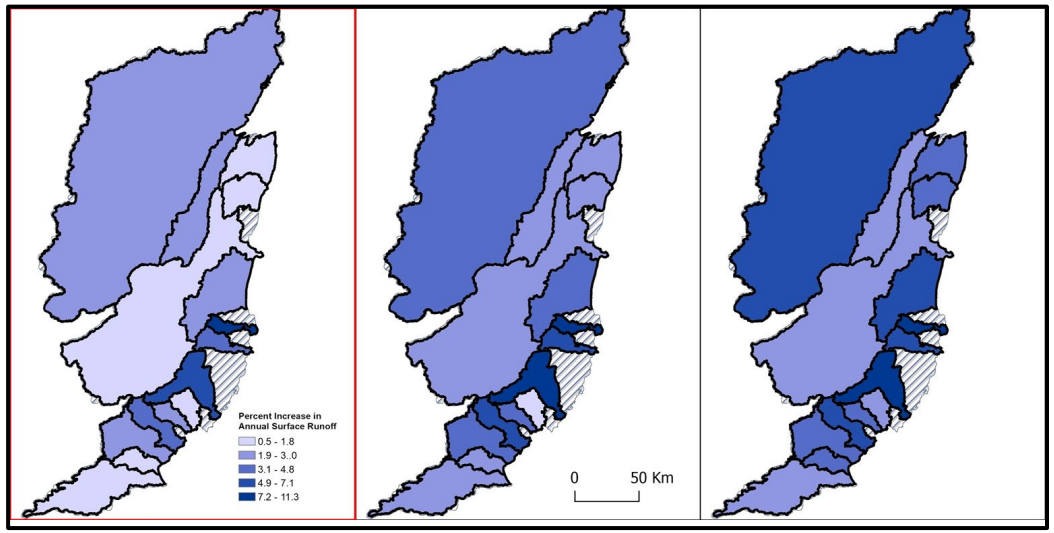
Field Work

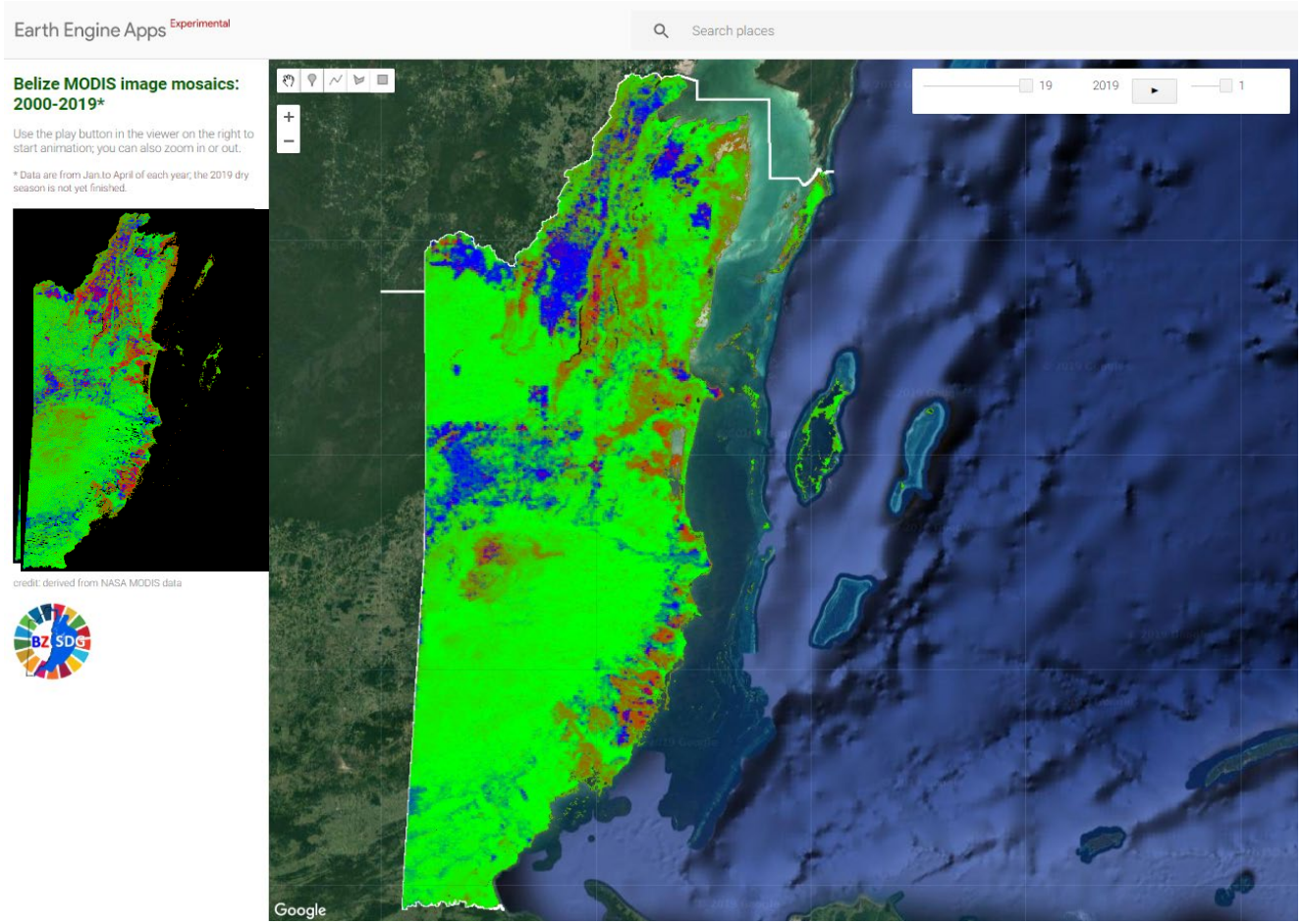


Hydrologic & LCLUC Modeling

(R. Griffin, E. Cherrington, V. Martin, C. Evans)







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Earth Engine Apps Experimental

Search places

Belize River Watershed forest cover change, 2001-2018 (option 2)

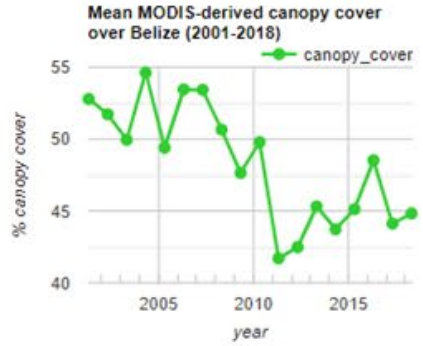
instructions: swipe left to display forest cover maps; swipe right for source spectrally unmixed MODIS images

Legend:

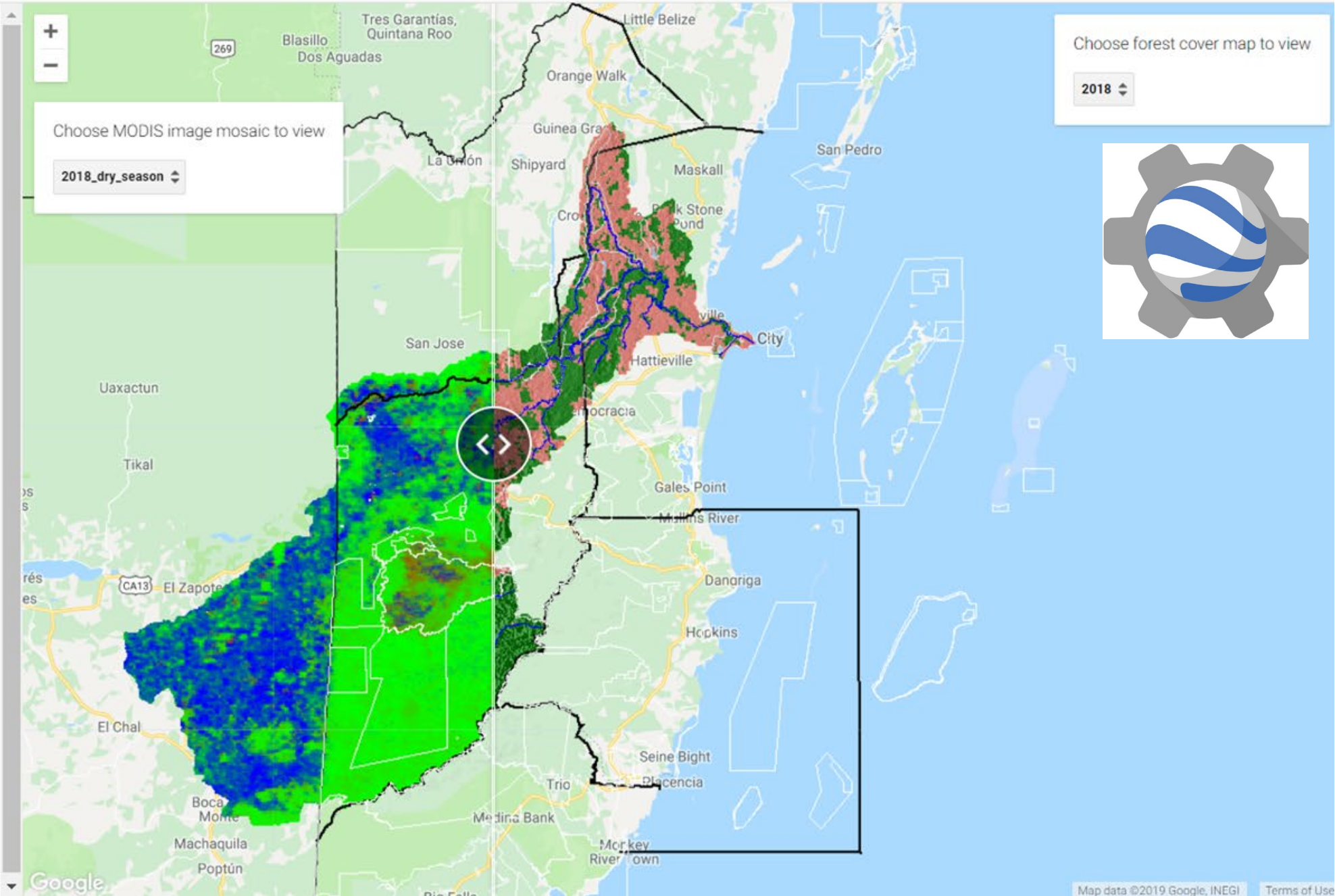
non-forest forest

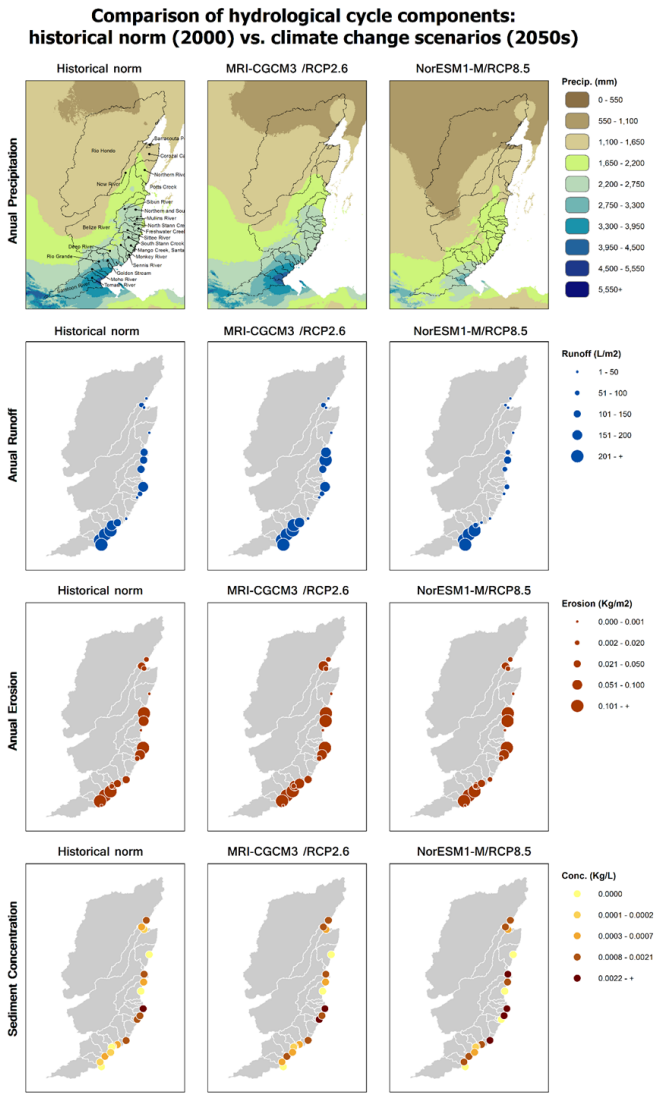
Other visualizations:

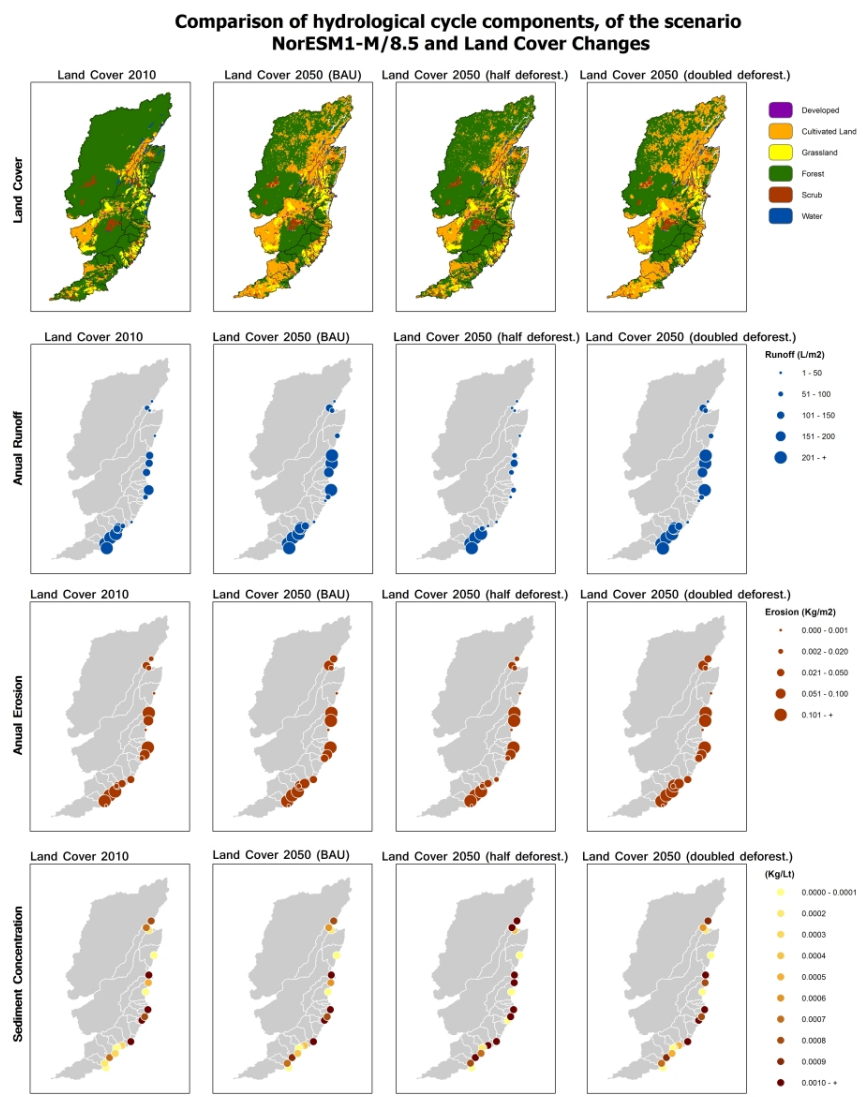
Option 1: compare 2 forest cover maps



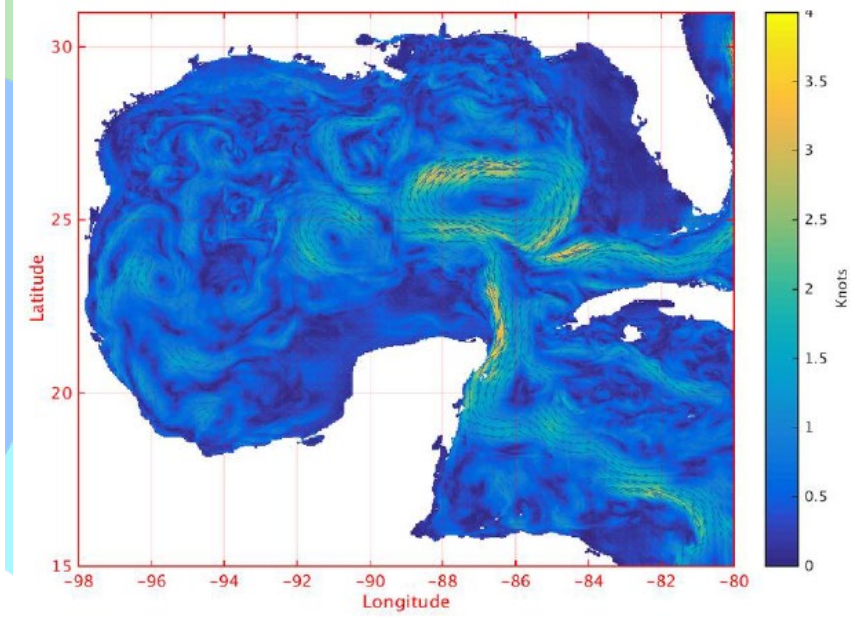
credit: derived from NASA MODIS data







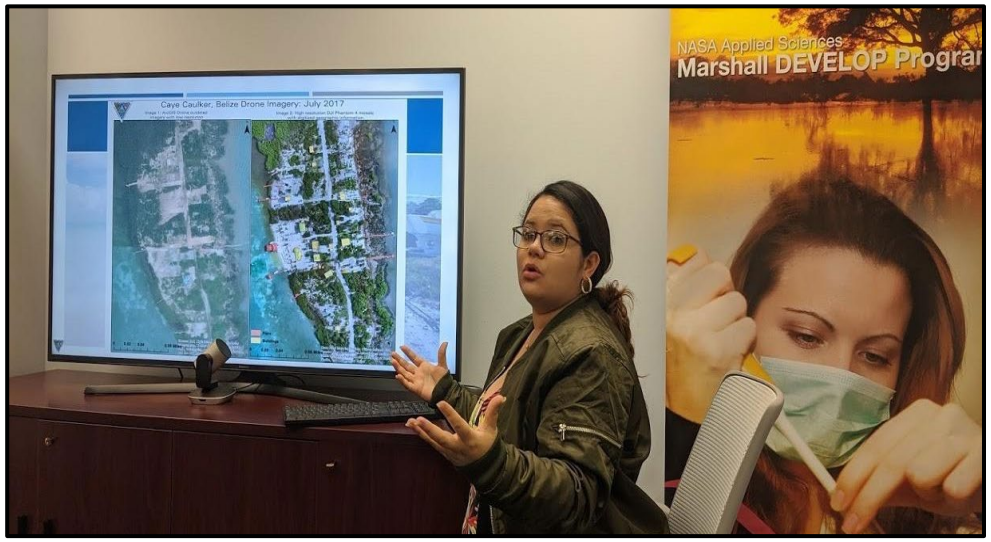
source: Cherrington et al. (2015)



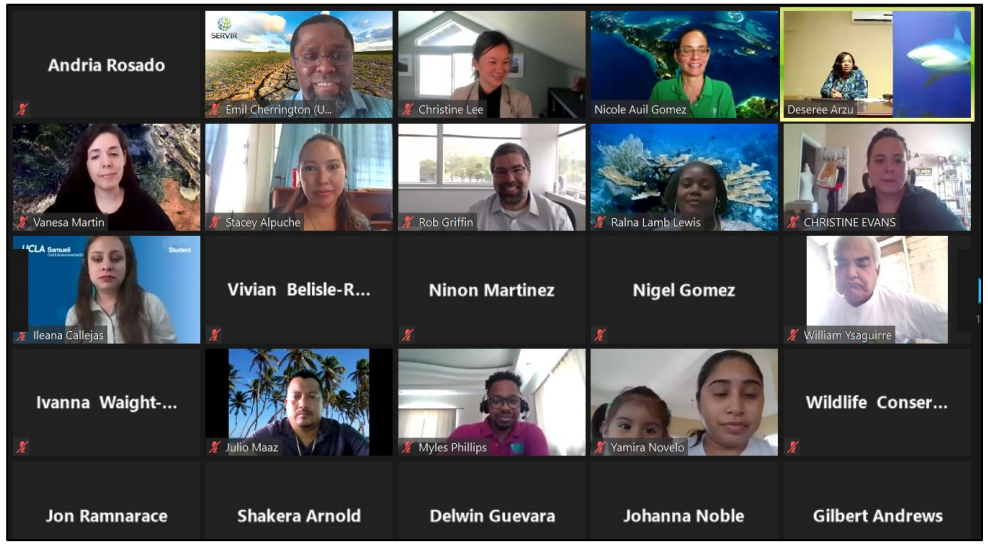
source: NOAA

SDGs and Capacity Building

(C. Lee, N. Auil Gomez, E. Cherrington)



Andria Rosado, CZMAI, January 2020 in Huntsville



April 2021 Virtual Workshop with BZ Stakeholders

"WCS is thrilled to be partnering on this exciting project that builds on our in-water data collection and NASA's Earth observation data in ways I could not have imagined. We came into this with a land-to-sea approach, but really seeing how our partners have used historical and current data to assess land use scenarios, runoff, sedimentation, and water quality to offer predictions of future states of our land, watersheds and seascape is just exciting. We need to now apply these in national decision processes to meet Belize's commitments to the UN SDGs, as our priority."

Nicole Auil Gomez, Belize Country Director for the Wildlife Conservation Service

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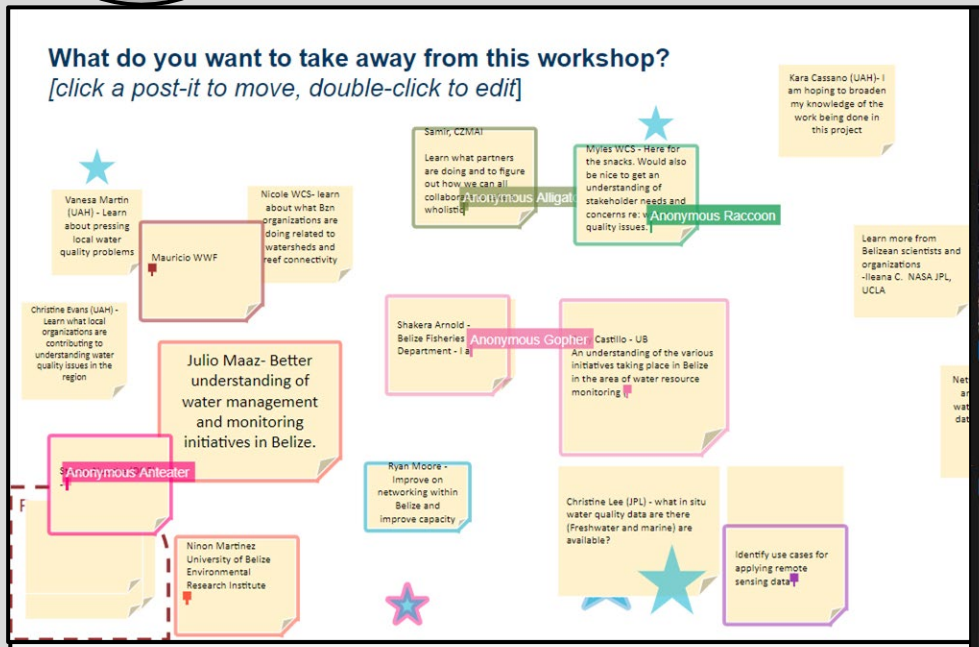
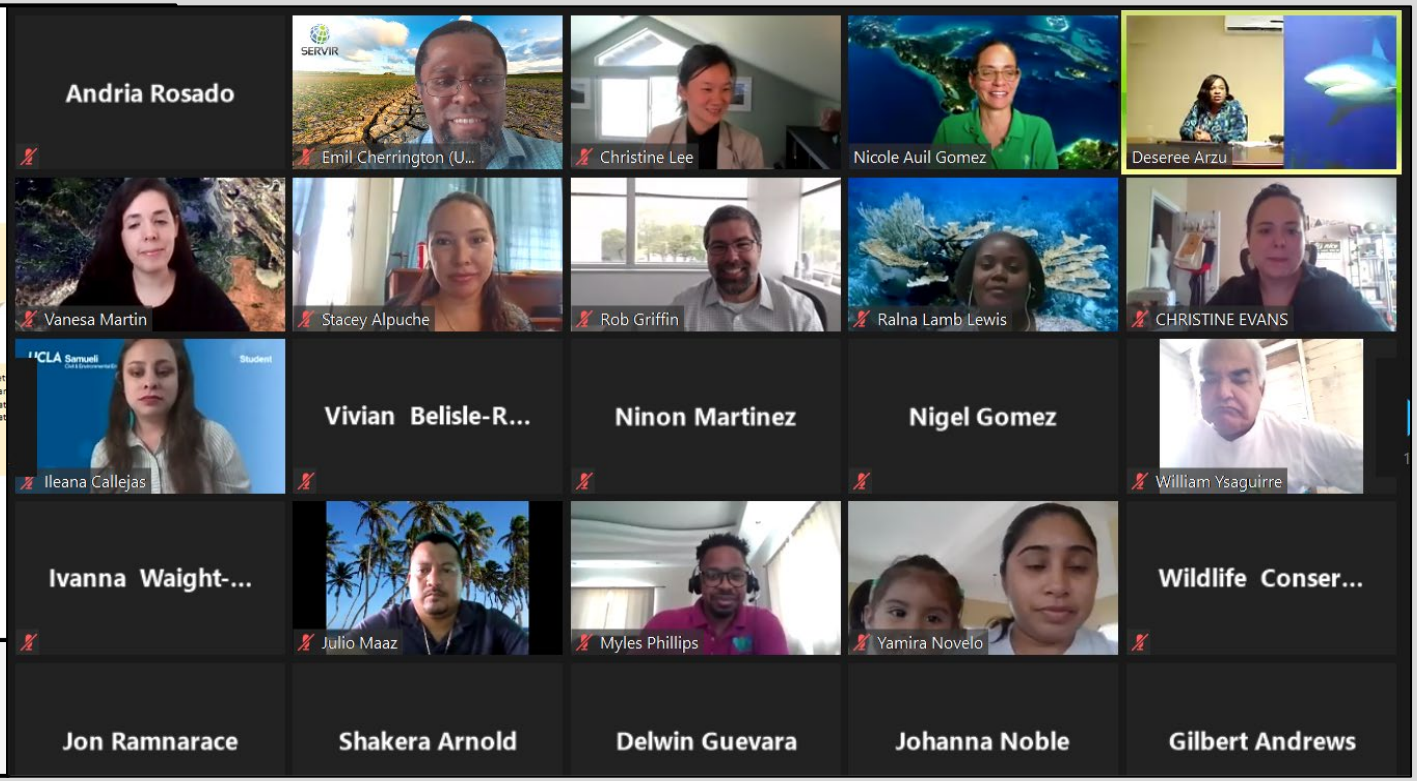
Workshop outcomes

Arlene Young, Director of CZMAI: "I would like to keep abreast of what's occurring in the field as it pertains to water resource management and monitoring initiatives taking place and potentially look at areas for collaboration where the university can partake and partner with you all in the field…"

Andria Rosado, Data Manager at CZMAI: "...Improving coordination and collaboration in water quality monitoring across agencies in the government and outside of the government."



Interactive brainstorming sessions with all participants about workshop expectations



Meetings

Ministry of Agriculture, Fisheries, Forestry, Environment, Sustainable Development and Immigration, Coastal Zone Management Authority & Institute, US Embassy - Belize, Ministry of Blue Economy and Civil Aviation, National Biodiversity Office, Climate Change Office

CZMAI :

- Interested in trainings on modeling softwares used by Vanesa (TerrSet) and Christine (NSPECT)
- Also in training on NASA DEVELOP tool: ORCA
- Willing to share water quality samples for UGA to continue tweaking their atmospheric corrections of satellite imagery
- Continuing communications with UCLA/JPL to expand on the coral bleaching effort

Department of Environment:

- Adapting our modeling workflow for their individual goals and AOIs
- DOE has pollution control mandate, and modeling provides perspective on that

Summary: Considerations

- How have we calibrated 20+ yrs of sat. data to adequately estimate WQ parameters?
- How can in situ + RS data be combined for Belize's reporting on indicators + targets related to SDGs 14 + 15?
- How can this work be integrated into the operations of the relevant govt. agencies?
- What policies / regulations need to be put in place to ensure attaining the SDGs?
- Which agencies need to be engaged to ensure attainment of the SDGs, and successful implementation of this project?

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Questions?

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me: cae0004@uah.edu

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