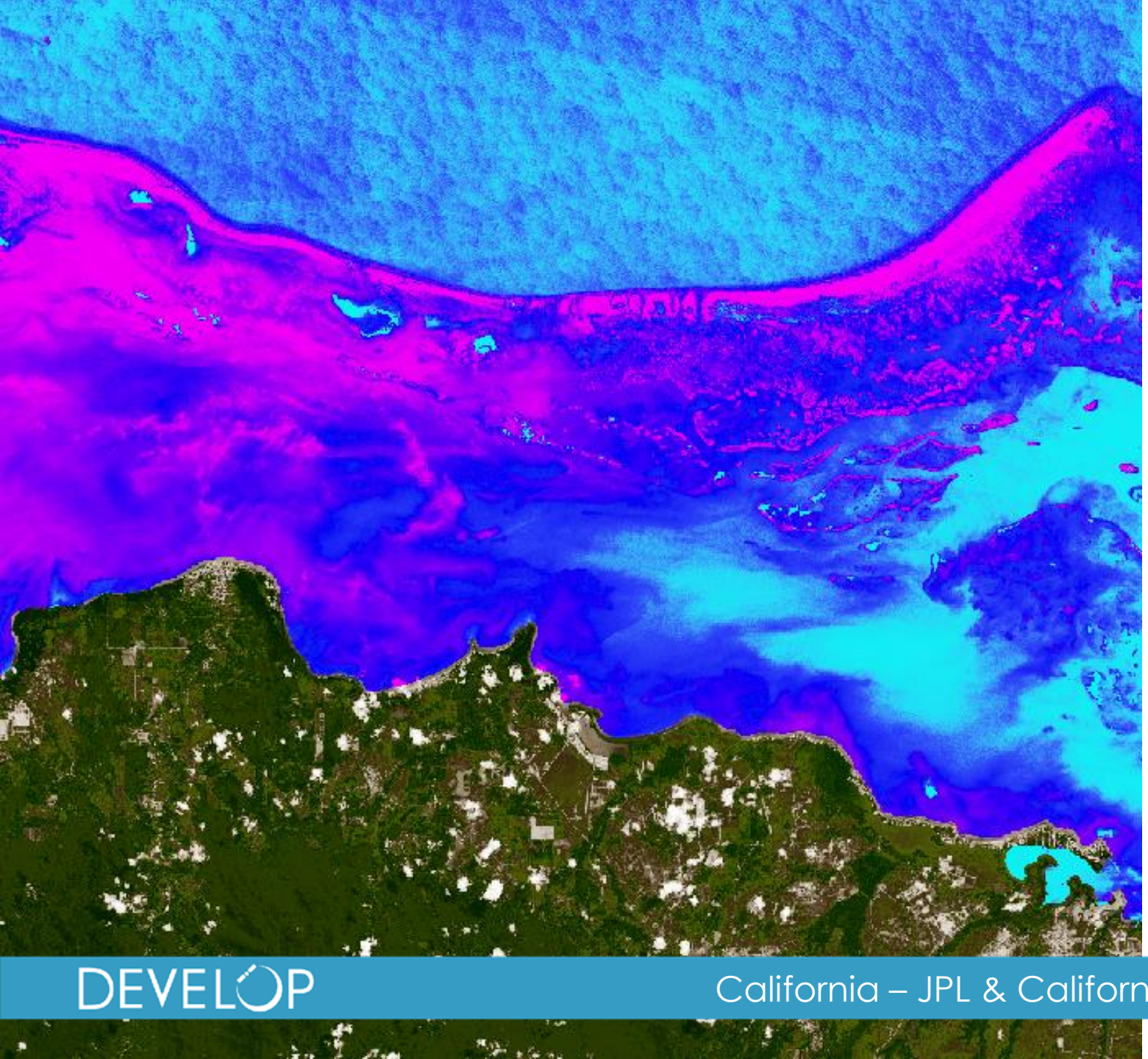


National Aeronautics and Space Administration

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

Charles Devine

Alana Higgins

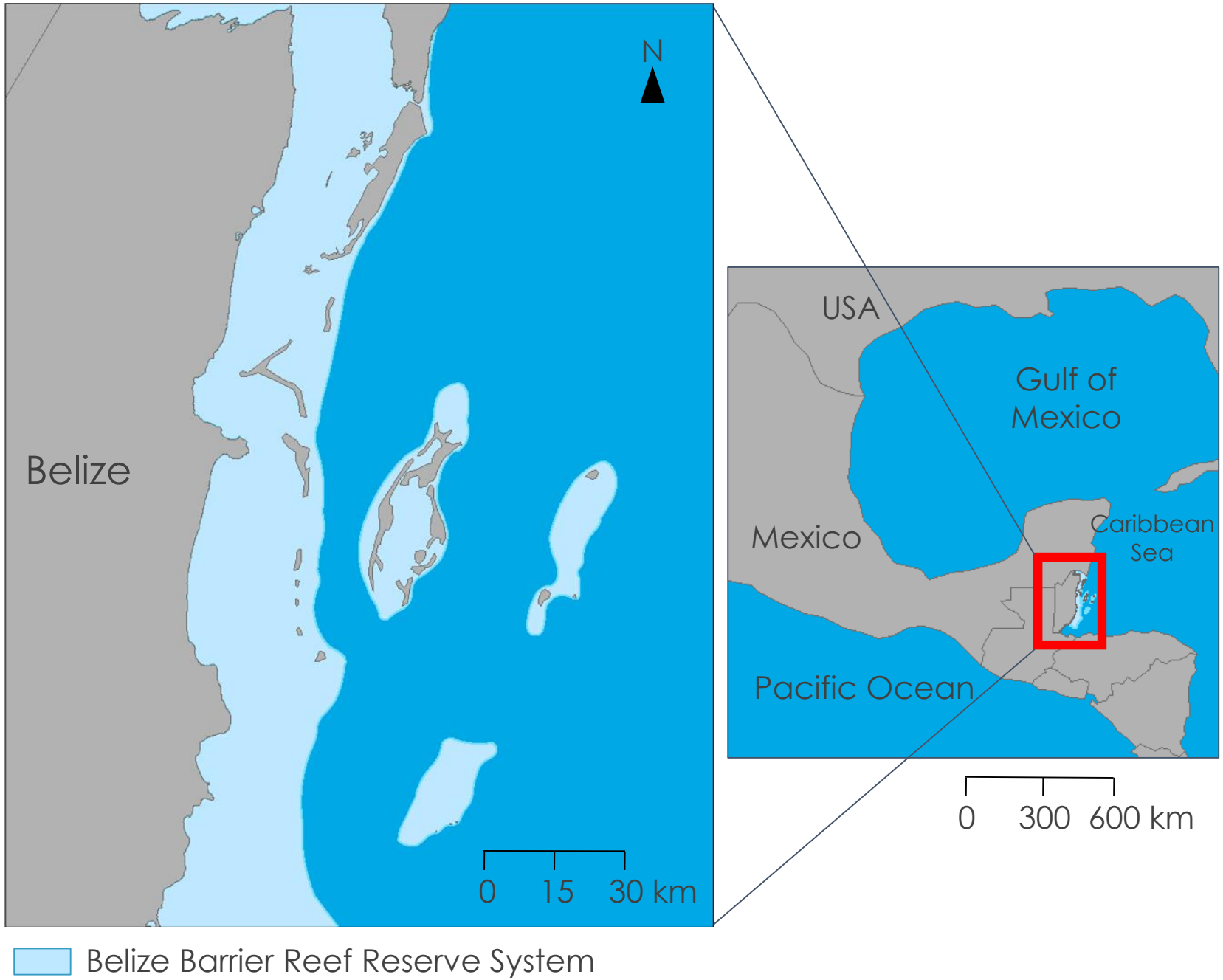
Alice Lin

Sophia Skoglund

Study Specifics

Study Area

- Belize Barrier Reef Reserve System
- Located along Central American coastline
- Impacted by water quality changes



Study Specifics

Study Period

- February 2013 to present
- Emphasis on period before and after Hurricane Earl in August 2016

Hurricane Earl over Central America
Image Source: Naval Research Laboratory Monterrey, NASA

Objectives

1. **Support** project partners in efforts to improve coastal management

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1. **Support** project partners in efforts to improve coastal management

2. **Create** a Google Earth Engine (GEE) dashboard to generate maps and time series information for chlorophyll-a & turbidity

3. **Validate** GEE results with ACOLITE algorithm outputs to ensure accuracy

4. **Apply** dashboard to coastal case studies to identify reef areas that may be vulnerable to poor water quality

Project Timeline

University of California, Berkeley

Spring 2019

- Graduate students from the University of California, Berkeley
- Derived **turbidity** in GEE using Level 2 data from Landsat 8 and Sentinel-2
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- Collaboration between JPL and ARC
- Expanded tool to derive **chlorophyll-a** from Sentinel-2
- Developed user-friendly interface
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DEVELOP Fall 2019

- Continue expanding tool to meet partner needs

Image Source: NASA

Partners

Wildlife Conservation Society (WCS)

Coastal Zone Management Authority and Institute (CZMAI)

Image Source: European Space Agency (ESA) Copernicus

Community Concerns

- The Belize Barrier Reef supplies numerous **ecosystem services**, such as shoreline protection, tourism, habitat for marine species, and fisheries.
- This reef system contributes to approximately **12 to 15% of the Belize GDP**.
- Natural disturbances and human activities can have **detrimental effects on coastal water quality**.
- Improving water management practices requires a robust **monitoring system** that is spatially and temporally comprehensive.

Image Source: ESA Copernicus

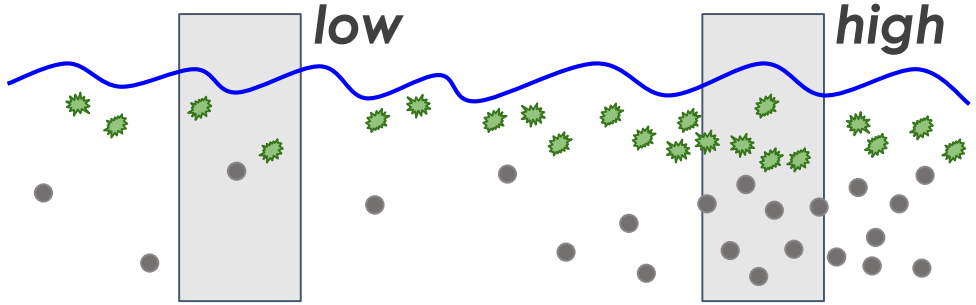
Water Quality Parameters

Chlorophyll-a

- Photosynthetic pigment
- High [chl-a] suggests an overabundance of algae

Turbidity

- A measure of water clarity



Sea Surface Temperature

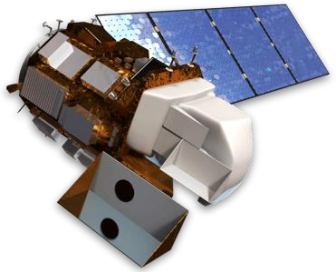
- Changes in water temperature can have dramatic effects across an ocean ecosystem. Such change can alter ocean physics (circulation), chemistry (nutrient levels), and biology (species survival). Typically, optimal coral growth occurs in water temperatures of 25 to 29 °C.

Earth Observations

Data Acquisition and Processing

Landsat 8

Operational Land Imager (OLI)

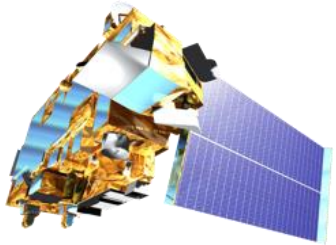


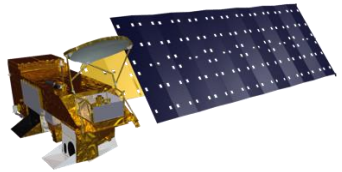
Sentinel-2

Multispectral Imager (MSI)

Terra & Aqua

Moderate Resolution Imaging Spectroradiometer (MODIS)





GEE

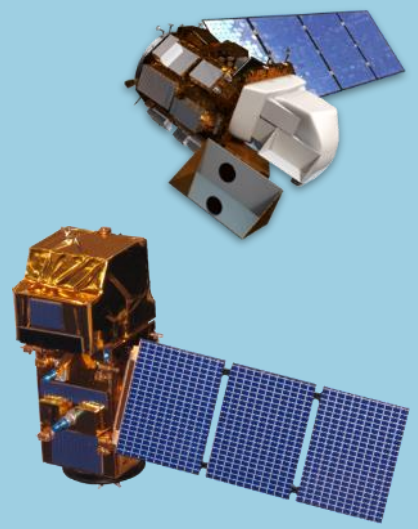
- Atmospherically corrected datasets already hosted
- Land + cloud masking

Image Sources: NASA, ESA

Methodology

Turbidity – Started by UC Berkeley PhD Students

Select data: Landsat 8 OLI, Sentinel-2 MSI



Select algorithm: Nechad

$$T = \frac{(A_T)(P_W)}{1 - (P_W / C)}$$

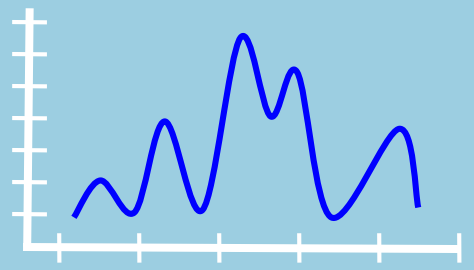
T = turbidity

P_W = water-leaving reflectance

A_T, C = calibration parameters

Implement algorithm into GEE script

Time series analysis



Spatial analysis

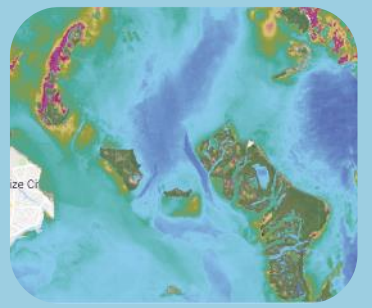


Image Source: NASA, ESA

Methodology

Chlorophyll-a

Select data: Sentinel-2 MSI

- Surface reflectance
- 6 to 12 day return
- 10 to 60 m resolution

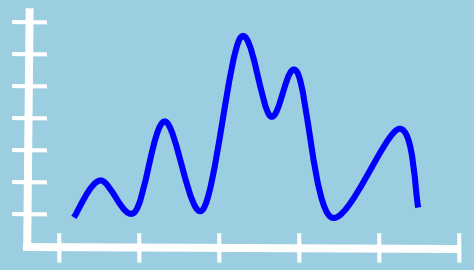
Select algorithm: Mishra

$$NDCI = \frac{R_{rs}(708) - R_{rs}(665)}{R_{rs}(708) + R_{rs}(665)}$$

→ equation for Chl-a (mg / m^3)

Implement algorithm into GEE script

Time series analysis



Spatial analysis

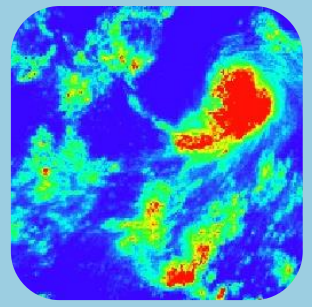
Image Source: ESA

Complementary Water Quality Parameters

PRECIPITATION

PERSIANN Climate Data Record – NOAA

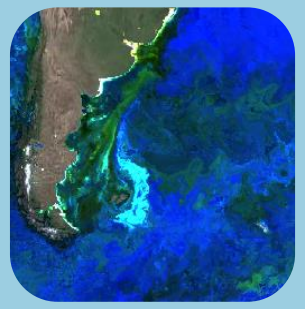
- Estimated global precipitation in mm
- Several month lag time



AQUA + TERRA MODIS – NASA

- Readily available level 3 products in GEE
- 1 to 2 day return
- 1 km spatial resolution

SEA SURFACE TEMPERATURE



CHLOROPHYLL-A (OC3)

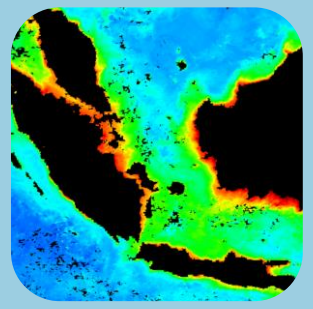
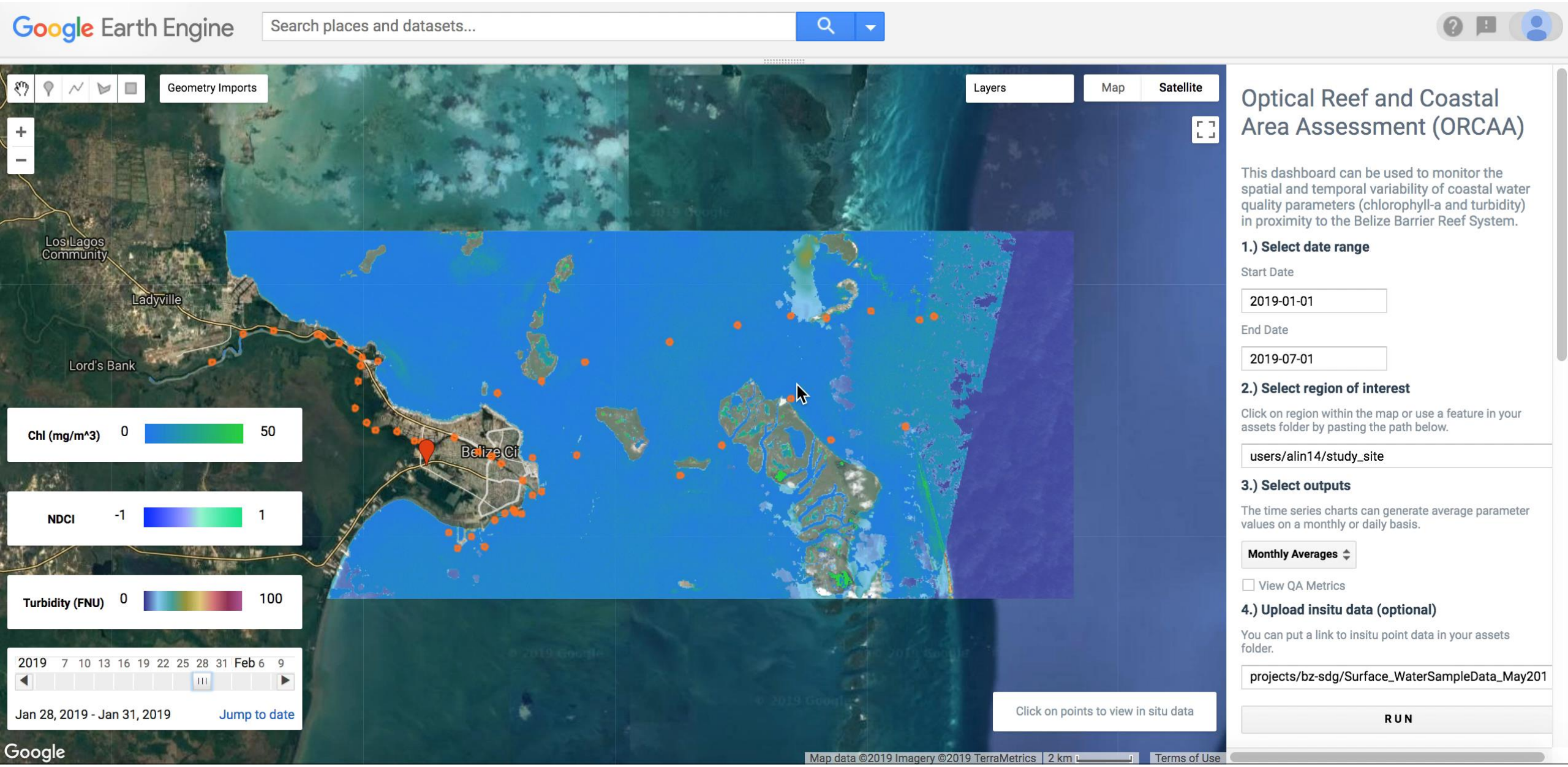


Image Sources: NOAA, NASA, Winarso & Marini (2014)

Optical Reef and Coastal Area Assessment (ORCAA)

Video Demo



Optical Reef and Coastal Area Assessment (ORCAA)

This dashboard can be used to monitor the spatial and temporal variability of coastal water quality parameters (chlorophyll-a and turbidity) in proximity to the Belize Barrier Reef System.

1.) Select date range

Start Date

2019-01-01

End Date

2019-07-01

2.) Select region of interest

Click on region within the map or use a feature in your assets folder by pasting the path below.

users/alin14/study_site

3.) Select outputs

The time series charts can generate average parameter values on a monthly or daily basis.

Monthly Averages

☐ View QA Metrics

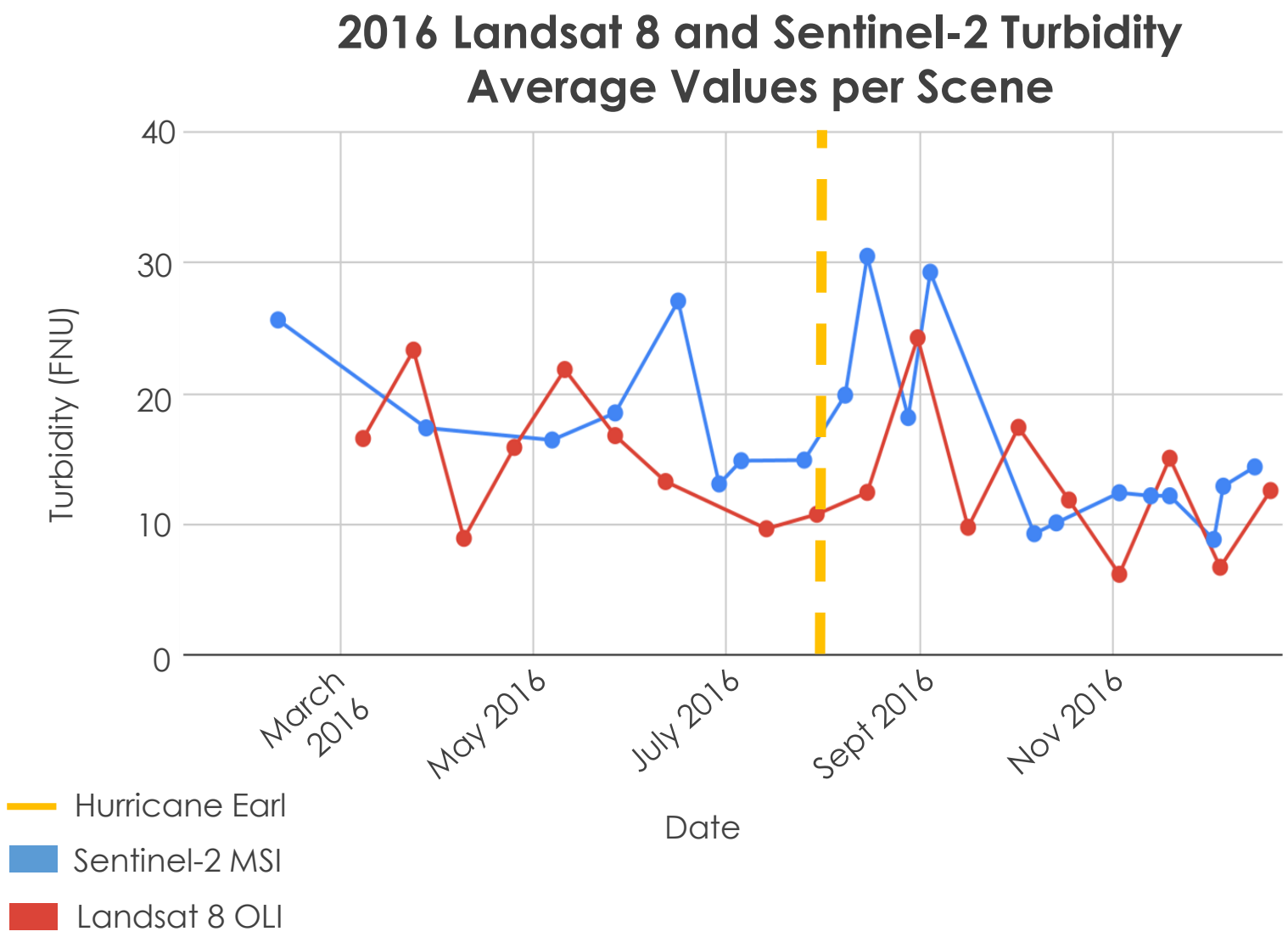
4.) Upload insitu data (optional)

You can put a link to insitu point data in your assets folder.

projects/bz-sdg/Surface_WaterSampleData_May201

RUN

Results: Time Series

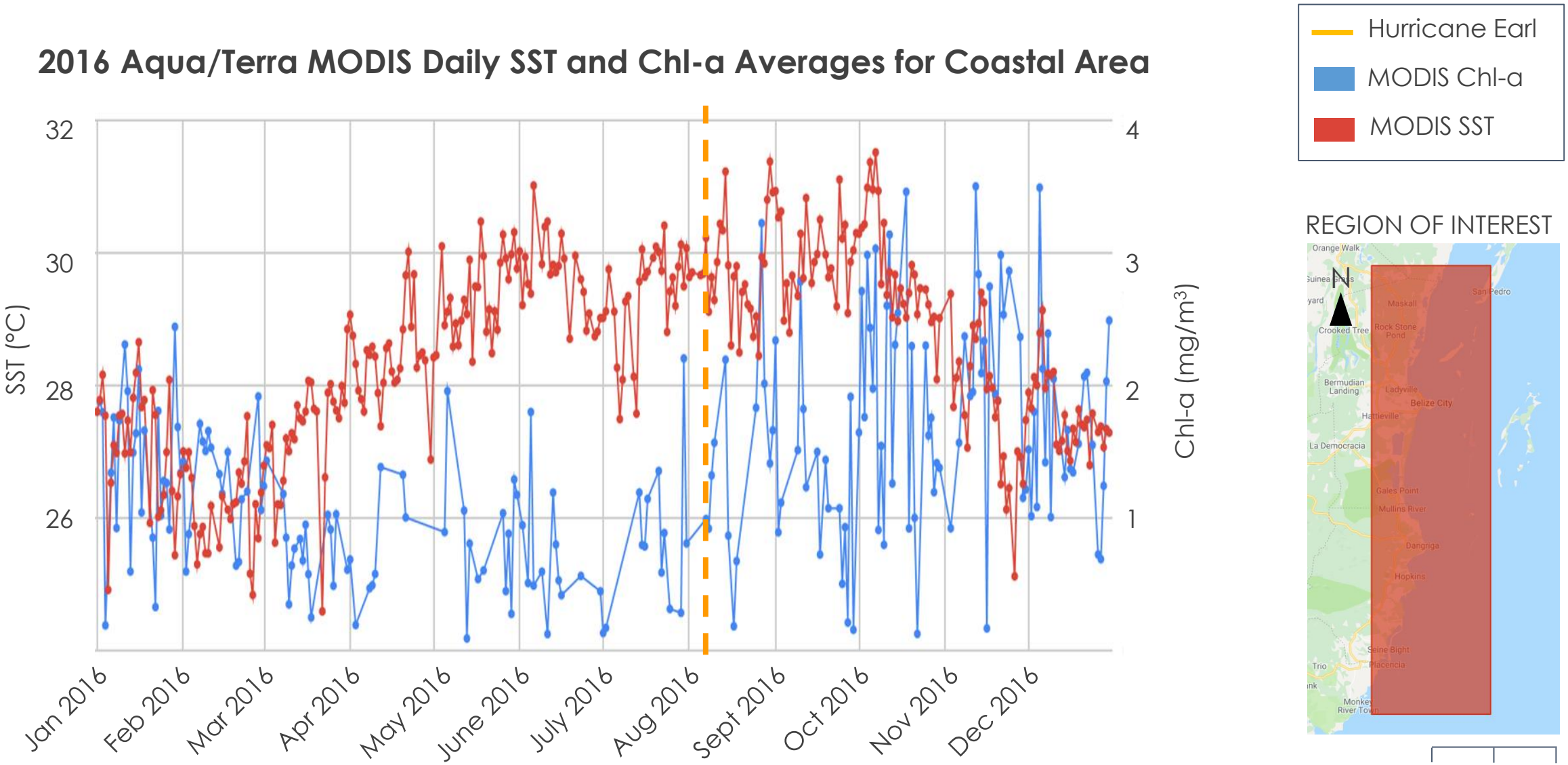


Blue: Sentinel-2 Average turbidity concentration values per available scene

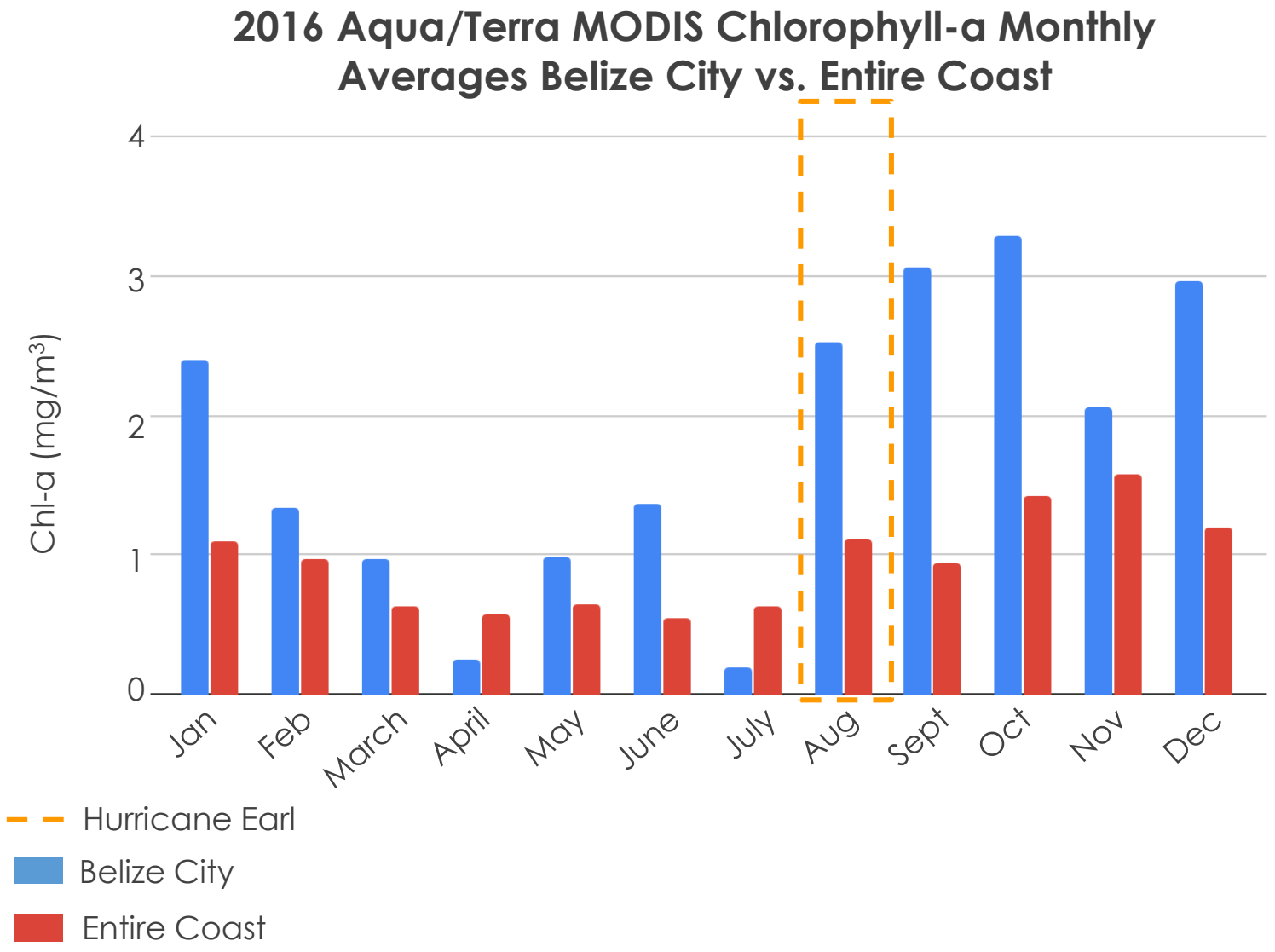
Red: Landsat 8 Average turbidity concentration values per available scene

Region of interest used for this time series:

Results: Time Series



Results: Time Series

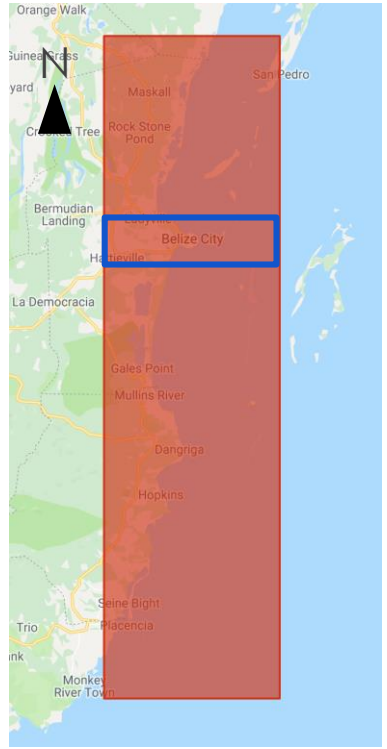


Blue: Monthly average chl-a concentration value amongst all available pixels per day surrounding **Belize City**

Red: Monthly averages for entire **coastal area**

Region of interest used for this time series:

Entire Coast vs. Belize City



Results: Validation

Assessed feasibility of using surface reflectance data from Sentinel-2 to accurately reproduce water quality outputs from ACOLITE

- January 1 and March 23, 2019
- n = 5000 (random sample)

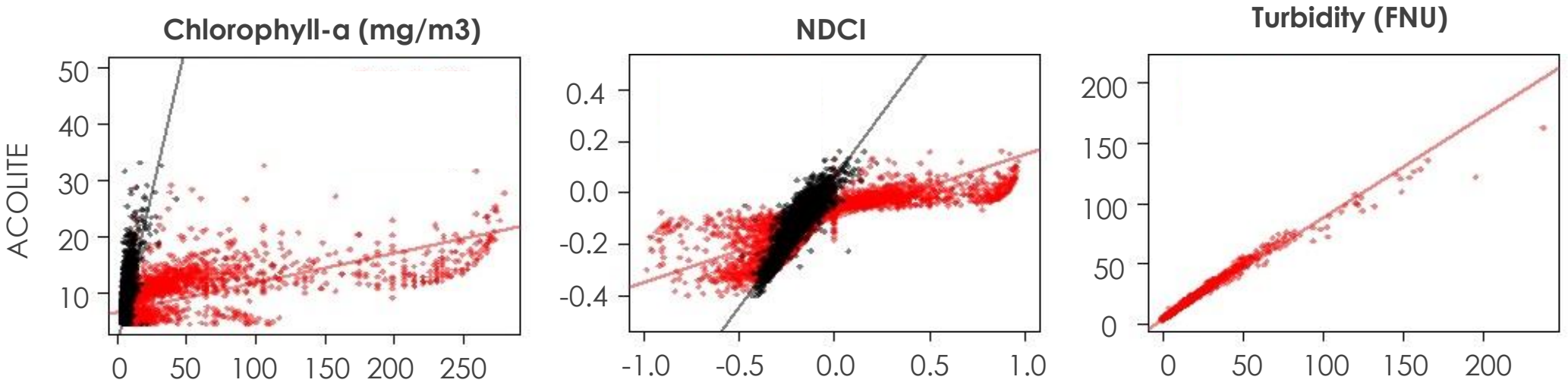
Metrics used:

- Linear regression (R^2)
- Root mean square error (RMSE)

Tested the following relationships:

- Sentinel-2 S2_SR product vs. ACOLITE
- Surface reflectance data from Ben Page (University of Minnesota)
  - Water-specific atmospheric correction

Results: Validation



Water quality parameters derived from:

Red
Sentinel-2 surface reflectance from S2_SR Level-2A product in GEE

Black
Sentinel-2 surface reflectance produced by Ben Page

Conclusions

Satellite remote sensing, combined with the Google Earth Engine platform, enhances monitoring of coastal waters over larger spatial and temporal scales.

Pre- & post-Earl analyses demonstrate the importance of monitoring across time.

Validation of our tool's output is a critical step in ensuring accuracy.

Image Source:
NASA Landsat 8

Future Work

Reliance on ACOLITE for validation	Challenges with shallow, nearshore waters	Poor atmospheric correction
Employ *in situ* data in ground truthing	Calibrate current chl-a algorithm w/ *in situ*, and/or explore other algorithms	Incorporate ocean color specific atmospheric correction to expand and improve available dataset

Check for regional correlation between water quality parameters & reef health.

"healthy" remains subjective in coral reef ecology

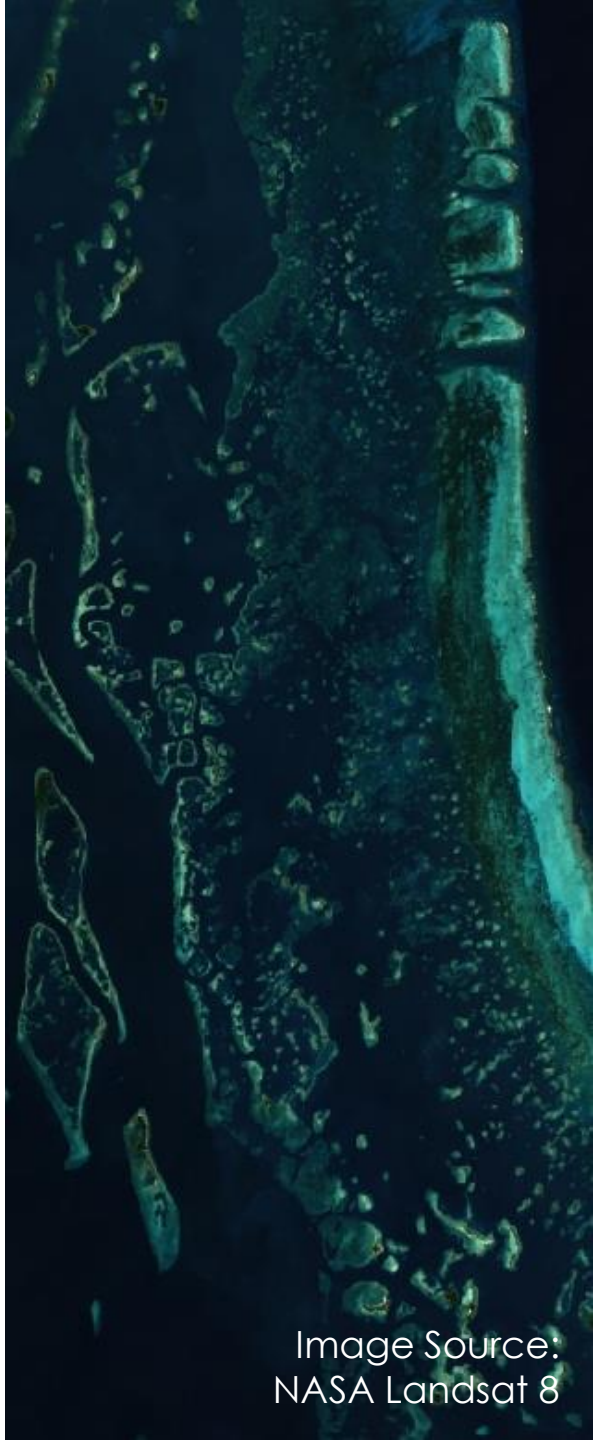


Image Source: NASA Landsat 8

Acknowledgements

DEVELOP

JPL

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Project Co-Lead

Alana Higgins

ARC

Charlie Devine
Project Co-Lead

Sophia Skoglund

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