

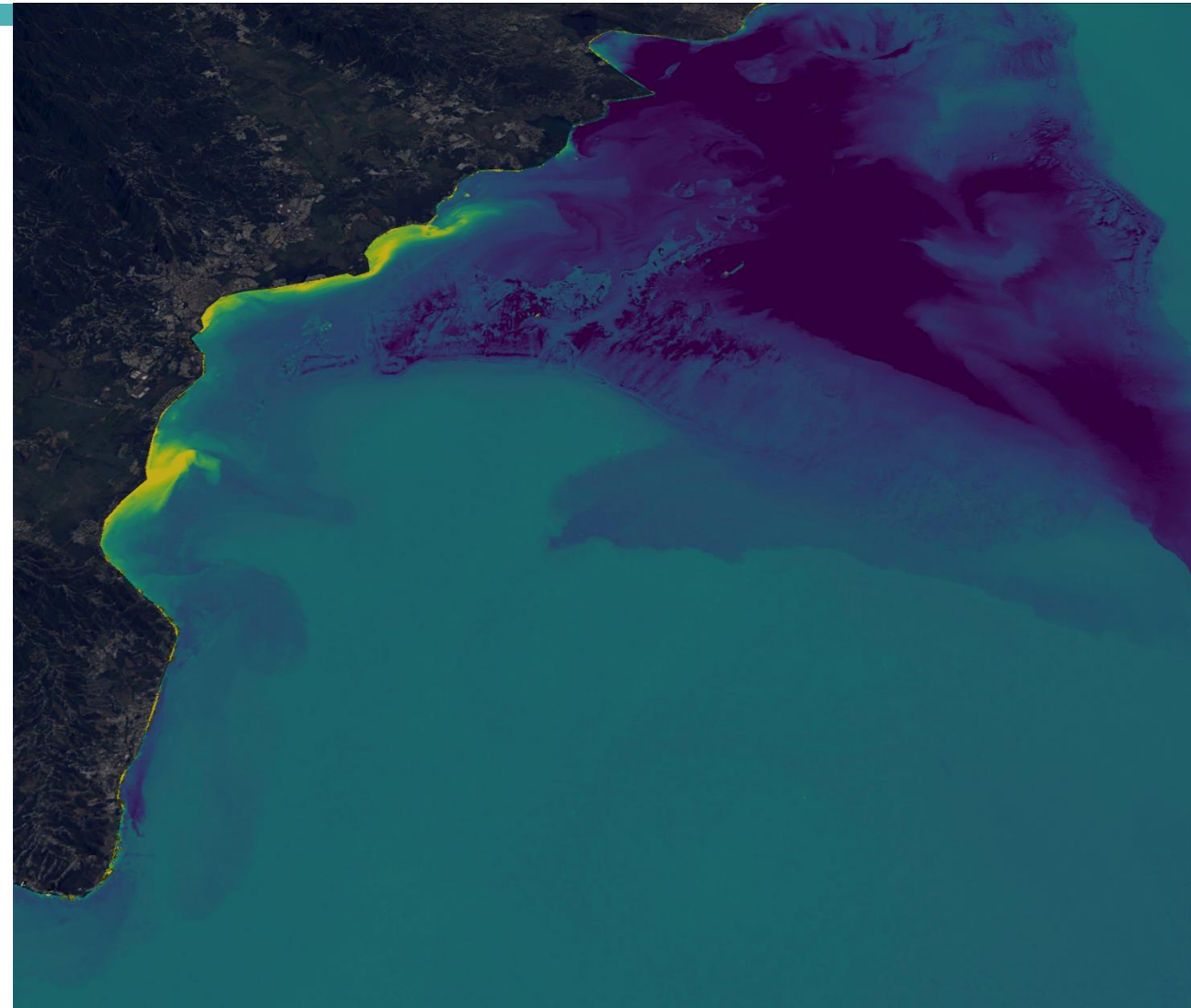


ORCAA

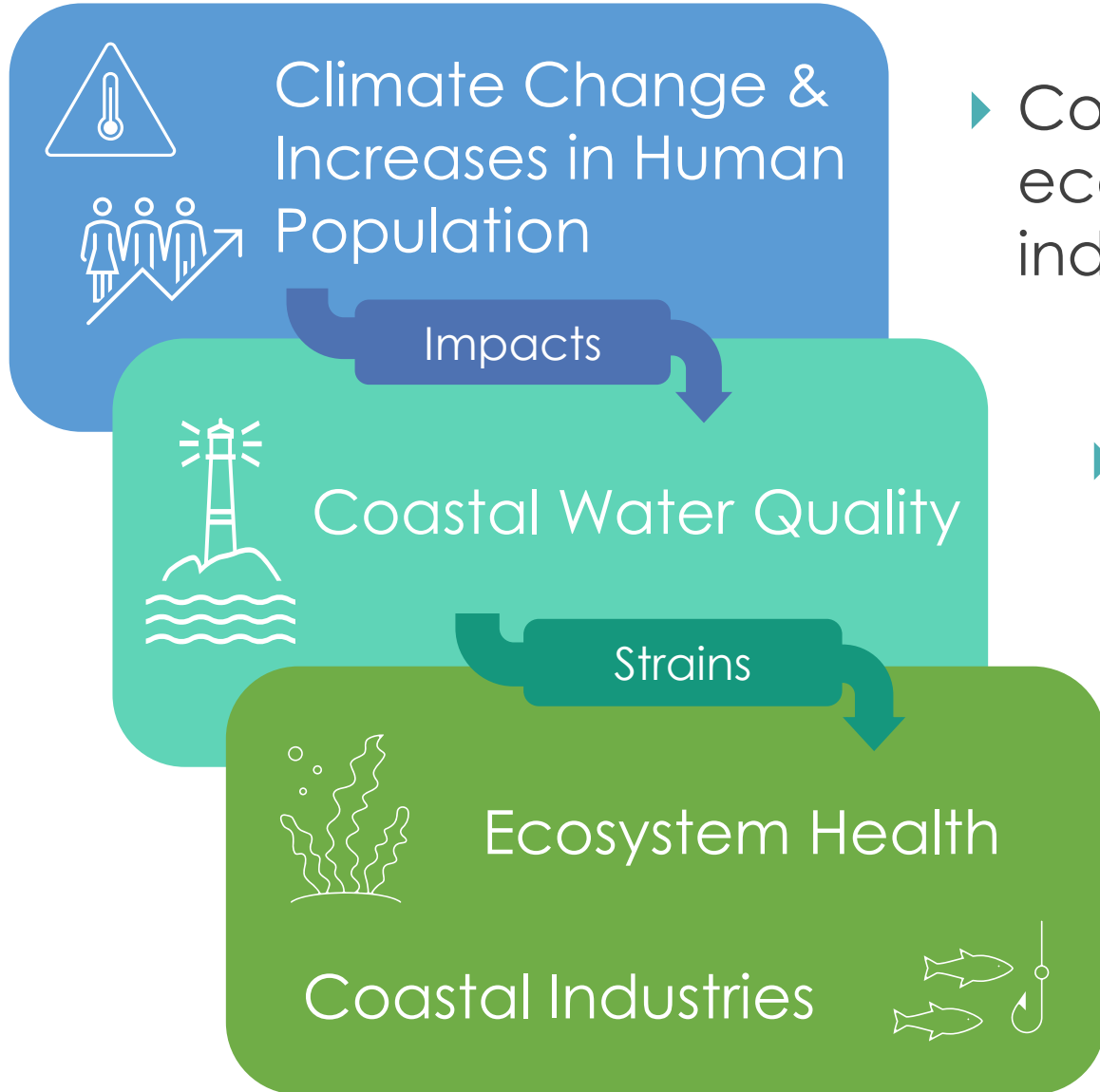
Water Resources

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

Tasos Tentoglou
Eleda Fernald
David Carrasco
Adam Weingram



BACKGROUND

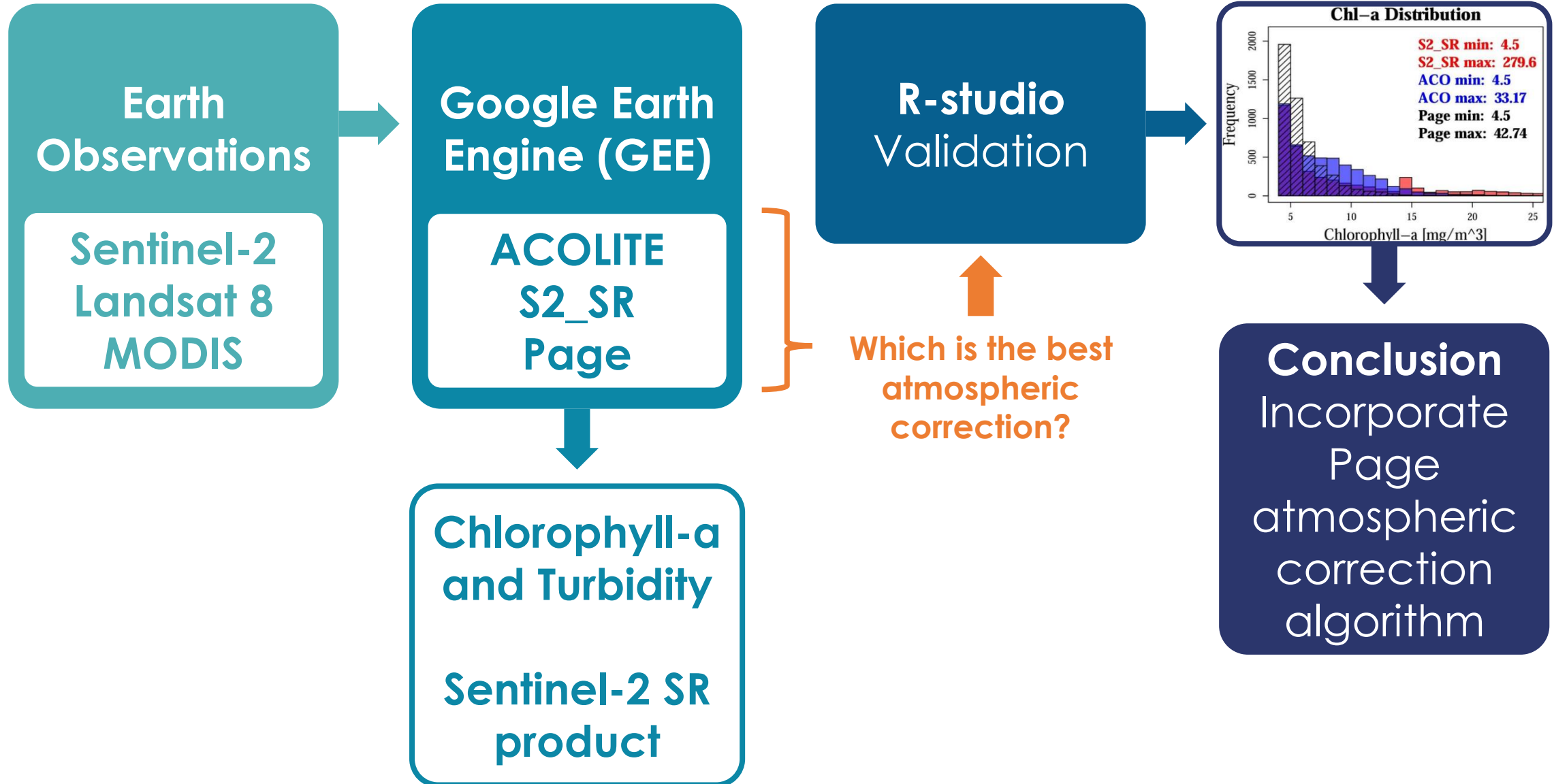


- ▶ Coastal water quality influences ecosystem health and human industries

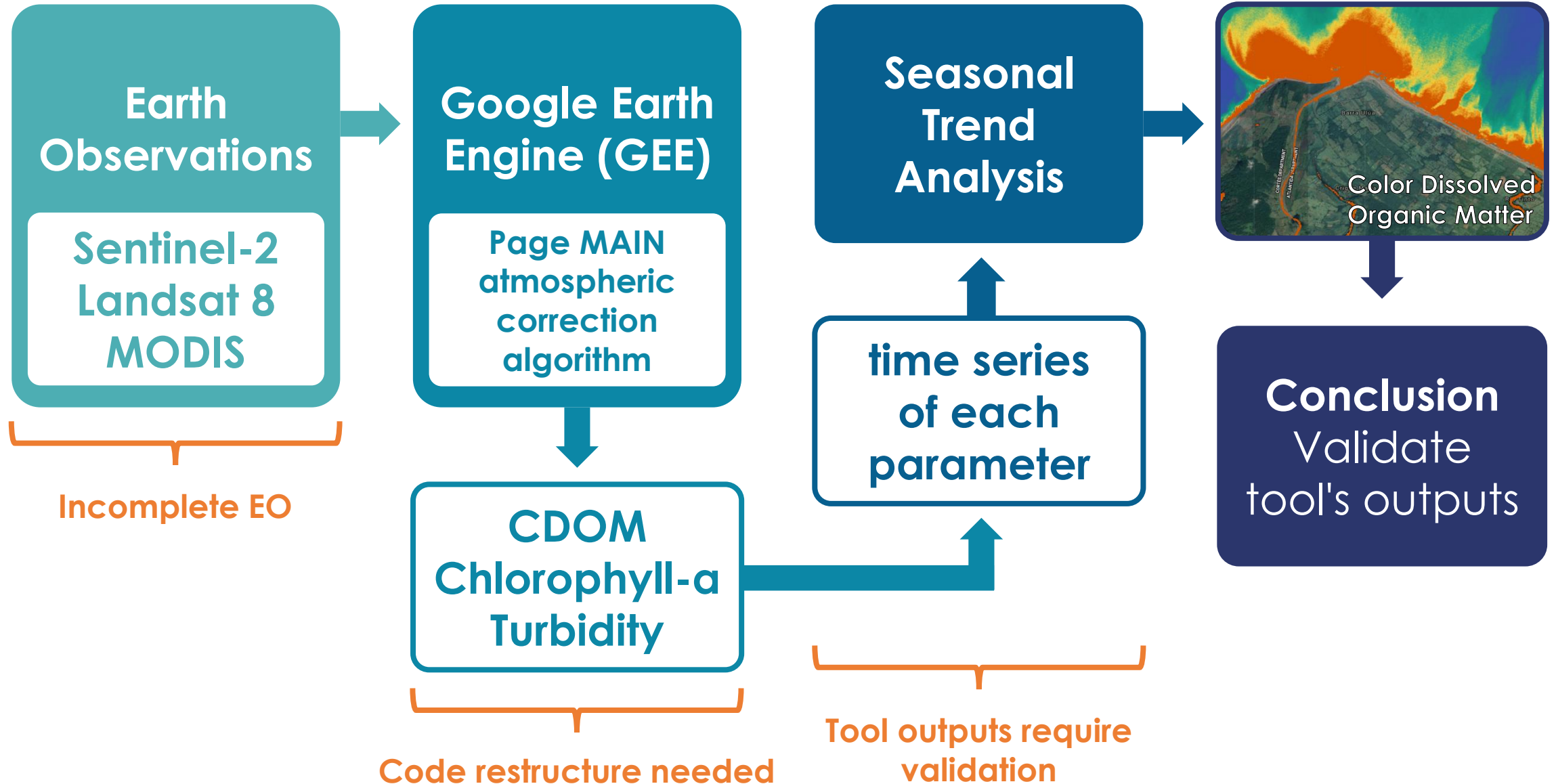
- ▶ Water quality indices should be monitored to improve understanding + management

- ▶ ORCAA: coastal water quality monitoring tool for Mesoamerican Barrier Reef

ORCAA 1.0 (Summer 2019)



ORCAA 1.0 (Fall 2019)



OBJECTIVES



Expand
the **spatial
scope** for
better global
applicability



Extend
the **temporal
range** by adding
Landsat 5 TM
and Landsat 7
ETM+



Restructure
codebase into
modules with
documented
APIs



Update
**pluggable
interface** to
include new
functionalities
and datasets

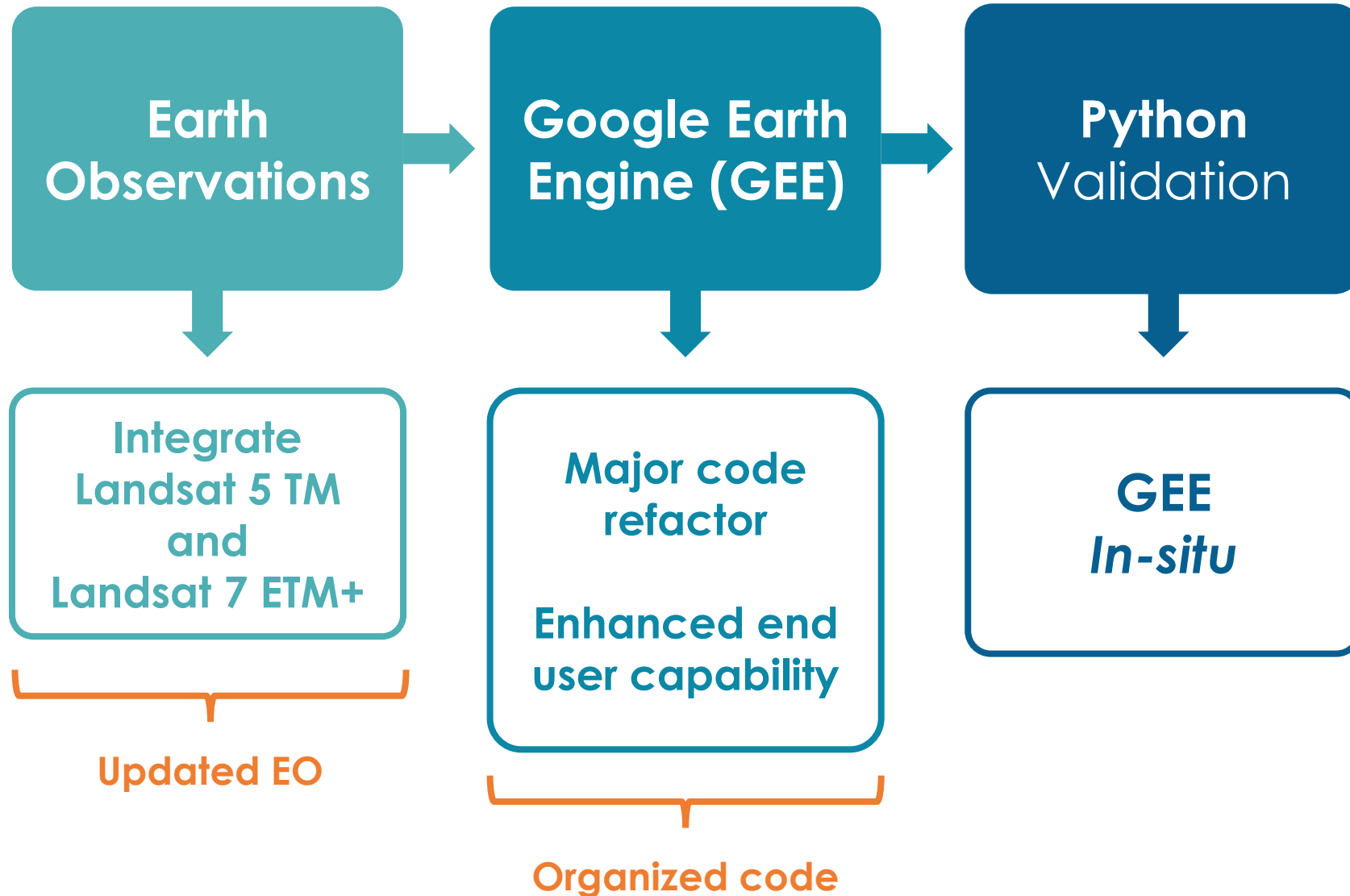


Adapt water quality
indices for Landsat 5
and 7

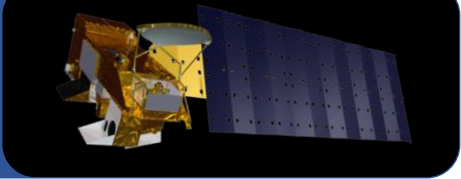


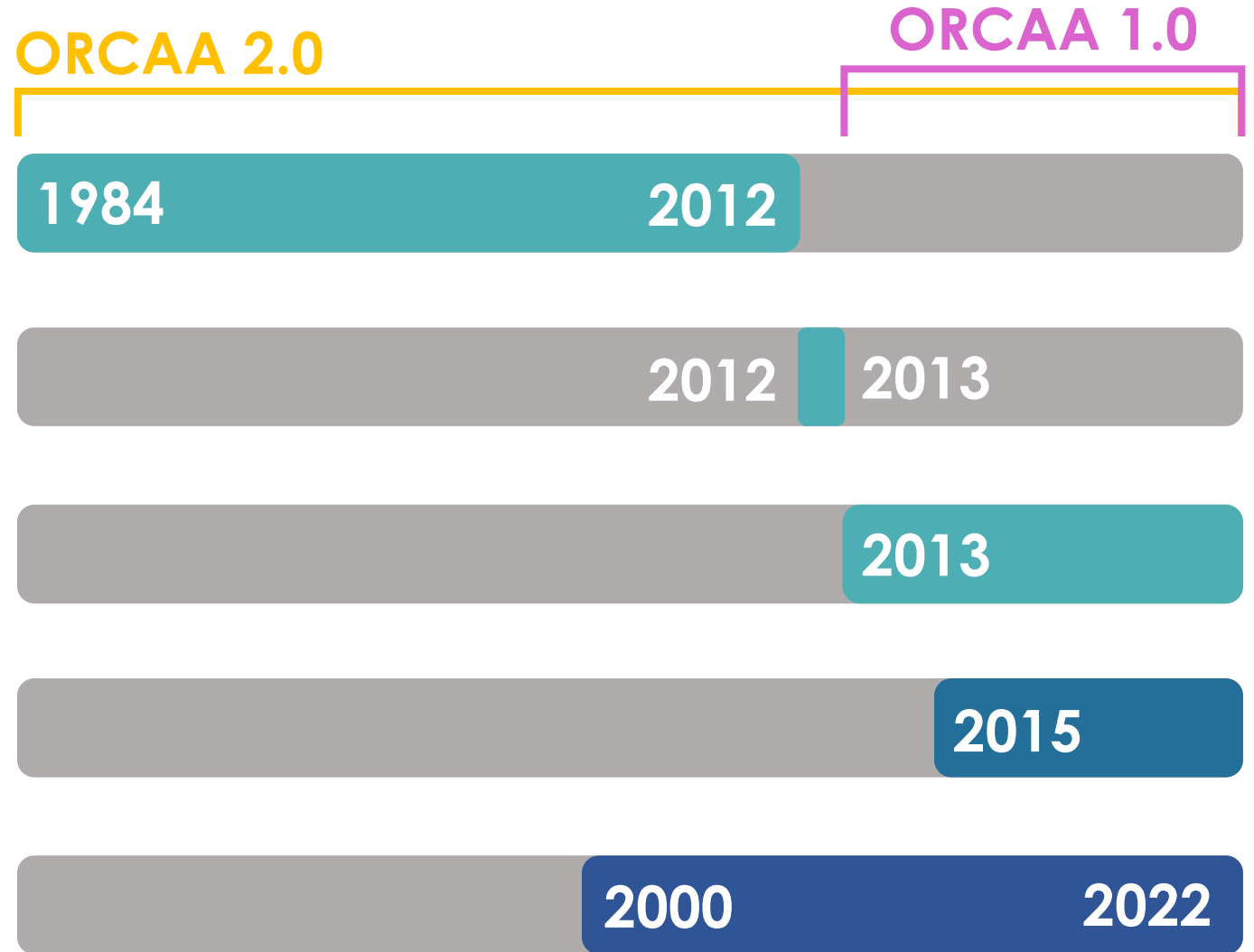
Validate the tool's
outputs using *in situ*
data

ORCAA 2.0 (ORCAA Water Resources)

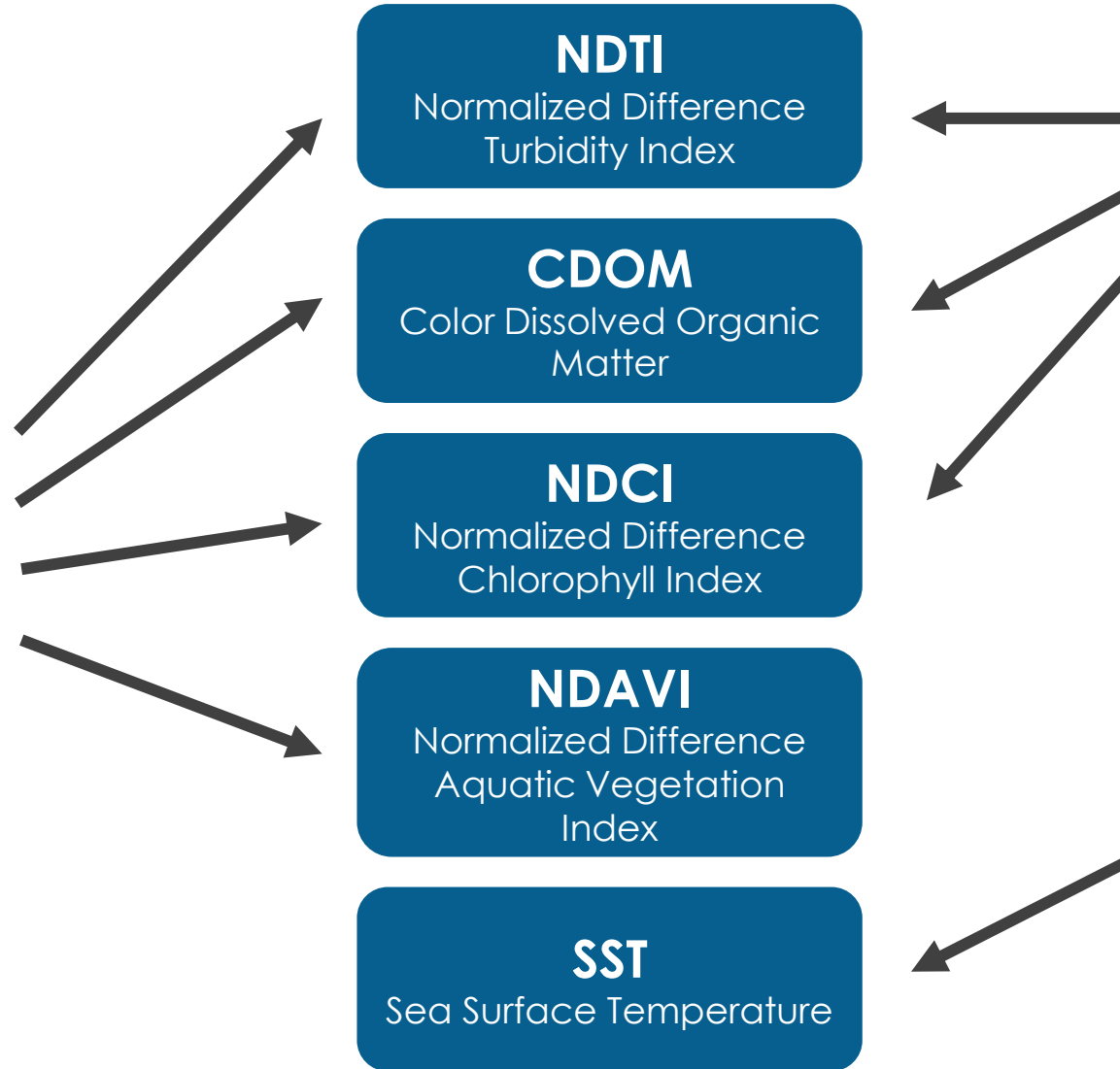
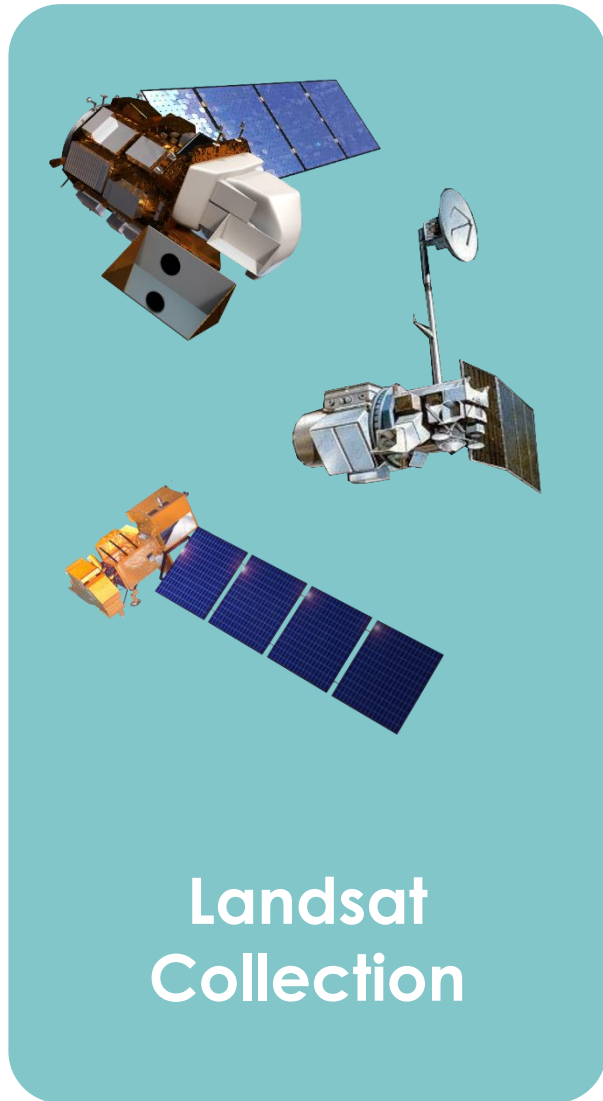


EARTH OBSERVATIONS

Landsat 5 TM	
Landsat 7 ETM+	
Landsat 8 OLI	
Sentinel-2 MSI	
Aqua/Terra MODIS	

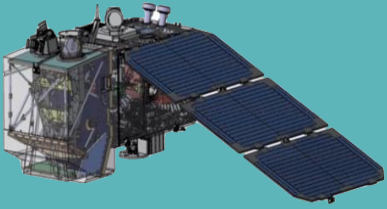


WATER QUALITY PARAMETERS

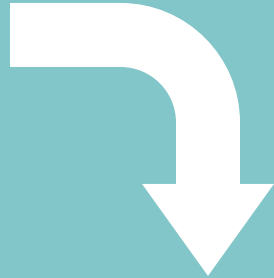


METHODOLOGY

Atmospheric Correction



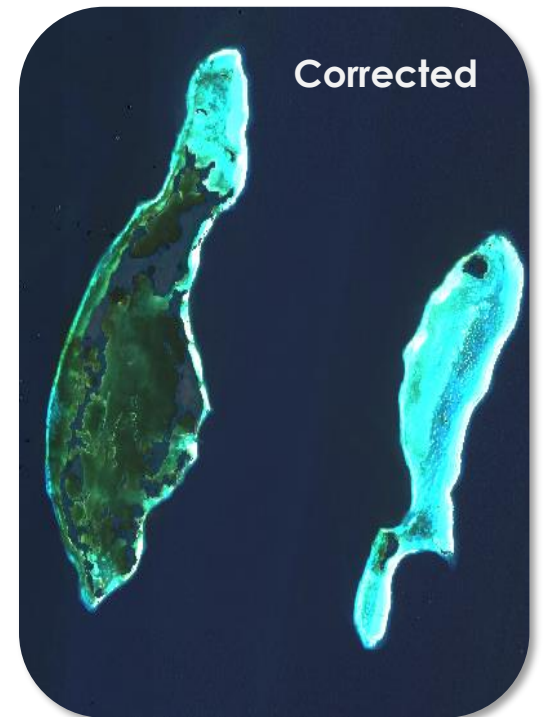
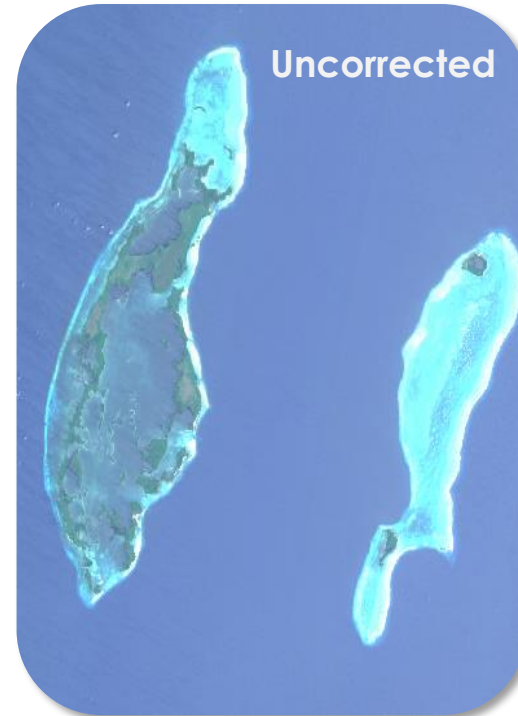
Sentinel-2 Platform



MAIN Algorithm

Modified Atmospheric Correction for
Indland Waters (MAIN) algorithm

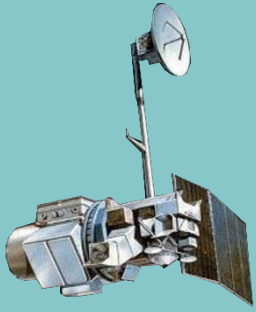
Utilizes NDWI for cloud masking



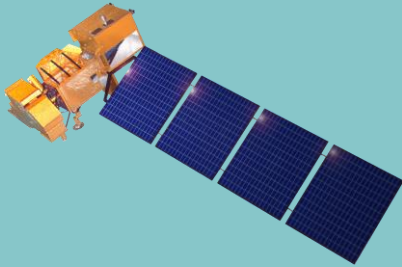
METHODOLOGY

Cloud Masking

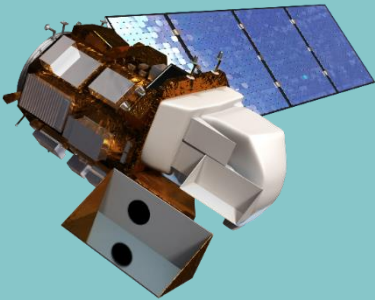
Landsat 5 TM



Landsat 7 ETM+



Landsat 8 OLI



Pixel QA



ORCAA 2.0 Demo

The screenshot shows the ORCAA 2.0 demo interface within the Google Earth Engine web application. The browser address bar shows the URL: `code.earthengine.google.com/?accept_repo=users/ttentoglou/ARC_ORCAAWaterResources`. The Google Earth Engine logo and search bar are at the top. The left sidebar contains the title "Tool for Optical Reef and Coastal Area Assessment (ORCAA)" and a description: "This dashboard can be used to monitor the spatial and temporal variability of coastal water quality parameters." Below this is a "Select a template:" section with a "Select a Template" button. A "Display Images on the Map" section includes "Start Date" (2017-01-01) and "End Date" (2021-12-31) input fields, and three checkboxes: "True Color (Landsat)" (checked), "True Color (Sentinel-2)", and "ND Aquatic Vegetation Index (Landsat)". The main map area shows a satellite image of a coastal region with labels like "San Felipe", "Backlanding", "Crooked Tree", "Water Bank", "Indian Creek", "Burnham Hall", "Flowers B", "Bermudian Landing", "Rancho Dolores", "Big Falls", "La Democracia", "Churchyard", "Belmopan", "Crossing Landing Bank", "Dry Creek", "Bocotora", and "Gales Point". A large blue overlay box titled "ORCAA" contains the text: "Tool for Global Optical Reef and Coastal Area Assessment" and "The NASA DEVELOP ORCAA Water Resources team created this tool under the guidance of science advisors from the University of Puerto Rico, NASA JPL, NASA MSFC, and NASA ARC for stakeholders and researchers to monitor near real-time Normalized Difference Turbidity Index (NDTI), chlorophyll-a, Colored Dissolved Organic Matter (CDOM), Normalized Difference Chlorophyll Index (NDCI), Normalized Difference Aquatic Vegetation Index (NDAVI), and sea surface temperature." At the bottom of the overlay box is a "BEGIN" button with a mouse cursor pointing at it. The right sidebar has tabs for "Layers", "Map", and "Satellite".

code.earthengine.google.com/?accept_repo=users/ttentoglou/ARC_ORCAAWaterResources

Google Earth Engine

Search places and datasets...

Scripts Docs Assets orcaa_core.js Get Link Save Run Reset Apps

Tool for Optical Reef and Coastal Area Assessment (ORCAA)

This dashboard can be used to monitor the spatial and temporal variability of coastal water quality parameters.

Select a template:

Select a Template

Display Images on the Map

Start Date

2017-01-01

End Date

2021-12-31

☒ True Color (Landsat)

☐ True Color (Sentinel-2)

☐ ND Aquatic Vegetation Index (Landsat)

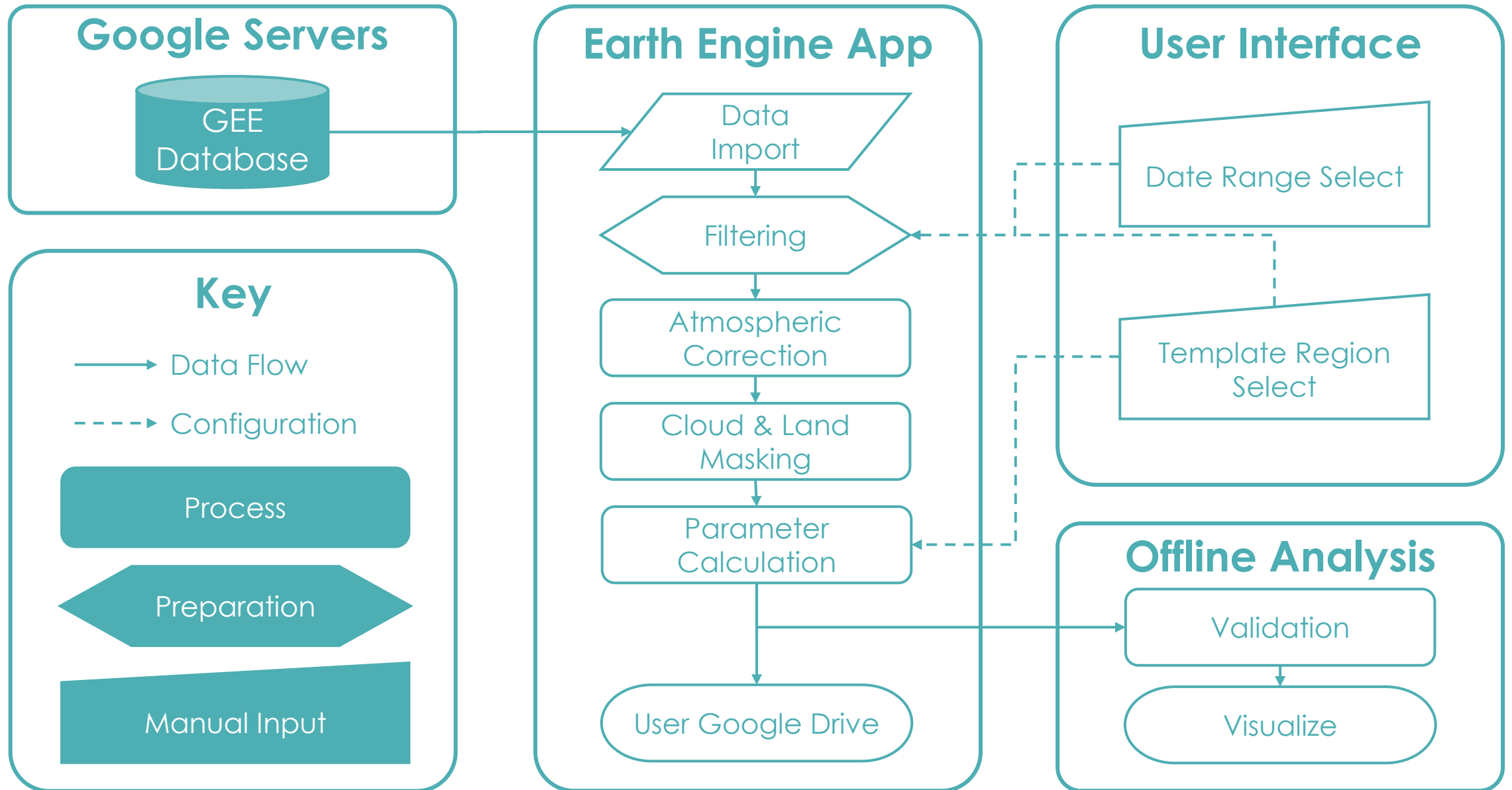
ORCAA

Tool for Global Optical Reef and Coastal Area Assessment

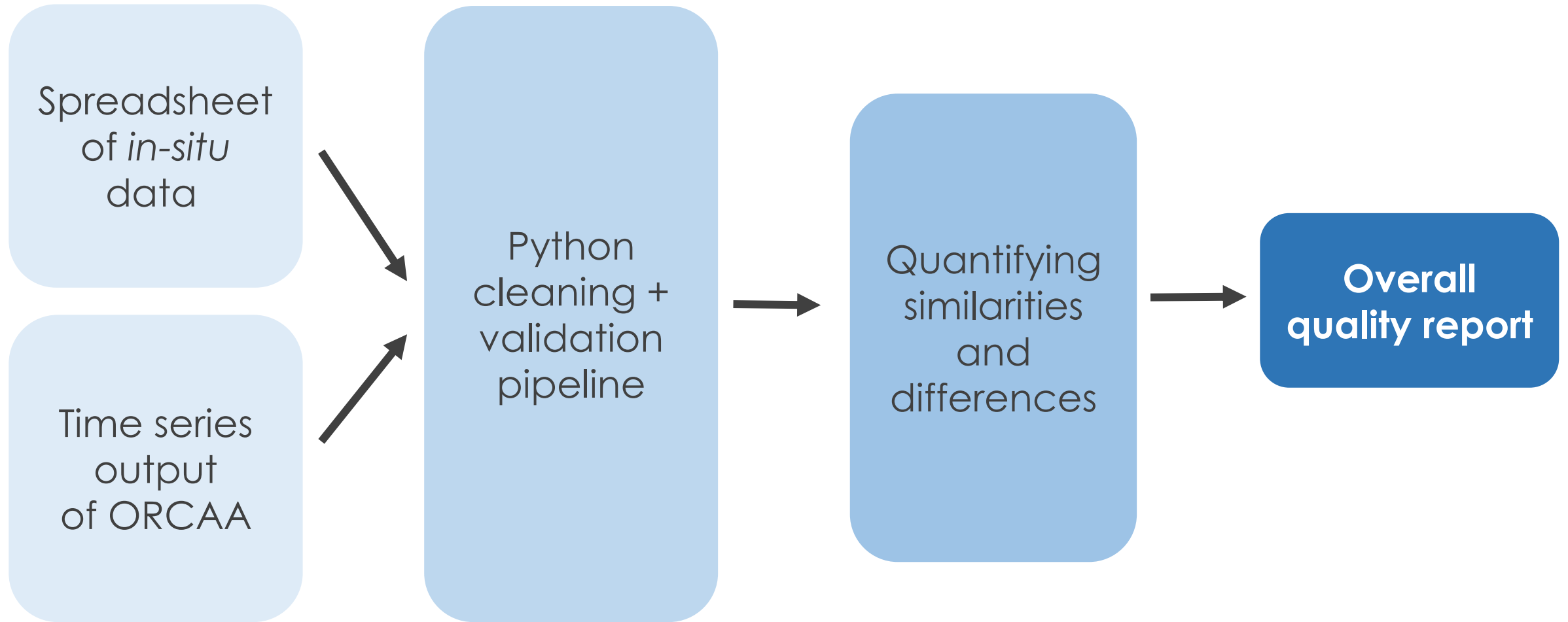
The NASA DEVELOP ORCAA Water Resources team created this tool under the guidance of science advisors from the University of Puerto Rico, NASA JPL, NASA MSFC, and NASA ARC for stakeholders and researchers to monitor near real-time Normalized Difference Turbidity Index (NDTI), chlorophyll-a, Colored Dissolved Organic Matter (CDOM), Normalized Difference Chlorophyll Index (NDCI), Normalized Difference Aquatic Vegetation Index (NDAVI), and sea surface temperature.

BEGIN

WORKFLOW for Time Series Data



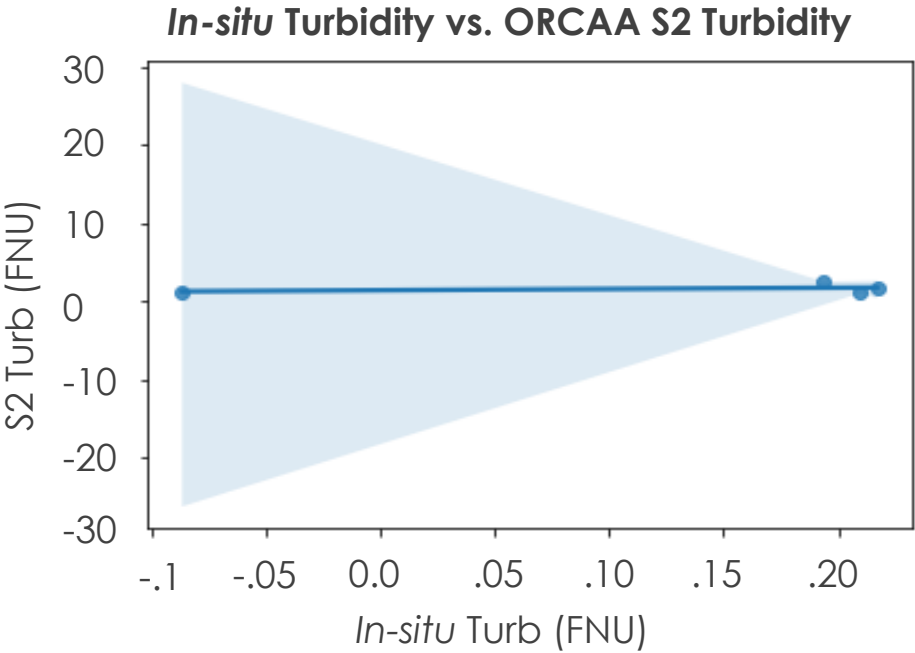
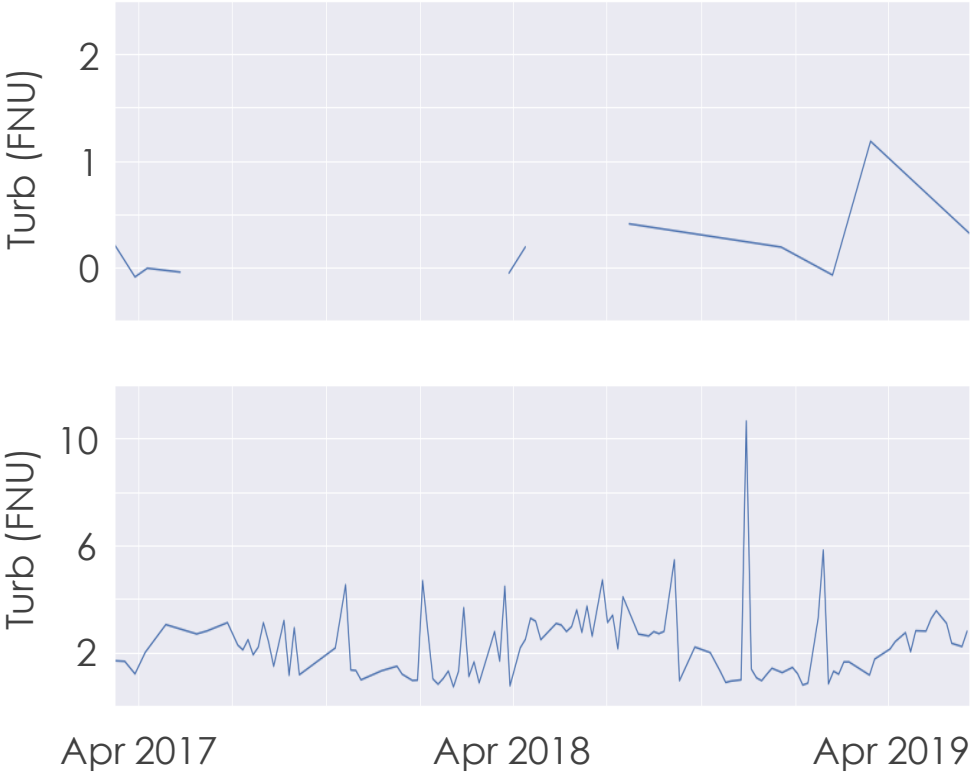
WORKFLOW for Validation Procedure



VALIDATION

Turbidity

In-situ Turbidity (top) vs. ORCAA S2 Turbidity (bottom)

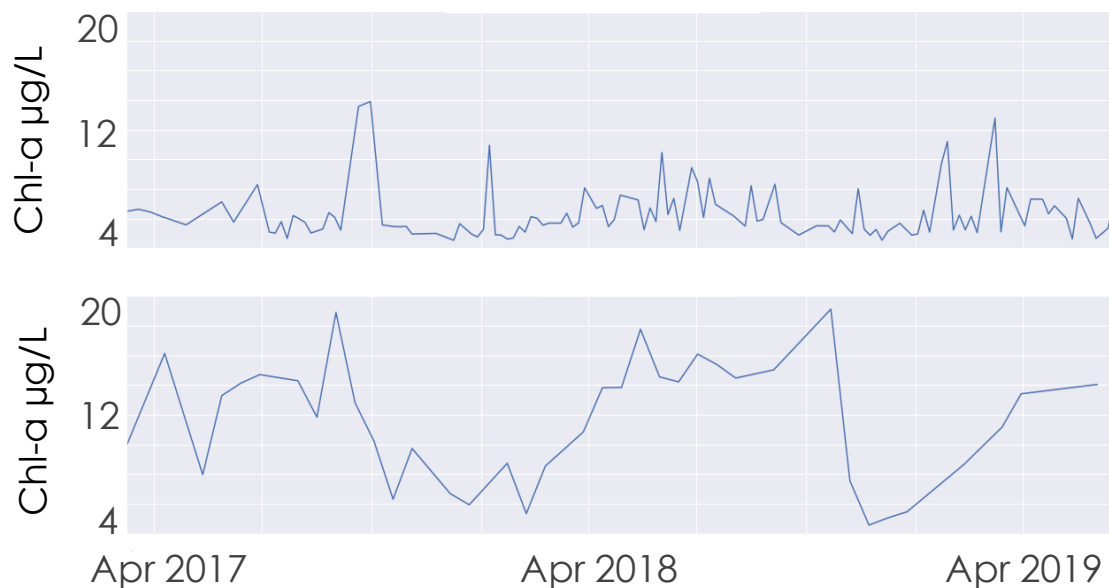


<i>In-situ</i> vs. ORCAA S2 Turbidity	
RMSE	2.41
r	0.36

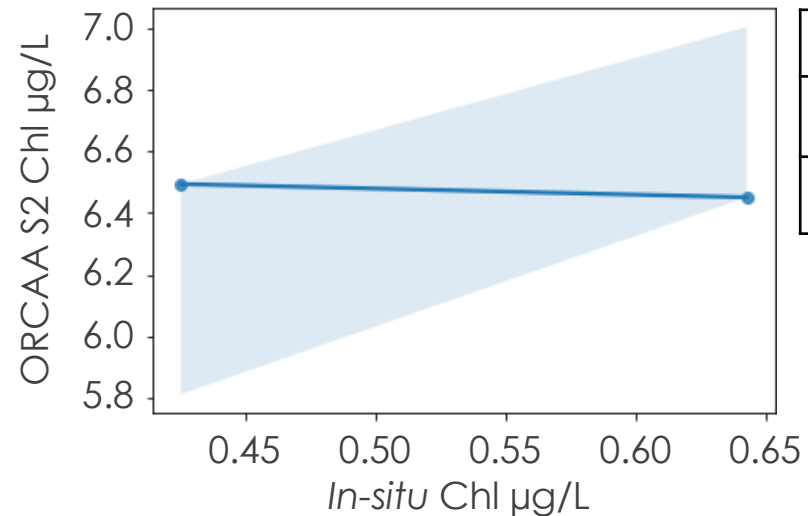
VALIDATION

Chlorophyll-a

Puerto Rico ORCAA: S2 Chl-a (top) vs. LS8 Chl-a (bottom)



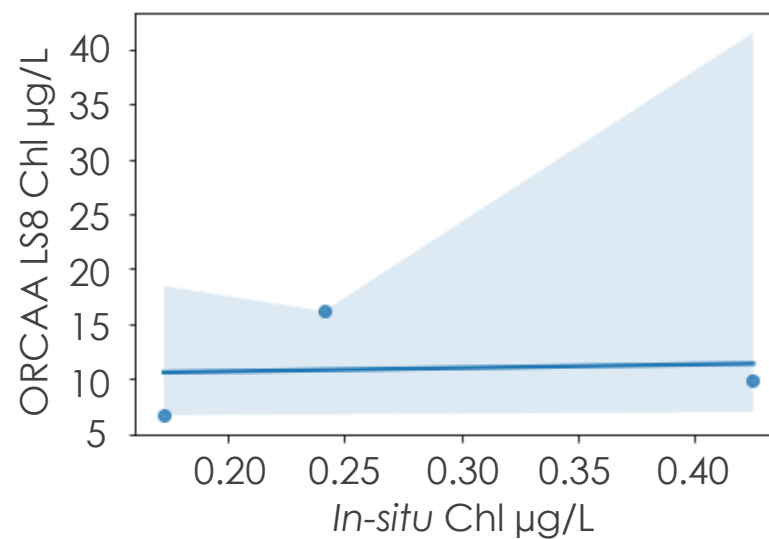
In-situ vs. ORCAA Sentinel-2



***In-situ* vs. ORCAA S2 Chl-a**

RMSE	35.27
r	-1.0

In-situ vs. ORCAA Landsat 8



***In-situ* vs. ORCAA LS8 Chl-a**

RMSE	128.37
r	0.09

LIMITATIONS & UNCERTAINTIES

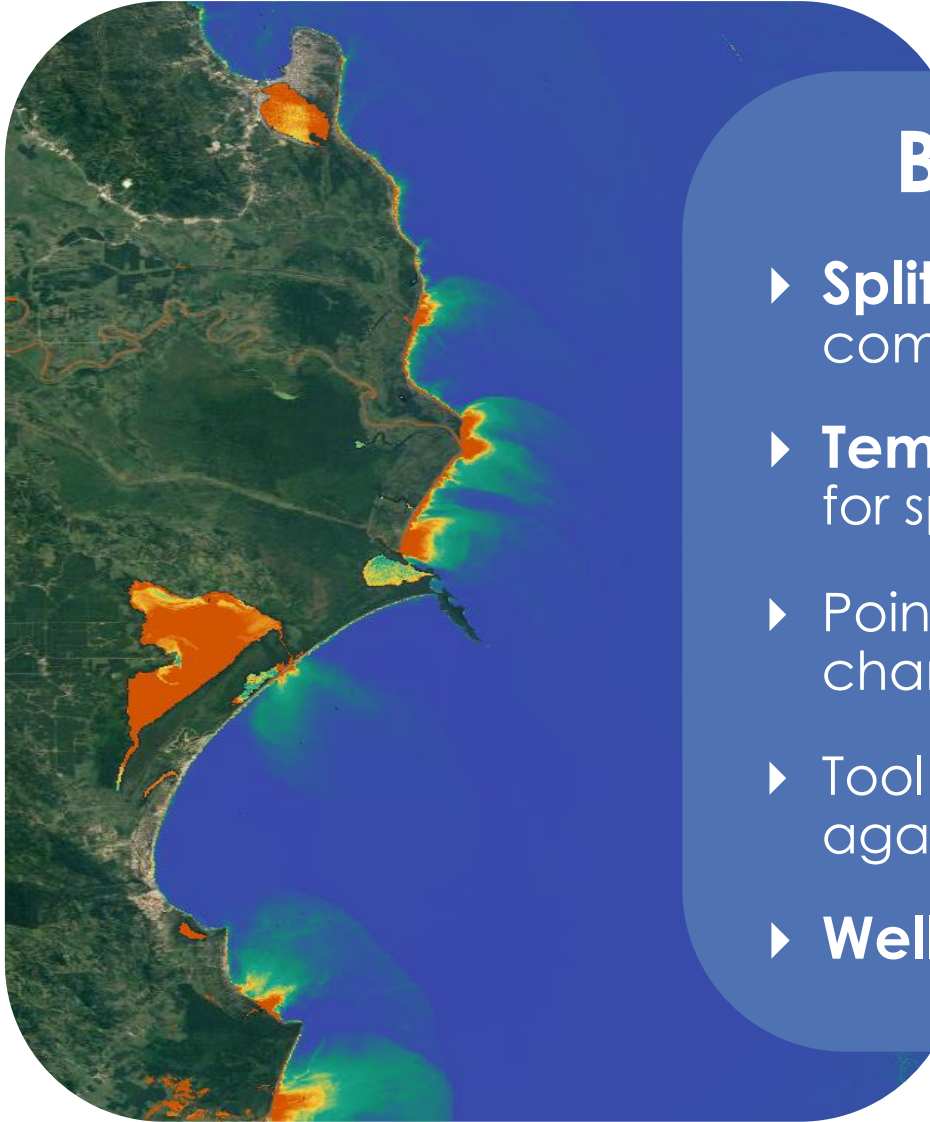
DATA

- ▶ Limited to GEE available products
- ▶ Possible atmospheric correction noise
- ▶ Sun glint and bottom albedo reflectance

VALIDATION

- ▶ Limited *in-situ* data for ORCAA 2.0 parameters
- ▶ Some *in-situ* data points do not fall under a satellite overpass
- ▶ Possible field work collection errors

CONCLUSIONS



Benefits of ORCAA 2.0:

- ▶ **Split screen** function enables visual comparison
- ▶ **Template functionality** provides a model for spatial expansion
- ▶ Point inspection **time series charts** of changes in water quality parameters
- ▶ Tool outputs for model templates **validated** against *in situ* data
- ▶ **Well-organized and documented code**

FUTURE WORK



Add more templates from which users may choose preexisting geometries



Validate tool's NDAVI, SST, turbidity, and land/water outputs for Caribbean and California regions



Validate all of tool's outputs (chlorophyll-a, CDOM, NDAVI, SST, turbidity, land/water) for more regions



Correct for bottom albedo and sun glint



Incorporate atmospheric correction code that is not obfuscated

ACKNOWLEDGEMENTS

Science Advisors

- ▶ Dr. Juan Torres-Pérez (NASA Ames Research Center)
- ▶ Dr. Christine Lee (NASA Jet Propulsion Laboratory)
- ▶ Dr. Kelly Luis (NASA Jet Propulsion Laboratory)
- ▶ Benjamin Holt (NASA Jet Propulsion Laboratory)
- ▶ Dr. Emil Cherrington (NASA Marshall Spaceflight Center)
- ▶ Dr. William Hernandez (University of Puerto Rico)
- ▶ Dr. Roy Armstrong (University of Puerto Rico)

Mentors

- ▶ Britnay Beaudry (Science Systems and Applications, Inc., NASA Ames Research Center)
- ▶ Hayley Pippin (Science Systems and Applications, Inc., NASA Ames Research Center)

This material contains modified Copernicus Sentinel data (2015 - 2022), processed by ESA.

ACKNOWLEDGEMENTS

Past Contributors

▶ ***Belize Water Resources I JPL/ARC Summer 2019 NASA DEVELOP Team***

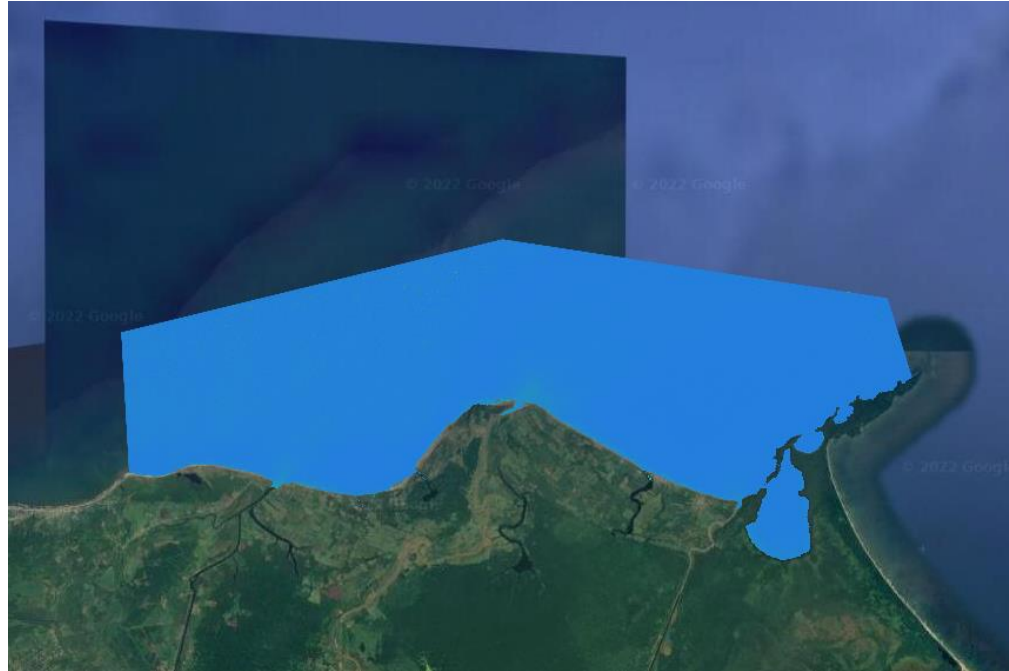
- ▶ Alice Lin
- ▶ Charles Devine
- ▶ Sophia Skoglund
- ▶ Alana Higgins

▶ ***Belize & Honduras Water Resources II JPL Fall 2019 NASA DEVELOP Team***

- ▶ Hayley Pippin
- ▶ Vanessa Valenti
- ▶ Arbyn Olarte
- ▶ Roxana Pilot

SLIDES BEYOND ARE BONUS SLIDES

WATER QUALITY PARAMETERS - Chlorophyll-a



Chlorophyll-a (mg/m^3)



0 75

- ▶ "Normalized Difference Chlorophyll Index" (NDCI)
- ▶ This parameter has options for using Landsat or Sentinel-2 imagery

Increased
Chlorophyll-a
concentrations



Higher surface
photosynthetic
activities

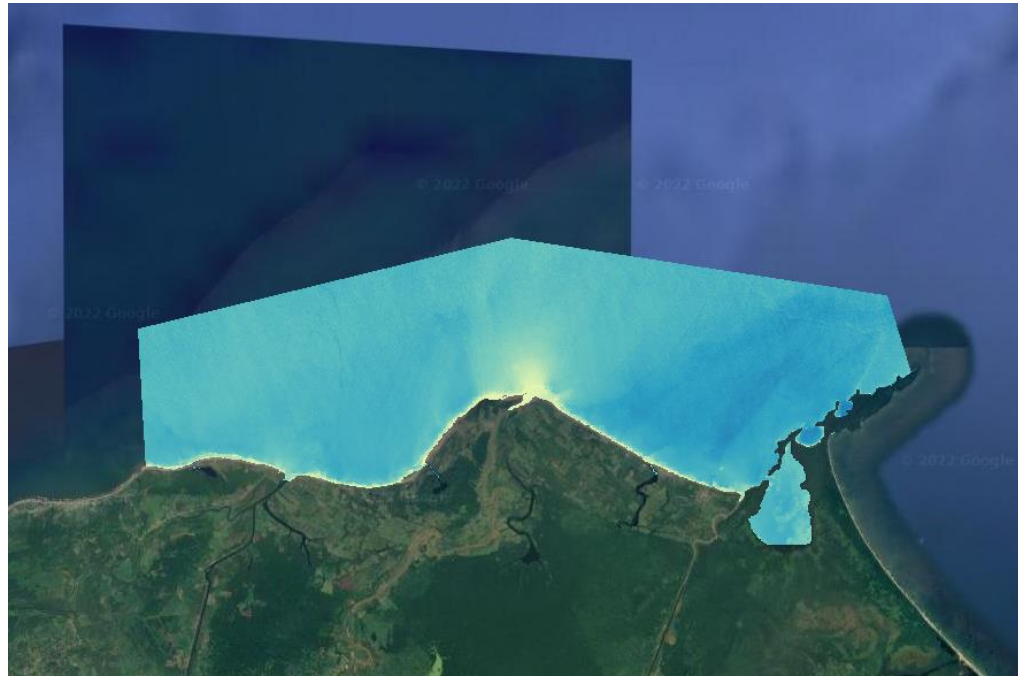


Elevated
phytoplankton
densities



Algal blooms

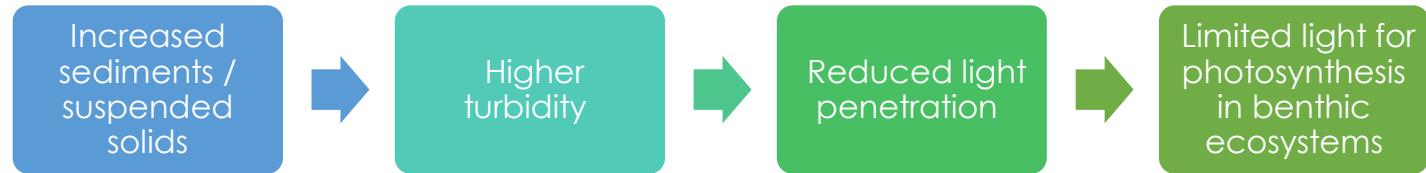
WATER QUALITY PARAMETERS - NDTI



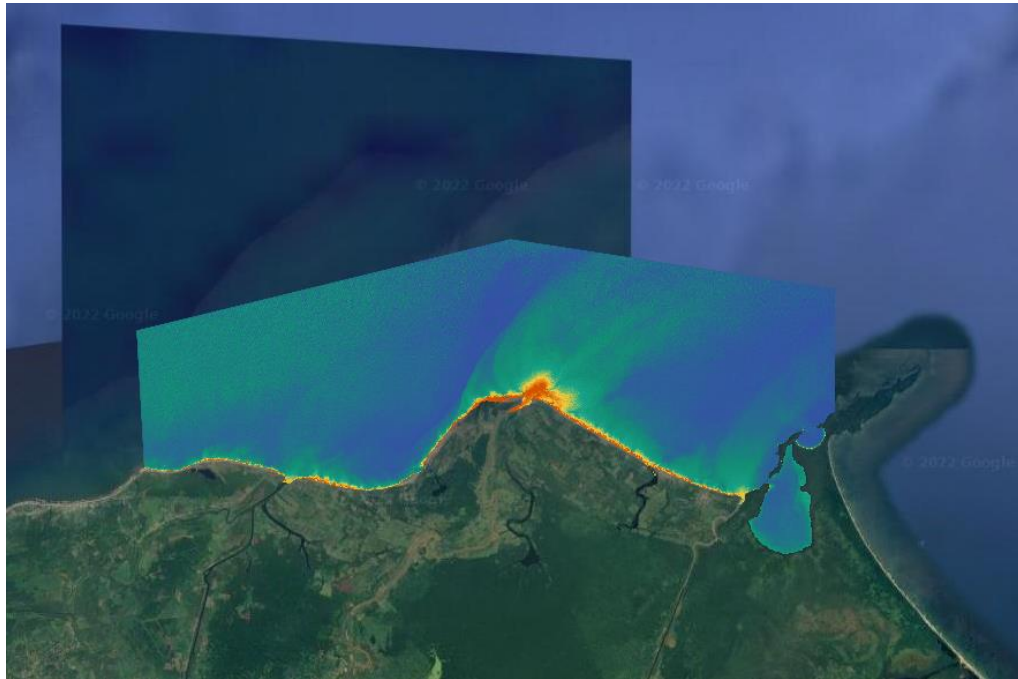
Turbidity



- ▶ "Normalized Difference Turbidity Index"
- ▶ This parameter has options for using LANDSAT or Sentine-2 imagery



WATER QUALITY PARAMETERS - CDOM



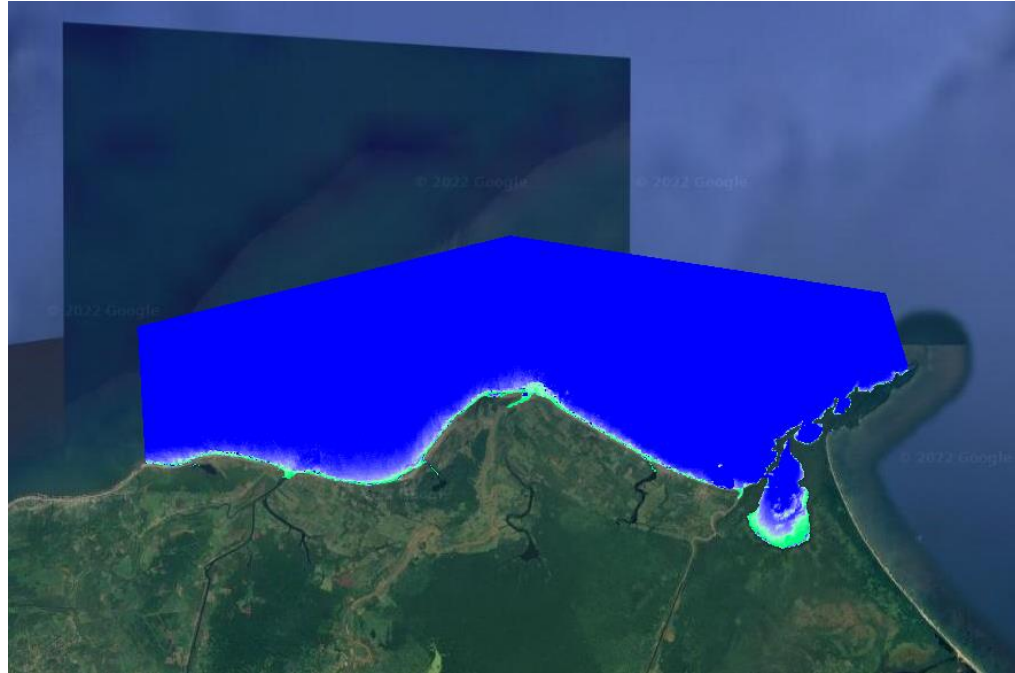
Color Dissolved Organic Matter



- ▶ “Color Dissolved Organic Matter”
- ▶ This parameter has options for using Landsat or Sentinel-2 imagery



WATER QUALITY PARAMETERS - NDAVI



Aquatic Vegetation



- ▶ "Normalized Difference Aquatic Vegetation Index"
- ▶ This parameter is calculated using LANDSAT imagery

WATER QUALITY PARAMETERS - SST



- ▶ "Sea Surface Temperature"
- ▶ This parameter is calculated using MODIS imagery

Sea Surface Temperature

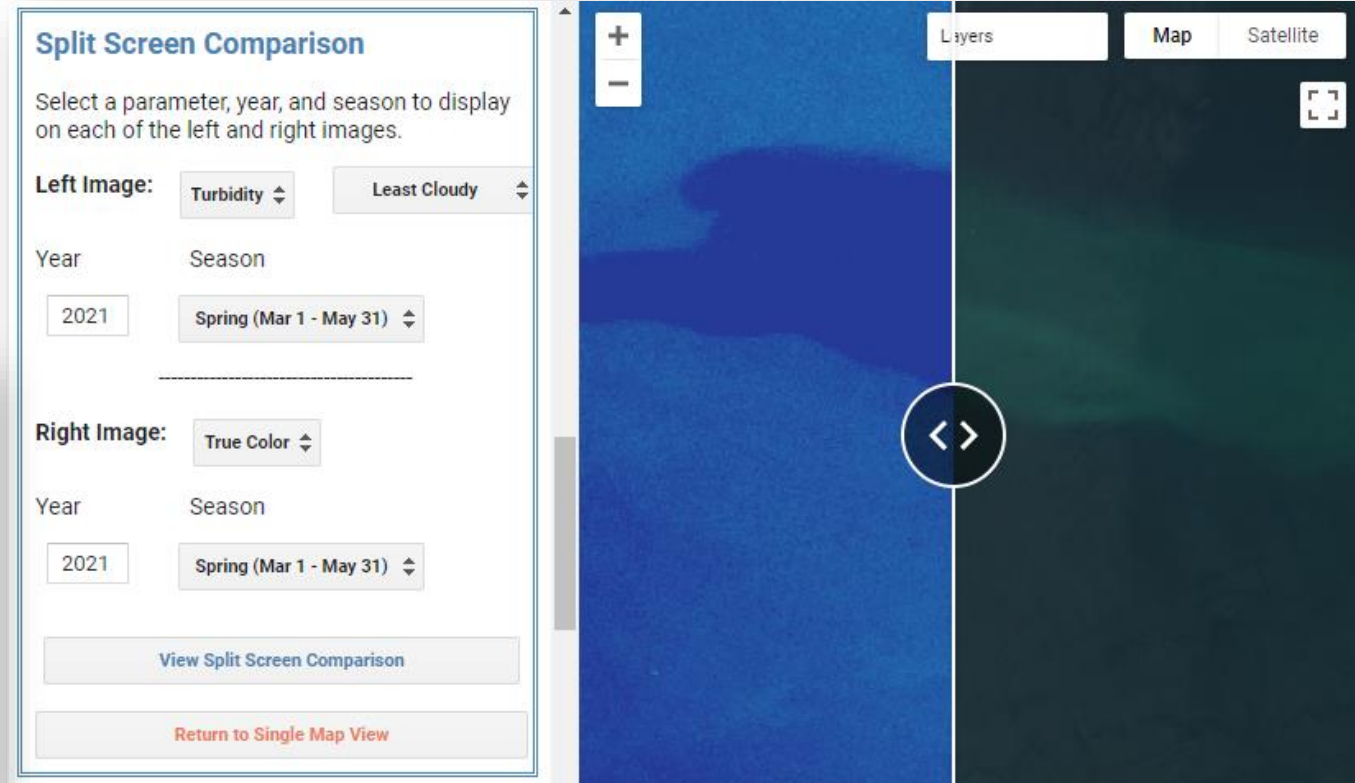
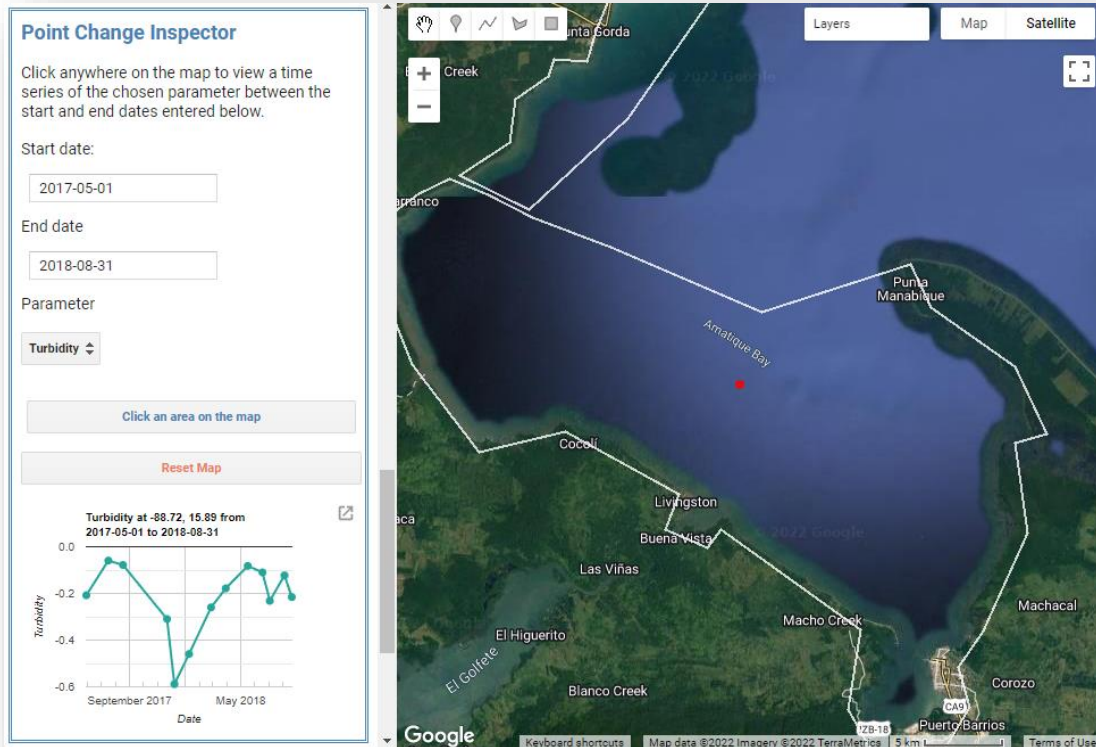


15

32

ORCAA 2.0 Enhanced - Functionalities

- ▶ Split Screen Comparison
- ▶ Point Change Inspector

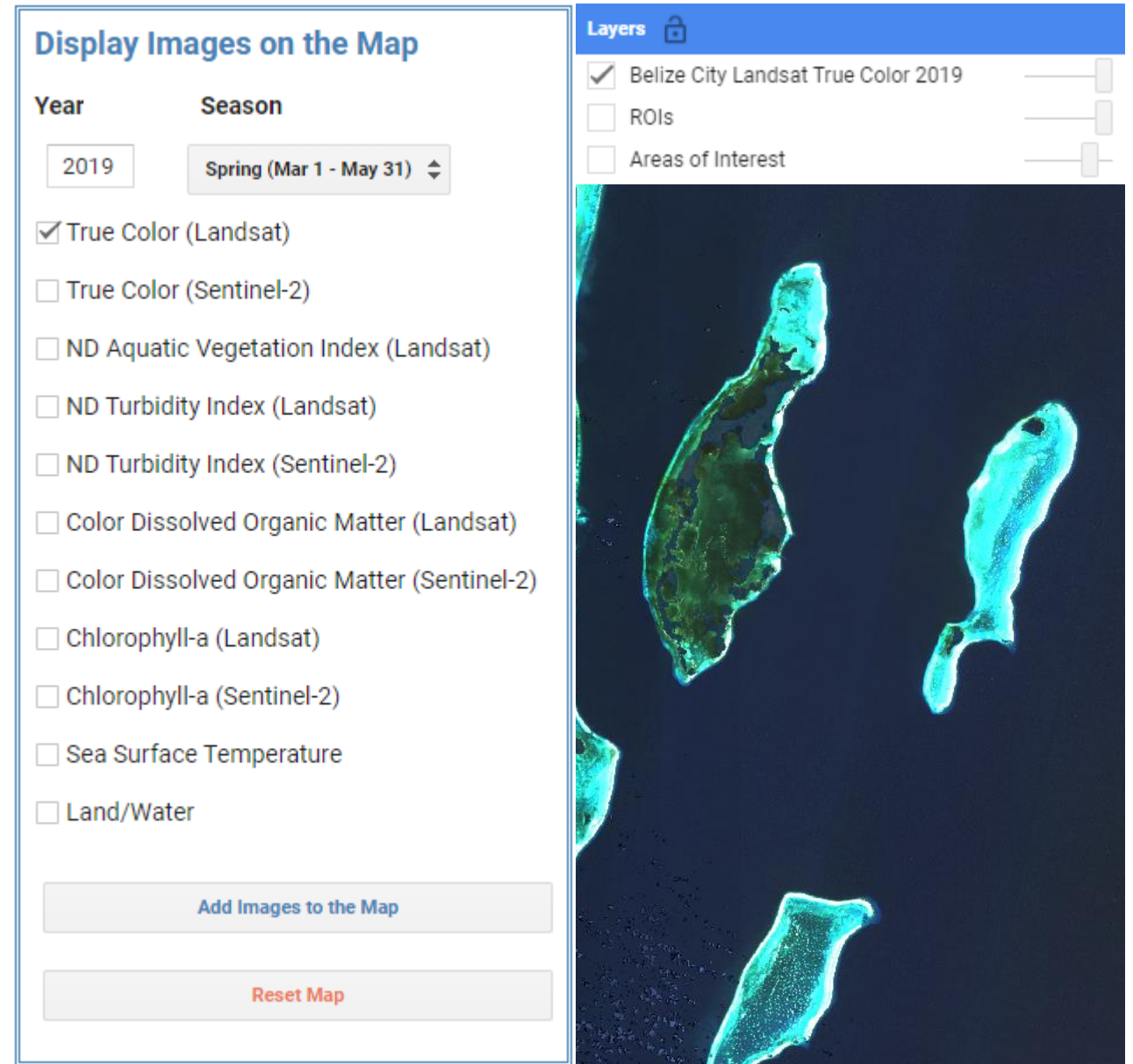


- ▶ Geographical Templates
- ▶ Time Series Chart Generation

METHODOLOGY

Parameter Calculation

- ▶ User selects desired parameters
- ▶ Parameters calculated in parallel on Google Cloud Servers
- ▶ Results displayed to user
 - ▶ User can hide/show layers
 - ▶ Split screen comparison available



METHODOLOGY

Template Regions

Select a template:

The Caribbean



Select area type:

Preset Geometries



Cockroach Bay



- ▶ **Templates in tool:**
 - ▶ Caribbean
 - ▶ Coastal California
- ▶ **Algorithms were tuned to appropriate oceanic conditions**
- ▶ **Outputs validated against ground truth data**

METHODOLOGY

Region of Interest Import & Filtering

Retrieved from
GEE's Database



Applied spatial,
temporal, and
metadata filters



Imagery
clipped to study
site areas

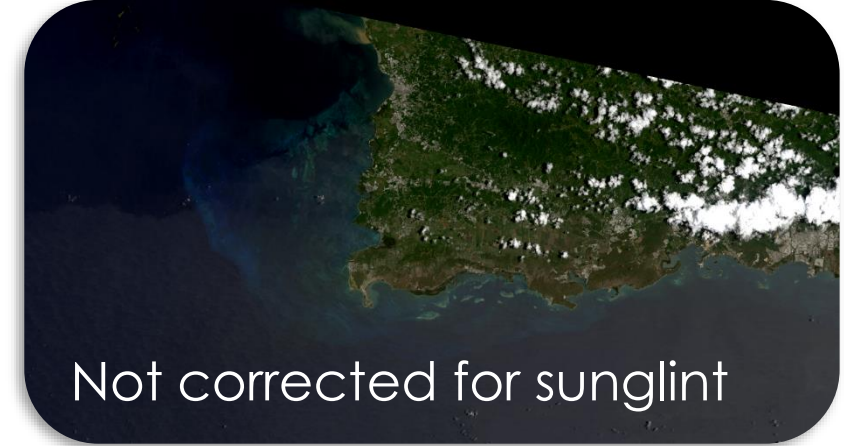
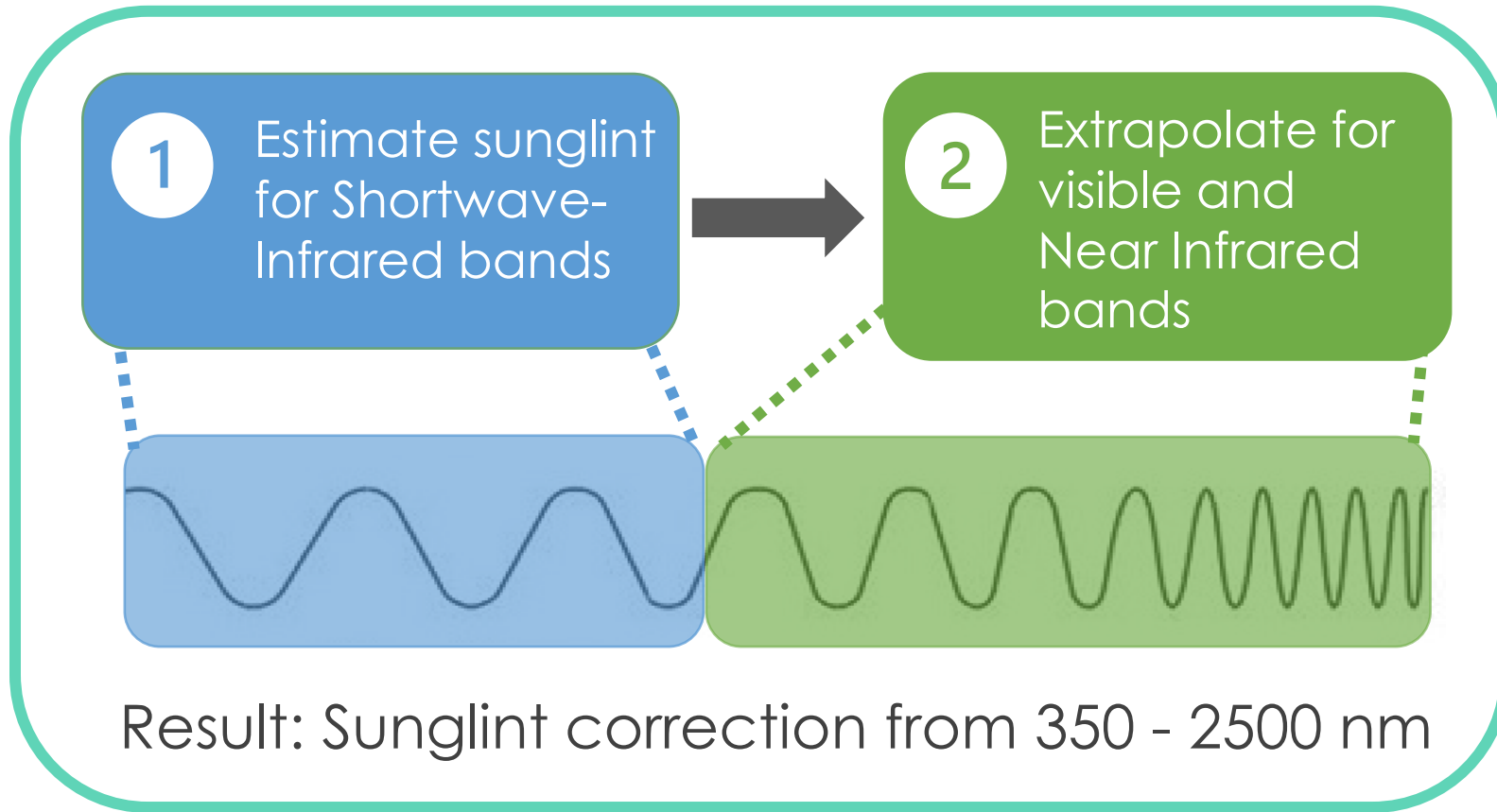
- ▶ World Database of Marine Protected Areas (WDPA)

- ▶ Filter to only coastal, marine areas

- ▶ Clip imagery to sites in the Caribbean and California Coast

FUTURE WORK

Sunglint correction



SOFTWARE ARCHITECTURE

