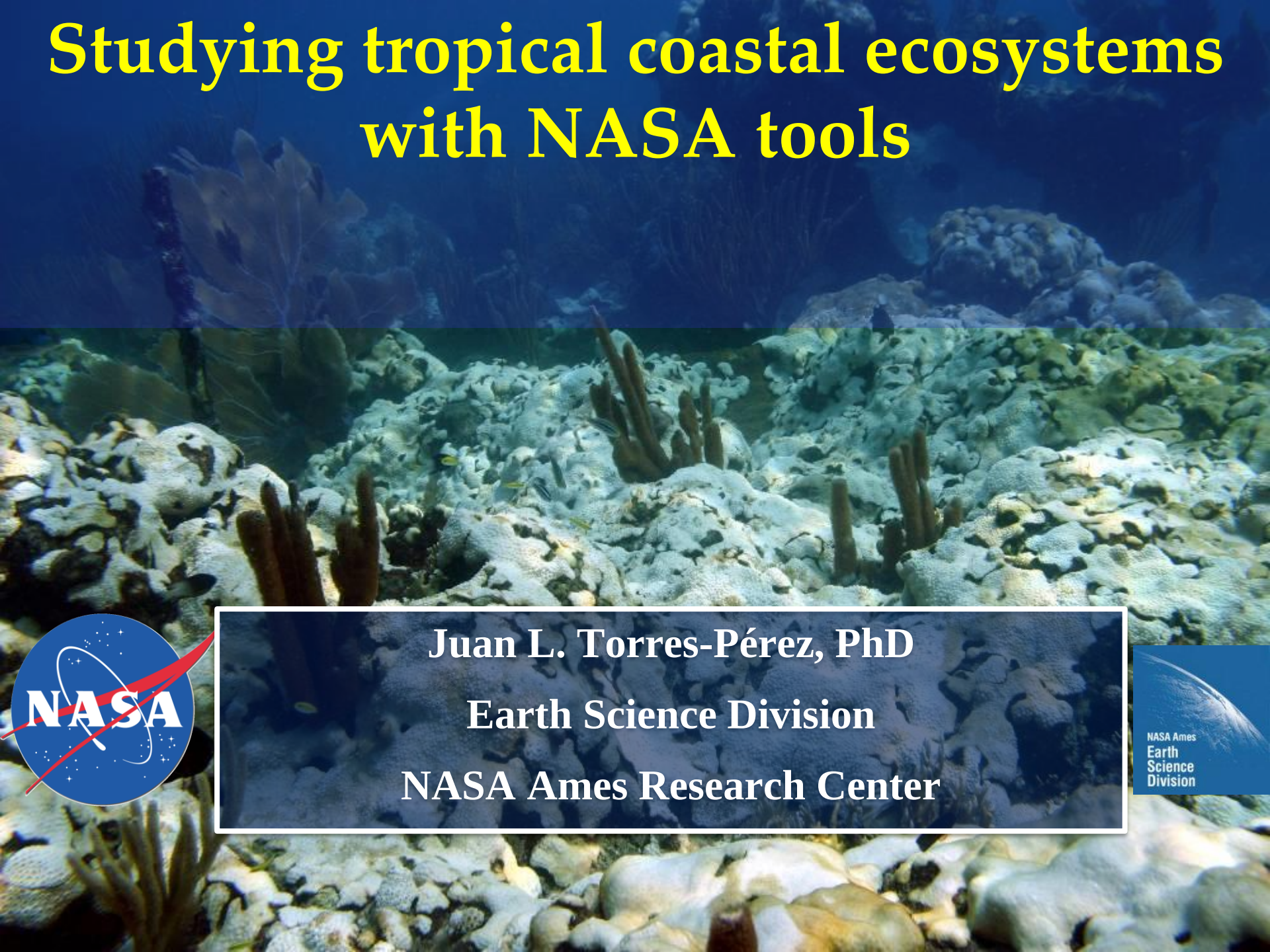
Studying tropical coastal ecosystems with NASA tools



Juan L. Torres-Pérez, PhD

Earth Science Division

NASA Ames Research Center

¿What is a marine biologist from Puerto Rico doing at the NASA Ames Research Center in the Bay Area?



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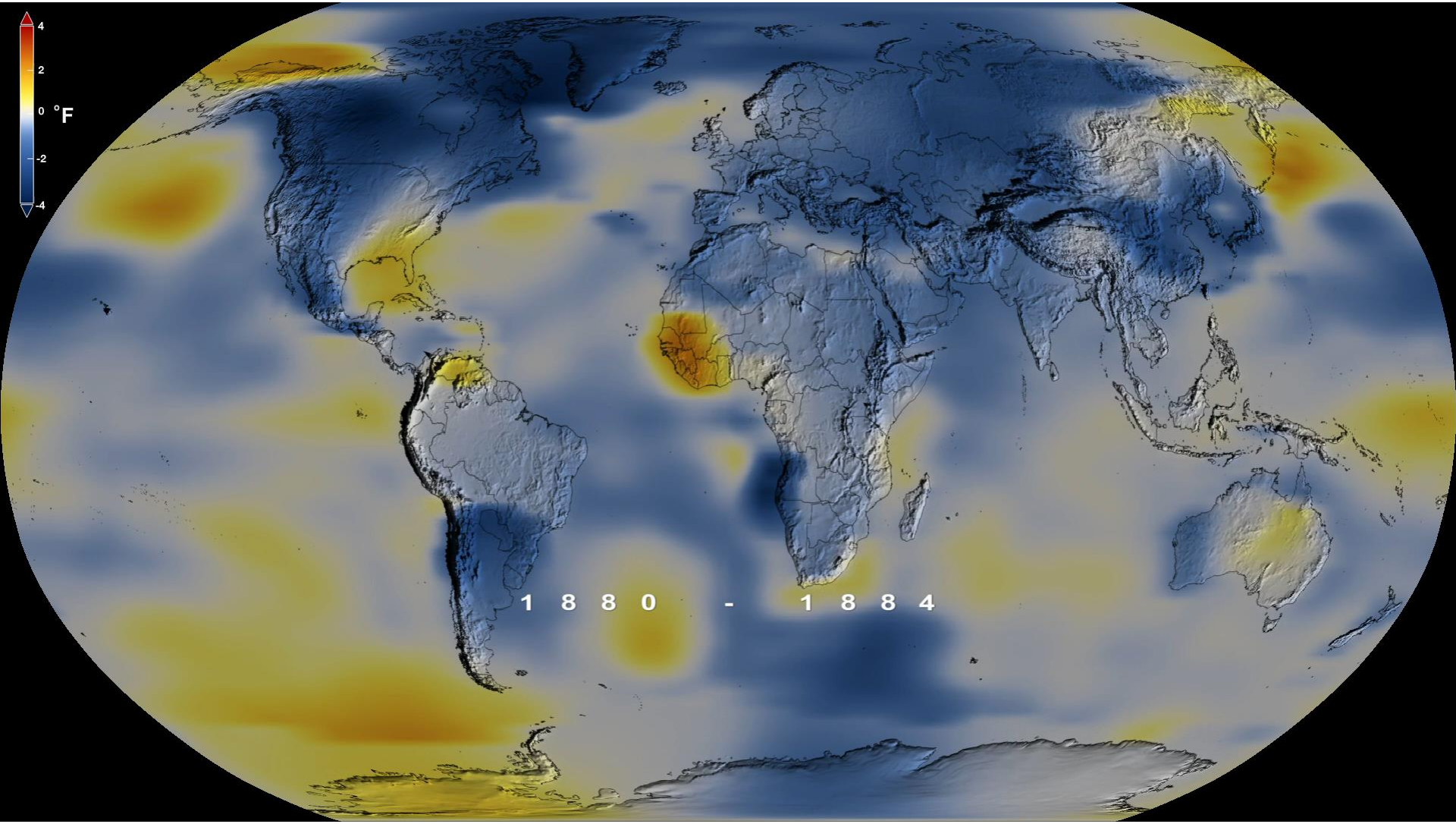
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Interesting facts about our changing climate

- **After the last Glacial Age, it took 5,000 years for superficial tempreatures to increase 4-7ºC**
- **In the 20th century alone, global temperatures have risen an average of 0.7ºC**
  - **This is 8X faster than previous warming events, and**
  - **5,000X faster than the average of all warming events in the history of Earth!**
- **2000-2020 are the warmest decades in recorded human history; the past 3 years (2021-2023) are the hottest ones registered**
- **Some consequences are: melting of polar ice sheets, sea level rise, increase in frequency and intensity of atmospheric events, catastrophic coastal and marine effects**

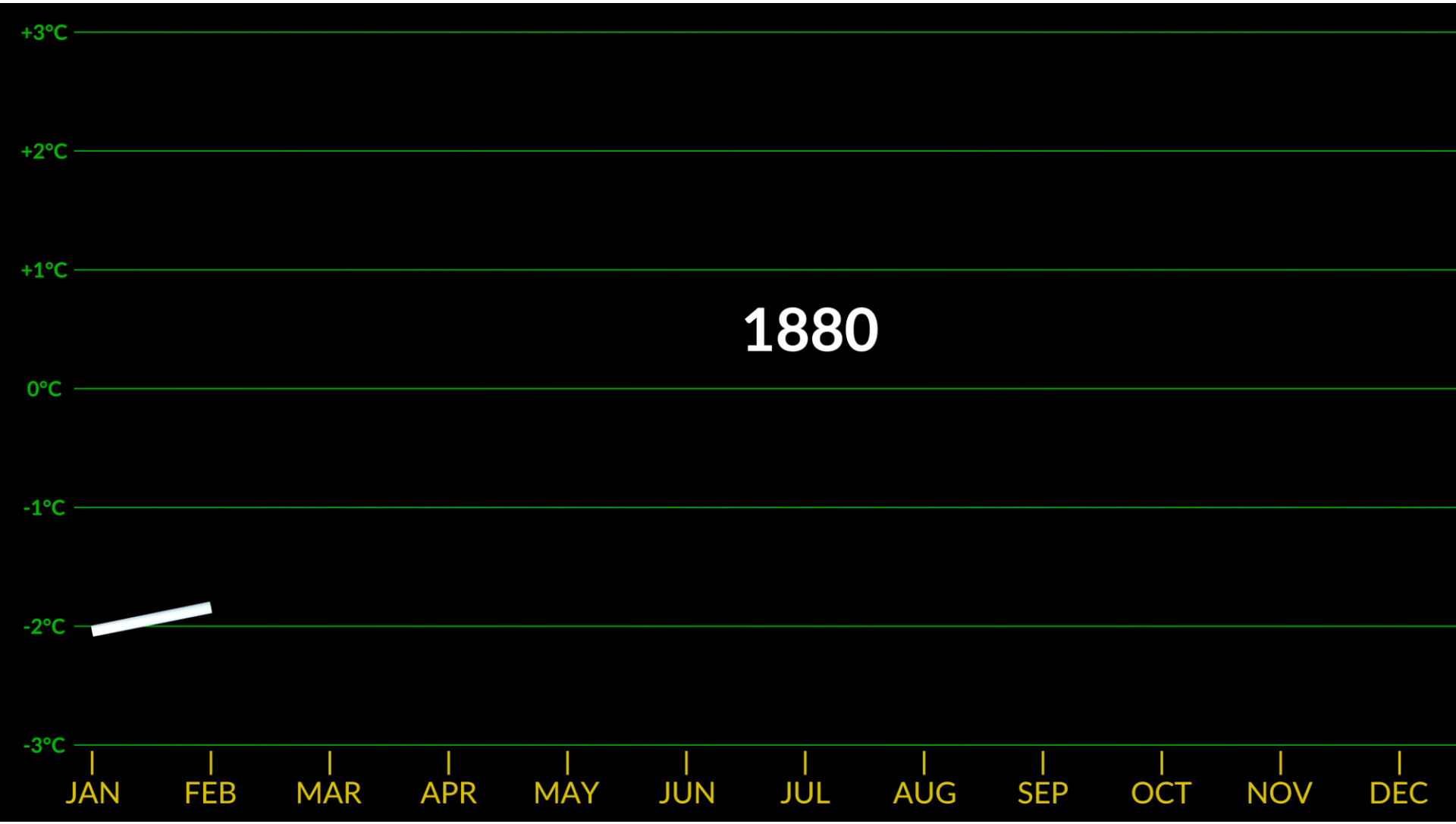


Credit: https://svs.gsfc.nasa.gov

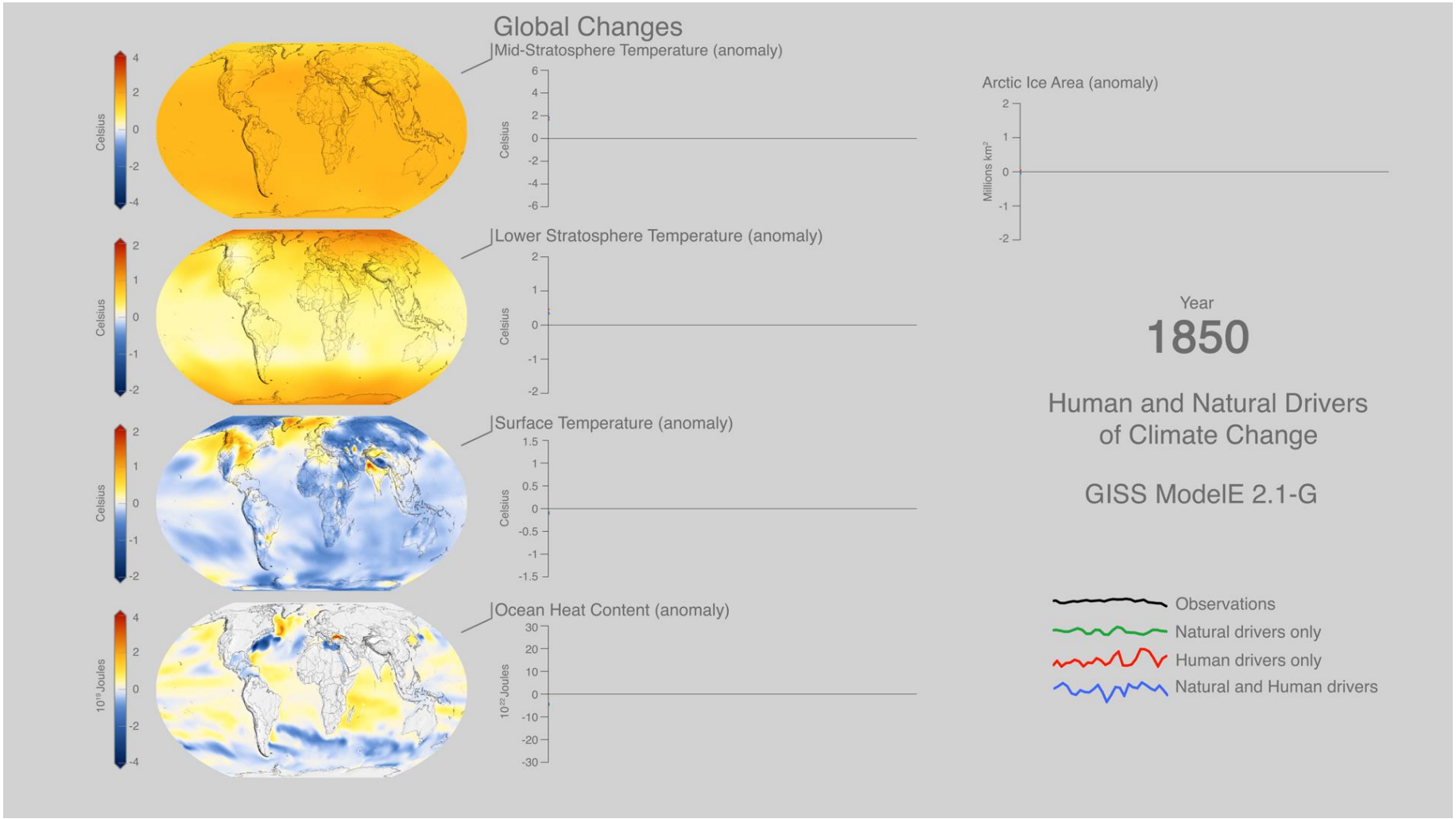
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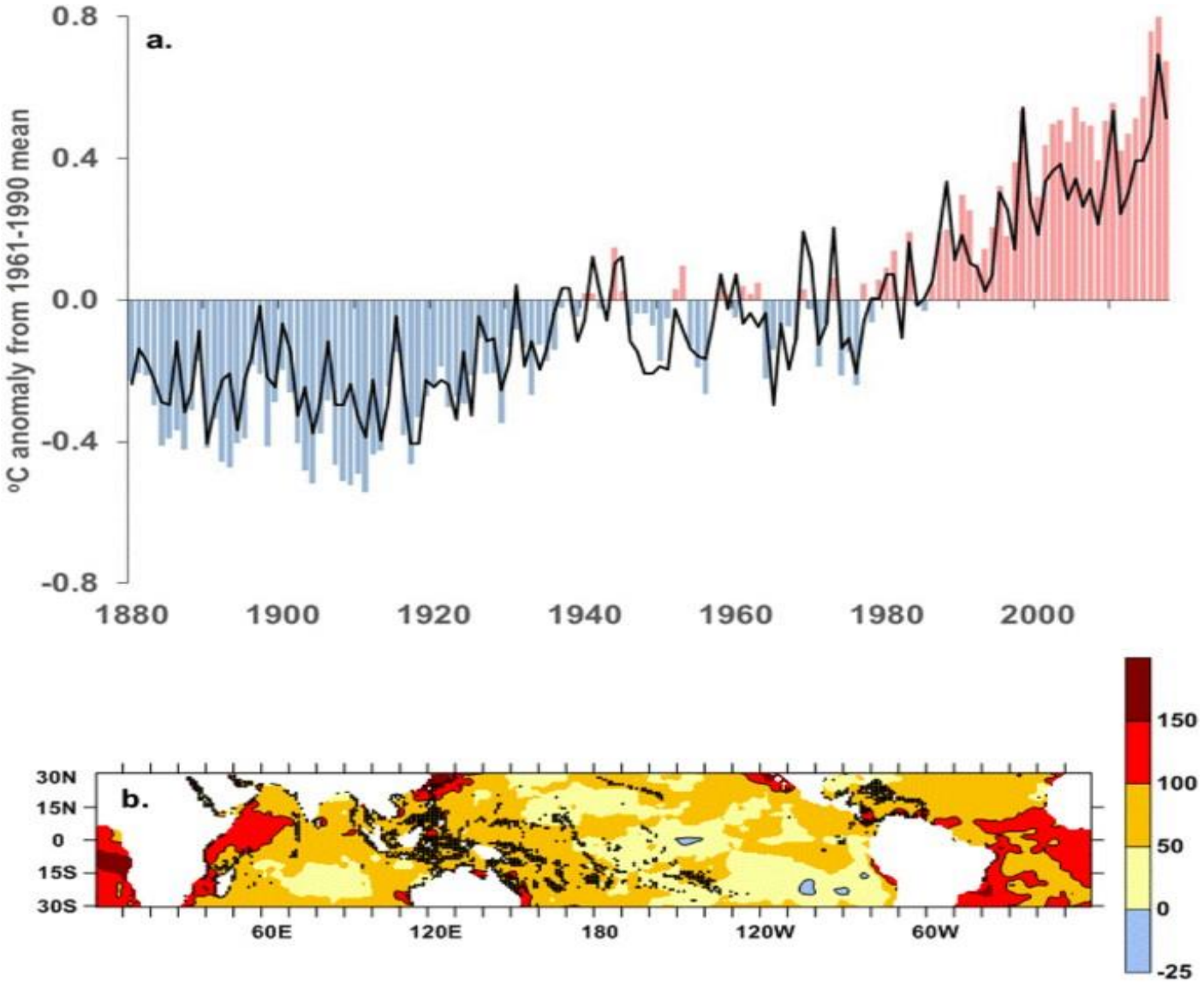
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Credit: https://svs.gsfc.nasa.gov



Credit: https://svs.gsfc.nasa.gov



From: Lough et al 2018

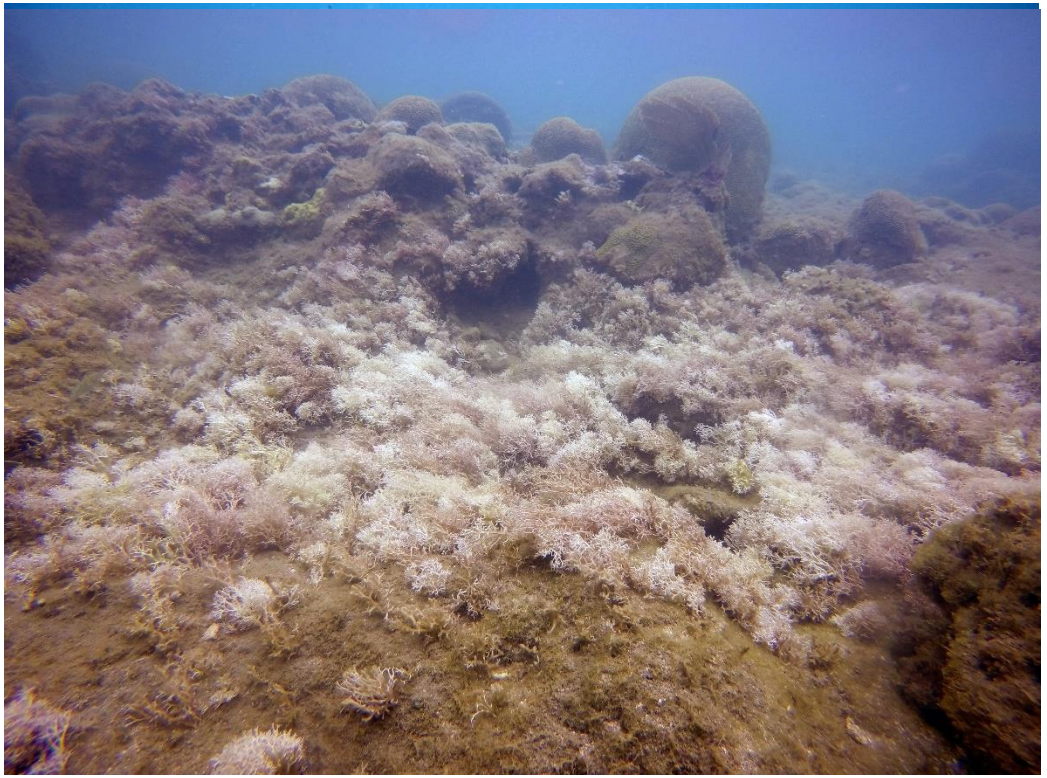
Coral Reefs
An endangered ecosystem

- **Coral reefs are among the most biodiverse marine ecosystems in the World**
  - Thousands of species of all sizes depend on these ecosystems
- **Many of these ecosystems are threatened by human-related activities and climate change**
- **While these cover less than 1% of the ocean floor, they provide sustenance for millions of people worldwide**



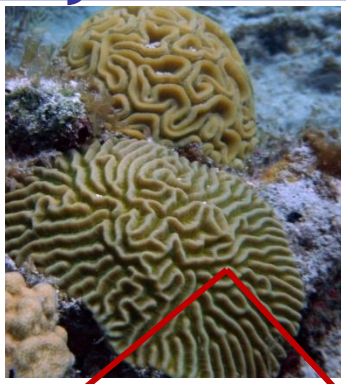
Coral Reefs
An endangered ecosystem

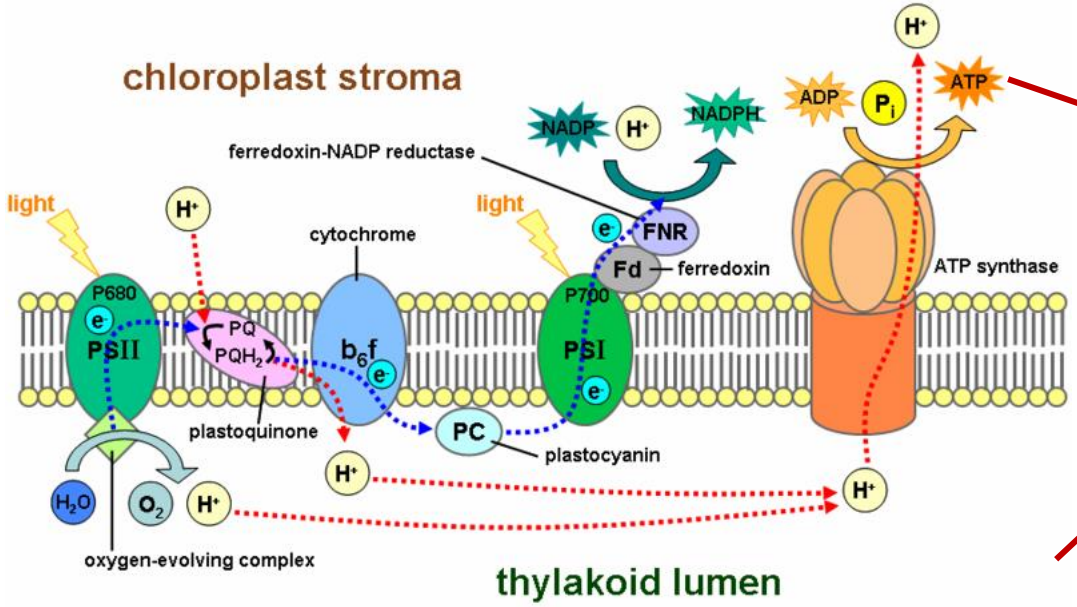
- **Many of these ecosystems are threatened by local human activities (mechanical damages, sediments from the watersheds, eutrophication) or by factors associated to climate change (increased sea surface temperatures and sea level, acidification)**
- **This may cause a dramatic change in the reef benthic composition in the next decades**

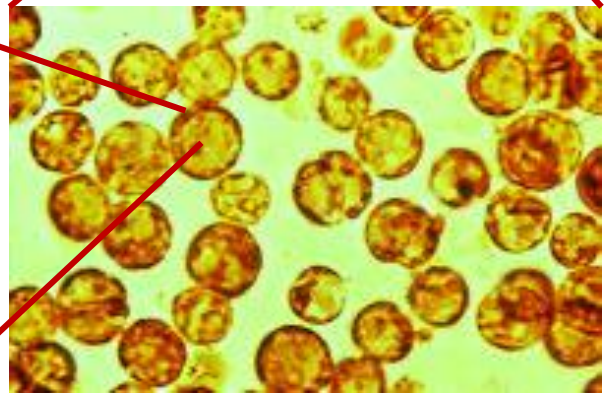


The stability of the reef depends on a symbiotic relationship and photosynthesis



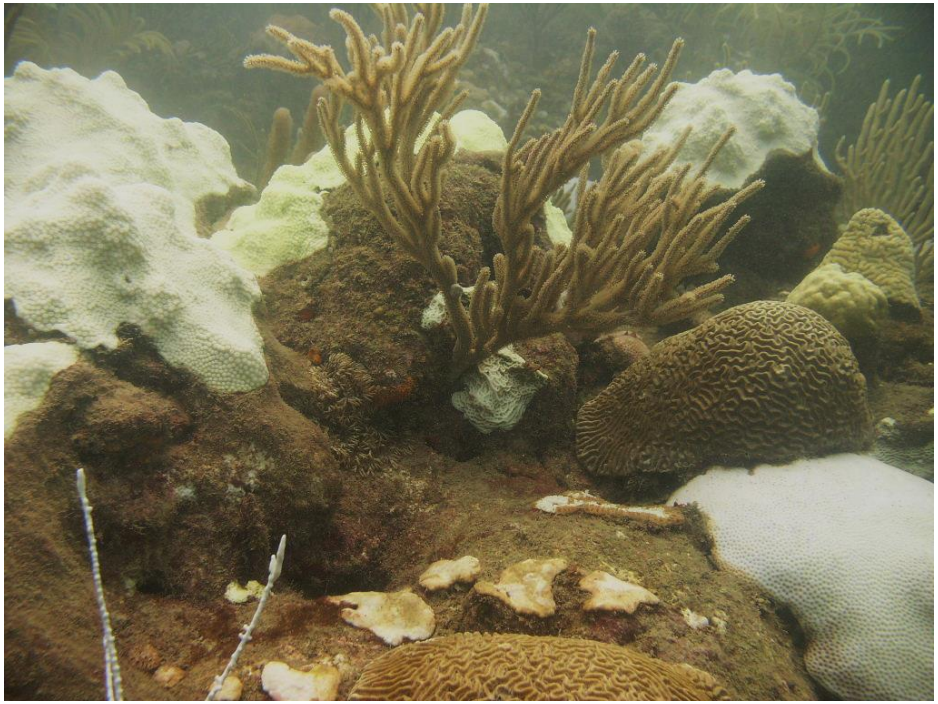






Coral Bleaching

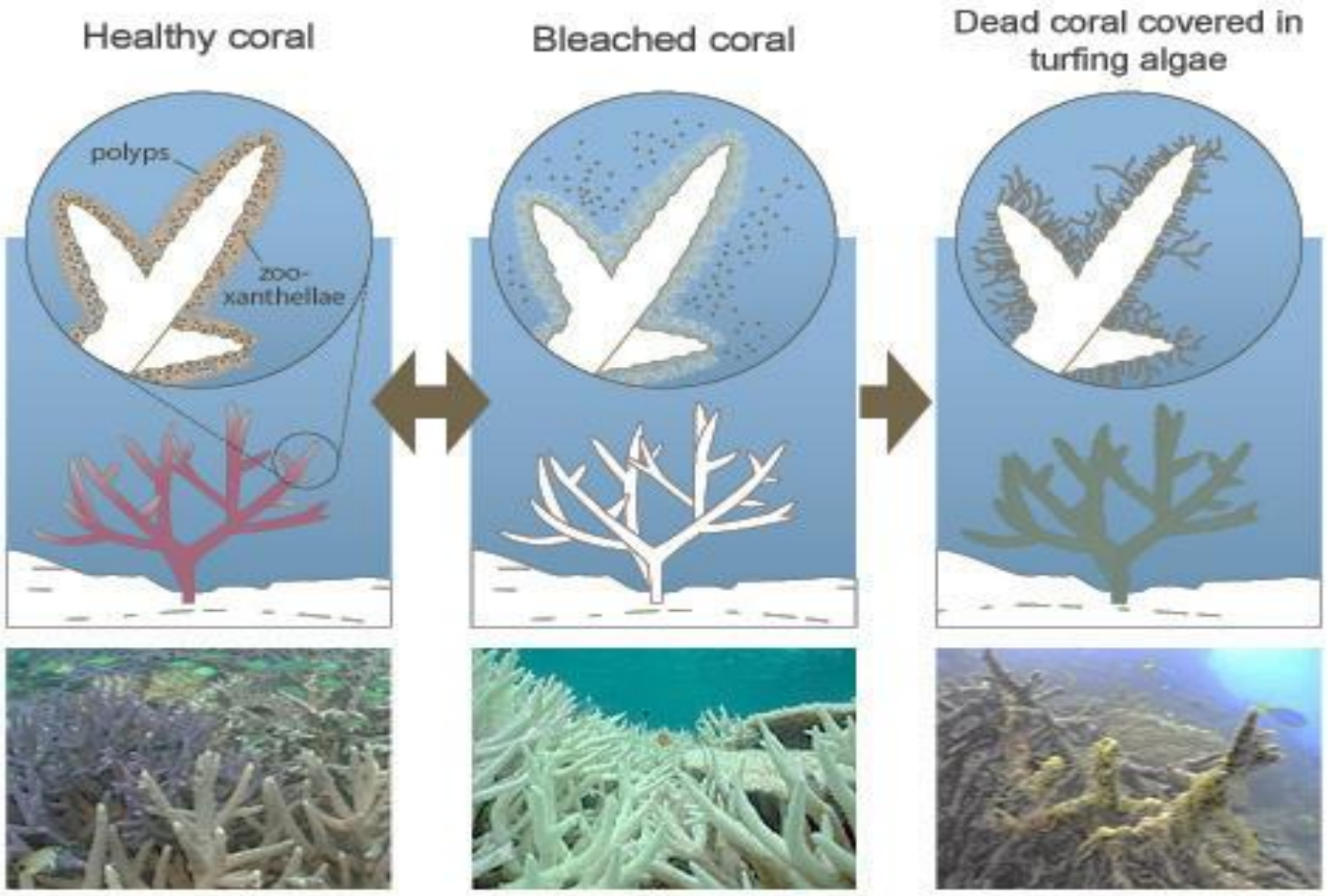
- **Mostly due to environmental factors:**
  - Drastic increases or decreases of water temperature
  - Sedimentation
  - UV radiation
- **Effects:**
  - Zooxanthellae lose their pigments
  - Zooxanthellae are expulsed by the coral
  - Both
- **Consequences:**
  - Reduced coral resistance to diseases
  - Reduced competitiveness with other benthic organisms particularly filamentous algae
  - Colony death
  - Reduced ecosystem resilience







What is coral bleaching?



Credit: www.gbrmpa.gov.au

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Great Barrier Reef

Great Barrier Reef: 93% of reefs hit by coral bleaching

Comprehensive aerial survey reveals full extent of the devastation caused by abnormally warm ocean temperatures



Michael Slezak

@MikeySlezak

email

Tuesday 19 April 2016 16.00 EDT

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38



Coral bleaching in March at Lizard Island on the Great Barrier Reef. XL Catlin Seaview Survey

Survey confirms worst-ever coral bleaching at Great Barrier Reef

By Dennis Normile | Apr. 19, 2016 , 6:00 PM

NOAA HOME WEATHER OCEANS FISHERIES CHARTING SATELLITES CLIMATE RESEARCH COASTS CAREERS

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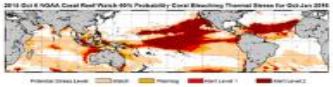
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NOAA declares third ever global coral bleaching event

Bleaching intensifies in Hawaii, high ocean temperatures threaten Caribbean corals

October 8, 2015

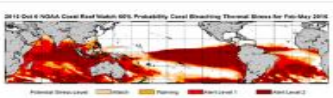
As record ocean temperatures cause widespread coral bleaching across Hawaii, NOAA scientists confirm the same stressful conditions are expanding to the Caribbean and may last into the new year, prompting the declaration of the third global coral bleaching event ever on record.



October 2015–January 2016: NOAA's standard 4-month bleaching outlook shows a threat of bleaching continuing in the Caribbean, Hawaii and Kiribati, and potentially expanding into the Republic of the Marshall Islands. (Credit: NOAA)

Waters are warming in the Caribbean, threatening coral in Puerto Rico and the U.S. Virgin Islands, NOAA scientists said. Coral bleaching began in the Florida Keys and South Florida in August, but now scientists expect bleaching conditions there to diminish.

"The coral bleaching and disease, brought on by climate change and coupled with events like the current El Niño, are the largest and most pervasive threats to coral reefs around the world," said Mark Eakin, NOAA's Coral Reef Watch coordinator. "As a result, we are losing huge areas of coral across the U.S., as well as internationally. What really has us concerned is this event has been going on for more than a year and our preliminary model projections indicate it's likely to last well into 2016."



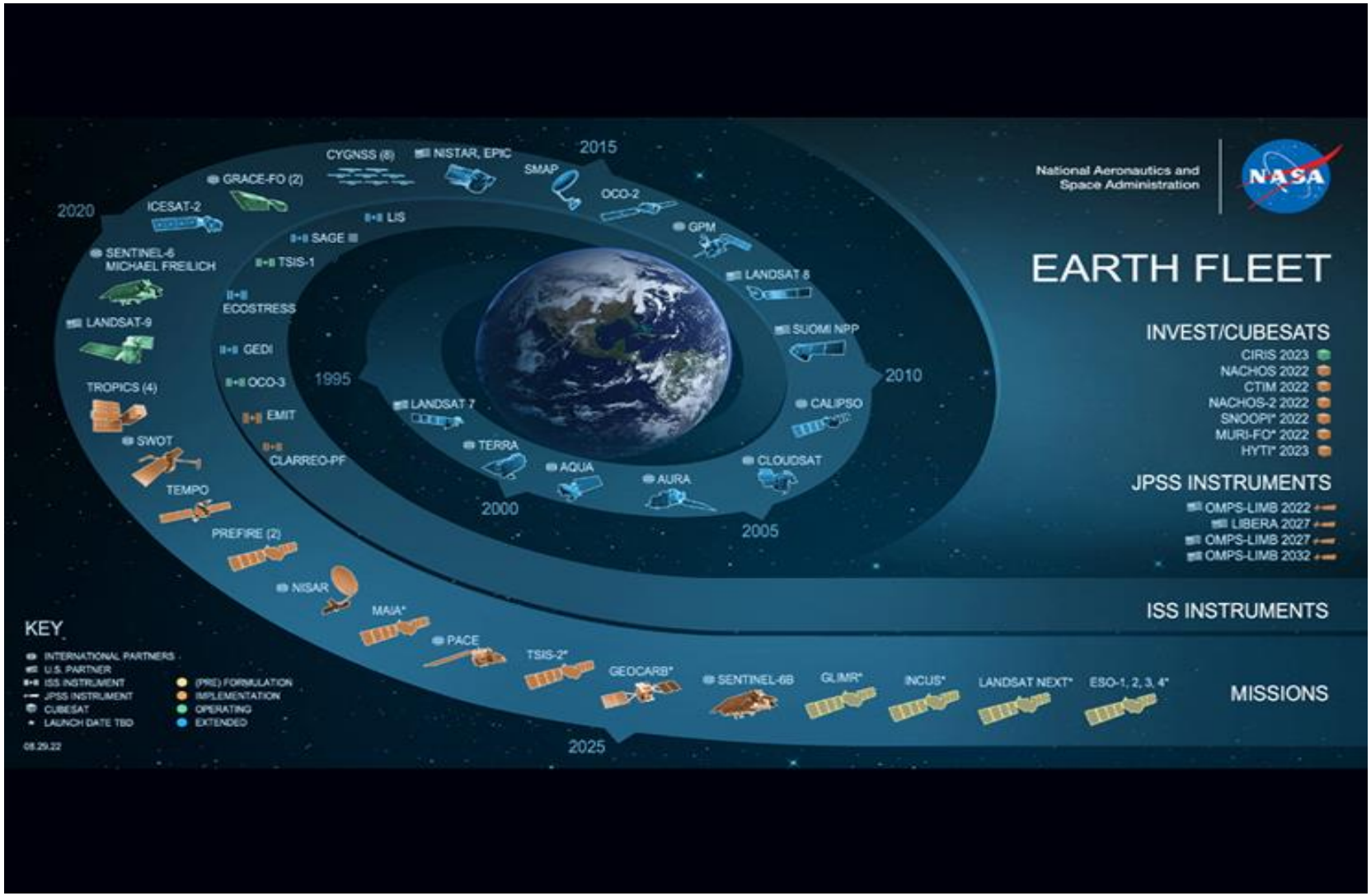
February–May 2016: An extended bleaching outlook showing the threat of bleaching expected in Kiribati, Galapagos Islands, the South Pacific, especially east of the dateline and perhaps affecting Polynesia, and most coral reef regions in the Indian Ocean. (Credit: NOAA)

While corals can recover from mild bleaching, severe or long-term bleaching is often lethal. After corals die, reefs quickly degrade and the structures corals build erode. This provides less shoreline protection from storms and fewer habitats for fish and other marine life, including ecologically and economically important species.



What are some technologies that we have used to study these shallow-water ecosystems?

NASA Earth-viewing satellite fleet

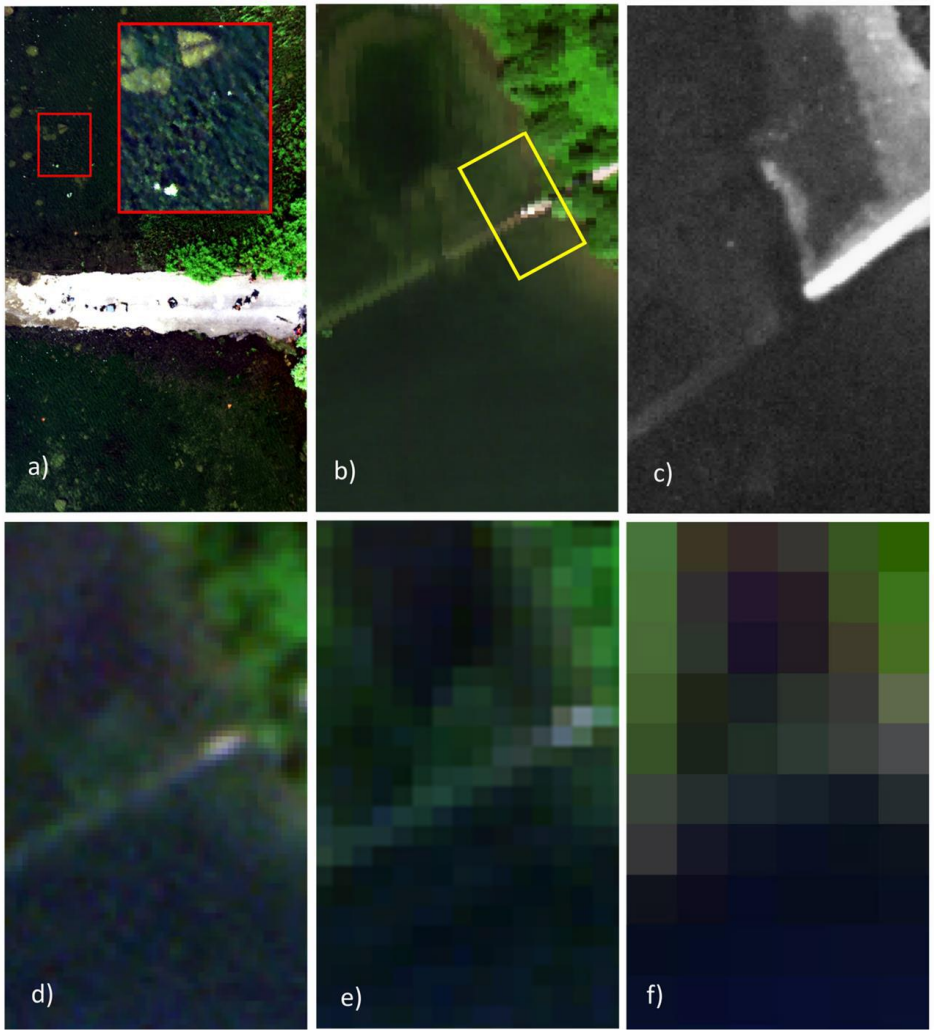


Considerations when choosing satellite data

- **Temporal resolution of data acquisition – Daily? Weekly? Monthly?**
- **Spatial Resolution – depends on the satellite: meters to km**
- **Spectral Resolution – multispectral vs. hyperspectral**
  - Where in the electromagnetic spectrum are the satellite bands? Visible? IR? SWIR?
- **Longevity of the Satellite Mission**
  - Landsat has the longest record of satellite data (since 1970's).
- **Geographical and Atmospheric Conditions at the Study Site**
  - Coastal ecosystems in general tend to be small (seagrass beds) or narrow (beaches)
  - Tropical zones typically have more cloud cover year round
- **Is the data freely available, or is there a cost associated with data acquisition?**
- **Are there any future missions being planned?**
  - Surface Biology and Geology (SBG)
  - Plankton, Aerosol, Cloud, Ocean Ecosystem (PACE)

Spatial resolution effects

A. **3cm – Hyperspectral CASI sensor – drone-based**
B. **1m – CASI sensor (at higher altitude) in a drone**
C. **~1-1.5m – Panchromatic photography**
D. **3m – Planet Scope**
E. **10m – Sentinel-2**
F. **30m – Landsat 8**



Credit: Rowan & Kalacska 2021

Ventajas de las Observaciones Satelitales

- **Available for large regions**
  - Only source of global information for some parameters
- **Long time series and data continuity**
  - Tracks progress
  - Establishes baselines and trends
- **Consistency and comparability**
  - Among multiple countries
- **Diversity of measurements**
  - Many different physical parameters
- **Complements traditional statistical methods**
  - Cross-check with in situ data
- **Mostly free and open access**

Limited water sampling locations

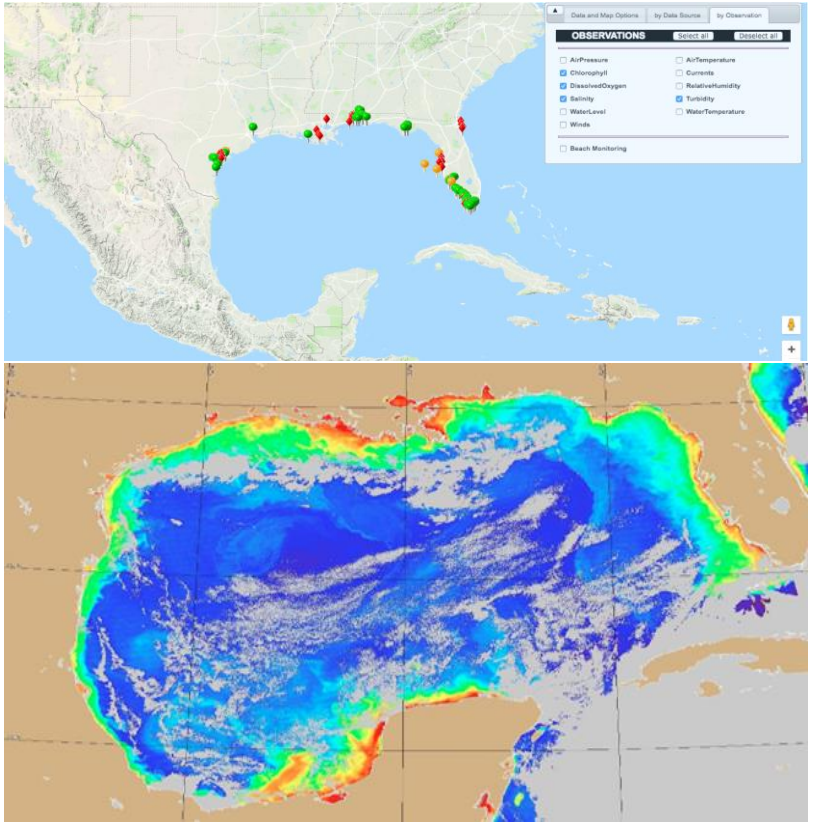


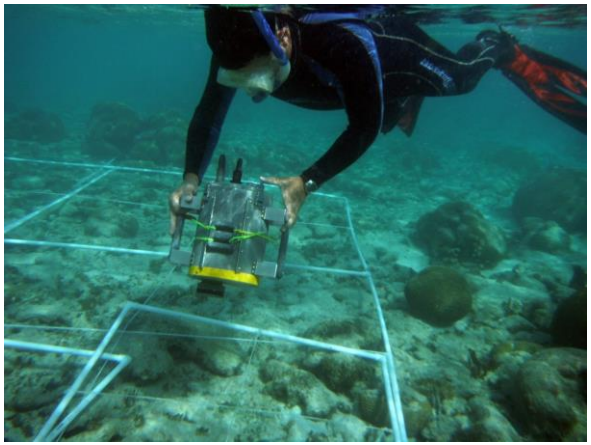
Image Credit (top) http://data.gcoos.org; (bottom) 2013 MODIS Aqua image showing elevated chlorophyll-a levels

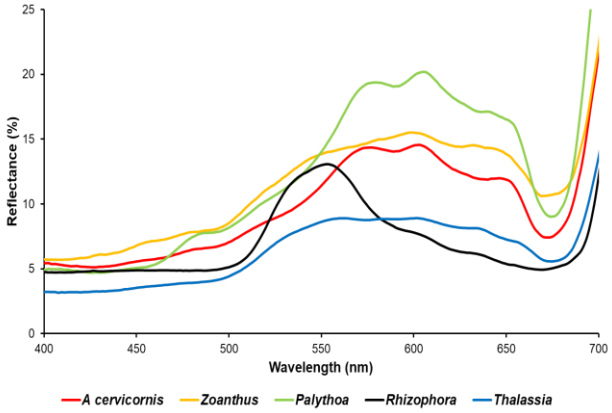
Tools used to monitor extreme changes in coral reefs health

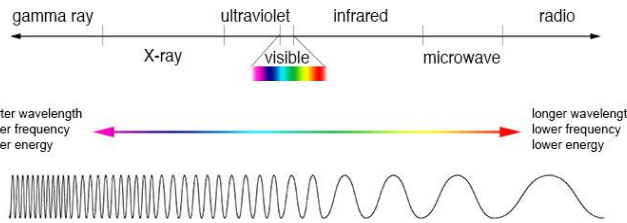
- **Tradicionally it involves the collection of in-situ data including photo or video transects**
- **Sampling of colonies to measure concentration of pigments**
- **Recently, remote sensing techniques either in the field(spectroscopy) or with high resolution instruments capable of sampling great extensions (drones, satellite images [WV-2,3], citizen science tools [NeMO-Net])**

Some techniques to study these phenomena remotely

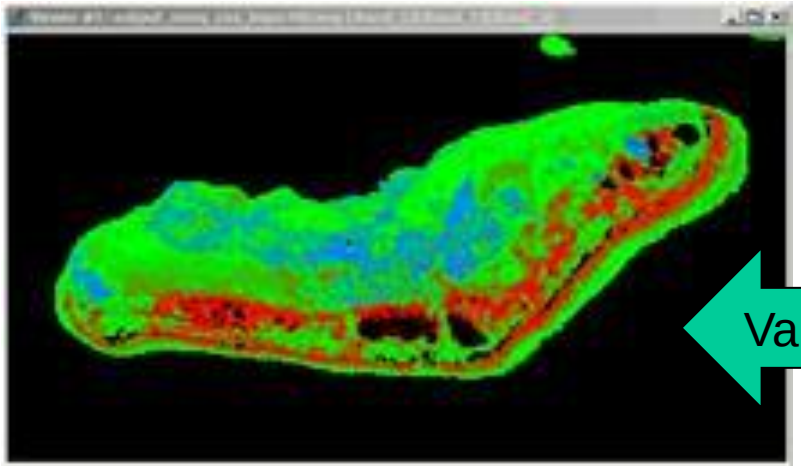
- **<u>Spectroscopy</u> – Is the study of the interaction between matter and the electromagnetic spectrum**
- **Used to validate satellite imagery**



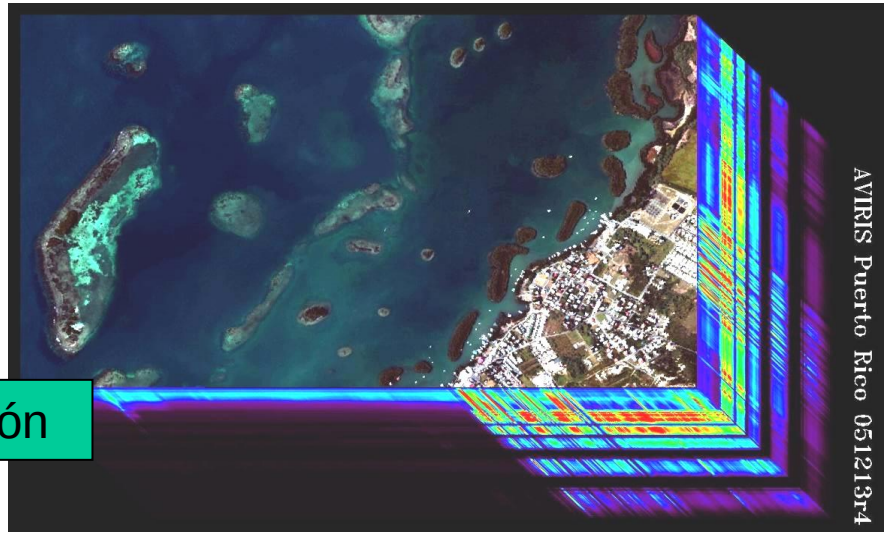




Torres-Pérez et al. 2012 Rem. Sens; 2015 PLoSONE

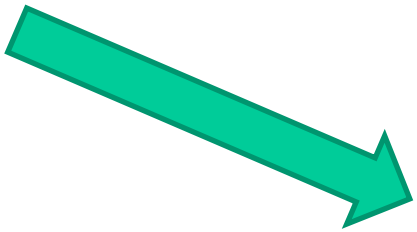


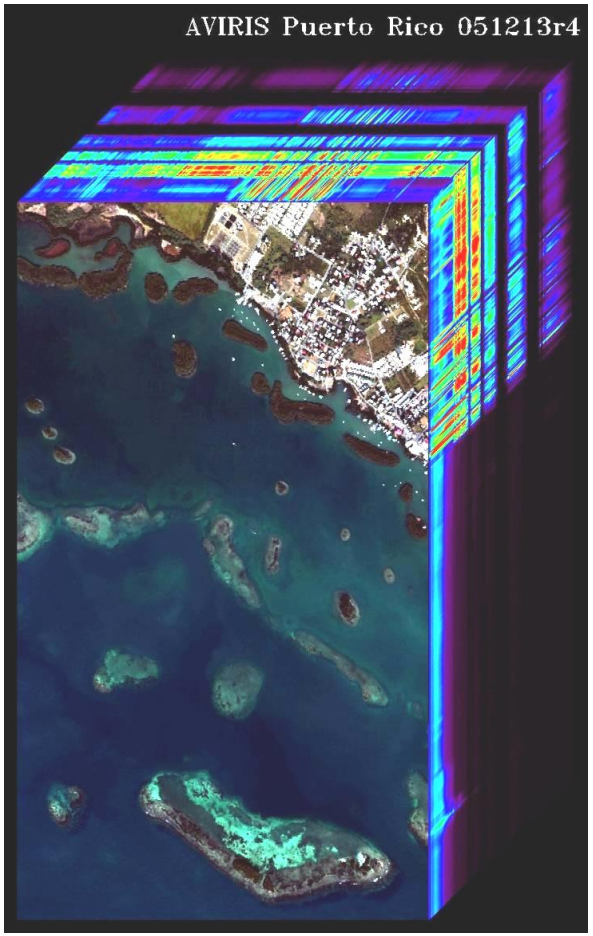
Validación



Then, how do we connect pigments with satellite images?





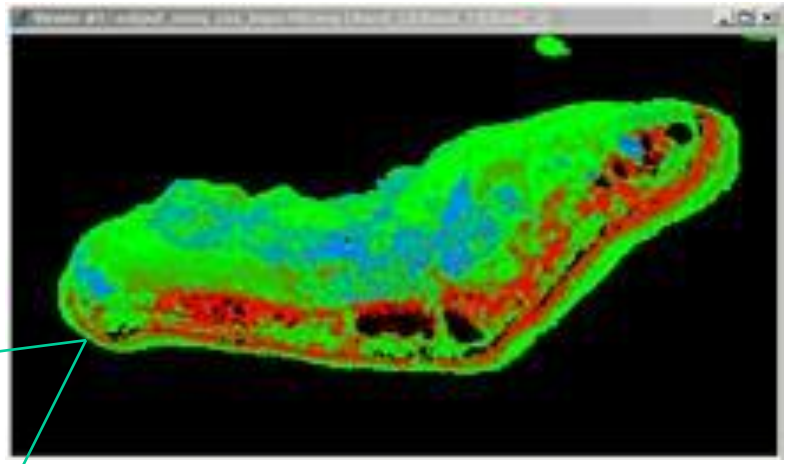


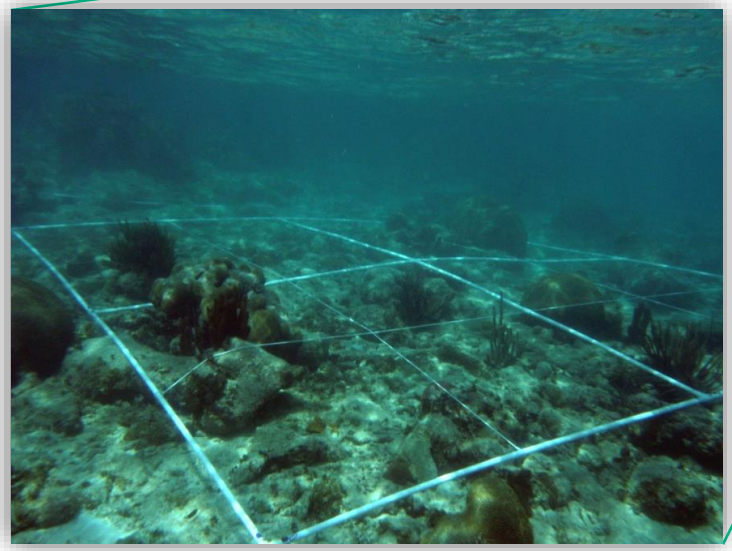
We need to know:

1. **The pigments**
2. **The signals associated with such pigments**
3. **Where in the visible spectrum these absorb**
4. **Algorithms to relate these to the remote images**



There are so many components in a single pixel!!

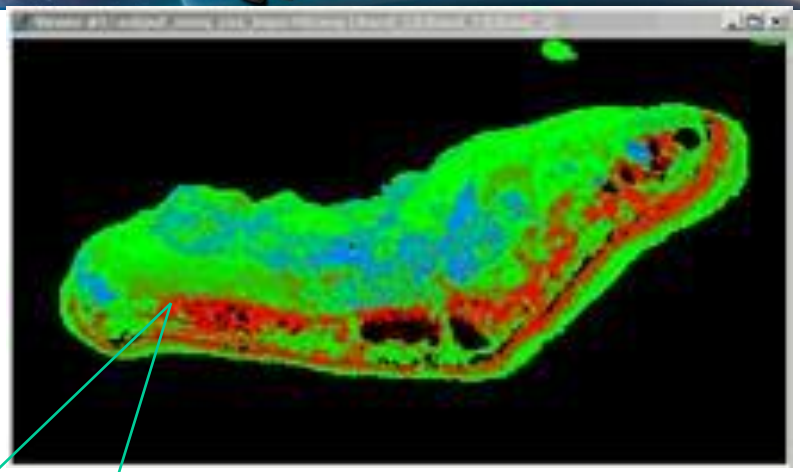




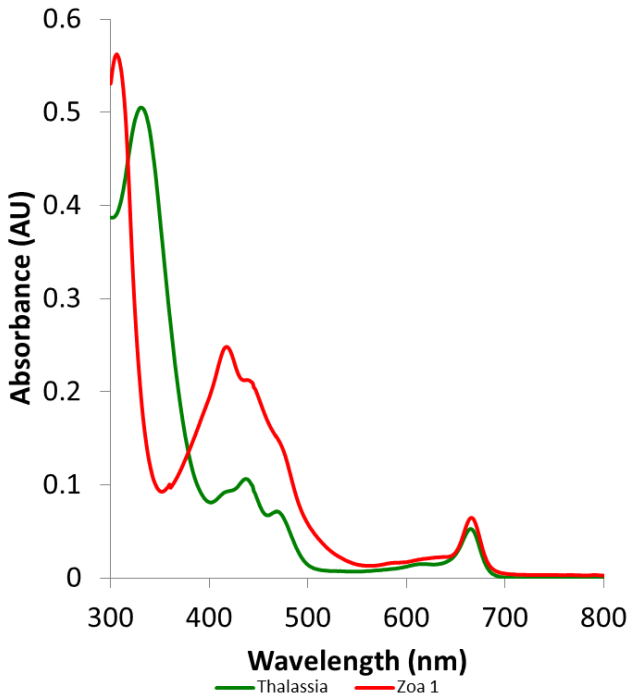
1. Hard corals (1 to X # of Spp.)
2. Seagrasses
3. Gorgonians
4. Calcareous algae
5. Filamentous algae
6. Dead corals
7. Etc.

The contents of a single pixel:

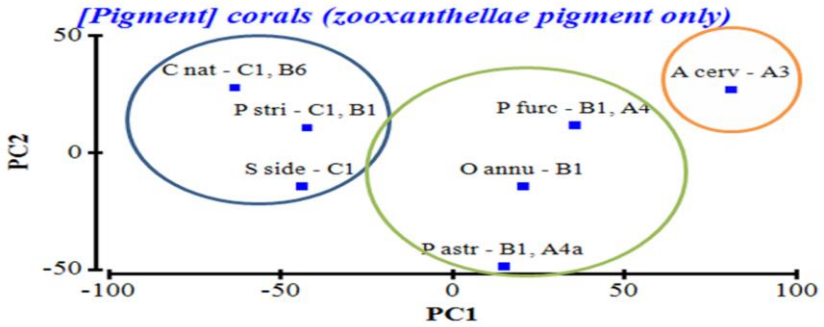
Benthic components may have similar colors, but often their signal is different.

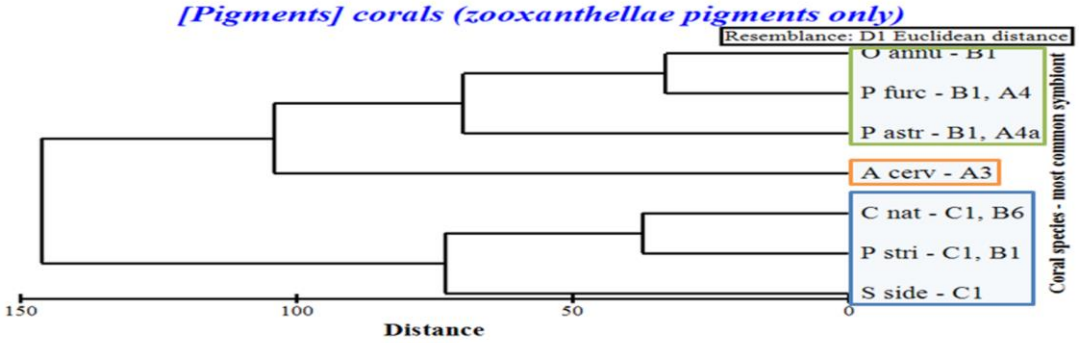


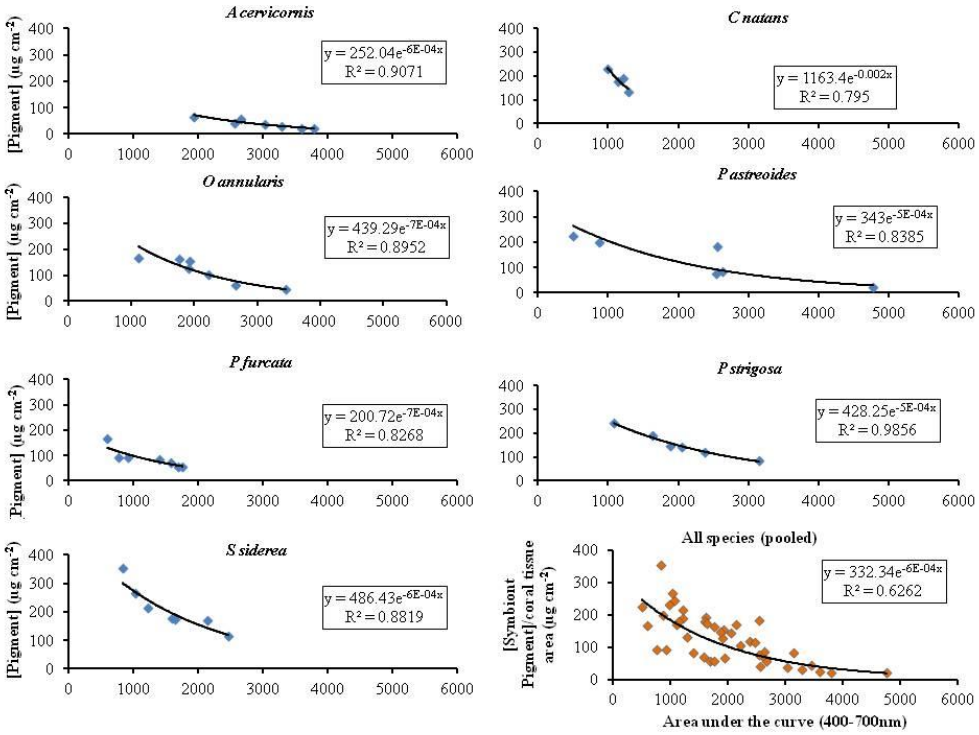




We can use this technique to identify coral species to some extent and to follow bleaching events from start to finish



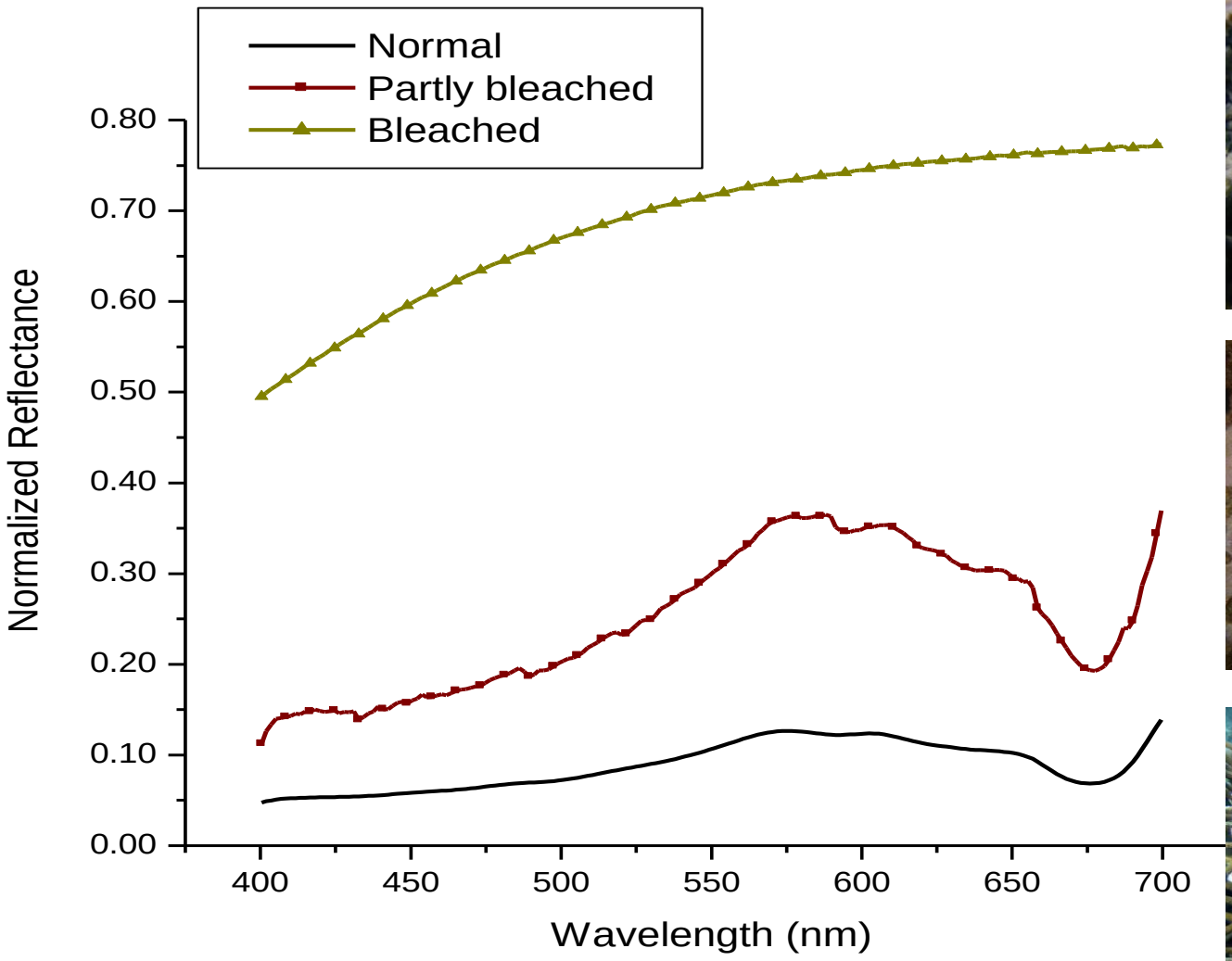


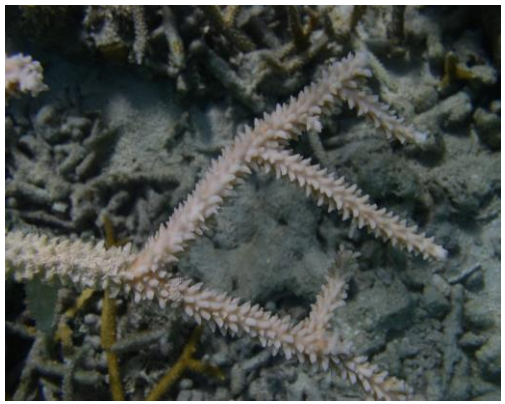


Torres-Pérez et al. 2015 PLoSONE






Normal
Partly bleached
Bleached
Normalized Reflectance
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
400
450
500
550
600
650
700
Wavelength (nm)







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Ames

Discovery Innovations Solutions

NEMO-NET: A CITIZEN SCIENCE TOOL TO CHARACTERIZE GLOBAL CORAL REEFS



VED CHIRAYATH, PHD
UNIV OF MIAMI
JUAN L. TORRES-PÉREZ, PHD
CORAL REEF BIOLOGIST
NASA AMES RESEARCH CENTER

NASA AMES LABORATORY FOR ADVANCED SENSING

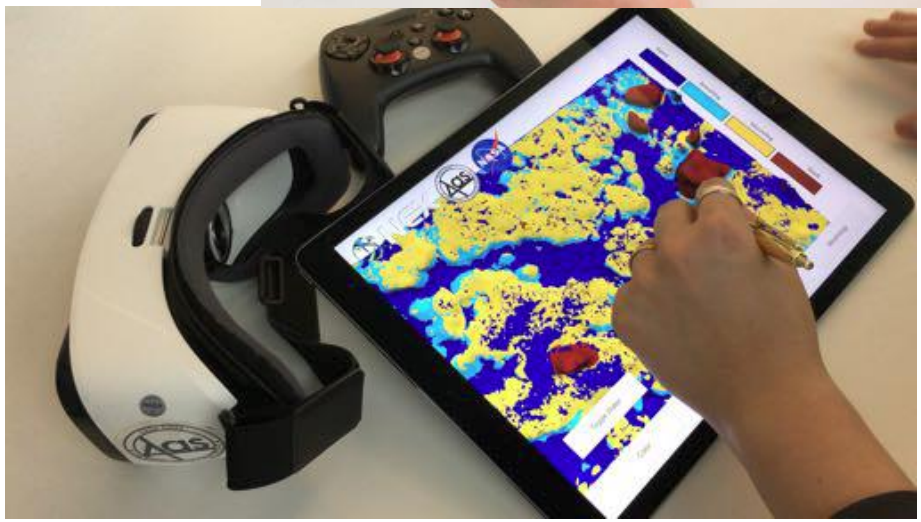
NASA

NeMO-Net (The Neural Multimodal Observation & Training Network for Global Coral Reef Assessment (Chirayath, PI)



Objectives: Develop an algorithm to identify coral reef components, and

Quantify percent cover of corals and their spatial distribution at the smallest scale possible using satellite and drone images



The app is available for iPads & iPhones, and now for Androids

Free!!!!!

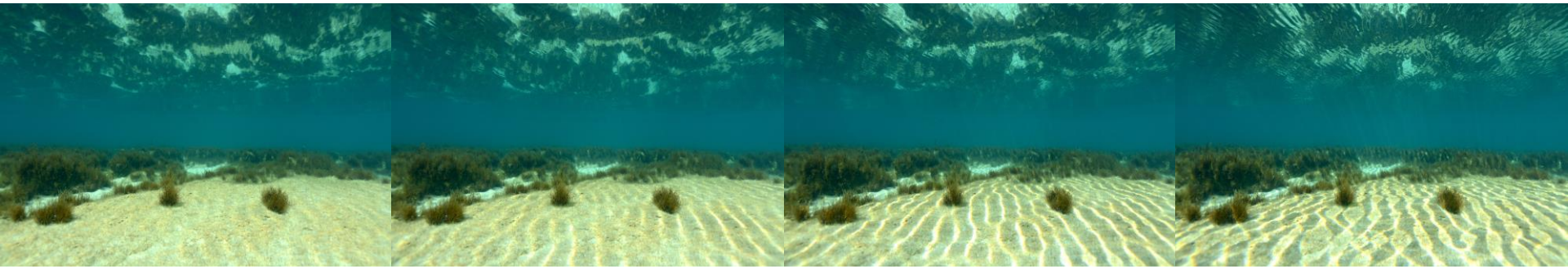
Soon: NeMO-Net en Español!!

OCEAN WAVE FLUID LENSING PHENOMENON

Caustics



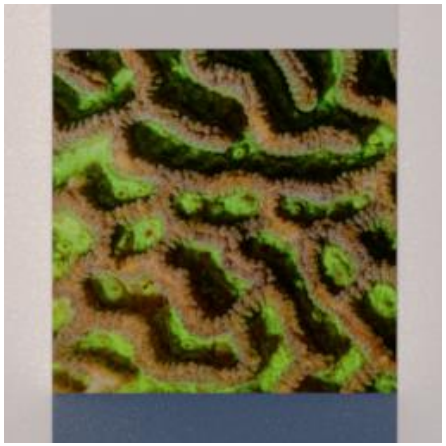
Fluid lenslets and evolution of caustics



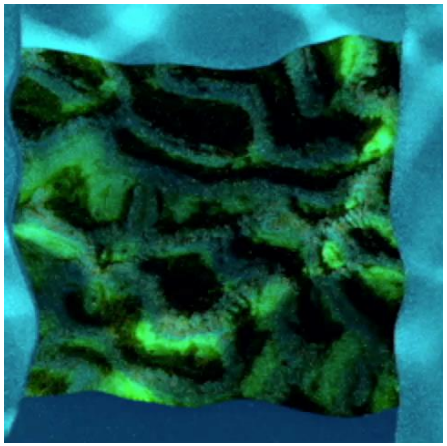
FluidCam

2D Fluid Lensing, Coral Test Target, Depth = 4.5m, MSL

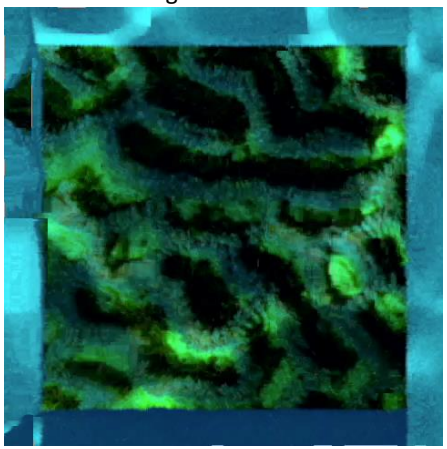
No Fluid



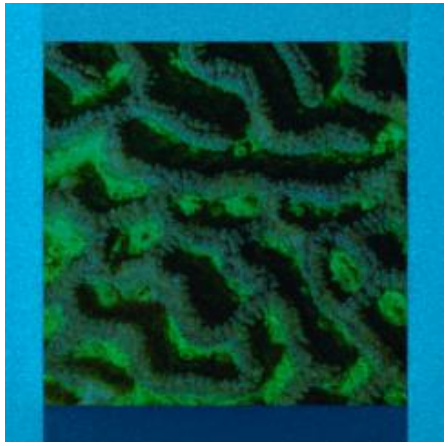
Raw Distorted Frames



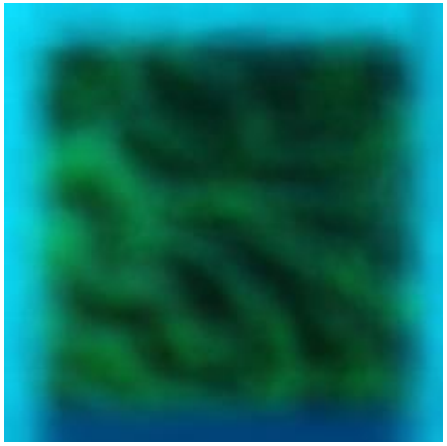
2D Fluid Lensing Results



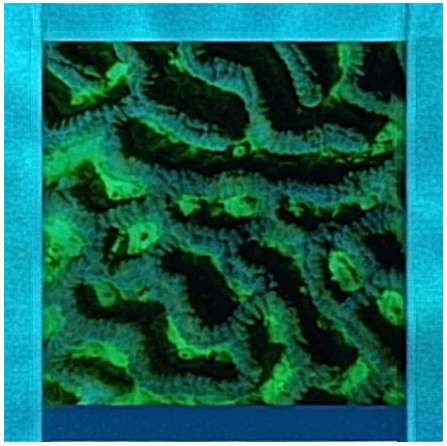
Flat Fluid



Mean Image



2D Fluid Lensing Integration



National Aeronautics and Space Administration

FluidCam



NASA AMES
LABORATORY FOR ADVANCED SENSING

National Aeronautics and Space Administration

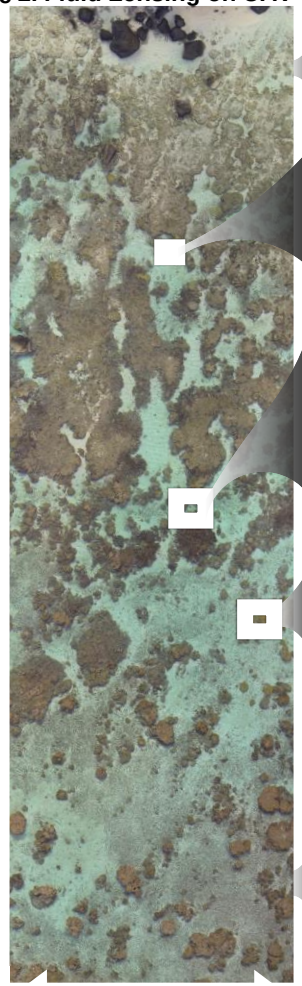
Ames

Discovery Innovations Solutions

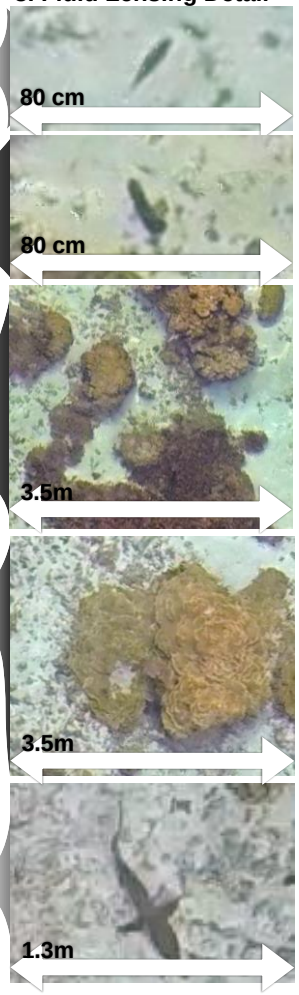
1. Best Remote Sensing Image



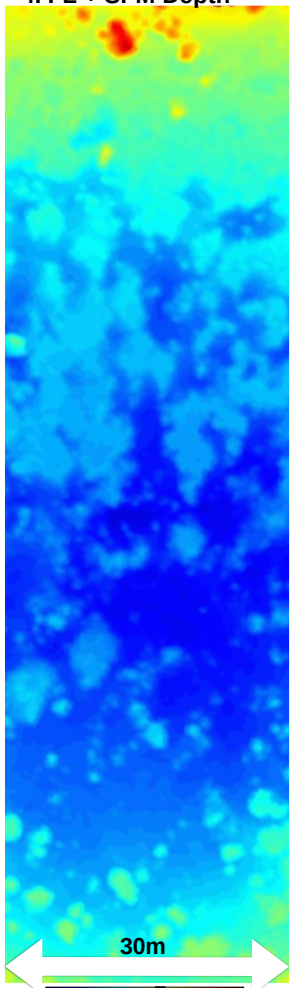
2. Fluid Lensing on UAV



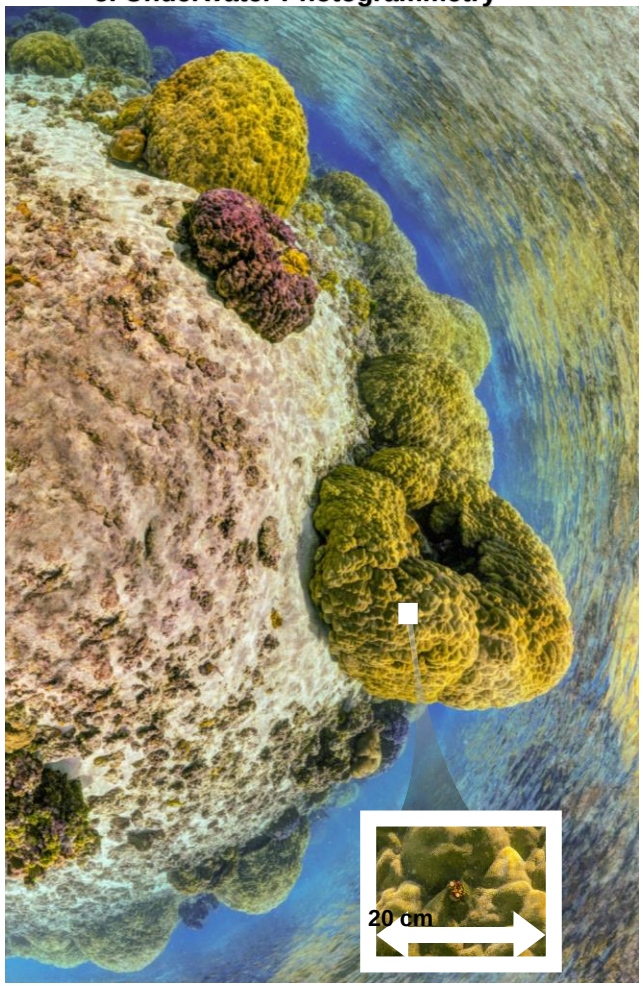
3. Fluid Lensing Detail



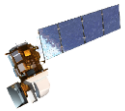
4. FL + SFM Depth

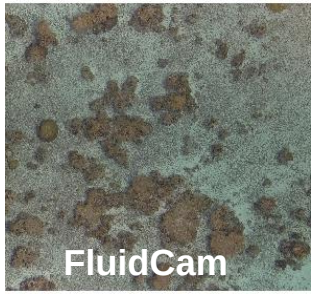


5. Underwater Photogrammetry



NEMO-NET DATA SOURCES

Sensor	Effective Spatial Resolution	3D	Spectral Bands	Locations
 Underwater AUV	0.1 - 5 cm	YES	3	Australia, Great Barrier Reef, Pacific
FluidCam & MiDAR (NASA)	**0.1 - 1 cm**	**YES**	**3-8**	American Samoa, Guam, Western Australia, Puerto Rico, Indo-Pacfifc
 QuickBird (USGS)	0.65 m	NO	4	US Territories
WorldView-2/3 (LOF)	**0.5 - 3 m**	**NO**	**8**	Global
 CORAL PRISM (NASA)	7 m	NO	248	Hawaii, Mariana Islands, Palau, Guam, Great Barrier Reef
LandSat (USGS)	**30 m**	**NO**	**11**	Global







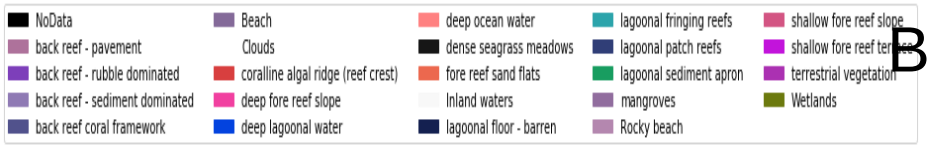


From geomorphology
2-D

To Biodiversity
3-Dimensional







Benthic composition at he highest taxonomic level possible!

PR mission (March 8-17, 2019) – La Parguera (Southwest, PR)

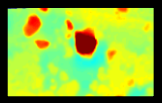


National Aeronautics and Space Administration

MM-Scale Airborne Fluid Lensing



MM-Scale Airborne Fluid Lensing DEM



M-Scale Airborne & Satellite Data



NeMO-Net Ingestion of Multi-Modal Data, Data Fusion, & Training

VR & App-based Active Learning & Interactive Training through IUCN, Mission Blue, & Partners

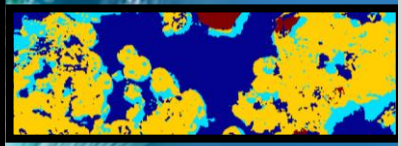


Level 1 Data & Existing Training Data Analysis



Active Learning Training of Coral Cover & Morphology Type

NeMO-Net Living Structure & Morphology Classification





App available at the Google & Apple Store free!!

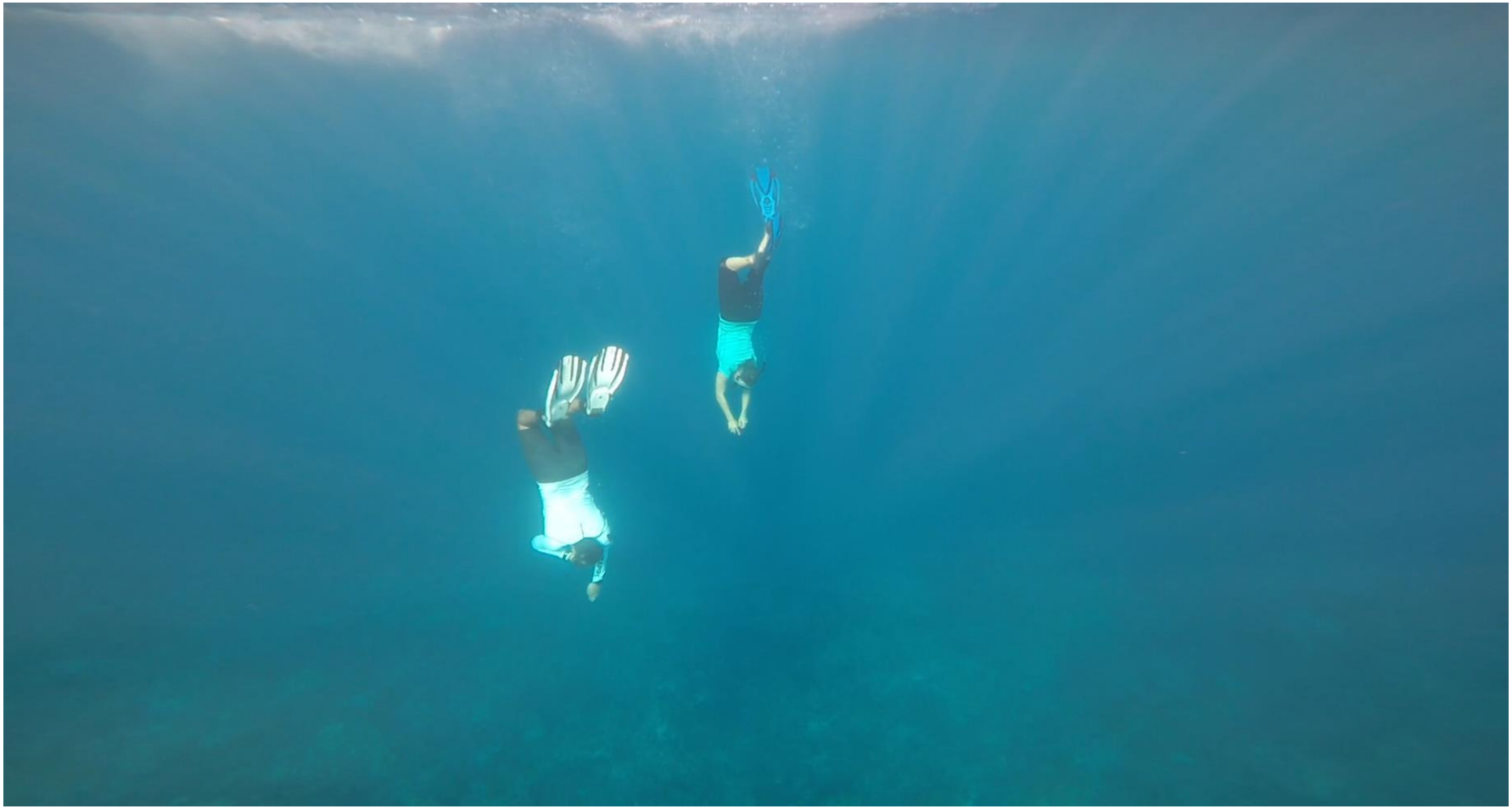


Science Partners

IUCN

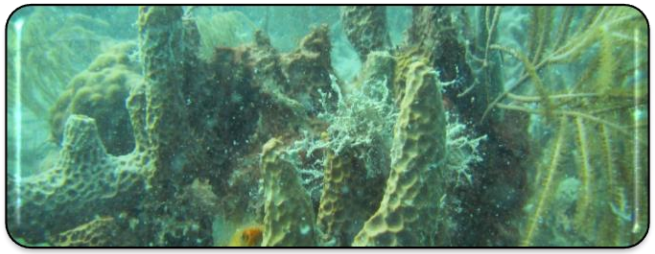
Khaled bin Sultan Living Oceans Foundation

MISSION BLUE™
SYLVIA EARLE ALLIANCE



Ocean Community Engagement and Awareness with NASA Observations and Science for Hispanic/Latino students (OCEANOS) (Torres-Pérez, PI)

- **ROSES F.6 SciAct**
- **4 years (2022-2025); $3.1M**
- **11 Co-I's**
- **Main objective: Increase the participation of Hispanic/Latinos in Science, Technology, Engineering and Maths (STEM), Particularly in oceanography**
- **Summer internships for low-income, first generation students (Puerto Rico)**





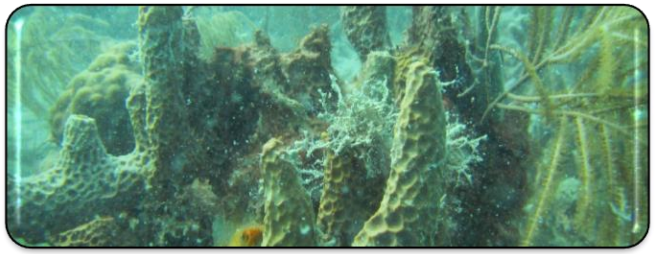


National Aeronautics and Space Administration

Ames

Discovery Innovations Solutions

Ocean Community Engagement and Awareness with NASA Observations and Science for Hispanic/Latino students (OCEANOS) (Torres-Pérez, PI)







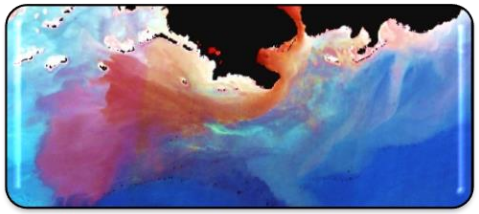
National Aeronautics and Space Administration

Ames

Discovery Innovations Solutions

Ocean Community Engagement and Awareness with NASA Observations and Science for Hispanic/Latino students (OCEANOS)







- **Ocean color with NASA data**
- **Bio-optical data collected with student-built instruments**
- **Biology and Ecology of coral reefs**
- **Field experiences in coastal zones in PR**
- **Use of NeMO-Net to classify coral reefs in PR**
- **Possibility of presenting project results at SACNAS each year**

Ocean Community Engagement and Awareness with NASA Observations and Science for Hispanic/Latino students (OCEANOS)



NASA DEVELOP project in Cali

Part I. Using NASA Earth observations to evaluate wetlands and land reclamation in Cali, Colombia

- **Spring 2024 (January-April)**

Part II. Investigating the "Island Heat" effect in low-income communities in Cali, Colombia

- **Summer 2024 (June-August)**





- **In collaboration with the DAGMA y Fundación Dinamizadores Ambientales**
- **Short-term projects conducted by university students at NASA Ames in California**
- **All the results will be available at the end of the project (technical paper, presentation, maps, etc.)**

¡Thank you!



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