National Aeronautics and Space Administration

Introduction to PACE Hyperspectral Observations for Water Quality Monitoring

Part 1: Introduction to PACE (Plankton Aerosol, Cloud, ocean, Ecosystem) Mission for Water Quality Monitoring

ARSET Host: Amita Mehta (NASA-GSFC & UMBC-GESTAR II)
Guest Instructor: Antonio Mannino, PACE Deputy Project Scientist, Oceans (NASA-GSFC)

September 25, 2024

About ARSET

About ARSET

- **ARSET provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools.**

- Trainings include a variety of applications of satellite data and are tailored to audiences with a variety of experience levels.

AGRICULTURE

CLIMATE & RESILIENCE

DISASTERS

ECOLOGICAL CONSERVATION

HEALTH & AIR QUALITY

WATER RESOURCES

About ARSET Trainings

- Online or in-person
- Live and instructor-led or asynchronous and self-paced
- Cost-free
- Bilingual and multilingual options
- Only use open-source software and data
- Accommodate differing levels of expertise

- Visit the ARSET website to learn more.

Introduction to PACE Hyperspectral Observations for Water Quality Monitoring Overview

Background

- Water quality monitoring in coastal ocean estuaries and inland lakes is critical for ecosystems and fisheries management and safe drinking water.

- Because of the limited spatial and temporal coverage of in situ water samples, remote sensing data are utilized to obtain water quality parameters in coastal and open oceans and inland water bodies.

- Multispectral sensors with limited, medium spectral bands (> 10 nm), e.g., Terra & Aqua-MODIS, NPP & JPSS VIIRS, Landsat-OLI, Sentinel-2 MSI, are widely used for deriving water quality parameters such as chlorophyll-a concentration, an indicator of algal bloom.

- Sentinel-3 OLCI has a few bands with a bandwidth of < 10 nm, also used for deriving water quality parameters such as chlorophyll-a concentration.

- While these sensors can detect algal blooms, they can not distinguish between toxic, harmful algal bloom (HAB) and non-toxic algae.

Why Hyperspectral Observations?

- HABs cause illness in humans if they consume contaminated seafood or drinking water or are exposed to HABs through swimming (NIEHS[1]).
- Hyperspectral observations (< 10 nm spectral bandwidth) help detect HAB organisms in water[2].

Table 1 from the NIEHS Report: Health Effects of HAB Organisms

Organism	Water Type	Color	Toxin	Target Tissue	Health Effects
Alexandrium sp.	Salt	Red or Brown	Saxitoxins	Nerves and Muscles	Paralytic shellfish poisoning, paralysis, death
Karenia brevis	Salt	Red	Brevetoxins	1. Nervous System 2. Respiratory System	1. Gastrointestinal illness, muscle cramps, seizures, paralysis 2. Respiratory problems, especially for asthmatics
Pseudo-nitzschia	Salt	Red or Brown	Domoic Acid	Nervous System	Amnesiac shellfish poisoning, vomiting, diarrhea, confusion, seizures, permanent short term memory loss, or death
Microcystis	Fresh	Blue-Green	Microsystin	Liver	Gastrointestinal illness, liver damage

[1] National Institute of Environmental Health Sciences (NIEHS). "Algal blooms". National Institute of Environmental Health Sciences: Environmental Health Topics. (2021, September 8)
[2] https://www.space4water.org/news/exploring-exciting-potential-hyperspectral-imaging-water-quality-monitoring

PACE: Global, Daily Hyperspectral Observations

https://pace.gsfc.nasa.gov/

- Past NASA Missions with Hyperspectral Sensors: EO Hyperion, HICO.
- Current NASA Mission with Hyperspectral Sensors: EMIT.
- In February 2024 NASA launched PACE, the newest hyperspectral mission:
  - Ocean Color Instrument (OCI) has bands between the 314.55 to 894.602 nm wavelength range with 5 nm bandwidth, and 8 bands in the shortwave infrared range.
  - PACE-OCI will improve detection of toxic algae and help monitor the health of coastal and open oceans and inland water bodies that can be resolved by the OCI footprint (>1 km^2). In the US, 150 to 200 lakes can be resolved by OCI.
- PACE also has polarimeters (HARP2 and SPEXone). Combined ocean and air observations will help us understand how aerosols might impact phytoplankton growth in the ocean.

Training Learning Objectives

By the end of this training participants will be able to:

- Review the capabilities of past and current hyperspectral missions useful for water quality applications.
- Examine key characteristics of the new NASA PACE satellite and hyperspectral sensors including their advantages and limitations.
- Access, analyze, and visualize PACE level-2 and -3 data for water quality monitoring in selected areas of interest using SeaDAS and Jupyter Notebook software.
- Assess the applicability of selected PACE level-2 and -3 water quality parameters to evaluate water quality in large bodies of water.

Prerequisites

- Fundamentals of Remote Sensing
- https://appliedsciences.nasa.gov/sites/default/files/2021-09/WQ_Estuaries_Part1.pdf
- SeaDAS Training
- Jupyter Notebooks and Python 3.X installed on your computer **(Optional)**

Training Outline

Part 1

Introduction to PACE (Plankton Aerosol, Cloud, ocean, Ecosystem) Mission for Water Quality Monitoring

September 25, 2024

10:00-11:30 AM

Part 2

Overview, Access, and Analysis of PACE Ocean Color Data Products

October 2, 2024

10:00-11:30 AM

Part 3

Access and Visualization of PACE/OCI Data using Python/Jupyter Notebook Software

October 9, 2024

10:00-11:30 AM

Homework

Opens October 9 – Due October 24 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.

Part 1

Introduction to the PACE Mission for Water Quality Monitoring

Part 1 – Trainers

Amita Mehta

ARSET Instructor

NASA-GSFC & UMBC-GESTAR II

Antonio Mannino

Guest Instructor

PACE Deputy Project Scientist (NASA-GSFC)

Part 1 Objectives

By the end of Part 1, participants will be able to:

- Review past and current hyperspectral missions useful for water quality applications.
- Identify key features of the NASA PACE hyperspectral satellite and instruments useful for monitoring water quality of large lakes and estuaries.
- Identify advantages and limitations of using PACE/OCI data for water quality monitoring.

How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.

National Aeronautics and Space Administration

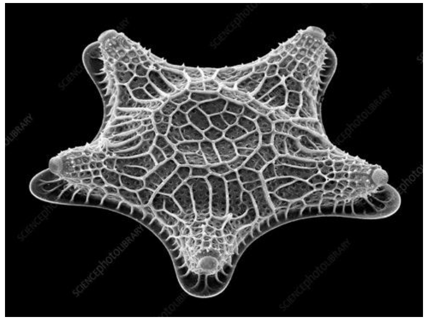
Introduction to PACE Hyperspectral Observations for Water Quality Monitoring

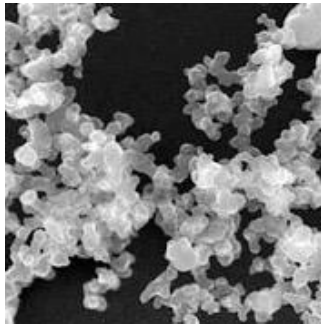
Part 1: Introduction to the PACE Mission for Water Quality Monitoring

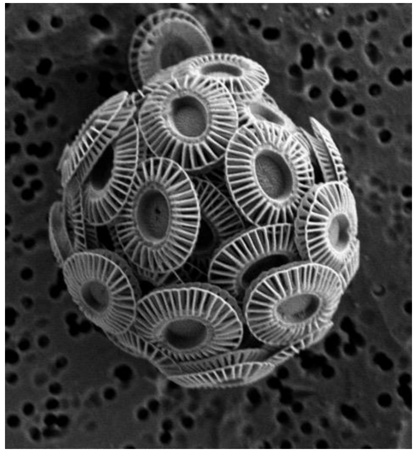
Antonio Mannino (NASA Goddard Space Flight Center)
Acknowledgements: Jeremy Werdell and the PACE Project

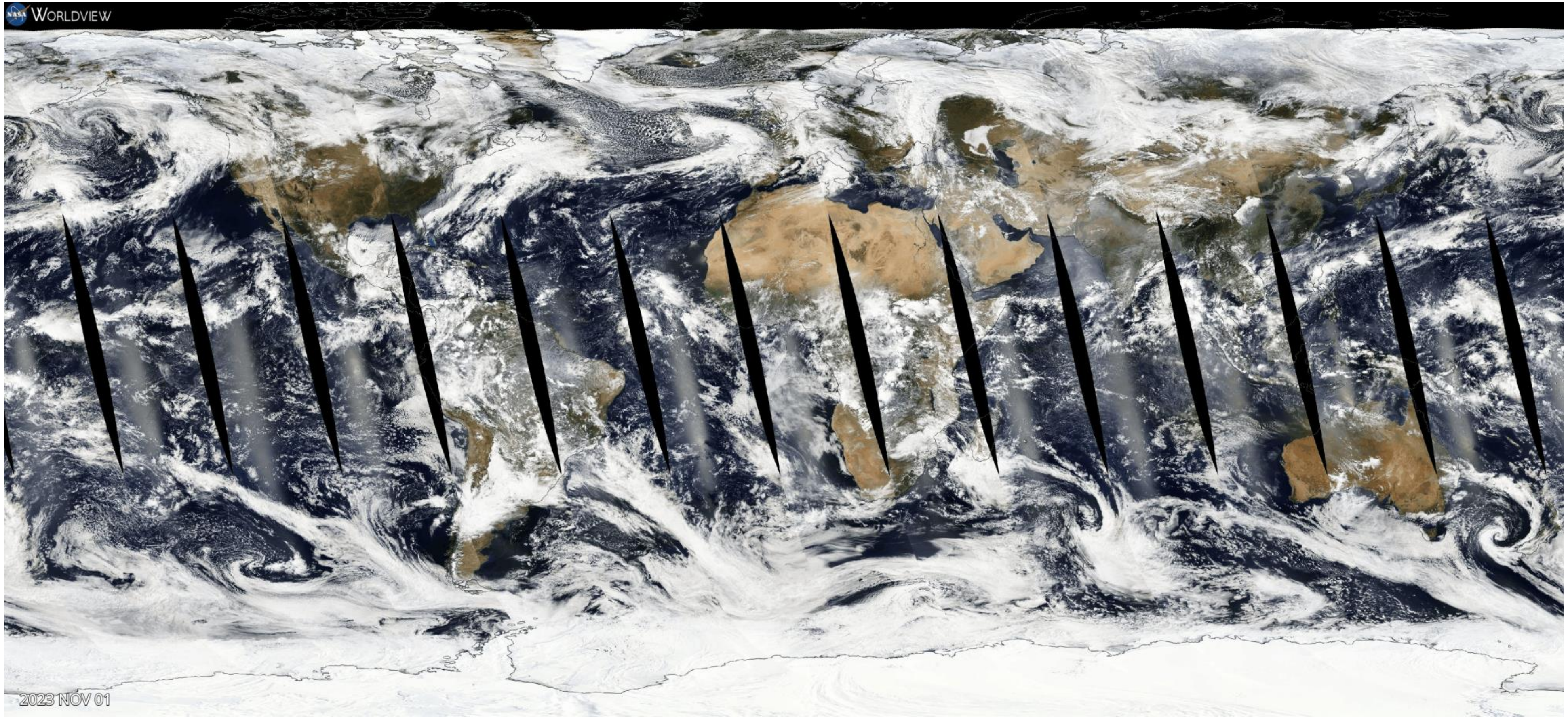
September 25, 2024

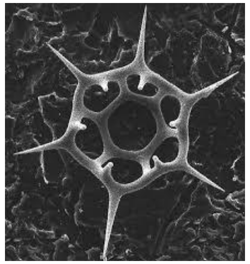
PACE will see invisible (microscopic) stuff from space.

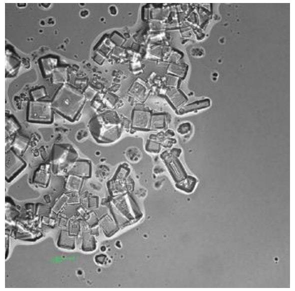


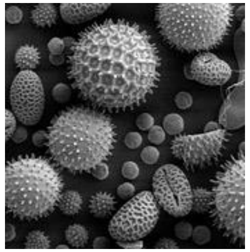


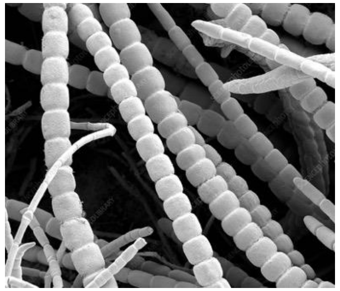


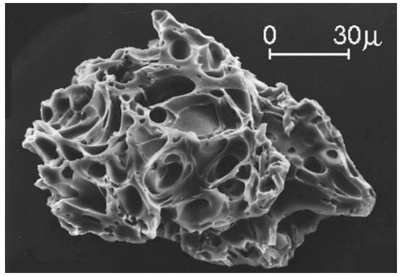






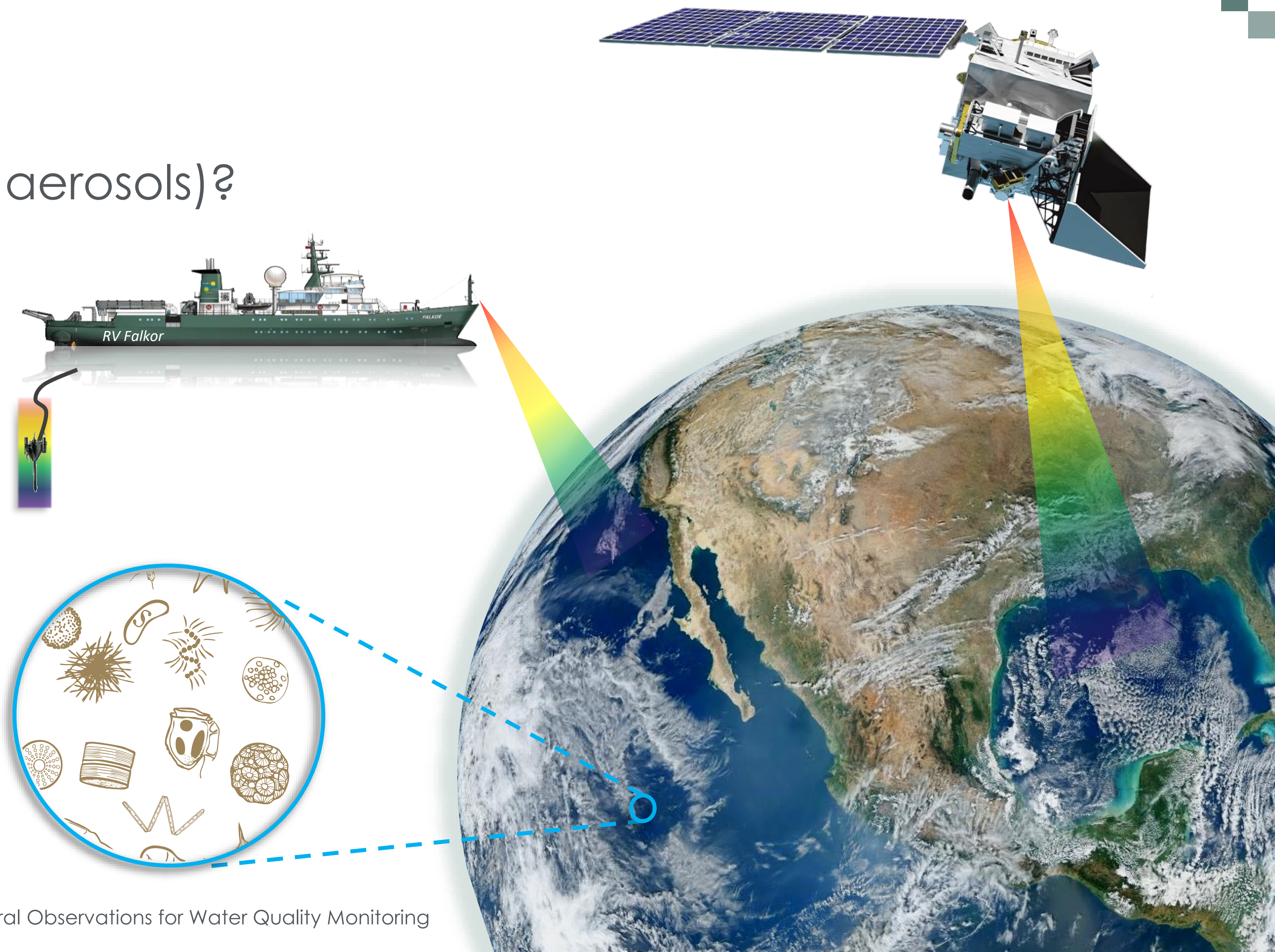




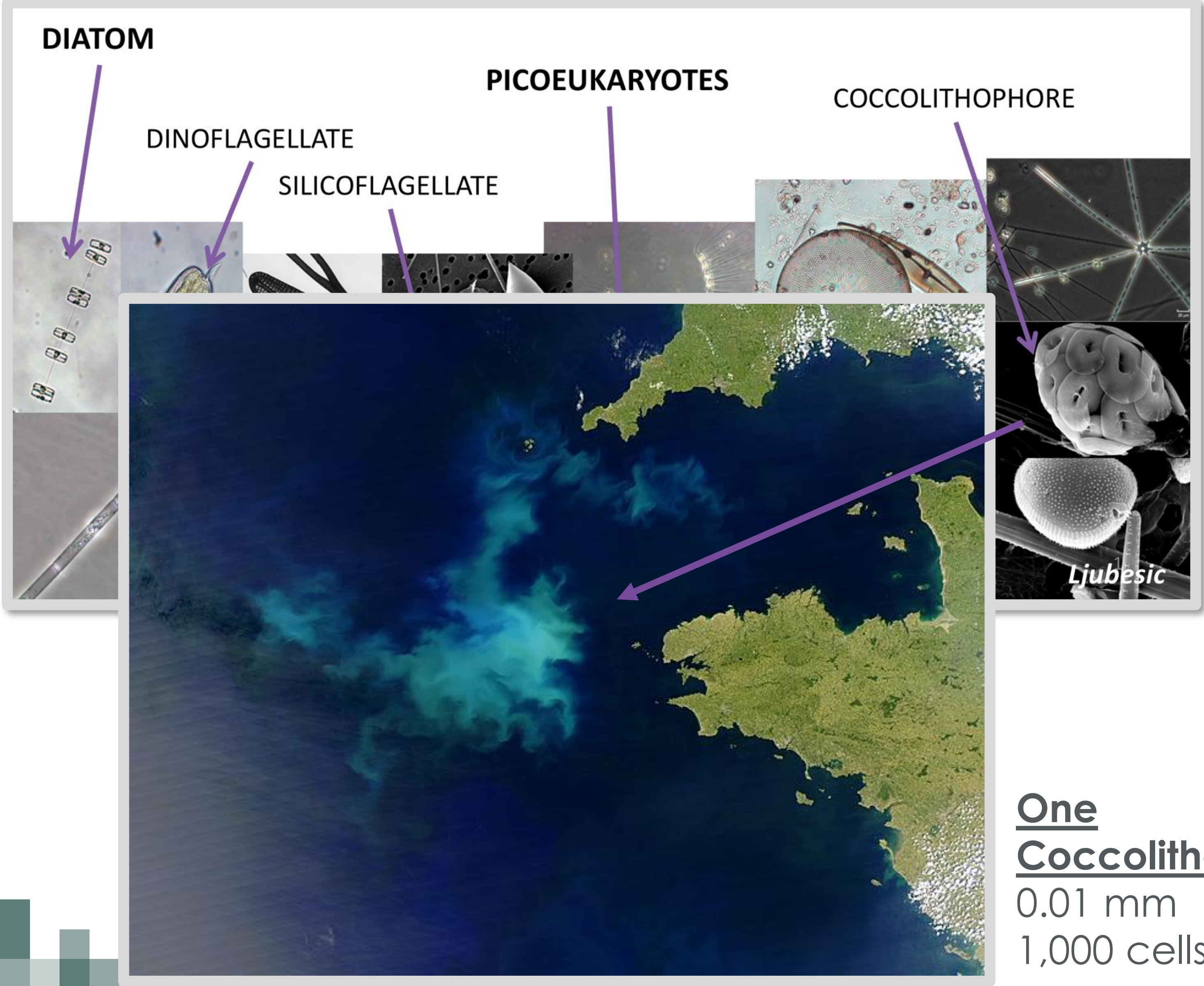


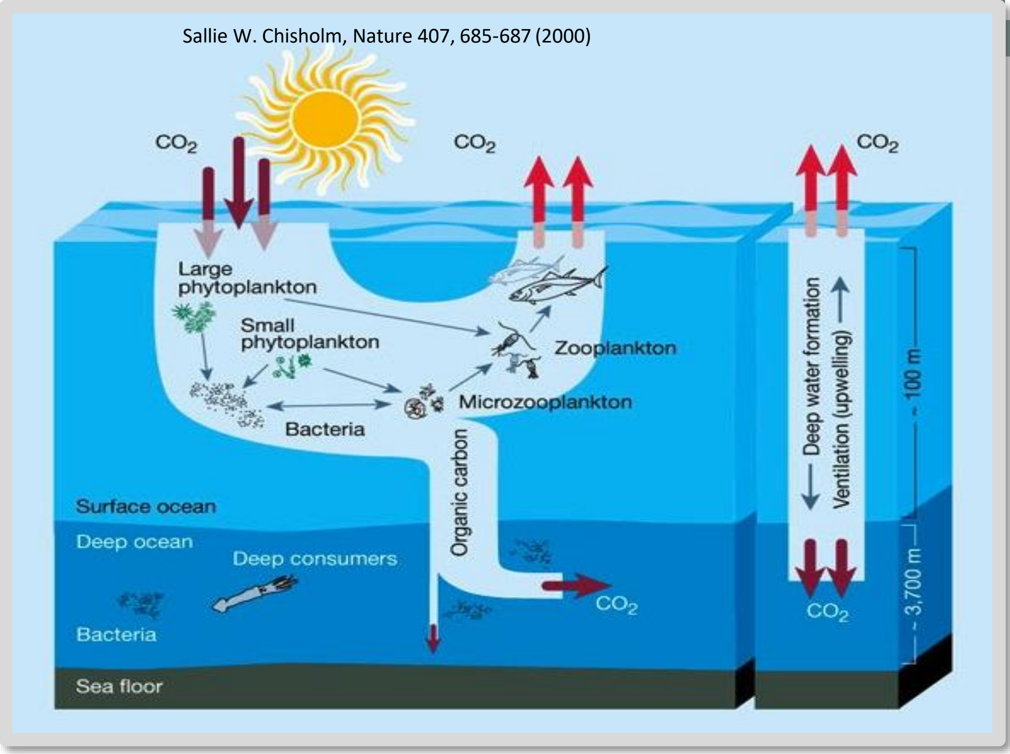
Why PACE?

- Why satellites?
- Why phytoplankton (& aerosols)?
- Why PACE?



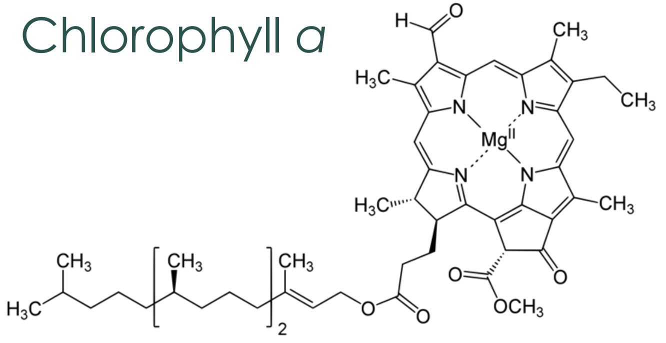
Phytoplankton on Earth





One Coccolithophore:
0.01 mm
1,000 cells/mL

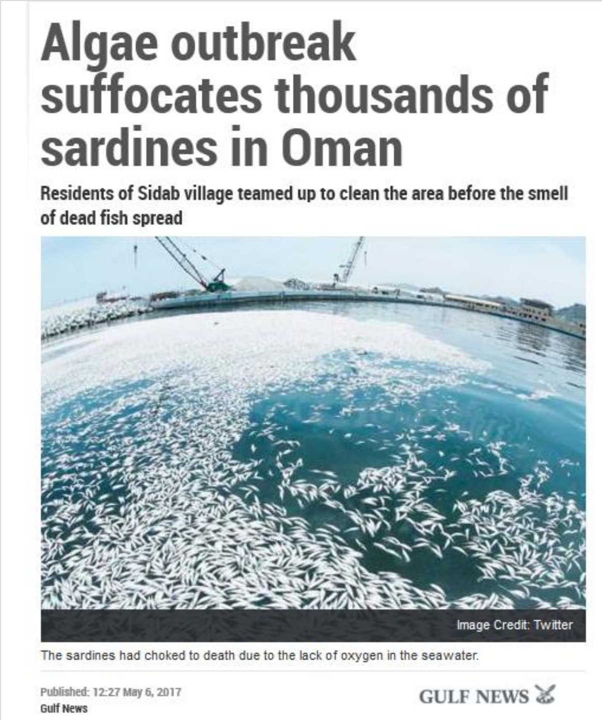
Chlorophyll *a*



Phytoplankton: Friend or Foe?

A satellite image from NOAA shows an aerial view of Lake Erie's massive 2011 algae bloom.

PHOTOGRAPH BY NASA/EARTH OBSERVATORY



Algae outbreak suffocates thousands of sardines in Oman

Residents of Sidab village teamed up to clean the area before the smell of dead fish spread

Image Credit: Twitter

The sardines had choked to death due to the lack of oxygen in the seawater.

Published: 12:27 May 6, 2017
Gulf News

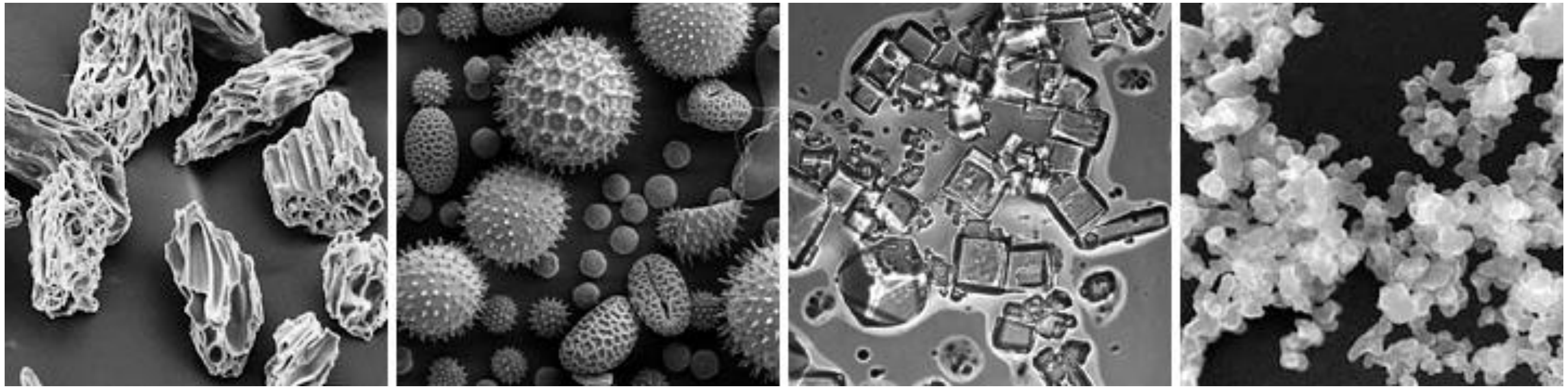
GULF NEWS

Photographs copyright (left to right) Western Sahara Project, Jonathan Jessup, Vox, Árni Friðriksson (cropped), and Jerem

Aerosols are highly variable and have many sources

…and they impact climate

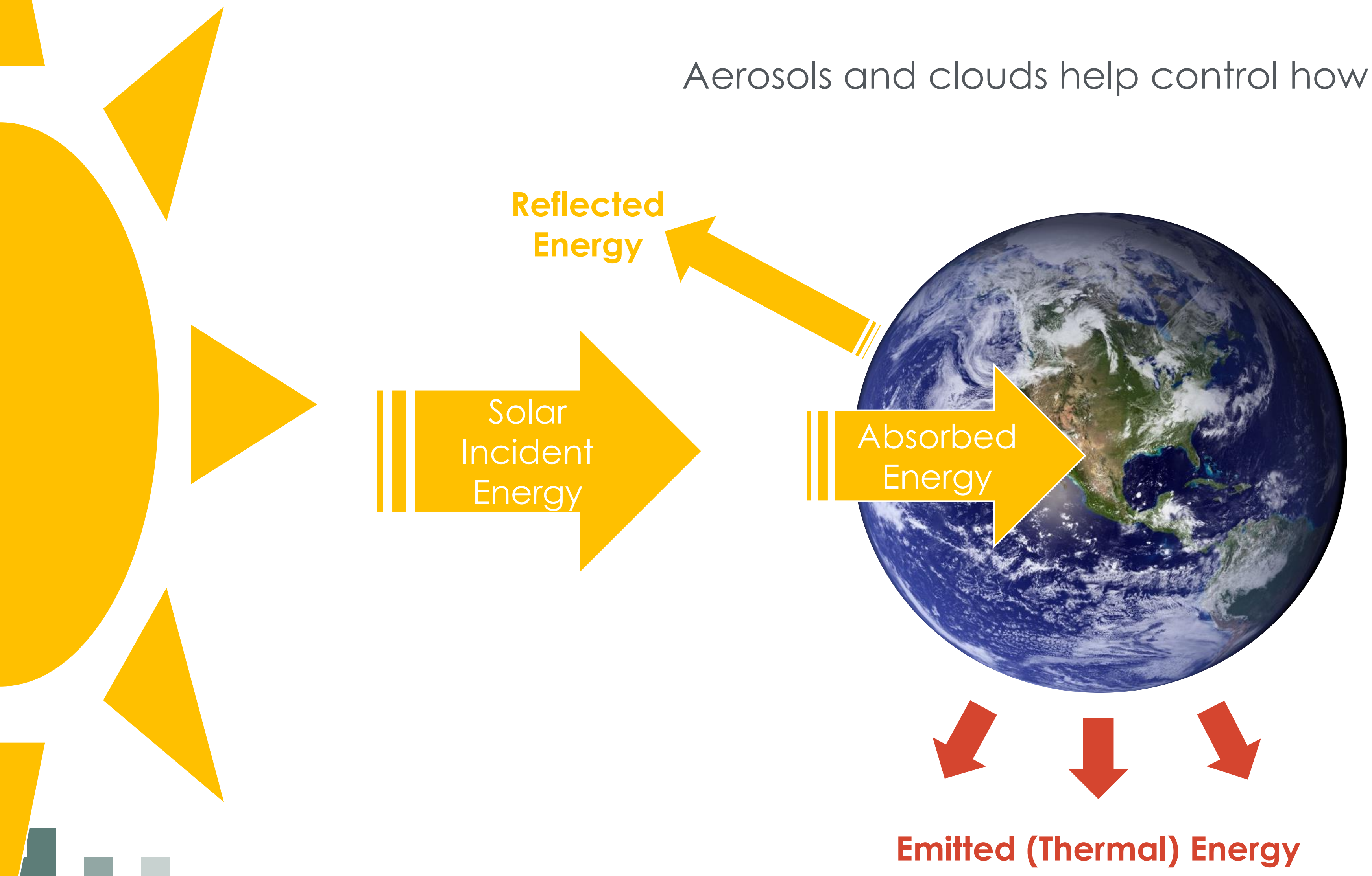
- Clouds (liquid and ice) are technically a type of aerosol, but we refer to them separately as a special category.



Micrographs Courtesy USGS, UMBC (Chere Petty), and Arizona State University (Peter Buseck).

Greenhouse gases change how much thermal energy is emitted

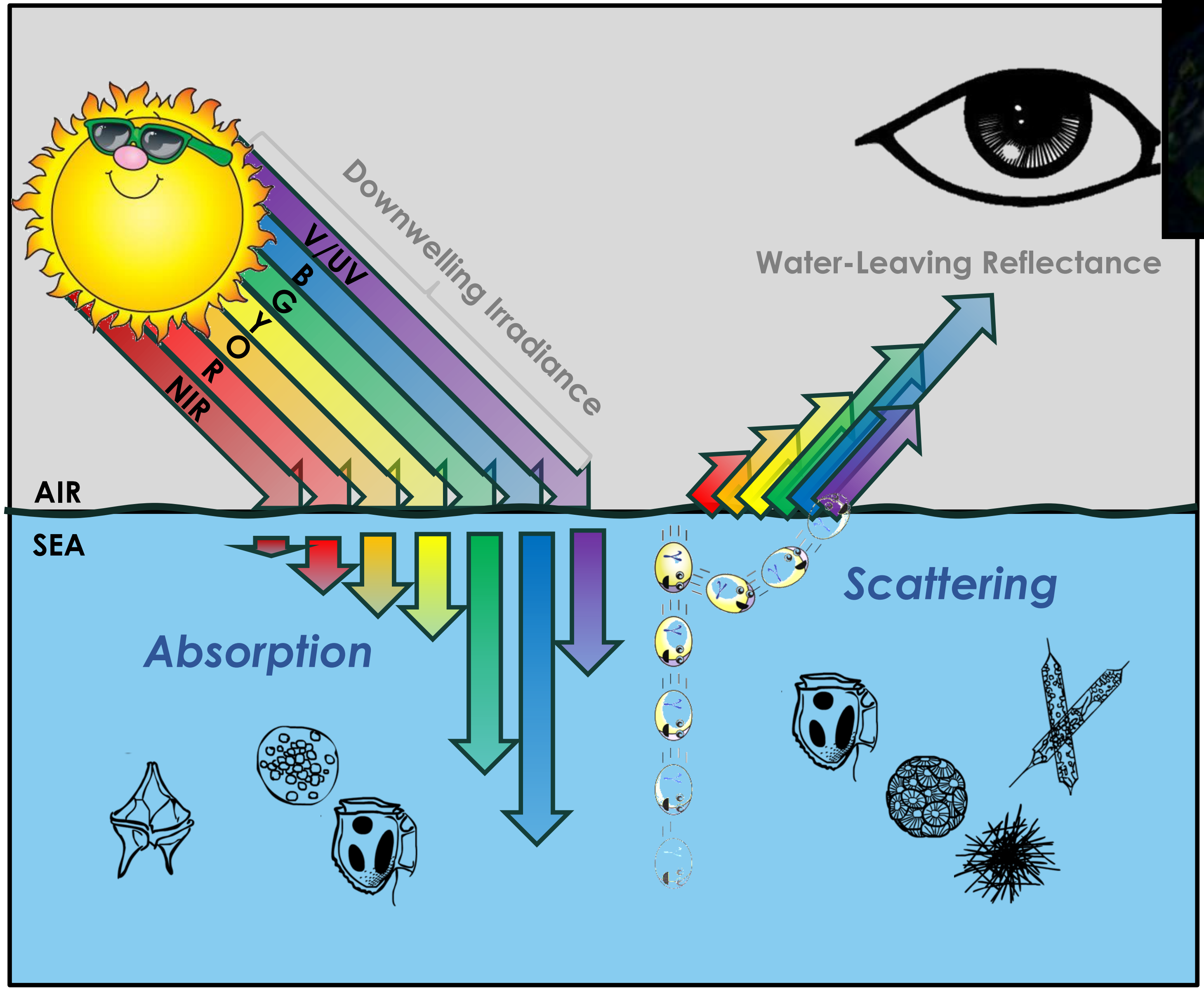
Aerosols and clouds help control how much energy is absorbed.

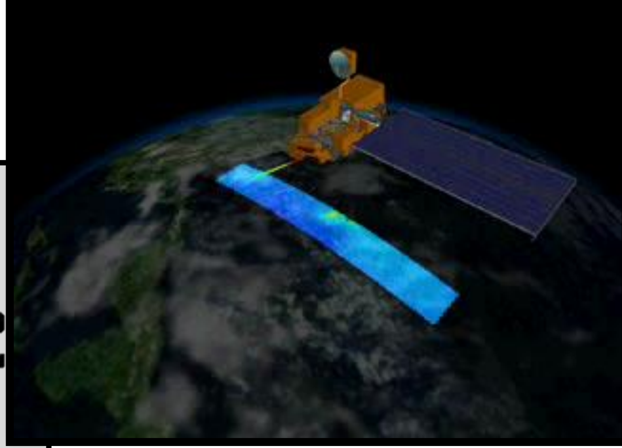


- Some aerosols **warm** our atmosphere (absorb energy).
- Some aerosols **cool** our atmosphere (reflect energy).

Ocean Color

- The "color" of the ocean or atmosphere is determined by the interactions of incident light with substances or particles present in the water or atmosphere.



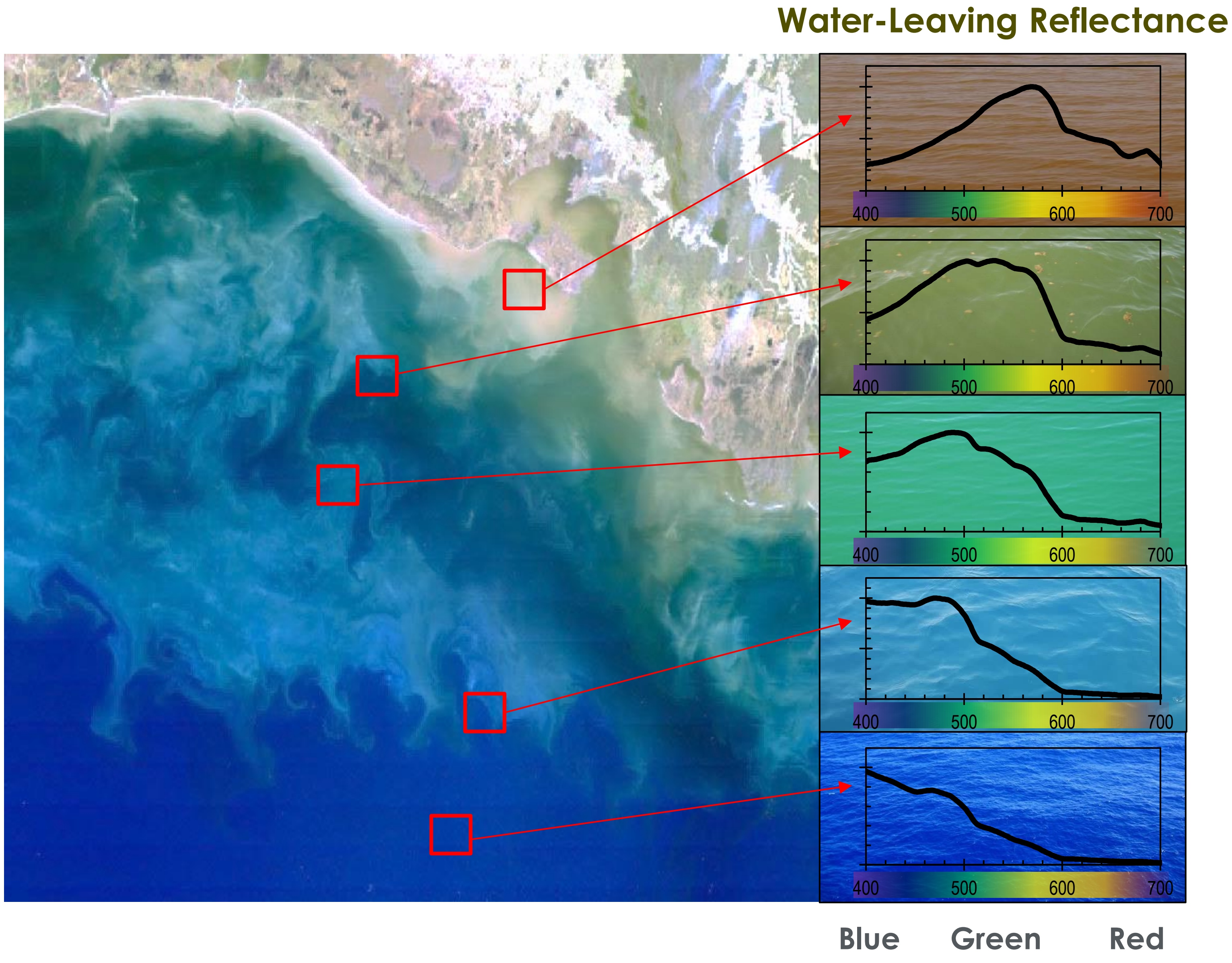


- The core satellite data are accurate measurements of light intensity from ultra-violet to shortwave infrared wavelengths.

What causes variation in the color of the ocean?

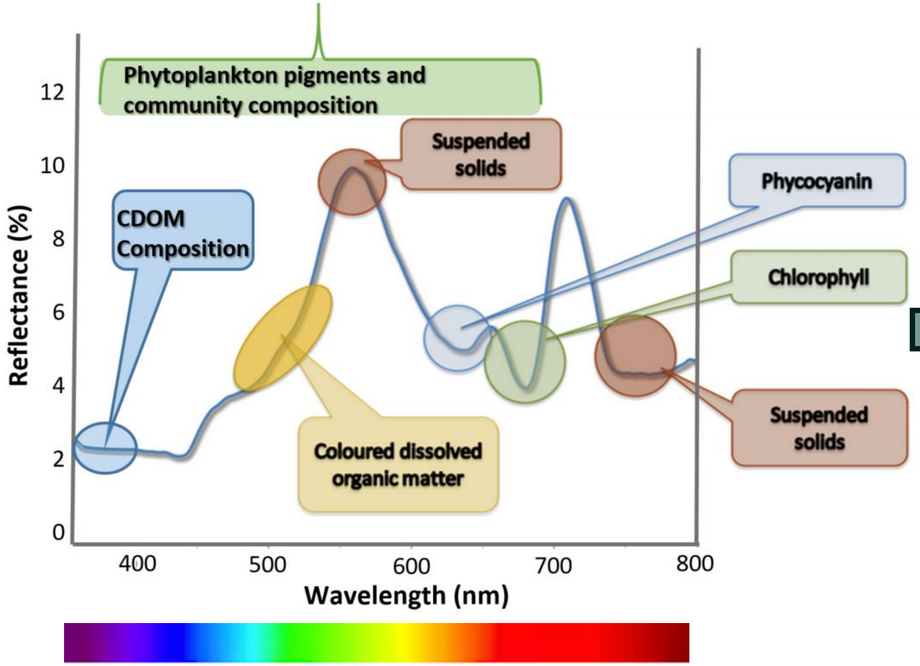
The color of the ocean is a function of light that is absorbed or scattered as a result of constituents in the water.

- Phytoplankton and pigments
- Dissolved organic matter
- Detritus (fecal pellets, dead cells)
- Inorganic particles (sediment)
- Water absorption



Hyperspectral Observations Enables Separation of Aquatic Constituents

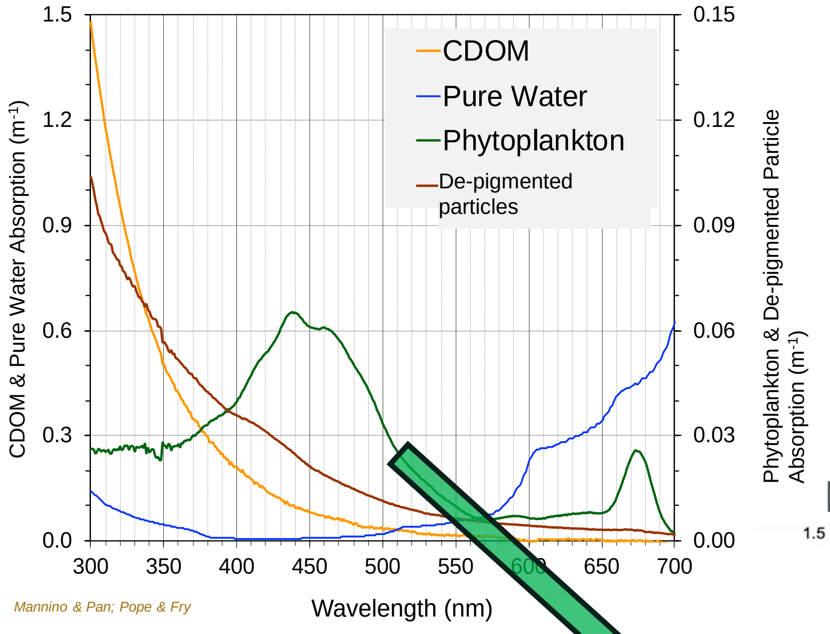
Water-Leaving Reflectance



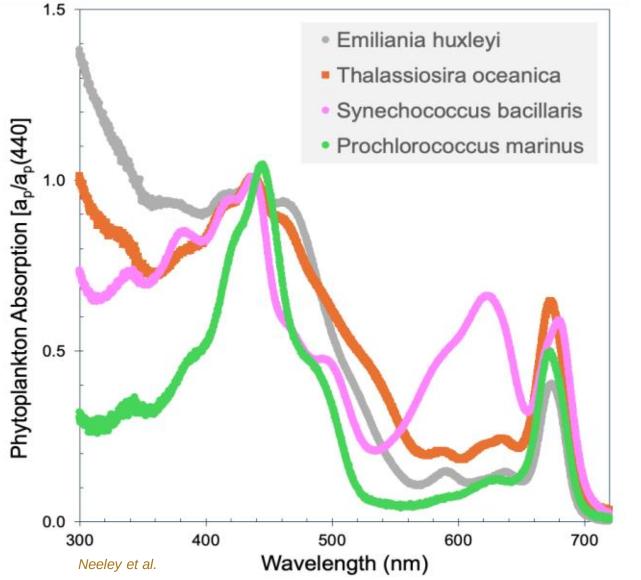
Figures adapted from Dierssen et al. 2023; JGR Biogeosciences

Reflectance (%) = Percent of sunlight (radiance) leaving the ocean surface from the sunlight (irradiance) entering through the ocean surface.

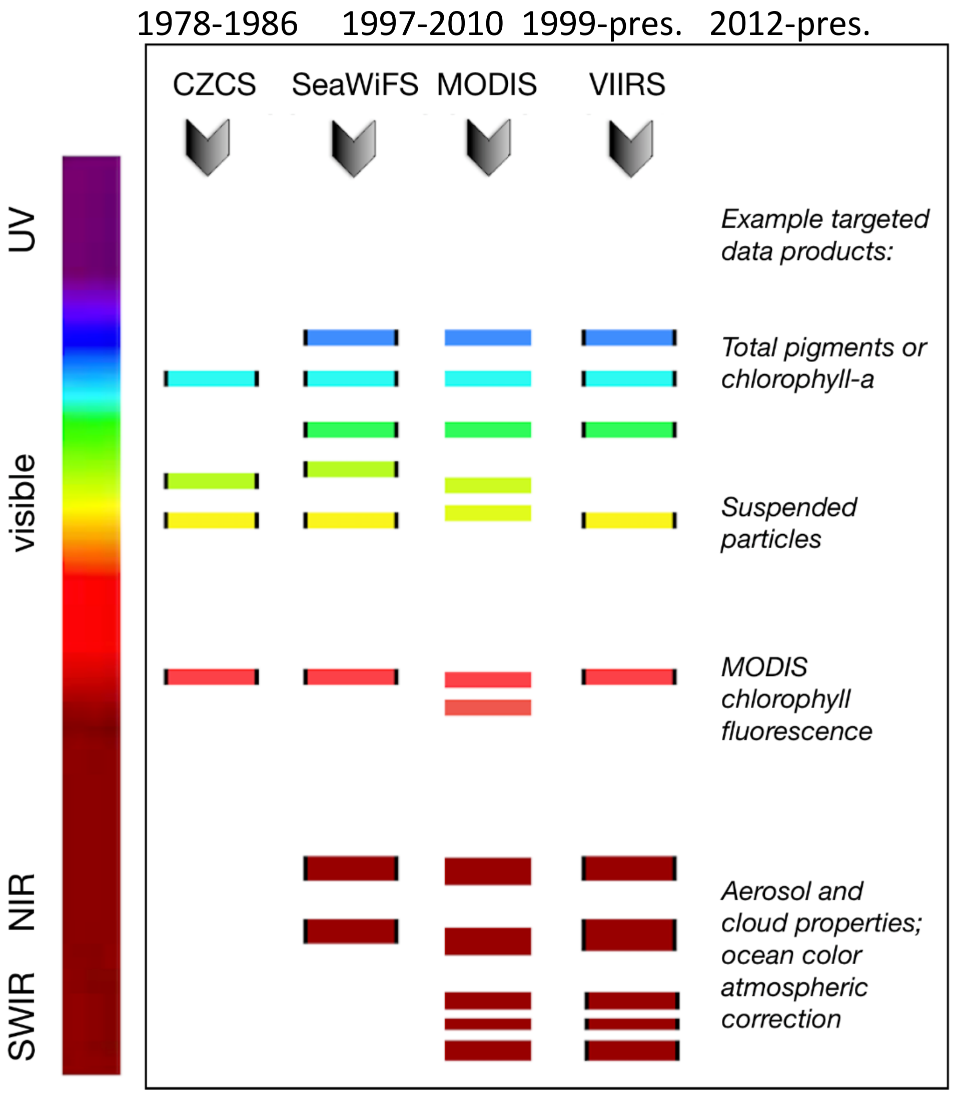
Absorption of In-Water Constituents



Phytoplankton Composition



Moving from Multi-Spectral Radiometry to Spectroscopy



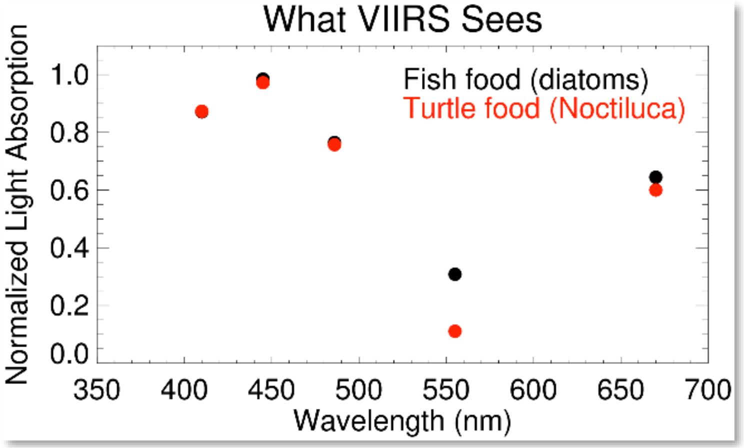
Example Diatom

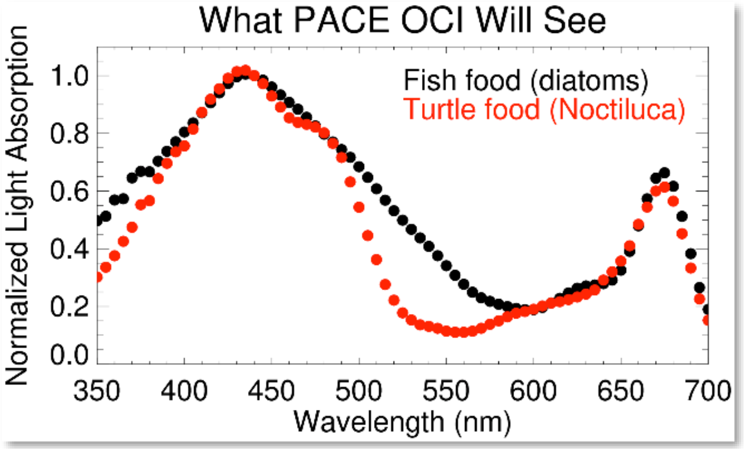
Linda Armbrecht, abc.com.au

Example Noctiluca

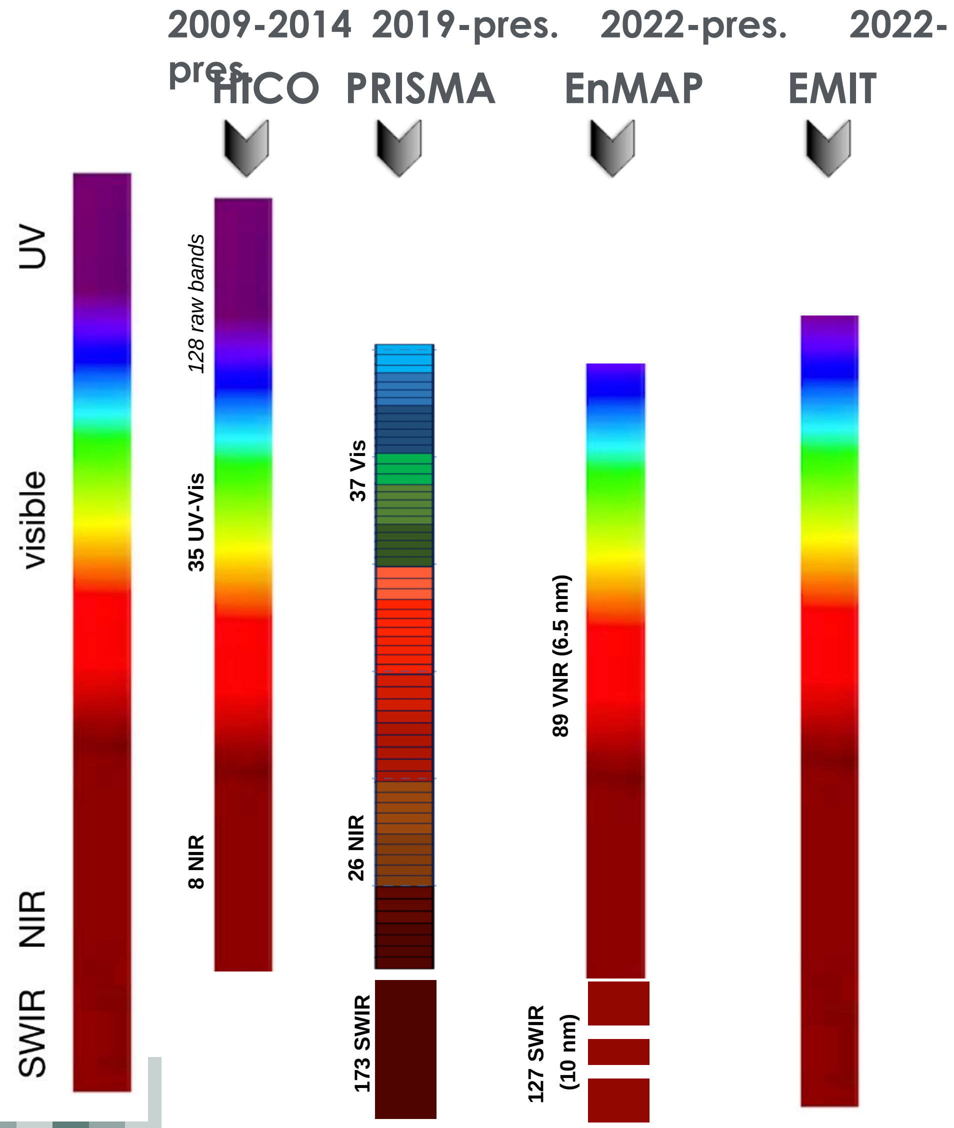
Joaquim Goes, LDEO

Signals from the ocean are small & differentiating between constituents requires additional information relative to what we have today.





Past and Current Hyperspectral Missions Used for WQ



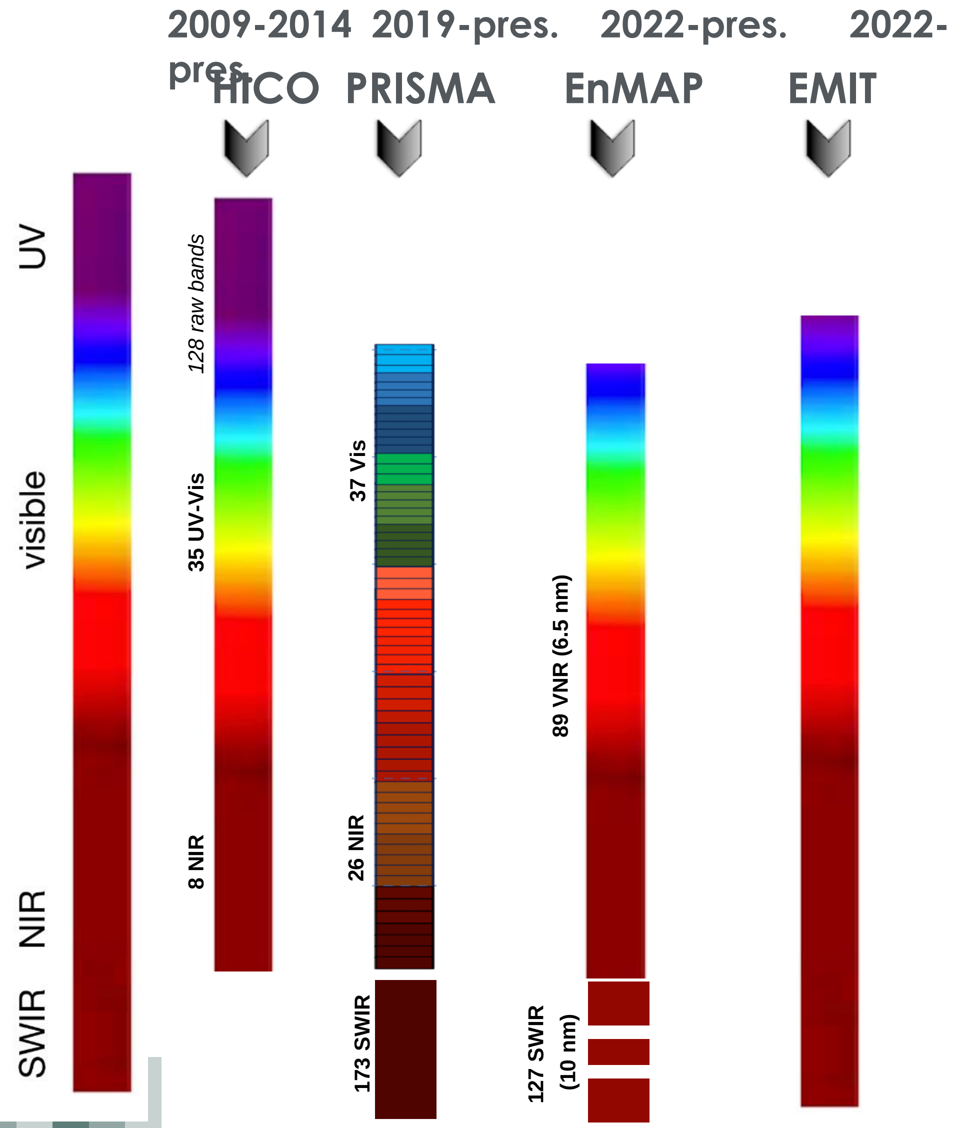
HICO (Navy/NASA, USA)

- Collected 10,000 scenes (~42 km x 192 km) at ~90 m spatial footprint from international Space Station
- Off-the-shelf sensor for coastal ocean color
- Bands smoothed to 10 nm for visible spectral range and 20 nm in NIR

PRISMA (ASI, Italy)

- Collects scenes 30 km x 30 km (up to 30 km x 1800 km) at 30 m spatial resolution
- Designed for land surface imagery and greenhouse gases; recently applied for water quality
- Bandwidths ~12 nm; spectral range: 400-1010 nm & 920-2505 nm

Past and Current Hyperspectral Missions Used for WQ (Continued)



EnMAP (DLR, Germany)

- Collects scenes 30 km x 390 km at 30 m spatial footprint
- Designed for atmospheric properties and land surface imagery and greenhouse gases; recently applied for water quality
- Bandwidths ~6.5 nm across the visible and NIR and ~10 nm for the SWIR; spectral range: 420-1000nm; 900-1390 nm; 1480-1760 nm, 1950-2450

EMIT (NASA, USA)

- Collects scenes 80 km x ~800 km/variable at 60 m spatial footprint from International Space Station
- Designed for mineralogy, land surface reflectance, atmospheric dust for climate radiative forcing; used for greenhouse gases; presently exploring water quality applications
- Bandwidths <8.5 nm across the spectral range: 380-2500 nm

NASA/Kim Shiflett

Pace Instruments

OCI

00-894.6 nm
os (or less)
2260 nm
coverage

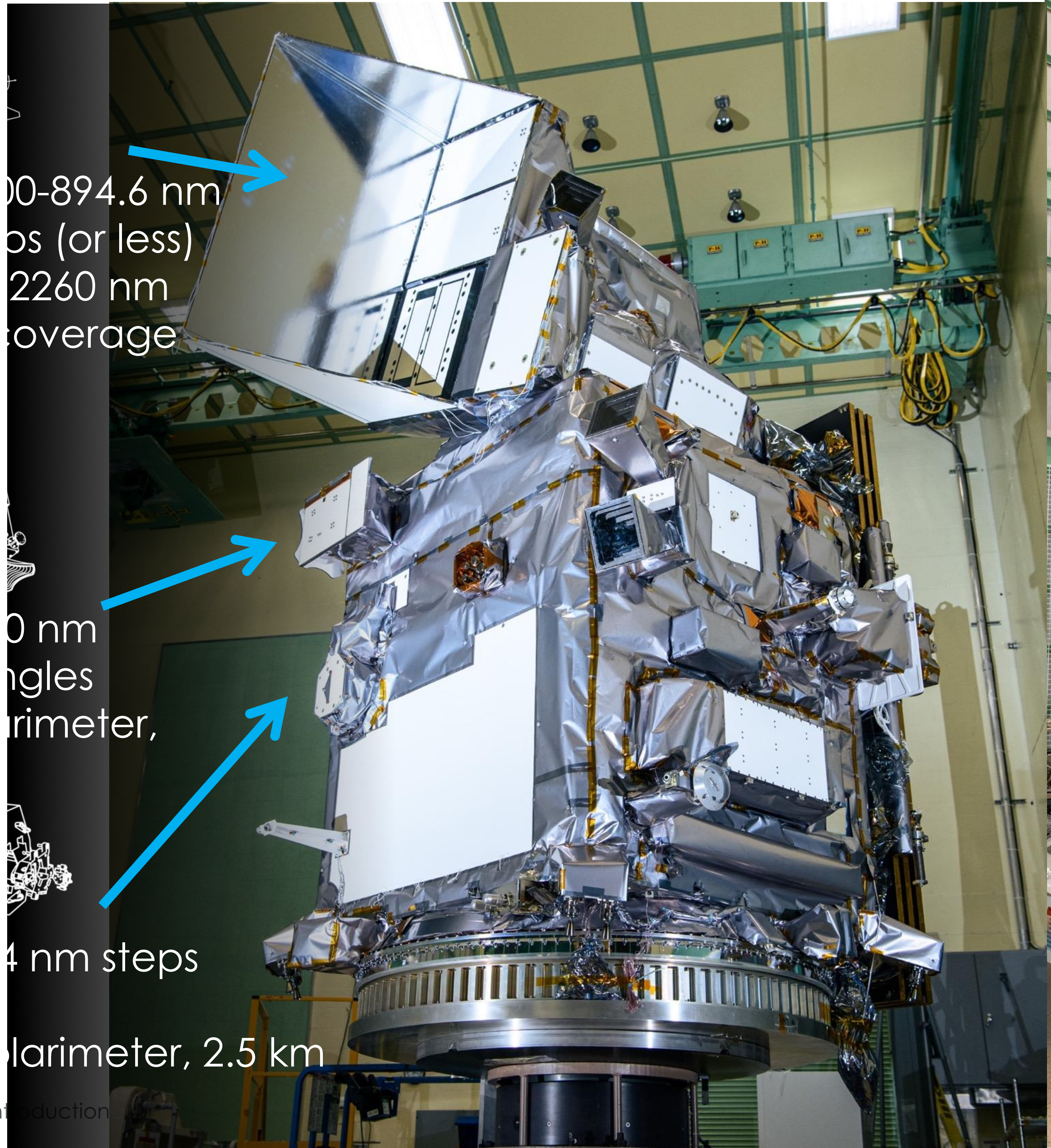
HARP2

0 nm
ngles
rimeter,

SPEXone

4 nm steps

narrow larimeter, 2.5 km



OCI

0-894.6 nm
s (or less)
2260 nm
overage

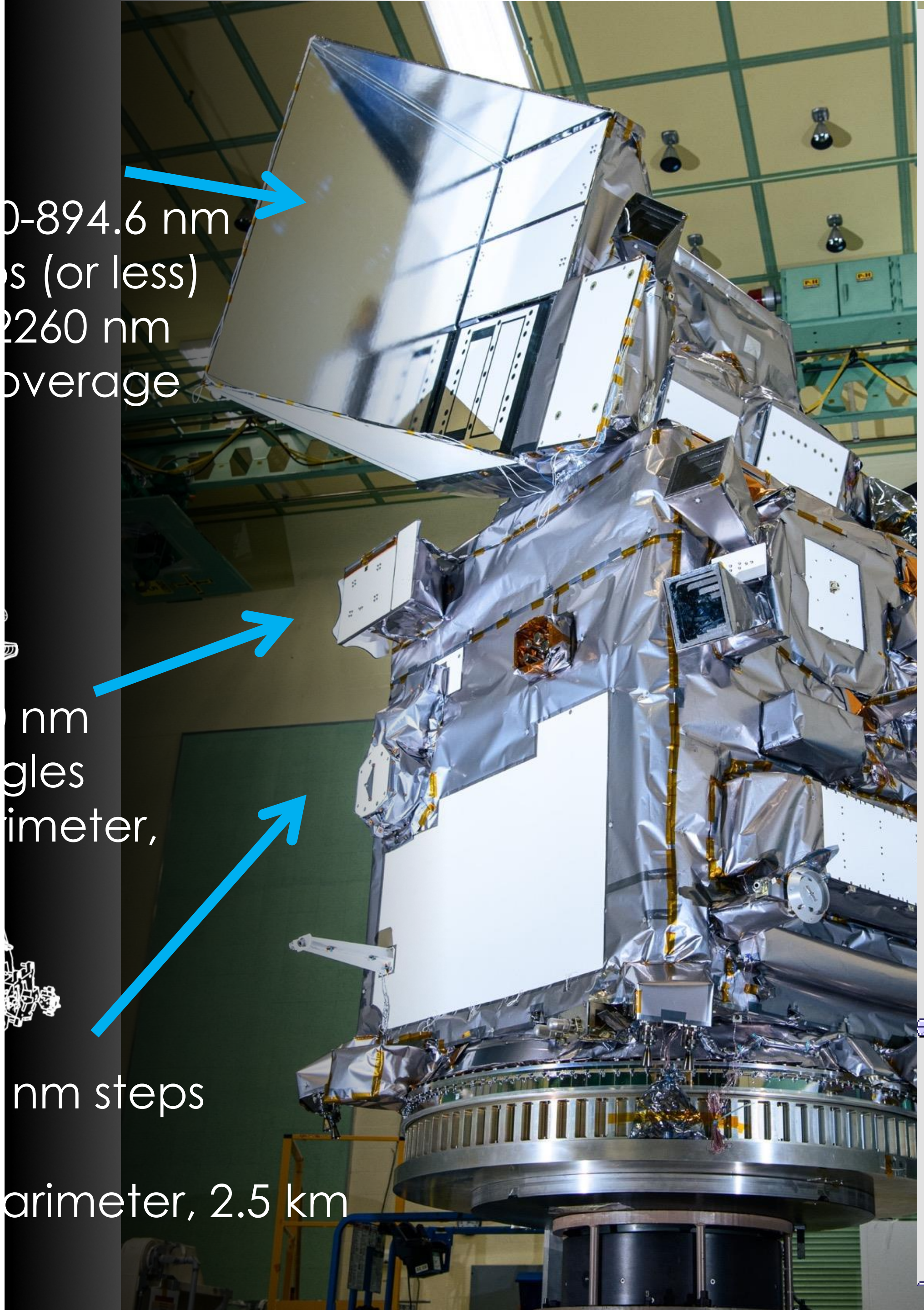
HARP2

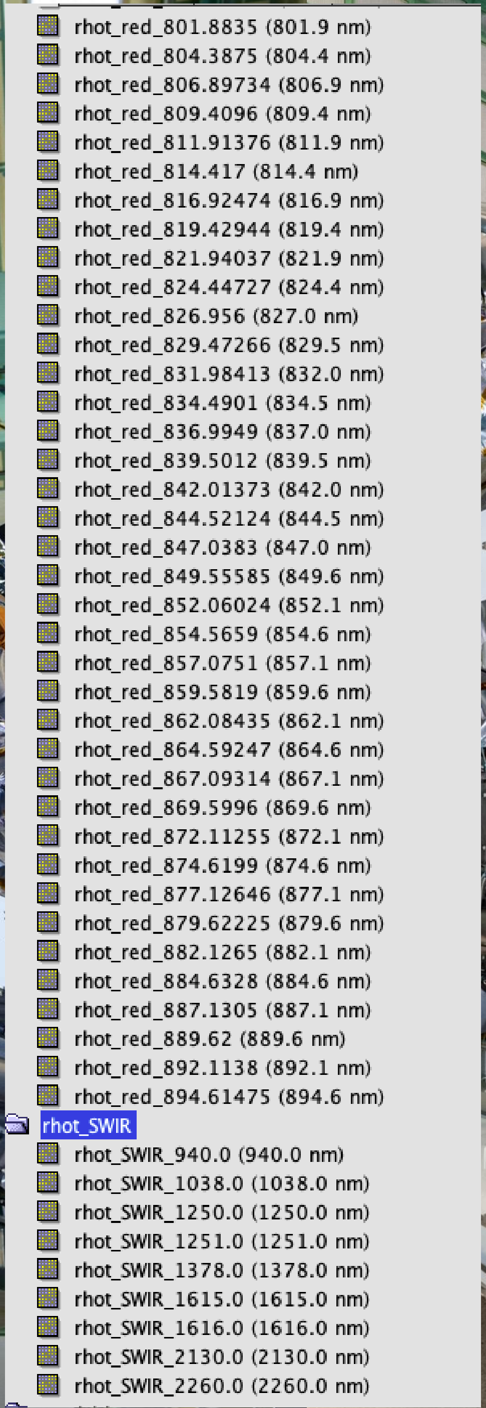
nm
gles
imeter,

SPEXone

nm steps

arimeter, 2.5 km





OCI

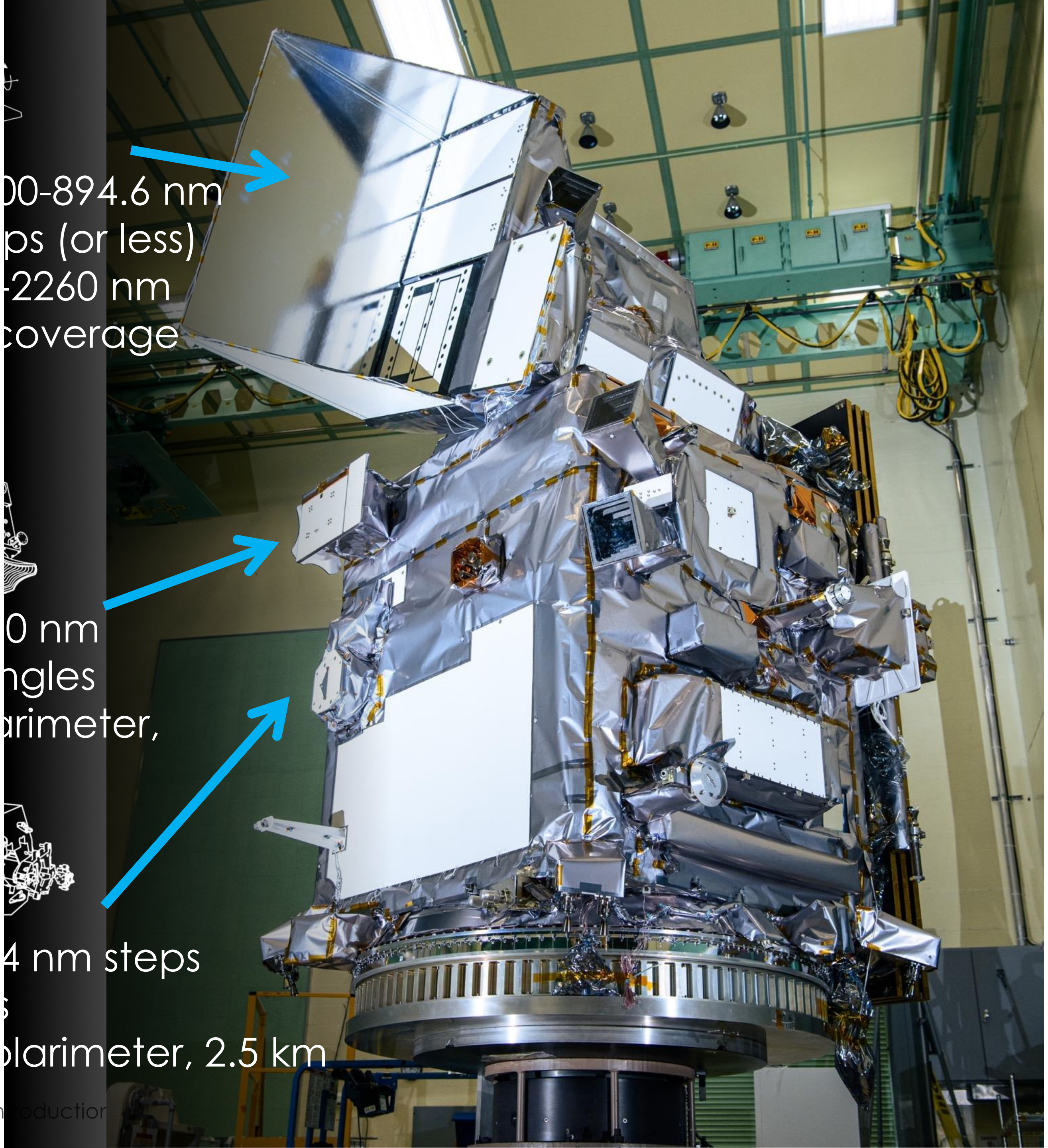
00-894.6 nm
ps (or less)
-2260 nm
coverage

HARP2

0 nm
ngles
arimeter,

SPEXone

4 nm steps
s
narrow olarimeter, 2.5 km

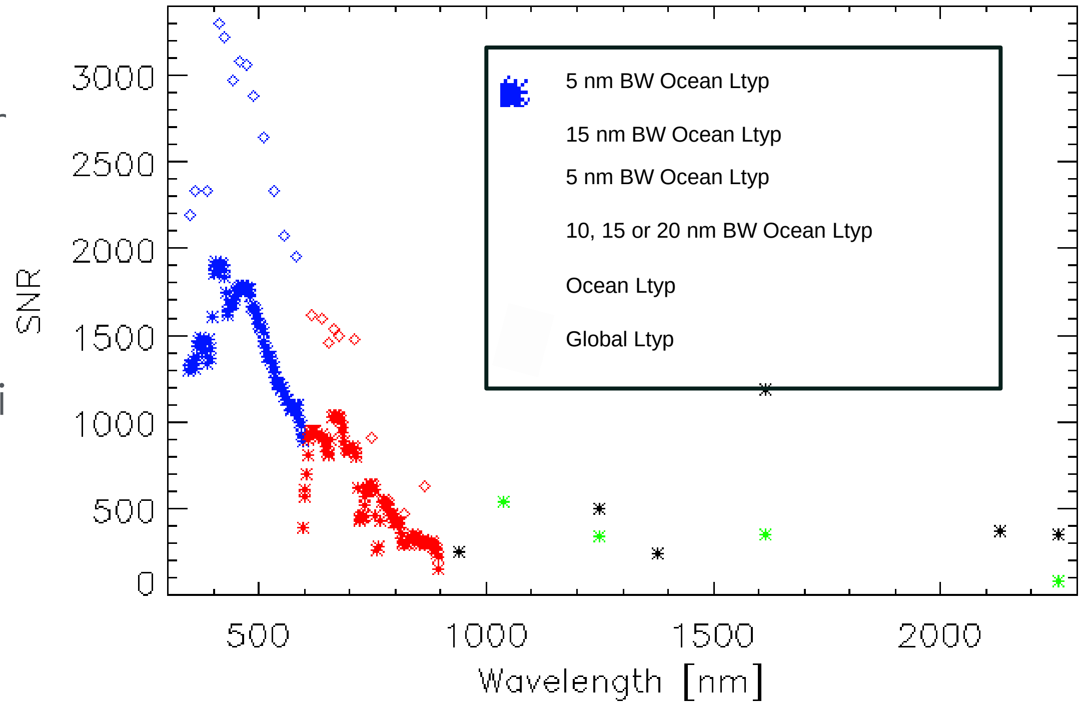


s not
sed in

PACE Ocean Color Advances and Limitations

Advances:

- Hyperspectral from 315 nm to 895 nm
- Spectral resolution of 5 nm bandwidths for Hyperspectral rar
- Spectral sampling of 1.25 or 2.5 nm for Hyperspectral range (184 bands)
- Amazing signal to noise ratio – even for 5 nm bandwidths
- High UV sensitivity from ~340 nm
- 9 Short-Wave Infrared (SWIR) bands for atmospheric correcti including turbid waters (3 ocean sensitive)
- Nearly daily global coverage
- HARP2 and SPEXone will aid in atmospheric correction



Limitations:

- Spatial resolution of ~1.1 km constrains use within inland and nearshore waters and near ice floes

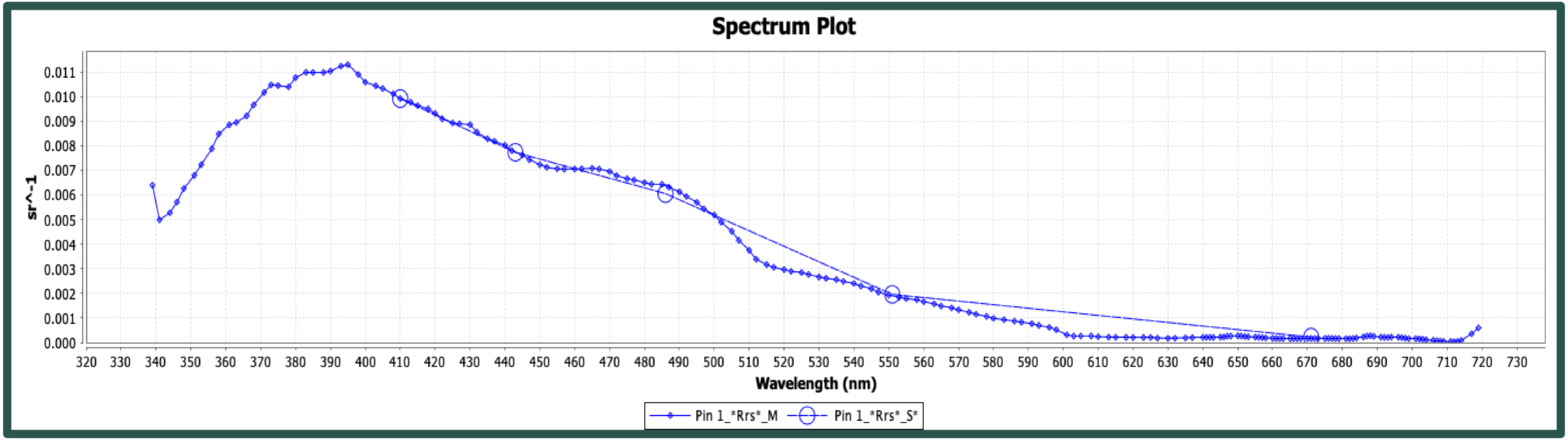
Challenges:

- Lack of verified hyperspectral algorithms
- Need for more comprehensive hyperspectral field measurements

OCI and VIIRS Rrs(445)

NOAA-20 VIIRS

PACE OCI

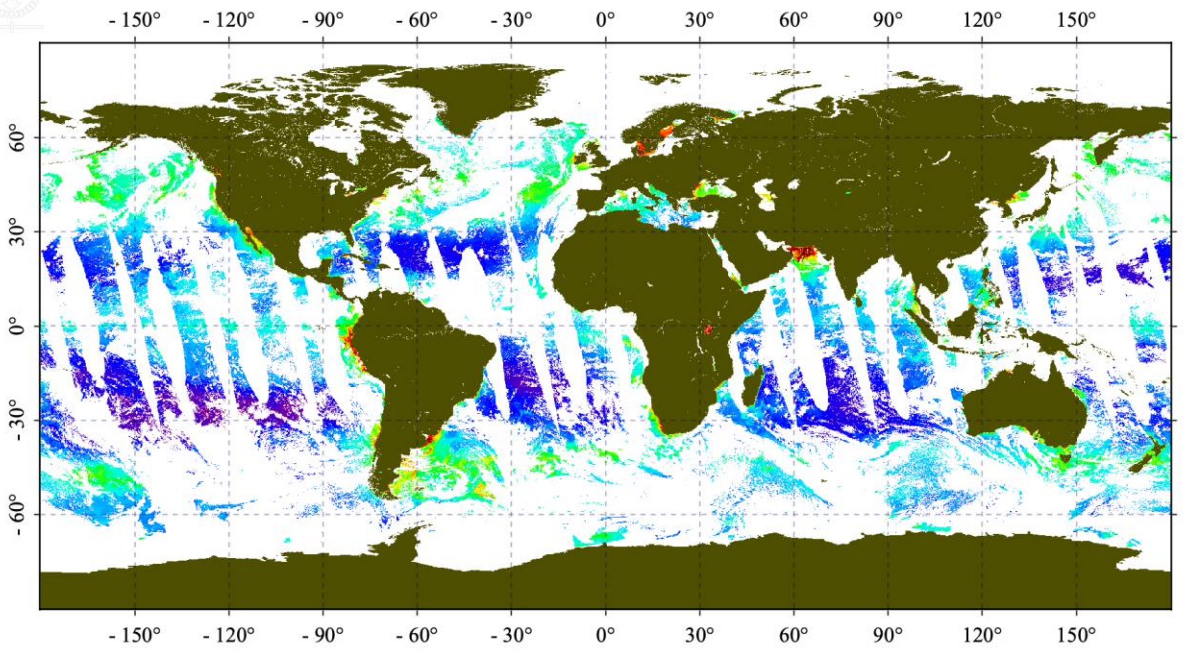


4-km Daily Composite from 23 March 2024

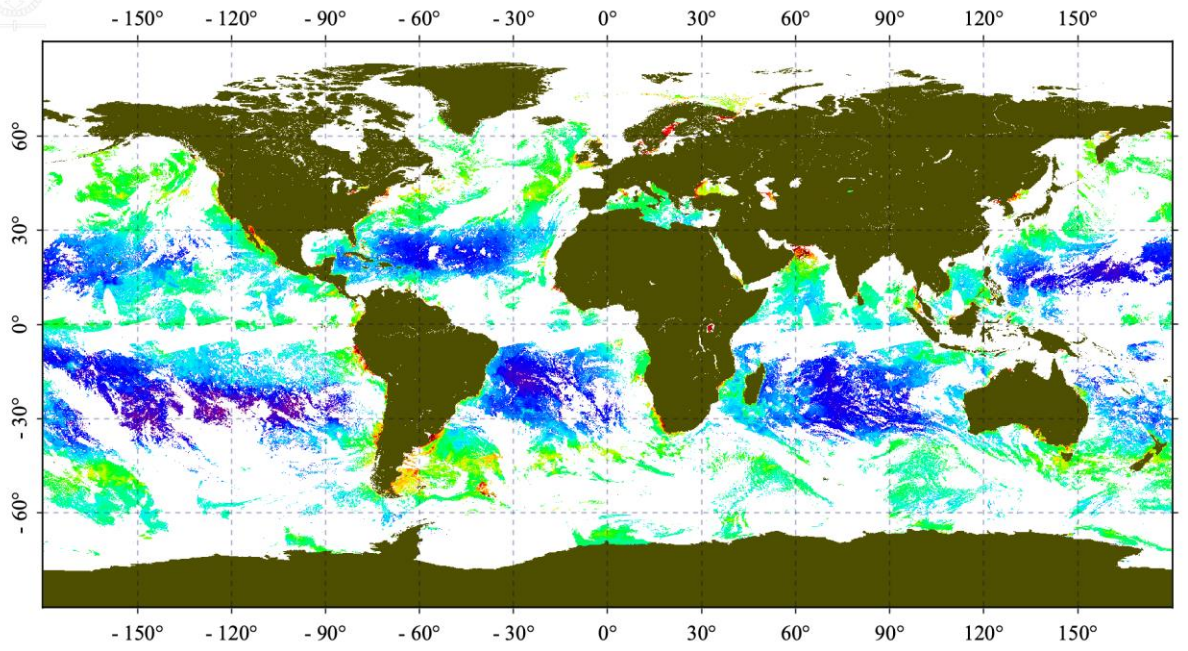
OCI and VIIRS Rrs retrievals agree well on global scales.

OCI & VIIRS Chlorophyll-a Comparison

NOAA-20 VIIRS



PACE OCI

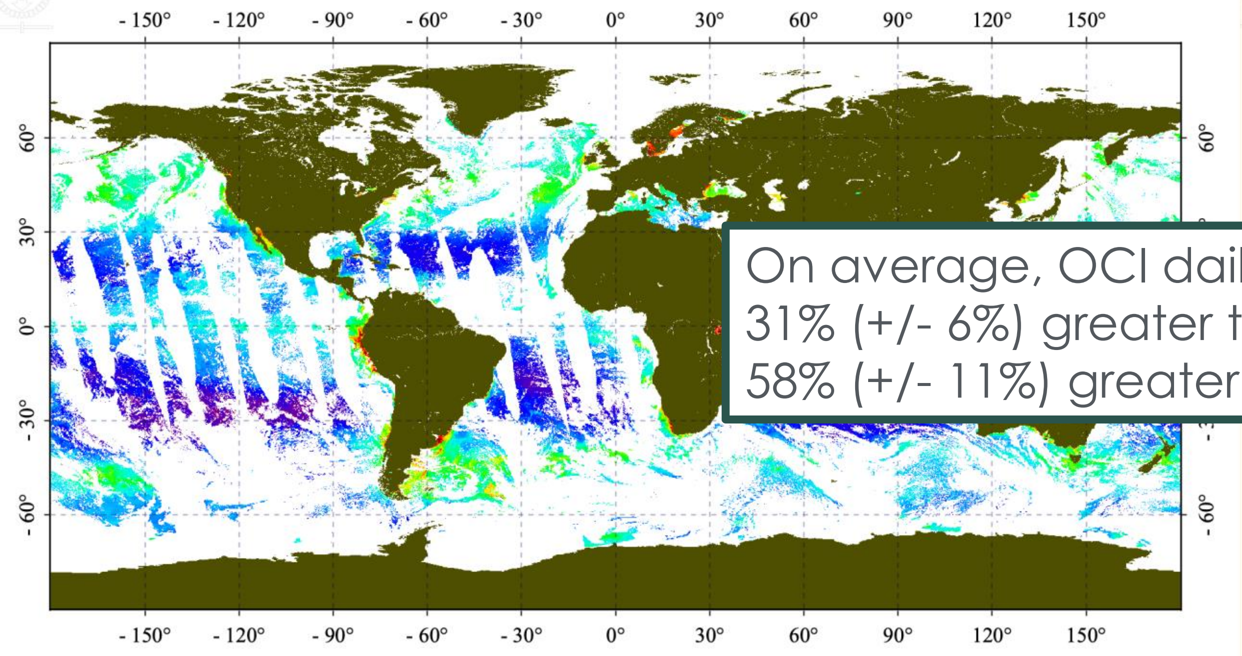


4-km Daily Composite from 17 March 2024

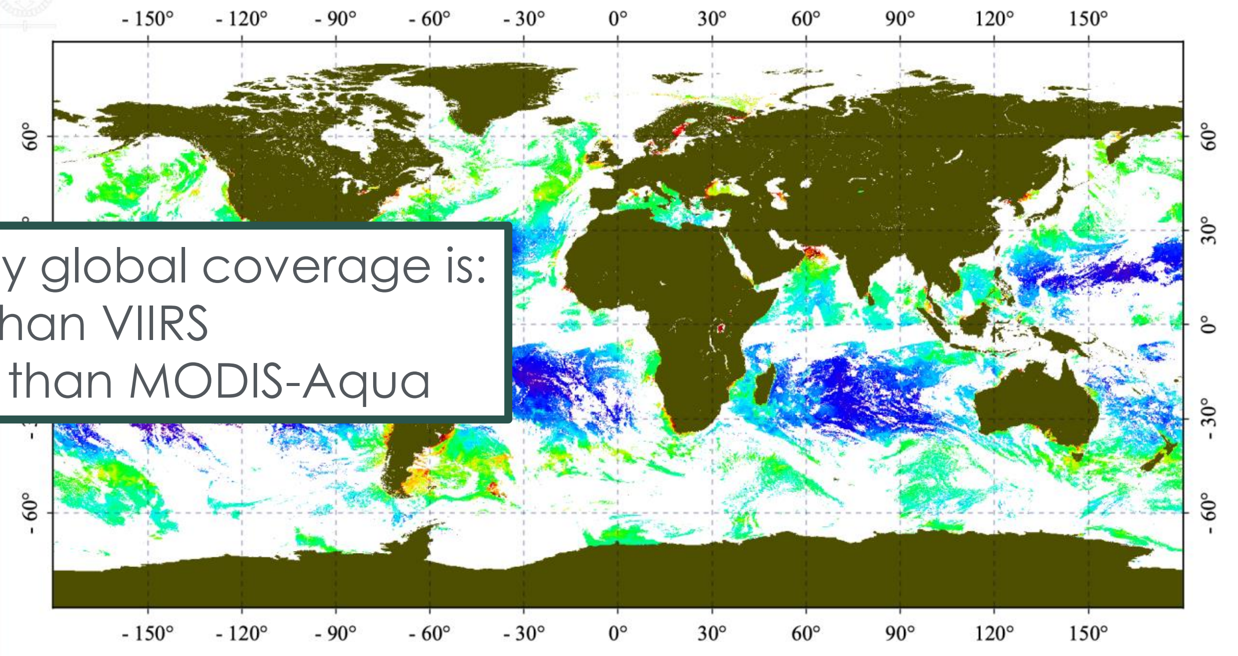
OCI and VIIRS chlorophyll retrievals agree well on global scales.

OCI & VIIRS Chlorophyll-a Comparison

NOAA-20 VIIRS



PACE OCI



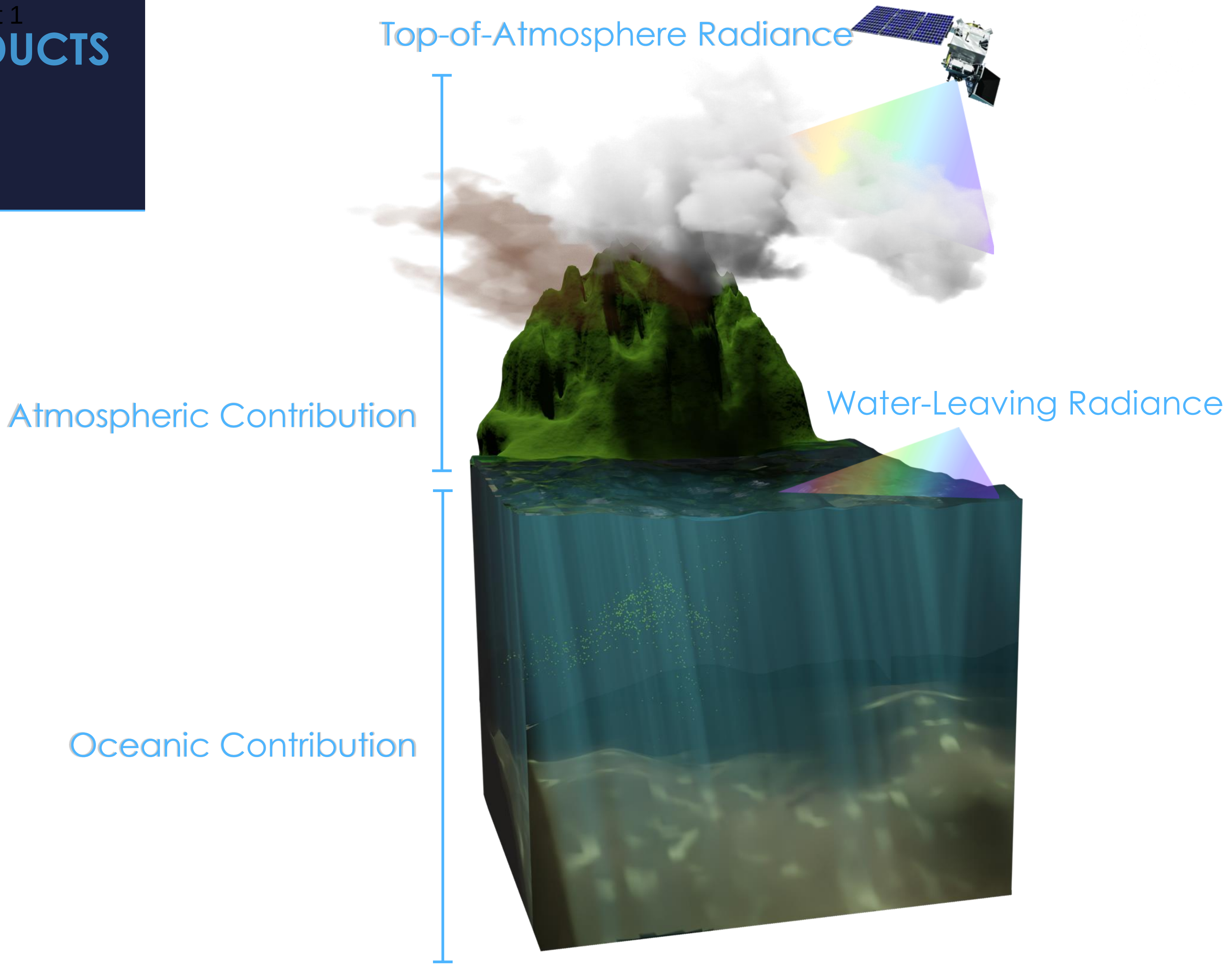
On average, OCI daily global coverage is:
31% (+/- 6%) greater than VIIRS
58% (+/- 11%) greater than MODIS-Aqua

4-km Daily Composite from 17 March 2024

OCI and VIIRS chlorophyll retrievals agree well on global scales.

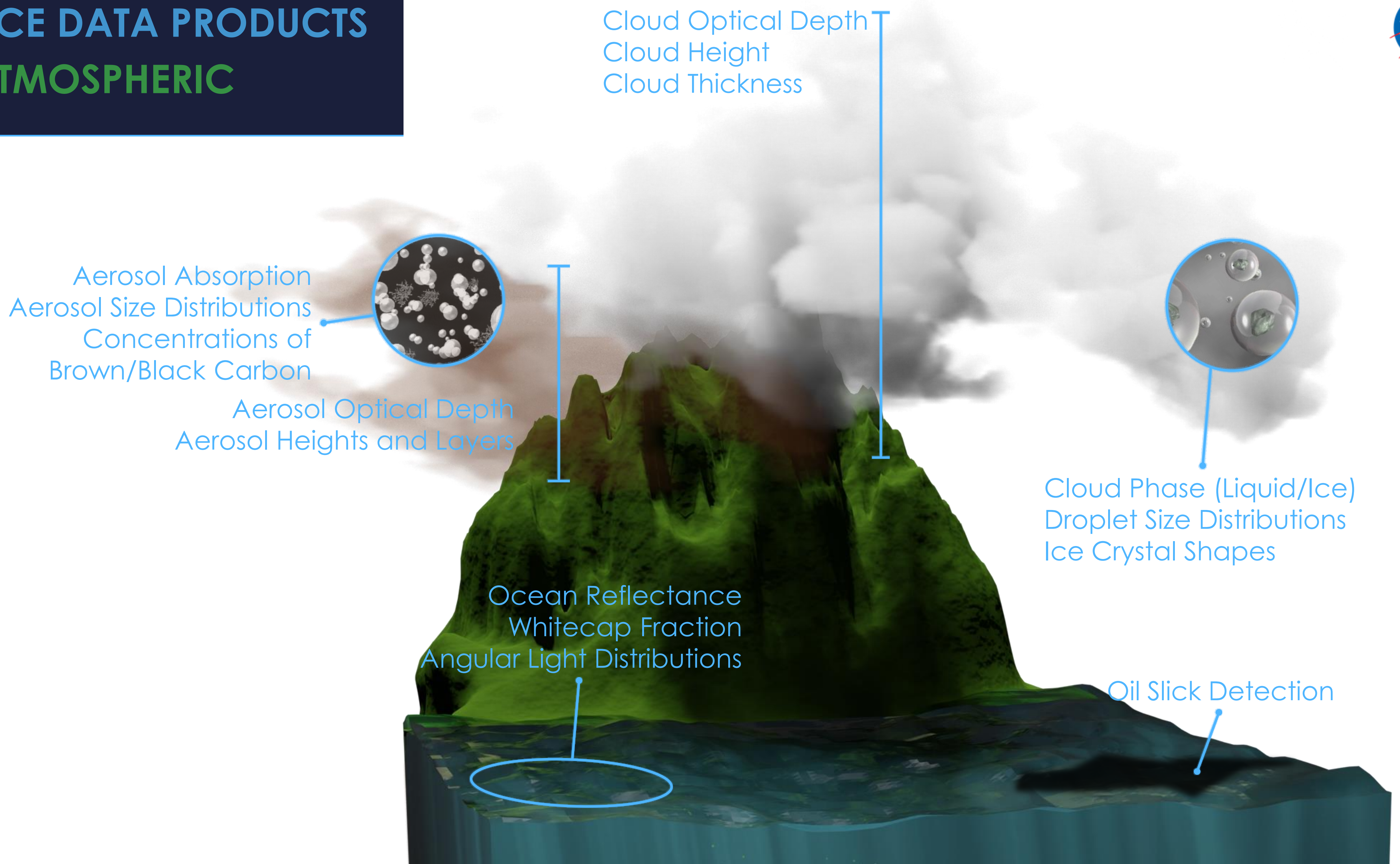
PACE DATA PRODUCTS

ATMOSPHERIC
OCEAN COLOR



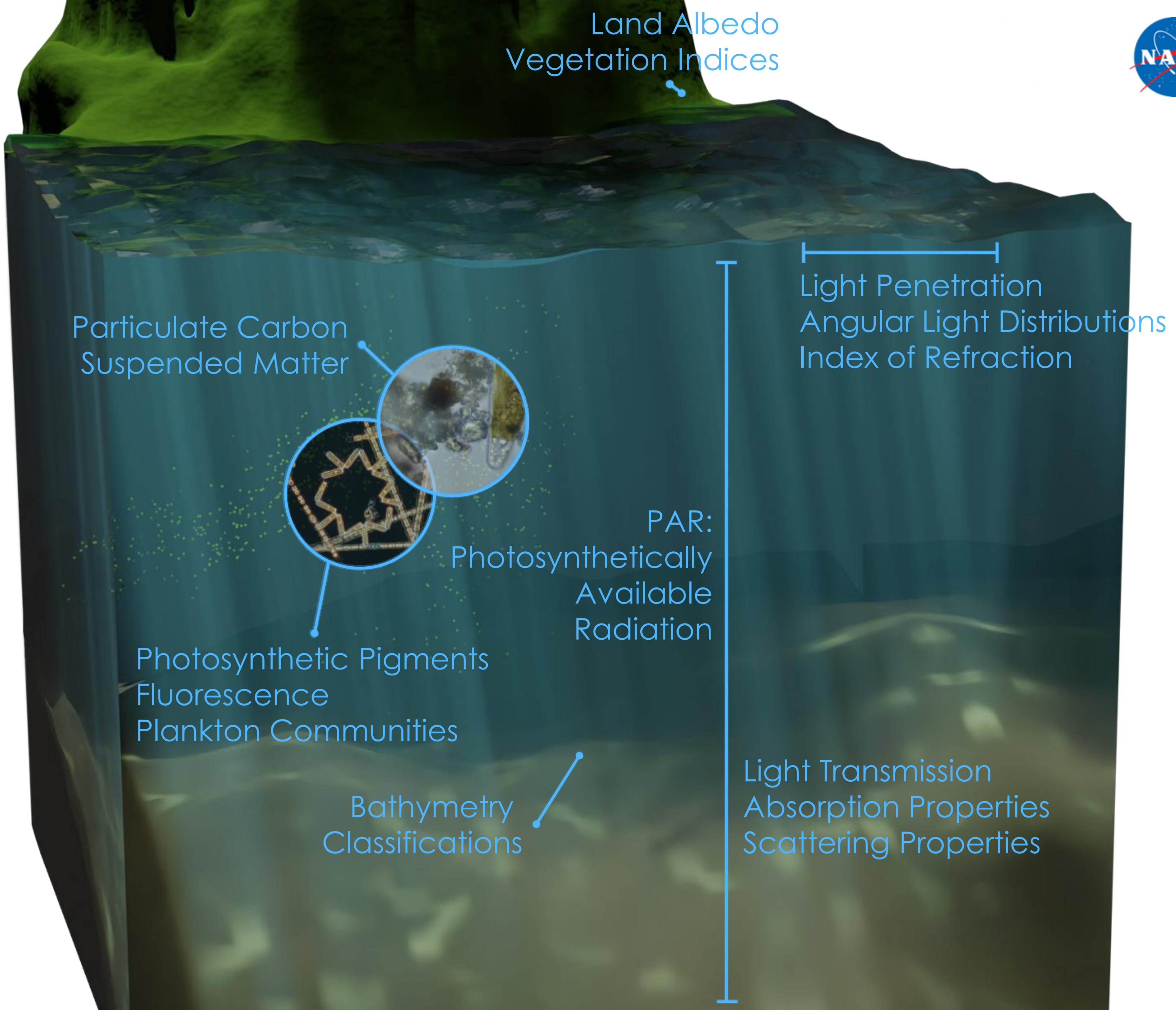
PACE DATA PRODUCTS

ATMOSPHERIC

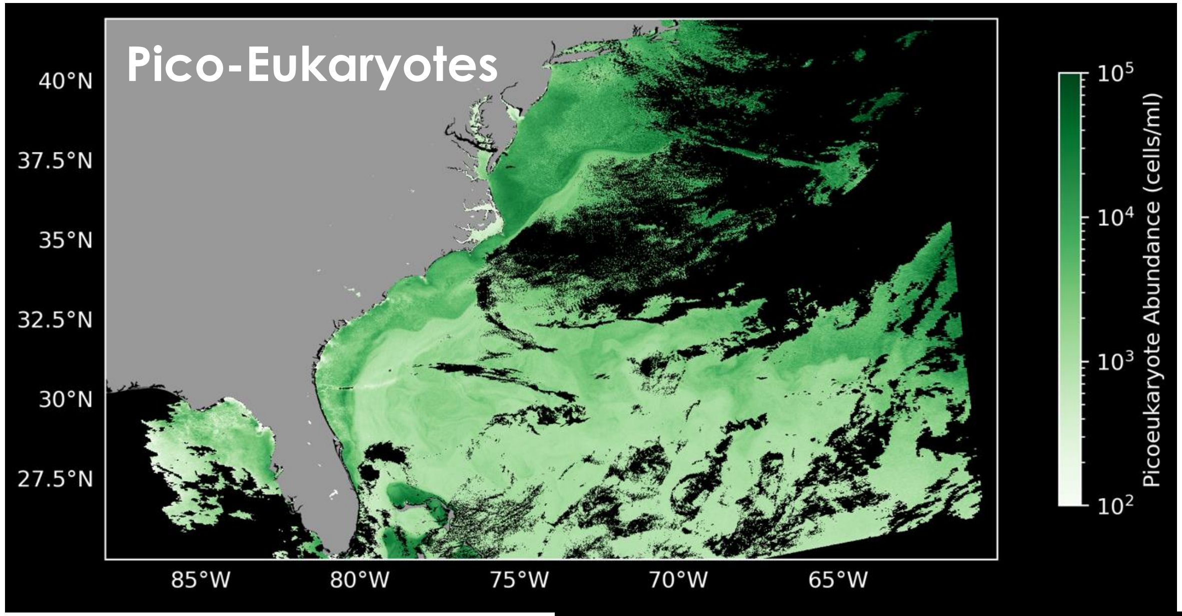


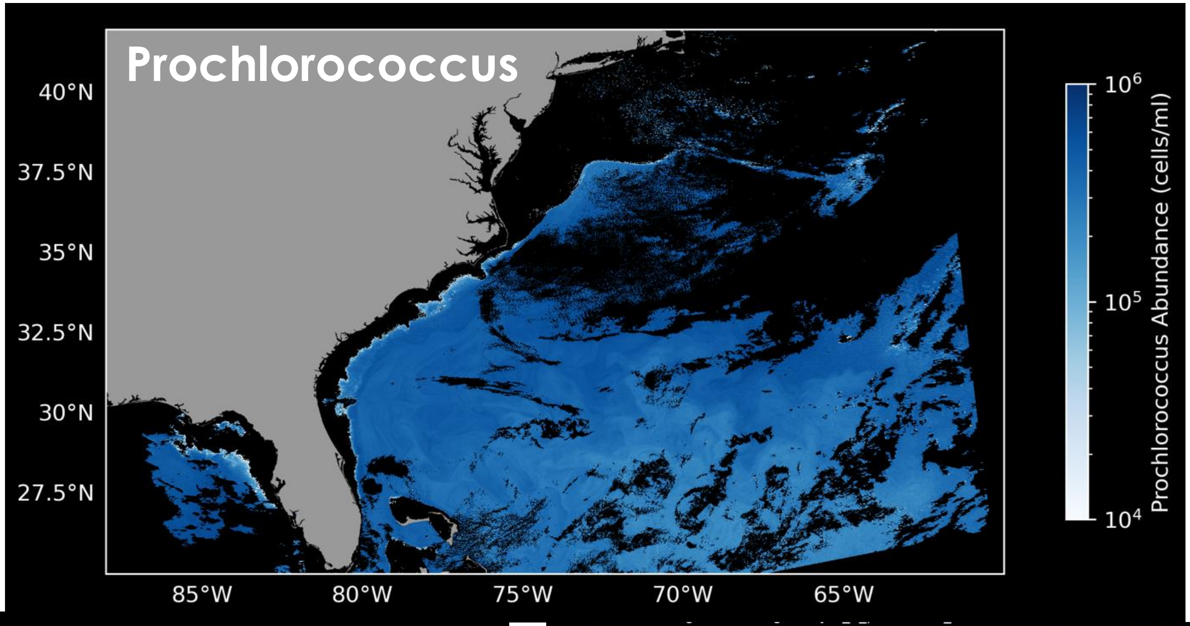
PACE DATA PRODUCTS

OCEAN COLOR

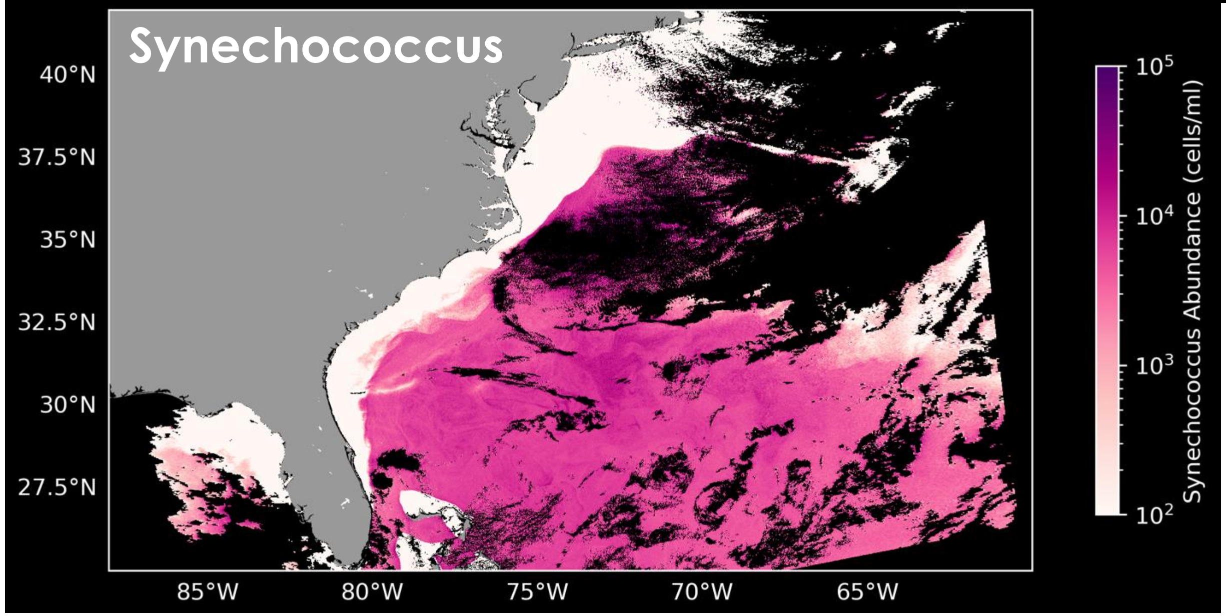


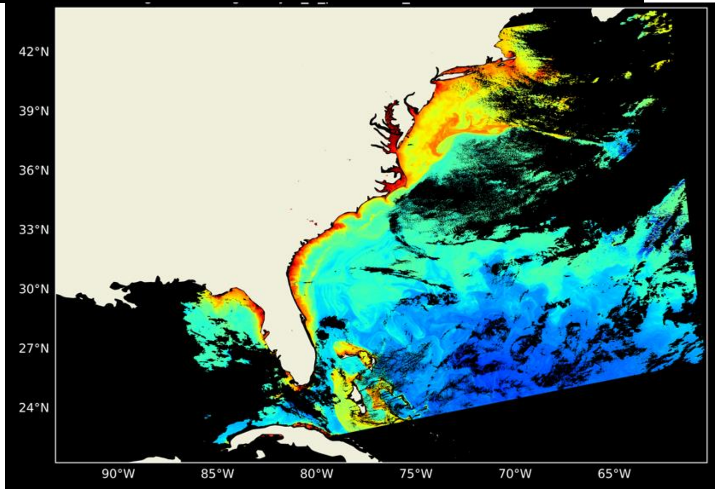
PACE OCI Phytoplankton Community Composition

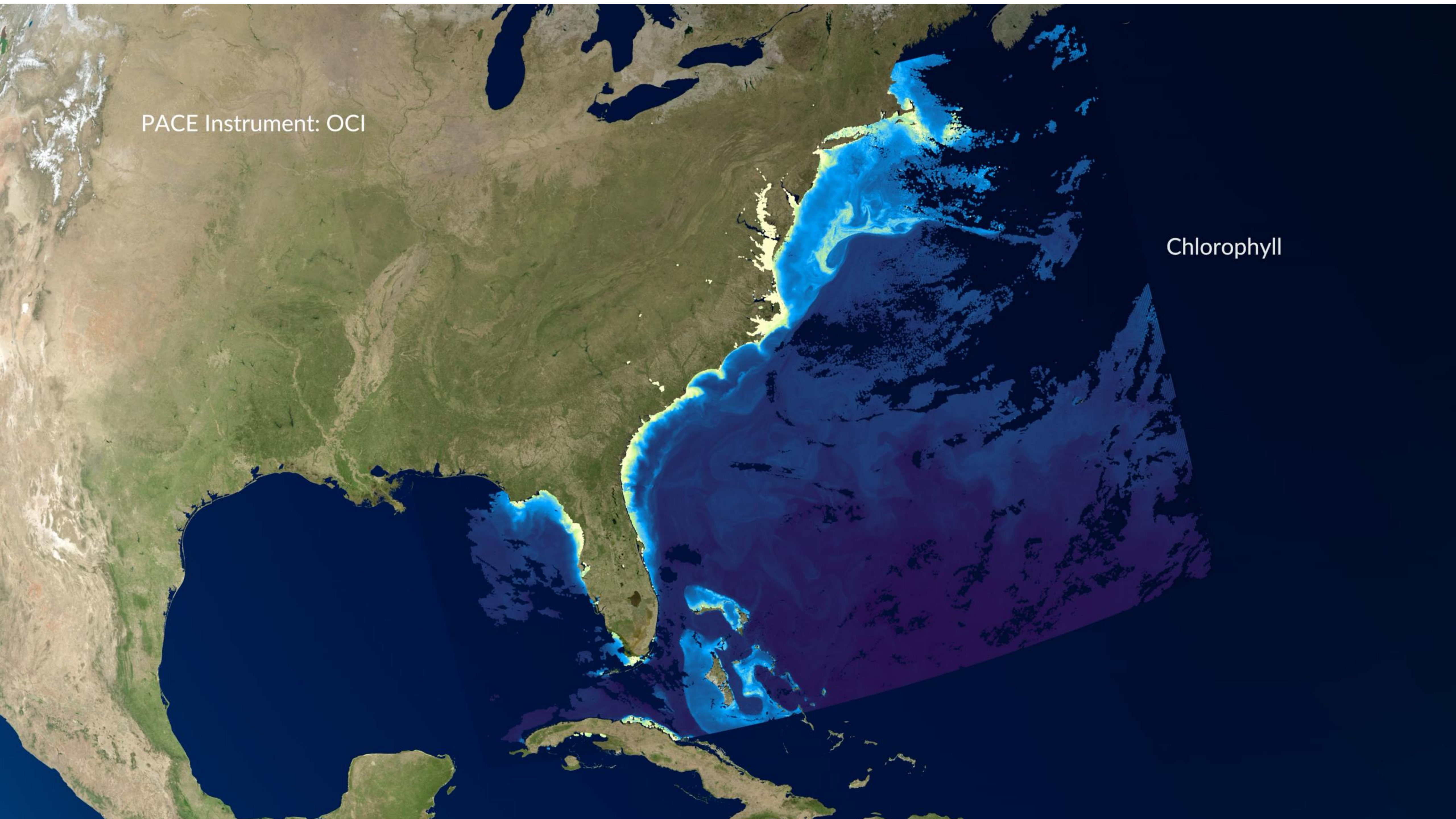




21 March 2024
Chlorophyll-a
Phytoplankton Community
MOANA Algorithm
Lange et al. 2020



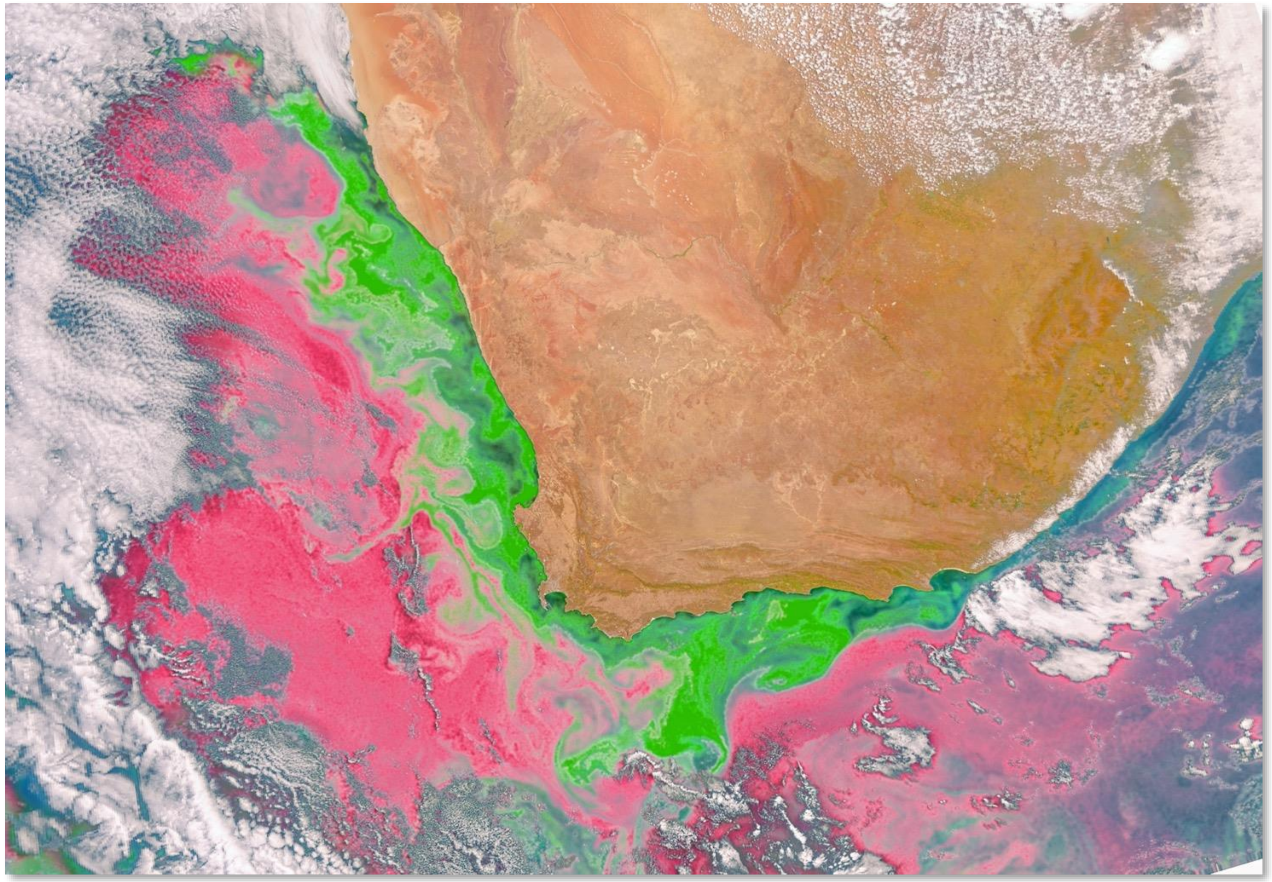



PACE Instrument: OCI
Chlorophyll

Data (Re)Processing & Release Status

- Initial data release on 11 April 2024
  - Level-1 radiometry from all 3 instruments
  - Heritage suite of ocean color products from OCI (all "provisional" -> EDS, OB.DAAC/OBPG)
- First reprocessing (tagged V2) completed in early July
  - First use of on-orbit (= solar diffuser) calibrations for all 3 instruments
  - Second wave of OCI products (all "TEST" -> OB.DAAC)
    - Terrestrial and aquatic surface reflectances (every 10 nm)
    - Terrestrial vegetation indices (~10 products)
    - Cloud optical properties and altitude
  - https://oceancolor.gsfc.nasa.gov/data/reprocessing/V2.0/pace/
- Second reprocessing (V3) to be conducted in coming months
  - First system vicarious calibration (HyperNAV)
  - TBD wave of products (all "TEST" -> OB.DAAC)
- Additional data products to be released pending review by Project + Pis
  - No predefined deadlines

Algorithms: PACE Phytoplankton Community Composition



Synechococcus and Autotrophic Picoeukaryotes, as seen by PACE off South Africa – 03/09/2024

MOANA Algorithm from Lange et al. 2020

Other Algorithms/Approaches:

- Kramer et al. 2022
  - Pigments and Absorption
- Chase et al. 2022
  - Diatom carbon relating absorption and phytoplankton imaging flow cytometry

See Cetinic et al. 2024

Data Levels

OB.DAAC Data Processing Levels

Level-1A

Raw instrument data and spacecraft telemetry in NetCDF4

Level-1B

Calibrated and geolocated instrument data

Level-1C

Calibrated, geolocated, and co-registered to a common grid

Level-2

Derived geophysical science data products

Level-3

Temporally and spatially composited (binned and mapped) global products

Level-4

Geophysical products derived from combined Level-3 inputs and/or models

Product Maturity Levels

Standard

Products are produced by an algorithm that has community consensus and have been validated.

Provisional

Results have been reviewed and are in family with heritage data products or other basis of expectation, but which have not yet been validated and may still contain significant errors.

Test

Results have not yet been reviewed by algorithm developers and/or may be known to have substantial errors in implementation that are under investigation.

Diagnostic

Products that are produced to support analysis of algorithm behavior, but that are not intended for science.

Data Products Availability

Data Products Table

Calibrated Radiometry and Polarimetry | Ocean Properties to be Produced by OCI | Atmospheric Properties to be Produced by OCI | Land Data Products to be Produced by OCI | Aerosol and Ocean Properties from HARP2 | Aerosol and Land Surface Properties from HARP2 | Cloud Properties from HARP2 | Ocean Surface Properties from HARP2 | Aerosol and Ocean Properties from SPEXone | Aerosol and Land Surface Properties from SPEXone | Aerosol and Ocean Properties from OCI + HARP2 + SPEXone

Access to data varies with its status (data maturity level). Provisional data are available through Earthdata Search, the OB.DAAC File Search and Level 3 & 4 Browser. Test and Diagnostic data are available through the OB.DAAC File Search and Level 3 & 4 Browser. See also "Access PACE Data".

What do colors in the "Availability" column mean?

Available	Coming soon!	Currently implementing and evaluating	No approach currently identified

Calibrated Radiometry and Polarimetry

Calibrated and geolocated radiometry and polarimetry as observed at sensor.

Product	L2 Suite	Description and Use	Units	Availability	Status	Additional Info
Spectral top-of-atmosphere radiances from OCI	*N/A*	Spectral radiance observed at the top of the atmosphere.	W m^{-2} um^{-1} sr^{-1}	Level-1B 1-km at nadir; daily - Level-1C; daily	Provisional	Level-1C draft data format and examples
Spectral top-of-atmosphere radiances and polarimetry from SPEXone	*N/A*	Spectral radiance and polarimetry observed at the top of the atmosphere, for all sensor viewing angles.	Various	Level-1B TBD; daily - Level-1C; daily	Provisional	Level-1C draft data format and examples
Spectral top-of-atmosphere radiances and polarimetry from HARP2	*N/A*	Spectral radiance and polarimetry observed at the top of the atmosphere, for all sensor viewing angles.	Various	Level-1B TBD; daily - Level-1C; daily	Provisional	Level-1C draft data format and examples

Ocean Properties to be Produced by OCI

Bio-optical and biogeochemical properties of seawater constituents in the sunlit upper ocean.

Product	L2 Suite	Description and Use	Units	Availability	Status	Additional Info
Spectral remote sensing reflectances	OC_AOP	Spectral color of the ocean in the ultraviolet-to-near infrared spectral range. Used as input into algorithms to retrieve information about colored dissolved organic matter,	sr^{-1}	Level-2 1-km at nadir; daily - Level-3 4-km; daily, 8-day, monthly, annual	Provisional	ATBD SAT members: Boss, Zhai, Krotkov, Chowdhary, Stamnes, Zhang

https://pace.oceansciences.org/data_table.htm

PACE Ocean Data Products L2 Suites 20240829

APPARENT OPTICAL PROPERTIES

- Remote Sensing Reflectance (Rrs) for 184 bands
- Rrs uncertainty
- Aerosol Optical Thickness
- ~~Angstrom exponent~~
- ~~Normalized Fluorescence Line Height~~
- Apparent Visible Wavelength (AVW)

INHERENT OPTICAL PROPERTIES

- Spectral phytoplankton absorption coefficients
- Spectral non-algal particle plus dissolved organic matter absorption coefficients
- ~~Spectral chromophoric dissolved organic matter absorption coefficients~~
- ~~Spectral non-algal particle matter absorption~~
- Spectral particulate matter absorption coefficients
- ~~Spectral slope coefficients of chromophoric dissolved organic matter absorption~~
- Spectral particle backscattering coefficients
- Total spectral backscattering coefficients
- Total absorption coefficients
- ~~Backscattering Slope~~
- ~~Non-algal particle matter absorption Slope~~
- Uncertainties (for some listed above)
- Diffuse attenuation coefficient (Kd_Lee)
- Kd_Lee uncertanties

BIOGEOCHEMISTRY

- Concentration Of Chlorophyll-a
- Concentration Of Particulate Organic Carbon
- ~~Concentration Of Particulate Inorganic Carbon~~
- Concentration Of Phytoplankton Carbon
- Chlorophyll-a uncertainties
- Phytoplankton Carbon uncertainty

PHOTOSYNTHETICALLY AVAILABLE RADIATION

- Daily PAR scalar 0-
- Daily PAR planar 0+
- Daily PAR planar 0-
- Instantaneous PAR planar 0+
- Instantaneous PAR planar 0-
- Instantaneous PAR scalar 0-

More Advanced Products to come:

- Water Quality Suite
- Phytoplankton Community Composition Suite
- Level 4
  - Net Primary Production

PACE Data Table →

Algorithm Descriptions: https://www.earthdata.nasa.gov/apt/documents

Water Quality Suite & Algorithms in Consideration

WATER QUALITY

- Water Clarity: Diffuse attenuation coefficient (Kd)
- Chlorophyll-a
- Turbidity: Suspended particulate matter (SPM)
- Colored dissolved organic matter (CDOM) absorption (a_g)

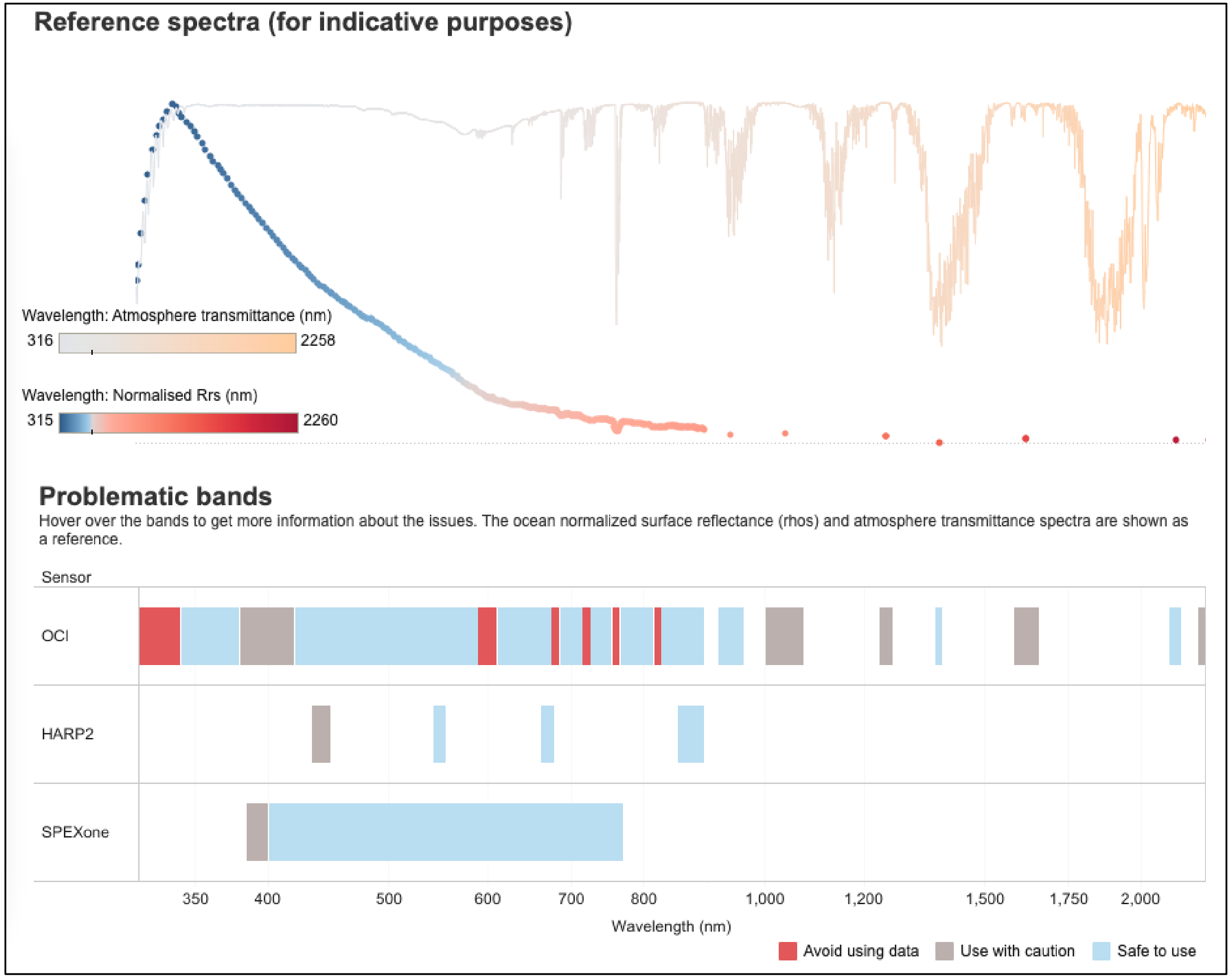
Inland and Coastal Waters Algorithms:

- **Aquaverse**: A mixture density neural network algorithm
  - Chlorophyll-a, CDOM absorption, Total Suspended Solids (~SPM), Phycocyanin
- **CYAN-Equivalent**:
  - Aquatic surface reflectances (r_s)
  - Cyanobacteria Index (CI_{cyano})
  - Cyanobacteria-Apparent Visible Wavelength (CI-AVW)
- Harmful Algal Blooms – TBD

Data Issues Under Investigation

Broad categories currently under investigation include:

- Geolocation
- Radiometric Performances
- On-Orbit Calibration Refinement
  - Instrument-to-instrument intercomparisons are only beginning
- Recommend avoiding, for now, particular bands influenced by instrument or atmospheric characteristics



OC Data Product Issues – 2

Ocean apparent optical properties suite (OC_AOP): spectral remote sensing reflectances (Rrs(l); sr^{-1}) and uncertainties (Provisional), apparent visible wavelength (Provisional), aerosol optical thickness (Diagnostic), and aerosol angstrom exponent (Diagnostic).

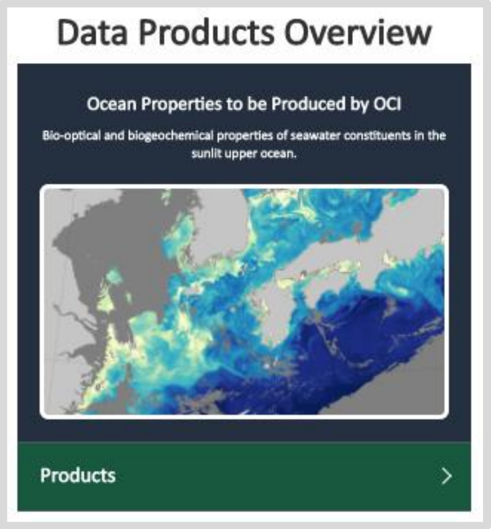
- No vicarious calibration applied yet; further reduction in bias for OC_AOP data product retrievals relative to ground truth is expected once vicarious calibration applied.
- Limited validation of Rrs(l) retrievals has been performed. Results show good agreement (to first order) with ground truth and with heritage multispectral satellite missions (e.g., VIIRS), but more measurements are needed to fully assess data quality.
- Performance of Rrs(l) retrieval in the ultraviolet (below 400 nm) has not yet been meaningfully reviewed and is likely to contain significant biases and erroneous variability.
- Corrections for absorbing gases have been applied, but refinement is on-going. Rrs(l) variability, especially in the red, is likely to contain residual artifacts from water vapor and oxygen absorption near 680, 720, 760, and 820 nm.
- Discontinuity in the observed radiances at the transition between the blue and red focal planes. This results in an artifact in Rrs(l) in the 590-610 nm region. Science algorithms should avoid use of data in this region.
- The current processing extends to higher view zenith angles than the heritage sensors. The atmospheric correction becomes increasingly difficult at these extreme geometries, and erroneously elevated reflectance has been observed in red wavelengths near scan edge. These data are flagged at Level-2 and masked at Level-3.
- Chlorophyll fluorescence line height (FLH) will be included in a future release.

OC Data Product Issues – 3

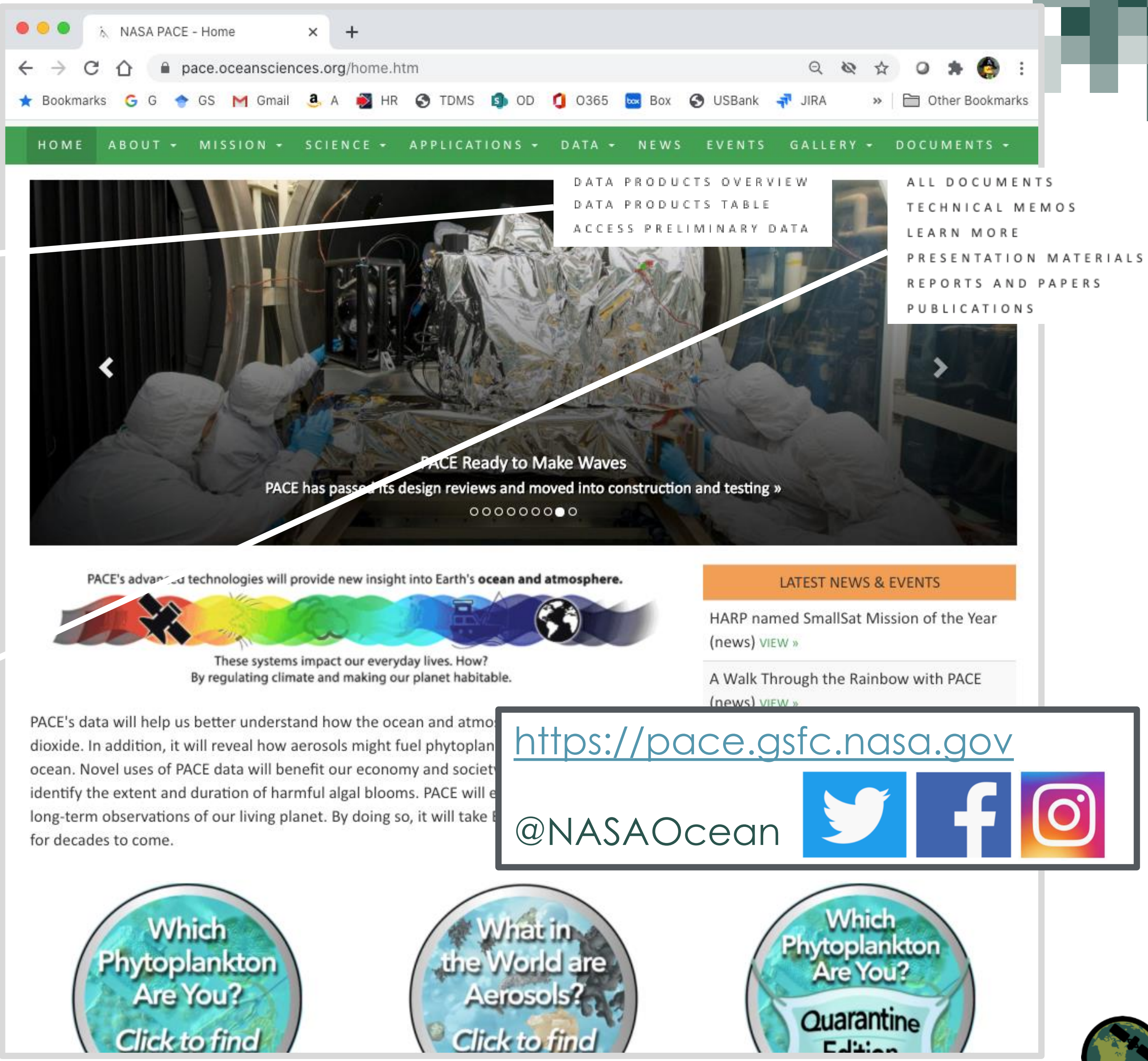
- Ocean Inherent Optical Properties Suite (OC_IOP) Known Issues:
  - Products are derived from Rrs(l). Algorithm failure and artifacts have been noted in highly productive and near-shore waters.
- Ocean Biogeochemical Properties Suite (OC_BGC) Known Issues:
  - Products are derived from Rrs(l)
- Ocean Photosynthetically Available Radiation (PAR) Suite Known Issues:
  - None
- Cloud Mask Suite (CLDMASK): Cloud Mask and Cloud-Adjacent Mask (Test) Known Issues:
  - Current implementation of the MERRA-2 snow/sea ice mask can cause blockiness around coasts where the land is snow-covered. This will be fixed in a forthcoming release.

Resources & Useful info

Data Product Descriptions + Access to Simulated Data & Characterizations



PACE Technical Memos & Other Documents



https://pace.gsfc.nasa.gov

@NASAOcean

PACE Data Access

Three Primary Options Include:

- Earthdata Search OB.DAAC Portal
- OB.DAAC Level 3 & 4 Browser
- OB.DAAC File Search

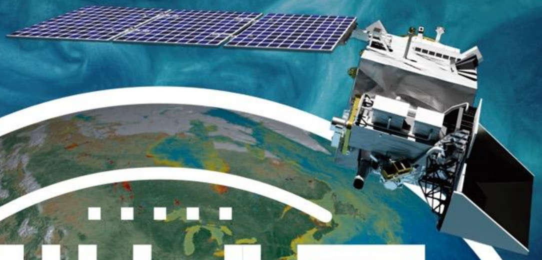
The OB.DAAC Level 1 & 2 browser does not support access to PACE data.

PACE Plankton, Aerosol, Cloud, ocean Ecosystem

PACE will revolutionize global marine and atmospheric science with its hyperspectral imaging radiometer and two multi-angle polarimeters.

Advances realized in Earth science relative to those from MODIS will be as profound as those achieved in astronomy moving from Hubble to JWST.

PACE is far more than an ocean color and aerosols continuity mission. Its capabilities make it a true mission of discovery across Earth system science.



Learn more about the PACE mission

Join the PACE CoP and/or Early Adopter Program

Part 1

Summary

Summary

- Description of PACE-OCI, HARP2, and SPEXone: Spectral, spatial, and temporal resolutions.
- PACE data products are available for oceans/estuaries, atmosphere, and land
- OCI Observations:
  - Hyperspectral from 315 nm to 895 nm, with spectral sampling of 2.5 nm
  - Will enable separation of aquatic constituents and phytoplankton community composition
  - Only hyperspectral observations with near-daily, global coverage
- HARP2 and SPEXone will aid in atmospheric correction
- Relatively low spatial resolution (1 km) constraints; use within inland and nearshore waters
- Hyperspectral algorithms need verification and require hyperspectral field measurements
- Overview of available PACE Data products and issues in Level-2 data products
  - Not completely calibrated, limited validation
  - Ongoing refinements to the atmospheric correction

Looking Ahead to Part 2

- Overview, Access, and Analysis of PACE Ocean Color Data Products
- Analysis and Visualization OCI Data Products Using NASA’s Open-Source SeaDAS Software

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 9/10/2024
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 24/10/2024**

- **Certificate of Completion:**
  - Attend all three live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

Trainers:

- Antonio Mannino
  - Antonio.mannino-1@nasa.gov
- Amita Mehta
  - Amita.v.mehta@nasa.gov

- ARSET Website
- Follow us on Twitter!
  - @NASAARSET
- ARSET YouTube

Visit our Sister Programs:

- DEVELOP
- SERVIR

Thank You!