

# PACE

# Plankton, Aerosol, Cloud, ocean Ecosystem advancing global and coastal ocean color science and applications

# PACE

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2021 United Nations Decade  
2030 of Ocean Science  
for Sustainable Development



CEOS WGCV IVOS 34 – 30 August 2022

# NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission

## Primary hyperspectral radiometer:

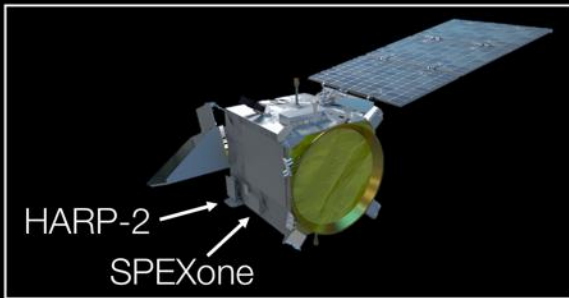
- Ocean Color Instrument (OCI) (GSFC)

## 2 contributed multi-angle polarimeters:

- HARP2 (UMBC)
- SPEXone (SRON/Airbus)

## Key characteristics:

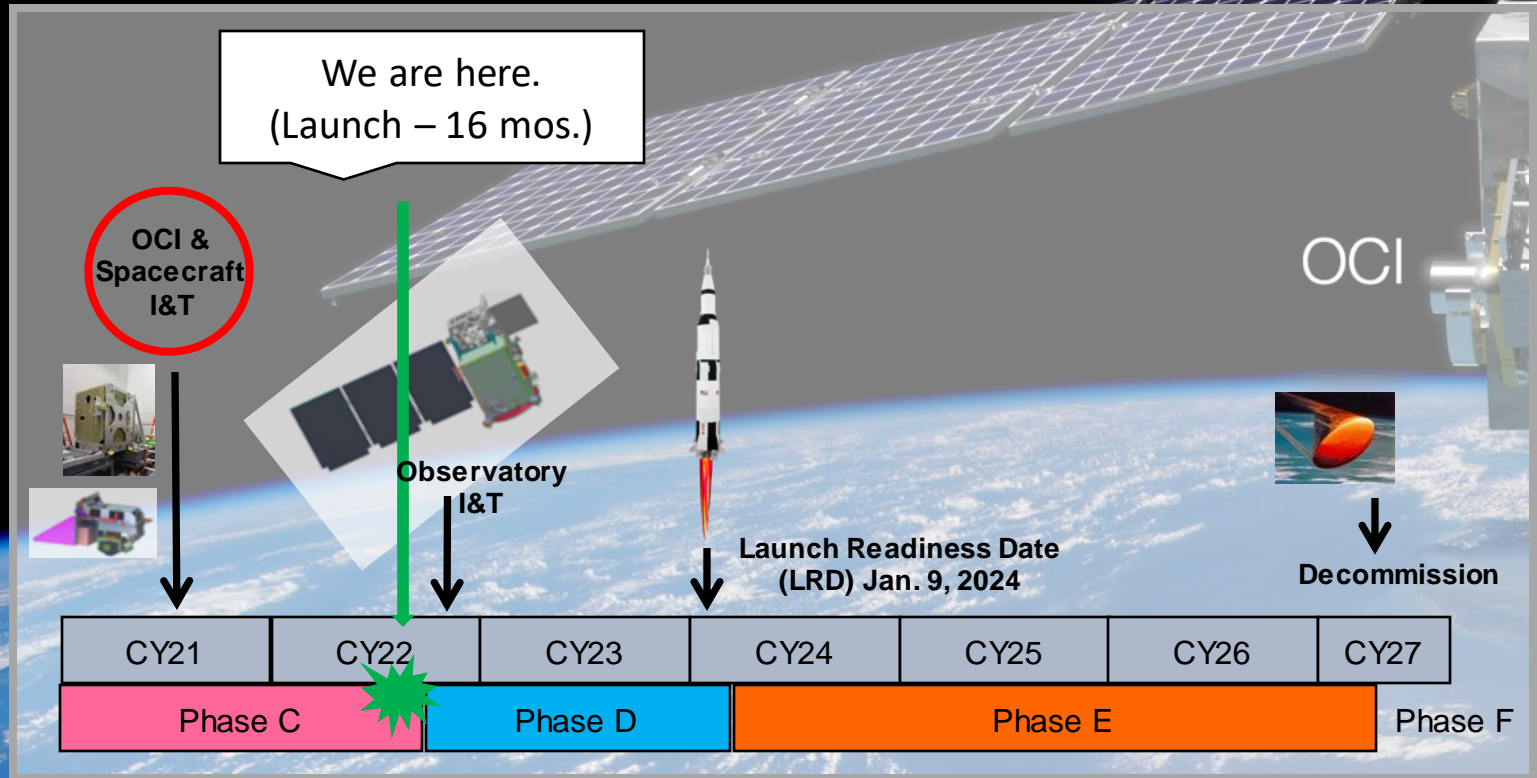
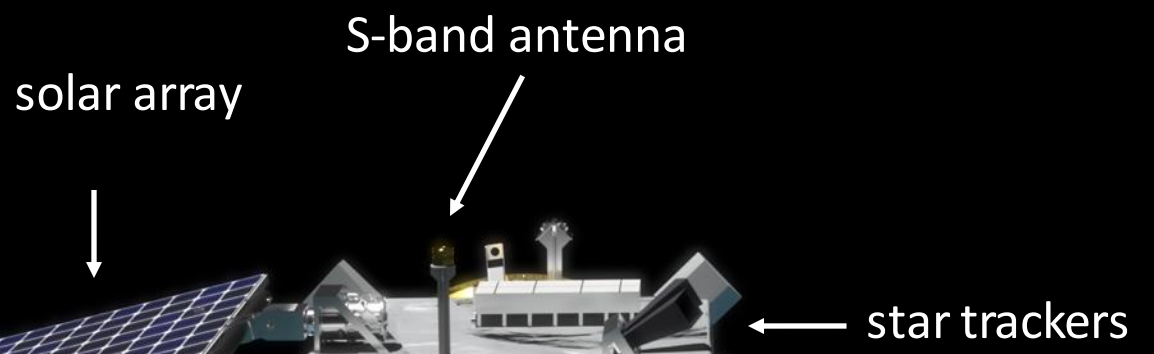
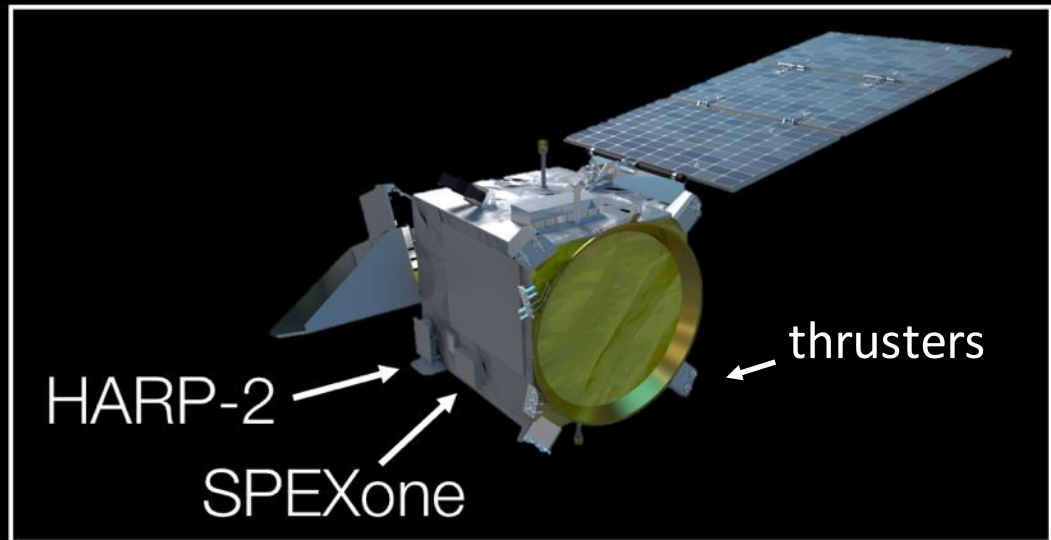
- 9 January 2024 launch
- 676.5 km altitude
- Polar, ascending, Sun synchronous orbit; 98° inclination
- 13:00 local Equatorial crossing
- 3-yr design life; 10-yr propellant
- Ka-band downlink rate 600 Mbps; avg Observatory 40 Mbps



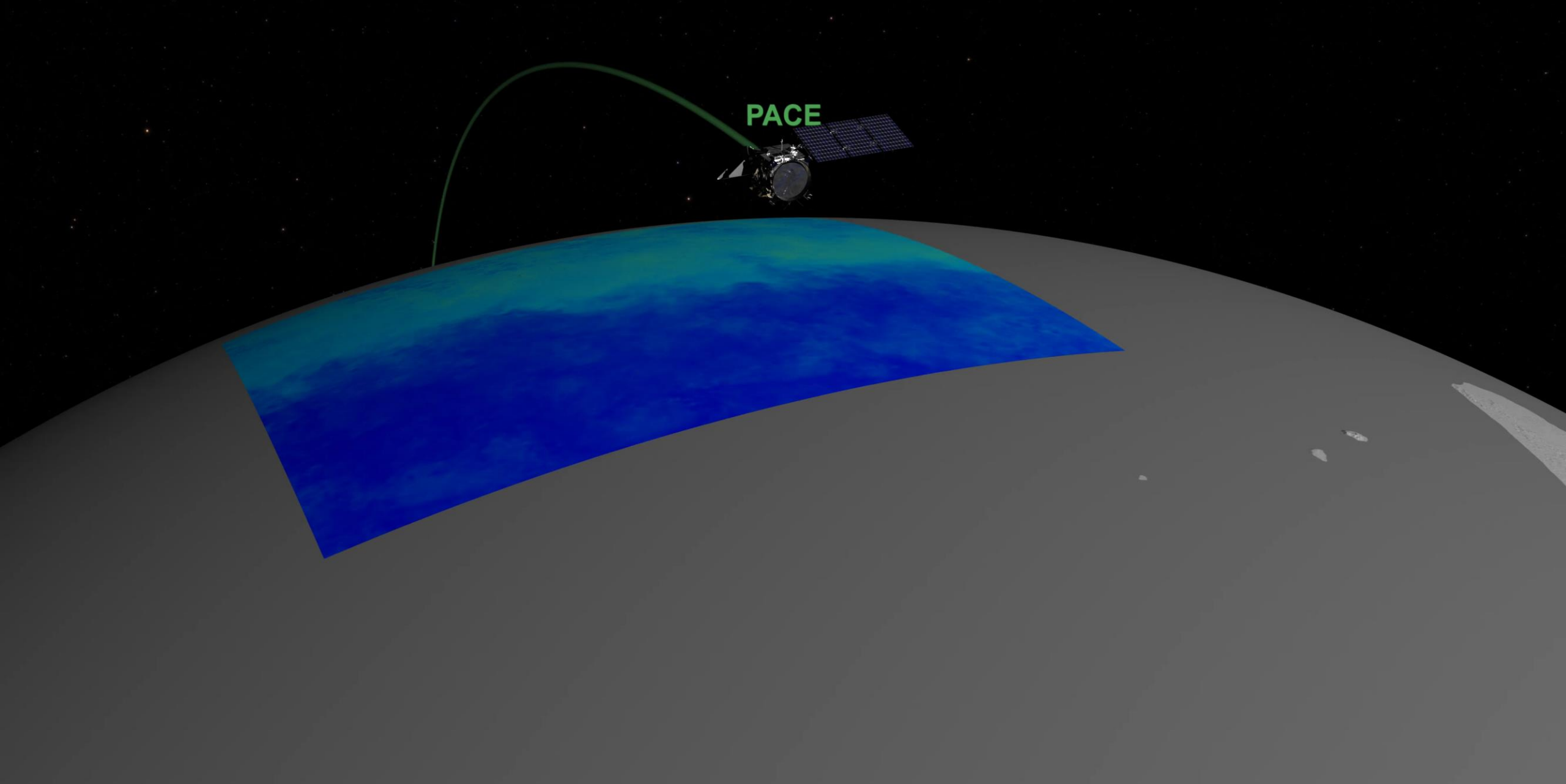
<https://pace.gsfc.nasa.gov>  
@NASAOcean



Additional beauty shots of the PACE observatory can be found at: <https://svs.gsfc.nasa.gov/12469>

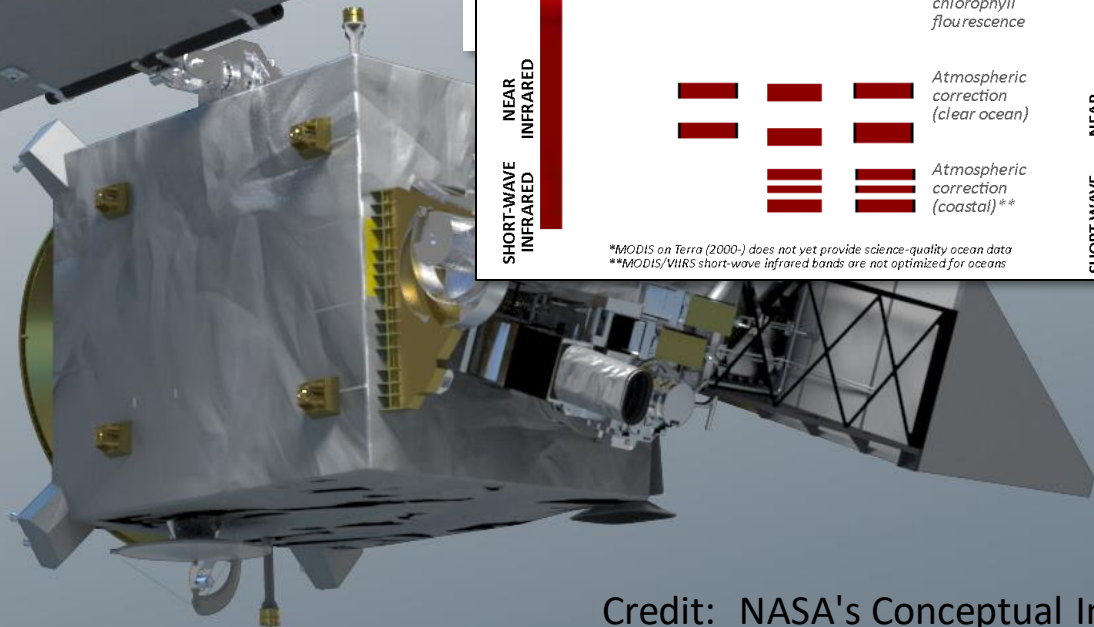
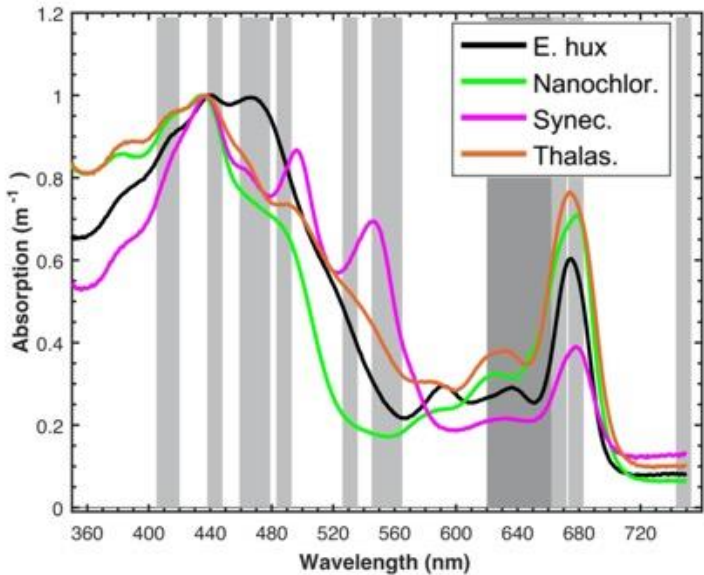
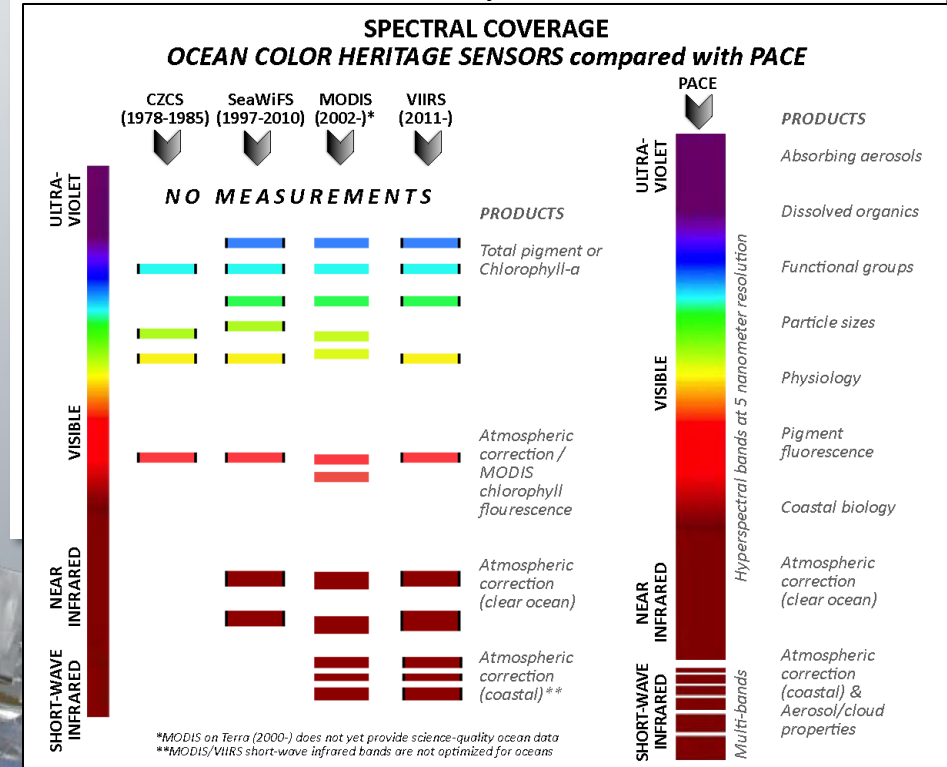
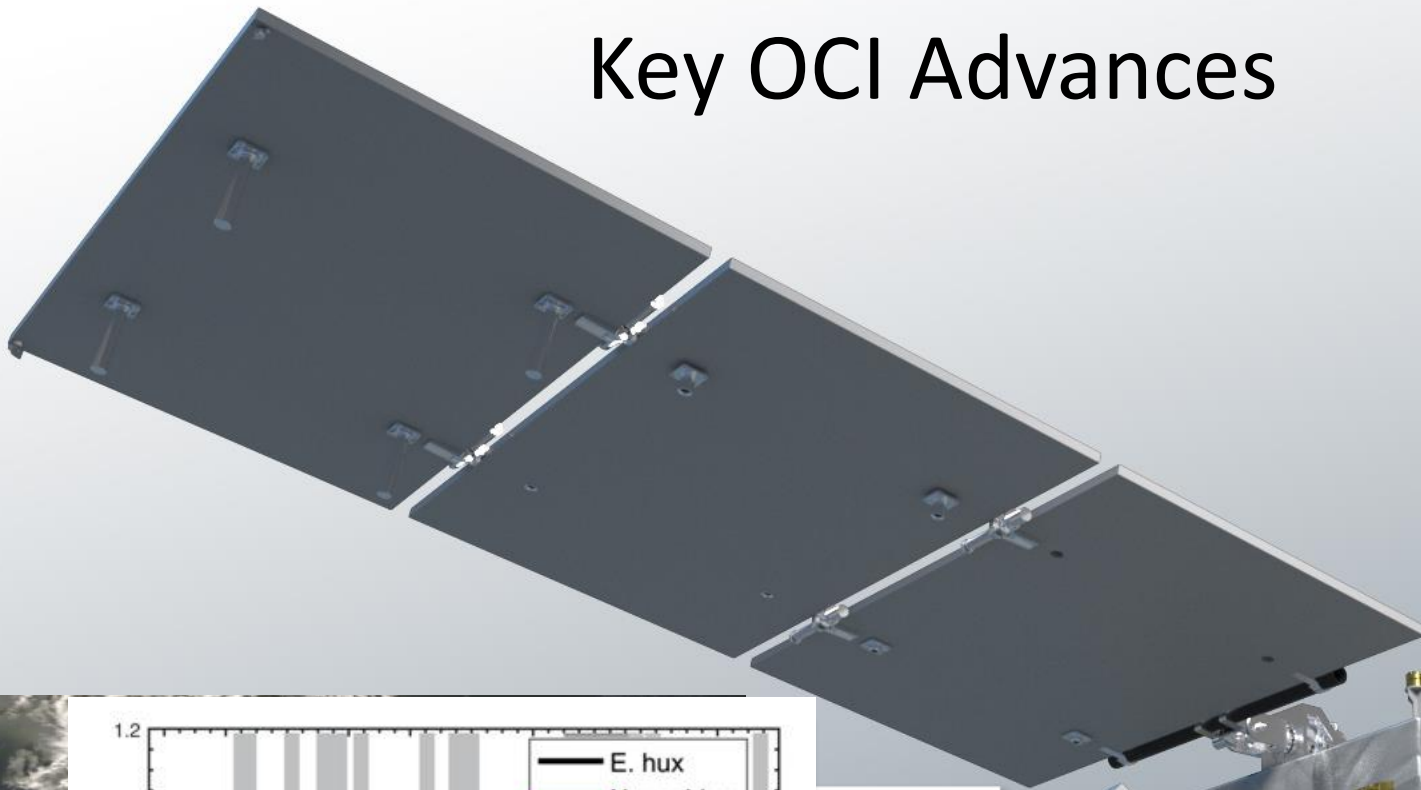


# PACE Science Objectives



# Key OCI Advances

- Hyperspectral scanning radiometer
- 5 nm resolution (320) 340-890 nm
  - Data at 2.5 nm steps



Credit: NASA's Conceptual Image Laboratory

Designed and built at NASA Goddard Space Flight Center



UMBC Hyper Angular Rainbow Polarimeter (HARP-2)



**Update**

- Flight unit undergoing environmental testing
- Delivery to GSFC for I&T in Fall 2022

- Excellent for cloud droplet size and ice particle shape/roughness retrievals
- *Provides cloud capabilities beyond those required of OCI*
- *Wide swath matches OCI, offering potentially improved atmos. correction*

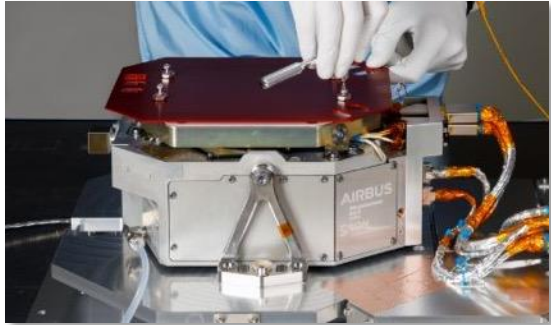
	HARP-2	SPEXone
UV-NIR range	440, 550, 670, 870 nm	Continuous from 385-770 nm in 5 nm steps
SWIR range	None	None
Polarized bands	All	Continuous from 385-770 nm in 15-45 nm steps
Number of viewing angles [degrees]	10 for 440, 550, 870 nm; 60 for 670 nm [spaced over 114°]	5 [-57°, -20°, 0°, 20°, 57°]
Swath width	±47° [1556 km at nadir]	±4.5° [106 km at nadir]
Global coverage	2 days	30+ days
Ground pixel	3 km	2.5 km
Heritage	AirHARP, Cubesat	AirSPEX

- Excellent for aerosol characterization
- *Addresses aerosol climate objectives beyond those required of OCI*

**OCI + SPEXone + HARP2**

- Greater information content than any current instrument suite for ocean color, aerosol, & cloud observations
- New data products: ocean color from multi-angle polarimetry, wind speed, etc.

SRON/Airbus Spectro-polarimeter for Planetary Exploration (SPEXone)



**Update**

- SPEXone flight unit delivered to GSFC; integrated to spacecraft
- 16 orbits of simulated data available online

# PACE Data Products – Atmospheric

DATA PRODUCTS

concentrations of brown/black carbon



aerosol absorption  
aerosol optical depth  
aerosol size distributions  
aerosol heights & layers

ocean reflectance  
whitecap fraction  
angular light distributions

## Top-of-atmosphere radiance

*What satellites see while orbiting hundreds of miles above Earth's surface*

**Atmospheric contribution**  
*Optical signature of the atmosphere itself, such as clouds and tiny particles known as aerosols*

## Water-leaving radiance

*Light exiting the ocean that gives it its color*

## Oceanic contribution

*How light is scattered and absorbed by seawater and the "stuff" contained in it*

cloud optical depth  
cloud height  
cloud thickness

cloud phase (liquid/ice)  
droplet size distributions  
ice crystal shapes

oil slick detection

# PACE – Ocean Color (plus Terrestrial)

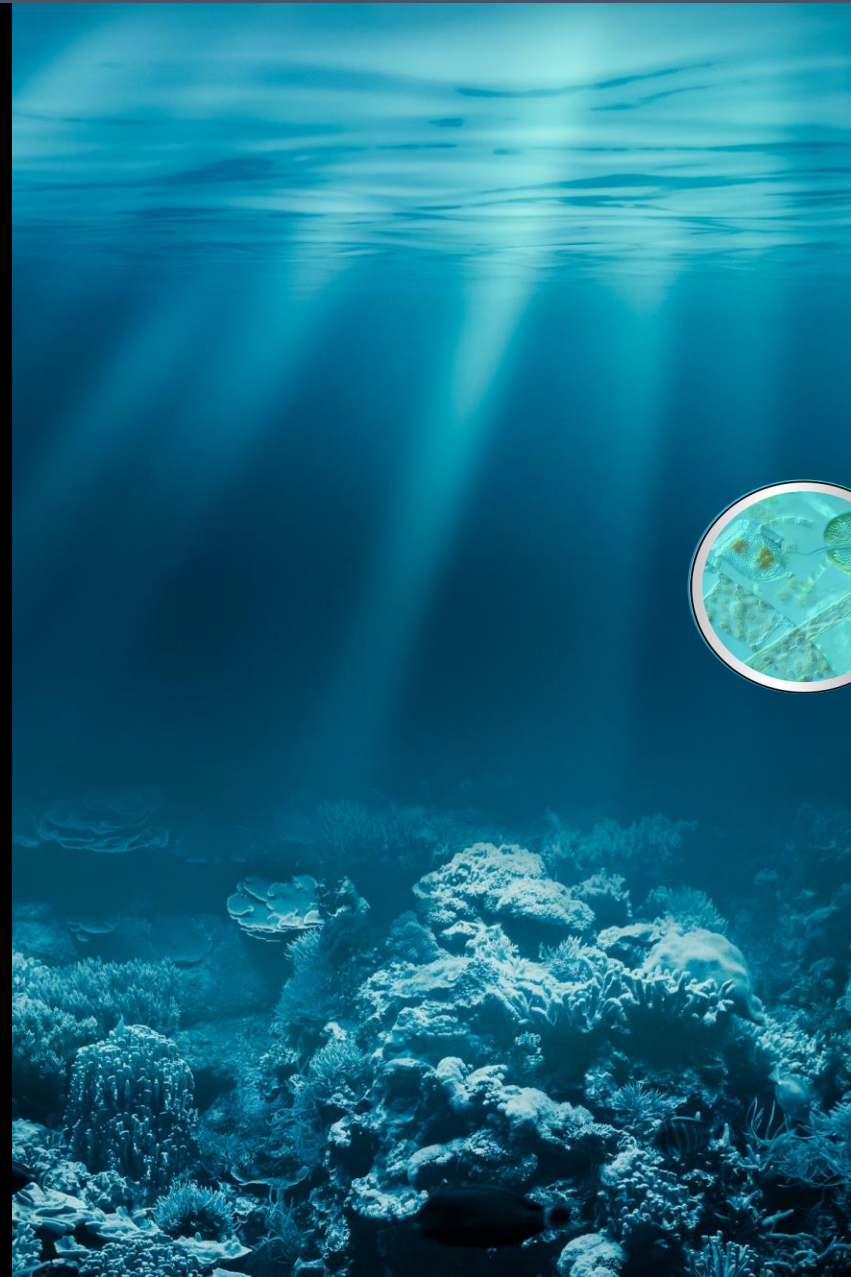
DATA PRODUCTS

light penetration  
angular light distributions  
index of refraction

light transmission  
absorption properties  
scattering properties

PAR: photosynthetically  
available radiation

bathymetry  
classifications



photosynthetic pigments  
fluorescence  
plankton communities

concentrations of  
particulate carbon &  
suspended matter

land albedo  
vegetation indices



# PACE data availability, formats & software

Data Level	Description	Format
Level 0	Lowest level science data (Raw Data; Consultative Committee for Space Data Systems (CCSDS) packets - <a href="https://public.ccsds.org/Pubs/133x0b2.pdf">https://public.ccsds.org/Pubs/133x0b2.pdf</a> )	CCSDS
Level 1A	Uncalibrated science data in self-describing archive format	netCDF4
Level 1B	Calibrated radiances, geo-located science data as observed	netCDF4
Level 1C	Calibrated radiances, geo-located, co-registered (resampled) science data	netCDF4
Level 2	Science products derived from Level-1B/C	netCDF4
Level 3	Temporally and spatially composited science products	netCDF4

<https://oceancolor.gsfc.nasa.gov>

The screenshot shows the OceanColor WEB website with the 'DATA' menu open. The menu items include: Overview, Search & Download Methods, Find Data, Direct Data Access, Data File Search, OPeNDAP, SeaBASS, Search, Browse, Submit, Projects, PRISM-CORAL Data, Browsers (Level 1&2 Browser, Level 3 Browser), Quality Assessment (Product Validation, Global L3 Trends, Mission Quality Monitor, More...), Level-3 Time Series Plotter, Overpass Predictor, and Help (Ask A New Question, Search Existing Answers). A red circle highlights the 'Browsers' section, and a red arrow points from the 'Level 2' row in the table above to the 'Level 3 Browser' option.

The screenshot shows the OceanColor WEB website with the 'MISSIONS' menu open, highlighting 'PACE'. Below, the 'Sensor Summary' section is visible, including a list of instruments: Ocean Color Instrument, HARP2 polarimeter, and SPEXone polarimeter. The 'Data Access' section is circled in red and lists: PACE Simulated and Proxy Data, Prelaunch Instrument Characterization Data, and Ancillary Data for PACE Processing. A red arrow points from the 'Level 2' row in the table above to the 'Data Access' section.

<https://seadas.gsfc.nasa.gov>

The screenshot shows the SeaDAS website, titled 'The Official NASA/OB.DAAC Data Analysis Software'. It features a navigation menu with 'ABOUT', 'DATA', 'DOCS', 'PROCESSING', 'DOWNLOADS', and 'SUPPORT'. A 'Features' button is visible on the right side. A red arrow points from the 'Level 3 Browser' option in the OceanColor WEB screenshot to the SeaDAS website.



# PACE: Interdisciplinary applied science objectives

fisheries

biodiversity

HABs

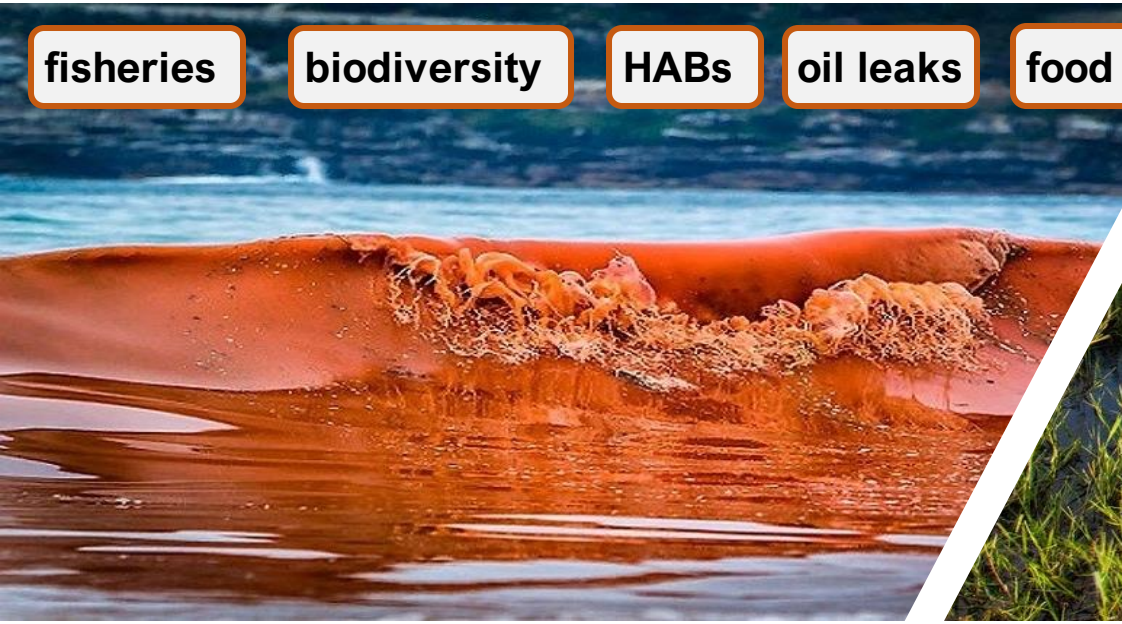
oil leaks

food security

wetlands

terrestrial ecosystems

land use & change



air quality

human health

disasters

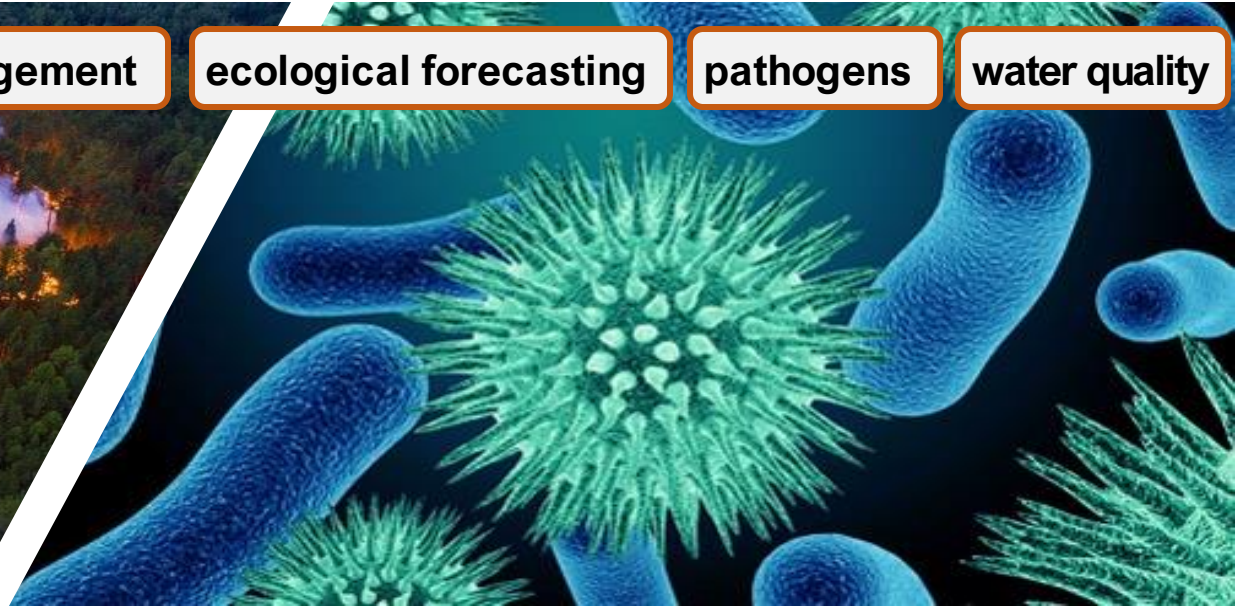
climate

resource management

ecological forecasting

pathogens

water quality

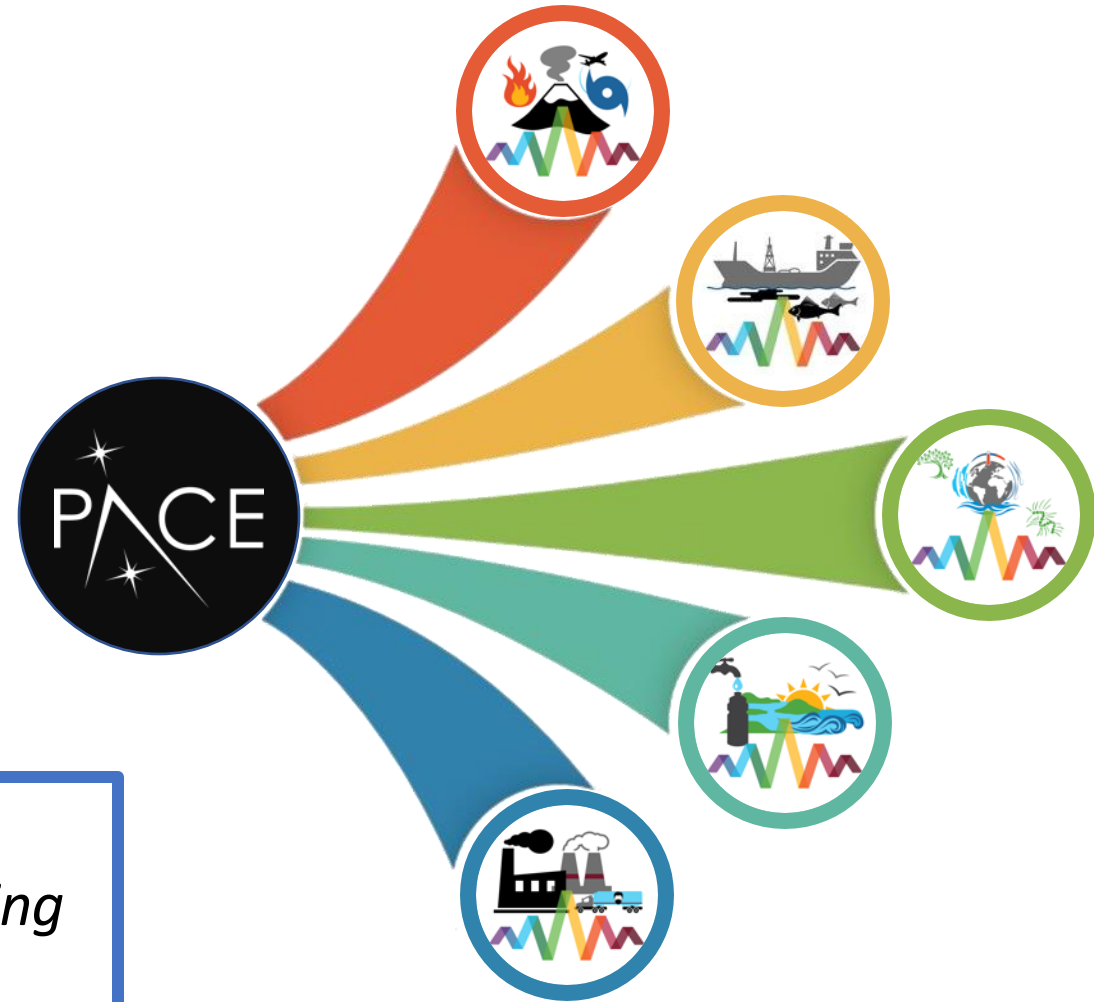




## PACE Applications Program

- Addressing community user needs & concerns with PACE data products
- Grow relevance & sustainability of PACE
- Demonstrate the societal value & utility of PACE

*The goal of the PACE Applications Program is to foster new partnerships and out-of-the-box thinking that will generate inventive solutions that aid society.*



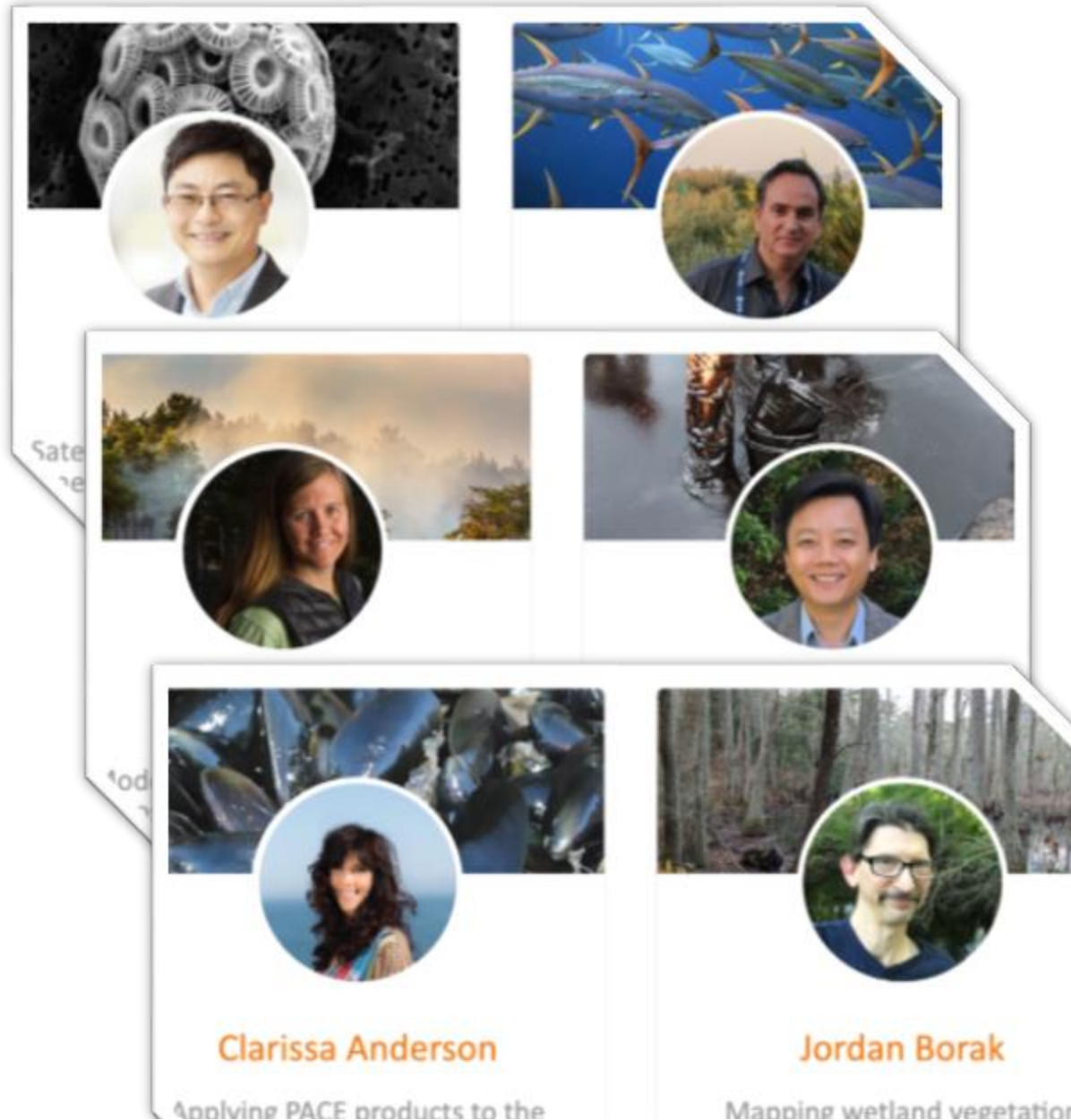


## PACE Early Adopter Program

The PACE Early Adopter program promotes applied science and applications research designed to scale and integrate PACE data into policy, business, and management activities that benefit society and inform decision making.

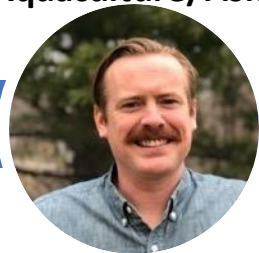
### Goals:

- Expand the user communities with tangible and potential applications that would benefit from the use of PACE data
- Facilitate feedback on PACE data products pre-launch
- Accelerate the use and integration of PACE products into applications post-launch by providing specific support to Early Adopters who commit to engage in pre-launch applied research



## PACE Early Adopters

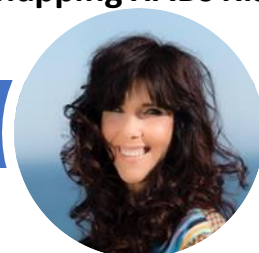
Aquaculture/Fisheries



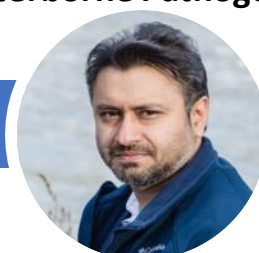
Marine mammals & Climate



Mapping HABs Risk



Waterborne Pathogens



Air-sea exchange

Oil Spills

Aquaculture/Fisheries

Aerosols & Human Health

HABs Detection



Data Integration



Water Clarity-Waters Resources



Water Clarity-Water Resources



Wetland Ecosystems

Food Security

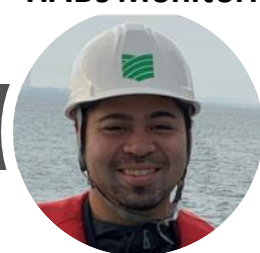
Mobile Apps & Decision Making

Data management

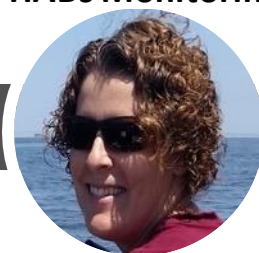
Air Quality & Human Health



HABs Monitoring



HABs Monitoring



Global Carbon Budget

Air Quality & Climate

HABs Monitoring

Data Integration





PACE

# PACE Applications Workshop



September 14-15, 2022  
Virtual Event



<https://www.eventbrite.com/e/pace-applications-workshop-2022-tickets-321347487987>



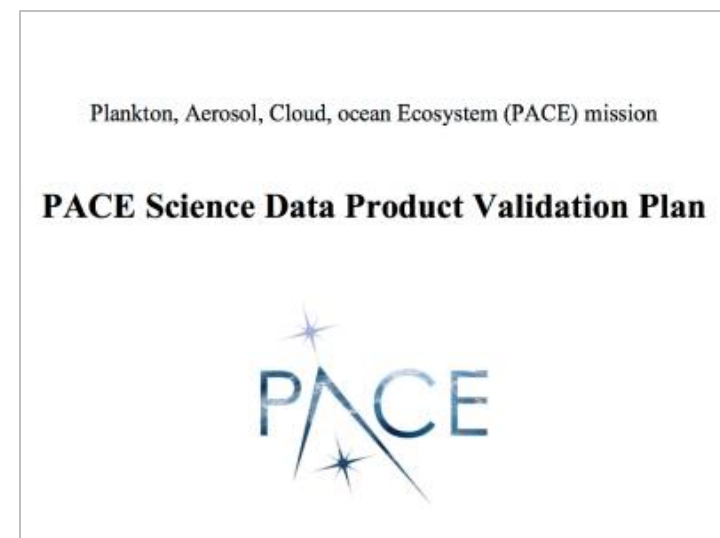
# Vicarious Calibration and Validation



- System Vicarious Calibration – *ongoing competition*
  - MarONet – Voss/Johnson/Yarbrough et al.
  - HyperNav - Barnard/SeaBird/Boss et al.
- Validation Activities
  - ROSES 2022 PACE Validation Science Team (PVST)
  - PACE Post-launch Airborne eXperiment (PACE-PAX)
  - Rely on existing infrastructure and data resources
    - AERONET-OC (**thank you Giuseppe!!!**)
    - AERONET
    - FRM4SOC
    - MAN, SKYNET, ARM, MPLNET, EARLINET, etc.
  - Establish new infrastructure (tbd)

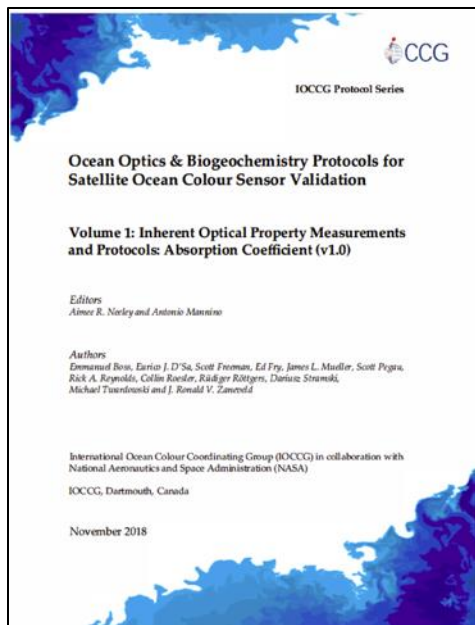


[https://pace.oceansciences.org/documents\\_more.htm?id=1758](https://pace.oceansciences.org/documents_more.htm?id=1758)



[https://pace.oceansciences.org/docs/PACE\\_Validation\\_Plan\\_14July2020.pdf](https://pace.oceansciences.org/docs/PACE_Validation_Plan_14July2020.pdf)

# Field Measurement Protocols - Published



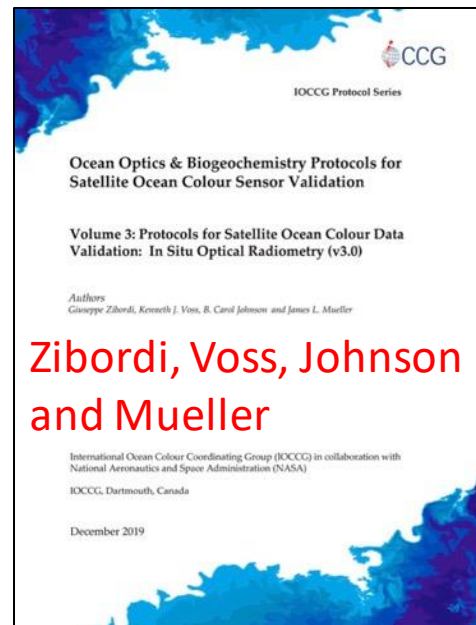
**Vol. 1.0**  
**Absorption**  
**(particles)**

**Nov. 2018**



**Vol. 2.0**  
**Beam**  
**Attenuation**

**April 2019**



**Zibordi, Voss, Johnson**  
**and Mueller**

**Vol. 3.0**  
**Radiometry**  
**for Validation**

**Dec. 2019**



**Vol. 4.0**  
**Inline Flow-**  
**Through IOPs**

**Nov. 2019**



**Vol. 6.0**  
**Particulate**  
**Organic**  
**Carbon**

**August 2021**

# resources & useful info

data product descriptions + access to simulated data & characterizations

PACE technical memos & other documents

### Data Products Overview

Ocean Properties to be Produced by OCI  
Bio-optical and biogeochemical properties of seawater constituents in the sunlit upper ocean.



Products >

NASA/TM-2018-219027/ Vol. 7  
PACE Technical Report Series  
Volume 7  
June 2018, Charles R. McClain, and P. Aroney Winkler, Editors

**Ocean Color Instrument (OCI) Concept Design Studies**

Shankar Dattam, Robert Arnone, Michael J. Behrenfeld, Bruce Cooper, James Cornett, Robert E. Ryan, Bruce Pinner, David Paulsen, Aron Bratton, Alexander Stoecken, Leifland L. W. McManis, Clifford Hickey, James Swadlow, Steve Anderson, Frederick S. P. O. Weiss, Robinson, Sergio R. Siqueiros, Ryan Henderson, Taty Winkler, and Aroney Winkler

Extended UV Capability for Ozone Retrieval  
Chlorophyll Fluorescence Requirements  
Estimates for Optimal Sensing of Coastal Features  
Analyses Supporting an OCI 1038 nm Band  
Analysis of OCI SWIR Bands  
Strategy & Requirements: Solar & Lunar Calibrations  
Ltyp and Lmax Calculations for the OCI  
Analysis of OCI Spectral Resolution Considerations

[Dec-18] Ocean Color Instrument (OCI) Concept Design Studies [MORE >](#)

NASA/TM-2018-219027/ Vol. 6  
PACE Technical Report Series  
Volume 6  
June 2018, Charles R. McClain, and P. Aroney Winkler, Editors

**Data Product Requirements and Error Budgets Consensus Document**

Shankar Dattam, James Cornett, Brian A. Franz, Edwin M. Karadzich, Leifland L. W. McManis, Frederick S. P. O. Weiss, and Aroney Winkler

Ocean Color Science Data Product Requirements  
OCI Pointing Knowledge & Control Requirements  
SNR Requirement: Assessment & Verification  
Derivation of OCI Systematic Error Approach  
Uncertainty in Ocean Color Observations  
Uncertainty in Aerosol Model Characterization

[Dec-18] Data Product Requirements and Error Budgets Consensus Document [MORE >](#)



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pace.oceansciences.org/home.htm

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DATA PRODUCTS OVERVIEW  
DATA PRODUCTS TABLE  
ACCESS PRELIMINARY DATA

ALL DOCUMENTS  
TECHNICAL MEMOS  
LEARN MORE  
PRESENTATION MATERIALS  
REPORTS AND PAPERS  
PUBLICATIONS

PACE Ready to Make Waves  
PACE has passed its design reviews and moved into construction and testing »

PACE's advanced technologies will provide new insight into Earth's ocean and atmosphere.

LATEST NEWS & EVENTS  
HARP named SmallSat Mission of the Year

These systems impact our everyday life  
By regulating climate and making our planet more habitable

PACE's data will help us better understand how the ocean absorbs carbon dioxide. In addition, it will reveal how aerosols might fuel the growth of the ocean. Novel uses of PACE data will benefit our economy and help us identify the extent and duration of harmful algal blooms. Long-term observations of our living planet. By doing so, we can better understand our planet for decades to come.

Which Phytoplankton Are You?  
Click to find out...

Seadas

ABOUT DATA DOCS PROCESSING DOWNLOADS SUPPORT

<https://seadas.gsfc.nasa.gov>

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

@NASAOcean



<https://seadas.gsfc.nasa.gov>