The NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission:

Ushering in an era of daily, global hyperspectral satellite radiometry and polarimetry

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Living Planet Symposium, 23-27 May 2022

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

PACE will support studies of:

- ocean biology, ecology, & biogeochemistry
- atmospheric aerosols
- clouds
- land

Primary hyperspectral radiometer:

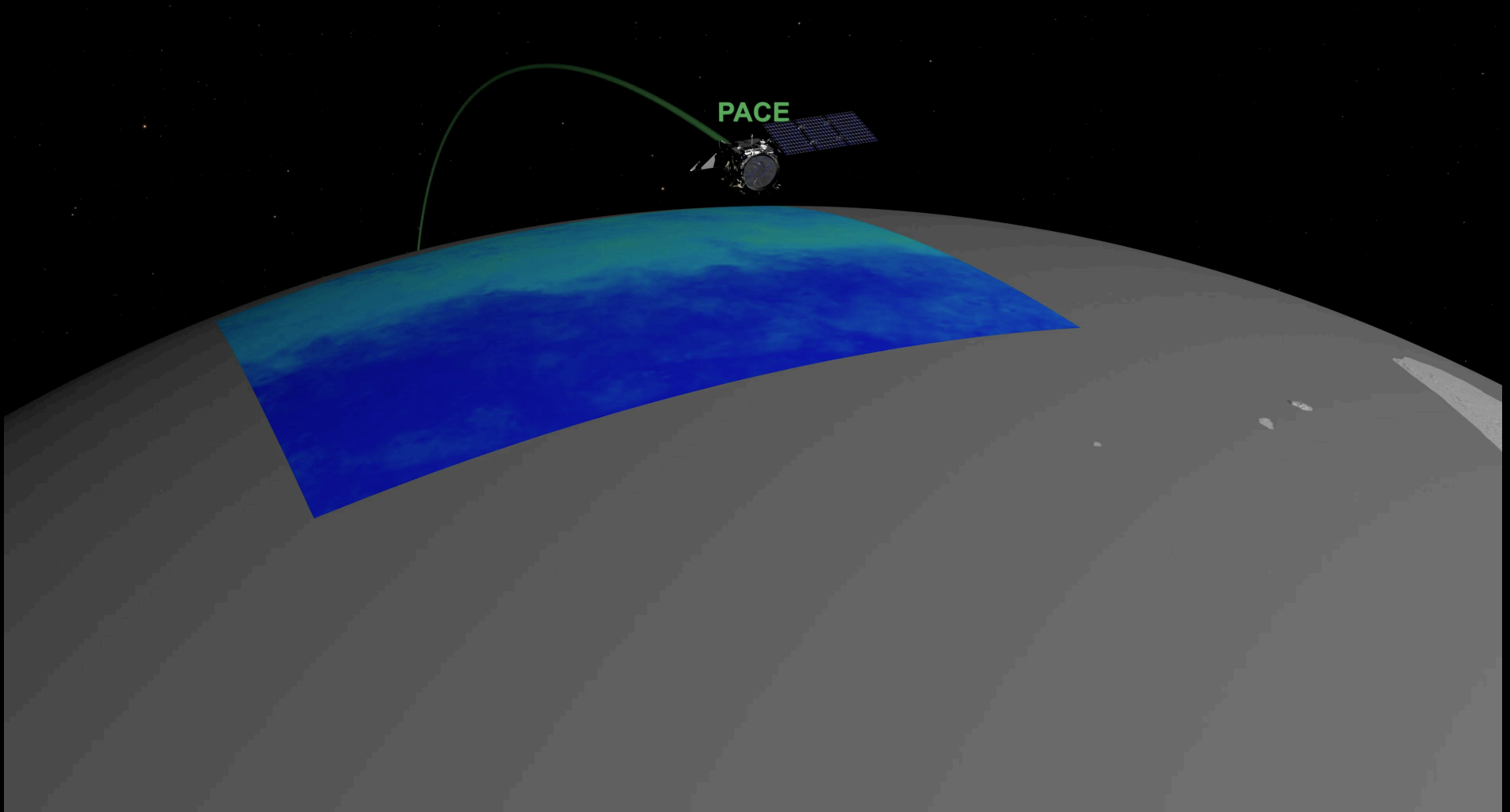
- Ocean Color Instrument (OCI) (GSFC)

2 contributed multi-angle polarimeters:

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

History:

- 2003-ish preliminary concept studies
- 2011 NASA Climate Change Initiative
- 2012 Science Definition Team
- 2014 first PACE science team
- 2015 mission directed to GSFC



Legacies:

- SeaWiFS, MODIS, VIIRS
- POLDER, MISR

Key characteristics:

- January 2024 launch
- Falcon 9 from KSC/Cape Canaveral, Florida
- 676.5 km altitude
- polar, ascending, Sun synchronous orbit; 98^{o} inclination
- 13:00 local Equatorial crossing
- 6-9 hour average data latency (24 hr max.)

Extend key systematic **ocean** biological, ecological, & biogeochemical essential climate variables records, as well as **cloud** & **aerosol** essential climate variables

Make **new global measurements of ocean color** that are essential for understanding the global carbon cycle & ocean ecosystem responses to a changing climate

Collect **global observations of aerosol & cloud properties**, focusing on reducing the largest uncertainties in climate & radiative forcing models of the Earth system

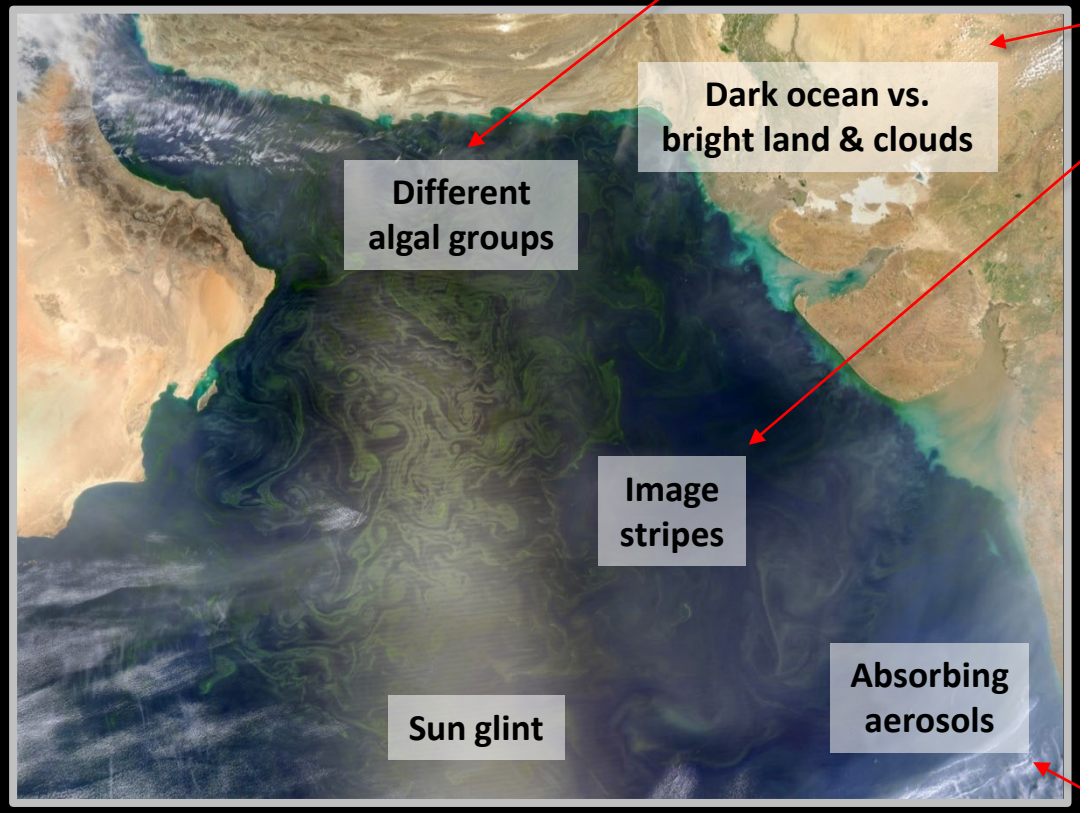
GSD of 1 ± 0.1 km^2 at nadir

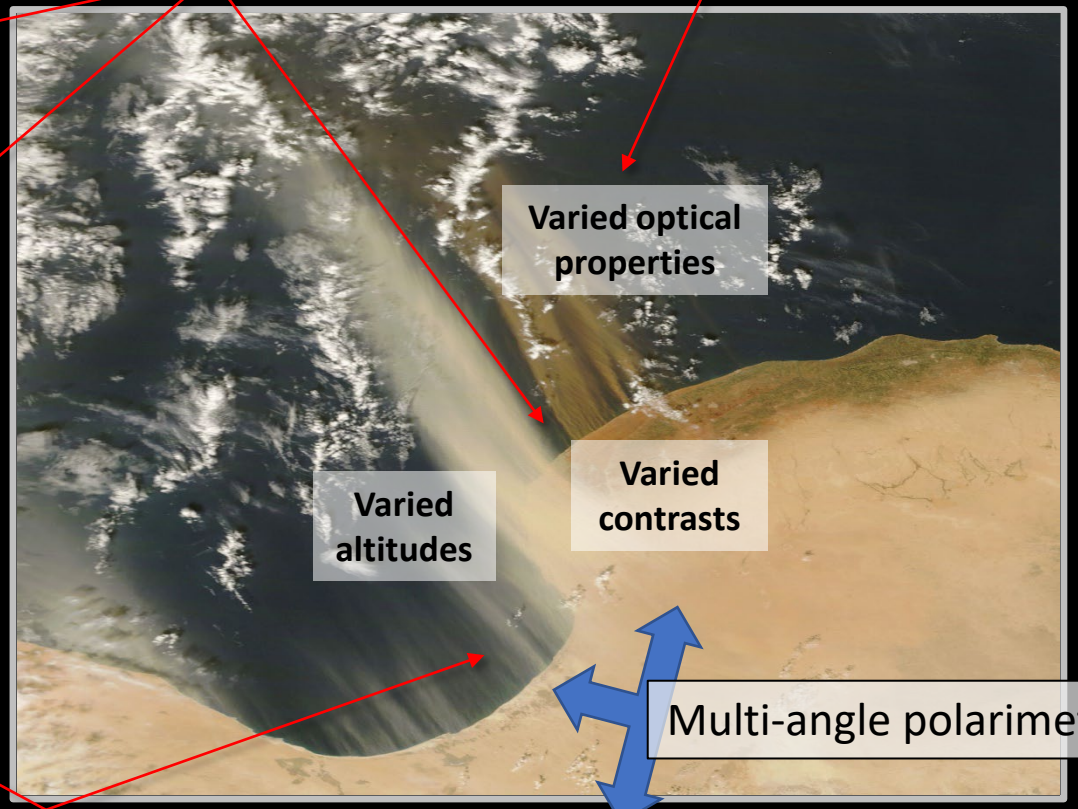
Twice-monthly lunar calibration & onboard solar calibration (daily, monthly, dim)

Spectral range from 340-890 @ 5 nm

940, 1038, 1250, 1378, 1615, 2130, 2260 nm

Instrument performance requirements



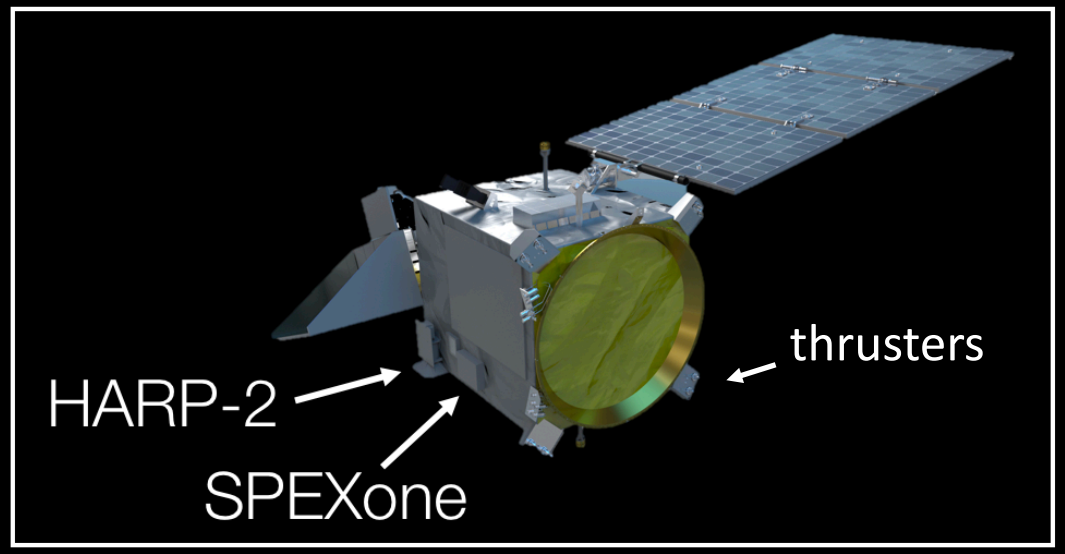


Tilt ± 20°

Spectral range goal of 320-890 @ 5 nm

Improve our understanding of how **aerosols influence ocean ecosystems & biogeochemical cycles** and how **ocean biological & photochemical processes affect the atmosphere**

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



solar array

S-band antenna

star trackers

OCI

We are here.
(Launch – 19 mos.)

OCI & Spacecraft I&T

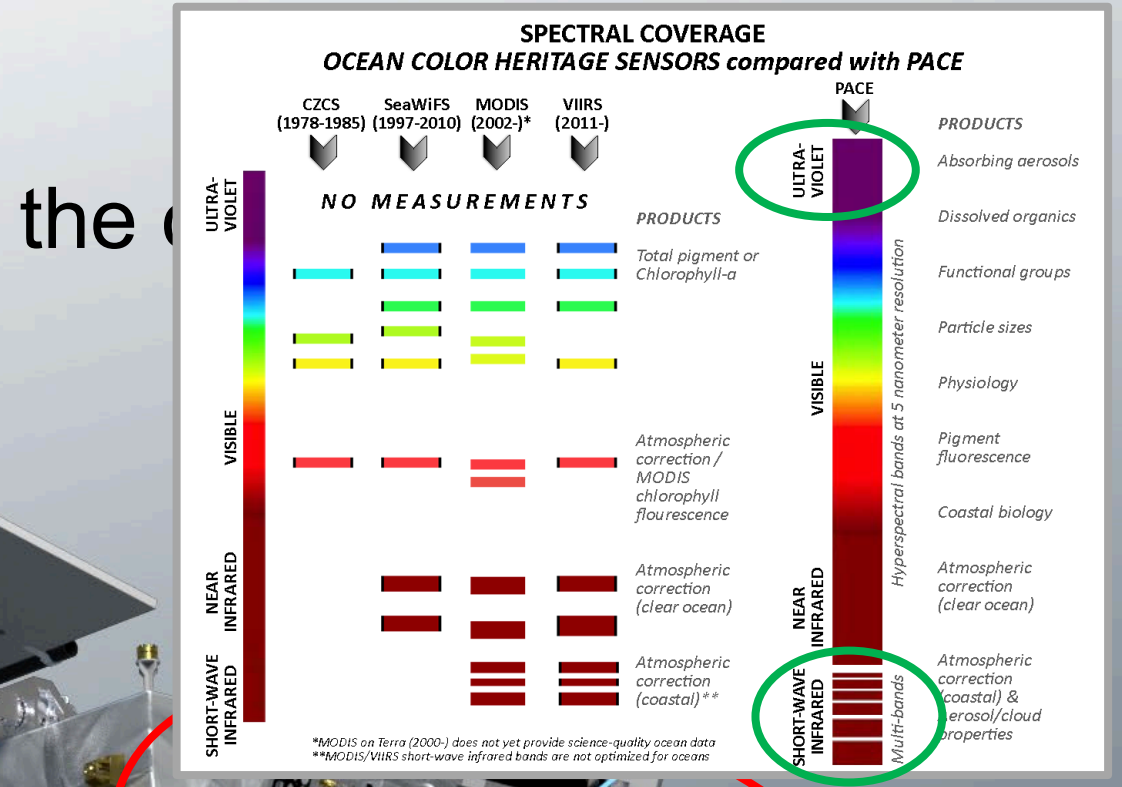
Observatory I&T

Launch Readiness Date (LRD) Jan. 9, 2024

Decommission

CY21	CY22	CY23	CY24	CY25	CY26	CY27
Phase C		Phase D	Phase E			Phase F

the



- hyperspectral scanning radiometer
- (320) 340 – 890 nm, 5 nm resolution, 2.5 nm steps+
- plus, 940, 1038, 1250, 1378, 1615, 2130, and 2250 nm
- *single science pixel to mitigate image striping*
- 1 – 2 day global coverage
- ground pixel size of 1 km^2 at nadir
- ± 20^o fore/aft tilt to avoid Sun glint
- twice monthly lunar calibration
- daily on-board solar calibration
- <0.5% total system error for VIS-NIR
- SNRs optimized for ocean color science
- simulated top-of-atmosphere data available

intent / goal is migration to advanced spectral matching and anomaly/derivative methods

+ with 1.25 nm steps in several spectral regions
* developed primarily for mechanical processing assessments

UMBC Hyper Angular Rainbow Polarimeter (HARP-2)

Update

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

	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

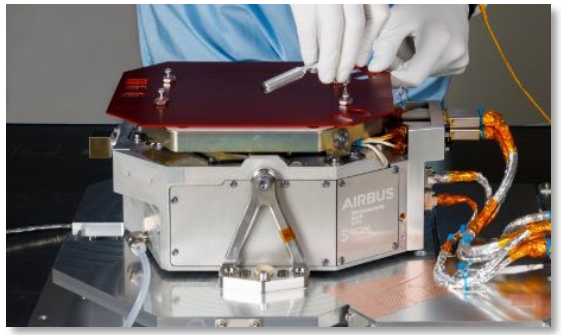
- Excellent for cloud droplet size and ice particle shape/roughness retrievals
- *Provides cloud capabilities beyond those required of OCI*
- *Wide swath matches OCI, offering potentially improved atmos. correction*

- 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)

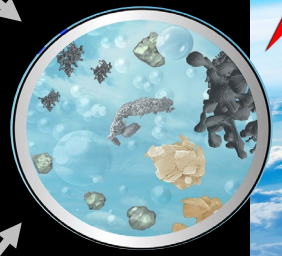


Update

- SPEXone flight unit delivered to GSFC, with midpoint testing complete
- 16 orbits of simulated data available online

planned data products (1)

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

planned data products (2)

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

science community engagement

Current Science & Applications Team (SAT#2) intact through mid-2023
Next team (SAT#3) expected to be competed via NASA ROSES-23

PACE Validation Science Team (PVST) to be assembled ~6 months prior to launch (as of today, this would be ~mid-2023) via late ROSES-22 amendment

- Preliminary focus on validation of threshold products (ocean color radiometry, AOT, clouds)
- Evolution into validation of derived/advanced products, including polarimetry, & closure experiments
- Separate but complementary PACE Post-launch Airborne eXperiment (PACE-PAX)
- International partnerships & synergies welcome!

Two System Vicarious Calibration teams in the middle of their second year

- Third year funded; down-select to one still possible

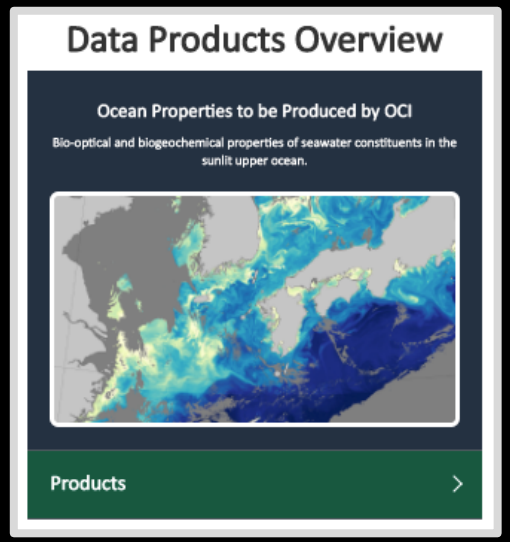
Applications Program, Early Adopters, & Community of Practice

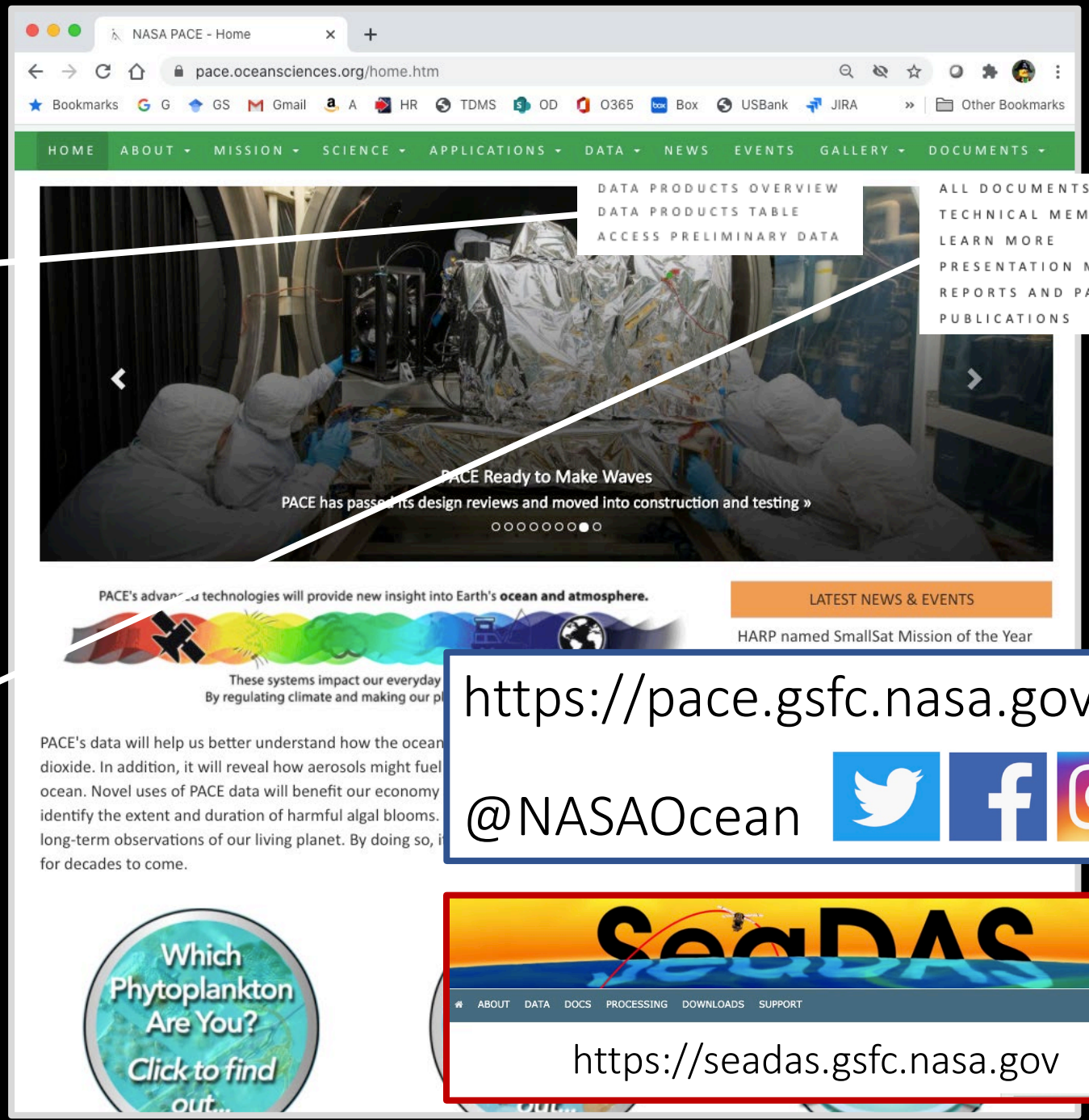
- Join and get involved @ https://pace.oceansciences.org/applications.htm !

resources & useful info

data product descriptions + access to simulated data & characterizations

PACE technical memos & other documents





https://pace.gsfc.nasa.gov

@NASAOcean

Thanks to my co-authors and colleagues: Antonio Mannino
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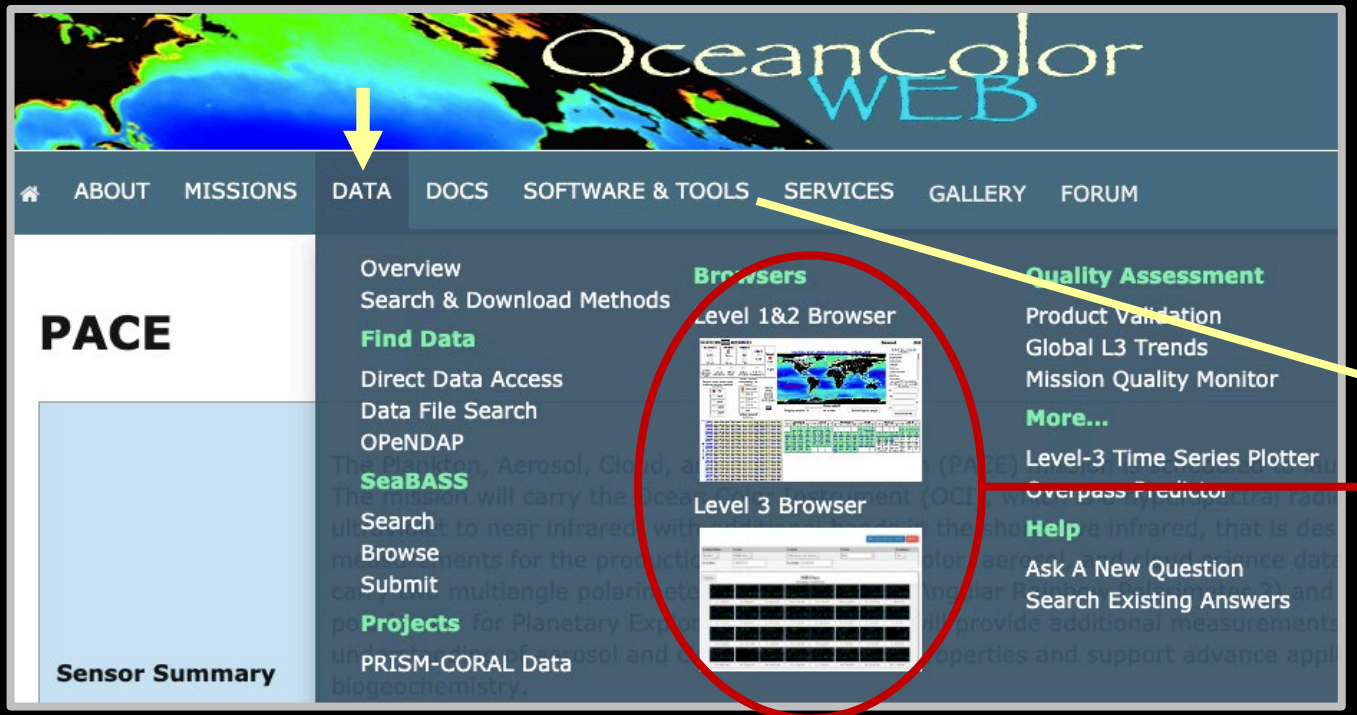
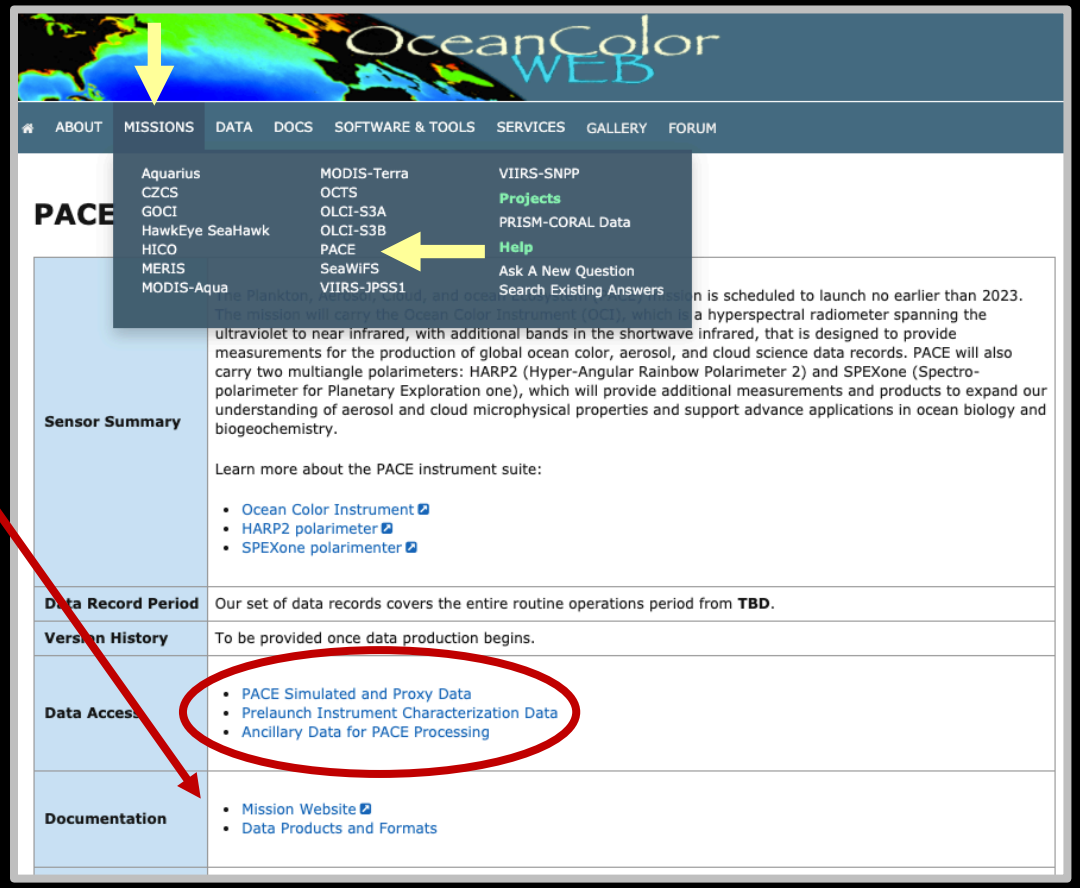
Lorraine Remer
Laura Lorenzoni

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 - https://public.ccsds.org/Pubs/133x0b2.pdf)	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





https://seadas.gsfc.nasa.gov