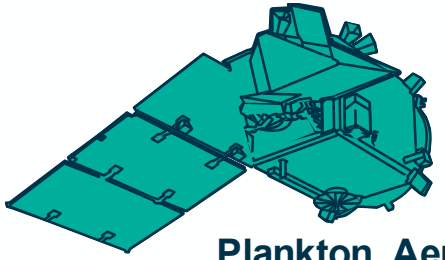
Status and data availability of the NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission and the PACE Postlaunch Airborne Experiment (PACE-PAX)

Kirk Knobelspiesse, NASA Goddard Space Flight Center, Greenbelt, MD, USA and the PACE and PACE-PAX teams

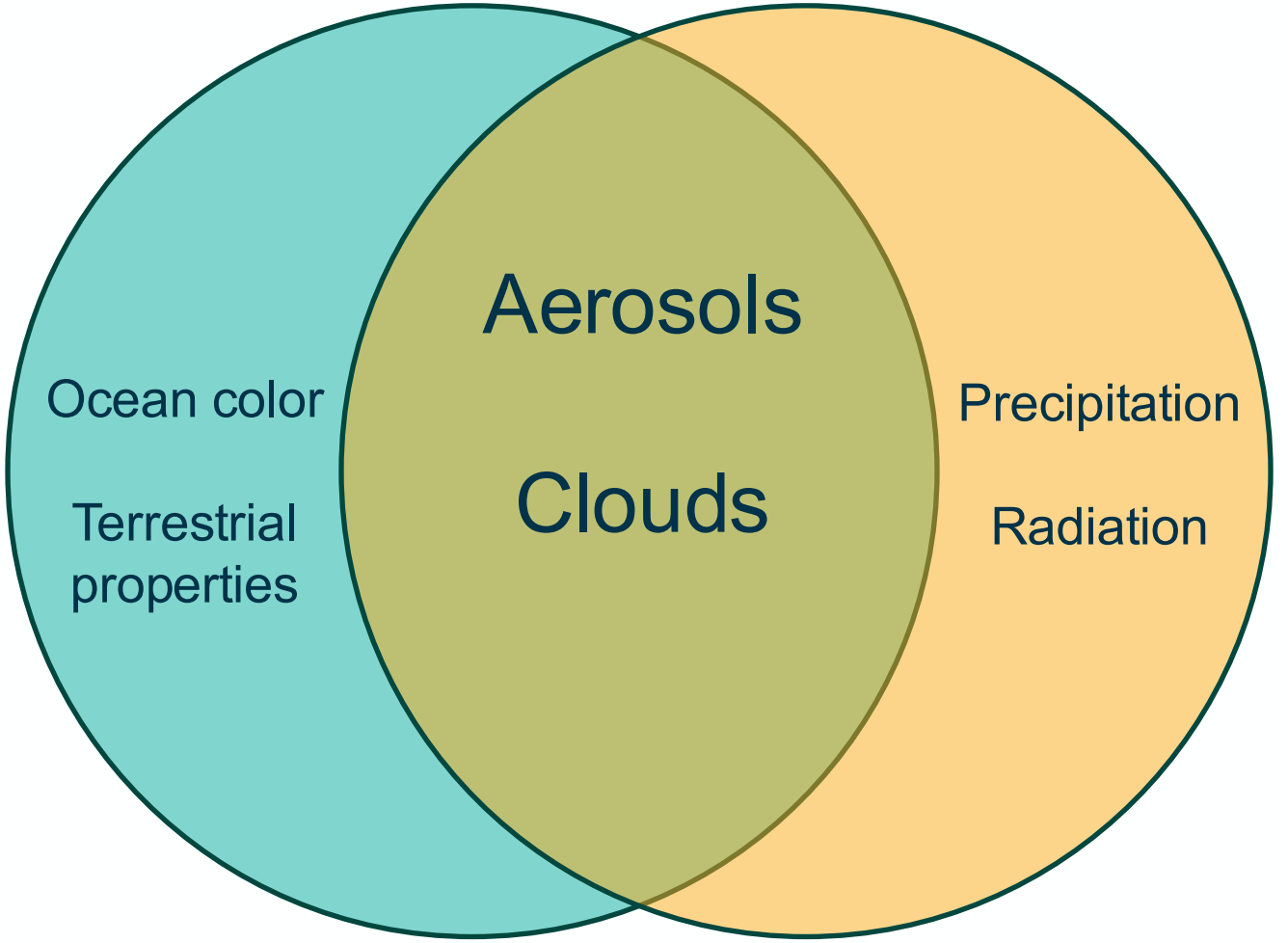
Or: PACE and EarthCARE as Venn diagrams

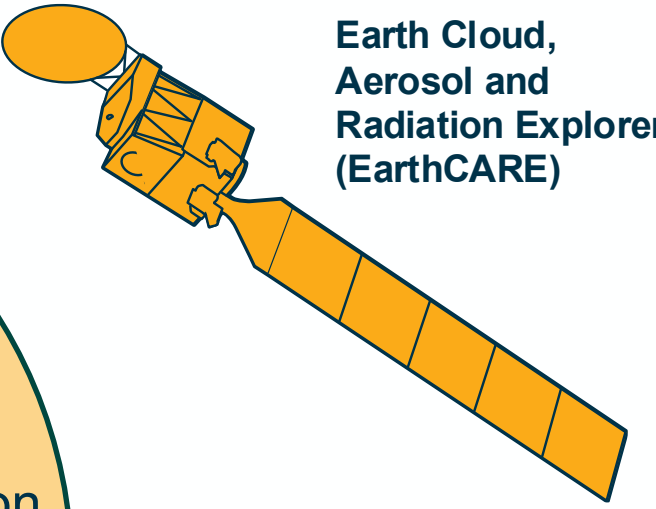


Plankton, Aerosol, Cloud, ocean Ecosystem Mission (PACE)

pace.gsfc.nasa.gov

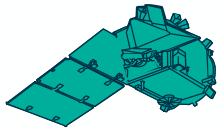
Science objectives



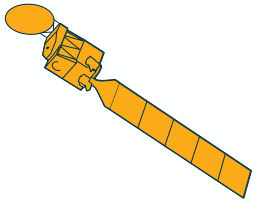


Earth Cloud, Aerosol and Radiation Explorer (EarthCARE)

PACE and EarthCARE have different instruments



Science instruments



Ocean Color Instrument (OCI)*

Spectro-Polarimeter for Planetary Exploration one (SPEXone)

Hyper-Angular Rainbow Polarimeter 2 (HARP2)

*primary instrument

Atmospheric LIDar (ATLID)

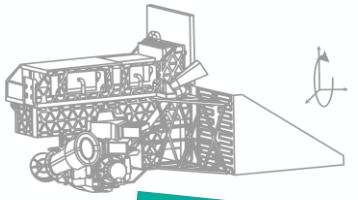
Cloud Profiling Radar (CPR)

Multi-Spectral Imager (MSI)

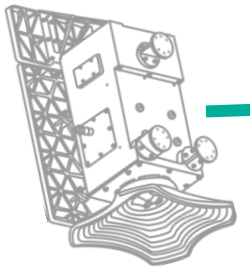
Broad-Band Radiometer (BBR)

PACE instruments

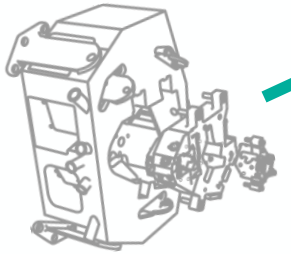
OCI
340-890 nm in 2.5 nm steps, 7 discrete SWIR: 940-2260 nm
1-2 day coverage; ±20° tilt; 1.2km
NASA Goddard Space Flight Center
Primary instrument is a wide swath imaging spectrometer with high accuracy

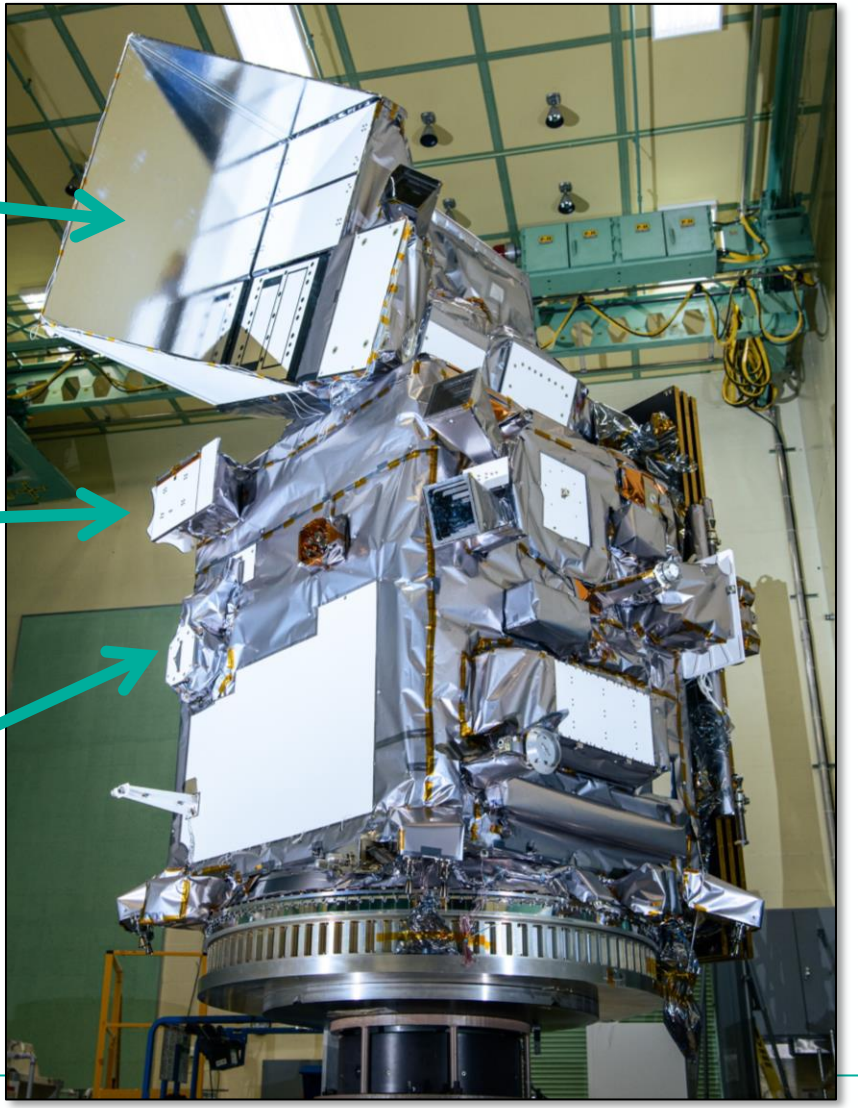


HARP2
440, 550, 670, 870 nm, 10-60 viewing angles
wide swath polarimeter; 3 km resolution, gridded to 5.2km
University of Maryland Baltimore County
Contributed wide swath imaging polarimeter



SPEXone
380-770 nm in 2-4 nm steps, 5 viewing angles
narrow swath polarimeter; 2.5 km, gridded to 5.2km
SRON, Airbus NL
Contributed narrow swath imaging spectrometer





PACE instruments

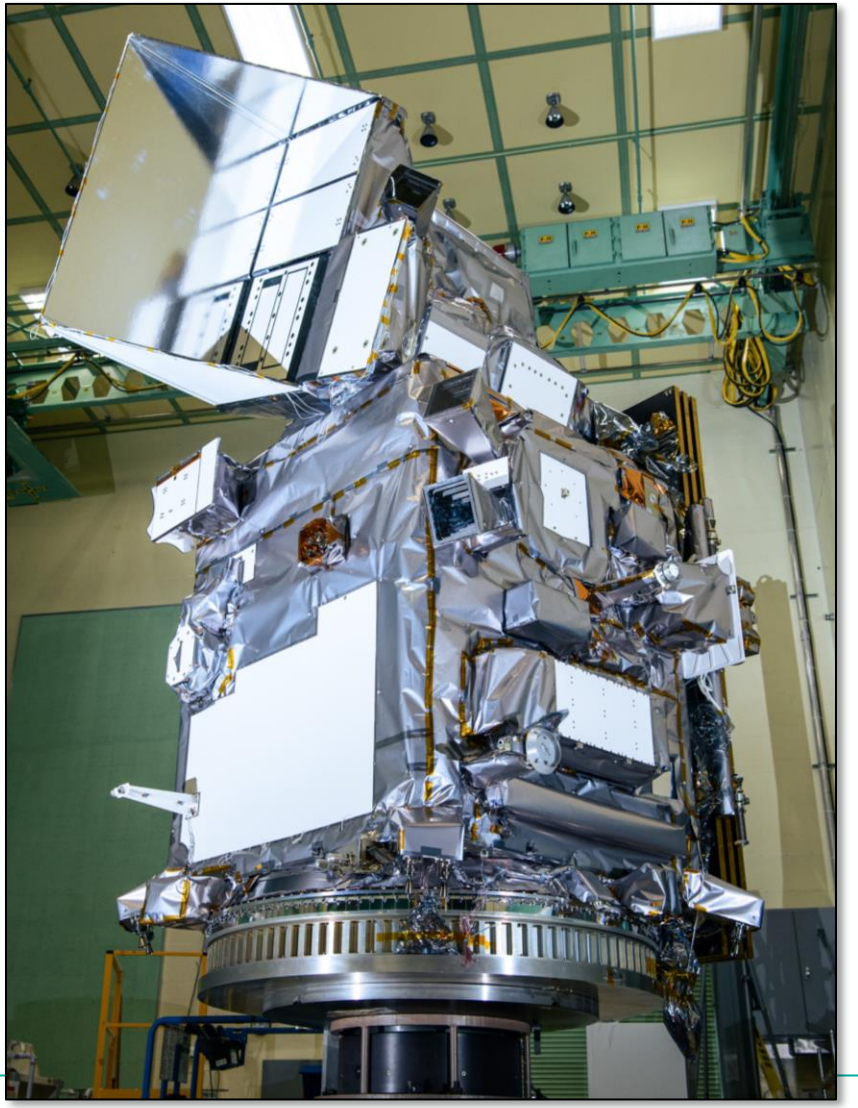
Mission Status

Phase E (prime mission operations) through mid-Apr 2027
PACE expects to be considered for mission extension (2027-2029; TBC).
Lifetime fuel ~10 years

All instruments and the spacecraft are operating nominally
processes to address, quickly recover from, or permanently mitigate all anomalies have been established/executed

Required (heritage) products available; advanced* are available and emerging
* OCI phytoplankton community composition, land, coastal + inland aquatic, others
* All polarimetric geophysical datasets

Recent reprocessing oceancolor.gsfc.nasa.gov/data/reprocessing
* OCI version 3.2
* HARP2, SPEXone, version 4.0



PACE atmosphere product suites

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

OCI

- **Trace Gases** [TRGAS]: Column NO_2, Ozone
- **Cloud mask** [CLOUD_MASK]
- **OCI Clouds** [CLOUD]: Cloud top pressure/height, COD, Column water path, Ice fraction, Droplet effective radius
- **UV Aerosol Index** [UVAI_UAA]
- **Unified Aerosol Algorithm** [AER_UAA]: AOD, AOD_{fine}, Aerosol layer height, SSA

HARP2

- **Polarimetric Clouds** [CLOUD_GPC]: Droplet effective radius, Droplet effective variance, Cloud liquid water path, Cloud droplet number concentration, Cloud liquid index

SPEXone

- **FastMAPOL** [MAPOL_OCEAN]: AOD, SSA, Aerosol size/shape/refractive index, Aerosol height, ocean properties *ocean only*
- **RemoTAP** [AER_RTAPLAND, AER_RTAPOCEAN]: AOD, SSA, Aerosol size/shape/refractive index, Aerosol height, ocean/land reflectance/BRDF

Nadir resolution 1.2x1.2km

7x7 grid: nadir 8.4x8.4km resolution

Swath based common Level 1C grid 5.2x5.2km

PACE atmosphere product suites

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

- **Trace Gases** [TRGAS]: Column NO_2, Ozone
- **Cloud mask** [CLOUD_MASK]

Nadir resolution

OCI

HARP2

SPEXone

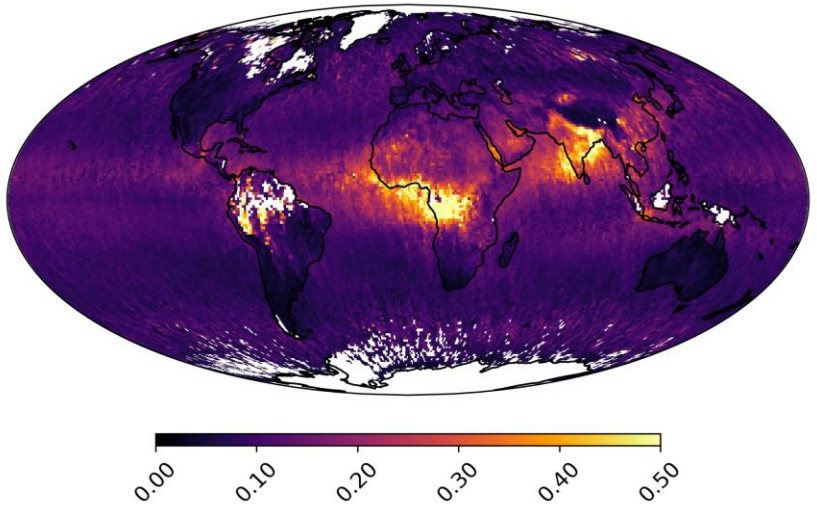
- **RemoTAP** [AER_RTAPLAND, AER_RTAPOCEAN]: AOD, SSA, Aerosol size/shape/refractive index, Aerosol height, ocean/land reflectance/BRDF

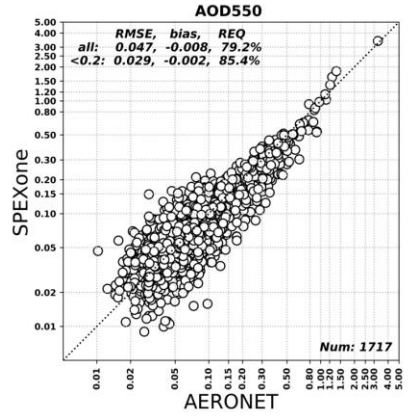
Product suites in development

- **MAIAC**: Aerosol, surface properties (**OCI**)
- **AtmoNR**: volumetric 3D cloud reconstruction (**HARP2**)
- **GRASP**: aerosol, surface properties (**HARP2**)
- **FastMAPOL Coastal**: aerosol by component, detailed ocean properties (**HARP2**)
- **FastMAPOL Land**: aerosol, land BRDF, BPDF (**HARP2**)
- **MAPP**: 3 sensor synergy aerosol, ocean products (**OCI + HARP2 + SPEXone**)

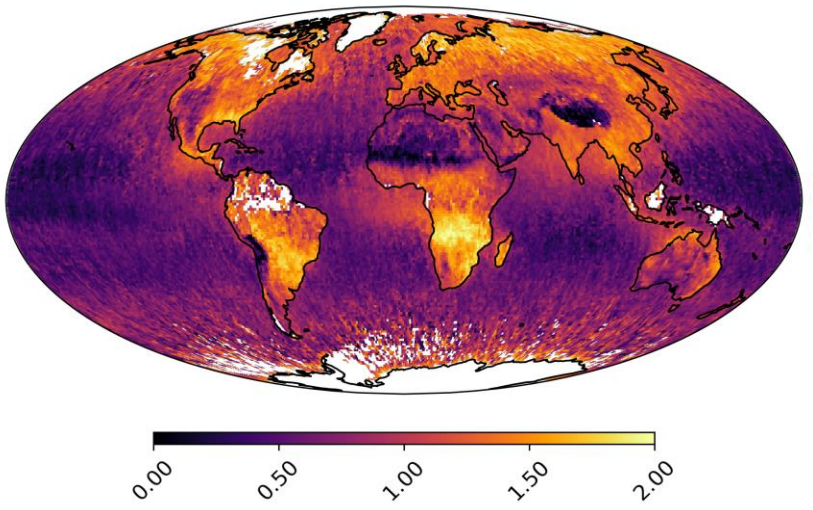
2 years of SPEXone RemoTAP data

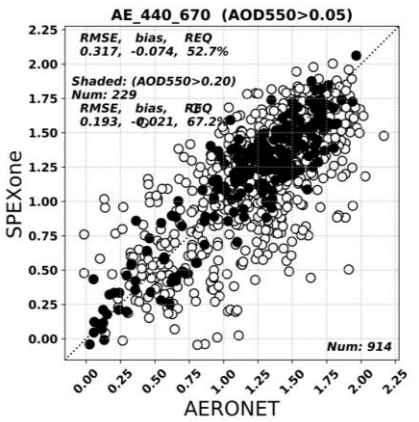
Aerosol Optical Depth



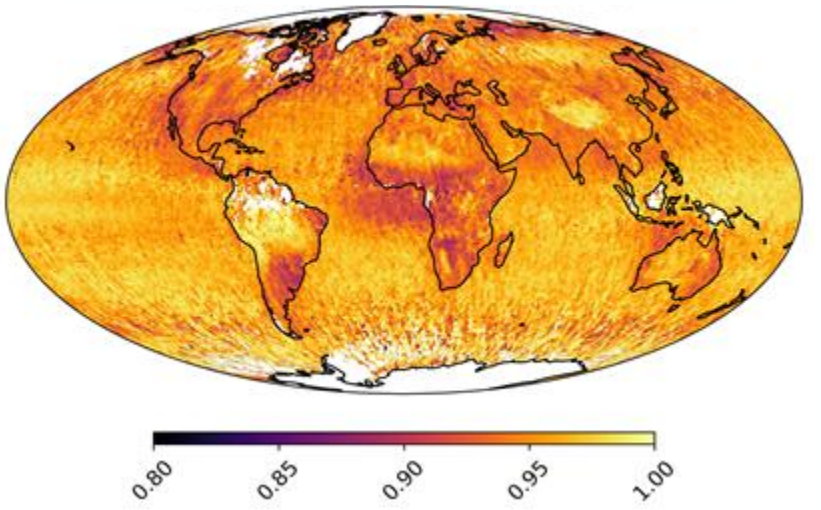


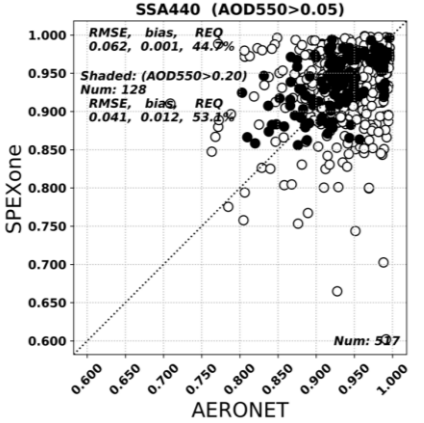
Ångström exponent





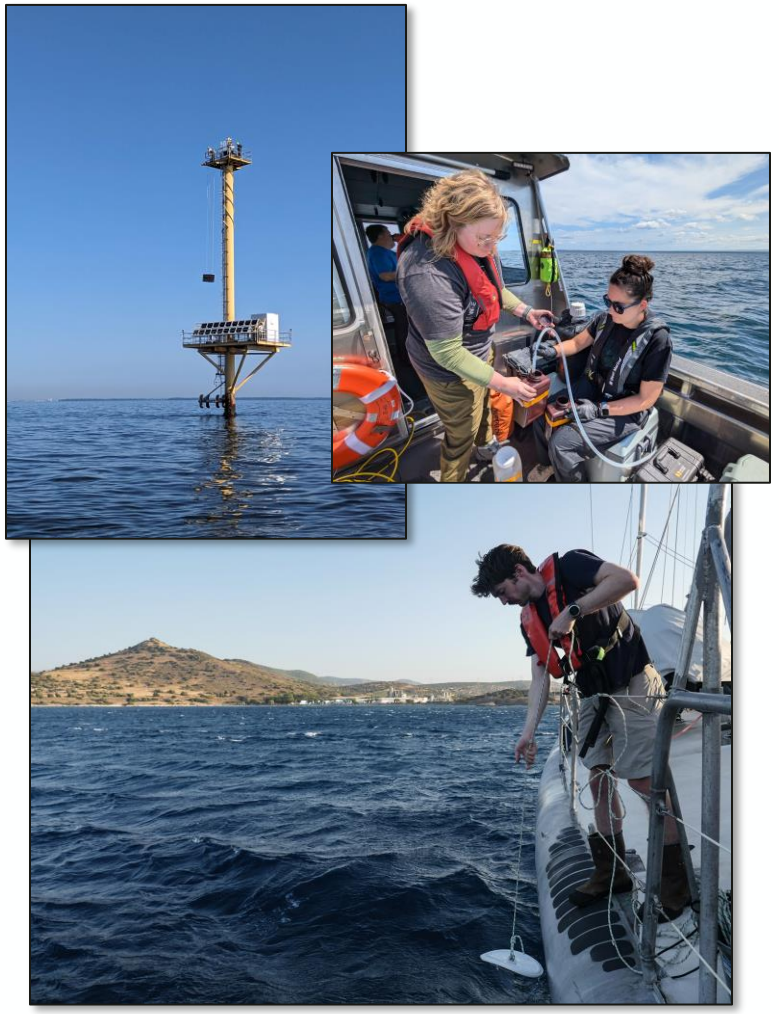
Single Scattering Albedo





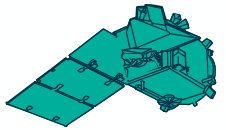
Fu, G., et al: Aerosol Retrievals From SPEXone on the NASA PACE Mission: First Results and Validation, Geophysical Research Letters, 52(4), e2024GL113525, https://doi.org/10.1029/2024GL113525, 2025.

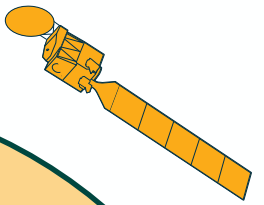
PACE & EarthCARE validation



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

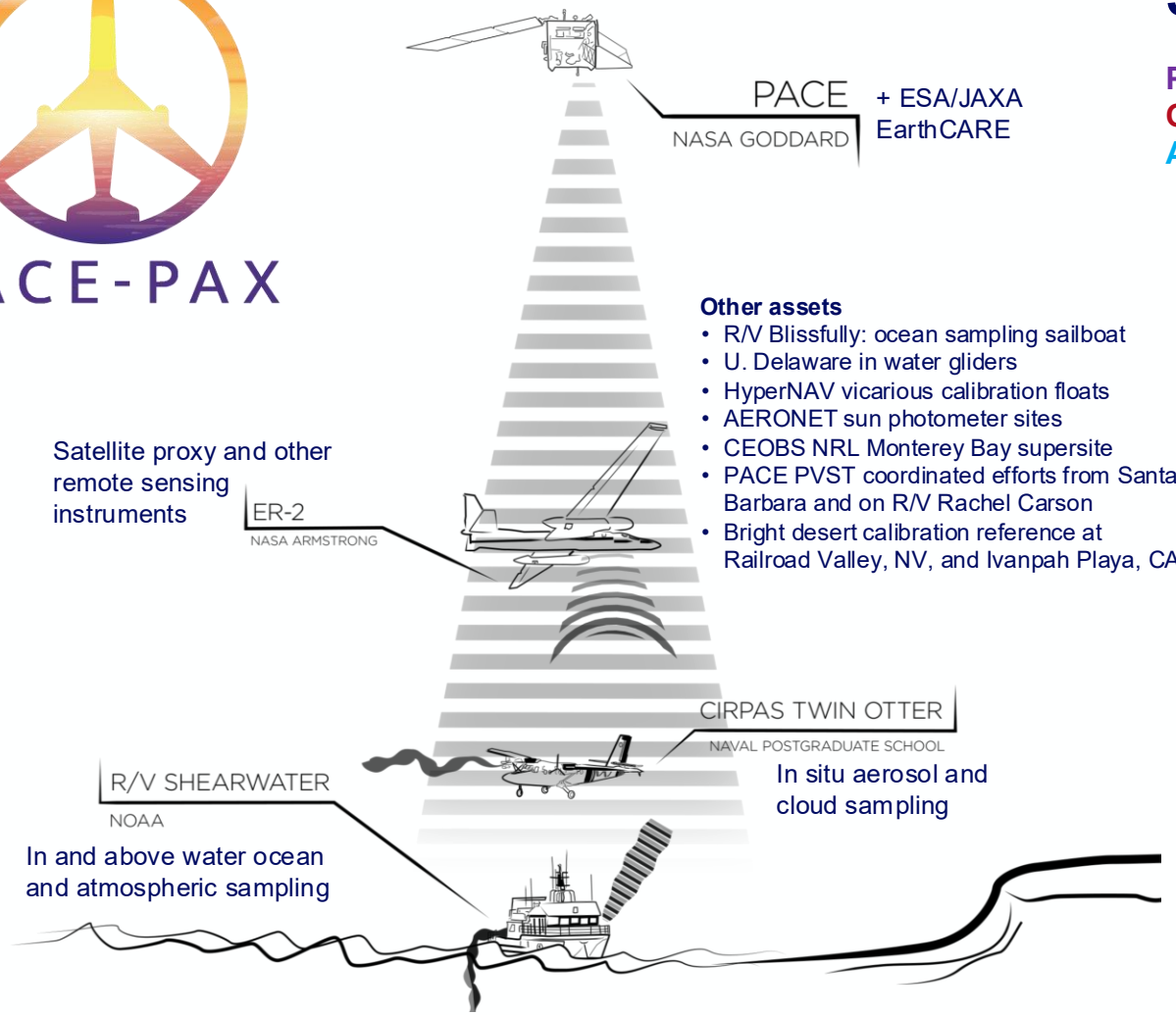
Validation activities





PACE Postlaunch Airborne eXperiment (PACE-PAX)

PACE-PAX



September 3-30th, 2024, California and vicinity

PACE-PAX website: https://pace.oceansciences.org/pace-pax.htm
Ocean archive (SeaBASS) DOI: 10.5067/SeaBASS/PACE-PAX/DATA001
Atmosphere archive (ASDC): DOI: 10.5067/SUBORBITAL/PACE-PAX/DATA001

Highlights

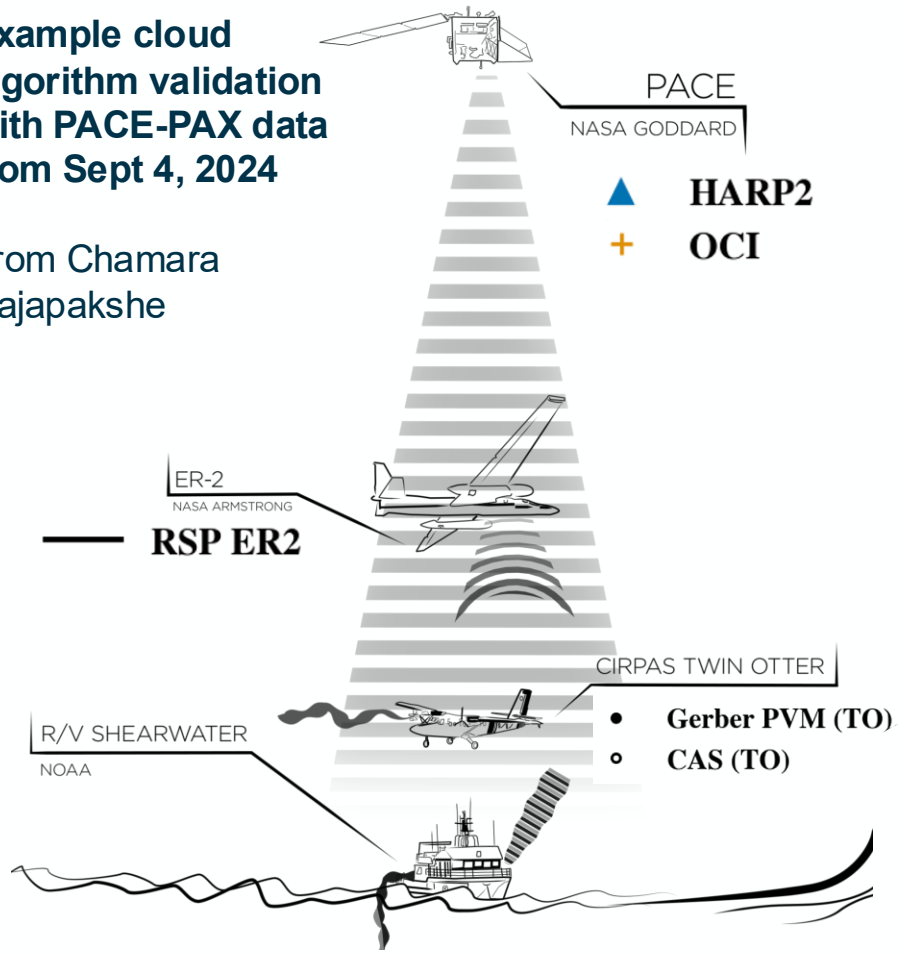
- 13 NASA ER-2 science flights, 80.9 flight hours
- 17 NPS/CIRPAS Twin Otter flights, 60 flight hours
- 15 day trips of the R/V Shearwater
- 9 day trips of the R/V Blissfully
- 16 days of observations during a PACE overpass
- 6 days of observations during an EarthCARE overpass
- Ground vicarious calibration at Ivanpah Playa, CA, overflights of Railroad Valley, NV
- Many overflights of AERONET, NEON, CEOBS ground sites
- Wildfires in Southern California, Red tides, and other events

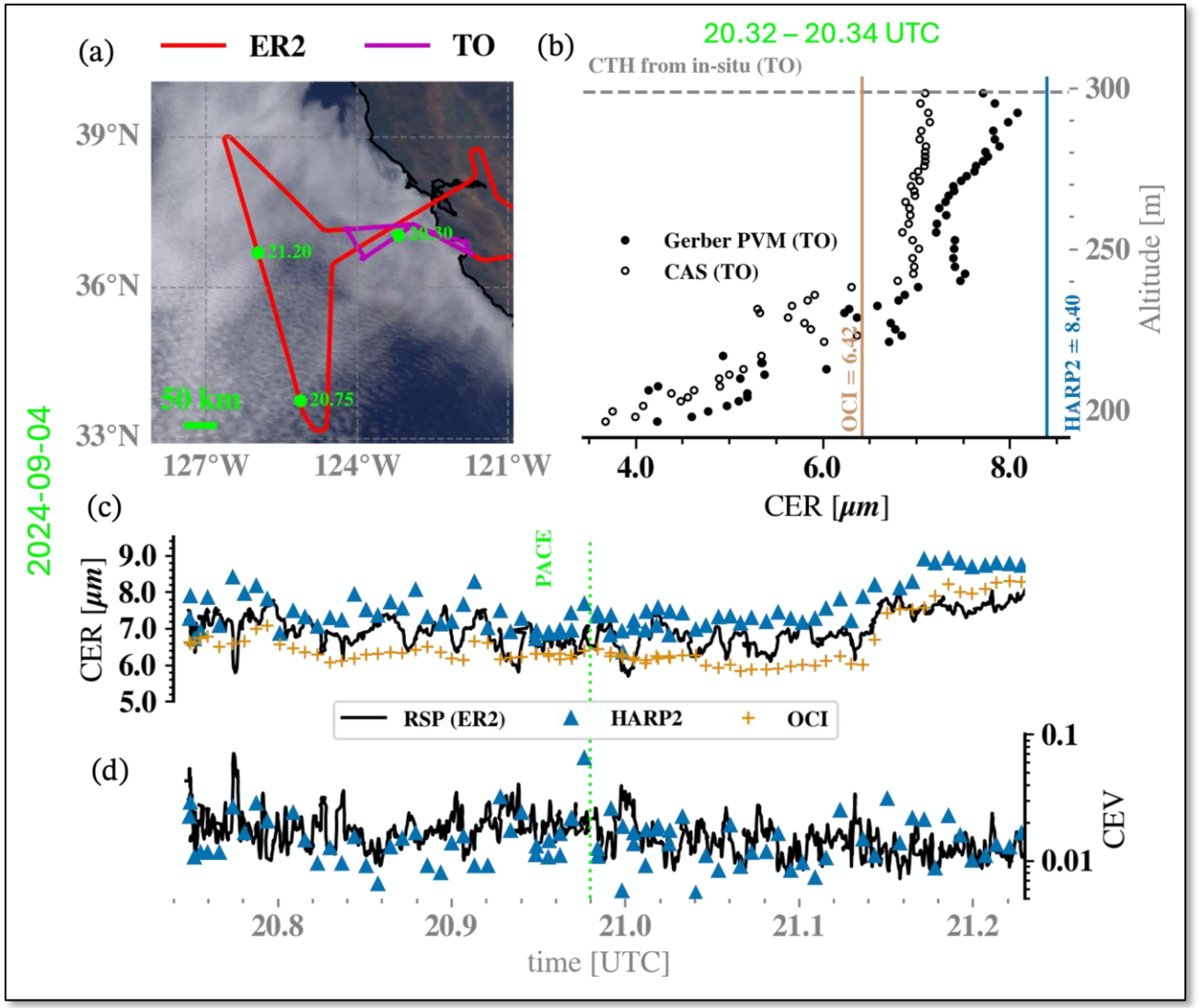
HSRL-2 lidar on ER-2 useful for ATLID validation

PACE Postlaunch Airborne eXperiment (PACE-PAX)

Example cloud algorithm validation with PACE-PAX data from Sept 4, 2024

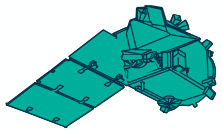
From Chamara Rajapakshe

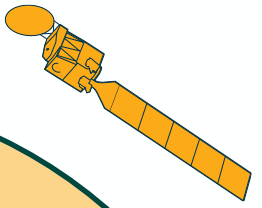




PACE & EarthCARE have different orbits

Orbit characteristics





Daytime ascending

13:00 local equator crossing

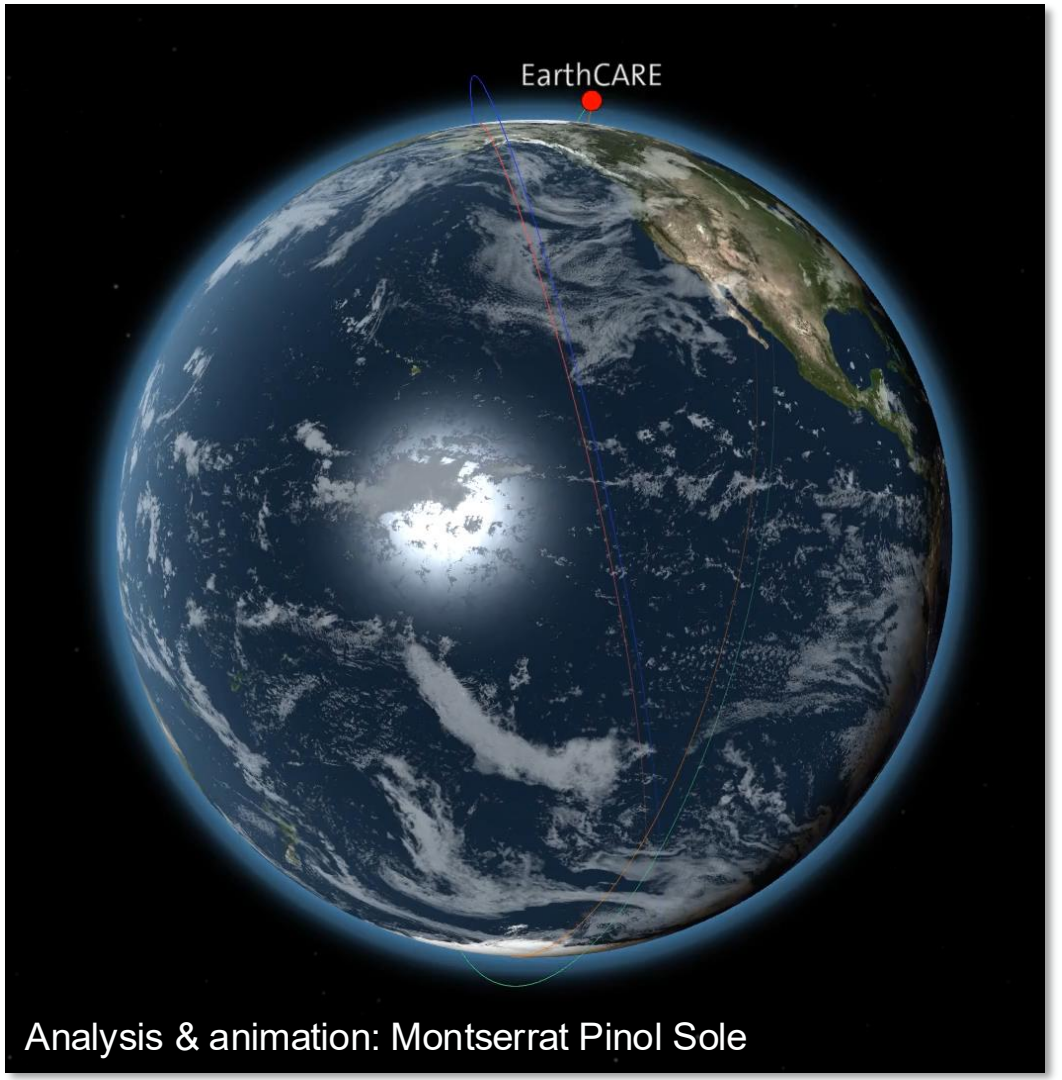
676km altitude

Orbit track crosses daily at ~ 45˚S

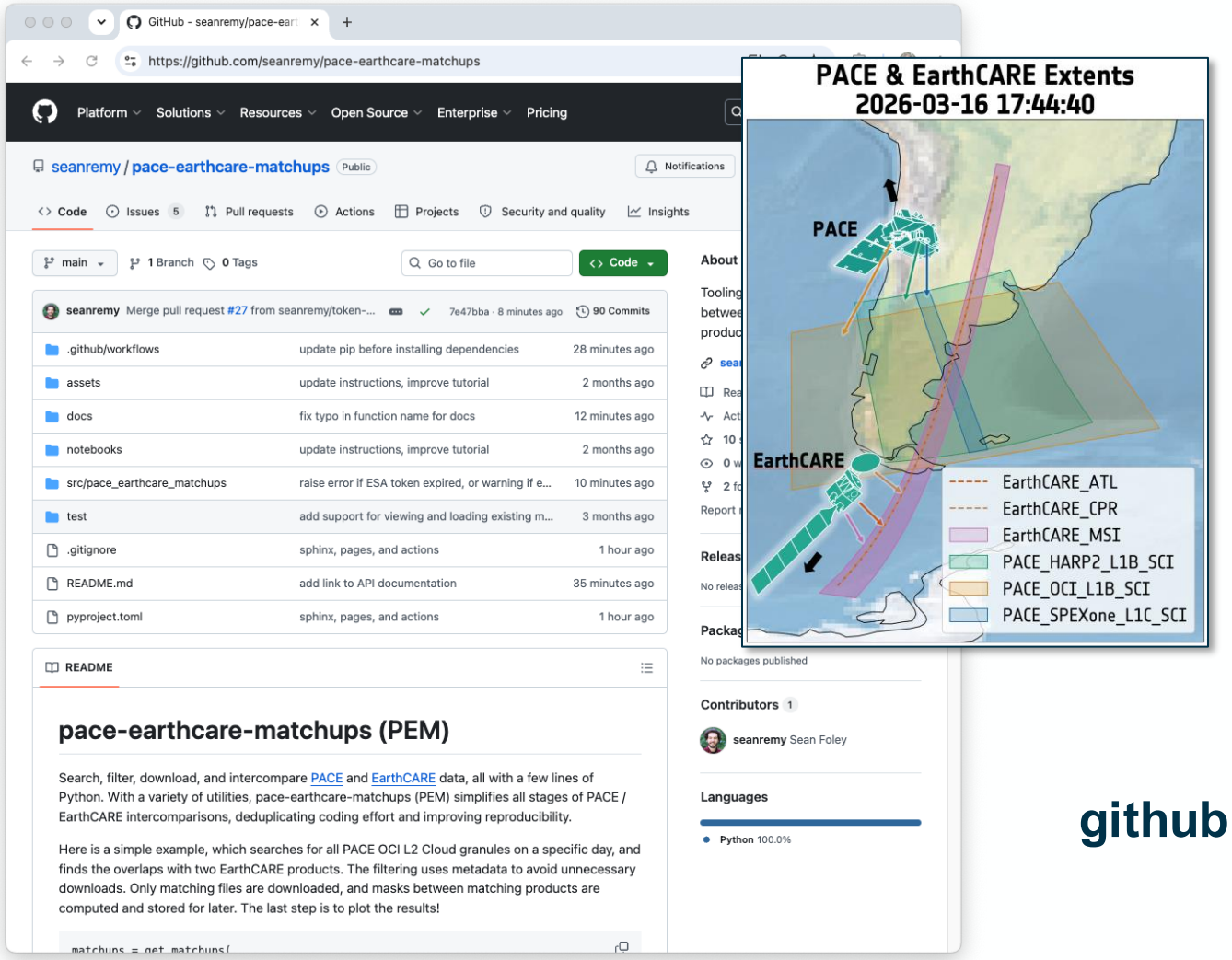
Daytime descending

14:00 local equator crossing

393km altitude



pace-earthcare-matchups (PEM)



pace-earthcare-matchups (PEM) is a python library to search, filter, download and intercompare coincident PACE and EarthCARE data

- PACE data via either NASA MAAP or Earthaccess
- EarthCARE data accessible through ESA MAAP

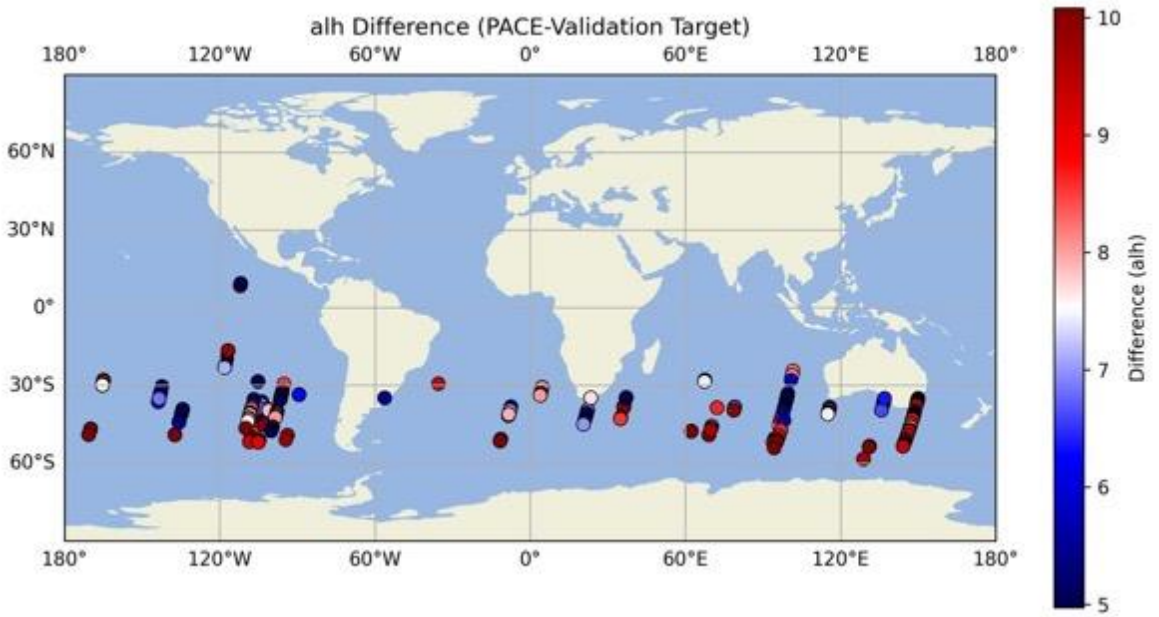
See poster P039 (day 1/3), Sean Foley
"PACE / EarthCARE Matchups (PEM): An intercomparison library in Python for the NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) and EarthCARE missions"

github.com/seanremy/pace-earthcare-matchups

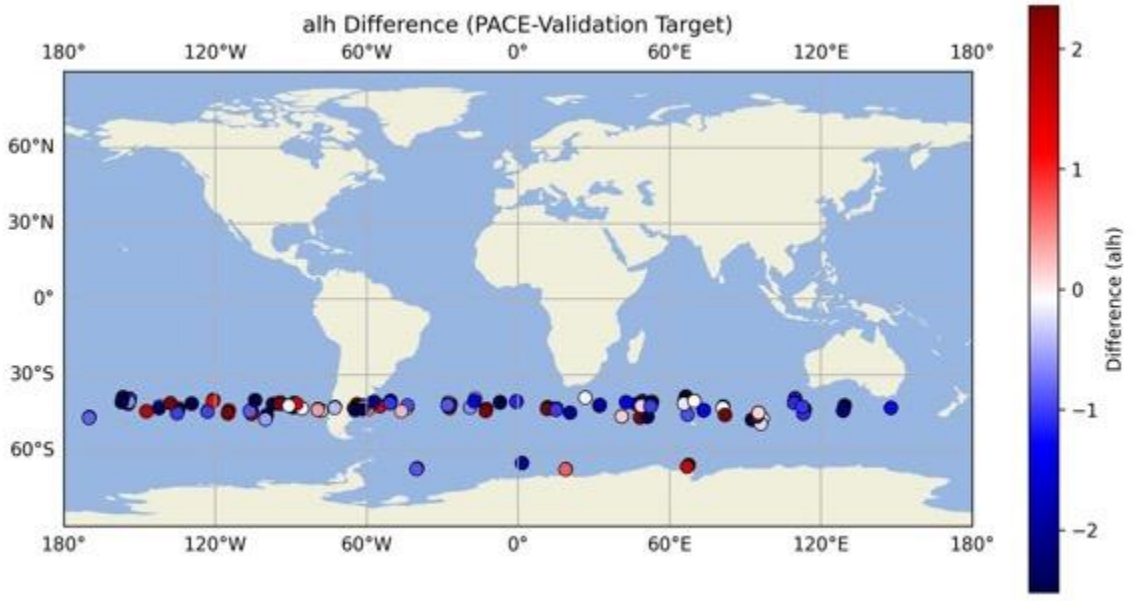
pace-earthcare-matchups (PEM)

PEM example: PACE FastMAPOL Aerosol layer height (ALH) validation with respect to EarthCARE/ATLID

PACE/HARP2 FastMAPOL ALH



PACE/SPEXone FastMAPOL ALH

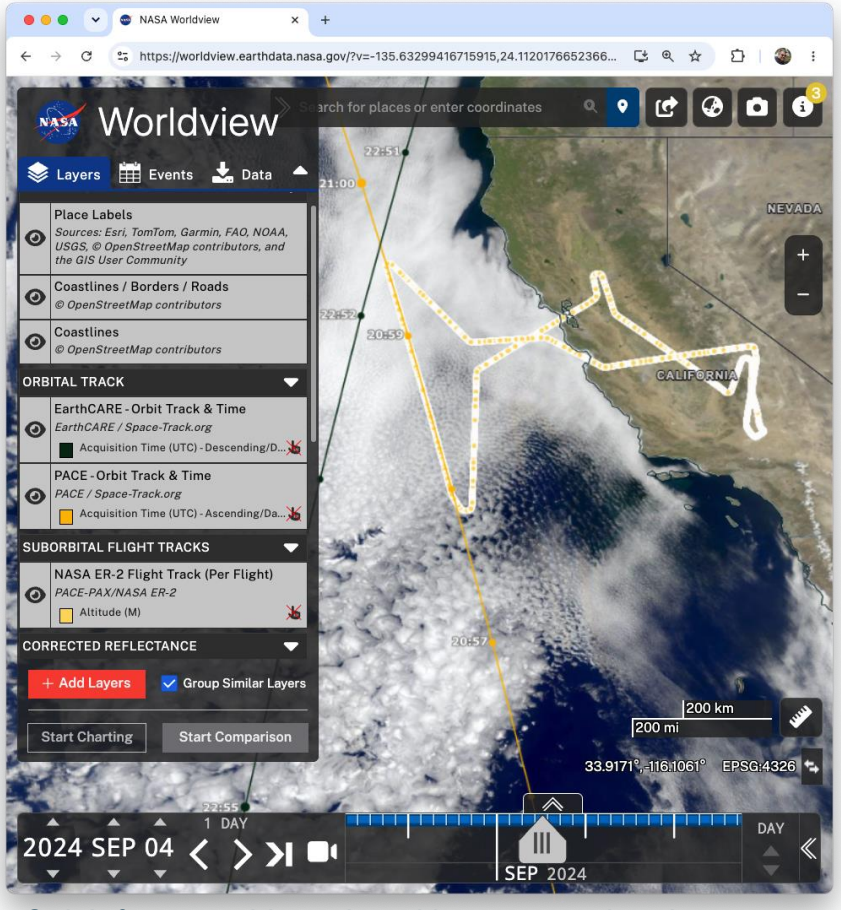


From Meng Gao

PACE (NASA Earth Science) data access

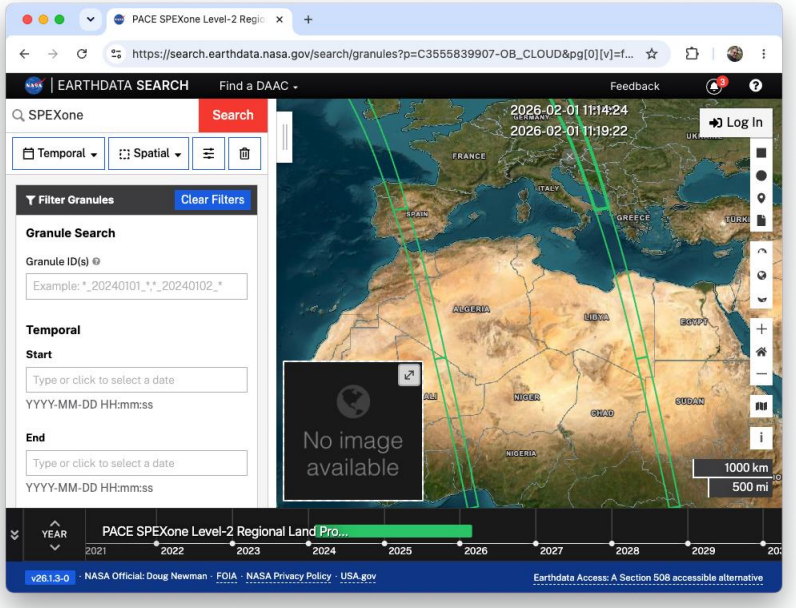
In addition to PEM, one can use:

worldview.earthdata.nasa.gov

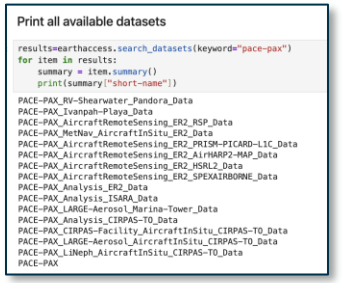


Quick & easy orbit track and imagery exploration
This realization: https://go.nasa.gov/4ufX3fG

search.earthdata.nasa.gov

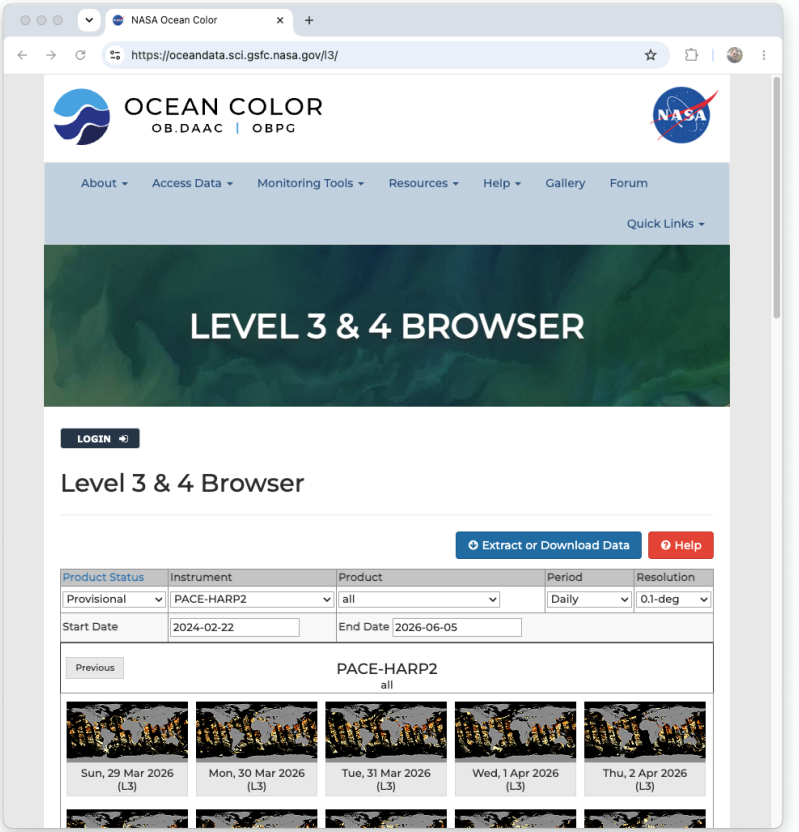


earthaccess.readthedocs.io

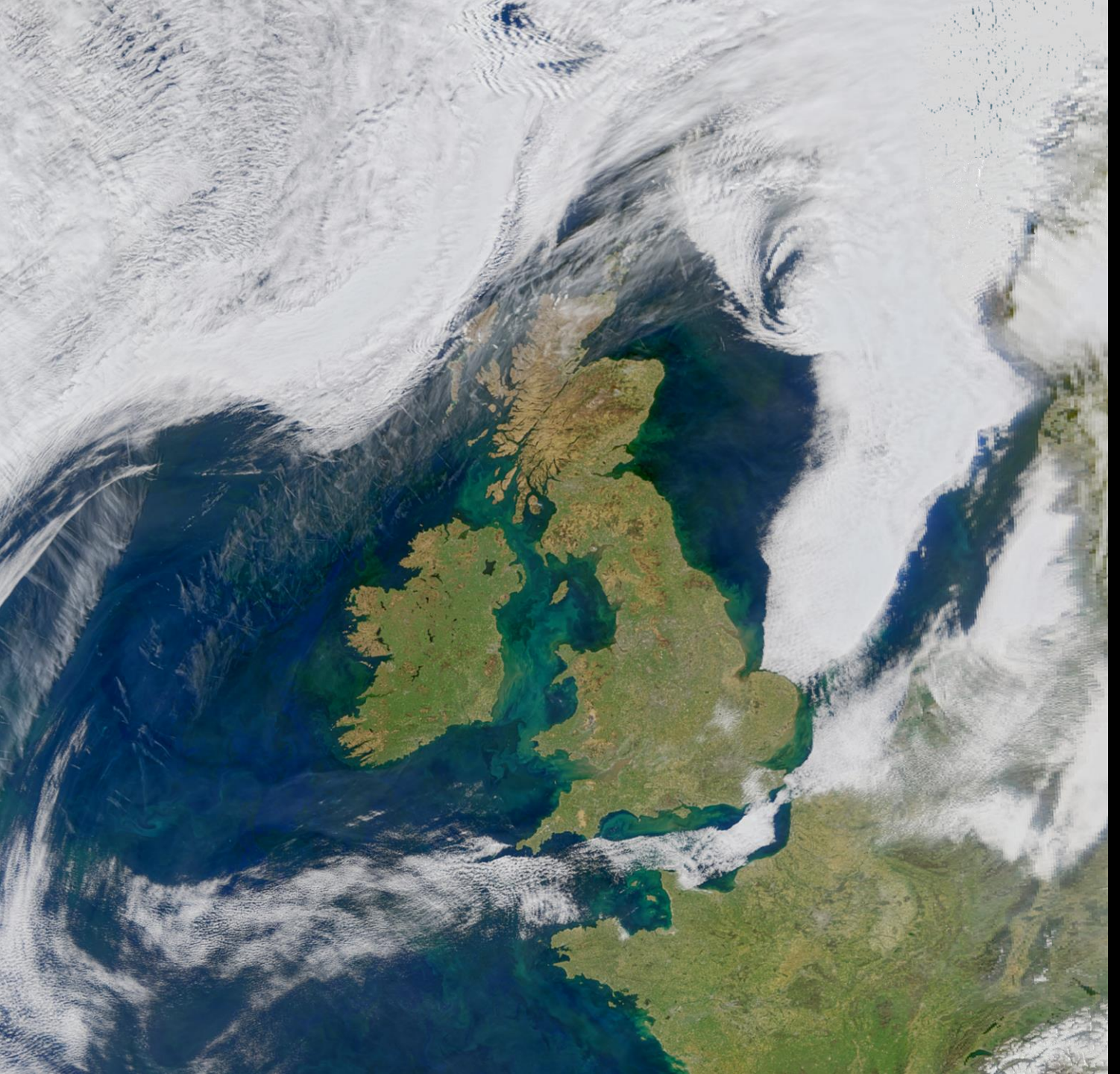


Python library for data access

Level 3 & 4 browser
oceandata.sci.gsfc.nasa.gov/l3/



Includes test products, not cloud based



Thank you!

For emailed updates, news, trainings, and more, join the PACE Community of Practice

pace-community-join@lists.nasa.gov
(subject “subscribe”)

pace.gsfc.nasa.gov

Help Hub: nasa.github.io/oceandata-notebooks

Other links in this talk:

PACE data table pace.oceansciences.org/data_table.htm
PACE reprocessin oceancolor.gsfc.nasa.gov/data/reprocessing
PACE-PAX website pace.oceansciences.org/pace-pax.htm
PACE-PAX ocean DOI 10.5067/SeaBASS/PACE-PAX/DATA001
PACE-PAX atm. DOI 10.5067/SUBORBITAL/PACE-PAX/DATA001
PEM github.com/seanremy/pace-earthcare-matchups
Worldview worldview.earthdata.nasa.gov
Earthdata Search search.earthdata.nasa.gov
Earthaccess earthaccess.readthedocs.io
PACE Level 3&4 browser oceandata.sci.gsfc.nasa.gov/l3/

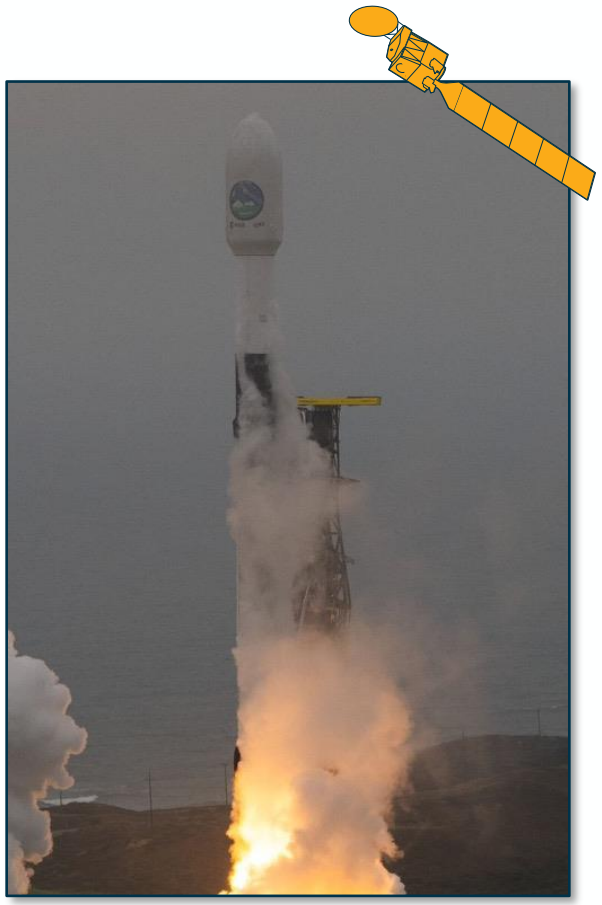
Image at left: PACE OCI, April 10, 2025
https://oceandata.sci.gsfc.nasa.gov/gallery/811

PACE & EarthCARE shared a vehicle to space

8 February 2024
Cape Canaveral, Florida

Launch vehicle

SpaceX Falcon 9
Block 5
B1081



28 May 2024
Vandenberg, California

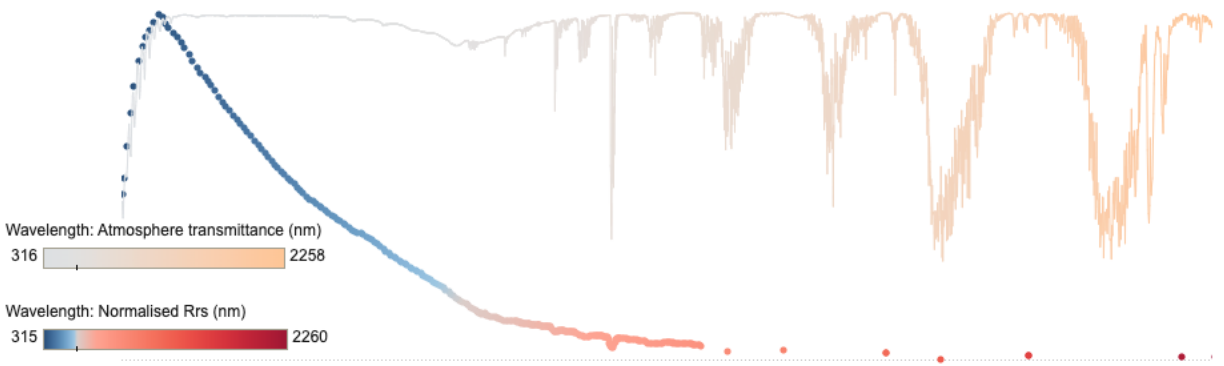
“ what you should know about PACE data”

pace.oceansciences.org/pace_data_matchups.htm

Known data issues

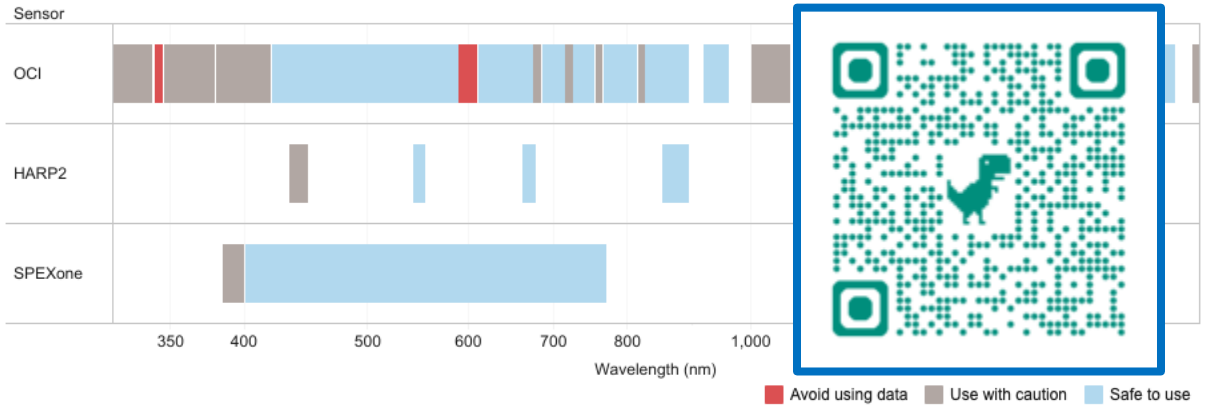
PACE is already providing high-quality data. However, some issues have to be noted before using it. Some particular bands, influenced by instrument or atmospheric characteristics, should be avoided for the moment.
Other issues affect the entire dataset, and some events affect data availability. See below for details.

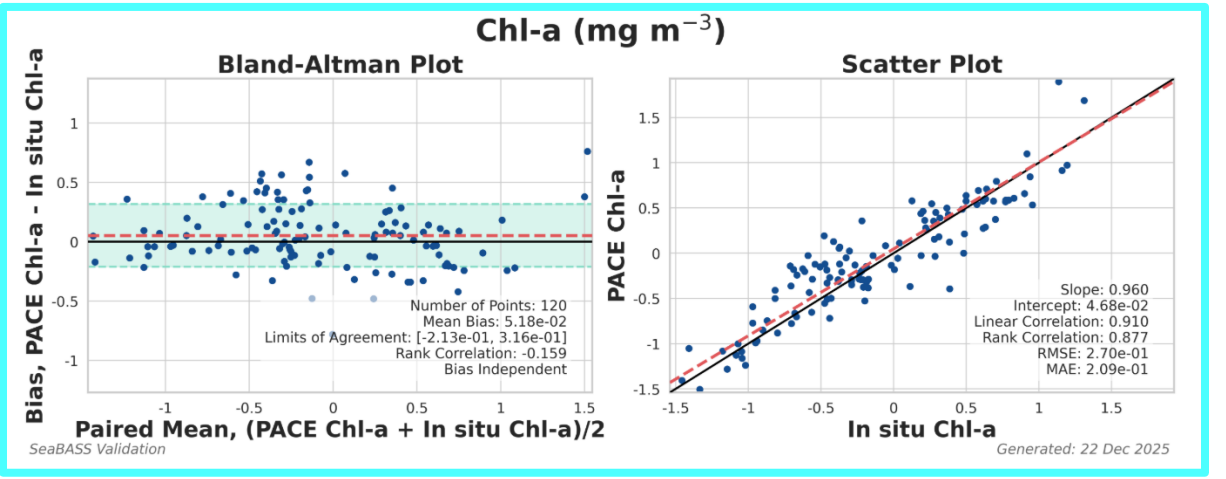
Reference spectra (for indicative purposes)

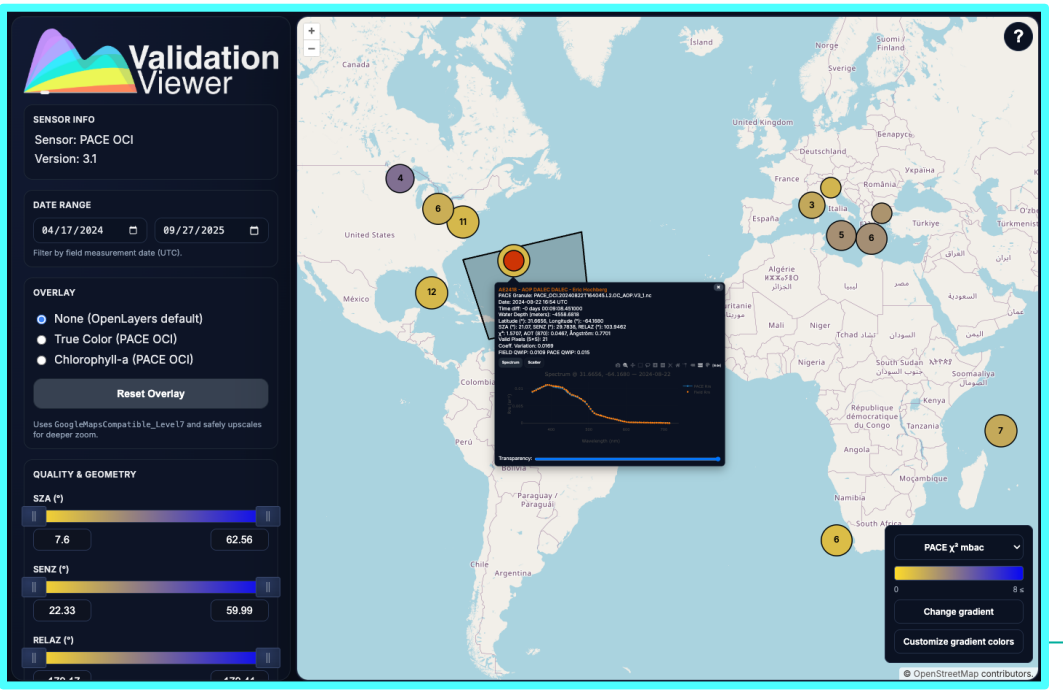


Problematic bands

Hover over the bands to get more information about the issues. The ocean normalized surface reflectance (rhos) and atmosphere transmittance spectra are shown as a reference.







Other relevant talks and posters

Today				
T306	10:30	12	Exploration of novel observations and multi-instrument synergy for studying aerosol and aerosol-cloud interaction in the frame of AIRSENSE project	Oleg Dubovik
Friday				
T503	9:24	12	Advancing Ocean and Land Surface Remote Sensing with EarthCARE's lidar ATLID	Gerd-Jan Van Zadelhoff
T504	9:36	12	The OCEAN (Ocean Color EarthCARE ANalysis) project	Marco Di Paolantonio
Posters				
P039			PACE / EarthCARE Matchups (PEM): An intercomparison library in Python for the NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) and EarthCARE missions	Sean Foley
P042			The First EarthCARE MAAP Hackathon	Beniamino Abis