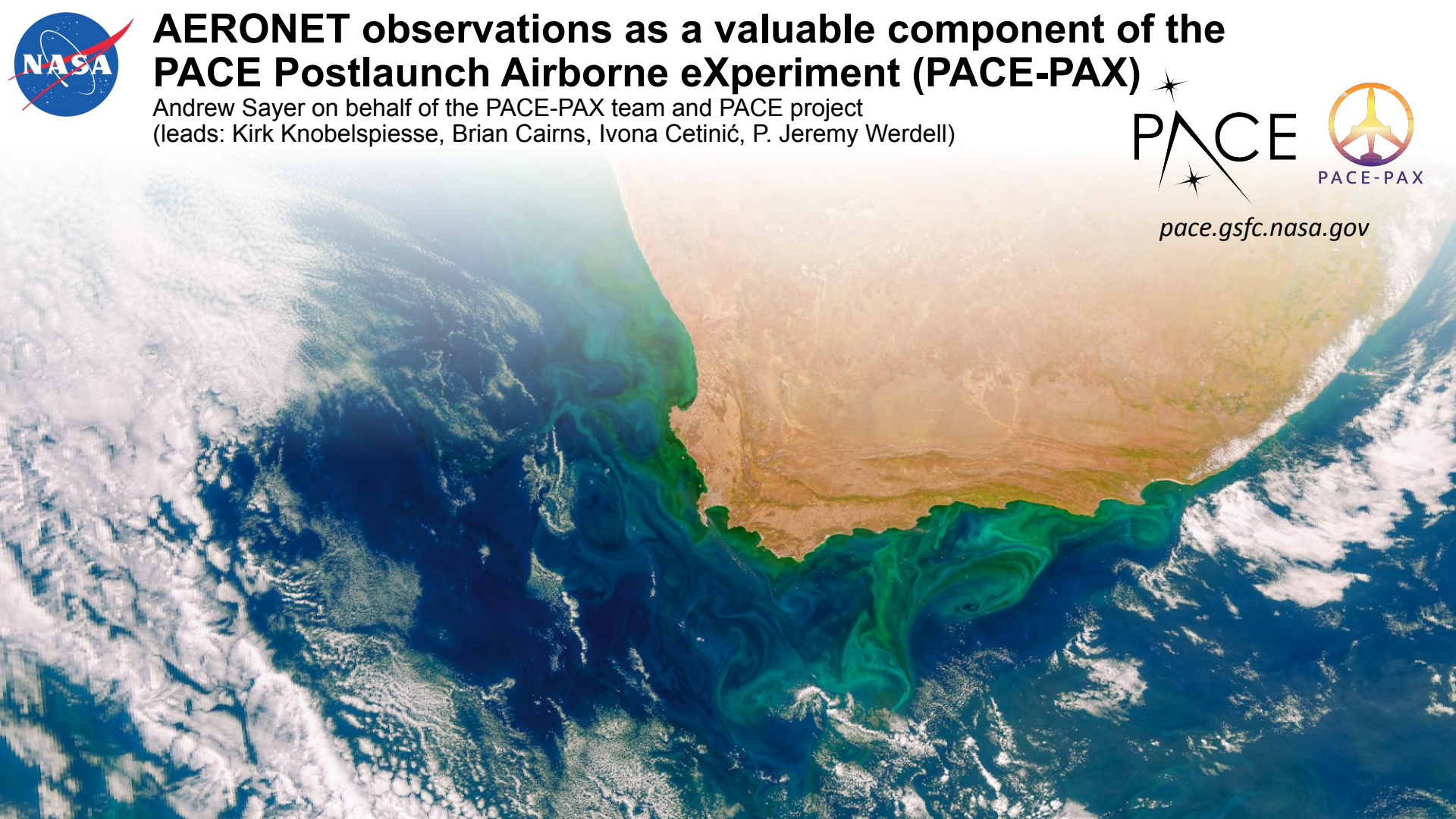


AERONET observations as a valuable component of the PACE Postlaunch Airborne eXperiment (PACE-PAX)

Andrew Sayer on behalf of the PACE-PAX team and PACE project
(leads: Kirk Knobelspiesse, Brian Cairns, Ivona Cetinić, P. Jeremy Werdell)



pace.gsfc.nasa.gov



OCI



340-890 nm in 2.5 nm steps
7 discrete SWIR, 940-2260 nm
1-2 day coverage $\pm 20^\circ$ tilt, 1km



HARP2



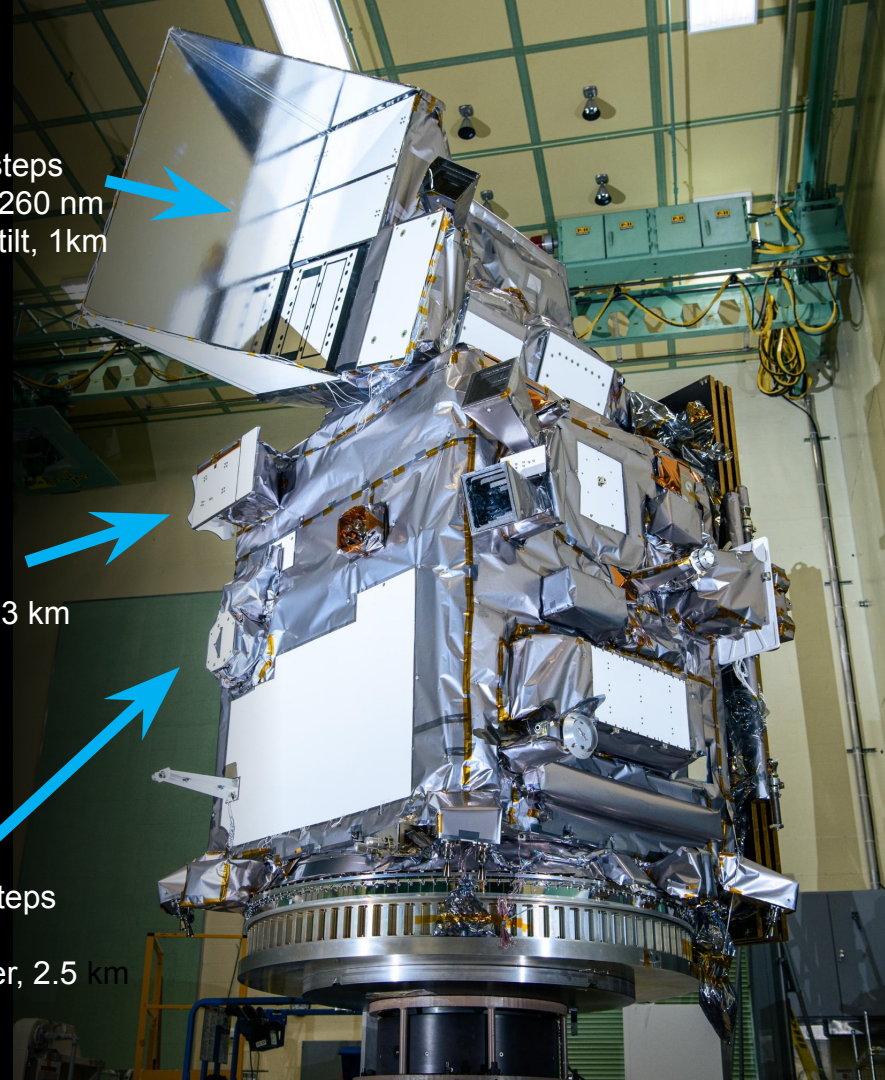
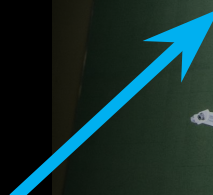
440, 550, 670, 870 nm
10-60 viewing angles
wide swath polarimeter, 3 km



SPEXone



380-770 nm in 2-4 nm steps
5 viewing angles
narrow swath polarimeter, 2.5 km



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

PACE will extend key systematic ocean color, aerosol, & cloud climate data records, reveal the diversity of organisms fueling marine food webs, and introduce new methods to observe aerosols and clouds, the largest source of climate uncertainty.

Characteristics:

- February 8th launch, April 11th initial data release
- 676.5 km, polar, ascending orbit, 98°
- Sun synchronous, 13:00 Equatorial crossing
- Global (land and ocean) data
- Data to OB.DAAC (oceancolor.gsfc.nasa.gov)

NASA PACE - Data Products

pace.oceansciences.org/data_table.htm

PACE Plankton, Aerosol, Cloud, ocean Ecosystem

HOME ABOUT MISSION SCIENCE APPLICATIONS DATA LEARN MORE NEWS EVENTS GALLERY DOCUMENTS

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 SPfBios | Aerosol and Land Surface Properties from SPfBios | Aerosol and Ocean Properties from OCI | HARP2 | SPfBios

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	Description and Use	Units	Availability	Status	Additional Info
Spectral top-of-atmosphere radiances from OCI	Spectral radiance observed at the top of the atmosphere	$W m^{-2} \mu m^{-1} sr^{-1}$	Level 2B 1.4 km at nadir only Level 2C 1.4 km at nadir only	Provisional	Level 2C draft data format and examples
Spectral top-of-atmosphere radiances and polarimetry from SPfBios	Spectral radiance and polarimetry observed at the top of the atmosphere, for all sensor viewing angles	Various	Level 2B 710 nm only Level 2C 440 nm	Provisional	Level 2C draft data format and examples
Spectral top-of-atmosphere radiances and polarimetry from HARP2	Spectral radiance and polarimetry observed at the top of the atmosphere, for all sensor viewing angles	Various	Level 2B 710 nm only Level 2C 440 nm	Provisional	Level 2C draft data format and examples

Ocean Properties to be Produced by OCI					
Bio-optical and biogeochemical properties of seawater constituents in the surface upper ocean					
Product	Description and Use	Units	Availability	Status	Additional Info
Spectral remote sensing reflectance	Spectral color of the ocean in the ultraviolet-to-near infrared spectral range. Used as input into algorithms to retrieve information about dissolved organic matter, phytoplankton, non-algal particles, and other aquatic constituents. Provided in continuous 2.5-nm steps from 350 to 717.5 nm with a resolution bandwidth (FWHM) of 5-nm	sr^{-1}	Level 2 1.4 km at nadir only Level 2 1.4 km at nadir only 9.5 nm monthly, annual	Provisional	ATBD SAT members: Siso, Zhu, Stramski, Choudhury, Stammers, Zhang In situ measurement protocols
Apparent visible wavelength	An optical water quality index reported as the weighted harmonic mean of visible range (350-700 nm)	nm	Level 2 1.4 km at nadir only Level 2 1.4 km at nadir only 9.5 nm, monthly, annual	Test	ATBD
Spectral diffuse attenuation coefficients	Spectral diffuse attenuation of downwelling irradiance at multiple wavelengths between 350 and 700 nm. Provides indices of water clarity and light penetration.	m^{-1}	Level 2 1.4 km at nadir only Level 2 1.4 km at nadir only 9.5 nm, monthly, annual	Test	ATBD SAT members: Siso, Stramski, D'Onofrio In situ measurement protocols
Spectral phytoplankton absorption coefficients	Spectral absorption coefficients for total phytoplankton absorption at multiple wavelengths between 350 and 700 nm. Provides information on phytoplankton physiology, abundance, and community composition.	m^{-1}	Level 2 1.4 km at nadir only Level 2 1.4 km at nadir only 9.5 nm, monthly, annual	Provisional	ATBD SAT members: Tournier, Stramski, Choudhury, Stammers, Slingo, Barnes, Stammers, Choudhury In situ measurement protocols
Spectral non-algal particle plus dissolved organic matter absorption coefficients	Spectral absorption coefficients for non-algal particulate and dissolved organic matter at multiple wavelengths between 350 and 700 nm. Provides information on the concentrations of the dissolved component of organic carbon and the detrital (non-algal) component of the particulate assembly.	m^{-1}	Level 2 1.4 km at nadir only Level 2 1.4 km at nadir only 9.5 nm, monthly, annual	Provisional	ATBD SAT members: Tournier, Stramski, Barnes, Stammers, Choudhury In situ measurement protocols
Spectral chlorophyll a and phaeococyanin absorption coefficients	Spectral absorption coefficients for chlorophyll a and phaeococyanin at multiple wavelengths between 350 and 700 nm. Provides information on the concentration of the dissolved component of organic carbon.	m^{-1}	TBD	Test	SAT member: Stramski In situ measurement protocols

NASA PACE - Data Products

pace.oceansciences.org/data_table.htm



PACE has many data products

... some are currently available, others coming soon, being tested, or potential future development



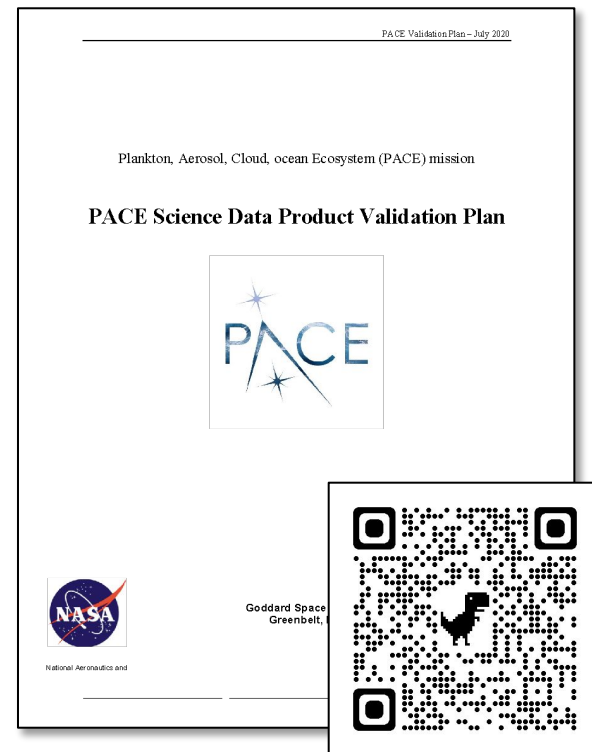
PACE validation plan

Our mission requirements include validation

*“post-launch field validation work is required to evaluate the PACE science data products ... **within 12 months of commissioning**. The PACE validation programs (provided by HQ PACE Science) shall include the following for the mission duration:*

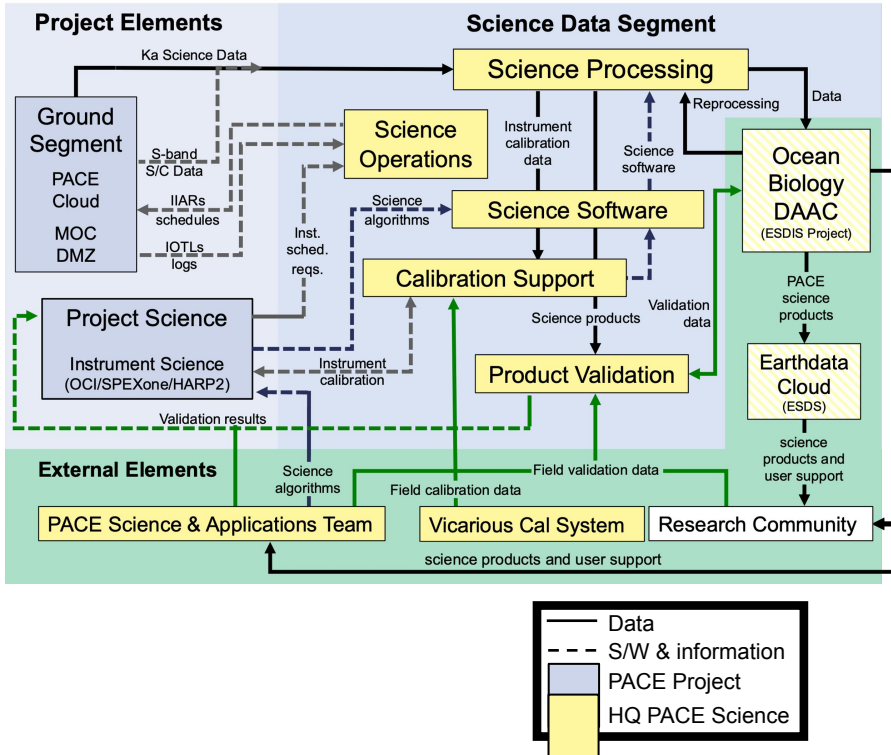
- a) *Shipboard and aircraft campaigns as required ...*
- b) *Autonomous instrument systems that collect continuous records of any of the individual data products...”**

The PACE Science Data Product Validation Plan describes activities to meet these requirements



pace.oceansciences.org/documents.htm

PACE validation plan



- NASA Ocean Ecology Lab field support group
- PACE Validation Science Team (PVST)
- Existing community activities
 - Instrument networks e.g. AERONET, ARM, Cloudnet
 - Ongoing field activities
- OEL hosted archive and analysis system (SeaBASS)
- **PACE Postlaunch Airborne eXperiment**

Related: System Vicarious Calibration

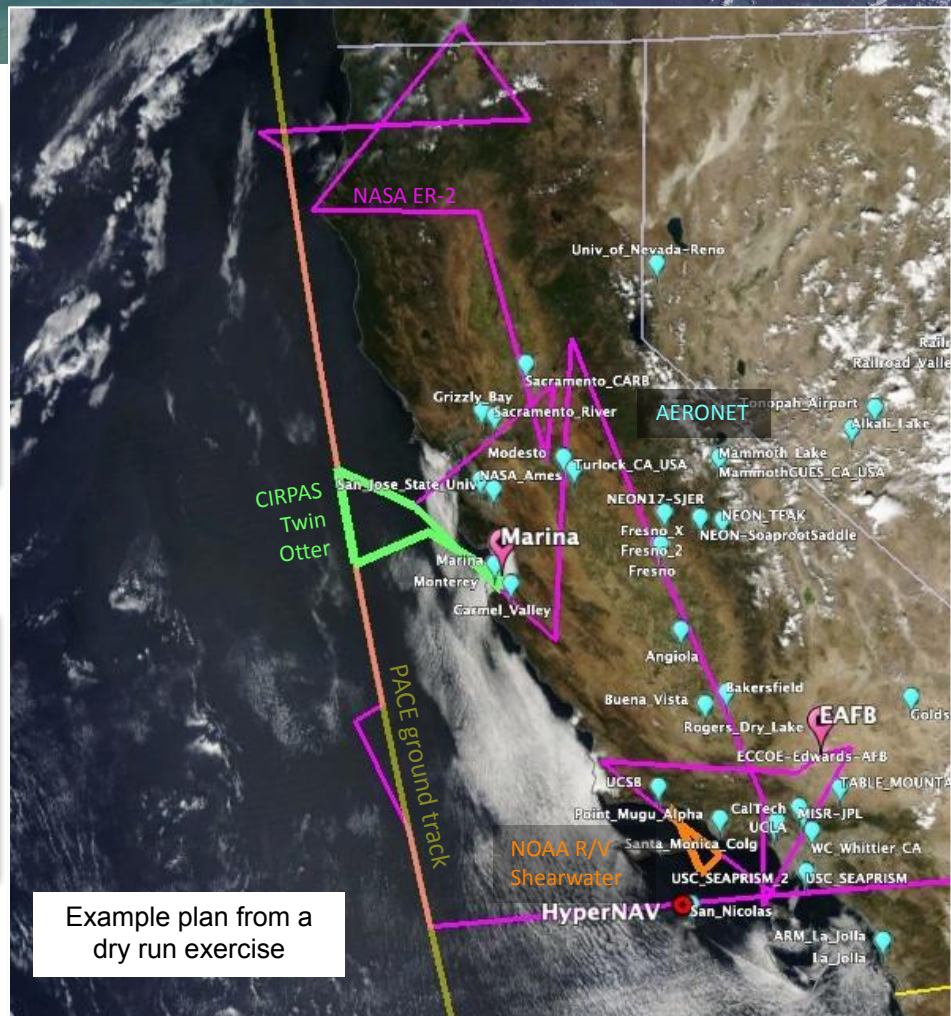
Autonomous regular measurement of ocean water leaving radiance for OCI vicarious calibration. Two systems:

- HyperNAV – Lagrangian profiling buoys (Crete + TBD)
- MarONet – fixed mooring based on MOBY (W. Australia)
- MOBY refresh – fixed mooring (Hawaii)



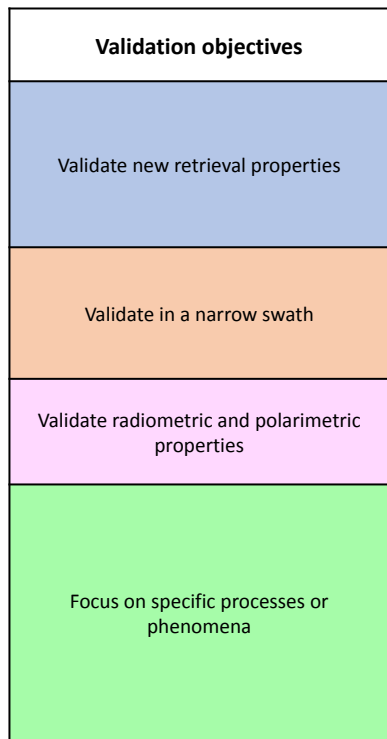


PACE Postlaunch Airborne EXperiment





How we designed PACE-PAX



Needed so products can mature from “provisional” to “standard” status

Enables validation of narrow swath PACE/SPEXone and EarthCARE

Traceability for satellite and airborne instrument characterization

Target uncommon special cases

Start with several top-level objectives



How we designed PACE-PAX

Validation objectives	Measurement objectives	Importance, w
Validate new retrieval properties	Land surface parameters	8
	Ocean radiometric parameters	10
	Aerosol parameters over the ocean	12
	Aerosol parameters over land	12
	Cloud parameters	12
	Ocean surface parameters	1
Validate in a narrow swath	Aerosol parameters over the ocean (PACE)	10
	Aerosol parameters over land (PACE)	10
	Cloud parameters (PACE)	5
	Aerosol parameters (EarthCARE)	8
	Cloud parameters (EarthCARE)	8
Validate radiometric and polarimetric properties	Validate large reflectances	6
	Validate large reflectances with high polarization	6
	Validate large reflectances with low polarization	6
	Overfly vicarious calibration sites	6
Focus on specific processes or phenomena	High aerosol loads over land	4
	High aerosol loads over ocean	4
	Multiple aerosol layers	1
	Aerosol under thin cirrus	2
	Aerosol above liquid phase cloud	4
	Broken clouds with complex structure	4
	Dust aerosols over ocean	4
	Aerosol and ocean parameters over turbid waters	2
	Aerosol and ocean parameters over biologically productive waters	4
	Smoke aerosols over ocean	1

Flow to specific measurement objectives

Prioritize with 'importance' metric



Validation Traceability Matrix

Identify needed measurements

Validation objectives	Measurement objectives	Importance, w
Validate new retrieval properties	Land surface parameters	8
	Ocean radiometric parameters	10
	Aerosol parameters over the ocean	12
	Aerosol parameters over land	12
	Cloud parameters	12
	Ocean surface parameters	1
Validate in a narrow swath	Aerosol parameters over the ocean (PACE)	10
	Aerosol parameters over land (PACE)	10
	Cloud parameters (PACE)	5
	Aerosol parameters (EarthCARE)	8
	Cloud parameters (EarthCARE)	8
Validate radiometric and polarimetric properties	Validate large reflectances	6
	Validate large reflectances with high polarization	6
	Validate large reflectances with low polarization	6
	Overfly vicarious calibration sites	6
Focus on specific processes or phenomena	High aerosol loads over land	4
	High aerosol loads over ocean	4
	Multiple aerosol layers	1
	Aerosol under thin cirrus	2
	Aerosol above liquid phase cloud	4
	Broken clouds with complex structure	4
	Dust aerosols over ocean	4
	Aerosol and ocean parameters over turbid waters	2
	Aerosol and ocean parameters over biologically productive waters	4
	Smoke aerosols over ocean	1

1c. Validate new retrieval properties: Aerosol properties over ocean

			Importance	Notes
	MA2FOOD MA2FNSR MA2FHPWP		12	4
	HSRL-2 AERONET-OC SUS SPEX-AV	Clear spectral properties and basic aerosol conditions from HSRL-2		
	Aerosol in situ instruments	Straight and level through aerosol plume		
	AERONET-OC, Shearwater, HyperNAV			

Geophysical properties: Aerosol spectral optical depth, Aerosol microphysical properties, Aerosol layer height, Ocean surface roughness (windspeed), Spectral ocean remote sensing reflectance

At least 2/3 required

For ocean properties, this could be achieved with either in water measurements from Shearwater, AERONET-OC or HyperNAV, or the HSRL-2

For aerosol properties, this could be either achieved with in situ data from the Twin Otter, or retrievals from passive instruments on the ER-2

4c. Validate radiometric and polarimetric properties: large reflectances with low polarization

			Importance	Notes
	A1HARIS, POCARD, PRISM, SUS, SPEX-AV	Far (180°) from solar principal plane	6	1
	AERONET-OC, Shearwater, HyperNAV	Turbid water		

Geophysical properties: Uniform marine stratocumulus clouds or optically thick ice clouds

Potential ER2 flight patterns over clouds:

Principal plane:

6h. Focus on specific processes or phenomena: aerosol and ocean properties over turbid waters

			Importance	Notes
	MA2FOOD MA2FNSR MA2FHPWP		2	1
	HSRL-2 AERONET-OC SUS SPEX-AV	Clear spectral properties and basic aerosol conditions from HSRL-2		
	Aerosol in situ instruments	Straight and level through aerosol plume		
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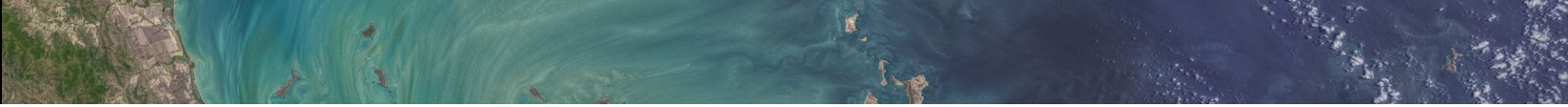


How we designed PACE-PAX

Importance weights provide for a way to assess multiple options, make flight planning decisions and assess overall success

Overall 1st dry run progress tracking

Validation objectives	ID	Measurement objectives	Importance, w	Observation time, h (hours)	Total observed (hours)	Fractional success 3/7	Fractional success 3/8	Fractional success 3/9	Total success	Remaining score
1. Validate new retrieval properties	a	Land surface parameters	8	1.0	1.0	0.0%	63.2%	0.0%	63.2%	2.9
	b	Ocean radiometric parameters	10	4.0	5.0	0.0%	46.5%	24.9%	71.3%	2.9
	c	Aerosol parameters over the ocean	12	4.0	6.5	0.0%	58.3%	22.0%	80.3%	2.4
	d	Aerosol parameters over land	12	4.0	4.0	0.0%	58.3%	4.9%	63.2%	4.4
	e	Cloud parameters	12	4.0	1.0	0.0%	0.0%	17.1%	17.1%	9.9
	f	Ocean surface parameters	1	4.0	0.5	0.0%	11.8%	0.0%	11.8%	0.9
3. Validate in a narrow swath	a	Aerosol parameters over the ocean	10	4.0	1.0	0.0%	0.0%	22.1%	22.1%	7.8
	b	Aerosol parameters over land	10	4.0	0.5	0.0%	0.0%	11.8%	11.8%	8.8
	c	Cloud parameters	5	1.0	1.0	0.0%	0.0%	52.8%	52.8%	2.4
4. Validate radiometric and polarimetric properties	a	Validate large reflectances	6	1.0	1.0	0.0%	63.2%	0.0%	63.2%	2.2
	b	Validate large reflectances with high polarization	6	1.0	0.0	0.0%	0.0%	0.0%	0.0%	6.0
	c	Validate large reflectances with low polarization	6	1.0	1.0	0.0%	0.0%	52.8%	52.8%	2.8
	d	Overfly vicarious calibration sites	6	2.0	1.0	0.0%	39.3%	0.0%	39.3%	3.6
6. Focus on specific processes or phenomena	a	High aerosol loads over land	4	1.0	0.0	0.0%	0.0%	0.0%	0.0%	4.0
	b	High aerosol loads over ocean	4	1.0	0.0	0.0%	0.0%	0.0%	0.0%	4.0
	c	Multiple aerosol layers	1	1.0	0.0	0.0%	0.0%	0.0%	0.0%	1.0
	d	Aerosol under thin cirrus	2	1.0	0.0	0.0%	0.0%	0.0%	0.0%	2.0
	e	Aerosol above liquid phase cloud	4	1.0	0.0	0.0%	0.0%	0.0%	0.0%	4.0
	f	Broken clouds with complex structure	4	1.0	0.0	0.0%	0.0%	0.0%	0.0%	4.0
	g	Dust aerosols over ocean	4	1.0	3.0	0.0%	0.0%	95.0%	95.0%	0.2
	h	Aerosol and ocean parameters over turbid waters	2	1.0	0.0	0.0%	0.0%	0.0%	0.0%	2.0
	i	Aerosol and ocean parameters over biologically productive waters	4	1.0	4.0	0.0%	95.0%	3.1%	98.2%	0.1
	k	Smoke aerosols over ocean	1	1.0	0.0	0.0%	0.0%	0.0%	0.0%	1.0
	total:			134	45	30.5	0.0%	25.2%	15.6%	40.8%



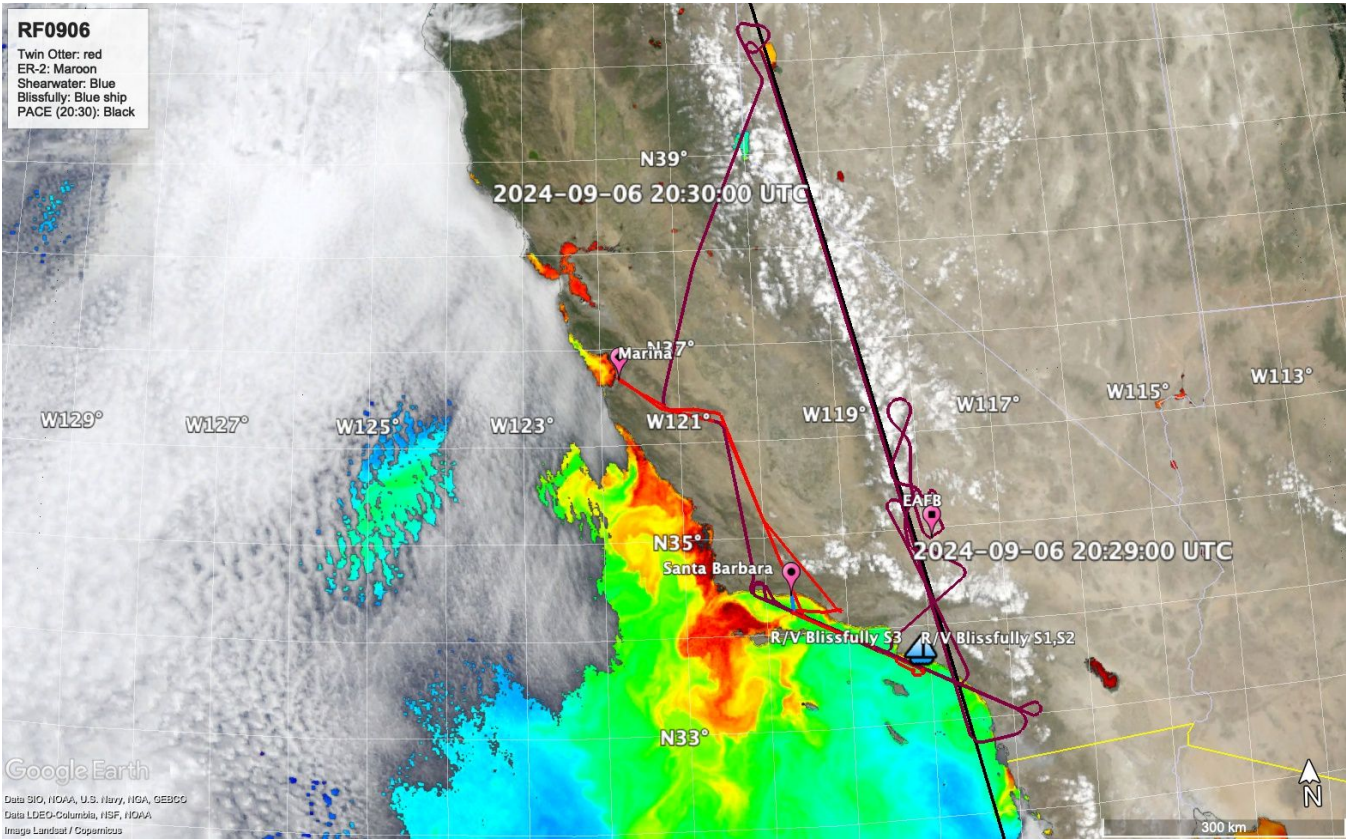
PACE-PAX instrumentation

Instrument	Platform	Role	Lead PI	Institution
AirHARP	ER-2	PACE/HARP2 polarimetry proxy	J. Vanderlei Martins	UMBC
PICARD	ER-2	PACE/OCI spectrometer proxy	J. Jacobson / K. Meyer	NASA ARC/GSFC
PRISM	ER-2	PACE/OCI spectrometer proxy	David R. Thompson	JPL
SPEX Airborne	ER-2	PACE/SPEXone polarimetry proxy	B. van Dierenhoven	SRON
HSRL-2	ER-2	Aerosol/cloud/ocean Lidar	T. Shingler / J. Hair	NASA LaRC
RSP	ER-2	Multi-angle polarimeter ref.	B. Cairns / K. Sinclair	NASA GISS
Facility instruments	Twin Otter	Aerosol/cloud in situ instruments	Anthony Bucholtz	NPS
LARGE	Twin Otter	Aerosol/cloud in situ instruments	Luke Ziemba	NASA LaRC
LI-Nephelometer	Twin Otter	Aerosol phase functions	Adam Ahern	NOAA
ISARA	Twin Otter	In situ data synergy activity	Snorre Stamnes	NASA LaRC
Ocean instruments*	RV Shearwater	Day cruises, instrumentation TBD	Mike Ondrusek	NOAA
HyperNAV*	Ocean floats	Radiometric calibration ocean floats	Andrew Barnard	OSU
AERONET, AERONET-OC*	Surface	Aerosol prop., water leaving radiance	P. Gupta / E. Lind	NASA GSFC

*externally supported activities



September 6 flight



Twin Otter
 ER-2
 RV Shearwater
 RV Blissfully
 PACE

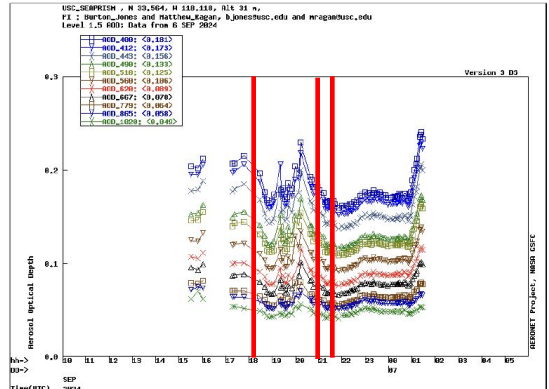
Background: RGB and
 PACE OCI Chlorophyll



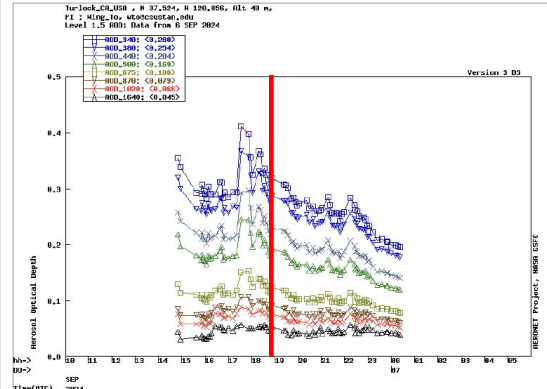
September 6 flight

20:56:00 ER2+TO+RB+USC_SeaPRISM

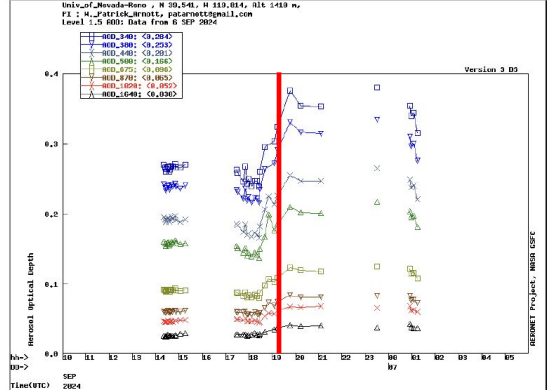
Usc_seaprisim



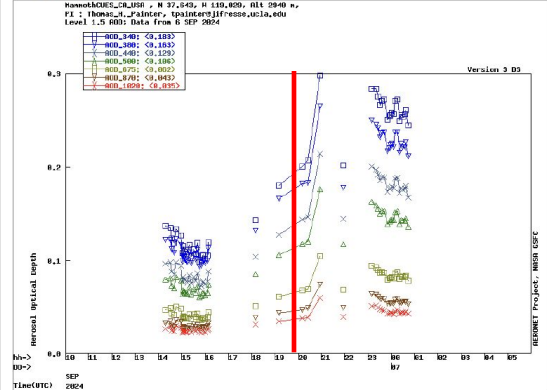
Turlock



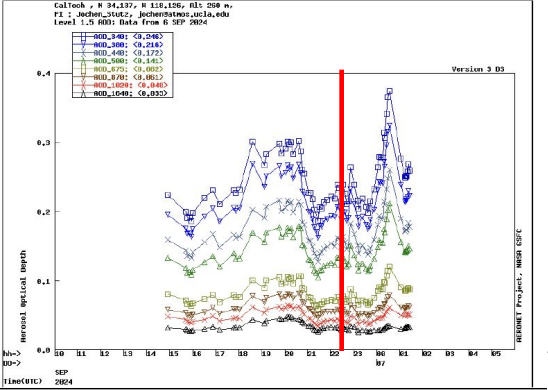
U. Nevada Reno



Mammoth CUES



CalTech



- Data product validation is crucial to PACE
- Validation activities are varied, many different teams contribute
- PACE-PAX is a dedicated PACE validation field campaign, happening now in California
- All data available at Langley DAAC end of March 2025

