NASA PACE mission and Protocol Activities

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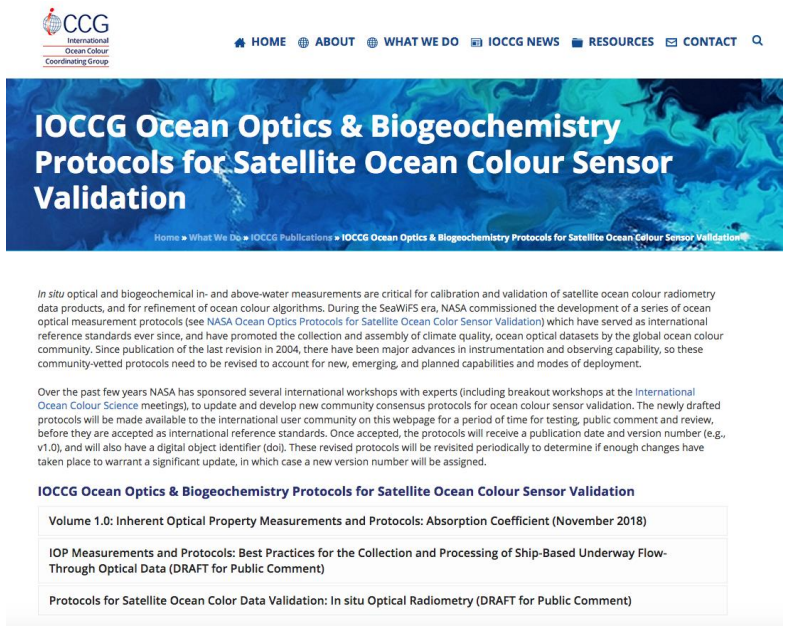
Aquatic Primary Production workshop, USRA, Columbia, MD, USA

Field Measurement Protocol Activities

Satellite data products require high quality field measurements with known uncertainties for satellite algorithm development and validation.

- Updating/developing community consensus protocols
- Protocol documents authored by experts in the field
- Shepherded largely by NASA Goddard personnel (thus far)
- Publications sponsored by IOCCG
  - Complete drafts posted on the IOCCG website for 60+ days for community comment
  - Authors/editors receive comments and revise the protocol document
  - Associate Editors identified to review revised protocols and confirm that reviewer comments are adequately addressed.
- Editing and formatting by lead editors and/or NASA Goddard TiMS
- Protocols as "living" documents (pdf files) – to be updated as required
- DOIs and archiving by IOC Best Practices (https://www.oceanbestpractices.net/)
  - Supported by the International Oceanographic Data and Information Exchange (IODE) of the Intergovernmental Oceanographic Commission (IOC) of UNESCO

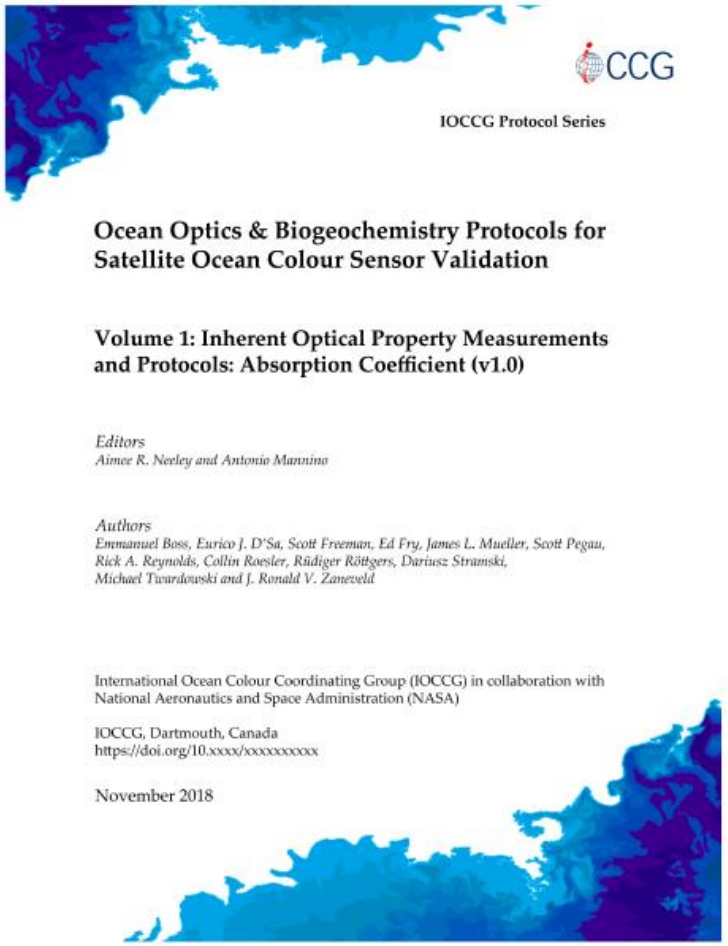


Working with TOS & Oceanography Magazine to promote broader community outreach

http://ioccg.org/what-we-do/ioccg-publications/ocean-optics-protocols-satellite-ocean-colour-sensor-validation/

Field Measurement Protocol Activities

- *Particle Absorption Coefficient*
- CDOM Absorption Coefficient
- Ship Flow-Through Optical Measurements
- Particle scattering
- Beam-C
- Particulate Organic Carbon
- Phytoplankton Taxonomy Product IDs (protocols to follow)
- Fluorometric Chl-a
- HPLC Pigments
- Primary Production (new start)
- …



IOCCG Protocol Series

Ocean Optics & Biogeochemistry Protocols for Satellite Ocean Colour Sensor Validation

Volume 1: Inherent Optical Property Measurements and Protocols: Absorption Coefficient (v1.0)

Editors
Aimee R. Neeley and Antonio Mannino

Authors
Emmanuel Boss, Eurico J. D'Sa, Scott Freeman, Ed Fry, James L. Mueller, Scott Pegau, Rick A. Reynolds, Collin Roesler, Rüdiger Röttgers, Dariusz Stramski, Michael Twardowski and J. Ronald V. Zaneveld

International Ocean Colour Coordinating Group (IOCCG) in collaboration with National Aeronautics and Space Administration (NASA)

IOCCG, Dartmouth, Canada
https://doi.org/10.xxxx/xxxxxxxxxx

November 2018

ocean chlorophyll
normalized land vegetation index

aerosol optical thickness

Broadly speaking, PACE has two fundamental science goals:

(1) Extend key systematic ocean color, aerosol, & cloud climate data records

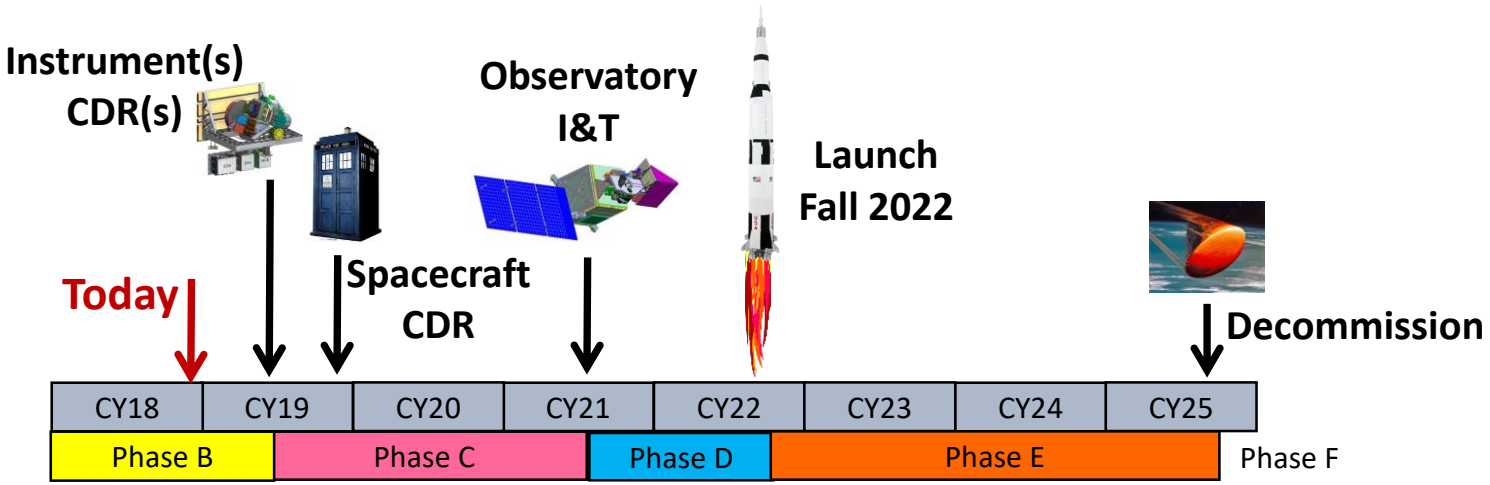
(2) Address new & emerging science questions using its advanced capabilities

cloud fraction

Mission characteristics

Key Mission Elements	
Mission management	NASA Goddard SFC
Ocean Color Instrument	NASA Goddard SFC
HARP2 polarimeter	UMBC
SPEXone polarimeter	SRON (Netherlands)
Spacecraft/Mission Ops	NASA Goddard SFC
Science data processing	NASA Goddard OBPG
Competed science teams	NASA Earth Sciences Div.

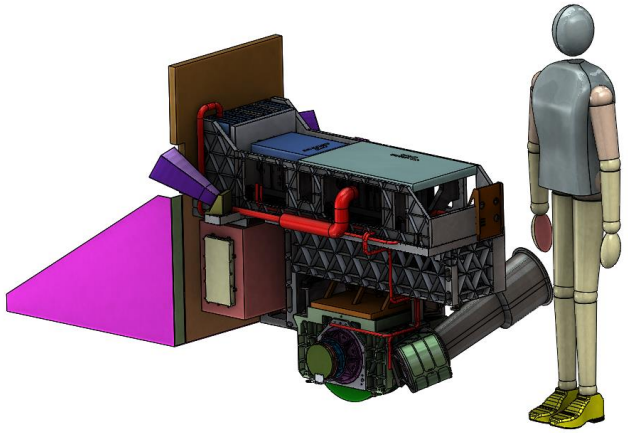
Key Mission Features	
Cost	$805M, Design-To-Cost
Life	3-yr, Class C, 10-yr fuel
Orbit	676.5 km, Sun sync, 1-pm
Coverage (OCI)	2-day global
RF Communications	Ka direct to ground 600Mbps



Plankton, Aerosol, Cloud and ocean Ecosystem (PACE) Instruments

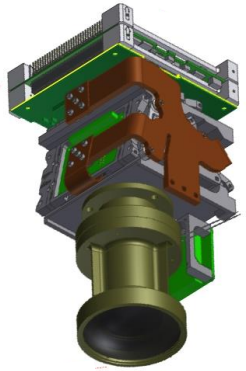
(Primary) Ocean Color Instrument (OCI)

Wide swath, UV-VIS imaging spectrometer with SWIR channels designed for ocean color applications, useful for aerosols and clouds



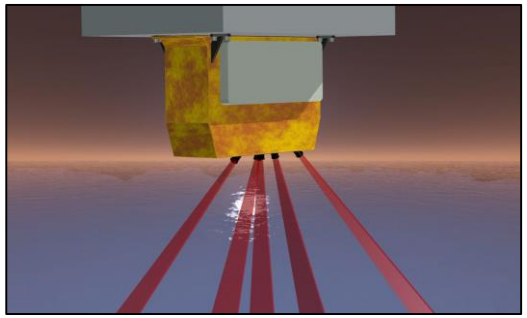
Hyper Angular Rainbow Polarimeter 2 (HARP2)

wide-swath multi-angle polarimeter, hyper angle capability



Spectro-Polarimeter for Planetary Exploration (SPEXone)

narrow-swath multi-angle polarimetric spectrometer



SPEXone and HARP2 are '**contributed**' instruments – "Do No Harm"

Polarimeters will be an excellent proof of concept for atmospheric correction, aerosol and cloud retrievals

Science Goals, Challenges, & Capabilities

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

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

Spectral range from 350-865 @ 5 nm

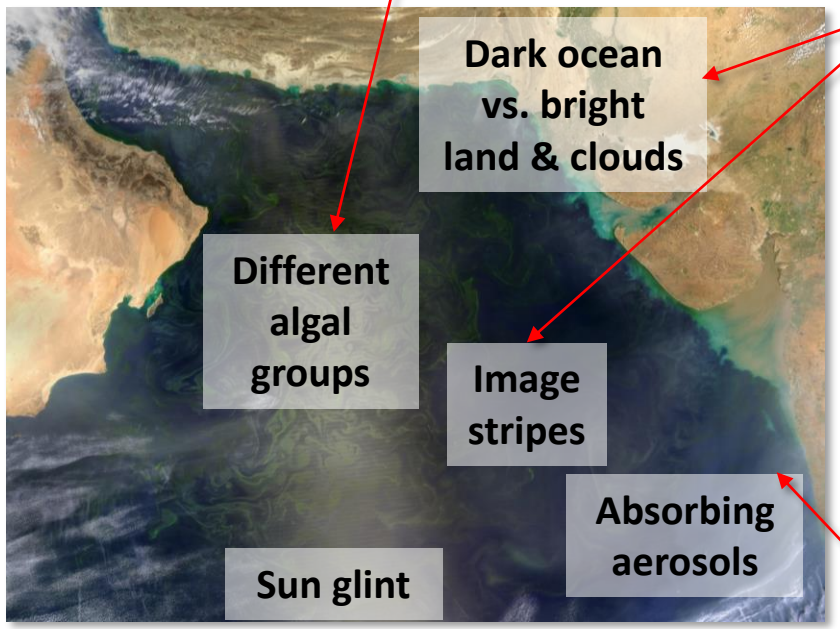
Instrument performance requirements

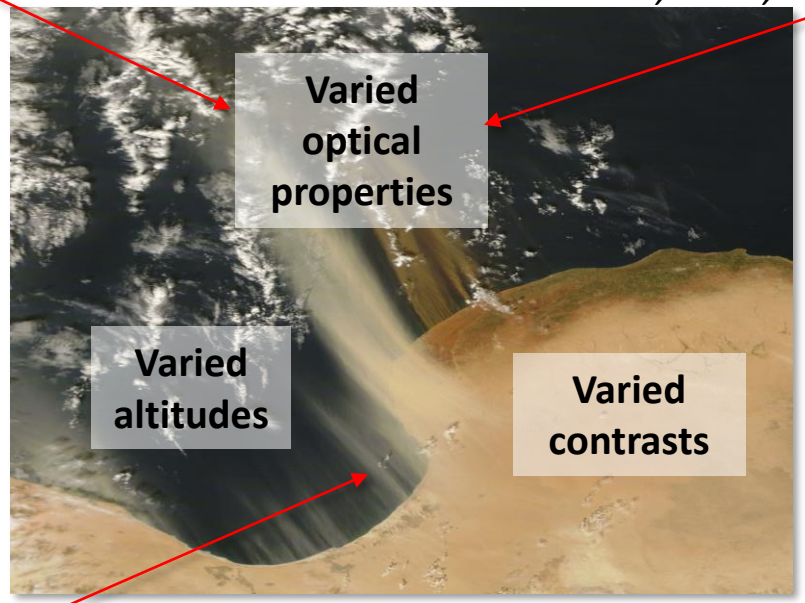
SWIR: 940, 1038, 1250, 1378, 1615, 2130, 2260 nm

Lunar calibration & onboard solar calibration (daily, monthly, dim)

Vicarious calibration system

Core data products, uncertainties, & a validation program





Tilt ± 20°

Spectral range goal of 320-865 @ 5 nm

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

Required science data products (OCI)

Required data products & additional expected data products:

Level 1 required (~threshold) products

Water-leaving reflectance	Aerosol optical thickness
Chlorophyll-a	Aerosol fine mode fraction
Phytoplankton absorption	Liquid / ice cloud optical thickness
NAP+CDOM absorption	Liquid / ice cloud effective radius
Particulate backscattering	Cloud layer detection ($\tau < 0.3$)
Diffuse attenuation	Cloud top pressure ($\tau > 3$)
Fluorescence line height	Shortwave radiation effect

Advanced & evaluation science data products

Incomplete list of advanced (~baseline) products

Carbon stocks & fluxes	Liquid / ice cloud water path
Phytoplankton pigments	Polarimeter-specific products
Phytoplankton physiology	Applied sciences-specific products
Community structure (PFTs)	Land data products (TBD)
Productivity	Your very favorite data product that
PAR, light attenuation, water quality	

General expectations for future PACE science teams:

- *Novel* methods for required products (exploit spectral capabilities)
- Methods for advanced products + scientific applications

Polarimetry on PACE

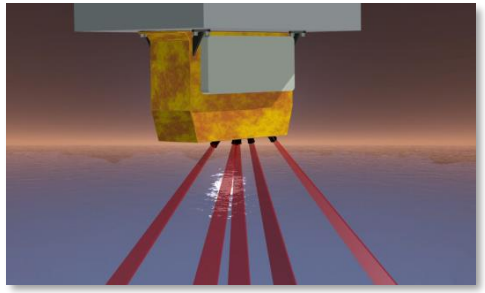
Two cubesat-sized *contributed* instruments

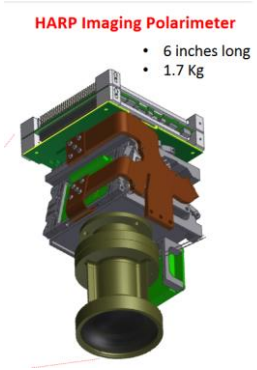
Spectro-Polarimeter for Planetary Exploration (SPEXone)

Contribution from the Netherlands (SRON, NSO, Airbus; TNO optics)

POC: Otto Hasekamp

Hyperspectral (UV) + narrow swath + high accuracy





Hyper Angular Rainbow Polarimeter (HARP-2)

Contribution from University of Maryland Baltimore County

POC: Vanderlei Martins

Hyperangular + wide swath

	SPEXone	HARP-2
Spectral range (resolution)	385-770 nm (hyperspectral 2 nm)	440, 550, 670 nm (10) + 870 nm (40 nm)
Polarimetric accuracy (DoLP)	0.002	< 0.01
# viewing angles	5 (-52°, -20°, 0°, 20°, 52°)	20 for 440, 550, 870 nm + 60 for 670 nm (114°)
Swath width	9° (100 km)	94° (1550 km)
Ground sample distance, TBD	5 km^2	2.5 km^2
Heritage	AirSPEX, SPEX/ASPIM	AirHARP, cubesat HARP for ISS

OCI-polarimetry synergy

OCI + SPEXone + HARP-2

- Hyperspectral + hyperangular + highly accurate radiometric & polarimetric observations = far 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.

Take home messages

PACE data products will only be as good as the field measurements used to develop algorithms and to calibrate the sensor and validate the data products.

- Possibilities for next competed science team
  - new approaches for existing data products (e.g., OCI spectral range!)
  - advanced & merged data products & science and interdisciplinary science
- Vicarious calibration system
- Field data - Validation
  - What do we need (field campaigns, communities, instruments, timing)?
    How do we ensure collection & availability of resources such as ships/aircraft?
  - Existing resources, docs, & partners of which to be aware?

Learn more about PACE

https://pace.gsfc.nasa.gov
@NASAOcean (Twitter)
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Technical Memo. series