PACE Science and Application Team Updates

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Plankton, Aerosol, Cloud and ocean Ecosystem (PACE) :
Synergies in Data, Science, and Applications

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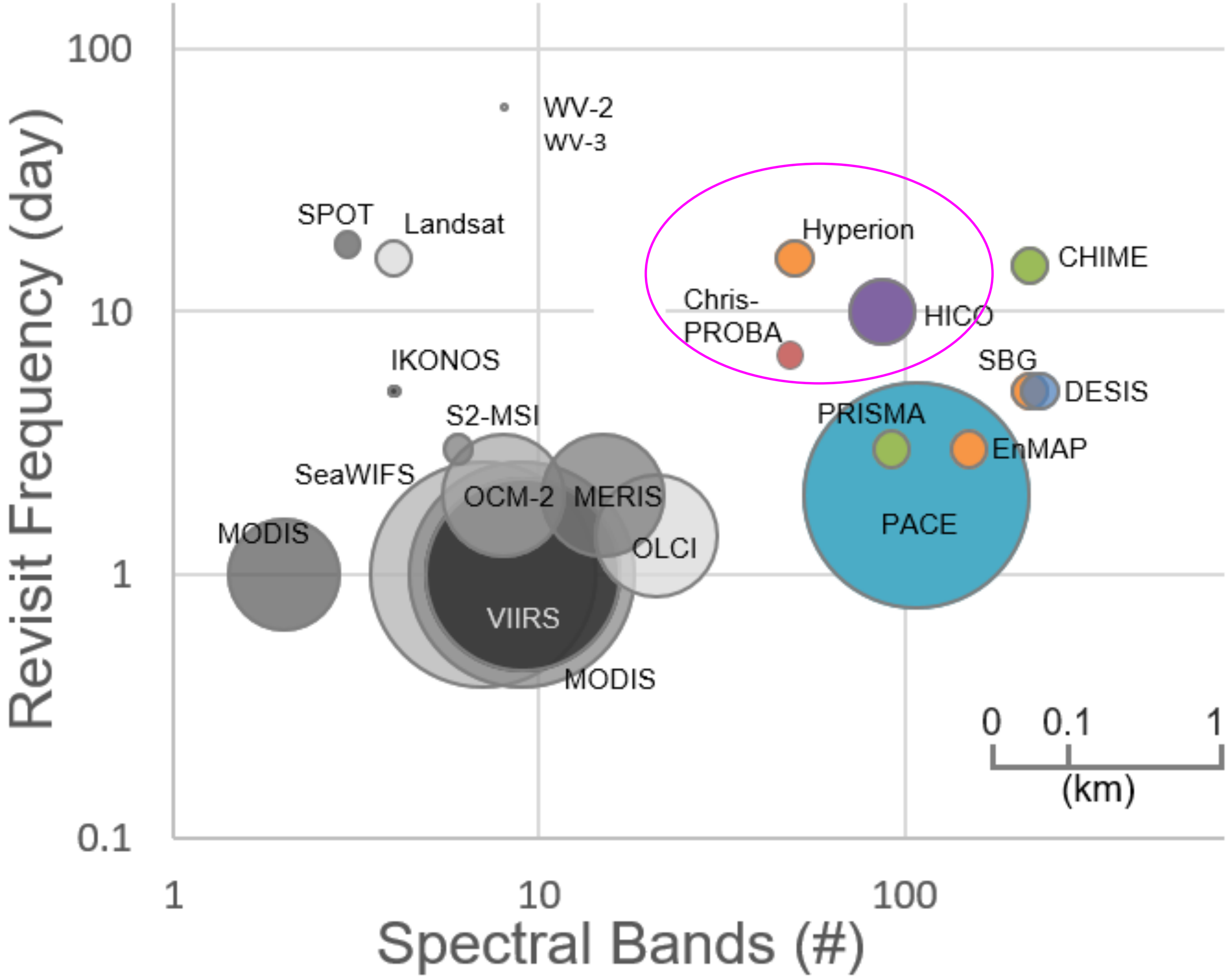
Hyperspectral Revolution



Dierssen et al. Frontiers. 2021

Global change
- latitudinal distributional shifts
- phenology shifts
- bloom dynamics

Biogeochemical modeling
- phytoplankton community composition
- nutrient cycling
- export of particles

Ecological processes
- rates of primary production
- nitrogen fixers, DMS producers, silicifiers, calcifiers
- trophic dynamics & food web efficiency

Ecological indicators
- hypoxia
- eutrophication
- informed monitoring and assessment

Environmental reporting
- meeting thresholds
- species composition
- detecting anomalies

Hazard Monitoring
- detection and tracking of harmful algal blooms
- assessing storm impacts
- monitoring oil spill extent and cleanup

Food Security
- finding pelagic and benthic habitats for fisheries
- locations/monitoring for aquaculture
- food safety & toxin production

Dierssen et al. 2021

Fig. 7. A host of new applications will be available with better discrimination of pelagic and benthic biodiversity promised by hyperspectral imagery.

frontiers in Environmental Science

REVIEW
published: 07 June 2021
doi: 10.3389/fenvs.2021.649528

Check for updates

Class	Essential Biodiversity Variable (EBV)	Wetlands	Benthic communities		Pelagic		
		Mangrove/ Salt marsh	Macro-phytes & Macroalgae	Coral	Phyto-plankton	Fish, Zoo-plankton	Apex Predator
Genetic Composition	Population genetic diversity						
Species Populations	Distribution						
	Abundance						
	Size/vertical distribution					**	
Species Traits	Pigments*					NA	NA
	Phenology						
Community Composition	Taxonomic diversity*						
Ecosystem Structure	Functional type*						
	Fragmentation/ heterogeneity						
Ecosystem Function	Net primary production					NA	NA
	Net ecosystem production					NA	NA

*Select types may be differentiated. ** using lidar techniques

Routine	Demon-strated	Unproven	Ecosystem Model

PACE

Living up to the Hype of Hyperspectral Aquatic Remote Sensing: Science, Resources and Outlook

Heidi M. Dierssen[1], Steven G. Ackleson[2], Karen E. Joyce[3], Erin L. Hestir[4], Alexandre Castagna[5], Samantha Lavender[6] and Margaret A. McManus[7]*

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PACE Science and Applications Team (SAT)

Monthly meetings to discuss mission/algorithm synergies, new papers & opportunities , gaps,

Credit OskarLandi

6-8 October 2021 Team Meeting UCONN Avery Point
Plus Streaming Totals: 75 Cities 195 Unique IP Addresses

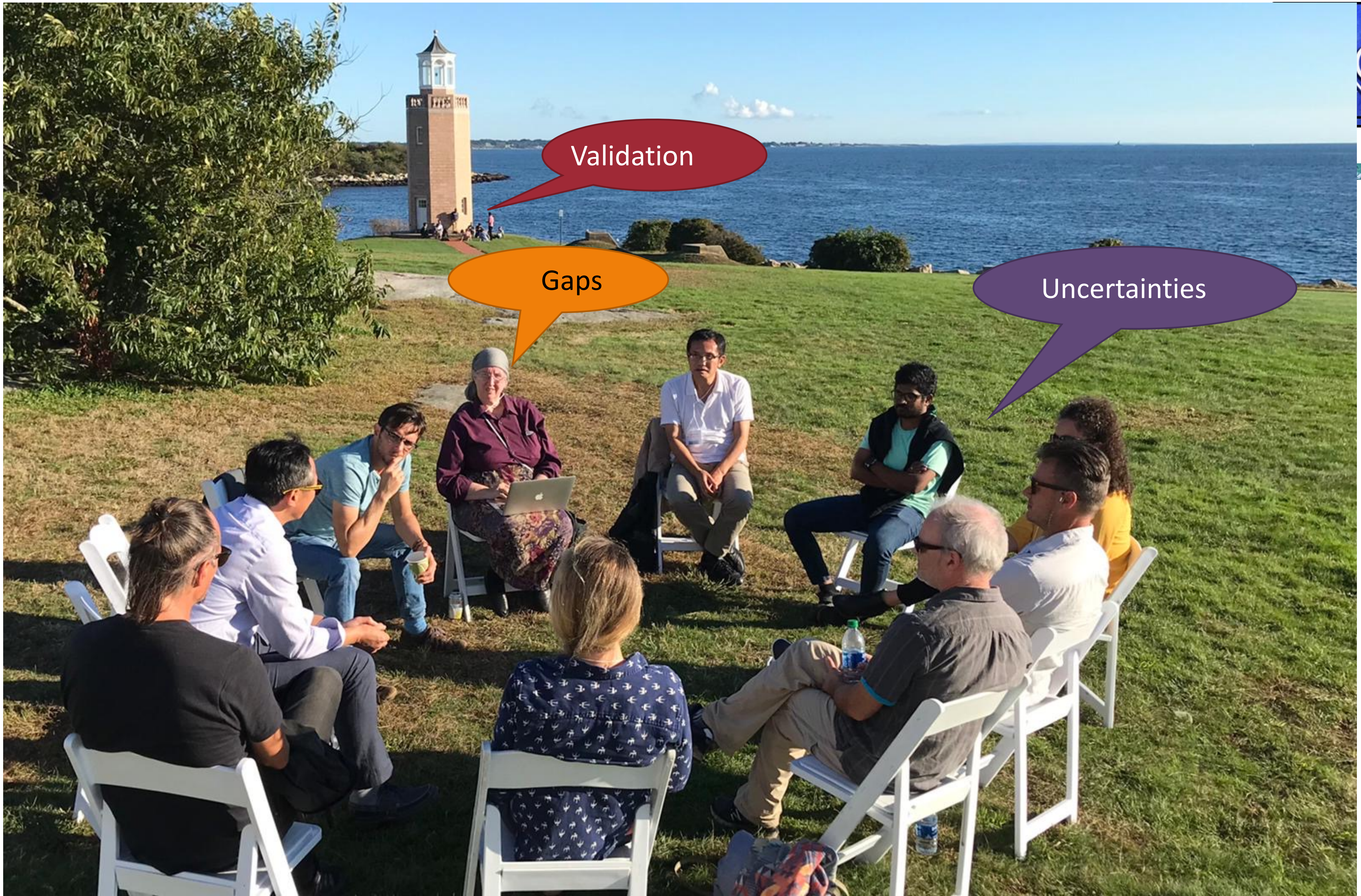
GOALS of Team

Algorithm development

<u>Algorithm production</u> implemented as Standard, Provisional, Test or Special

<u>Algorithm documentation</u> to be available online

<u>Algorithm implementation</u> with project team


Validation
Gaps
Uncertainties

Standard Product Suites So Far…

Suite OC_AOP

1.	Rrs	350-720 @ 2.5nm
2.	Rrs_unc	350-720 @ 2.5 nm
3.	aot	865
4.	angstrom	443/865 relative
5.	ipar	
6.	PAR	400-700nm integrated
7.	nflh	
8.	AVW	
9.	QWIP (TBD, but likely)	
10.	l2flags	

Suite OC_IOP

1.	a	SeaWiFS wavelengths or more
2.	bb	SeaWiFS wavelengths or more
3.	aph	SeaWiFS wavelengths or more
4.	aph_443_unc	
5.	adg_443	
6.	adg_443_unc	
7.	adg_s	
8.	bbp_443	
9.	bbp_443_unc	
10.	bbp_s	
11.	Kd	SeaWiFS wavelengths or more

Suite OC_BGC

1. chlor_a
2. POC
3. PIC
4. PhytoC

APPARENT VISIBLE WAVELENGTH (APV) USING HYPERSPECTRAL DATA

ELSEVIER

Remote Sensing of Environment

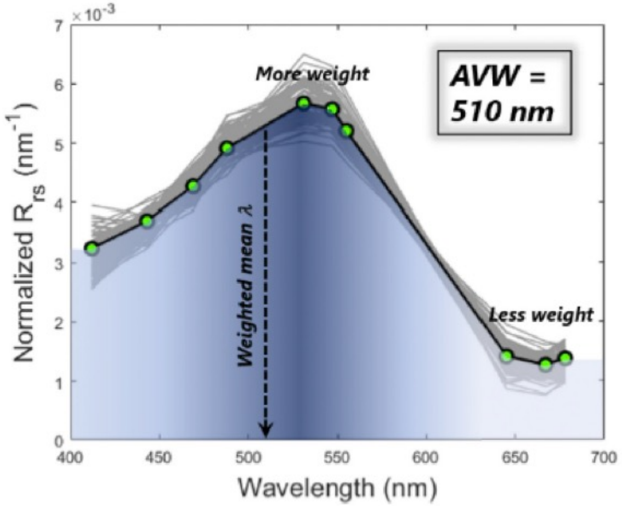
journal homepage: www.elsevier.com/locate/rse

150 shades of green: Using the full spectrum of remote sensing reflectance to elucidate color shifts in the ocean

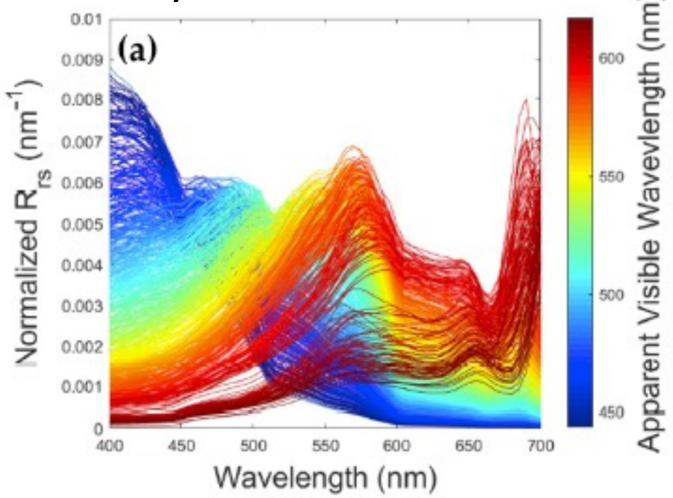
Ryan A. Vandermeulen[a,b,*], Antonio Mannino[b], Susanne E. Craig[b,c], P. Jeremy Werdell[b]

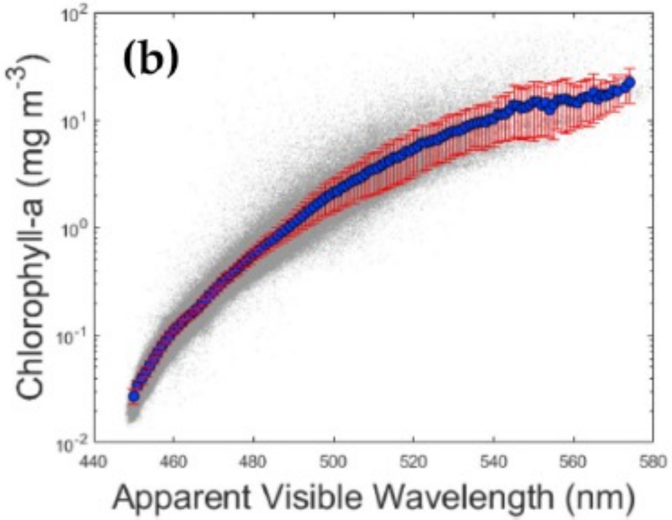
[a] Science Systems and Applications, Inc., Lanham, MD, 20706, USA
[b] NASA Goddard Space Flight Center, Greenbelt, MD, 20771, USA
[c] University Space Research Association, Columbia, MD, 21046, USA

$$AVW = \frac{\sum_{i=\lambda_1}^{\lambda_n} R_{rs}(\lambda_i)}{\sum_{i=\lambda_1}^{\lambda_n} \frac{R_{rs}(\lambda_i)}{\lambda_i}} = \left(\frac{\sum_{i=\lambda_1}^{\lambda_n} \lambda_i^{-1} R_{rs}(\lambda_i)}{\sum_{i=\lambda_1}^{\lambda_n} R_{rs}(\lambda_i)} \right)^{-1}$$



Synthetic Dataset





QWIP: A Quantitative Metric for Quality Control of Aquatic Reflectance Spectral Shape Using the Apparent Visible Wavelength

Heidi M. Dierssen[1]*, *Ryan A. Vandermeulen*[2,3], *Brian B. Barnes*[4], *Alexandre Castagna*[5], *Els Knaeps*[6] *and Quinten Vanhellemont*[7]

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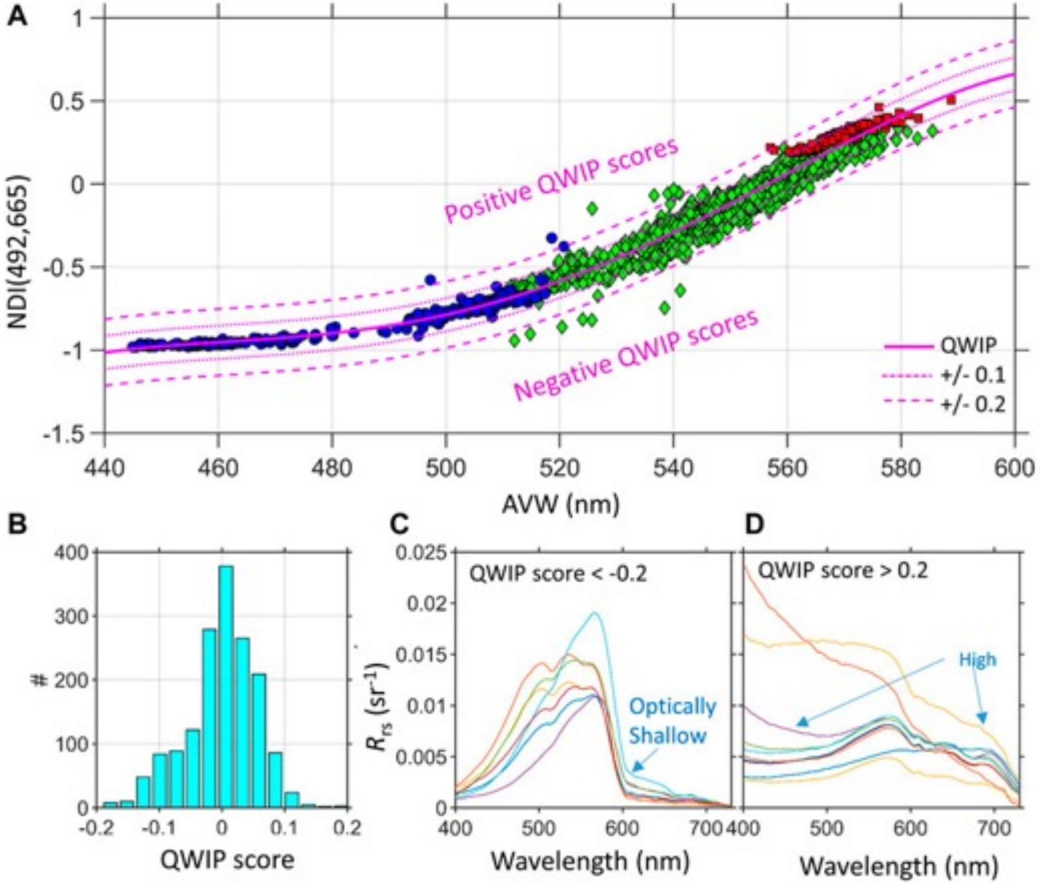
The colors of the ocean and inland waters span clear blue to turbid brown, and the corresponding spectral shapes of the water-leaving signal are diverse depending on the various types and concentrations of phytoplankton, sediment, detritus and colored dissolved organic matter. Here we present a simple metric developed from a global dataset spanning blue, green and brown water types to assess the quality of a measured or derived aquatic spectrum. The Quality Water Index Polynomial (QWIP) is founded on the Apparent Visible Wavelength (AVW), a one-dimensional geophysical metric of color that is inherently correlated to spectral shape calculated as a weighted harmonic mean across visible wavelengths. The QWIP represents a polynomial relationship between the hyperspectral AVW and a Normalized Difference Index (NDI) using red and green

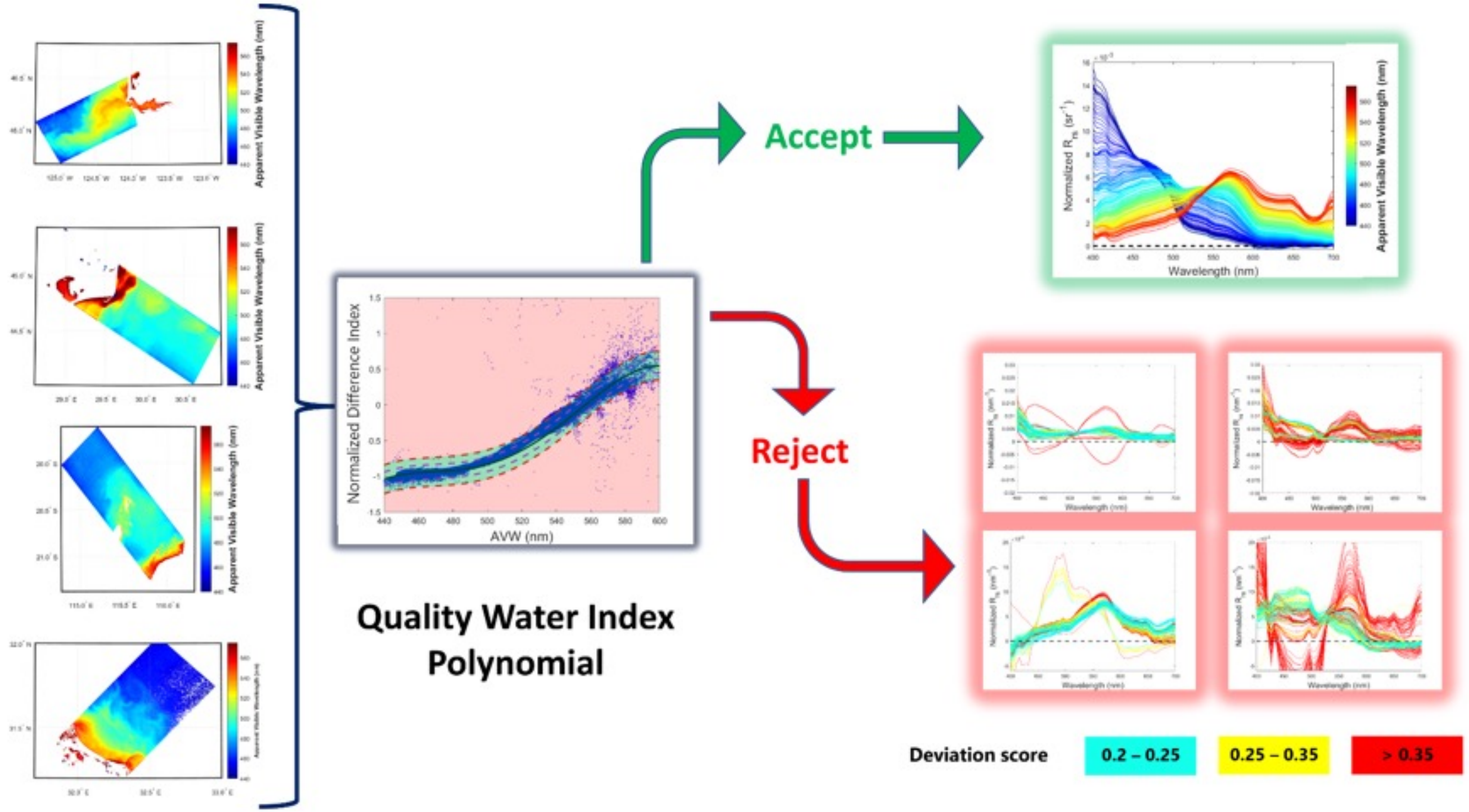
QWIP

Algorithm Development: The method was developed using a large global dataset of remote sensing reflectance (n = 1,629) compiled from different studies (CASCK-P dataset, see Dierssen et al. 2022).



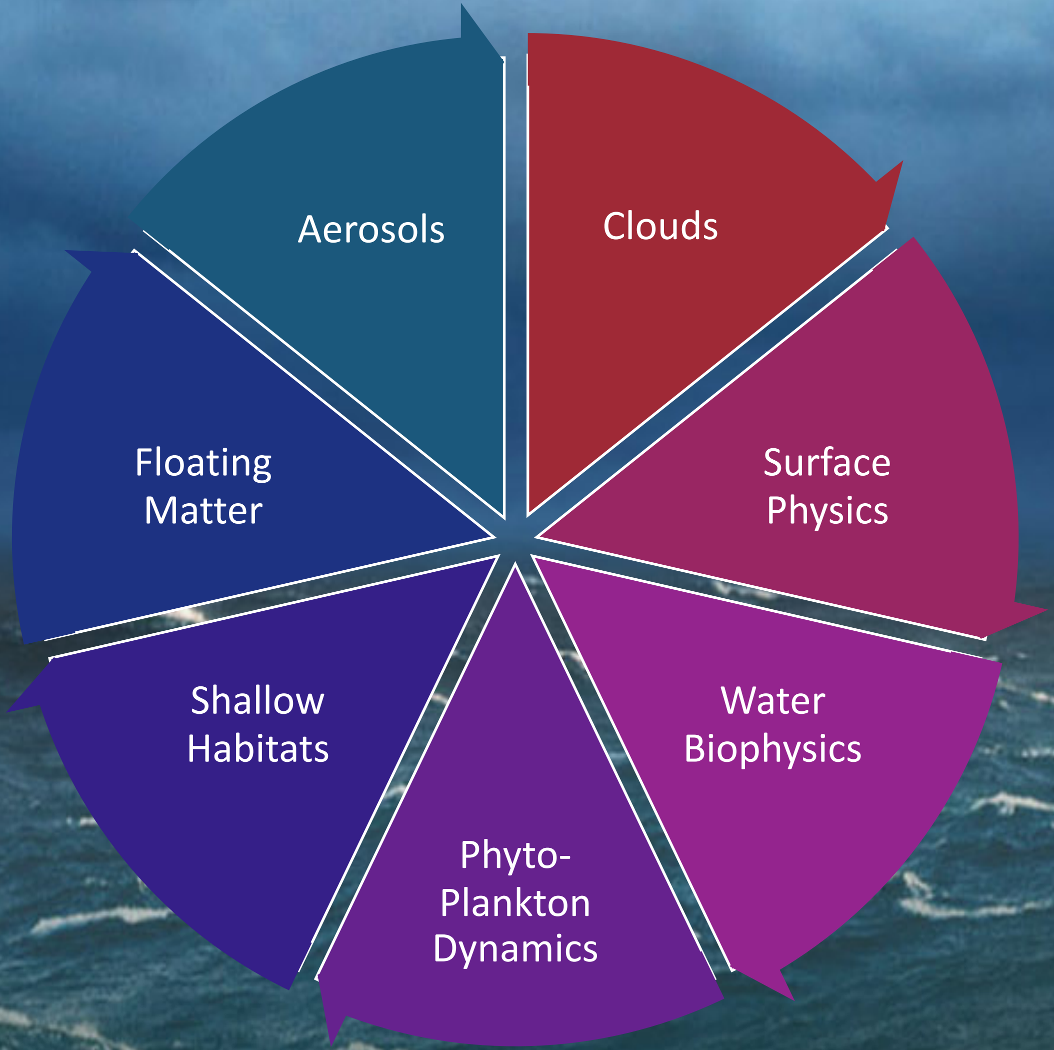
(A) The QWIP relationship between Apparent Visible Wavelength (AVW) and the Normalized Difference Index (NDI) with the CASCK-P training dataset showing the final tuned QWIP polynomial (thick magenta line) with different levels of QWIP scores (±0.1 dotted magenta and ±0.2 dashed magenta). Water types include: Blue-green (blue circles), Green (green diamonds) and Brown (red squares). (B) Histogram of the QWIP scores from (A) are predominantly within ±0.1 for the training data. (C) The remote sensing reflectance (R_{rs}) of outliers with negative QWIP scores < −0.2 were associated with optically shallow water features. (D) Outliers with QWIP scores > 0.2 exhibited higher blue associated with surface reflected skylight and higher overall magnitude spectra.

Satellite verification:



Comparing full spectral information against empirical indices enables a quick and efficient means of assessing the relative quality of satellite and/or in situ data. Mapped HICO scenes are passed through the QWIP procedure, and spectra are accepted/rejected based on a nominal acceptance threshold. As spectral data increasingly deviate from the polynomial relationship between AVW and NDI (490,665), the anomalous spectral features become more prominent.

PACE SCIENCE 24 TEAMS BY TOPIC



PACE SAT Provisional Algorithms Upcoming

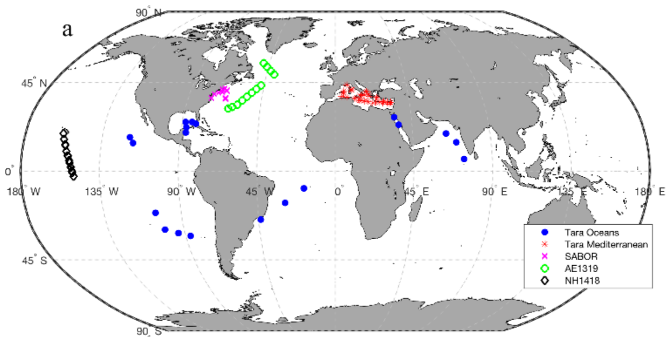
Unified algorithm for aerosol characterization from OCI	Unified Aerosol	Remer
Radiative Transfer Simulator and Polarimetric Inversion for PACE	Simulation Delivered	Zhai
Inverse retrieval of the ocean surface refractive index	OSIRIS	Ottaviani
Joint polarimetric aerosol and ocean color retrievals with deep learning	FastMAPOL	Gao
Algorithms to obtain inherent optical properties of seawater	3SAA (aph,ad,ag,bbp,Kd)	Stramski
The PACE-MAPP collaborative algorithm project	PACE-MAPP	Stamnes
Freshwater Hyperspectral HABs Algorithms		Shuchman
Retrieving water quality indicators via MDNs	Water Quality	Pahlevan
Chi factor and BRDF		Zhang
PACE UV Retrieval of Oceanic and Atmospheric Data products		Chowdhary
Spectral Derivative Methods for Quantifying Phytoplankton Pigments for PACE	Pigments	Siegel

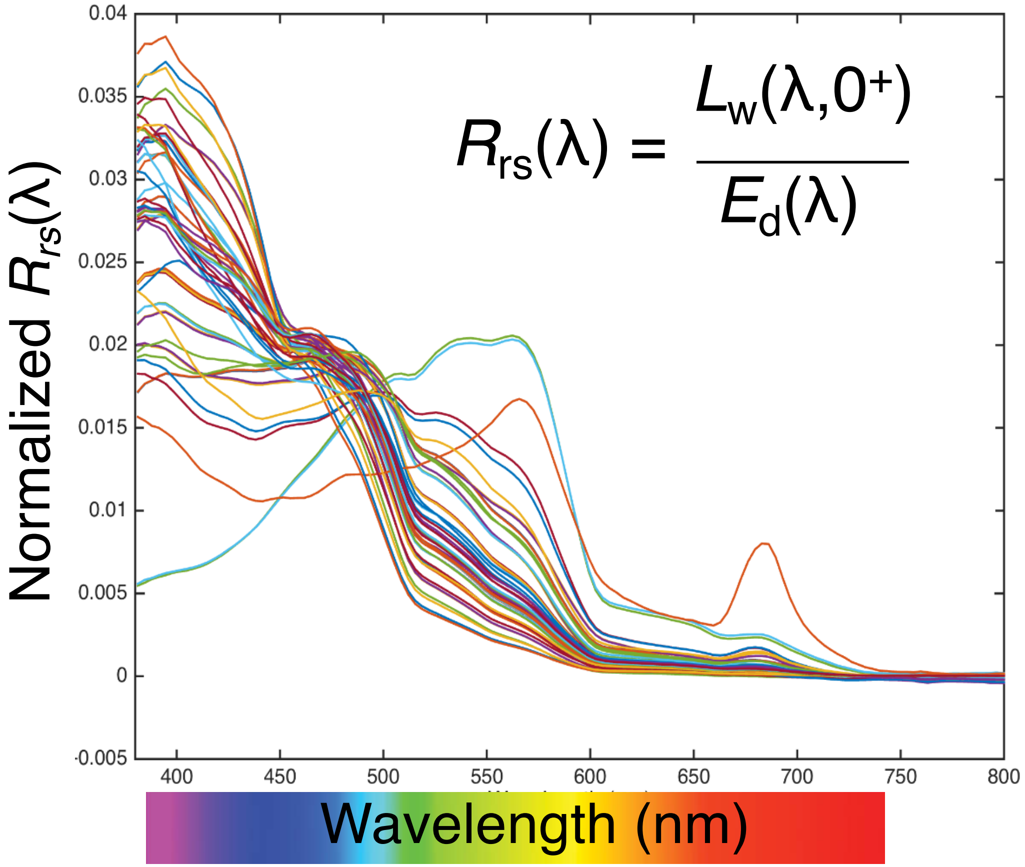
IOP Inversion and BRDF algorithms for PACE	ZTT Model IOP, BRDF	Twardowski
MAIAC Processing of OCI Over Land: Aerosol Chemical Speciation	MAIAC	Lyapustin, Go
HARP2 Level 1 Data Processing Plan		Xu
Remote sensing of cloud properties using PACE SPEXone and HARP-2	RSP Heritage	van Diedenhoven
Phytoplankton Algorithms and Data Assimilation: Preparing a Pre-launch Path to Exploit PACE Spectral Data		Rousseaux
PACE implementations for optically shallow waters		Barnes
A toolbox for the diagnostic assessment of spectral behavior	AVW	Vandermeulen
Radiative products for PACE	All things radiative	Boss, Frouin
Support for PACE OCI Cloud Products		Meyer
Hyperspectral algorithms for OCI atmospheric correction and UV penetration		Krotkov
Net Primary Production for PACE OCI	NPP, FLH, PhytoC	Westberry
HARP2		Vanderlei
SPEXONE - Aerosols	remoTAP	Hasekamp
Spectral Decomposition: Chl b, Chl c, and grouped photoprotective carotenoids	Pigments	Chase, Gaube

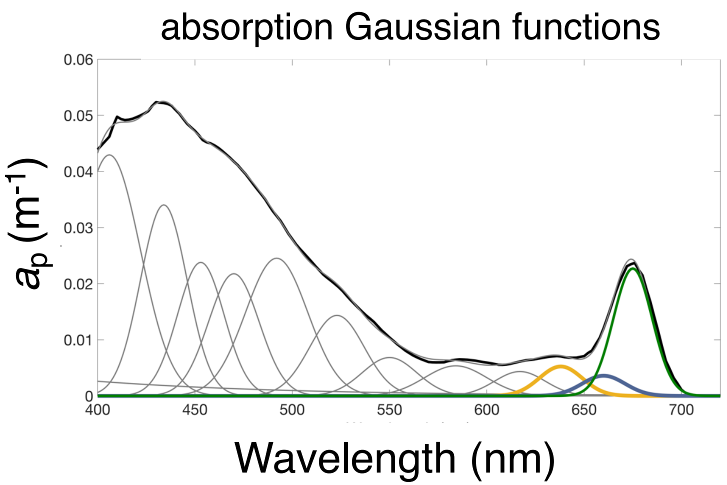
PACE SAT Review of Phytoplankton Community Composition from Space

Led by Ivona Cetinić and Cecile Rousseaux

Chase, Gaube et al. using Gaussian Functions to estimate Phytoplankton Pigments



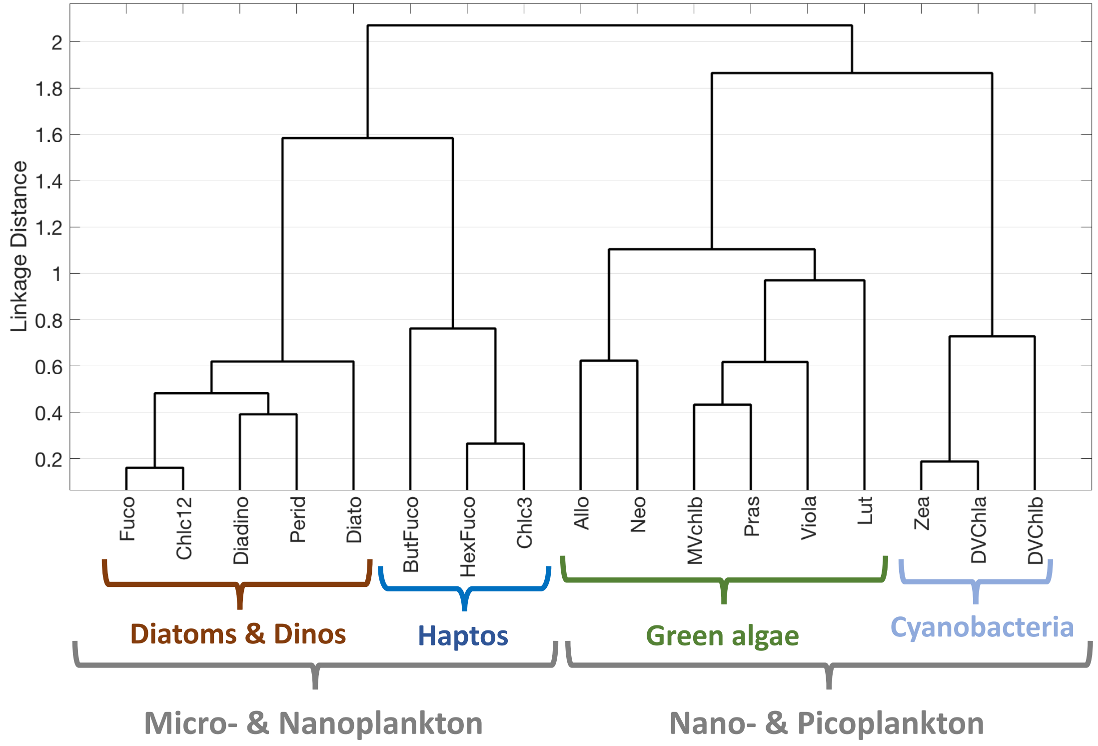


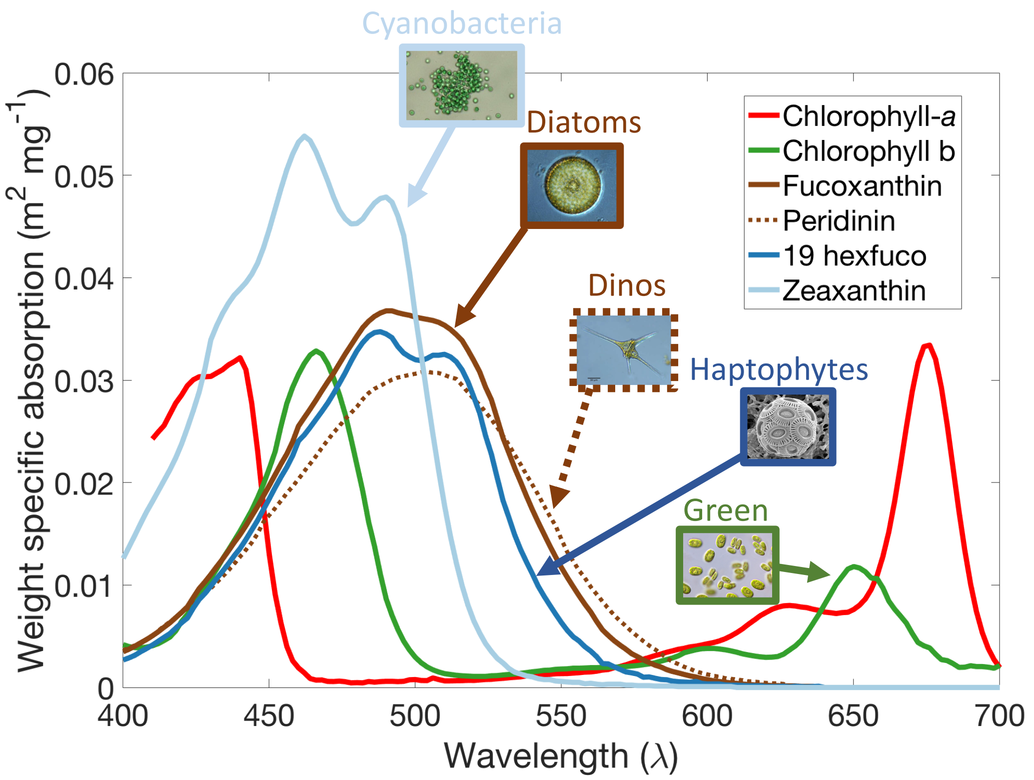


Chase et al. 2017, JGR-Oceans

Kramer & Siegel Modeling Pigments and Phytoplankton Community Composition (PCC)

Spectral derivative methods for estimating phytoplankton pigment concentrations





Kramer & Siegel JGR-Oceans [2019]

- Large degree of covariability among pigments
- Limits number of PFT groups can be retrieved using **HPLC pigments**

A Net Primary Production (NPP) algorithm for application to PACE OCI

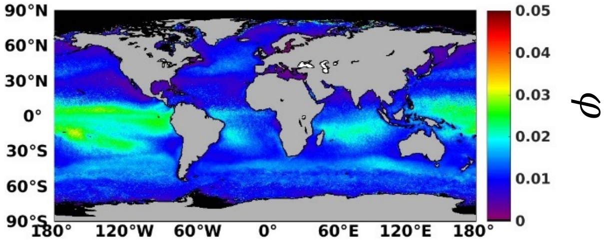
<u>Team members:</u>

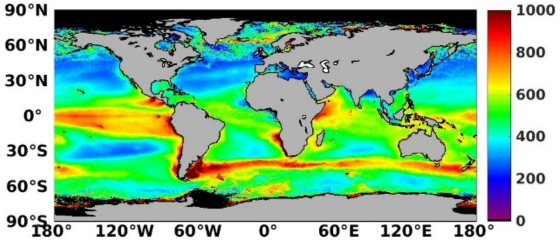
Toby Westberry (PI)

Mike Behrenfeld (Co-I)

Jason Graff (Co-I)

Keywords: Phytoplankton, photosynthesis, primary production, biomass, physiology, photoacclimation, fluorescence, growth rate

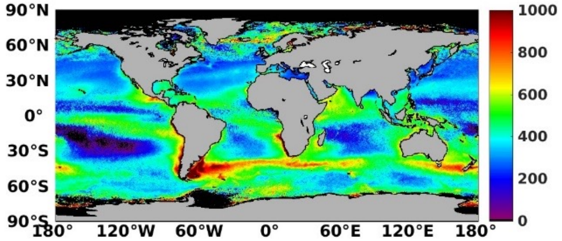




→

$$\Delta NPP = \left(\frac{\varphi}{\varphi_{thresh}} - 1\right)$$

∫ΔNPP = 10.9 Pg C

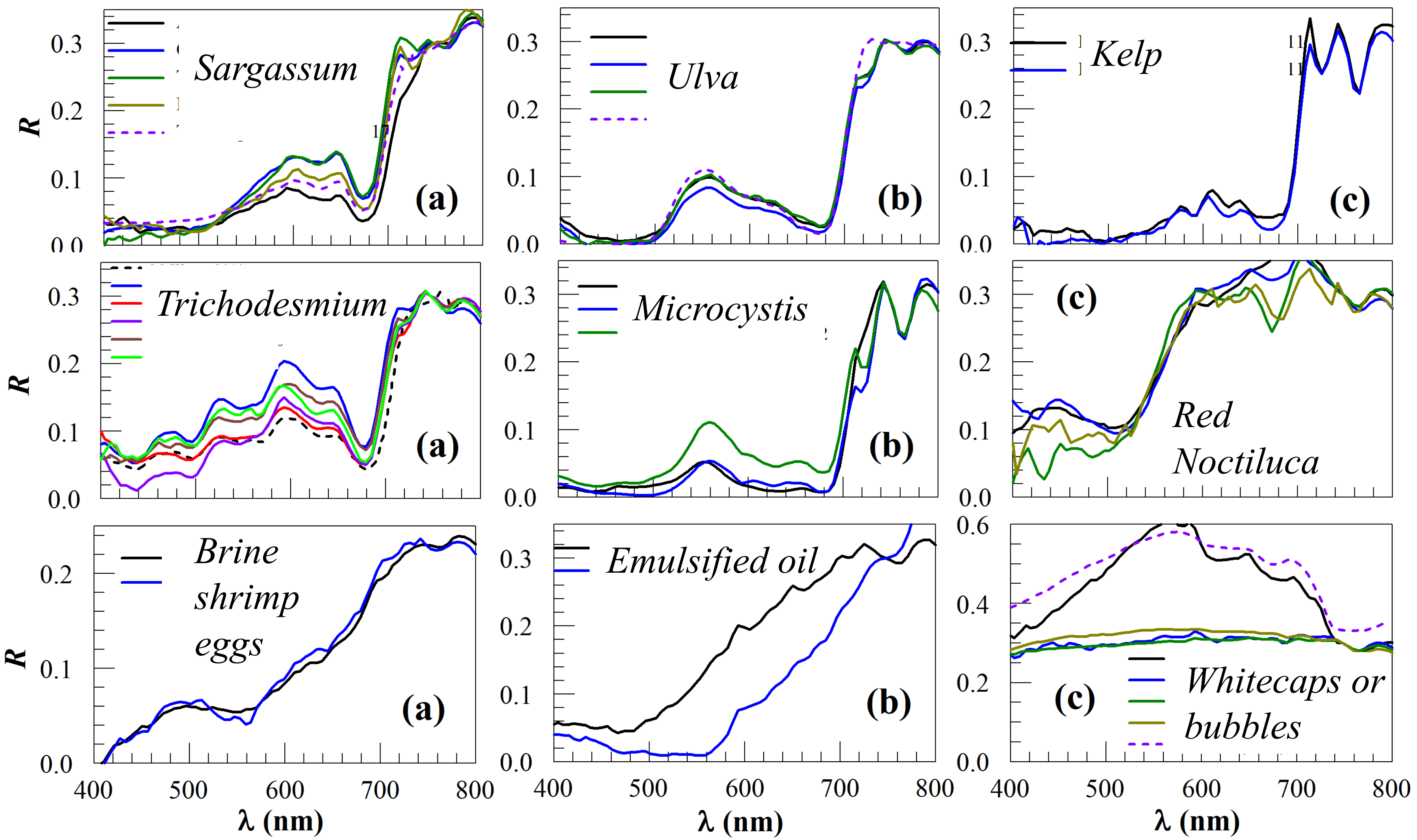


PACE measurements of *Sargassum* macroalgae

Project PI: Chuanmin Hu, University of South Florida

Co-PIs: Brian Lapointe (FAU) and Gustavo Goni (NOAA)

Examples with HICO



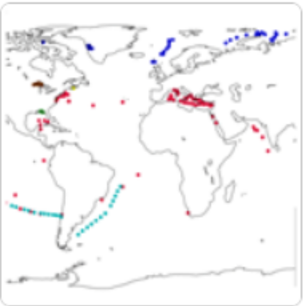
Hyperspectral Data is *critically needed* for algorithm development and validation

Earth Syst. Sci. Data, 12, 1123–1139, 2020
https://doi.org/10.5194/essd-12-1123-2020

ESSD | Articles | Volume 12, issue 2

Article | Assets | Peer review | Metrics | Related articles

Data description paper 19 May 2020



A global compilation of in situ aquatic high spectral resolution inherent and apparent optical property data for remote sensing applications

Kimberly A. Casey[1,2], Cecile S. Rousseaux[1,3,4], Watson W. Gregg[1,3], Emmanuel Boss[5], Alison P. Chase[5], Susanne E. Craig[4,6], Colleen B. Mouw[7], Rick A. Reynolds[8], Dariusz Stramski[8], Steven G. Ackleson[9], Annick Bricaud[10], Blake Schaeffer[11], Marlon R. Lewis[12], and Stéphane Maritorena[13]

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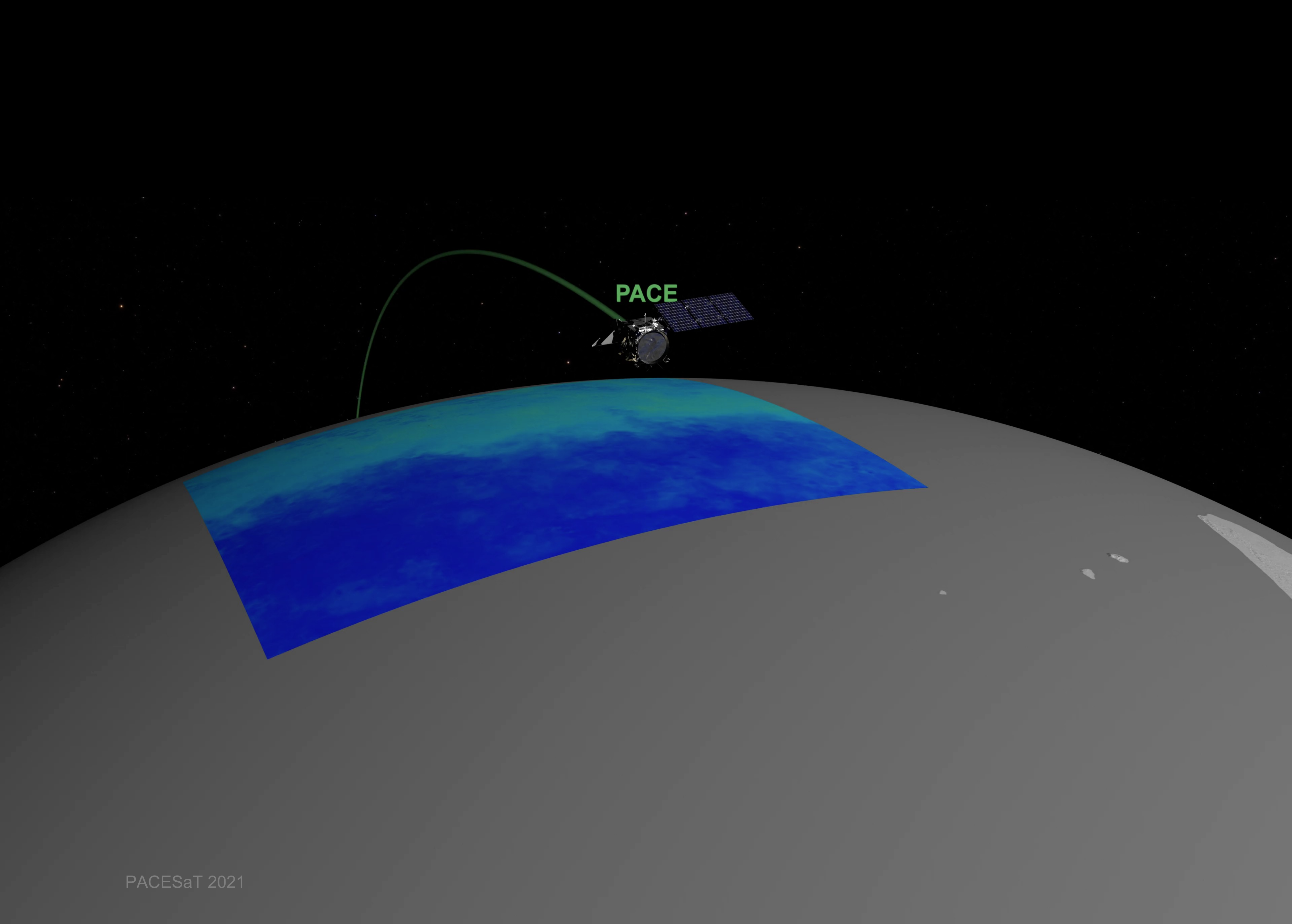
Received: 17 Jun 2019 – Discussion started: 22 Jul 2019 – Revised: 05 Dec 2019 – Accepted: 23 Jan 2020 – Published: 19 May 2020

PACE, GLIMR, SBG Synergies

What are the Opportunities for Synergies between Missions Pre-launch (2022-2024)?

- Collection of **new hyperspectral datasets** shared across missions
    - Simulated data with more realistic assumptions
    - Field and airborne campaigns proposed for all missions
- Development of **common algorithms and data products** across three science teams
- Shared working groups to better characterize aquatic biodiversity in terms of **phytoplankton community composition**
- Shared methods for calculating and distributing **Uncertainties** for products
- Development of **Coupled Ocean-Atmosphere Modeling** to achieve better joint retrievals
- Joint efforts to conduct **Vicarious Calibration and Product Validation**

Dr. Heidi Dierssen, UConn



Questions