National Aeronautics and Space Administration

NASA

Ocean Color Research Team Meeting

27-28 Oct 2021

Virtual, Day 2

EXPLORE EARTH

Laura Lorenzoni, Program Manager

Joel Scott, Program Scientist

Welcome to Day 2

NASA Ocean Biology and Biogeochemistry Program

Virtual Platform Logistics

- WebEx Meetings virtual platform is being used to host our meeting.

- Please enter your full first/preferred and last name as your display/screen name.
  Please refrain from using initials or nicknames.
  You are welcome to add your pronouns to your display name.

- If you experience technical issues during the meeting, please send a private message directly to one of the hosts, Laura or Joel, using the chat feature.

- All attendees should have entered the meeting on ***mute*** with their cameras off.
  Please stay on mute with your camera off to preserve bandwidth, unless you are presenting.

Meeting Logistics

- Your meeting hosts are **Laura Lorenzoni** and **Joel Scott**.
- Presenters will receive a verbal, 1-minute warning when nearing the end of their allotted time. Please provide verbal cues to advance your slides.
- Please submit questions for the presenters through the chat and they will be answered, time permitting. Presenters, please check the chat after your presentation to follow-up on any questions.
- We will run from 1-4p ET with a break scheduled midway. Presenters, please keep to your allocated length to be respectful of everyone's time.
- Meeting proceedings (including slides notes) will be made public after the meeting via the Ocean Color website. https://oceancolor.gsfc.nasa.gov/meetings/

Code of Conduct

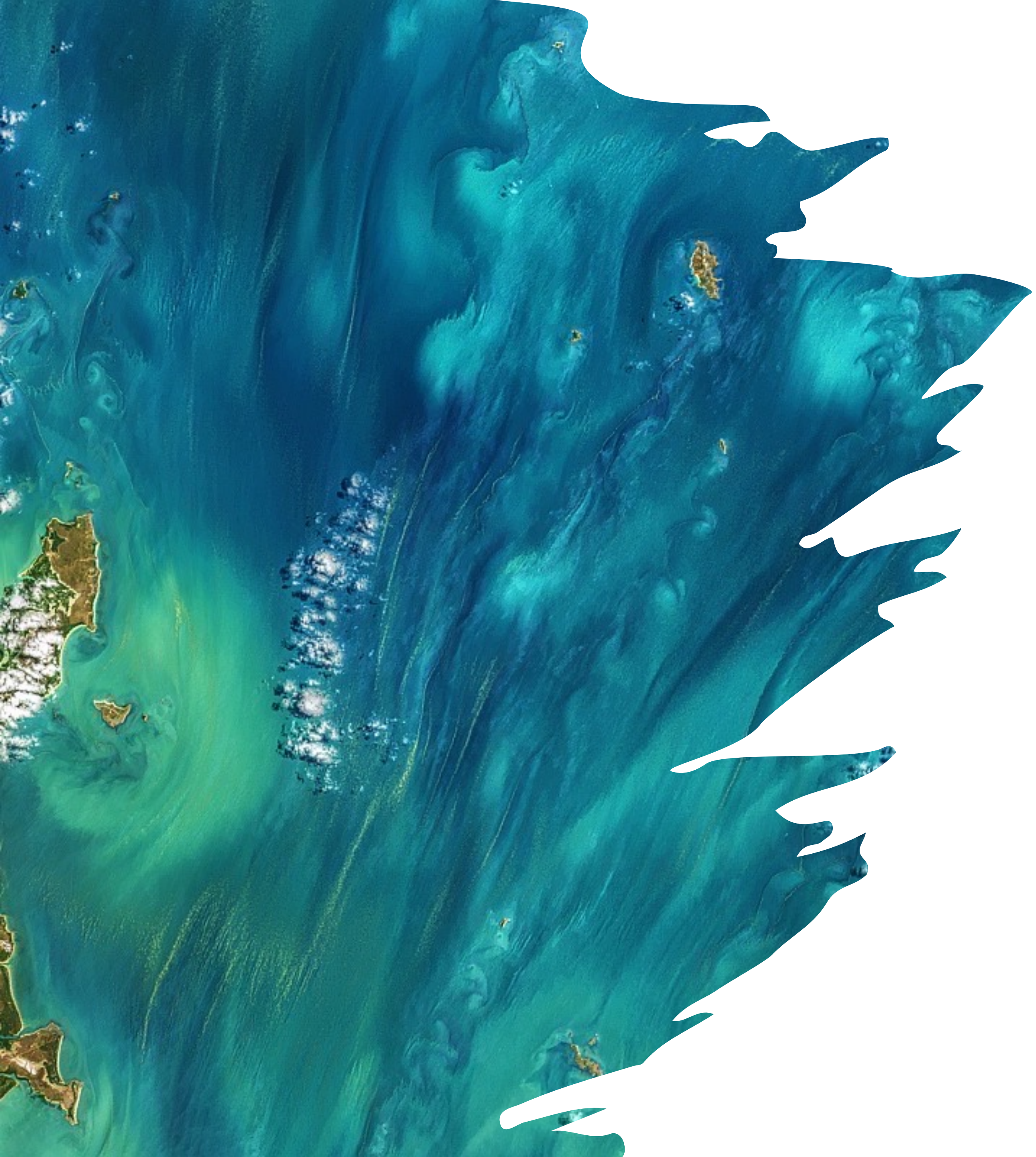
- Expected Behavior
  All participants are to...
  - Be treated with respect and consideration, valuing a diversity of views and opinions
  - Be considerate, respectful, and collaborative
  - Communicate openly with respect for others, critiquing ideas rather than individuals
  - Avoid personal attacks directed toward other participants
  - Be mindful of your virtual surroundings and of your fellow participants
  - Alert a host if you notice a dangerous situation or someone in distress
  - Respect the rules and polices of the virtual meeting space

- Unacceptable Behavior
  - Harassment, intimidation, or discrimination of any form will not be tolerated
  - Physical or verbal abuse of any participant
  - Examples of unacceptable behavior include, but are not limited to, verbal comments related to gender, sexual orientation, disability, physical appearance, body size, race, religion, national origin, inappropriate use of nudity and/or sexual images in the meeting space or in presentations or threatening or stalking of any participant.
  - Disruption of proceedings, panels, discussions, and/or lightning talks.

Code of Conduct (continued)

- Expected Behavior
  - Anyone requested to stop unacceptable behavior is expected to comply immediately.
  - Hosts may take any action deemed necessary and appropriate, including immediate removal from the meeting without warning.

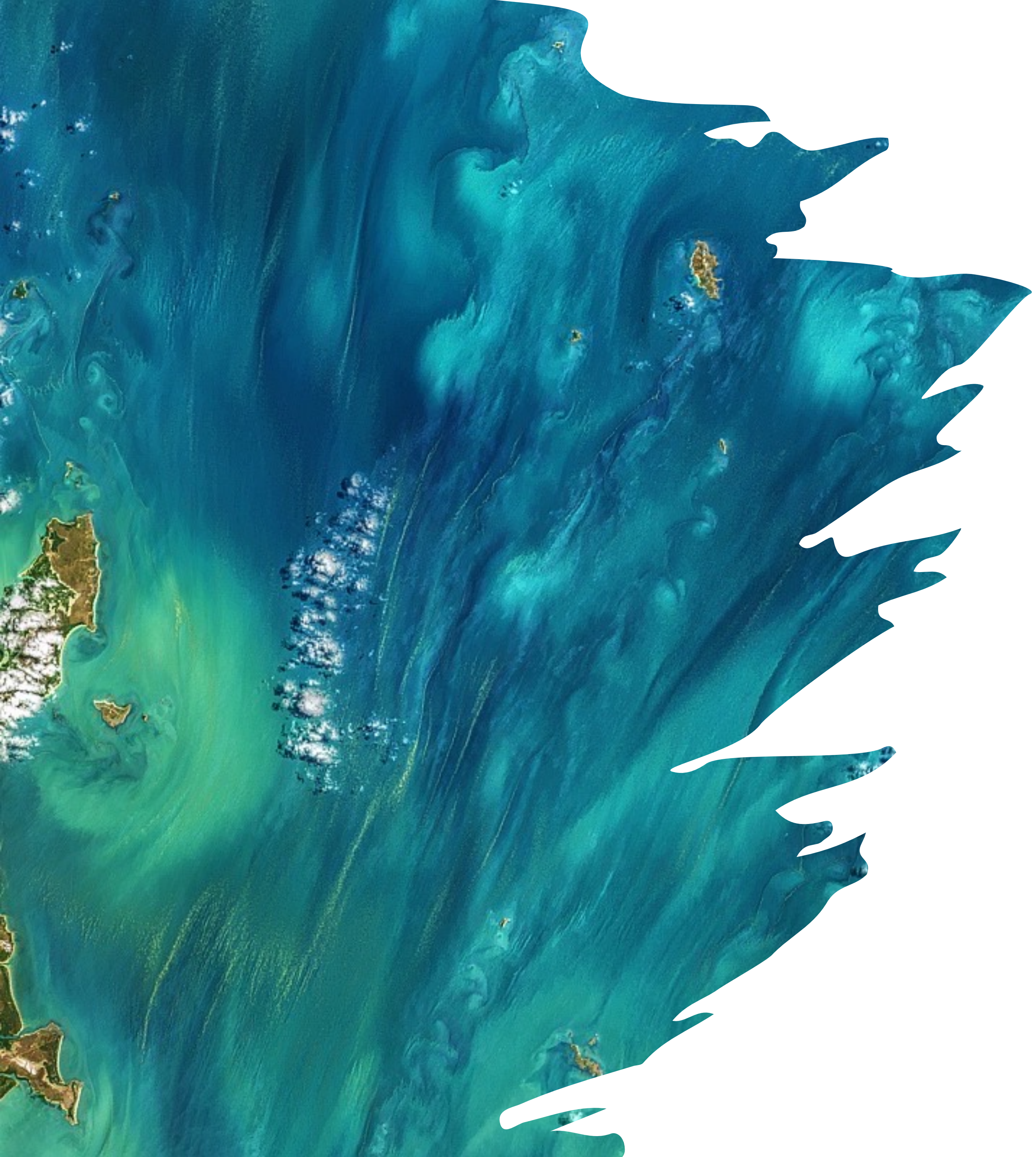
- Reporting Unacceptable Behavior
  - If you are the subject of unacceptable behavior or have witnessed any such behavior, please immediately notify a meeting host.
  - Notification should be done by contacting a host via direct chat or emailing your concern to laura.lorenzoni@nasa.gov or joel.scott@nasa.gov.
  - Anyone experiencing or witnessing behavior that constitutes an immediate or serious threat to public safety is advised to contact 911 or your local emergency number.



Agenda

October 27 (1-5p ET)
Day 1 focused on updates from NASA HQ and NASA OBB science, recent field campaigns, and research being conducted by MUREP awardees and early career scientists.

October 28 (1-4p ET)
Today will focus on updates from the NASA Ocean Biology Processing Group, NASA Ocean Color Flight/Missions, and future directions of ocean color remote sensing and OBB.



Thursday, October 28

- 1:00-1:05 Introduction to the afternoon/recap – **L. Lorenzoni**/NASA Headquarters
- 1:05-1:30 NASA Ocean Biology Processing Group Update – **B. Franz**/NASA GSFC
- 1:30-1:50 Field Program Support Group Update – **A. Mannino**/NASA GSFC
- 1:50-2:10 SeaBASS – **C. Proctor**/NASA GSFC
- 2:10-2:30 Flight program updates (PACE and PACE SVC) – **J. Werdell**/ NASA GSFC
  2:30-2:40 PACE SAT updates – **H. Dierssen**/UCON
- 2:40-2:50 PACE Applications updates – **N. Sadoff**/NASA GSFC
- **2:50-3:00 BREAK**
- 3:00-3:20 GLIMR – **J. Salisbury**/UNH
- 3:20-3:30 SBG – **K. Turpie**/UMBC
- 3:30-3:40 ACCP/AOS – **Chris Hostetler**/LaRC
- 3:40-3:55 NASA Ocean Biology & Biogeochemistry Future Directions – **L. Lorenzoni**, **J. Scott**/NASA Headquarters
- 3:55-4:00 Wrap up

NASA Ocean Biology Processing Group Satellite Ocean Color Update

Bryan Franz

NASA Goddard Space Flight Center

bryan.a.franz@nasa.gov

NASA Ocean Biology Processing Group

calibration, validation, software development, (re)processing, and distribution for a multitude of ocean color sensors

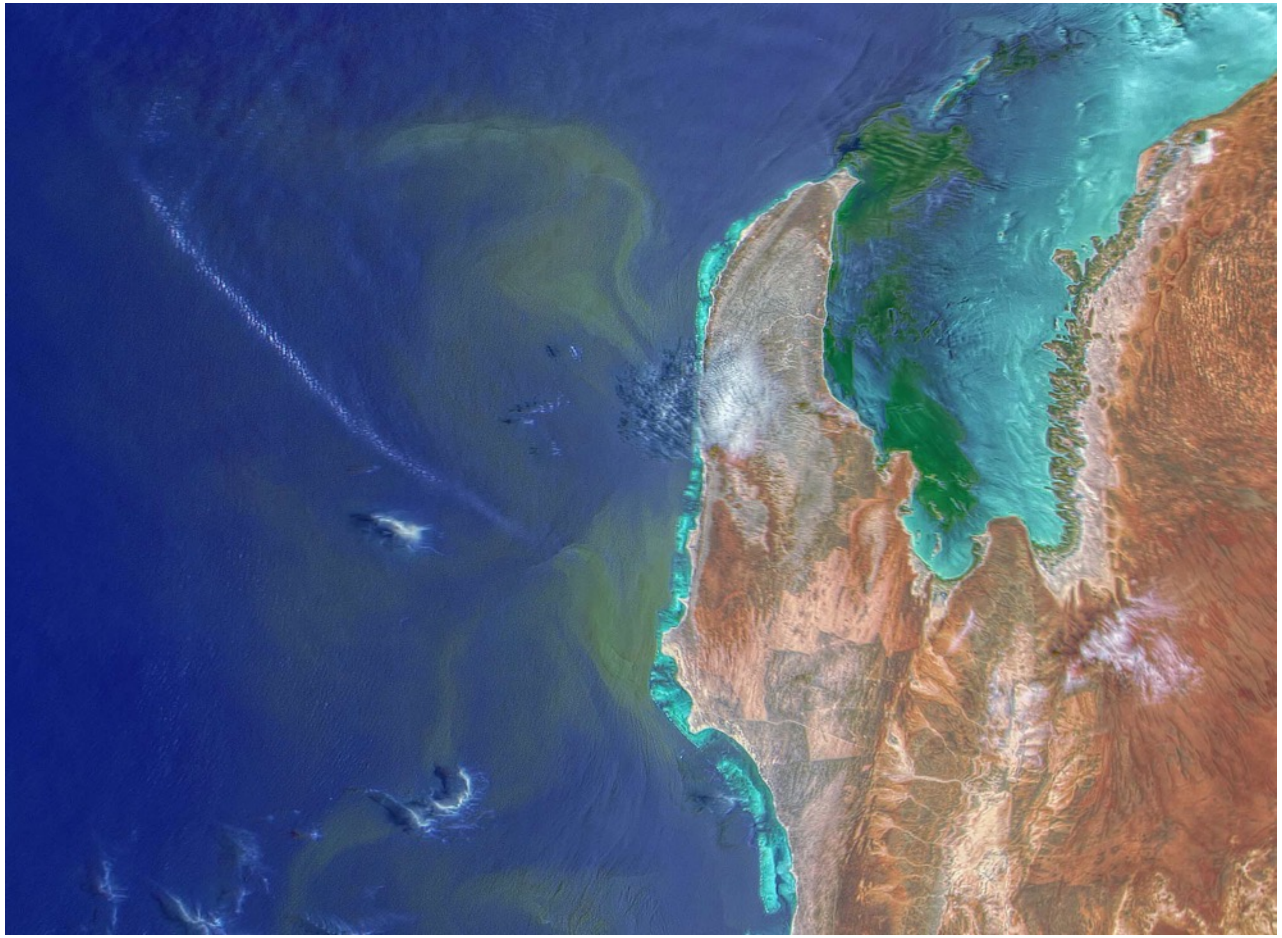
Global Processing & Distribution

- **VIIRS/JPSS1** (USA)
- **VIIRS/SNPP** (USA)
- **MODIS/Aqua** (USA)
- **MODIS/Terra** (USA)
- **OLCI/S3A** (Europe)
- **OLCI/S3B** (Europe)
- SeaWiFS (USA)
- MERIS (Europe)
- OCTS (Japan)
- CZCS (USA)

Regional Processing & Distribution

- **Hawkeye** (USA)
- GOCI (South Korea)
- HICO (USA)

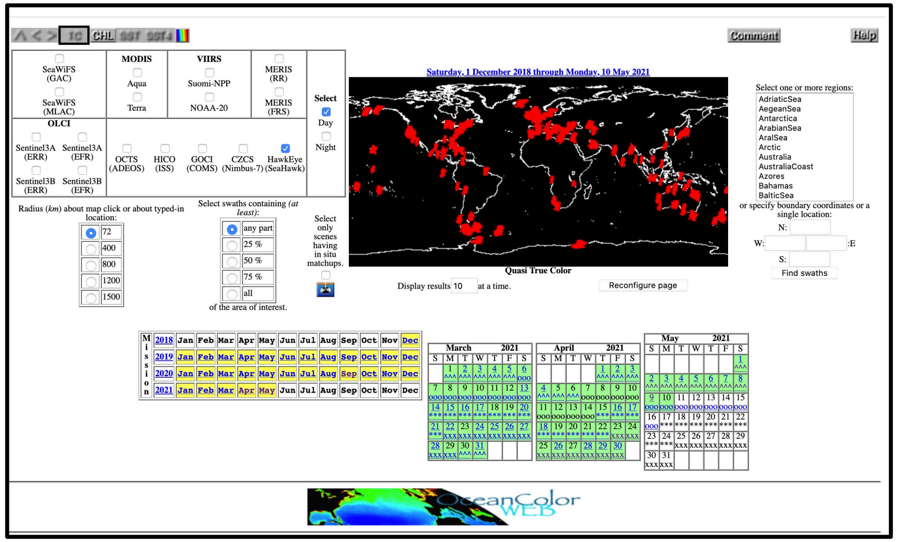
HawkEye/SeaHawk

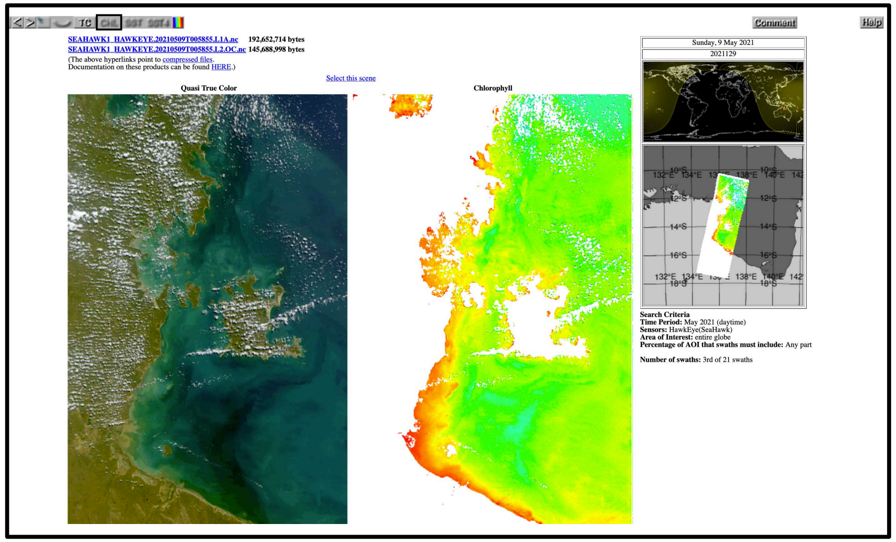


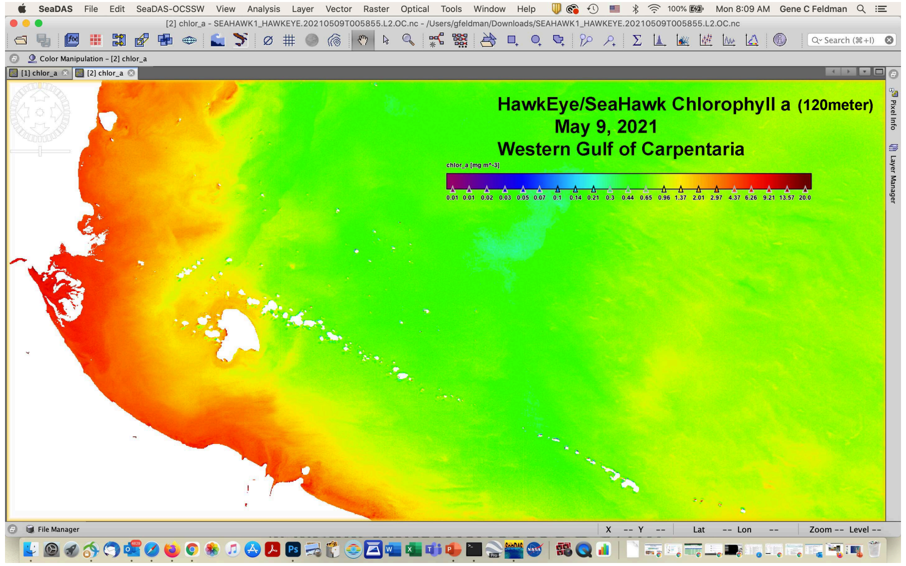
SeaHawk Fully Operational as of June 2021

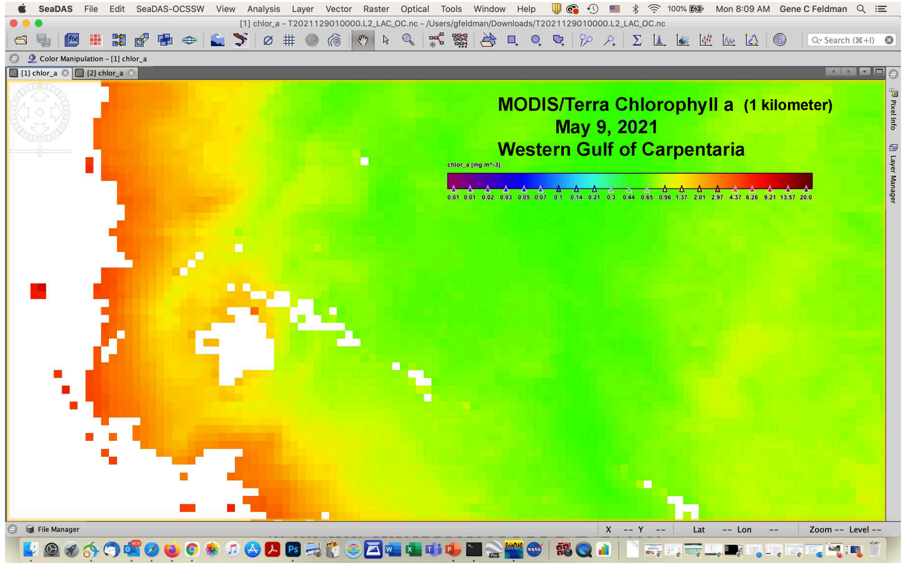
$1.6M sensor + cubesat (x2), $2.4M launch + 4 years ops

- 8 bands in vis-NIR, 120-m resolution, 200km x 700km
- over 1700 scenes collected to date
- 70-100 scenes per week anticipated
- user acquisition request system https://uncw.edu/socon/
- data access via Ocean Color Web







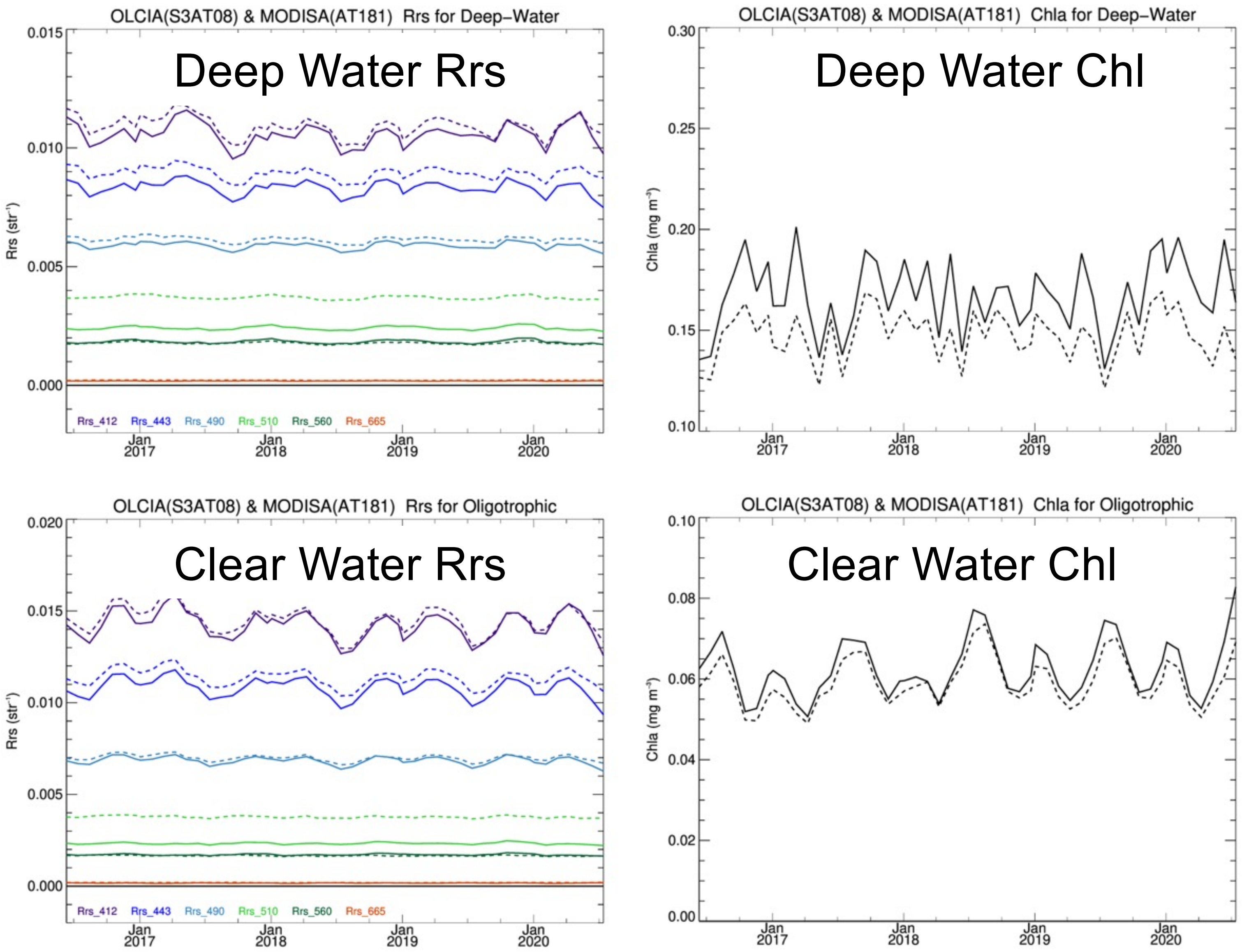


NASA OC Processing of OLCI – Coming Soon

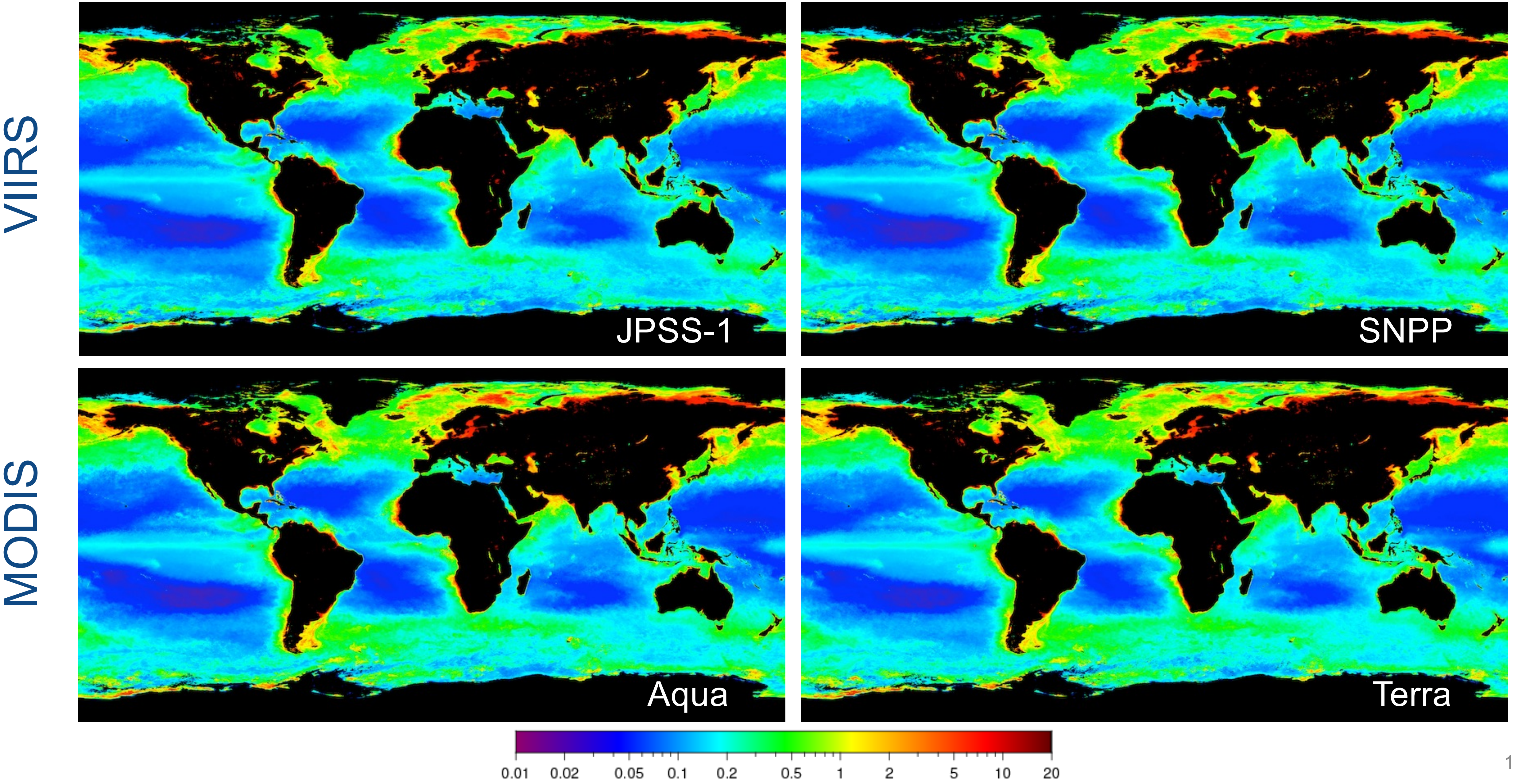
- challenge has been vicarious calibration.
- limited MOBY match-ups (narrow swath, glint losses).
- instability in MOBY-derived Lwn (deviations from norm in 2017).
- now using model-based vicarious cal and SeaWIFS chl climatology (following Werdell et al. 2007).

MOBY timeseries, nLw(412)

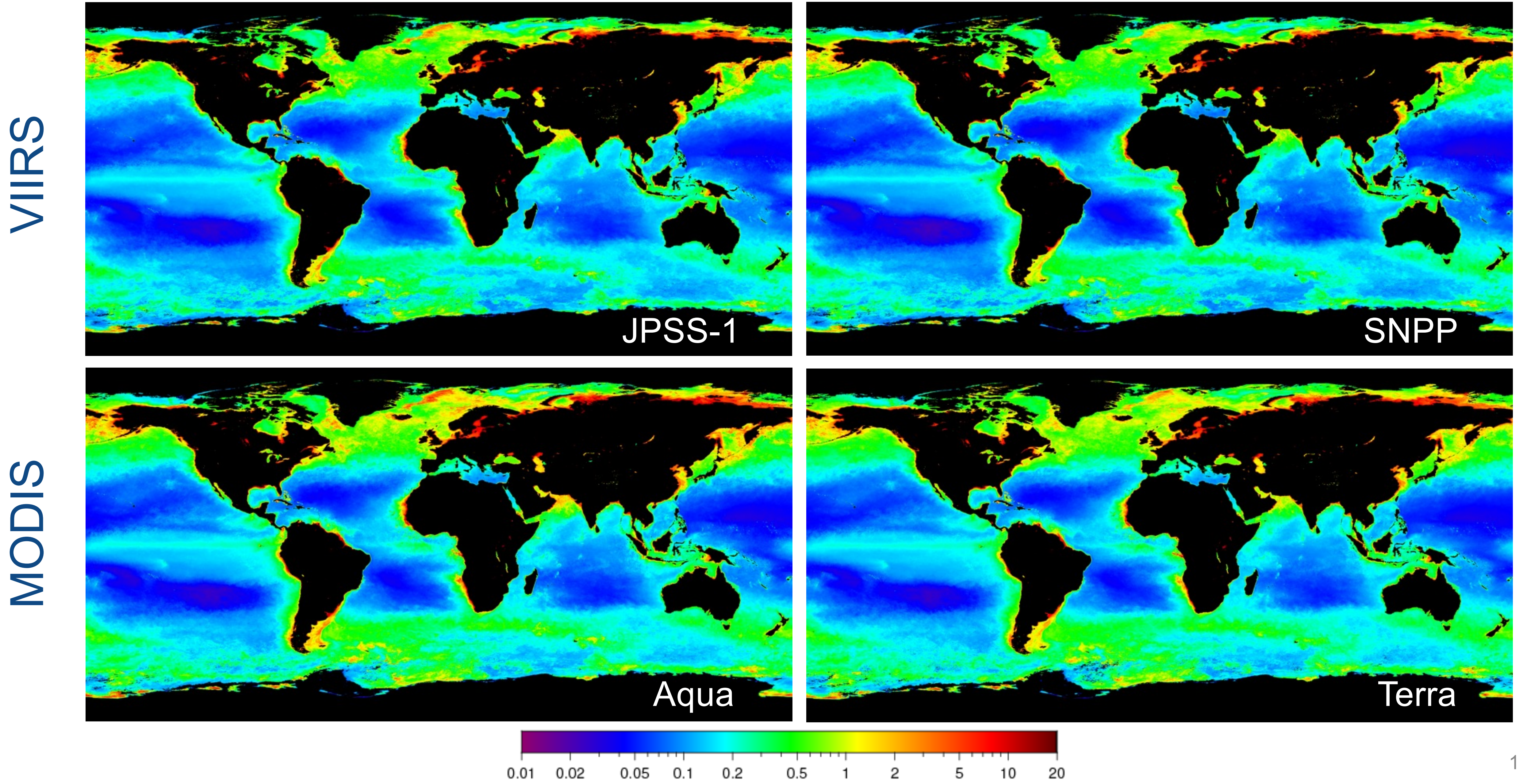
OLCI/S3A and MODIS/Aqua



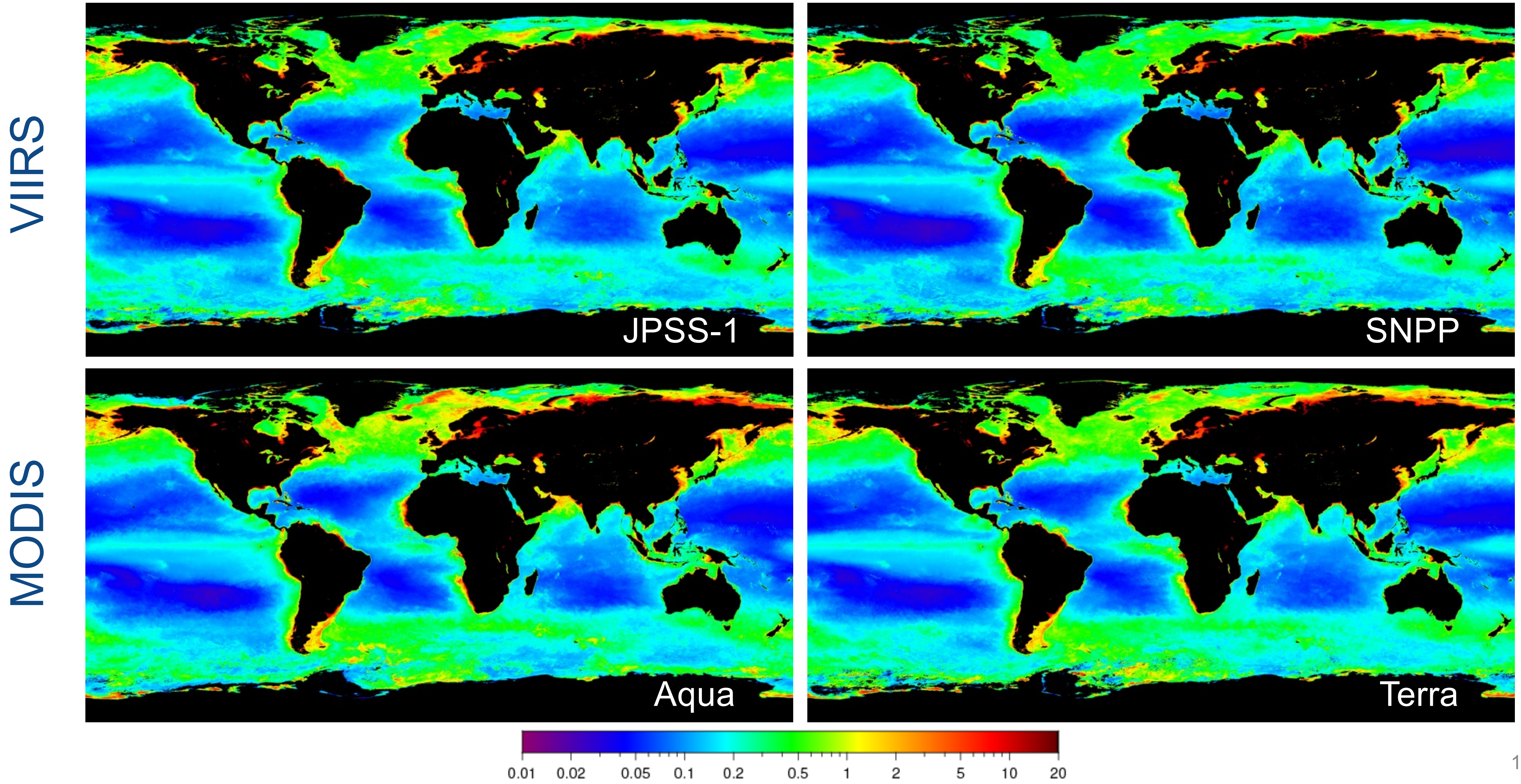
Annual Mean Chlorophyll Concentration for 2018



Annual Mean Chlorophyll Concentration for 2019

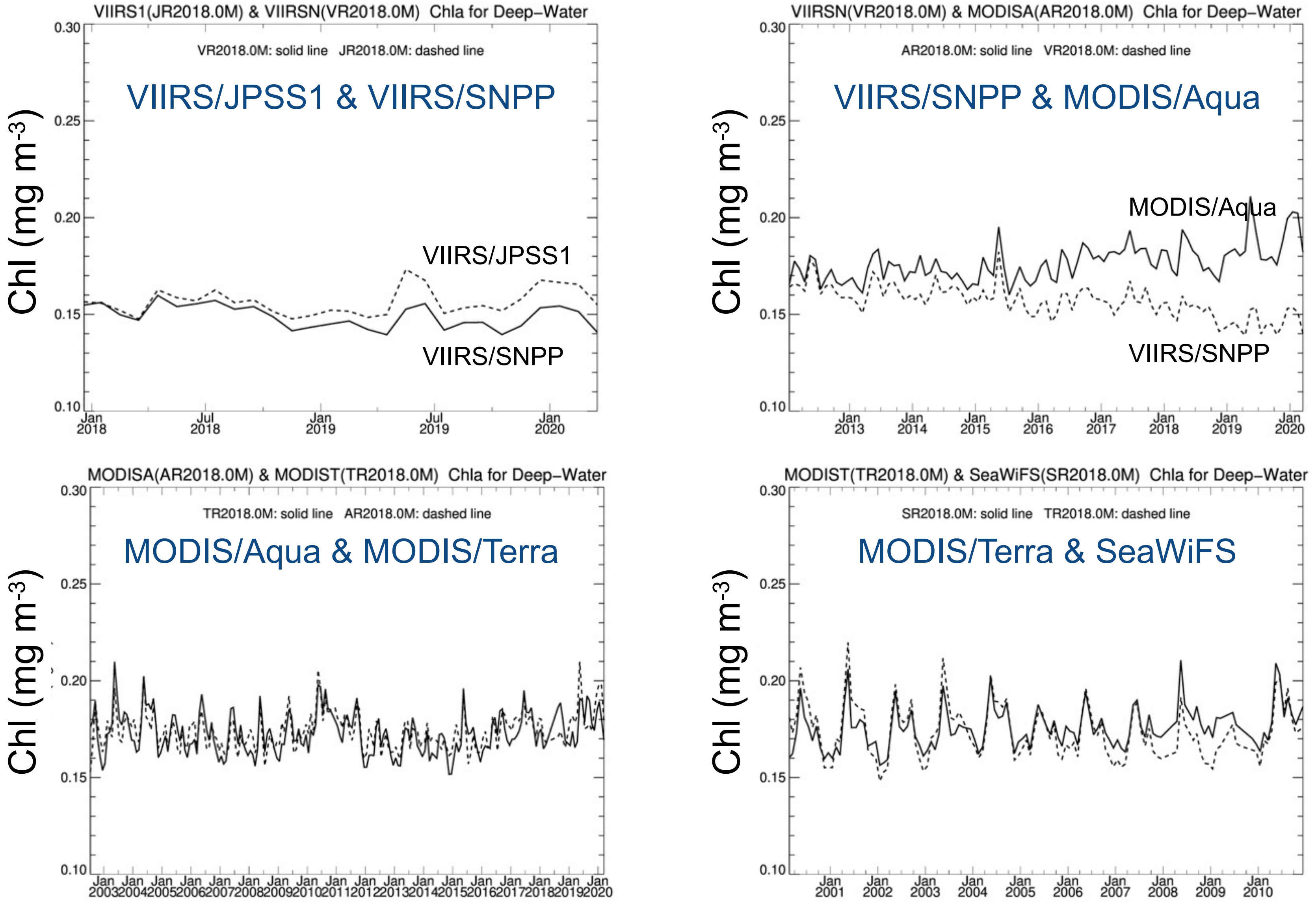


Annual Mean Chlorophyll Concentration for 2020



Global Deep-Water Chlorophyll Trends

- Comparison trends over common mission lifetime
- VIIRS/SNPP shows negative trend relative to VIIRS/JPSS1 & MODIS/Aqua
- SeaWiFS, MODIS/Terra, MODIS/Aqua in good agreement, with short-term deviations

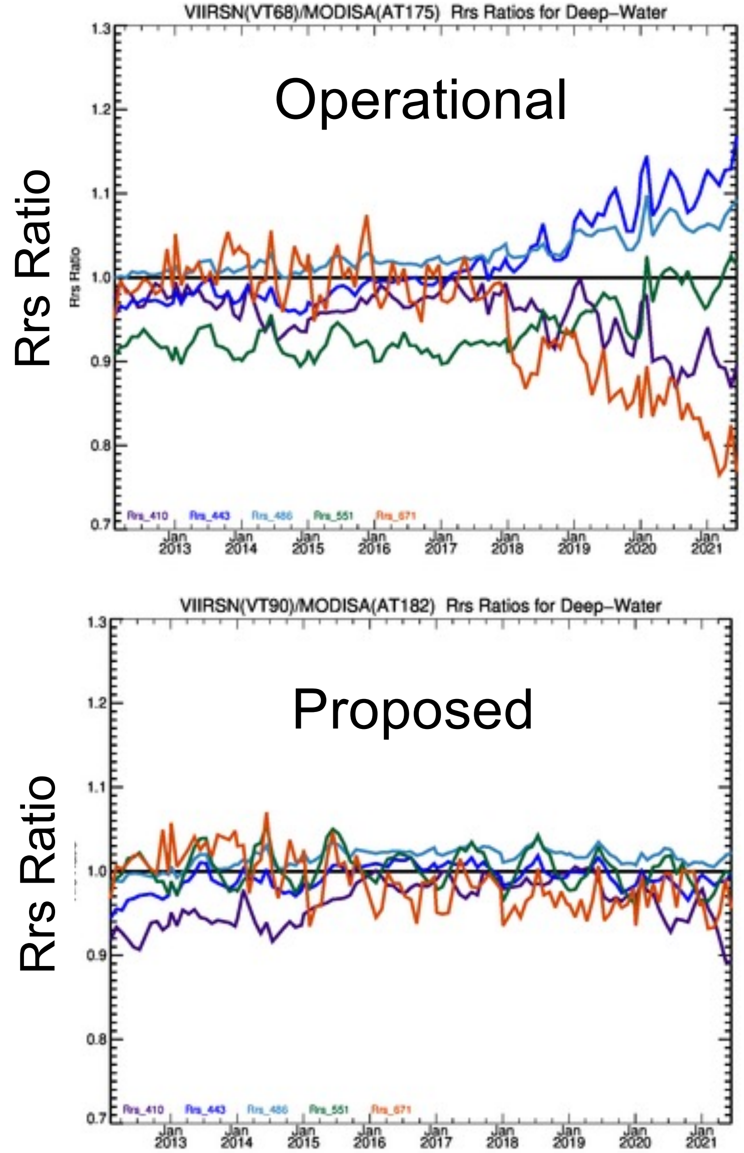


VIIRS/SNPP Calibration Update

Calibration Changes for Next Reprocessing

- **extension of lunar/solar time-series with new observations**
- revised model for fitting lunar time-series (exponential in time, linear in libration, applied to solar time-series)
- no lunar correction applied to M5,6,7 (no detectable trend)
- temporal gain adjustments for impact of modulated RSRs on ocean/atmosphere signal, for bands M1-M7
- relative detector corrections to reduce striping (flat fielding)
- **model-based vicarious calibration using chlorophyll climatology** (following *Werdell et al. 2007, Applied Optics*)

VIIRS/SNPP & MODIS/Aqua

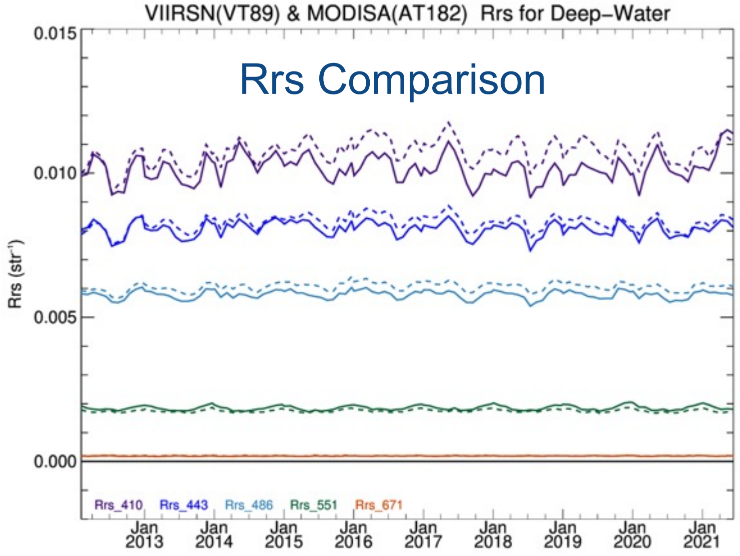


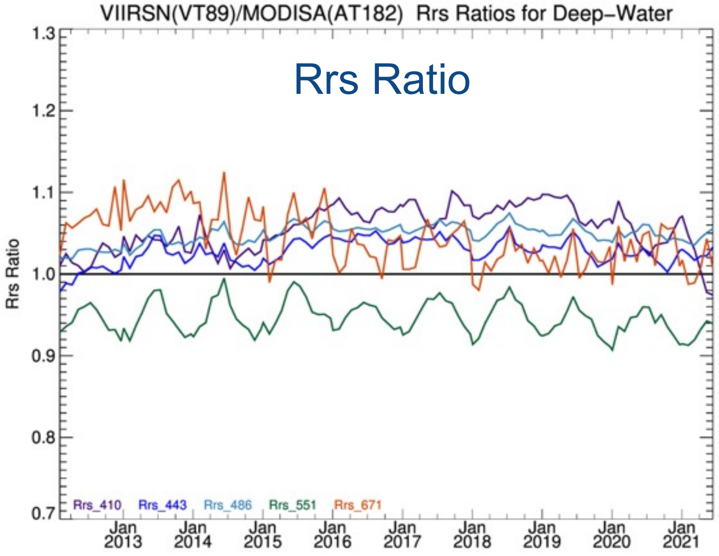
Global Deep-Water Rrs Trends

impact of SNPP/VIIRS vicarious calibration

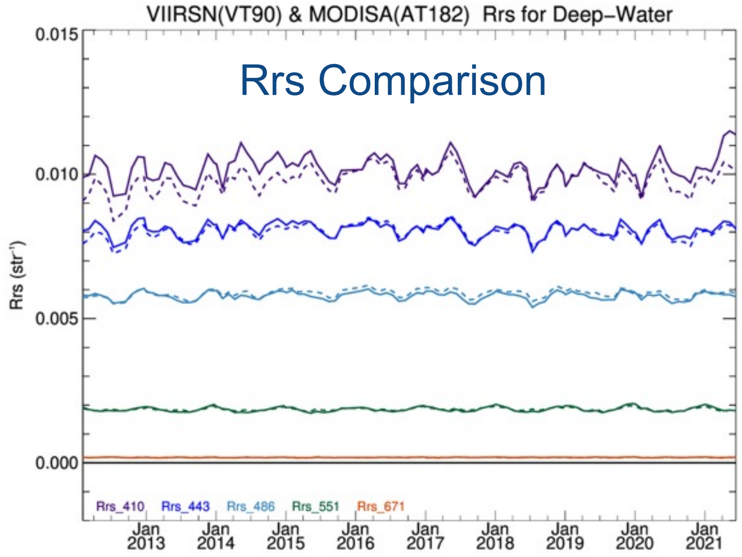
VIIRS/SNPP vs MODIS/Aqua

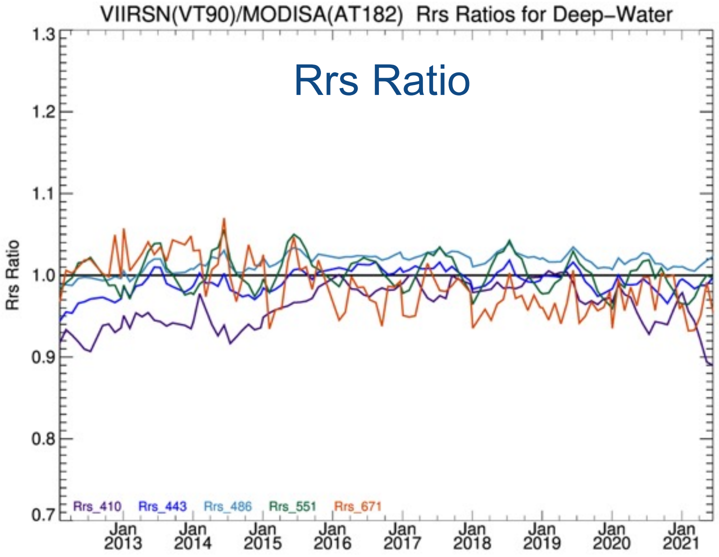
using MOBY vicarious cal
for VIIRS





using modeled vicarious cal
for VIIRS



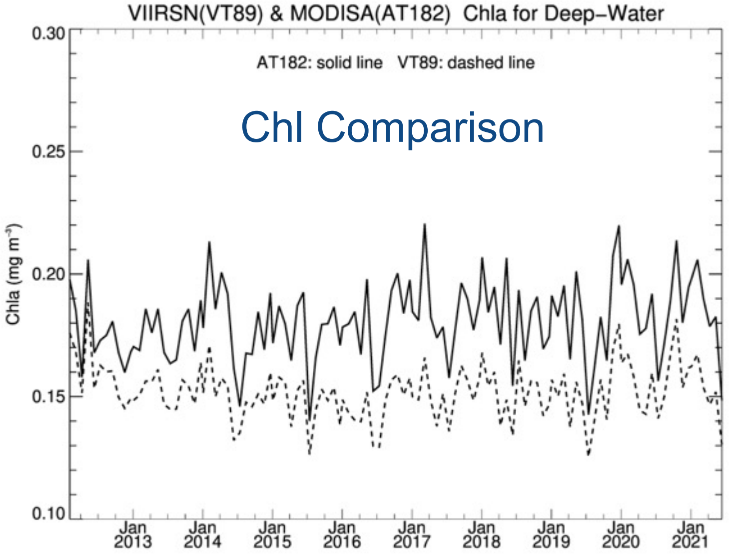


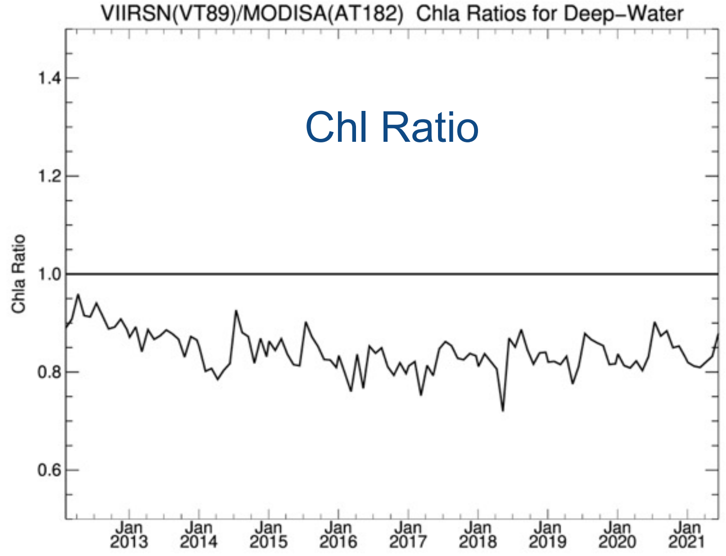
Global Deep-Water Chl Trends

impact of SNPP/VIIRS vicarious calibration

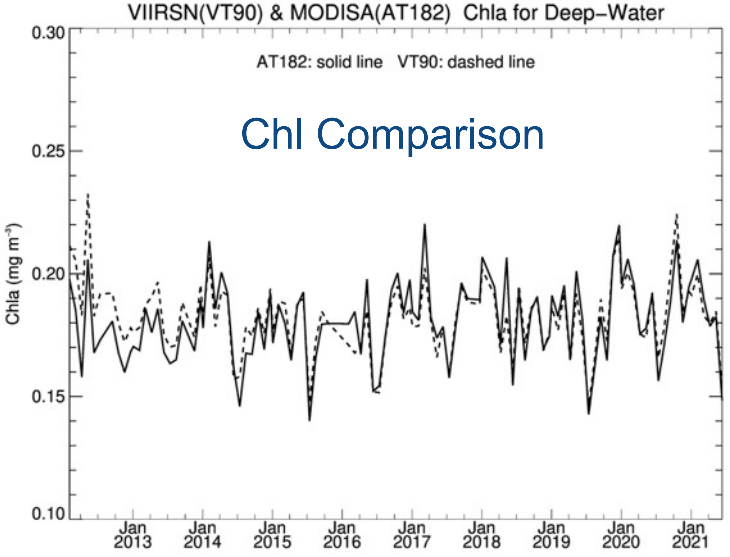
VIIRS/SNPP vs MODIS/Aqua

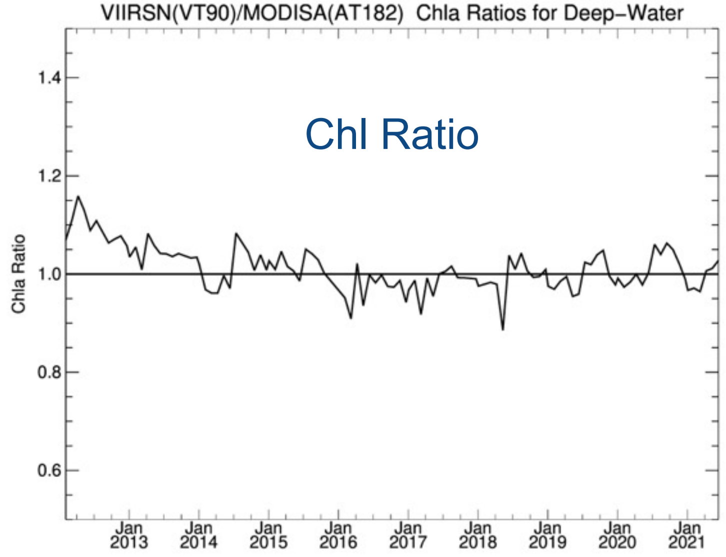
using MOBY vicarious cal
for VIIRS





using modeled vicarious cal
for VIIRS





Multi-mission Ocean Color Reprocessing Coming Soon

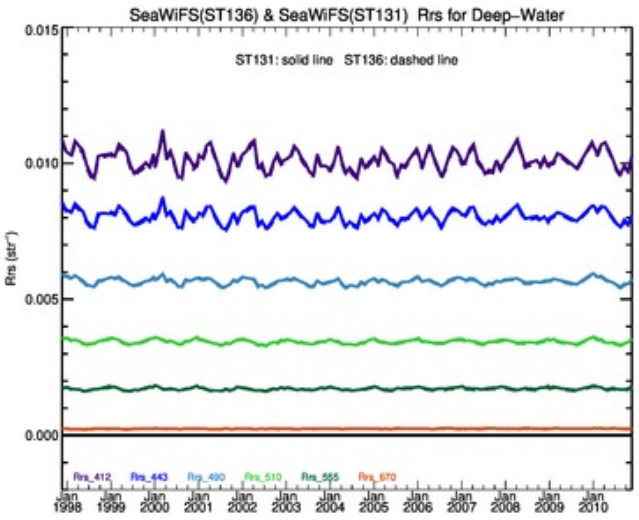
Missions:

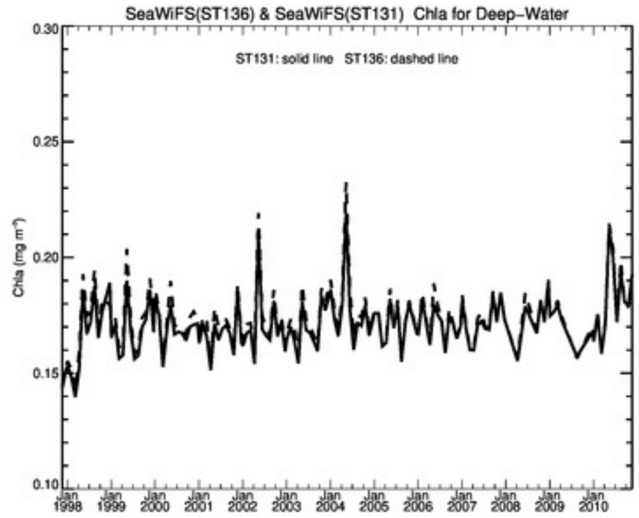
OLCI (S3A, S3B), MODIS (Aqua, Terra), VIIRS (SNPP, JPSS1), SeaWiFS, MERIS, OCTS, CZCS

Changes:

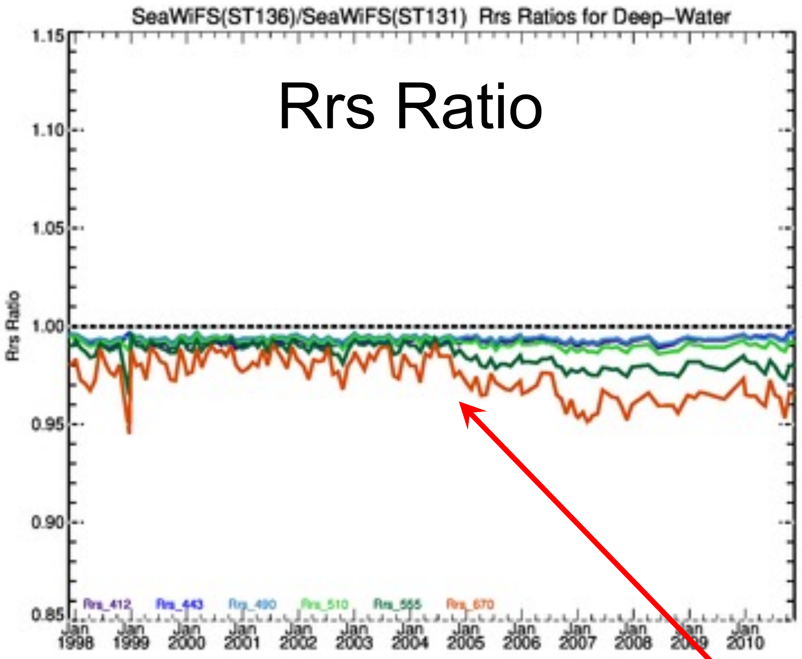
1. instrument and vicarious calibration updates
2. updates to ancillary data sources
   - from NCEP/TOMS-OMI/etc. to MERRA-2 assimilation product
3. updates to atmospheric correction methods and tables
   - multi-scattering aerosol selection, extended AOT range, improved/expanded absorbing gas corrections, Rayleigh hi-solz bug
4. updates to pure seawater optical properties (nw, aw, bbw)
   - apply temperature & salinity dependence (e.g., Werdell et al. 2013), bug in pure-water aw/bbw (off by few nm)
5. updates to masks and flags
   - reduced straylight masking (Hu et al. 2019, JGRO), absorbing aerosol flag based on MERRA-2 transport model
6. updates to derived product algorithms
   - Chl coefficient update (Hu et al. 2019, JGRO; O'Reilly and Werdell, 2019), PIC, PAR, etc.

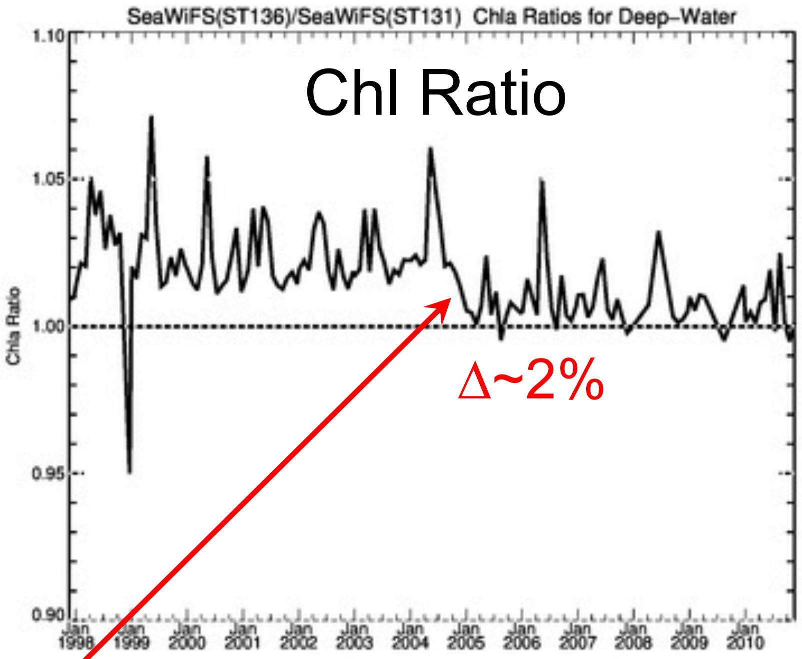
Impact of ancillary met & ozone change - SeaWiFS





ratio of global mean deep-water time-series
proposed/operational



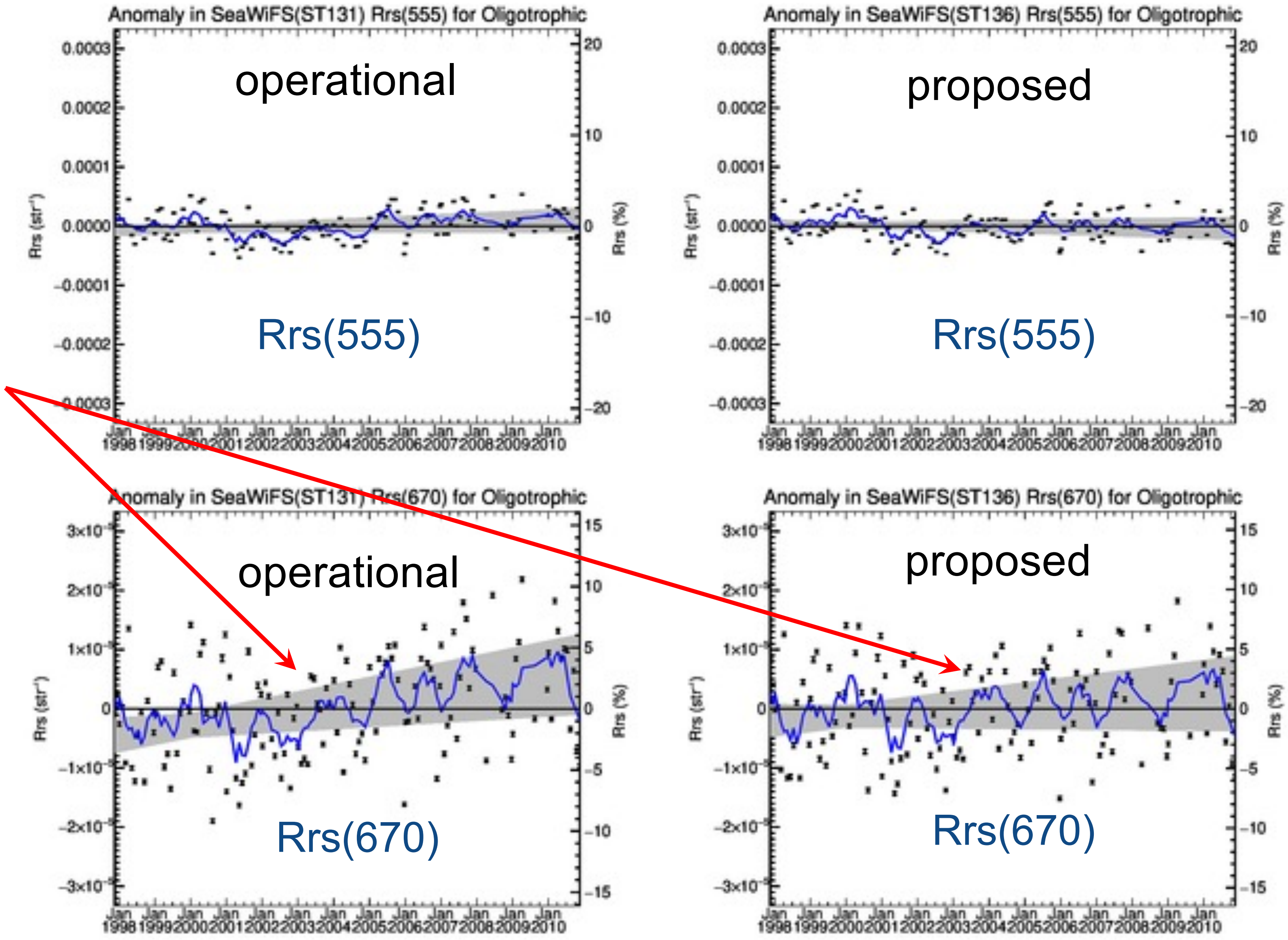


switch from EPTOMS to AURA/OMI ozone time-series Dec 2005

Impact of ancillary met & ozone change - SeaWiFS

showing de-seasonalized temporal anomalies for global oligotrophic waters

reduced discontinuity & trend due to improved consistency in ozone timeseries



CyAN

The Cyanobacteria Assessment Network

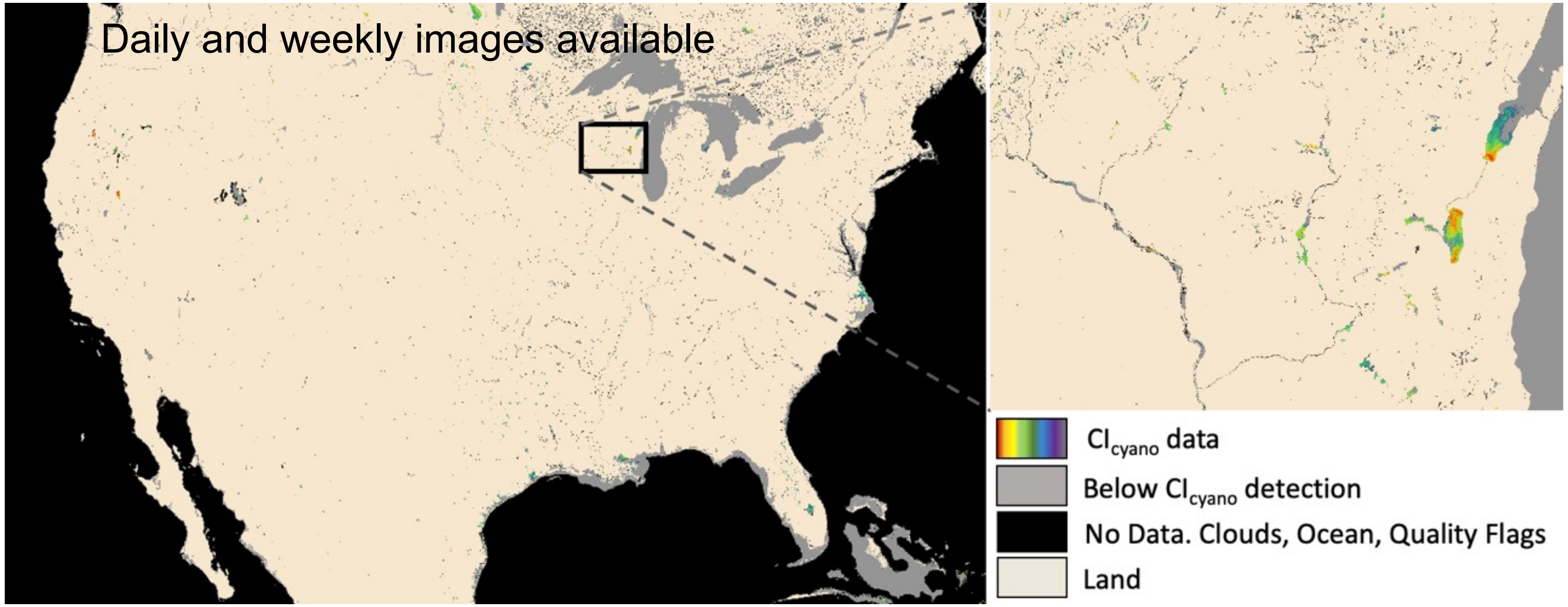
Using satellites to monitor cyanobacteria

CONUS and Alaska Coverage
MERIS, 2002-2012
OLCI, 2016-present Sentinel-3a and -3b

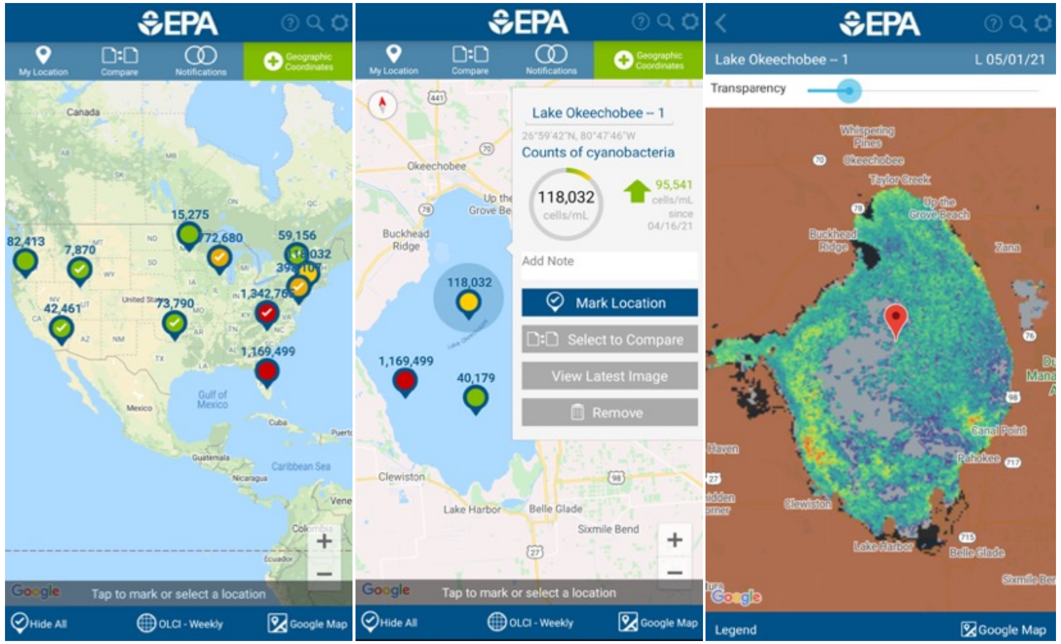
For CONUS
2,300 resolvable lakes with at least 3 pixels
15,450 waterbodies with sizes of at least 1 pixel

Exciting and recently released
Data Set now fully public
Inland Waters Data Set for CONUS and Alaska.
Providing $\rho(\lambda)$ and CI_{cyano} for inland waterbodies.
L2 files
L3-binned files
L3 standard mapped images (SMI)

Multi-agency project



CyAN App



Information distribution is a CyAN goal.

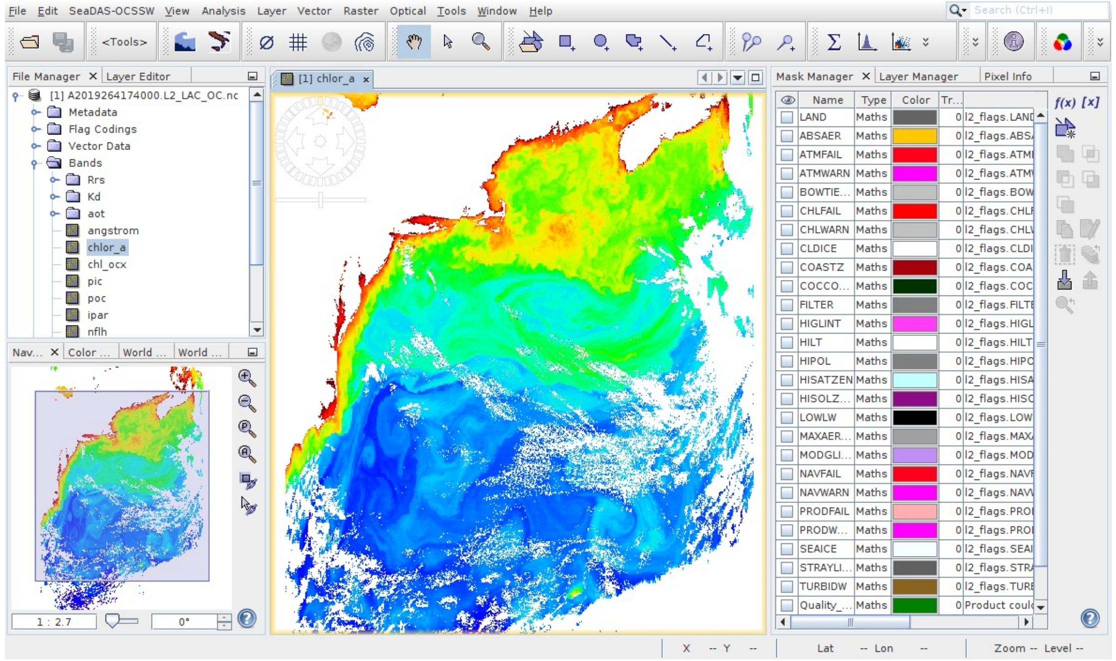
CyAN app gets data to the water managers and the public.

Web interface for all platforms
The app is for Android only.

SeaDAS 8.1.0

Collaboration with ESA SNAP Team

- Release: 8.0.0 February 2021; 8.1.0 June 2021.
- Built on SNAP framework, modified GUI
- Includes SeaDAS and Sentinel-3 Toolboxes
- Includes SeaDAS-OCSSW client-server module
- Other SNAP Toolboxes can also be installed.
- Enables continuation of joint development in visualization tools and capabilities.



SeaDAS 8 GUI

SeaDAS Toolbox

- NASA ocean color processing codes with GUI interface, and additional analysis tools.
- Can also be installed within SNAP.

SNAP = Sentinel Application Platform (developed for ESA by Brockmann Consult)

OceanColor Processing Support

Hawkeye, OCI/PACE, VIIRS (JPSS1, SNPP), MODIS(Terra, Aqua), OLCI(S3A, S3B), MERIS, SeaWIFS, GOCI, OLI(L8), ETM(L7), TM(L5), MSI(S2A,S2B), Aquarius, HICO, OCTS, CZCS, OSMI, OCM(1,2), MOS, SGLI

OB.DAAC User Working Group

What is a UWG?

- represents the science user community by providing recommendations for improvement of archive content and services provided
- more of a 'market focus group' for the DAAC than a formal NASA committee
- meets in person once a year, with quarterly teleconferences if deemed necessary
- membership comprised of users, data providers, NASA HQ, the DAAC, and ESDIS

Sounds great! Tell me more!

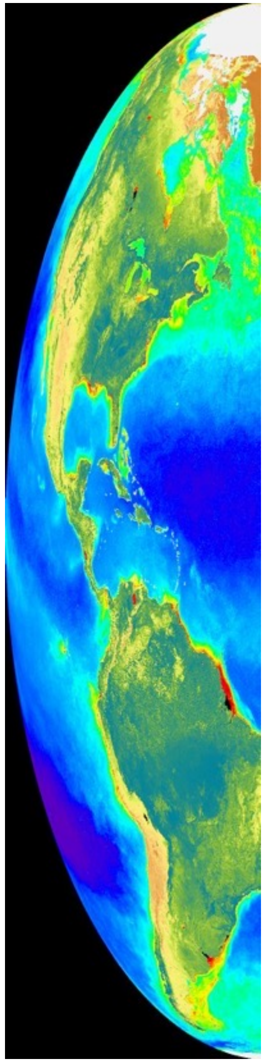
- a charter is being drafted
- invitations for membership will be sent soon
- first meeting anticipated for Winter/Spring 2022 (virtual)

Sounds great! How do I get involved?

If you would like to self-nominate (or nominate a colleague) for membership, please send an email to:

Sean.W.Bailey@nasa.gov

Summary



- Next multi-mission ocean color reprocessing coming soon (calibration updates, algorithm refinements)
- MODIS (Aqua & Terra) R2018.0 product quality/consistency still good, with reduction in detector, mirror-side, scan artifacts expected in next reprocessing (EOL 2025/26).
- SNPP VIIRS R2018.0 products showing significant late-mission drifts, largely resolved through updated instrument calibration to be applied in next reprocessing
- JPSS1 VIIRS R2018.0 products available, instrument is very stable with no temporal calibration yet required, some detector striping will be corrected in next reprocessing
- Consistently-processed L2/L3 OLCI products from S3A & S3B coming with next reprocessing (L1B currently available from OB.DAAC)
- Still supporting heritage missions (SeaWiFS, GOCI, HICO, etc.), and leveraging OBPG facilities for CyAN, SeaHawk, PACE, and GLIMR
- Contact Sean Bailey if interested in contributing to the OB.DAAC UWG

Field Support Group Update

Antonio Mannino

NASA Goddard Space Flight Center

antonio.mannino@nasa.gov

Field Support Group Update

Antonio Mannino
NASA Goddard Space Flight Center

- Introduction
- FSG Activities
- *in situ* Protocol updates
- Software tool
- Preparing for PACE
- Field work efforts

Core members:
Joaquin Chaves, Scott Freeman, Chris Kenemer, Aimee Neeley, Mike Novak & Crystal Thomas

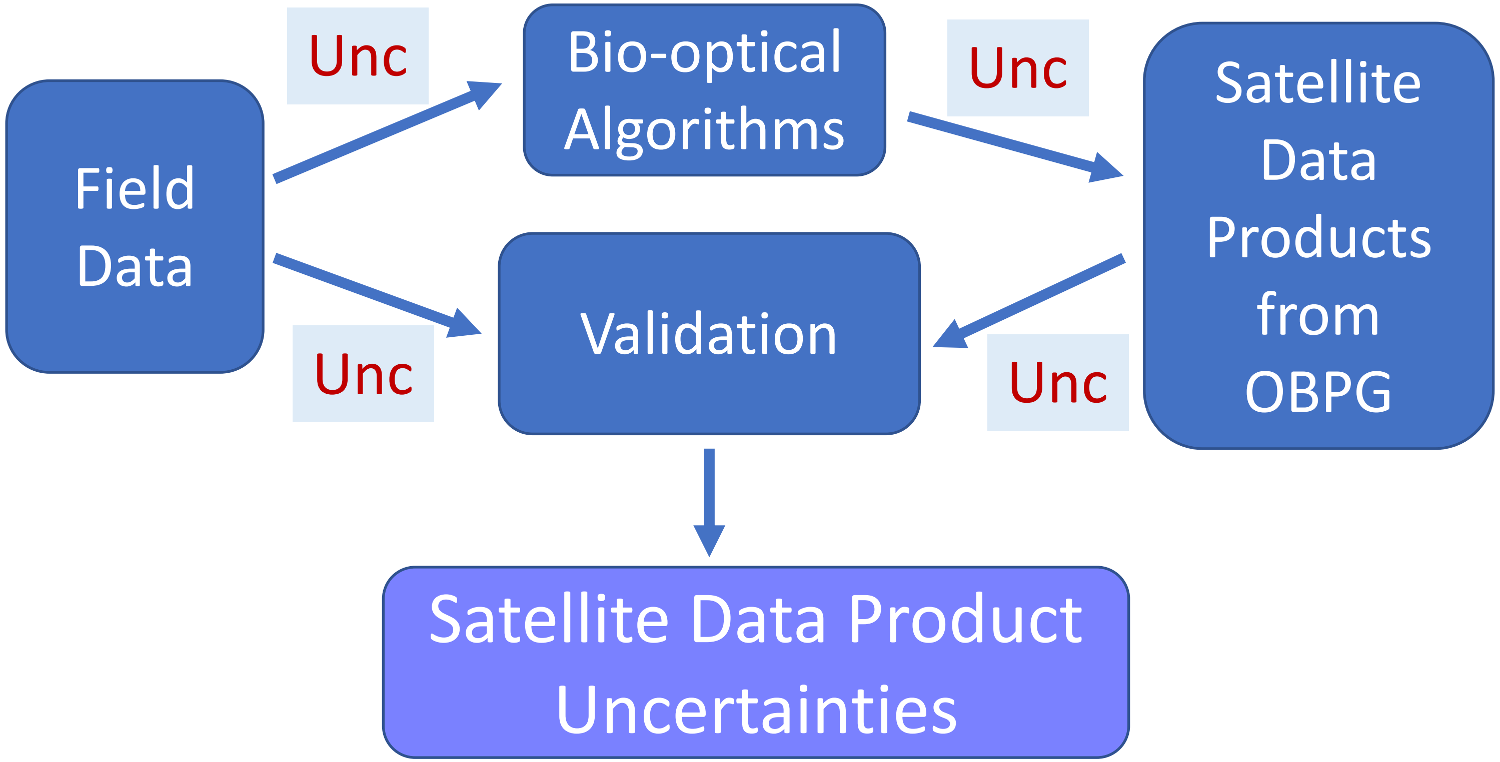
New core hires:
Harrison Smith (August 2021) & Chelsea Lopez (Sept. 2021)

Other contributors to FSG activities:
Andrea Andrew, Dirk Aurin, Paul Sobchenko, Ryan Vandermeulen

NASA OCRT Meeting – 27-28 October 2021

Why are field data necessary?

Why is knowing their uncertainties important?



- Both *satellite-derived data* and the *field measurements* have inherent uncertainty.
- Knowing and improving upon *field measurement* uncertainties allows for higher fidelity algorithms, satellite data products, and models.

Field & Lab activities in support of NASA

our Mission Statement:

Engage in activities to ensure the quality of NASA's optical and biogeochemical field datasets used in the development of Ocean Color (OC) satellite algorithms and in the validation of OC satellite data products (and models).

THIS IS CRITICAL TO PACE'S SUCCESS

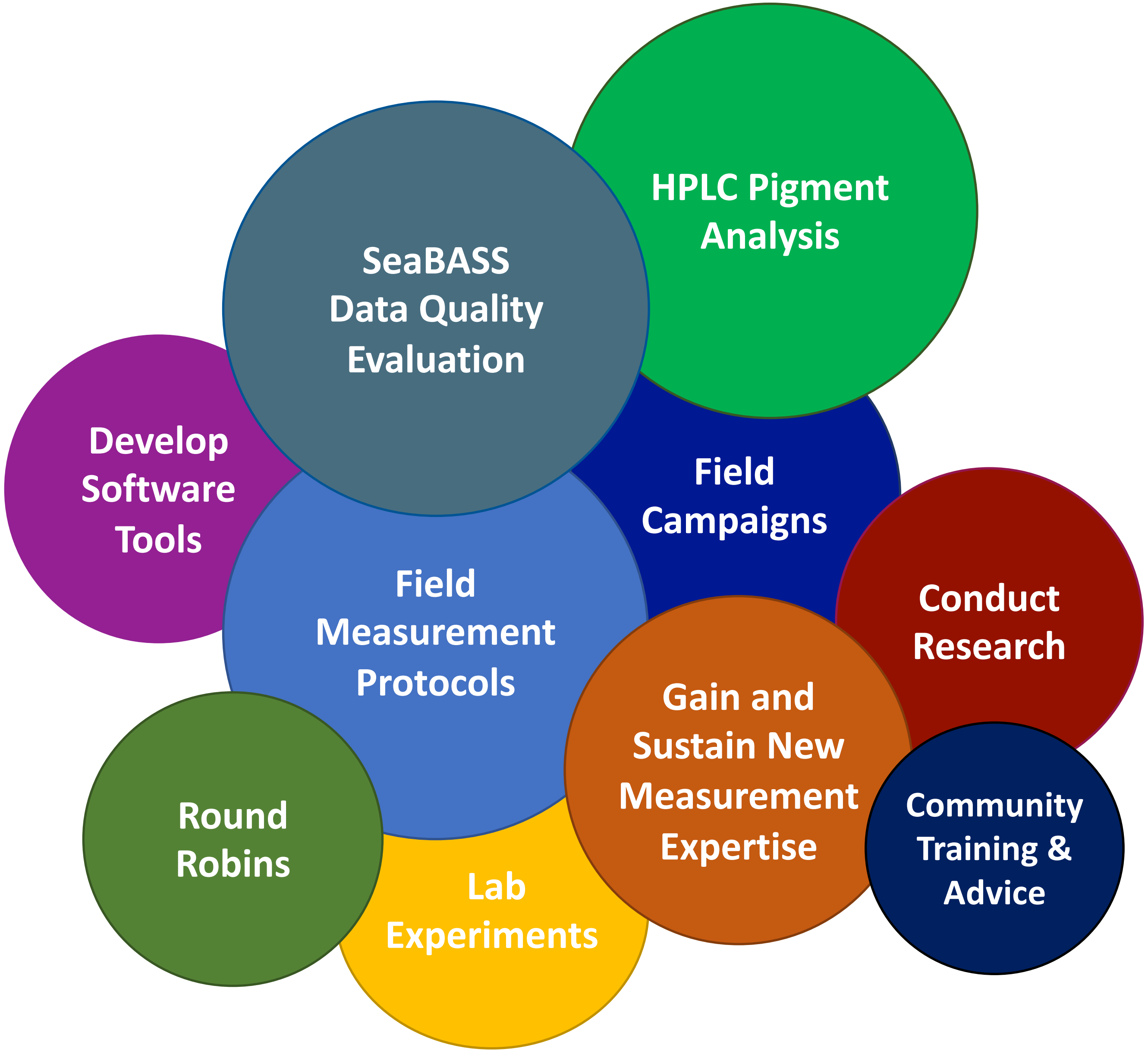
How do we accomplish this?

perform various activities to quantify and reduce uncertainties in field measurements

- field and lab measurements, experiments and community round robins
- data processing and analysis
- measurement protocols
- develop community software tools

Engage the scientific community in these activities

Field & Lab activities in support of NASA



Field & Lab activities in support of NASA

Activities

- HPLC pigment analysis
  - chl-a is a primary climate data record; other pigments for PCC and other data products
- Support SeaBASS: data quality evaluation; augmenting SeaBASS archive through data mining; establish relevant SeaBASS field variable names
- Field measurement protocols
  - Develop measurement protocols with the community of experts (IOCCG protocols)
  - In-house protocols: analytical HPLC; UHPLC & UHPLC-MS; phycobilins; etc.
- Consensus on standardizing data reporting (raw to final product) and provenance/documentation
- Field campaigns and lab experiments
  - Collect and report complete and high-quality data sets (CliVar, GO-SHIP, EXPORTS, … PACE validation)
  - Experiments with new field and lab instruments with the goal of improving data quality and development of protocols
- Acquire new expertise and sustain expertise in field and lab instrumentation and measurements
- Develop software tools for ourselves and the community (e.g., HyperInSPACE)
- Conduct research with aims relevant to our mission statement and NASA's goal *to study the Earth, including its climate, …* (nasa.gov/about) (e.g., ROSES, PACE, [past GEO-CAPE], etc.)

Our Staff

Core Members


Joaquin Chaves


Scott Freeman


Chris Kenemer


Aimee Neeley


Mike Novak


Crystal Thomas

Recent Core hires


Harrison Smith (Aug. 2021)


Chelsea Lopez (Sep. 2021)

Other contributing staff


Andrea Andrew


Dirk Aurin


Paul Sobchenko


Ryan Vandermeulen

Phytoplankton pigment analysis lab

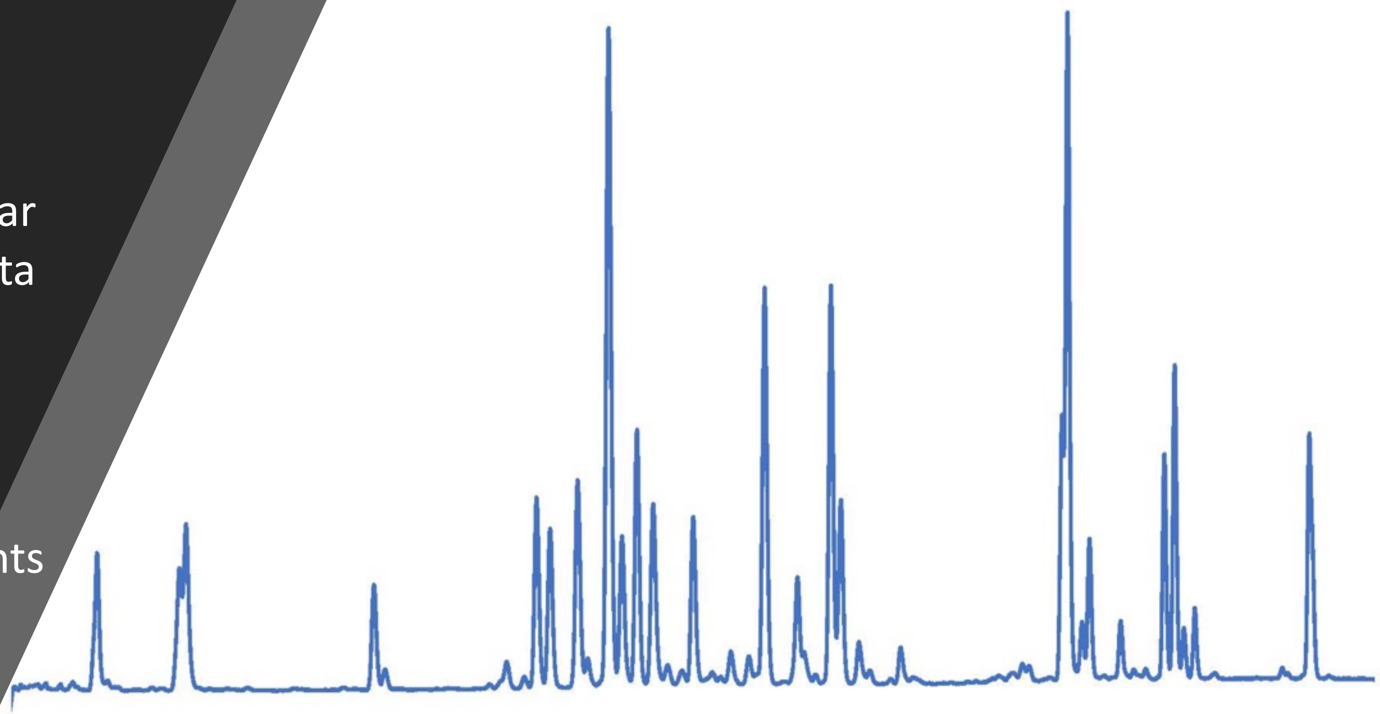
Why?

- Pigments influence ocean color in much of the ocean and inform on phytoplankton community composition
- Chlorophyll-a relates to biomass and physiology
  - Used in Primary Productivity models
- Maintain NASA's long-term ocean color Climate Data Record since SeaWiFS in late 1997.
- **Dedicated quality-assured lab necessary for validation and maintenance of chl-*a CDR*.**

What?

- Process ~3000 HPLC pigment samples per year
- On-going efforts to maintain and improve data quality and analytical efficiency
  - cross-calibration with Horn Point
  - international round robins
  - analysis on sources of uncertainty
- Methods development for phycobilin pigments
- Methods development for uHPLC and uHPLC-LC-MS

Chromatogram of pigments from High-Performance Liquid Chromatography (HPLC)



Technical lead contact: crystal.s.thomas@nasa.gov

SeaBASS data quality evaluation

<u>SeaBASS QA/QC subject matter experts</u>

<u>Aimee</u>: pigments, particle absorption, PCC, PSD

<u>Joaquin:</u> NPP, POC, CDOM abs., ac-s

<u>Mike/Chelsea:</u> CDOM and particle abs., DOC, POC, SPM

<u>Scott & Harrison:</u> radiometry, underway and profile absorption, attenuation, backscatter, VSF, particle size distribution

Effort managed by Chris Proctor

Objective: supports multi-mission satellite algorithm development and data product validation

- Perform ***quality assurance*** and ***quality control*** (QA/QC) on SeaBASS data file submissions
  - Develop QA/QC criteria
  - QA/QC of new submissions
  - QA/QC of past submissions
  - Data mining of key data sets outside of SeaBASS
- SeaBASS field data quality screening and re-processing for integration into a modern version of the NOMAD database

Process for Development of Field Measurement Protocols

Under the auspices of the IOCCG

Systematic development, revision, testing, and dissemination of field data collection protocols in collaboration with experts in academia and other federal agencies.

Assemble a Team of Subject Matter Experts
- Obtain travel support; hold workshop(s) to discuss and resolve challenges
- Establish a protocol document draft outline
- Identify lead/contributing authors

Writing of the protocol document
- Hold public workshops/breakouts; present progress at conferences
- Contact lead/contributing authors often

Draft Protocol posted on IOCCG website for Peer Review (60 days) by Community and Associate Editorial Peer Reviewers (AEPRs)
- Notify community

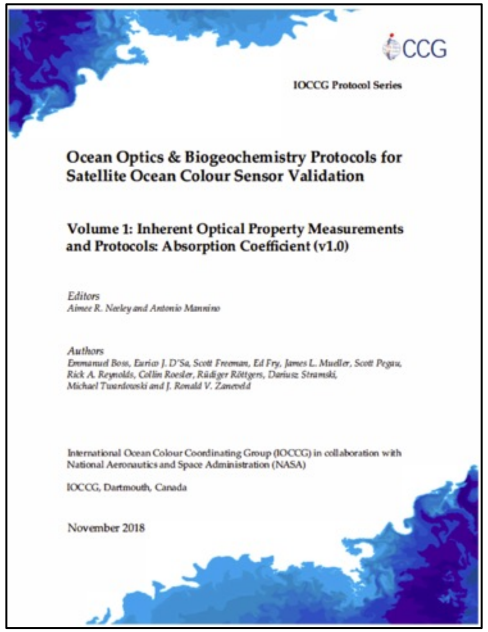
Revision of Protocols Based on Public and AEPR Comments

Final Peer Review by Associate Editorial Peer Reviewers
- Verify that authors adequately address review comments

Final Technical Revisions & Copy Editing/Proofreading

IOCCG obtains DOI and adds Front/Back cover pages
- "Final" version posted to IOCCG website

Status of Protocols - Published


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)

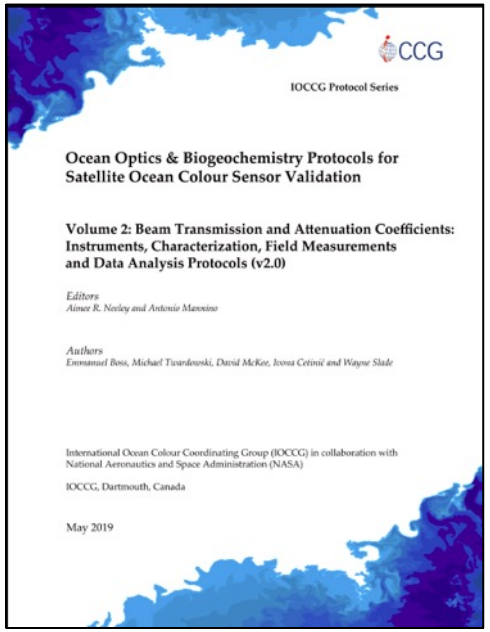
Editors
Aimee R. Neeley and Antonio Mannino

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

November 2018


IOCCG Protocol Series

Ocean Optics & Biogeochemistry Protocols for Satellite Ocean Colour Sensor Validation

Volume 2: Beam Transmission and Attenuation Coefficients: Instruments, Characterization, Field Measurements and Data Analysis Protocols (v2.0)

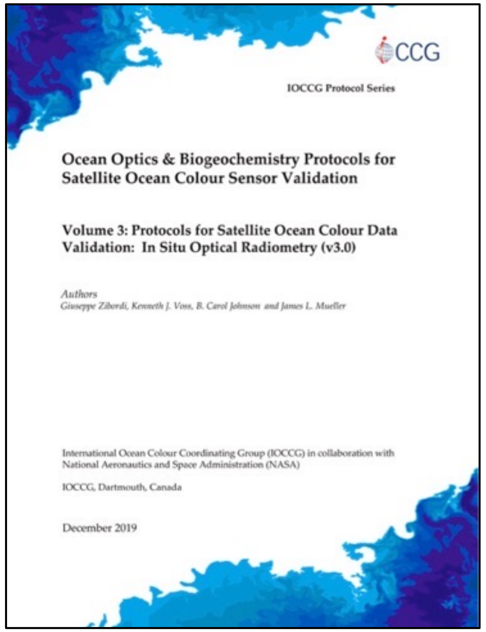
Editors
Aimee R. Neeley and Antonio Mannino

Authors
Emmanuel Boss, Michael Twardowski, David McKee, Ivona Cetinić and Wayne Slade

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

IOCCG, Dartmouth, Canada

May 2019


IOCCG Protocol Series

Ocean Optics & Biogeochemistry Protocols for Satellite Ocean Colour Sensor Validation

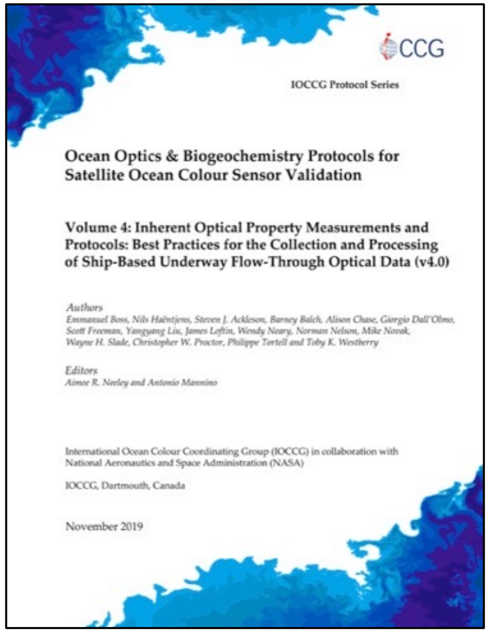
Volume 3: Protocols for Satellite Ocean Colour Data Validation: In Situ Optical Radiometry (v3.0)

Authors
Giuseppe Zibordi, Kenneth J. Voss, B. Carol Johnson and James L. Mueller

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

IOCCG, Dartmouth, Canada

December 2019


IOCCG Protocol Series

Ocean Optics & Biogeochemistry Protocols for Satellite Ocean Colour Sensor Validation

Volume 4: Inherent Optical Property Measurements and Protocols: Best Practices for the Collection and Processing of Ship-Based Underway Flow-Through Optical Data (v4.0)

Authors
Emmanuel Boss, Nils Haëntjens, Steven J. Ackleson, Barney Balch, Alison Chase, Giorgio Dall'Olmo, Scott Freeman, Yangyang Liu, James Loftin, Wendy Neary, Norman Nelson, Mike Novak, Wayne H. Slade, Christopher W. Proctor, Philippe Tortell and Toby K. Westberry

Editors
Aimee R. Neeley and Antonio Mannino

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

IOCCG, Dartmouth, Canada

November 2019


IOCCG Protocol Series

Ocean Optics & Biogeochemistry Protocols for Satellite Ocean Colour Sensor Validation

Volume 6: Particulate Organic Matter Sampling and Measurement Protocols: Consensus Towards Future Ocean Color Missions

Authors:
Joaquín E. Chaves, Ivona Cetinić, Giorgio Dall'Olmo, Meg Estapa, Wilford Gardner, Miguel Goñi, Jason R. Graff, Peter Hernes, Phoebe J. Lam, Zhanfei Liu, Michael W. Lomas, Antonio Mannino, Michael G. Novak, Robert Turnewitsch, P. Jeremy Werdell, Toby K. Westberry

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

IOCCG, Dartmouth, Canada

August 2021

Vol. 1.0 Absorption (particles)	Vol. 2.0 Beam Attenuation	Vol. 3.0 Radiometry for Validation	Vol. 4.0 Inline Flow-Through IOPs	Vol. 6.0 Particulate Organic Carbon
Nov. 2018	April 2019	Dec. 2019	Nov. 2019	August 2021

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

Status of Protocols – CDOM Absorption

IOCCG Protocol Series

Ocean Optics & Biogeochemistry Protocols for Satellite Ocean Colour Sensor Validation

Vol. 5.0

CDOM Absorption

Authors
Antonio Mannino, Michael G. Novak, Norman B. Nelson, Mathias Belz, Jean-François Berthon, Neil V. Blough, Emmanuel Boss, Annick Bricaud, Joaquin Chaves, Carlos Del Castillo, Rossana Del Vecchio, Eurico J. D'Sa, Scott Freeman, Atsushi Matsuoka, Richard L. Miller, Aimee Neeley, Rüdiger Röttgers, Maria Tzortziou, Jeremy Werdell

- Sample Collection and Filtration
- Reference Material
- Liquid Waveguide Spectroscopy
- Dual-Beam Spectrophotometry
- Data analysis and uncertainties
- Round Robin Results

- Protocol has undergone review by AEPRs & Community
- Currently being revised per those comments
  - Updating CDOM reference material to SRFA-III
  - Merging of LWCC UV-Vis and spectrophotometer UV
- Back to AEPRs *circa* Dec. 2021
- Final version in 2022

Status of Protocols – Primary Productivity

IOCCG Protocol Series

Ocean Optics & Biogeochemistry Protocols for Satellite Ocean Colour Sensor Validation

Vol. 7.0 Aquatic Primary Productivity

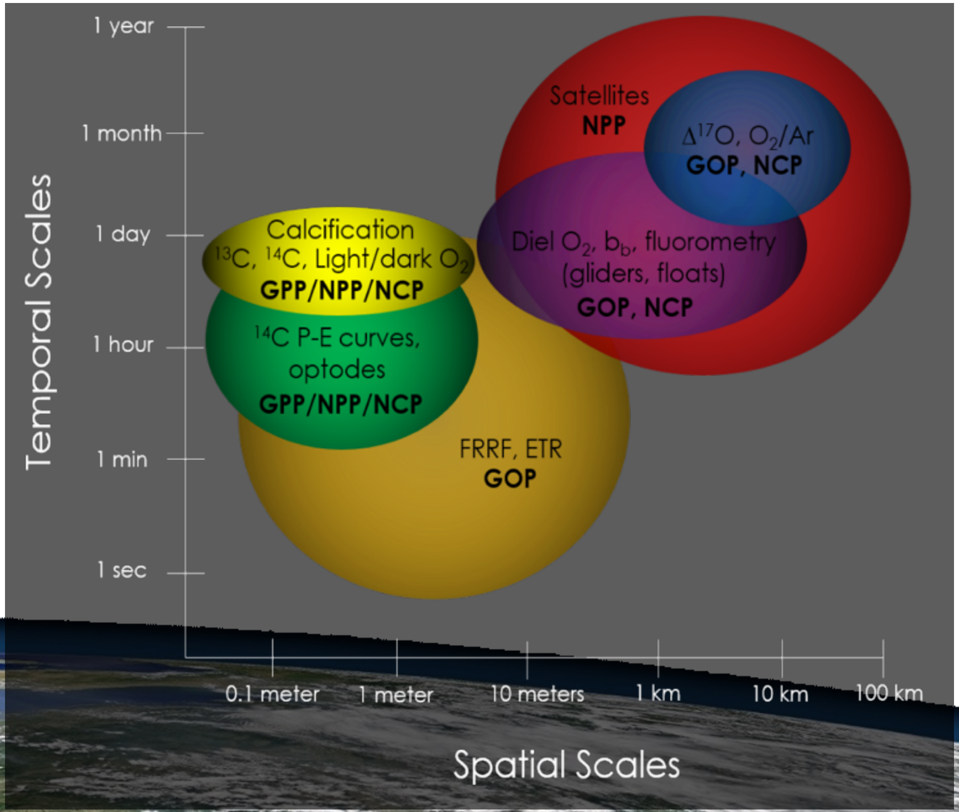
Contributors

Balch, W.M., Carranza, M., Cetinic, I., Chaves, J.E., Duhamel, S., Erickson, Z., Fassbender, A., Fernandez-Carrera, A., Ferrón, S., García-Martín, E., Goes, J., Gomes, H., Gorbunov, M., Gundersen, K., Halsey, K., Hirawake, T., Isada, T., Juranek, L., Kulk, G., Langdon, C., Letelier, R., López-Sandoval, D., Mannino, A., Marra, J., Neale, P., Nicholson, D., Silsbe, G., Stanley, R., Vandermeulen, R.A.

edited by R.A. Vandermeulen, J. E. Chaves

DEADLINE:
review comments
by Nov. 10, 2021

- Protocol posted for community & AEPR review in August 2021
- **Comments due by Nov. 10, 2021**



Status of Protocols – Scattering Properties

IOCCG Protocol Series

Ocean Optics & Biogeochemistry Protocols for Satellite Ocean Colour Sensor Validation

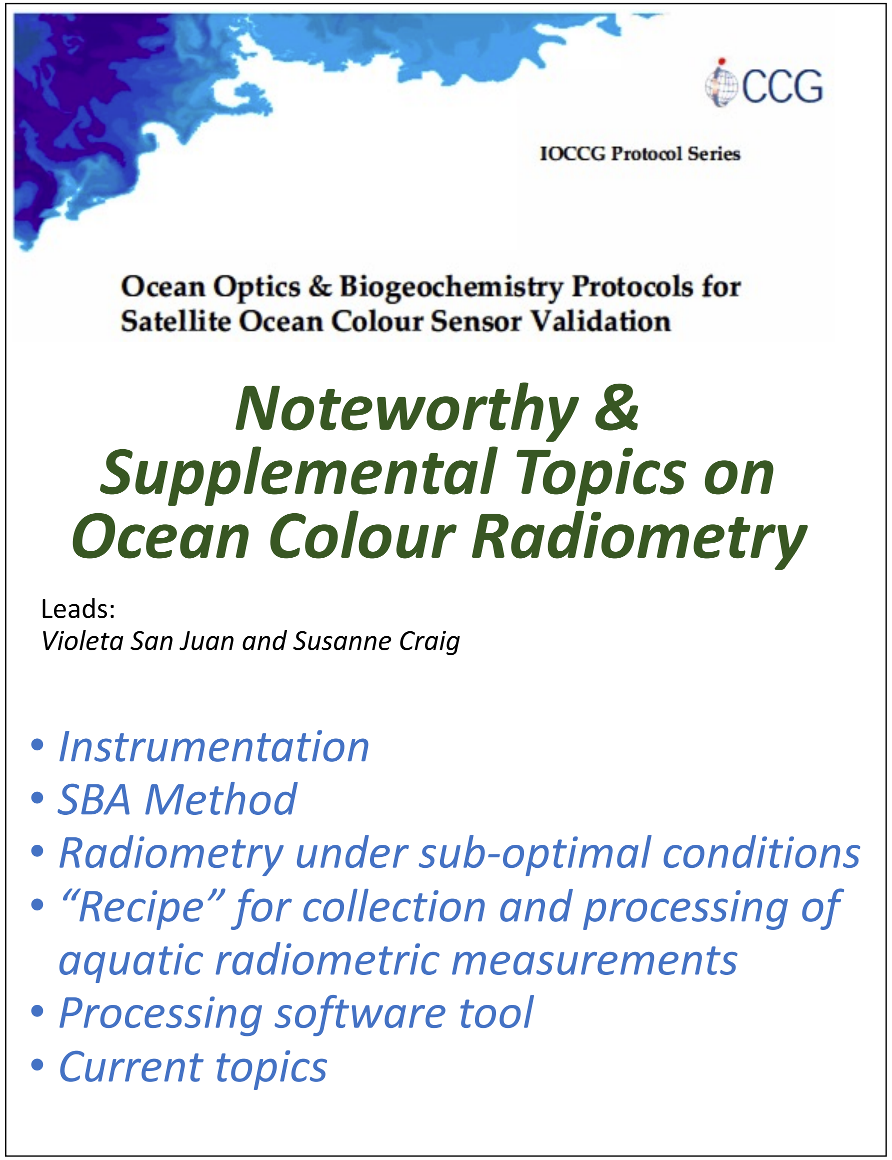
Vol. 8 Volume Scattering Function, scattering, and backscattering coefficients

Authors
Wayne Slade, Mike Twardowski, Emmanuel Boss, Xiaodong Zhang, Dariusz Stramski, James M. Sullivan, David Dana, David McKee, Giorgio Dall'Olmo, Deric Gray, Steve Ackleson, Barney Balch …

- Instrumentation
- Measurement Process
- Deployment & Data Processing
- Current Topics

- Draft protocol in preparation
- Post protocol for community & AEPR review by end of 2021/early 2022.

Status of Protocols – more radiometry


IOCCG Protocol Series

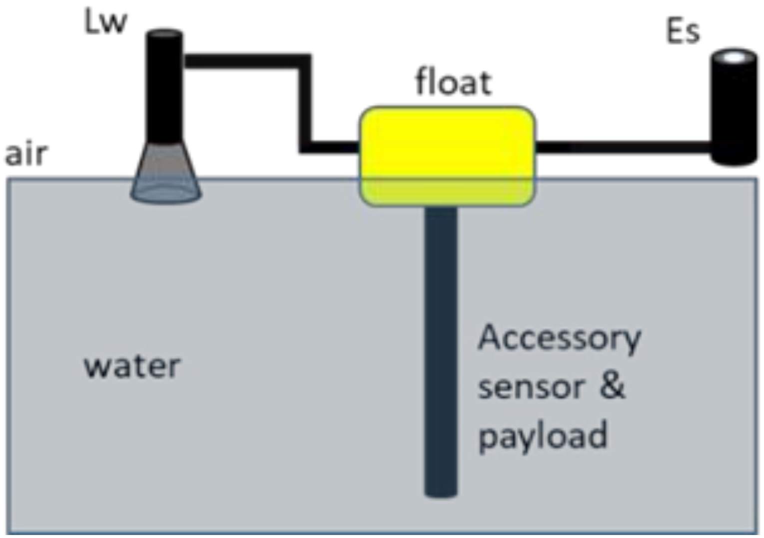
Ocean Optics & Biogeochemistry Protocols for Satellite Ocean Colour Sensor Validation

Noteworthy & Supplemental Topics on Ocean Colour Radiometry

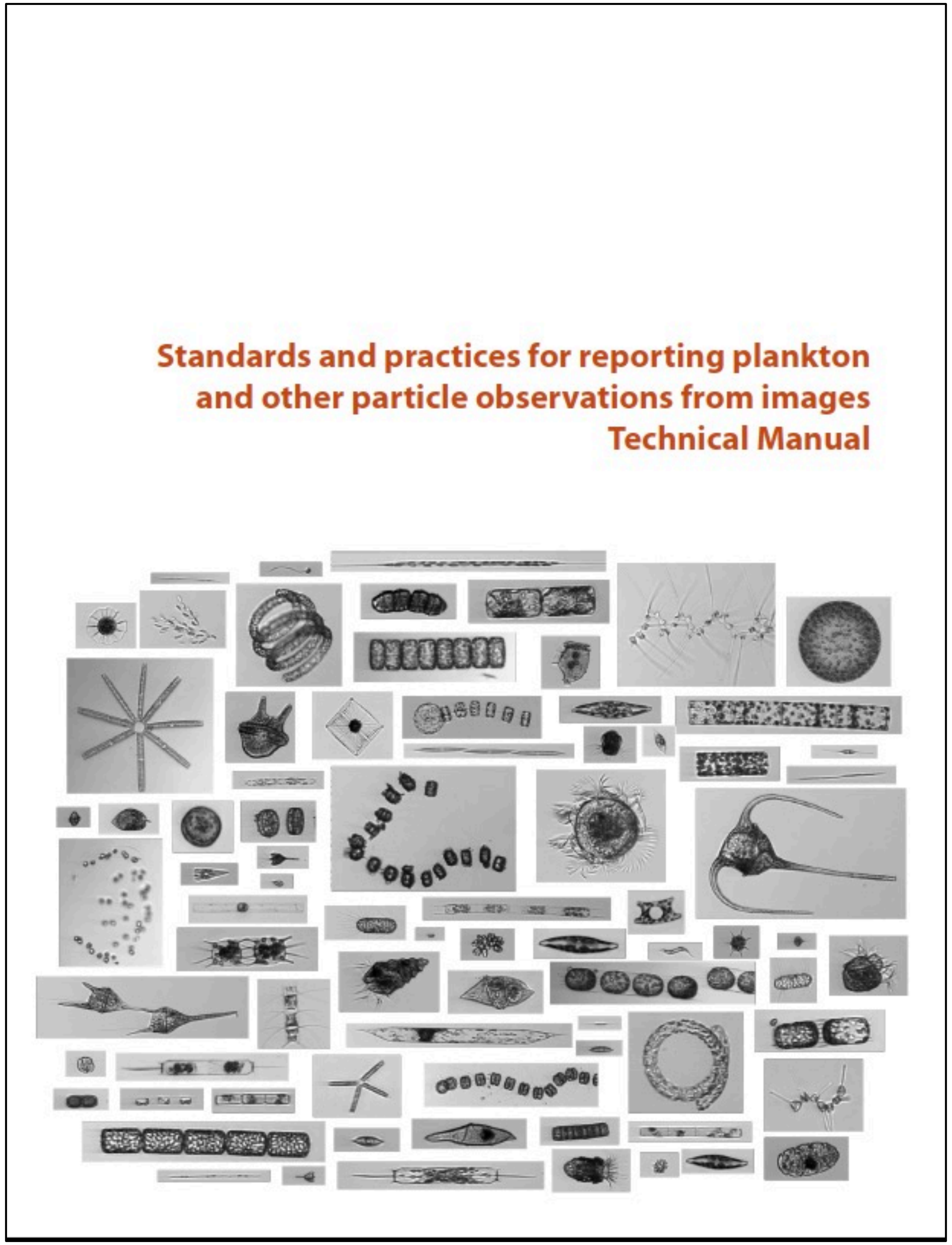
Leads:
Violeta San Juan and Susanne Craig

- *Instrumentation*
- *SBA Method*
- *Radiometry under sub-optimal conditions*
- *"Recipe" for collection and processing of aquatic radiometric measurements*
- *Processing software tool*
- *Current topics*

- Document is in planning stages
- A chapter describing the "on-water" skylight-blocked approach (SBA) by Lee et al. is posted on the IOCCG website



Reporting Data from Particle Images



Published August 2021

Neeley, Aimee, Beaulieu, Stace E., Proctor, Chris, Cetinić, Ivona, Futrelle, Joe, Soto Ramos, Inia, Sosik, Heidi M., Devred, Emmanuel, Karp-Boss, Lee, Picheral, Marc, Poulton, Nicole, Roesler, Collin S., Shepherd, Adam, "Standards and practices for reporting plankton and other particle observations from images", 2021-07-26, DOI:10.1575/1912/27377, https://hdl.handle.net/1912/27377

NSF NASA OCB Ocean Carbon & Biogeochemistry

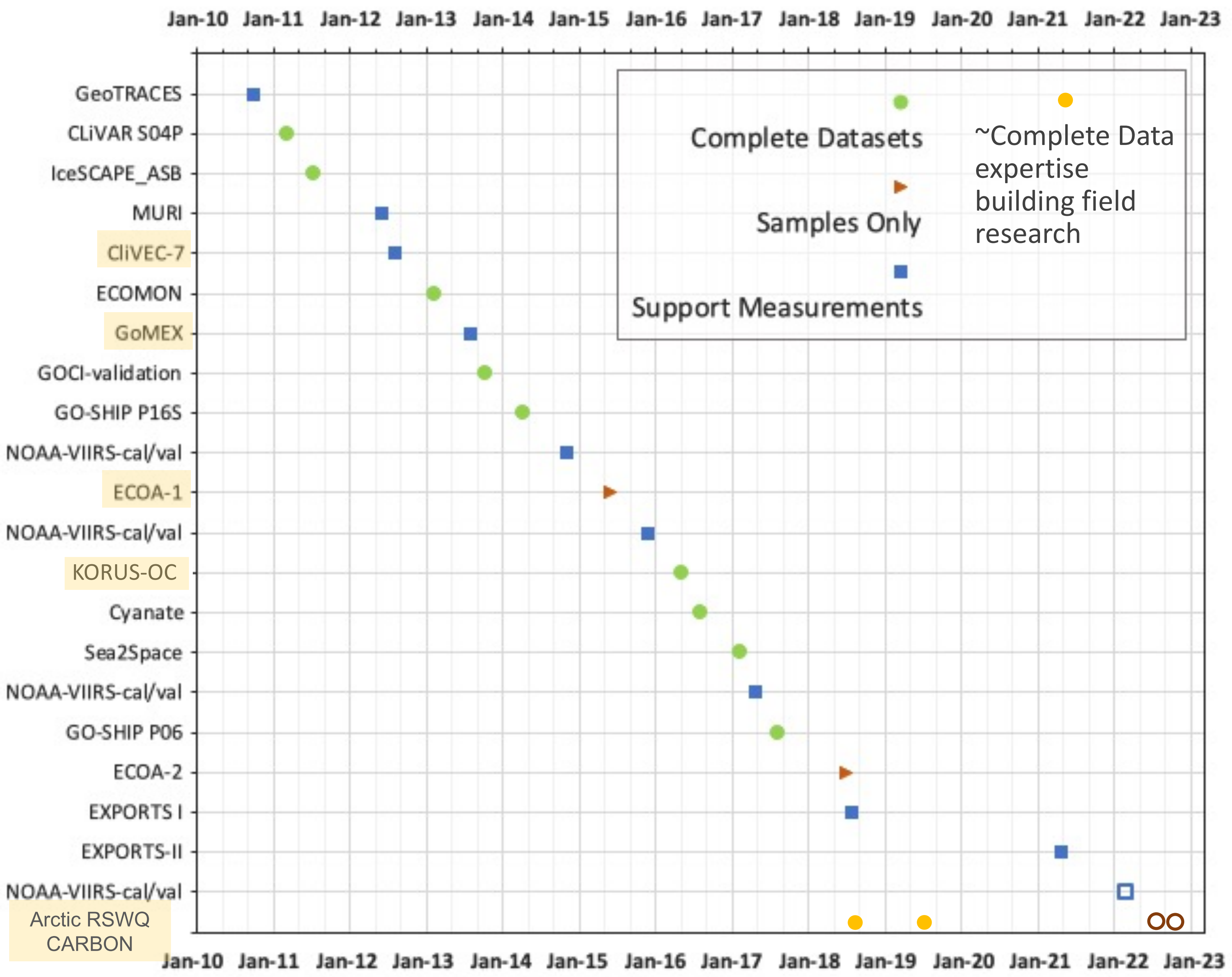
Planned Protocol Activities

- Future Protocols
  - Phytoplankton community composition & biovolume – kicking off soon
  - Phytoplankton Carbon – kicking off soon
  - HPLC Pigments update – in-house activity underway
  - Suspended Particulate Matter (in house literature review)
  - Dissolved Organic Carbon (in house)
  - Phycobilin Pigments – in-house activity underway
  - Optical and Biogeochemical Properties in Very Turbid Waters
  - Particle Size Distribution (with PCC ?)
  - Particulate Inorganic Carbon
  - Fluorescence properties
  - Review ship-based atmospheric aerosol and trace gas measurement protocols
- Updates to current IOCCG protocols as required

Preparing for PACE Validation

PACE Ocean Products	OEL Capability	Protocols
***R*$_{rs}$** (350 to 720nm every 5nm @ 2.5nm steps) and spectral k_d	HyperPro, PySAS, C-OPS, RAMSES-II	**Vol. 3 & 9**
Spectral absorption coefficients (a_t, a_p, a_{ph}, a_{cdm}, a_g)	UV-Vis/IS, PSICAM, QFT-ICAM, ac-s, Ultrapath	**Vols. 1, 4 & 5**
Spectral backscatter coefficients (350 to 700 nm)	bb-9, bb3, VSF-9, HS6, SC6, VSF-R	**Vols. 4 & 8**
Chlorophyll-*a*	HPLCs, Turner A10	**NASA TM**
Phytoplankton pigments	HPLCs, Turner A10, Horiba Aqualog	**NASA TM & planning**
Phytoplankton community composition	FlowCAM, sorting flow cytometer; pigments	**planning**
Daily and instantaneous PAR	PAR sensors; radiometers above	**Vol. 3; NASA TM**
Fluorescence line height	Radiometers above	**~Vol. 3**
Net primary production (NPP)	Amperometric titrator (Winkler's)	**Vol. 7**
Particulate organic carbon	CHNS elemental analyzer	**Vol. 6**
Particulate inorganic carbon	Coulometer	**future**
Phytoplankton carbon	FlowCAM, BioRad S3e; TOC-V	**planning**
Dissolved organic carbon	TOC-L & TOC-V	**planning**
Suspended particulate matter	Ultra microbalance	**planning**
Particle size distribution	LISST 100x, 200x, FlowCAM, Coulter Counter	**planning**

Field Campaign Participation and Support



Support from other funding

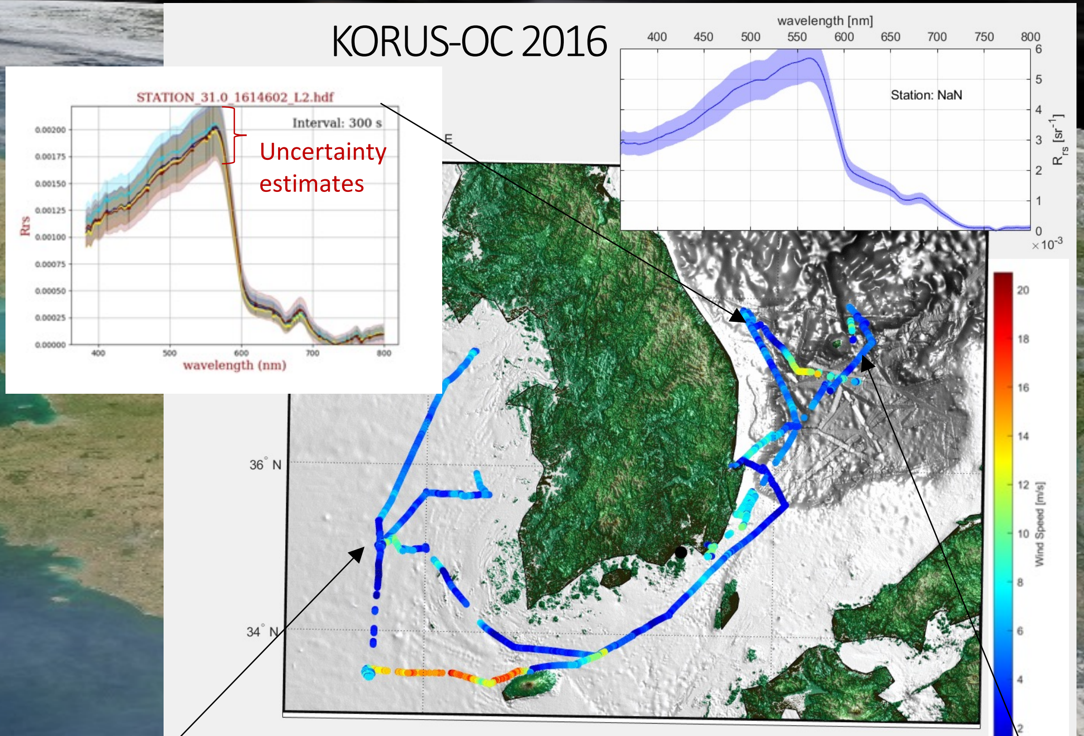
HyperInSPACE

Hyperspectral *In situ* Support FOR PACE

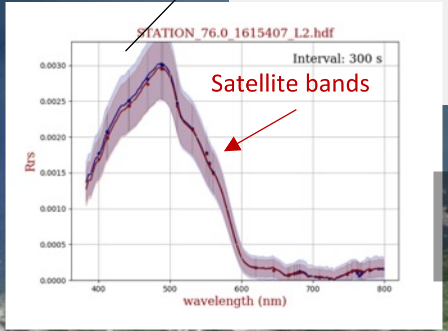
- **What?** Open source software for processing autonomous above water radiometry
- **Why?** Orbital platform validation & ocean color algorithm development
- **How?** Incorporates the latest science and protocols
  - Fully hyperspectral with polarization corrections
  - Satellite band extraction
  - Transparent, rigorous QA/QC
  - Traceable with automatic SeaBASS file creation
- **Status?** Available for download at

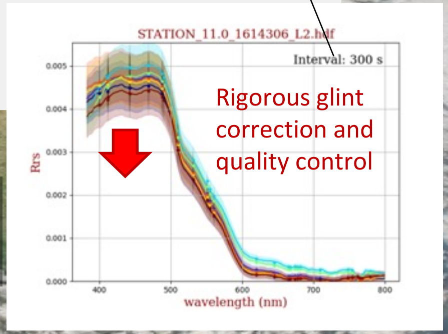
https://github.com/nasa/HyperInSPACE

KORUS-OC 2016



(Poor quality spectra retained in animation to highlight project challenges. Gaps represent nighttime and high wind events.)

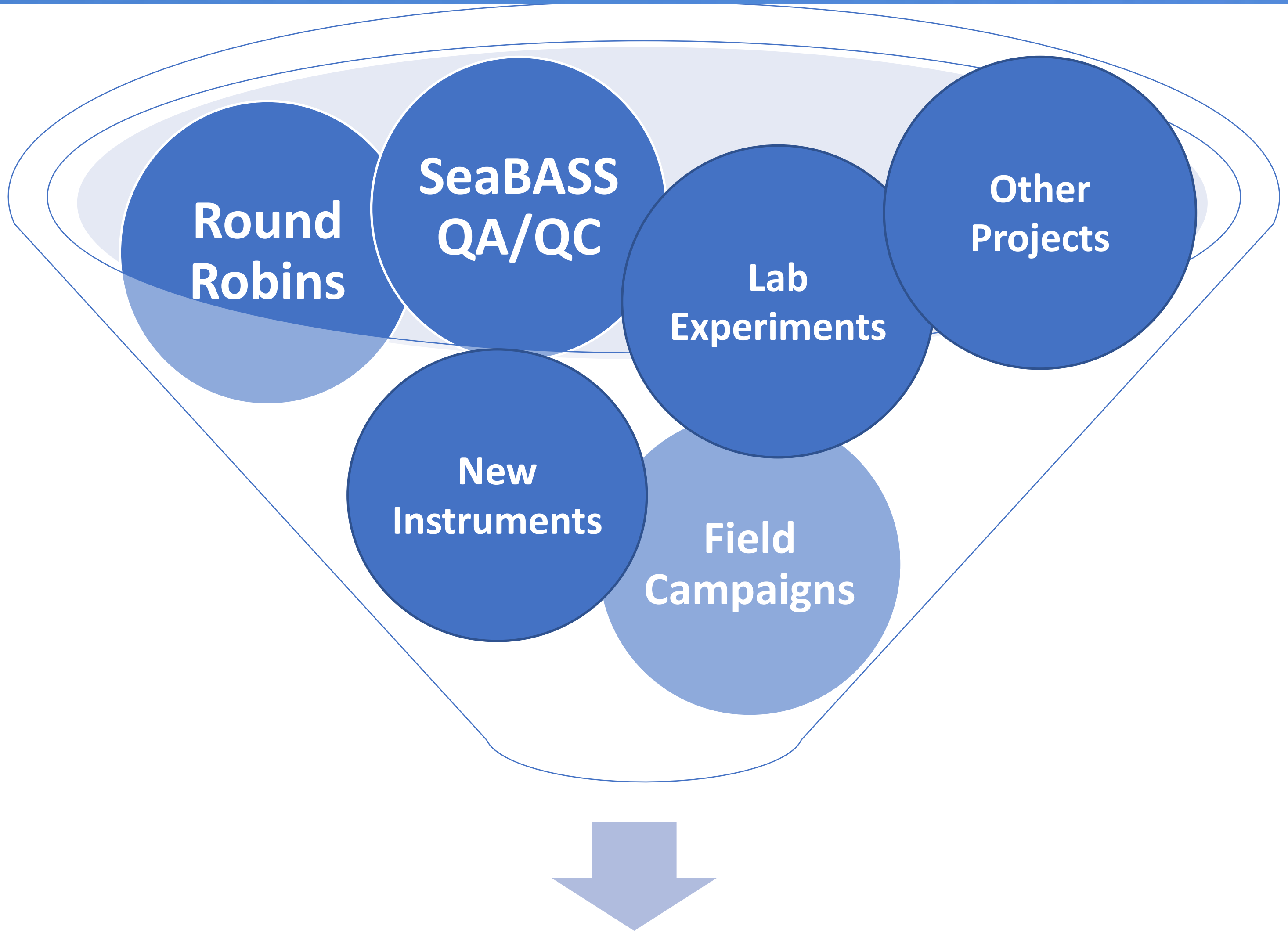




Dirk Aurin
NASA/GSFC Code 616

Conclusion

Everything we do feeds into improving knowledge of and reduction of *field measurement* uncertainties and thus through interdependence **improve satellite data products and knowledge of their inherent uncertainties**.



Quantify and Reduce Measurement Uncertainties


Thank You
Questions / Follow-up
antonio.mannino@nasa.gov

SeaBASS Update

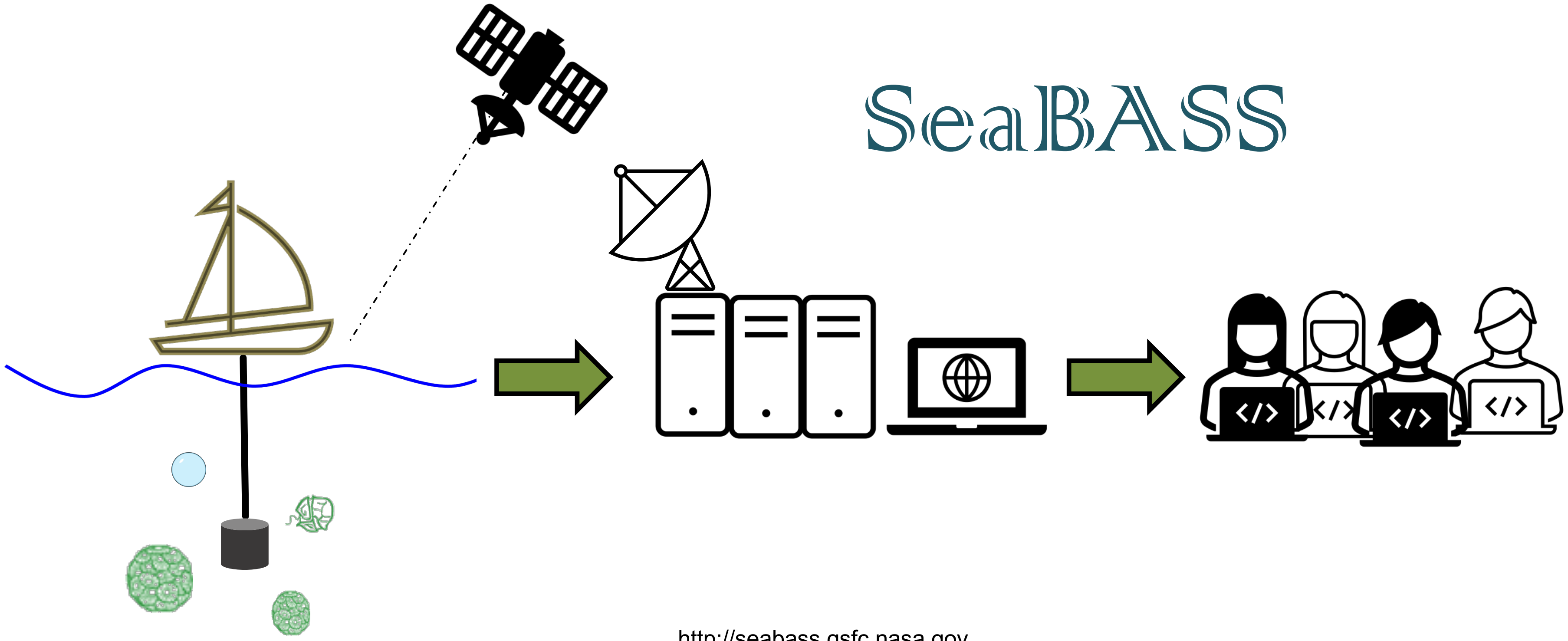
Chris Proctor

NASA Goddard Space Flight Center/SSAI

christopher.w.proctor@nasa.gov

SeaWiFS Bio-optical Archive and Storage System
NASA Ocean Color Research Team (OCRT)
Virtual Meeting, Oct 28, 2021

News, updates, and upcoming plans



SeaBASS News and Updates: Team is growing!

Chris Proctor
SeaBASS manager

Inia Soto Ramos
Data manager

David Norris
Developer

Noah Vegh-Gaynor
Developer

Violeta Sanjuan Calzado
NOMAD lead

The extended SeaBASS team includes many others:

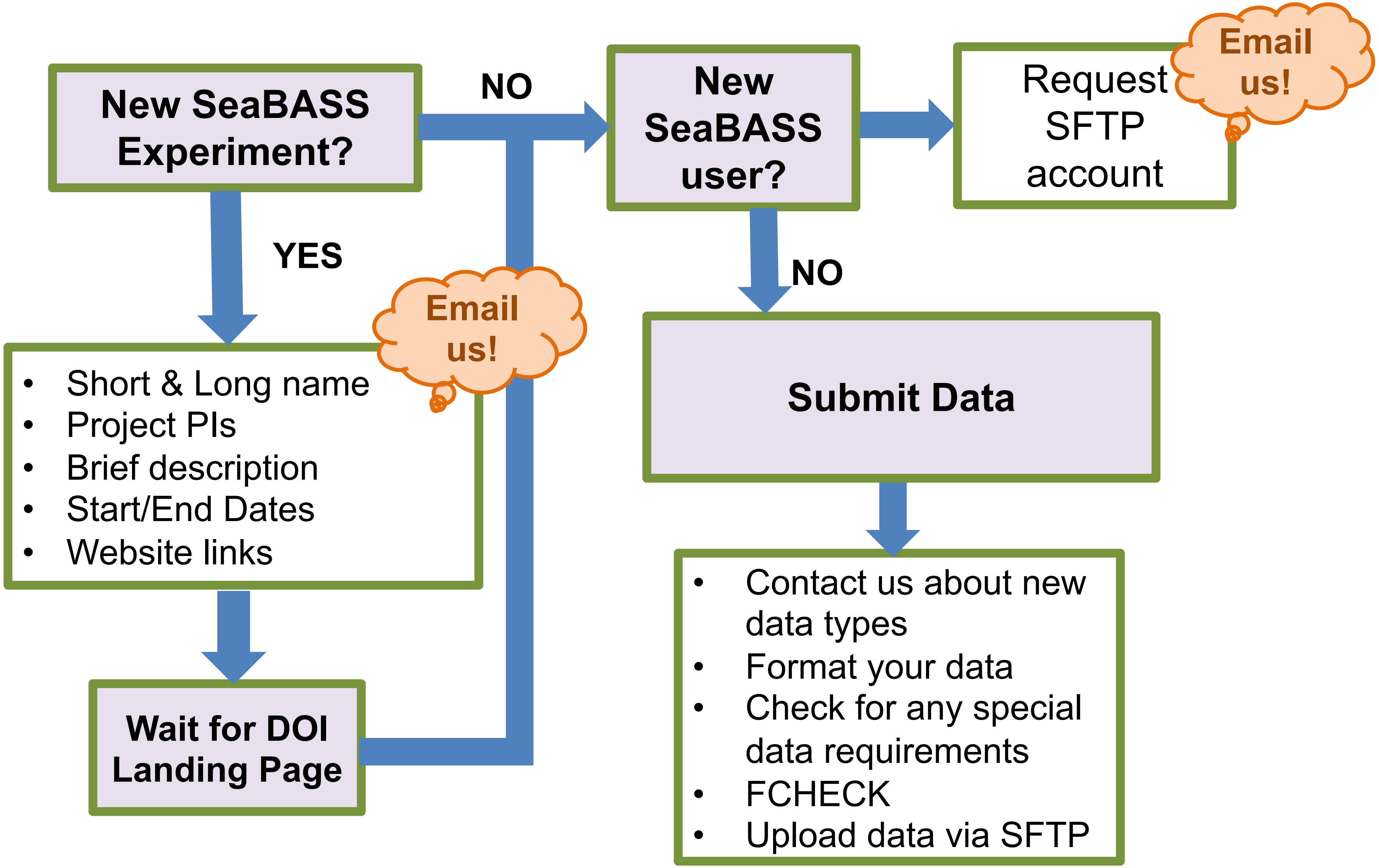
- SeaBASS SMEs within the Field Support Group
- PACE Validation Leads
- We also collaborate with others throughout OEL

SeaBASS News and Updates: Recently Archived Data

A few recent submission examples include:

- EXPORTS (North Pacific & North Atlantic):
  - Optical data, glider, HPLC, UVP, IFCB, carbon uptakes, sediment traps
- OTZ_WHOI – collaboration with EXPORTS
- Plankton imagery data from IFCB and UVP
- Many Arctic datasets: CFL, ArcticNet, Prudhoe_freshets, Arctic_RSWQ

I have new data, what should I do?



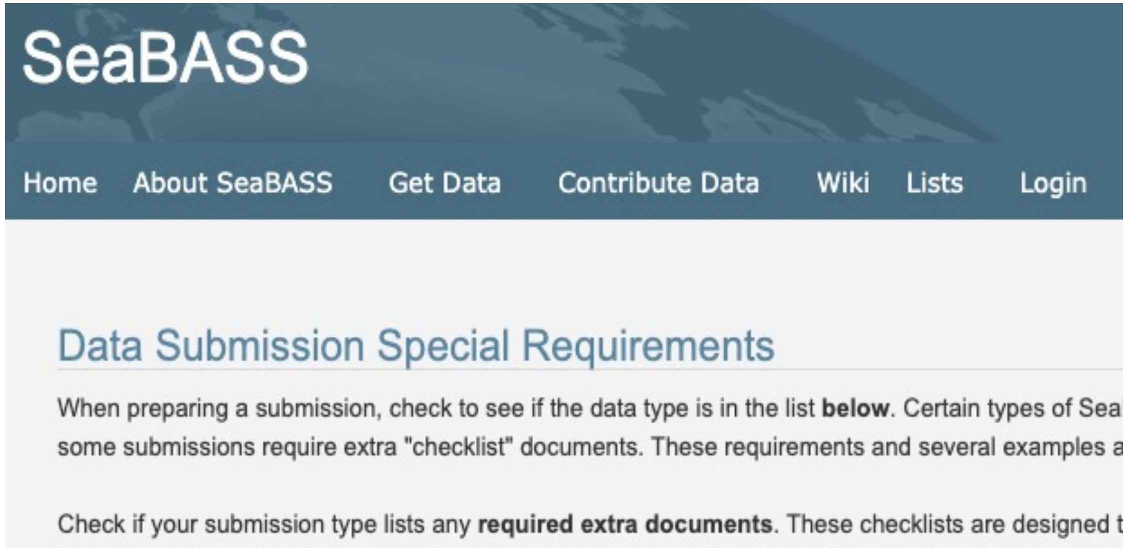
seabass@seabass.gsfc.nasa.gov

SeaBASS News and Updates: Data Requirements

- **Recently Updated**: AC-S data
- **New:** plankton imagery data, PSD, and others

- Reminder: requirements & checklists evolve
- **When submitting, please check requirements page for recent updates:**

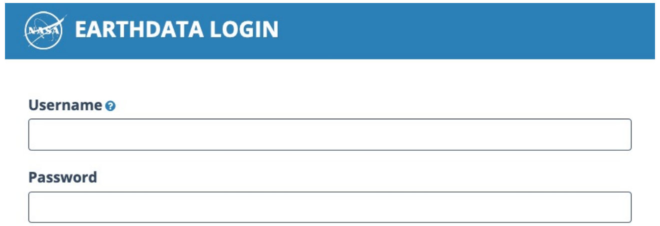
https://seabass.gsfc.nasa.gov/wiki/data_submission_special_requirements



SeaBASS News and Updates: Data Ordering Changes

https://seabass.gsfc.nasa.gov/wiki/Getting_Started

1. **Earthdata logins** now required to download SeaBASS data

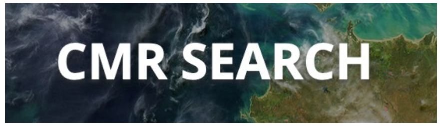


2. Data now served via ODPS Order Manager

OceanData Home ▸ Data Dashboard ▸ Order Manager ▸ 40b0339cc35d126e

Status for Order Id : 40b0339cc35d126e	
Order Id	40b0339cc35d126e
Email Address	christopher.w.proctor@nasa.gov
Base File Count	71
No Extract Possible	0
Base Files Staged Thus Far	71
Base Files Currently Staged	71
Base Files To Be Staged	0
Files Deleted	0
Percent Processed	100.00%
Status	STAGED
Show Files	
Download Files	

Why do you care about CMR? (Common Metadata Repository)



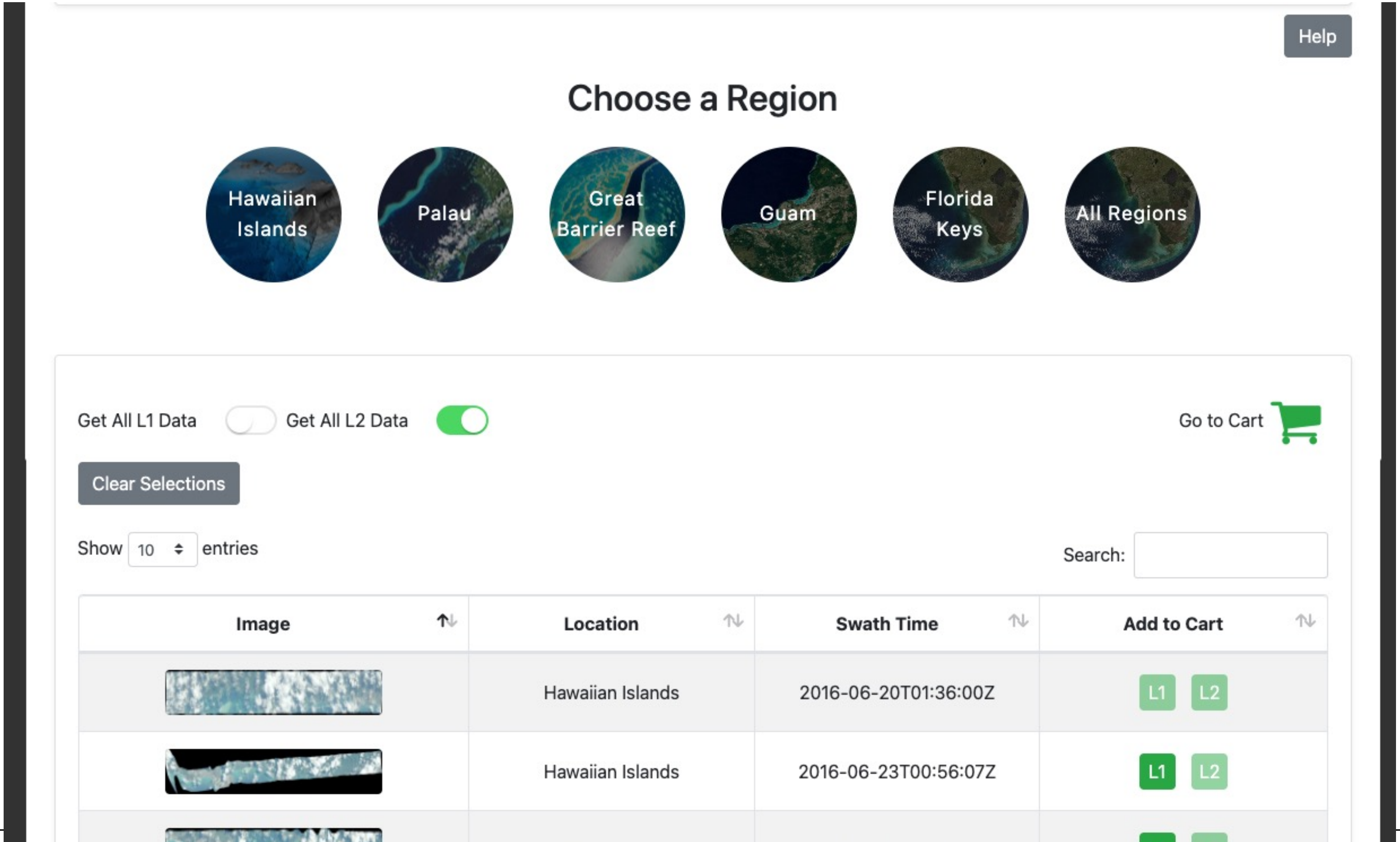
- Powerful API can find files across NASA Earthdata
- For example, enables our standalone match-up tools
  - fd_matchup.py included with SeaDAS in ocssw scripts

```
python3 fd_matchup.py
--sat modisa
--data_type oc
--max_time_diff 1
--seabass_file Arctic_RSWQ_Kaktovik_2019_HPLC.sb
```

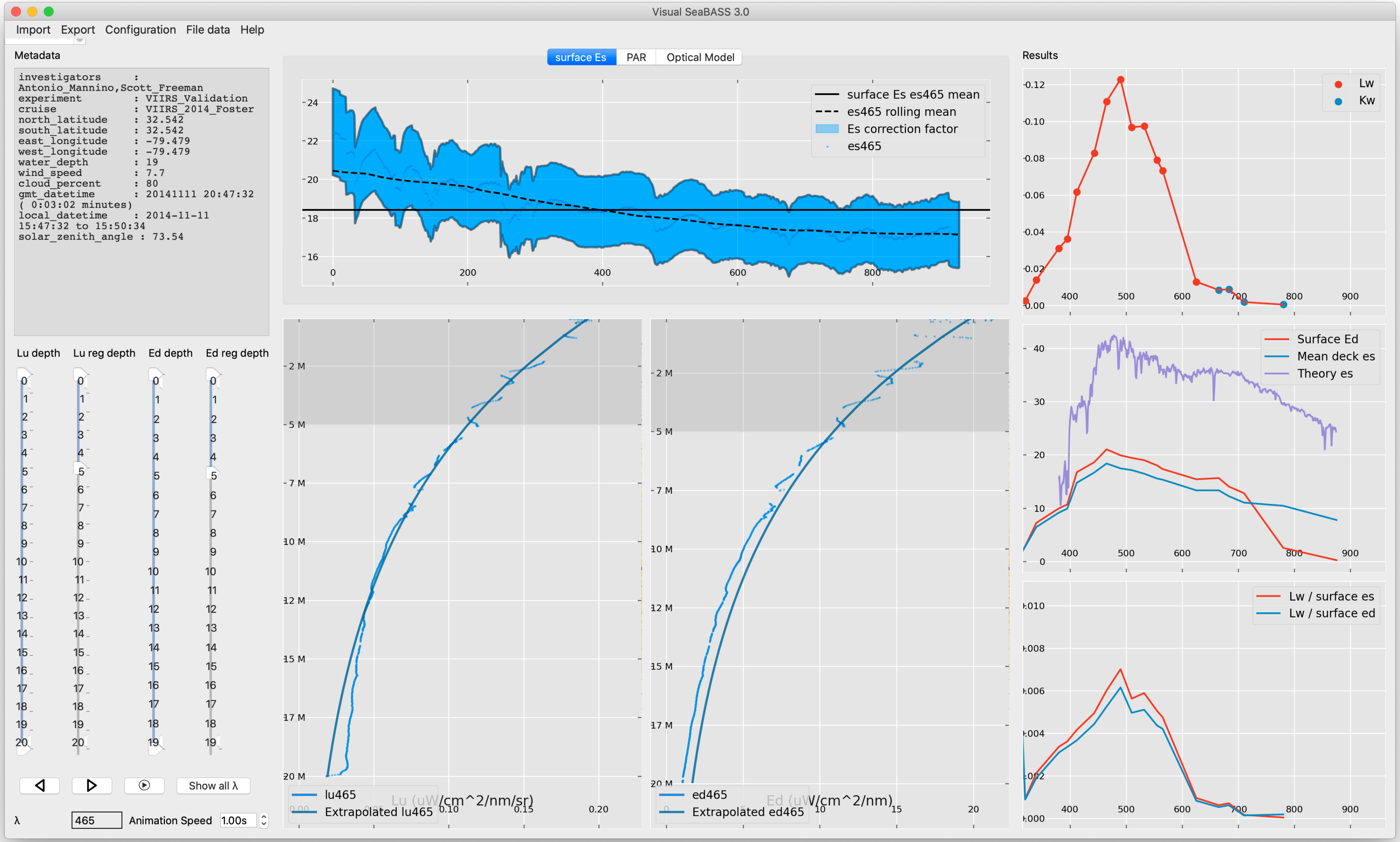
```
AQUA/MODIS granule match found: A2019215184500.L2_LAC_OC.nc
Download link:
https://oceandata.sci.gsfc.nasa.gov/cmr/getfile/A2019215184500.L2_LAC_OC.nc
```

CORAL Browser – aircraft & in situ data

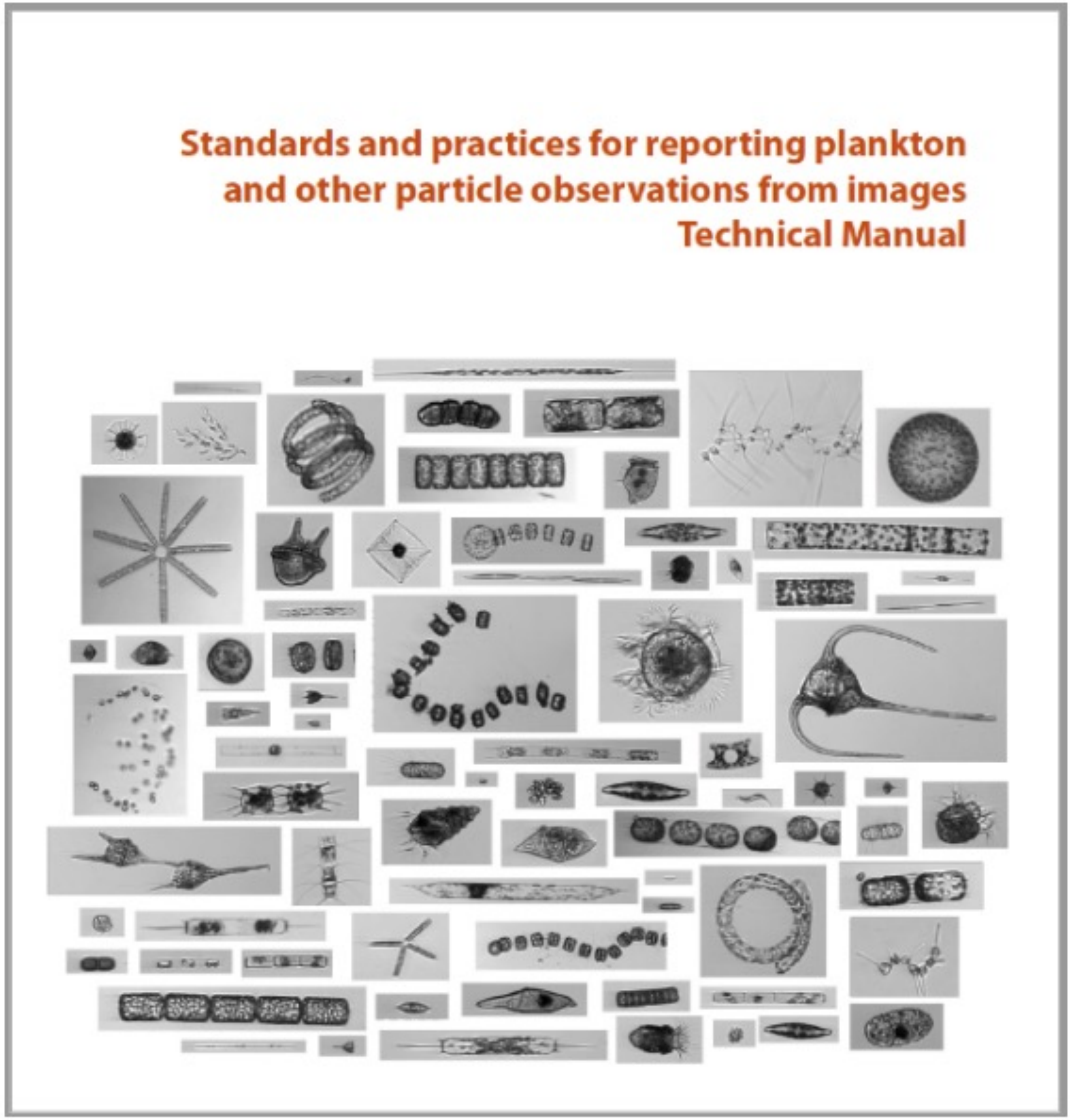
https://oceandata.sci.gsfc.nasa.gov/coral_browser/



In-water AOP Processor ("VSB 3.0")



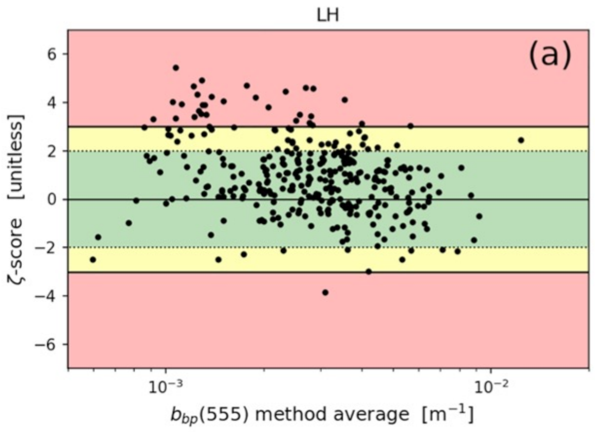
Recent accomplishment: strategies for storing new & complex data types



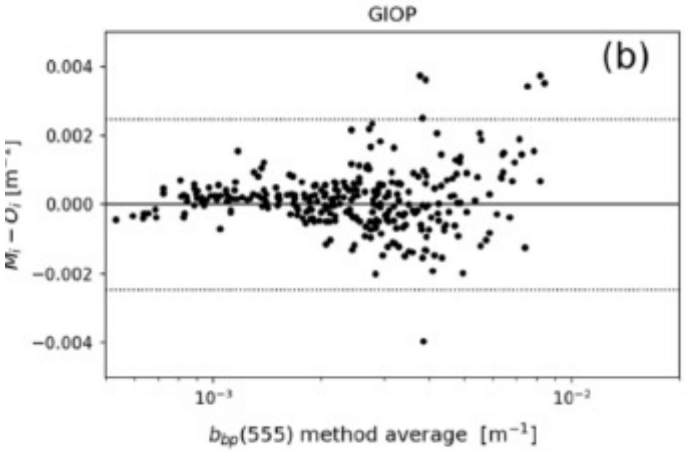
Future & Ongoing Work: Validation Improvements

- Clean-up & supplement existing validation datasets
- Upgrade validation results & figures for assessments, e.g.,

Bland-Altman plots (residual plots)



Zeta score plots



Future & Ongoing Plans

- Continue streamlining submission requirements and checklists
- Improve submission guidelines for other data types such as primary productivity
- Update ”Experiment" list interface & webpages
- Incorporate HAB in situ datasets & collaborate on OEL “CORAL browser” to add other aircraft-based ocean color data


Thank you
Questions?

Jeremy Werdell

PACE Project Scientist

NASA Goddard Space Flight Center

jeremy.werdell@nasa.gov

Keeping PACE with the NASA Plankton, Aerosol, Cloud, ocean Ecosystem mission

Keeping PACE with the NASA Plankton, Aerosol, Cloud, ocean Ecosystem mission

PACE

Jeremy Werdell
PACE Project Scientist

OCRT, October 2021

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

outline

brief background & observatory overview
mission update
science teams & community engagement
resources

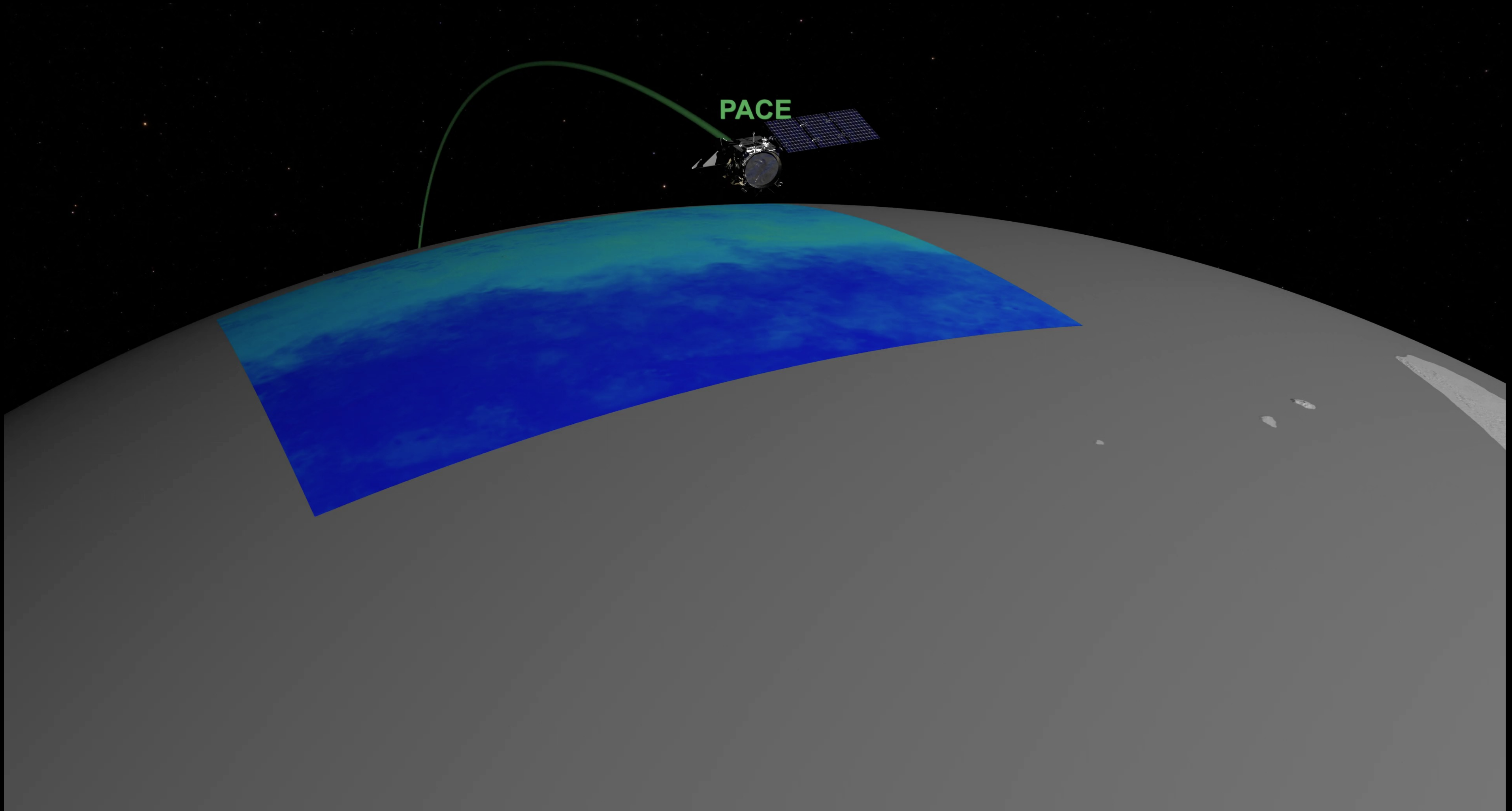
2021 2030 United Nations Decade of Ocean Science for Sustainable Development

PACE will support studies of:
- ocean biology, ecology, & biogeochemistry
- atmospheric aerosols
- clouds
- land

Primary hyperspectral radiometer:
- Ocean Color Instrument (OCI) (GSFC)

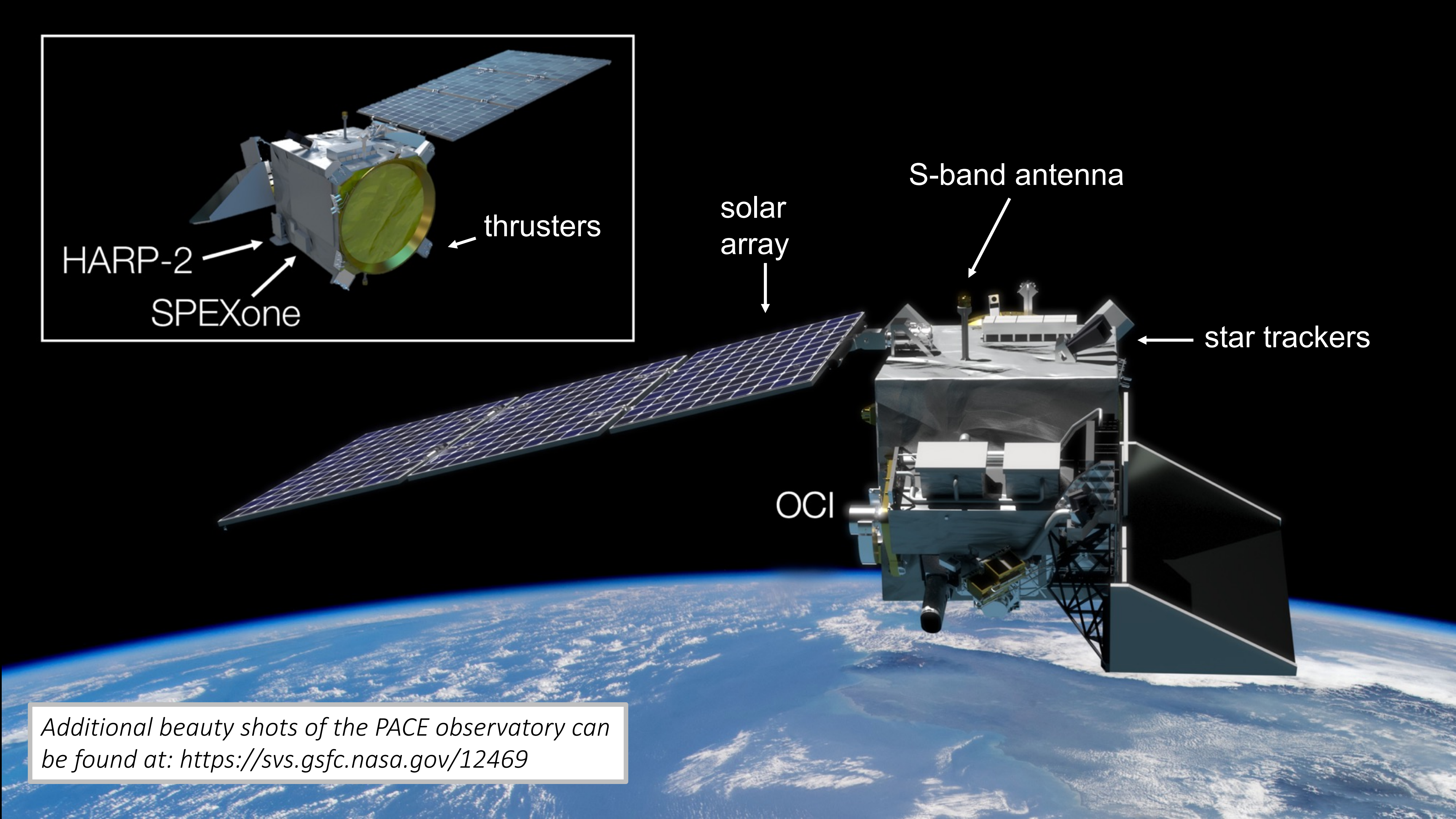
2 contributed multi-angle polarimeters:
- HARP2 (UMBC)
- SPEXone (SRON/Airbus)

Mission elements:
- Competed science teams (ESD)
- Competed SVC teams (ESD)
- Science analysis & processing (GSFC)
- Spacecraft (GSFC)
- Mission operations (GSFC)



Legacies:
- SeaWiFS, MODIS, VIIRS
- POLDER, MISR

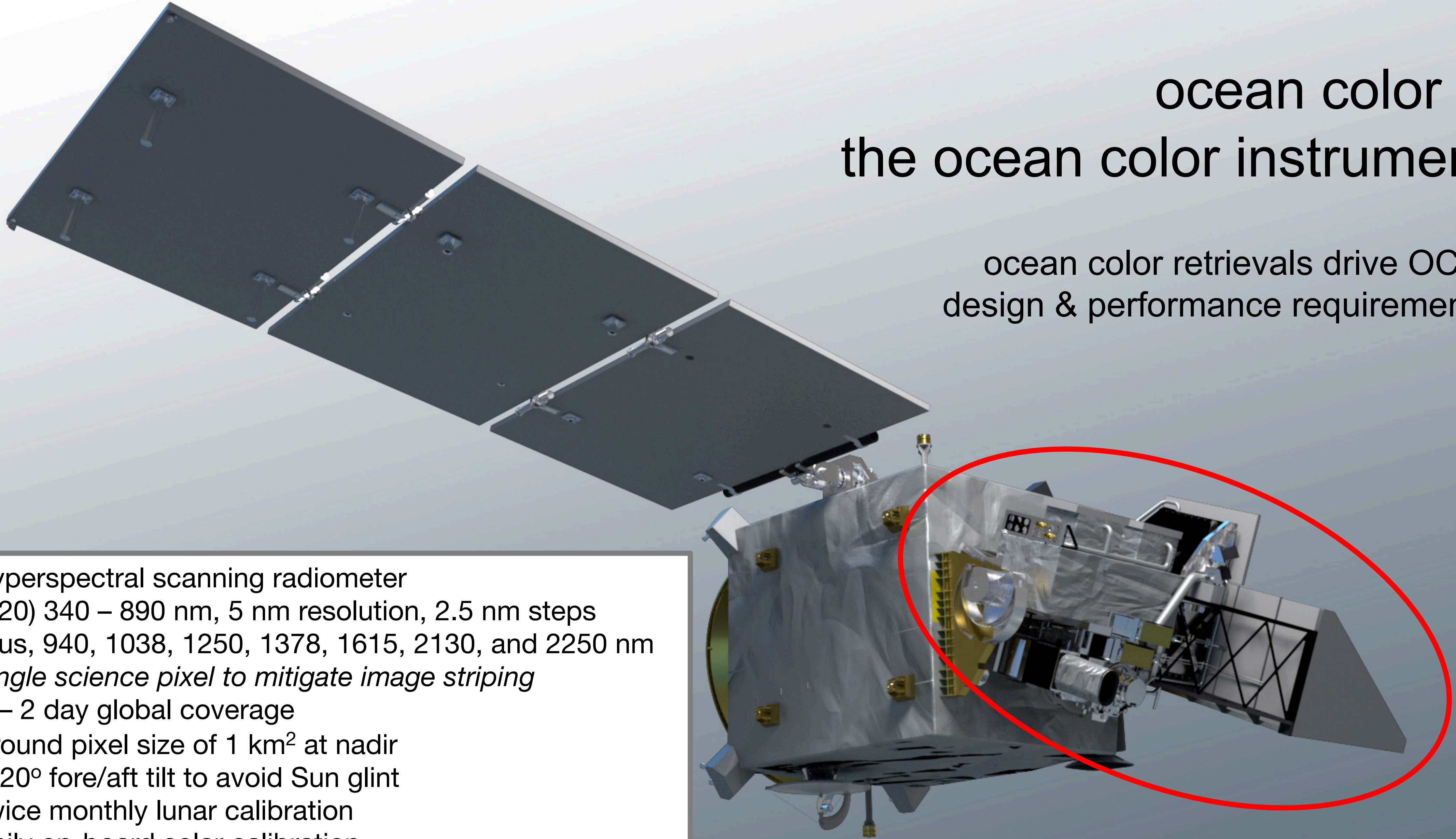
Key characteristics:
- winter 2023/24 launch
- Falcon 9 from KSC/Cape Canaveral
- 676.5 km altitude
- polar, ascending, Sun synchronous orbit; 98° inclination
- 13:00 local Equatorial crossing
- 3-yr design life; 10-yr propellant



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

ocean color & the ocean color instrument

ocean color retrievals drive OCI's design & performance requirements

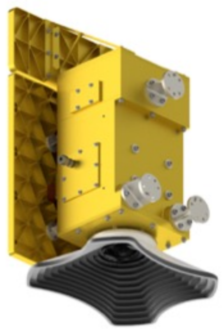


- hyperspectral scanning radiometer
- (320) 340 – 890 nm, 5 nm resolution, 2.5 nm steps
- plus, 940, 1038, 1250, 1378, 1615, 2130, and 2250 nm
- *single science pixel to mitigate image striping*
- 1 – 2 day global coverage
- ground pixel size of 1 km^2 at nadir
- ± 20^o fore/aft tilt to avoid Sun glint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

* developed primarily for mechanical processing assessments

\+ PyTOAST currently release; other variations coming soon

UMBC Hyper Angular Rainbow Polarimeter (HARP-2)

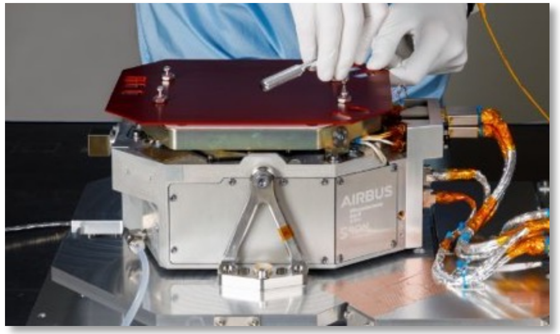


Update

- Delivery in Q1 2022, with flight build underway @ UMBC

	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

SRON/Airbus Spectro-polarimeter for Planetary Exploration (SPEXone)



Update

- SPEXone flight unit @ GSFC in storage, with testing complete
- Simulated data available (as of May)

OCI-polarimetry synergy

Spectro-Polarimeter for Planetary Exploration (SPEXone)

- Excellent for aerosol characterization
- *Addresses aerosol climate objectives beyond those required of OCI*

Hyper Angular Rainbow Polarimeter (HARP2)

- 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 atmospheric correction*

OCI + SPEXone + HARP2

- Far greater information content than any current (& planned) instrument suite for ocean color, aerosol, & cloud observations
- New data products: ocean color from multi-angle polarimetry, wind speed, etc.

schedule

Phase C – final design & fabrication

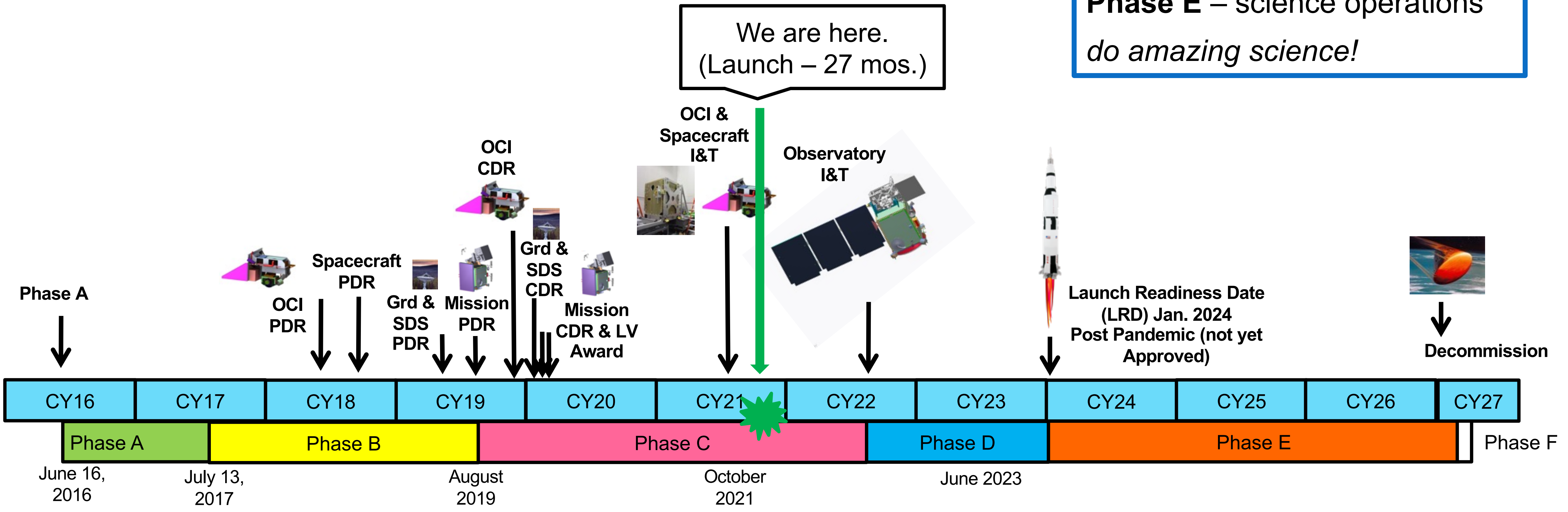
- all mission elements have passed Critical Design Reviews (CDRs)
- all mission elements will have System Integration Reviews (SIRs)
- engineering test units characterized; flight builds underway
- Project & HQ science implementing science capabilities

Phase D – system assembly, integration, testing, & launch

put everything together & get it on orbit

Phase E – science operations

do amazing science!



significant mission milestones (past 2 years)

- June 2019 – Mission PDR successfully completed
- Aug 2019 – Mission KDP-C (Applied Science fully funded)
- December 2019 – OCI CDR successfully completed
- February 2020 – launch vehicle successfully awarded to SpaceX
- February 2020 – Ground System CDR successfully completed
- February 2020 – Mission CDR and Spacecraft CDR successfully completed
- March 2020 – Completed OCI system level ETU Thermal Vacuum Testing # 1

PACE Plankton, Aerosol, Cloud, ocean Ecosystem

Ocean Color Instrument (OCI)

Engineering Test Unit Optical Module Assembly

11/06/19 – 12/11/19

PACE Plankton, Aerosol, Cloud, ocean Ecosystem

Ocean Color Instrument (OCI)

Engineering Test Unit
Thermal Vacuum Test Preparation

02/06/20 – 02/18/20

significant mission milestones (past 2 years)

- June 2019 – Mission PDR successfully completed
- Aug 2019 – Mission KDP-C (Applied Science fully funded)
- December 2019 – OCI CDR successfully completed
- February 2020 – launch vehicle successfully awarded to SpaceX
- February 2020 – Ground System CDR successfully completed
- February 2020 – Mission CDR and Spacecraft CDR successfully completed
- March 2020 – Completed OCI system level ETU Thermal Vacuum Testing # 1

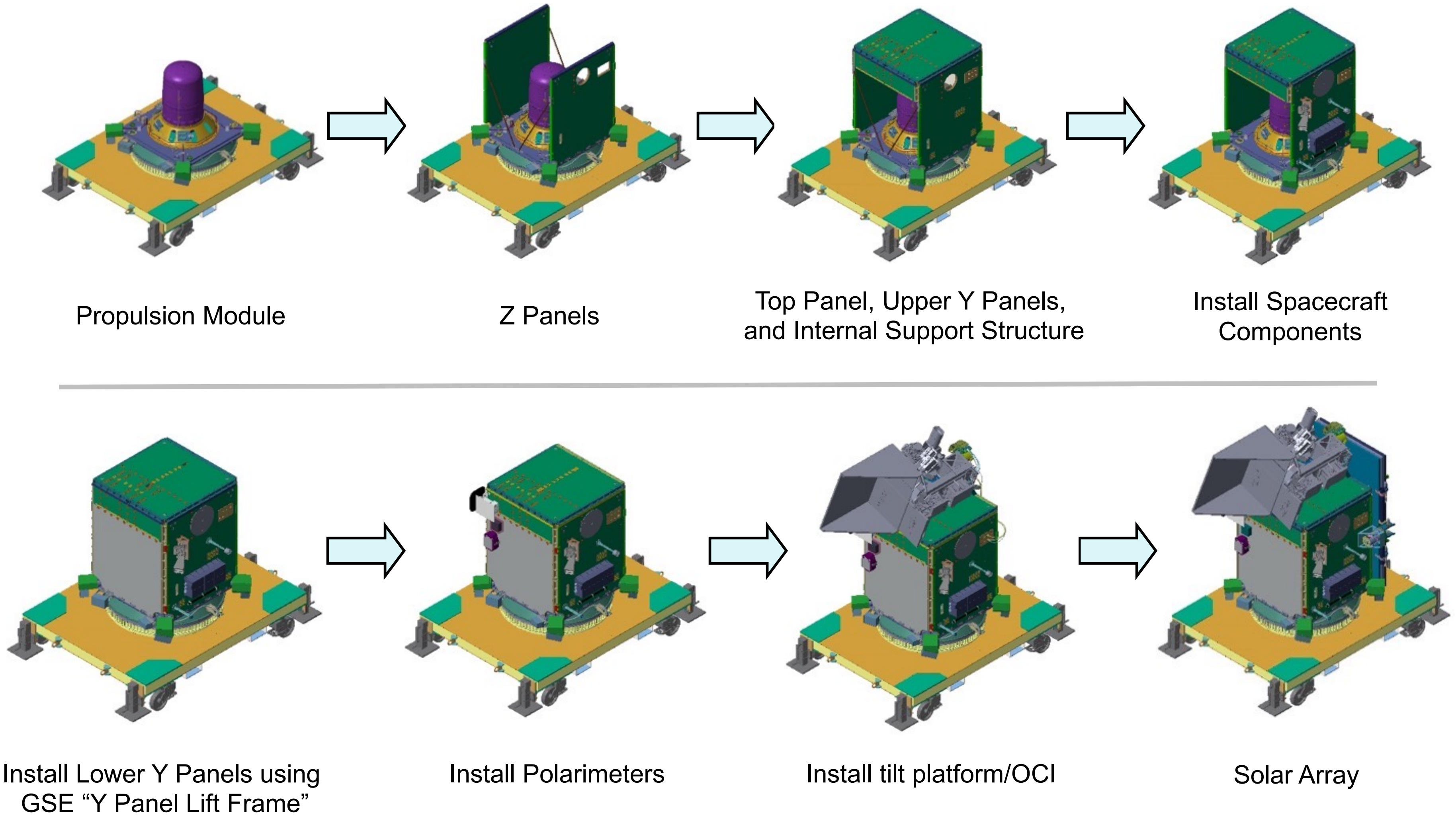
- July 2020 – First set of COVID restart activities initiated
- December 2020 – All elements of the Project had been restarted
- February 2021 – OCI Completed ETU Thermal Vacuum Testing #2
- April 2021 – SPEXone Instrument delivered to Goddard
- September 2021 – Start of Spacecraft and OCI system level I&T

Pandemic

covid impact summary

- all on site work halted from Mar 18 to Jul 27
- restart activities phased in monthly from late Jul to Dec
- the 4.5 month work stoppage, combined with pandemic-related operational inefficiencies, illnesses, and technical issues, resulted in a 10 month impact to the launch date
- all hardware build elements are currently up and operating, although GSFC is not fully accessible (50% capacity)
- the Project is projecting a 30 Jan 2024 launch date (to be approved)

I&T: observatory build sequence



FY22 is an incredibly important year for PACE!


MAGNETICALLY
CLEAN AREA

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

Heidi next talk

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

- Preliminary focus on validation of threshold products (ocean color radiometry, AOT, clouds)
- Evolution into validation of derived/advanced products, including polarimetry, & closure experiments
- Mission interested in collaborations / synergies / advanced planning with international partners
- **Separate but complementary PACE Post-launch Airborne eXperiment (PACE-PAX)**

System Vicarious Calibration team down-select planned for late 2022

- Two teams to one
- Coincides with end of 2nd project years
- Originally planned for mid-late 2021 after 1st project years

Applications Program & Early Adopters Natasha after Heidi

PACE Science Data Product Selection Plan pace.oceansciences.org/docs/PACE_Validation_Plan_14July2020.pdf

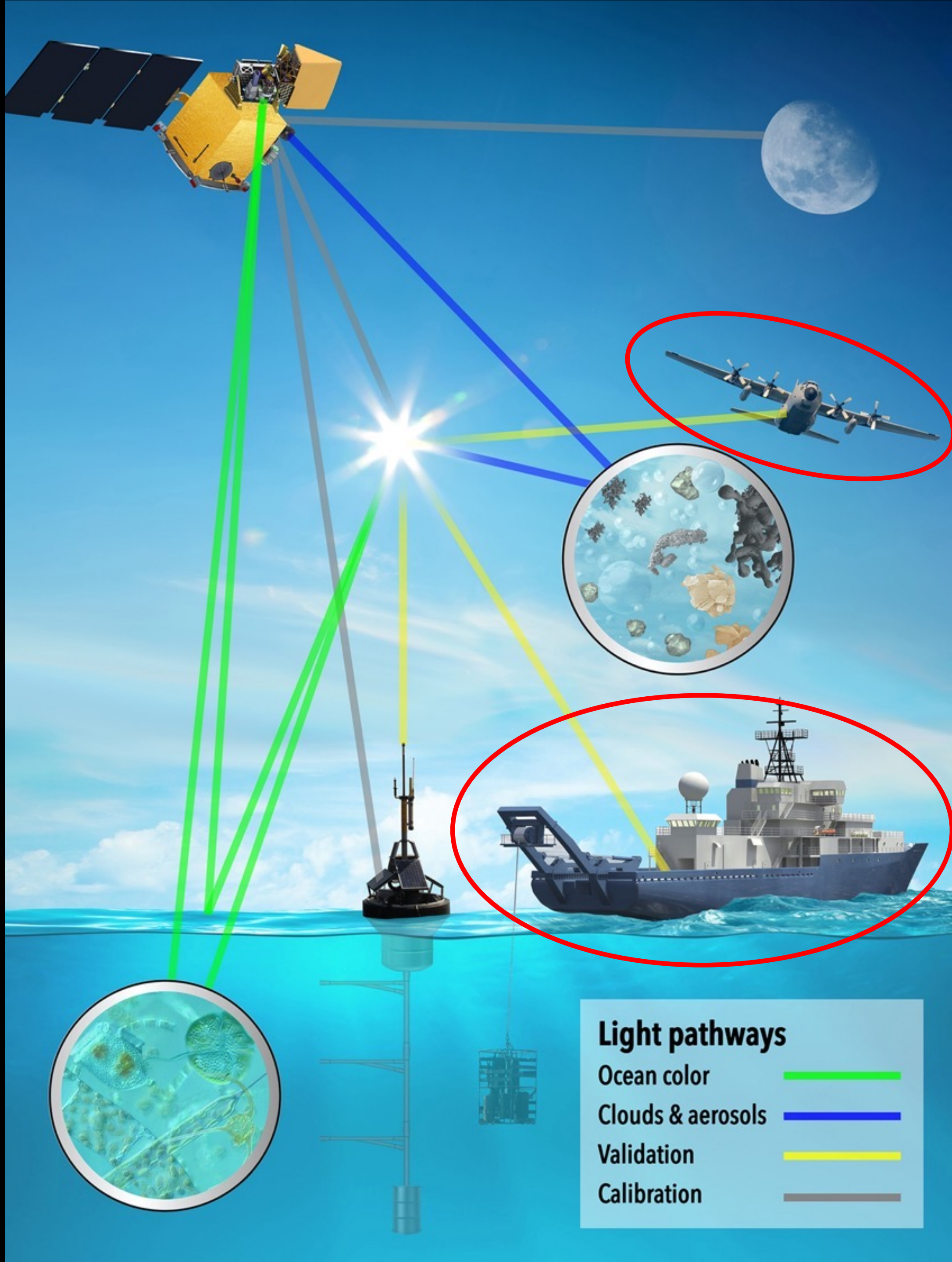
post-launch validation activities

PACE Validation Science Team (PVST)

- composition, scope, & execution TBD
- ROSES-22 late amendment
- selection ~late 2023 prior to launch
- in the field after first light (~spring 2024)

PACE-PAX

- planning underway (docs to be hosted @ *pace.oceansciences.org/campaigns.htm*)
- direct & proxy measurements
- US west coast, ~Sep 2024
- synergy with PVST anticipated
- not competed



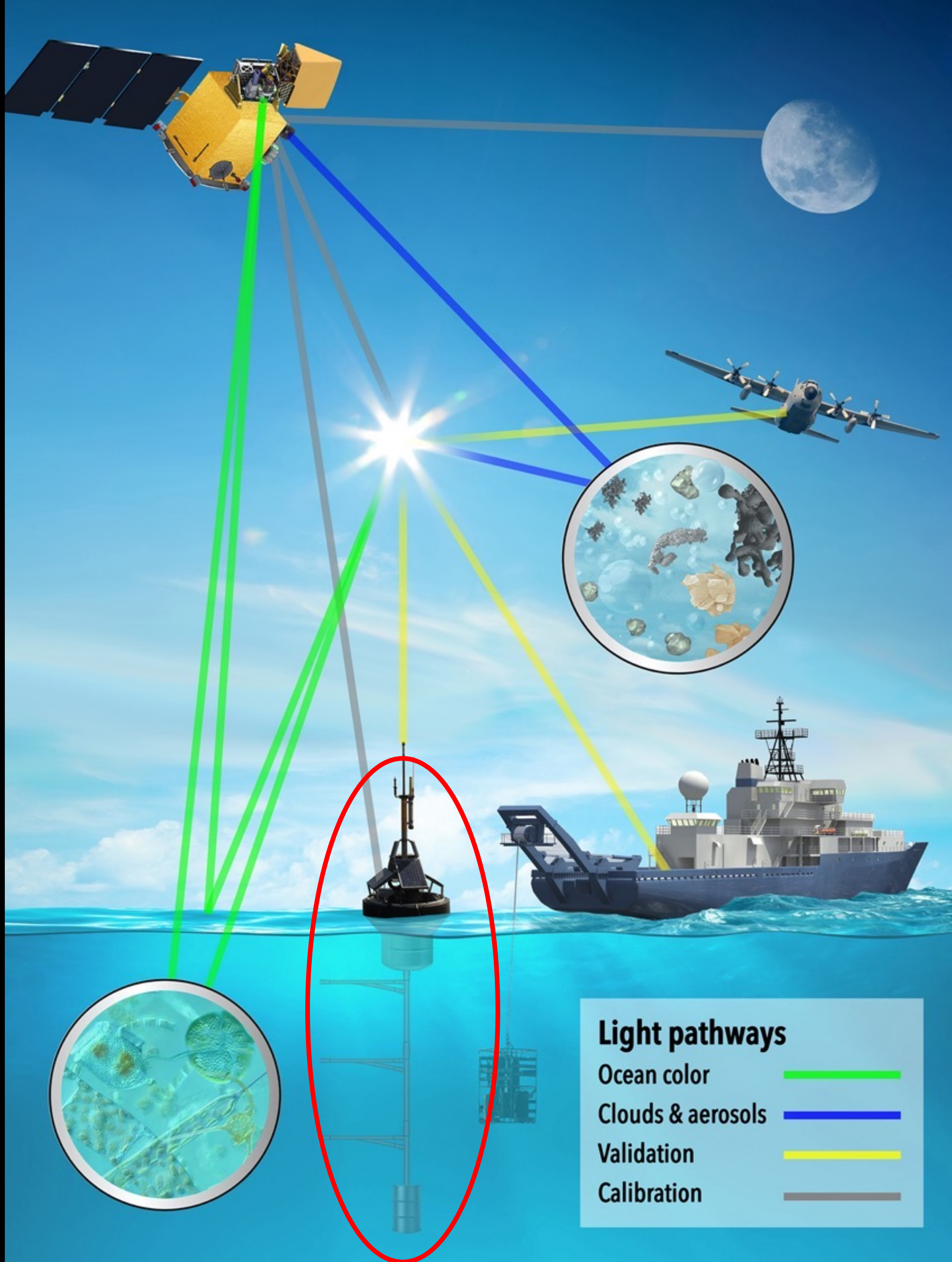
System Vicarious Calibration (SVC)

use of "truth" measurements to calculate another spectral absolute calibration once on orbit

(1) HyperNAV

SeaBird Scientific

radiometric float
- small
- portable
- profiling
- long-duration
- COTS legacies



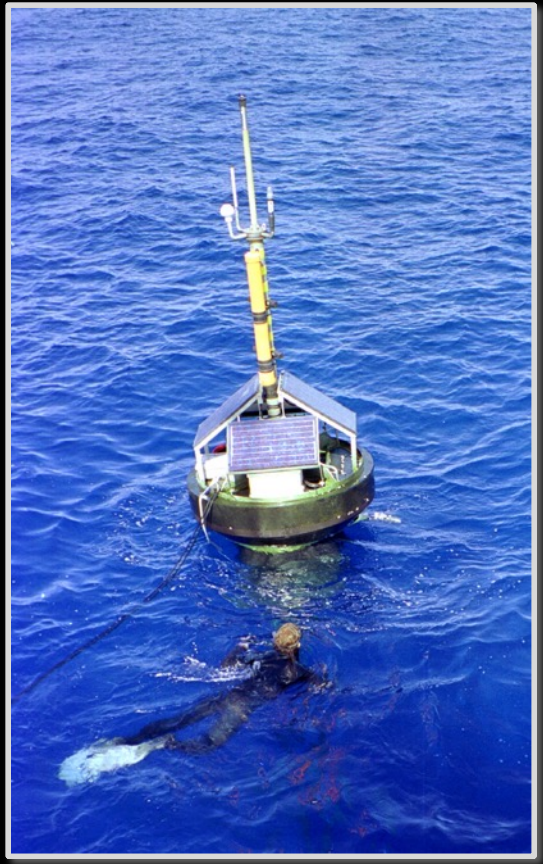
System Vicarious Calibration (SVC)

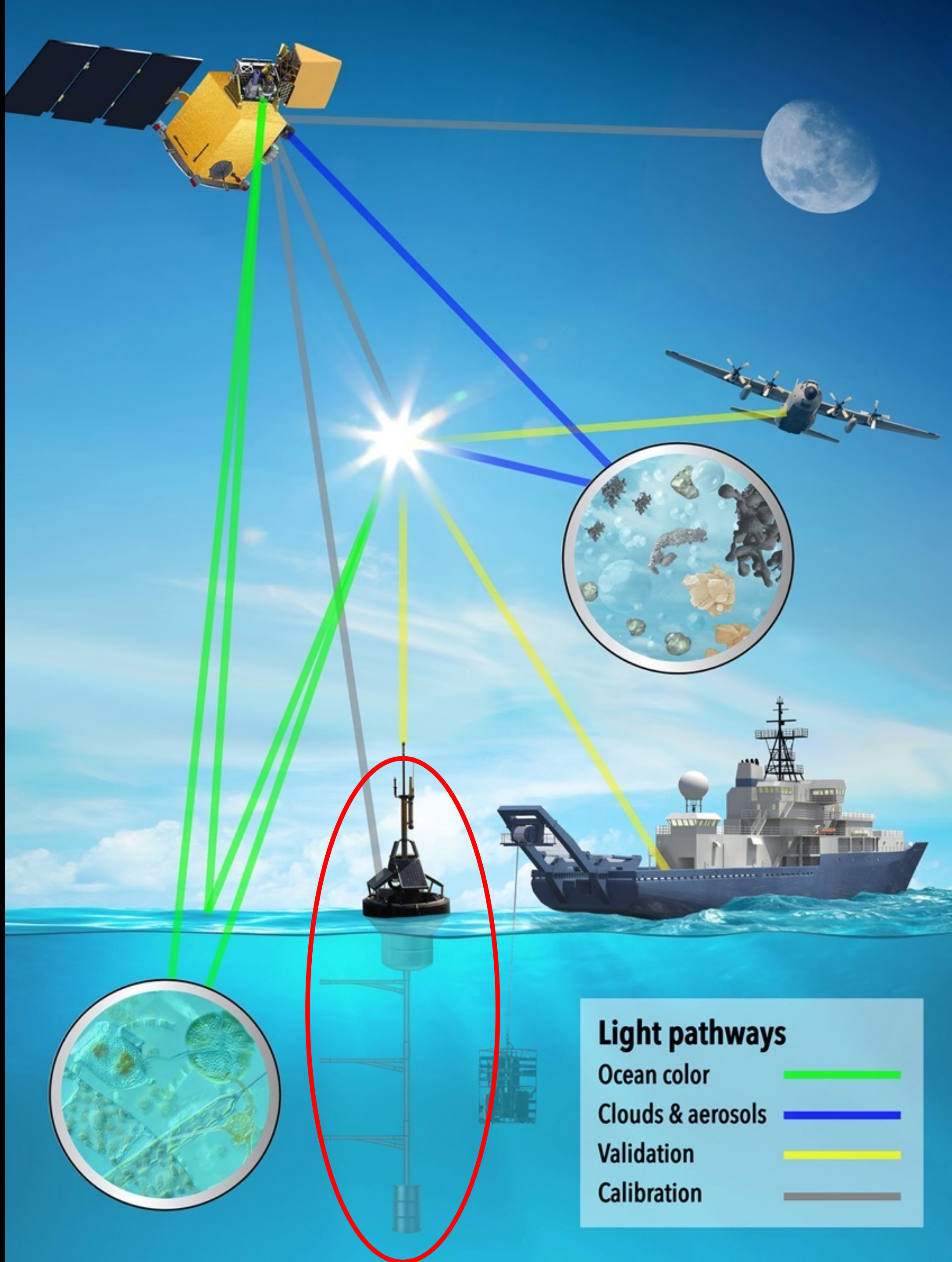
system requirements: hyperspectral UV-NIR, temporal stability, NIST-traceable, NRT data distribution (O[days])

(2) MarONet

U.Miami, NIST

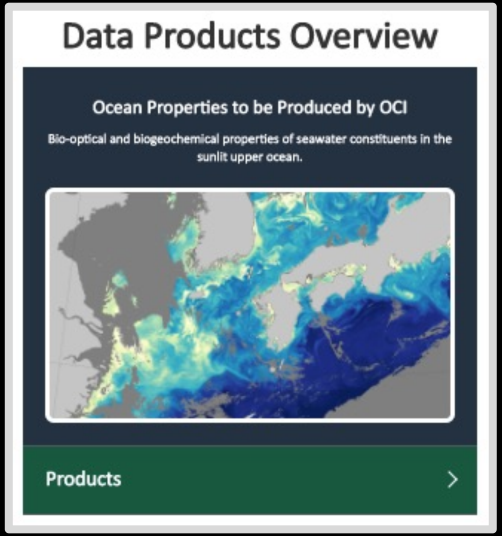
radiometric buoy
- large
- 20’ container
- 3 fixed arms
- long-deployment
- MOBY legacy



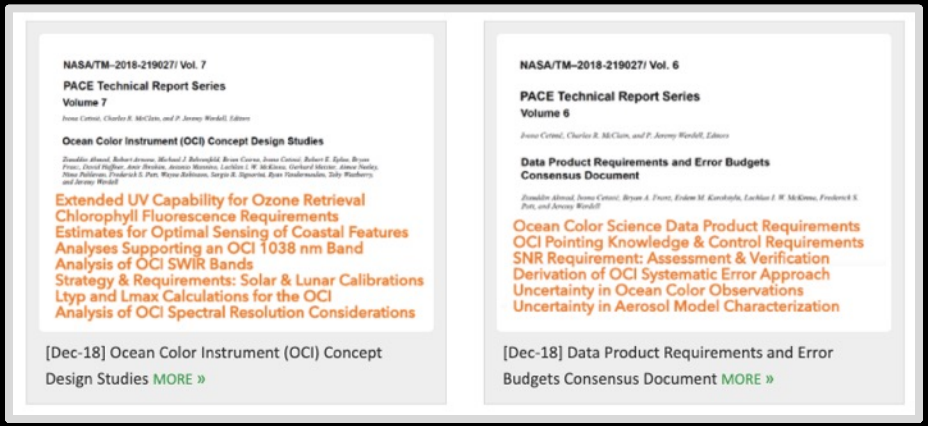


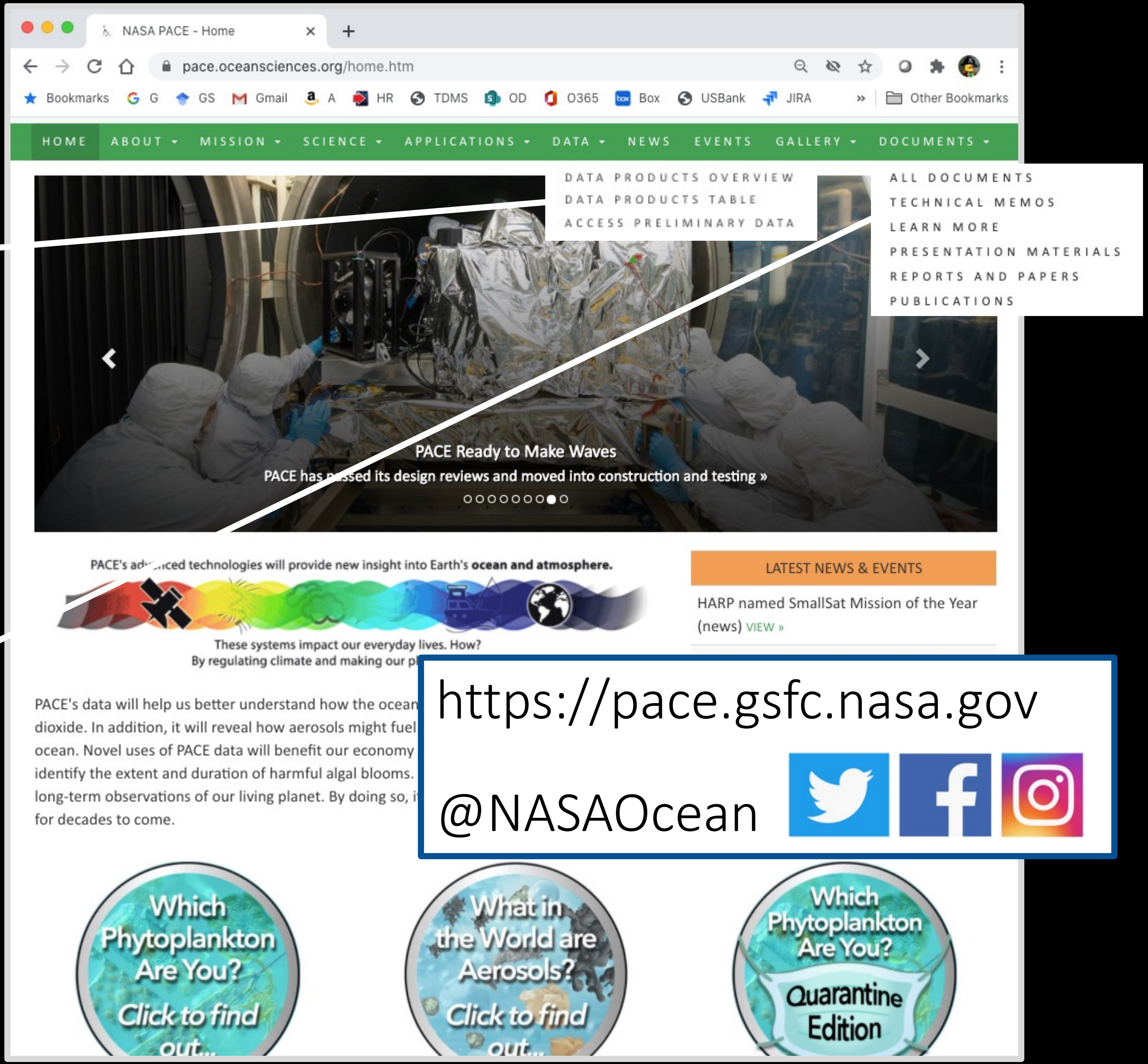
resources & useful info

data product descriptions + access to simulated data & characterizations



PACE technical memos & other documents





https://pace.gsfc.nasa.gov

@NASAOcean


PACE
Plankton, Aerosol, Cloud, ocean Ecosystem

Heidi Dierssen

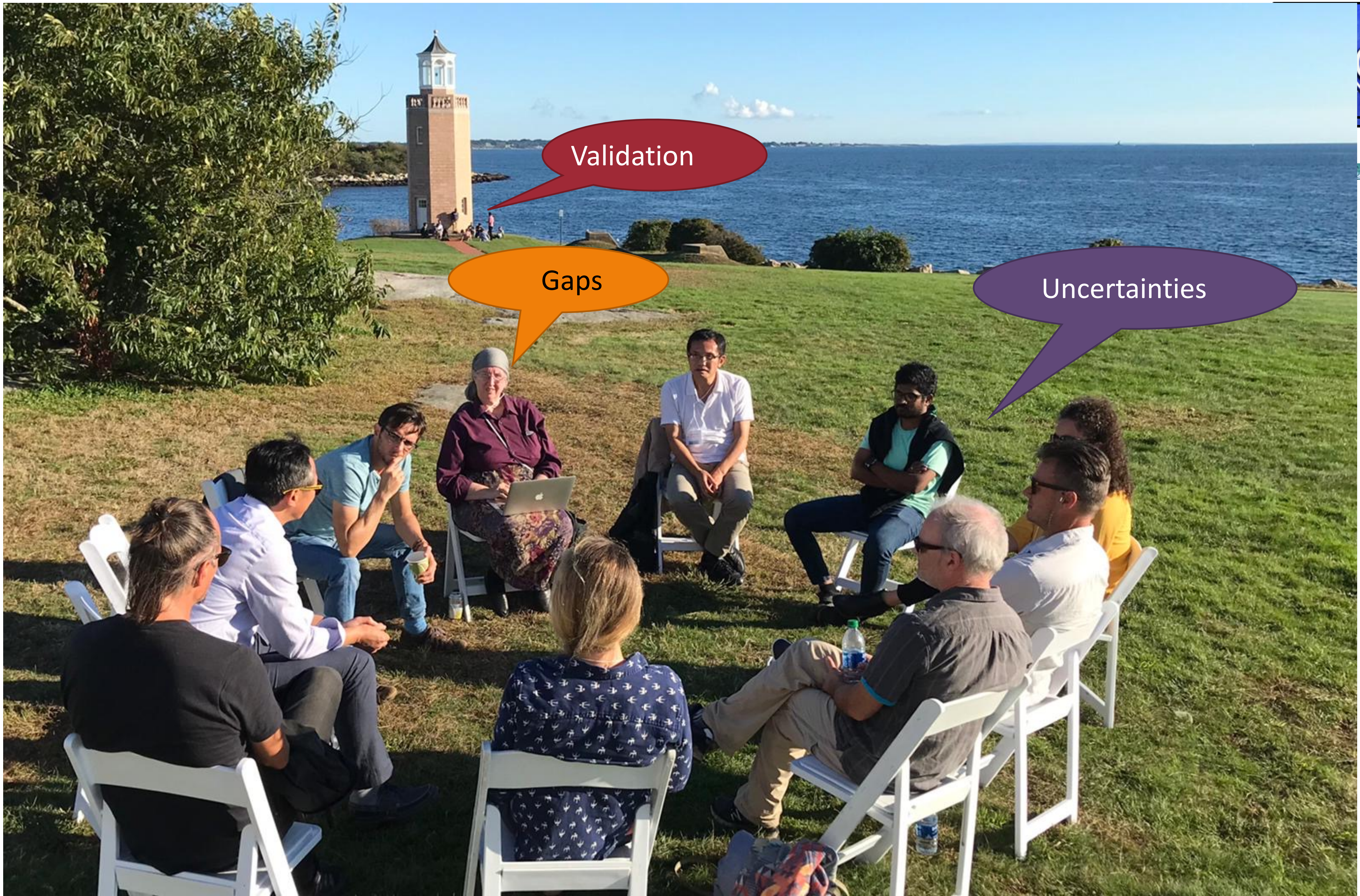
PACE Science & Application Team Lead

University of Connecticut

heidi.dierssen@uconn.edu

PACE Science and Application Team Updates

PACE Science and Applications Team (SAT)


Validation
Gaps
Uncertainties

GOALS of Team

- Algorithm production implemented as Standard, Provisional, Test or Special
- Algorithm documentation to be available online
- Algorithm implementation with project team

Mission Requirements

Table 1. Required Ocean Color Instrument (OCI) ocean color data products.

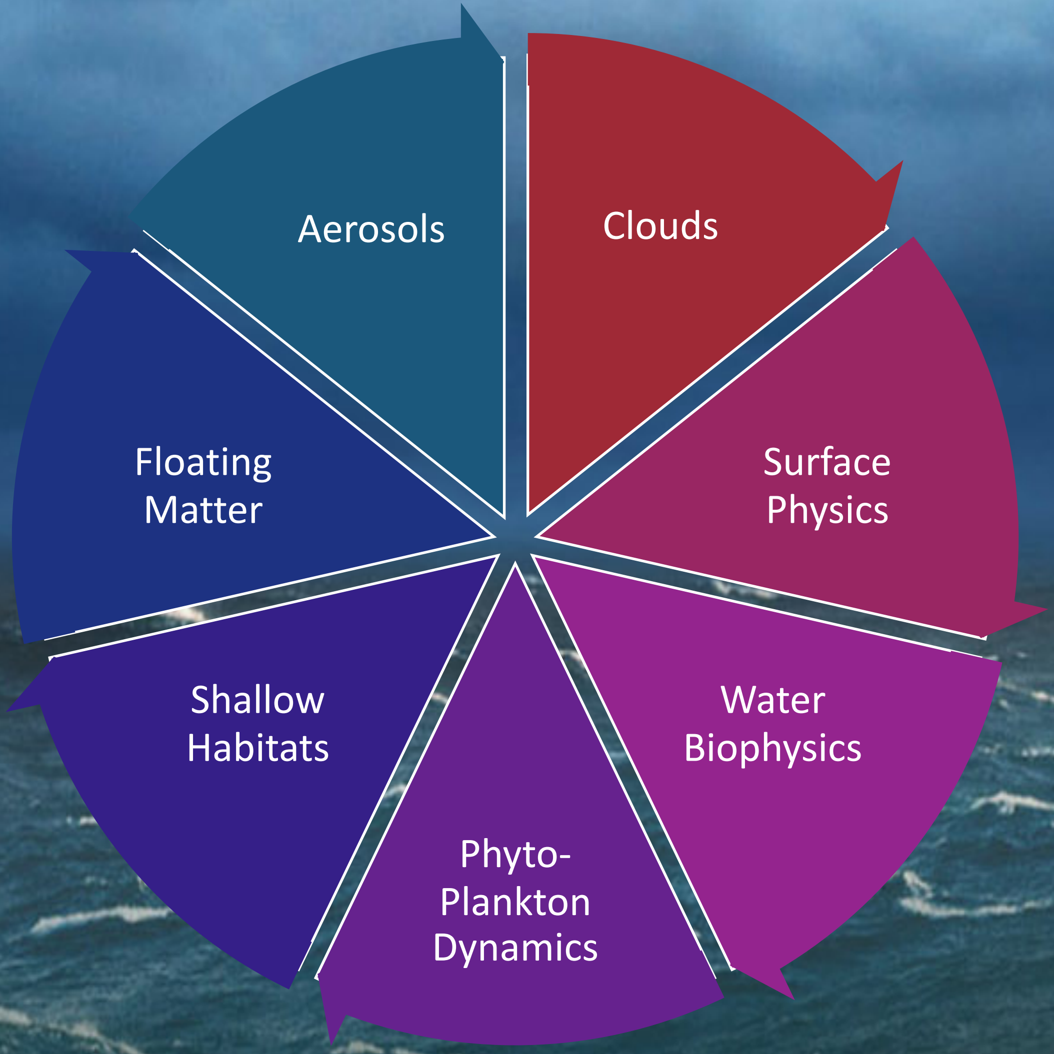
Data Product	Baseline Uncertainty
Water-leaving reflectances centered on (±2.5 nm) 350, 360, and 385 nm (15 nm bandwidth)	0.0057 or 20%
Water-leaving reflectances centered on (±2.5 nm) 412, 425, 443, 460, 475, 490, 510, 532, 555, and 583 (15 nm bandwidth)	0.0020 or 5%
Water-leaving reflectances centered on (±2.5 nm) 617, 640, 655, 665 678, and 710 (15 nm bandwidth, except for 10 nm bandwidth for 665 and 678 nm)	0.0007 or 10%
Ocean Color Data Products to be Derived from Water-leaving Reflectances	
Concentration of chlorophyll-a	
Diffuse attenuation coefficients 400-600 nm	
Phytoplankton absorption 400-600 nm	
Non-algal particle plus dissolved organic matter absorption 400-600 nm	
Particulate backscattering coefficient 400-600 nm	
Fluorescence line height	

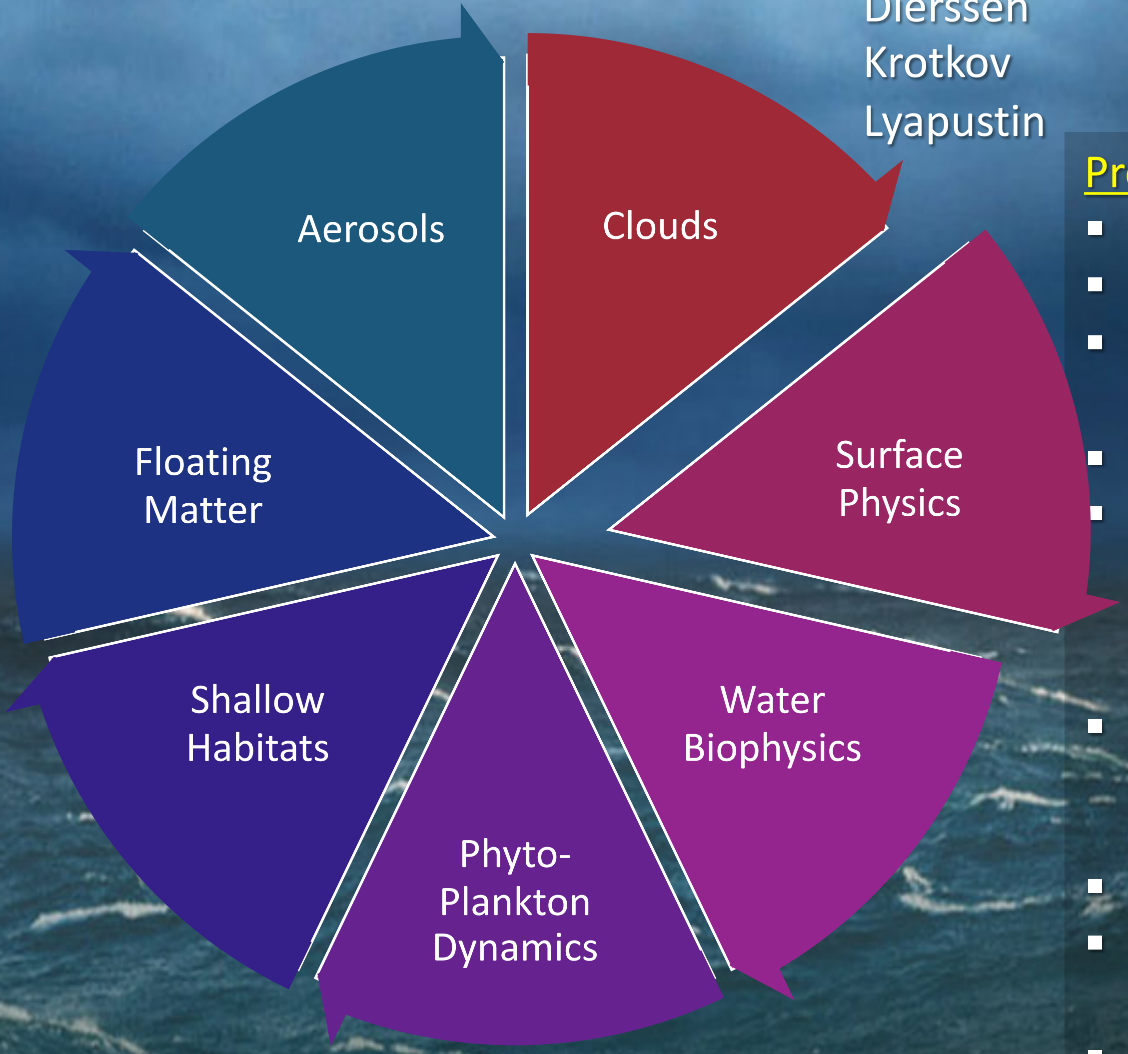
Table 2. Required OCI aerosol and cloud data products.

Data Product	Range	Baseline Uncertainty
Total aerosol optical depth at 380 nm	0.0 to 5	0.06 or 40%
Total aerosol optical depth at 440, 500, 550 and 675 nm over land	0.0 to 5	0.06 or 20%
Total aerosol optical depth at 440, 500, 550 and 675 nm over oceans	0.0 to 5	0.04 or 15%
Fraction of visible aerosol optical depth from fine mode aerosols over oceans at 550 nm	0.0 to 1	±25%
Cloud layer detection for optical depth > 0.3	NA	40%
Cloud top pressure of opaque (optical depth > 3) clouds	100 to 1000 hPa	60 hPa
Optical thickness of liquid clouds	5 to 100	25%
Optical thickness of ice clouds	5 to 100	35%
Effective radius of liquid clouds	5 to 50 µm	25%
Effective radius of ice clouds	5 to 50 µm	35%
Atmospheric data products to be derived from the above		
Water path of liquid clouds		
Water path of ice clouds		
Short-wave Radiative Effect		

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

PACE SCIENCE 24 TEAMS BY TOPIC



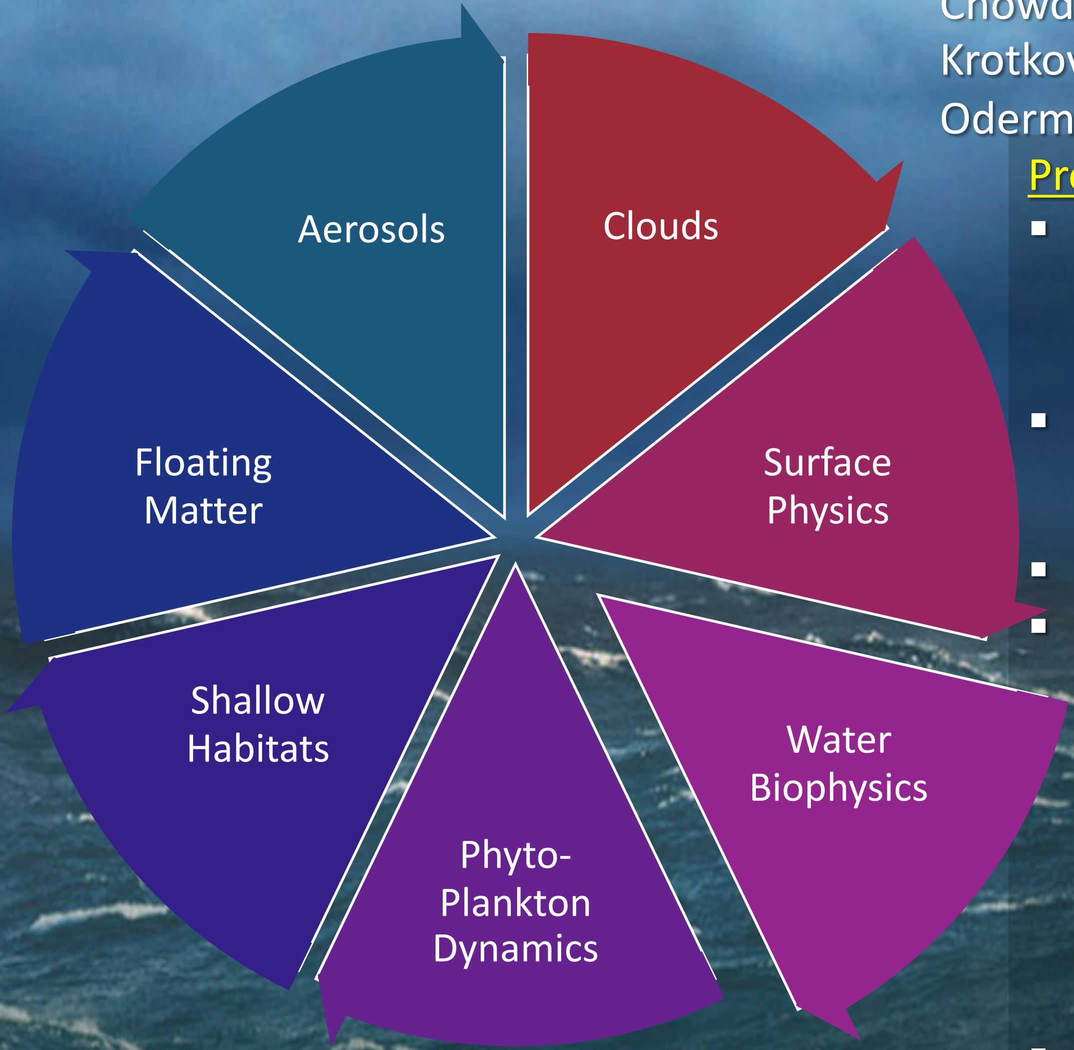


Science Team

Boss
Chowdhary
Dierssen
Krotkov
Lyapustin
Ottaviani
Twardowski
Zhai
Zhang

Properties

- Ocean Albedo $R(\lambda)$
- Land Albedo $R(\lambda)$
- Spectral Water-leaving Reflectance $R_w(\lambda)$
- Polarization Parameters
- Irradiance at Interface
  - Photosynthetically Available Radiation $E_d(0^+,PAR)$
  - Downwelling Irradiance $E_d(0^+, \lambda)$
- Irradiance Below Water Surface
  - Downwelling Irradiance $E_d(0^-,\lambda)$
  - Scalar Irradiance $E_o(0^-, \lambda)$
- Surface Index of Refraction
- Bidirectional Reflectance Function (BRDF)
- Whitecap Fraction/Factor

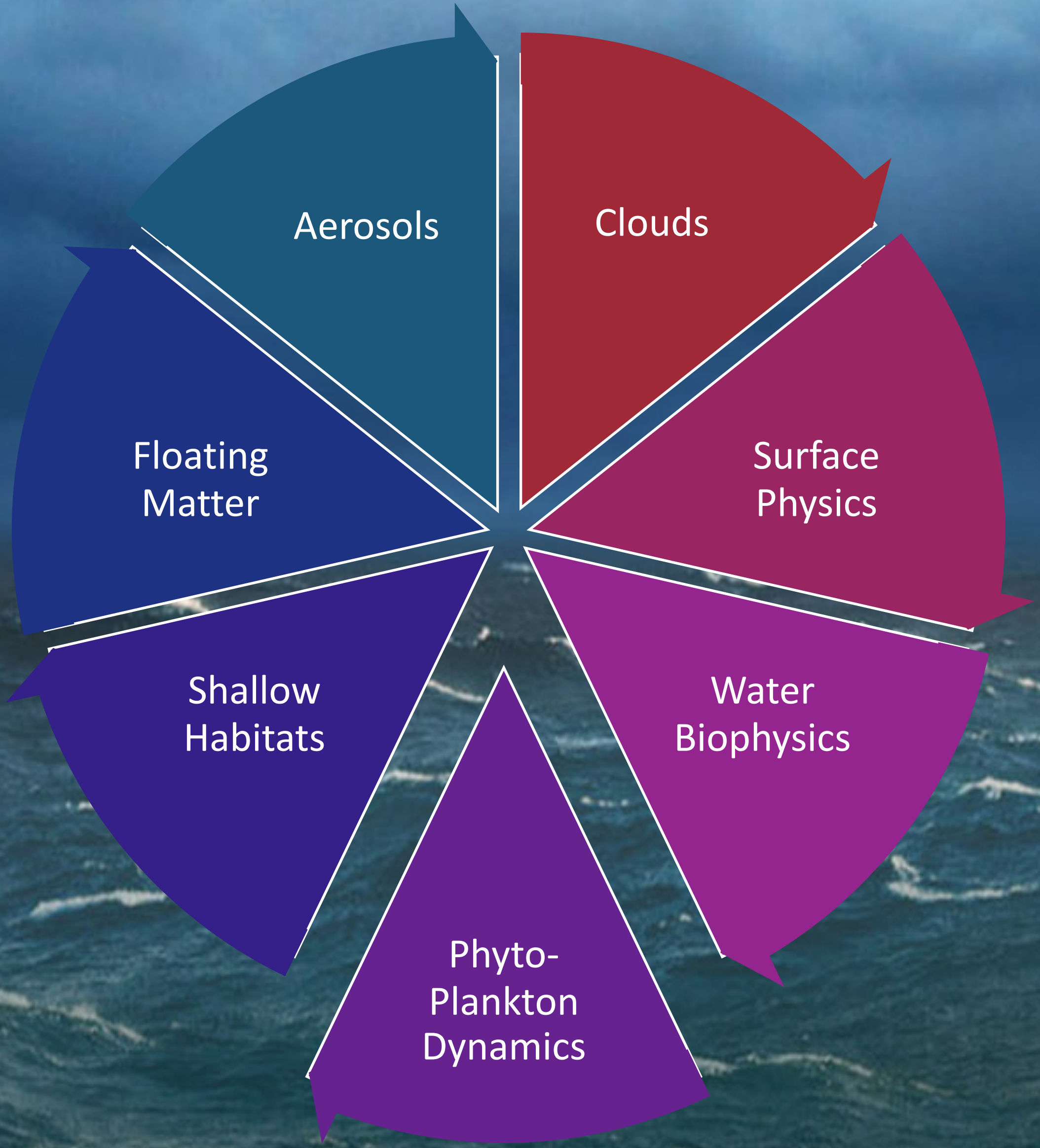


Science Team

Barnes
Boss
Chowdhary
Krotkov
Odermatt
Pahlevan
Stamnes
Stramski
Twardowski
Zhai

Properties

- Spectral Light Penetration
  - Downwelling Attenuation Kd(λ), Kd(PAR)
  - Scalar Attenuation Ko(λ)
- Turbidity
  - Suspended Particulate Matter (SPM)
  - Nephelometric Turbidity Unit (NTU)
- Vertical Stratification Properties
- Spectral Inherent Optical Properties (Deep and Shallow)
  - Absorption by Gelbstoff
  - Absorption by Phytoplankton
  - Absorption by Depigmented Particles
  - Volume Scattering Function
  - Backscattering
  - Particulate and Bubble Backscattering
  - Backscattering Ratio
- Shallow Bathymetry

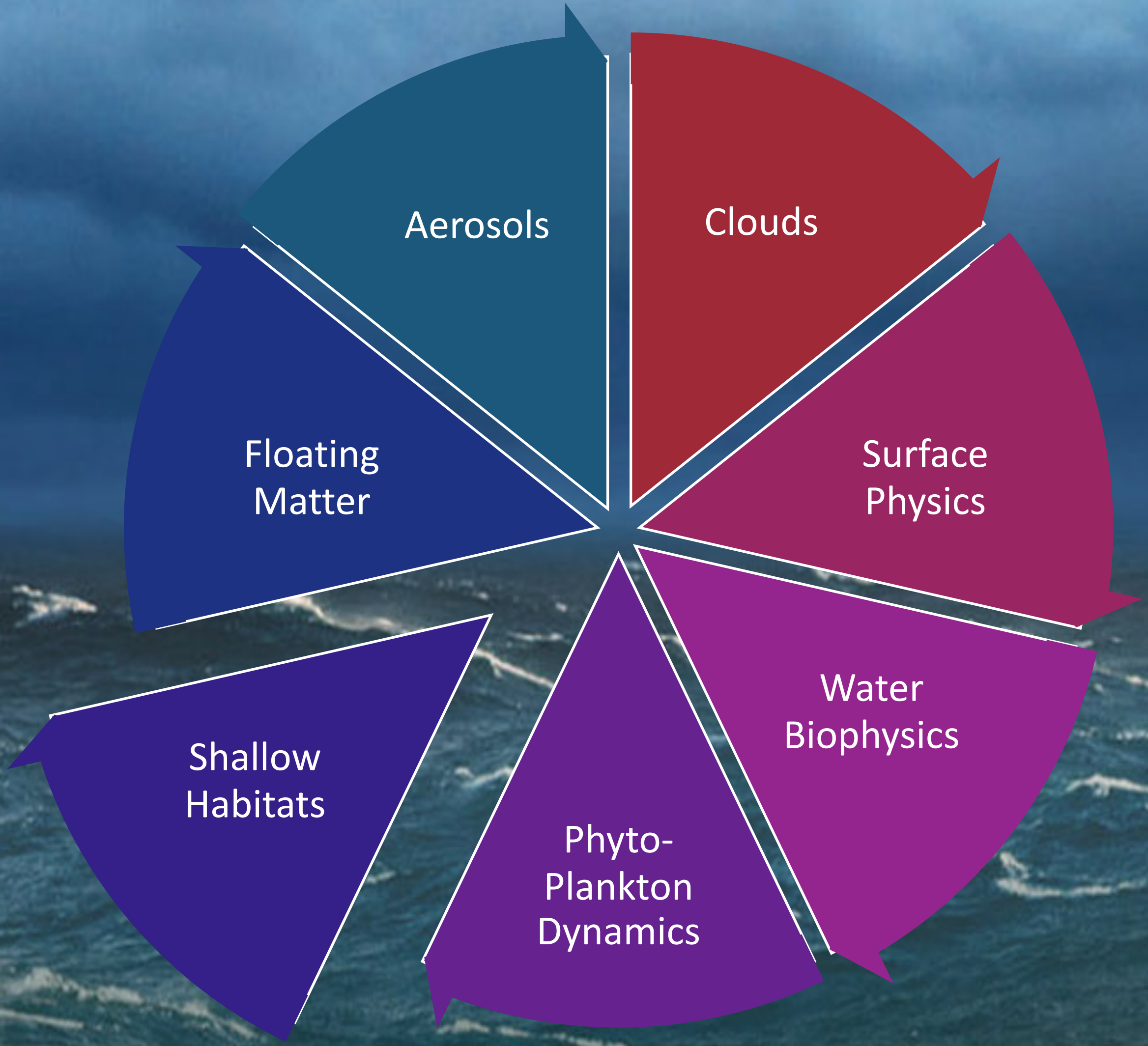


Science Team

Gaube
Pahlevan
Rousseaux
Shuchman
Siegel
Westberry

Properties

- Phytoplankton Pigment Concentration/Marker
  - Chlorophyll-a
  - Phycocyanin
  - Etc..
- Phytoplankton Composition
- Net Primary Productivity
- Fluorescence Line Height
- Adaptive Maximum Chlorophyll Index



Science Team

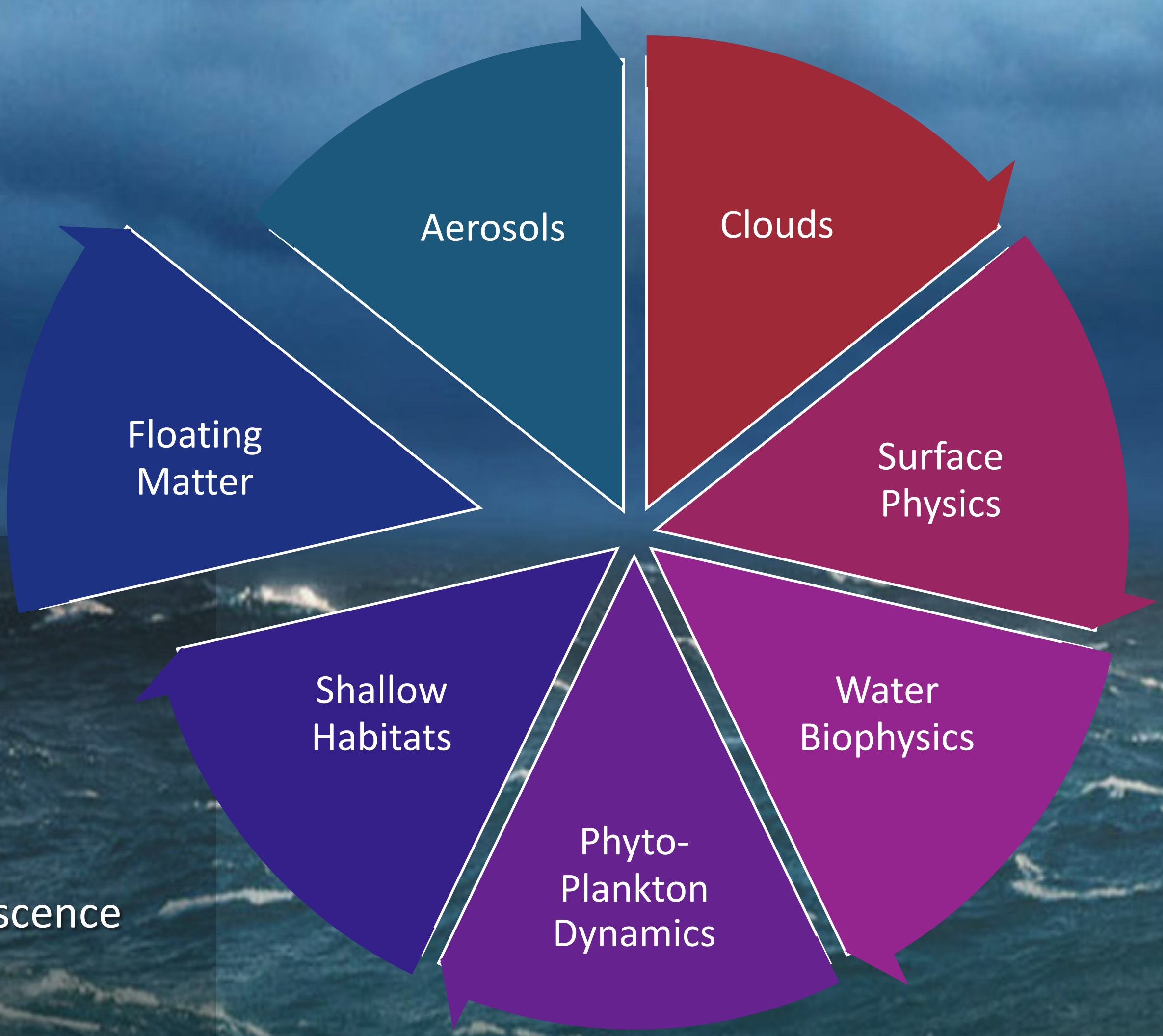
Barnes

Properties

- Benthic Classification
  - Coral
  - Seagrass
  - Shallow Algae
  - Sediment
- Benthic Condition
  - Change over time

Science Team
Hu
Ottaviani
Shuchman

Properties
- Sargassum Dynamics
  - Density
  - Depth
  - Carbon, nitrogen, phosphorous
  - Sun-induced fluorescence
- Oil Detection
- Surface Scum Index



PACE SAT Algorithms

Presentation		Last Name
Unified algorithm for aerosol characterization from OCI		Remer
Radiative Transfer Simulator and Polarimetric Inversion for PACE		Zhai
Retrievals of the Ocean Surface Refractive Index		Ottaviani
Joint polarimetric aerosol and ocean color retrievals with deep learning	FastMAPOL	Gao
Algorithms to obtain inherent optical properties of seawater		Stramski
The PACE-MAPP collaborative algorithm project		Stamnes
Freshwater Hyperspectral HABs Algorithms		Shuchman
Retrieving water quality indicators via MDNs		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		Siegel

Inversion algorithm for PACE	ZTT Model		Twardowski
MAIAC Processing of OCI Over Land: Aerosol Chemical Speciation			Go (Lyapustin)
HARP2 Level 1 Data Processing Plan			Xu
Remote sensing of cloud properties using PACE SPEXone and HARP-2			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			Boss
Support for PACE OCI Cloud Products			Meyer
Hyperspectral algorithms for OCI atmospheric correction and UV penetration			Krotkov
Net Primary Production for PACE OCI	NPP PACE, PhytoC		Westberry
Machine learning approaches for predicting phytoplankton community composition from ocean color			Craig
SpexONE - Aerosols		remoTAP	Hasekamp

Standard Semi-analytical Formulation

$$r_{rs,\infty} = \sum_{i=1}^{2} g_i \left(\frac{b_b}{a + b_b}\right)^i$$

Backscattering over absorption

Proportionality factor bidirectionalality of Incoming and reflected light

$$b_b = b_{b,water} + b_{b,large\ part.} + b_{b,small\ part.}$$

$$a = a_{water} + a_d + a_g + a_{ph}$$

ZTT (Zaneveld-Twardowski-Tonizzo) model

water Raman contribution (Westberry et al. 2013)

$$r_{rs}(\theta_s, \theta_v, \phi, V, a, b_b, \beta) \cong r_{rs,Raman}(\theta_s', a, b_b)$$

$$+ \frac{1}{\bar{\mu}_d(\theta_s', V, \frac{b_b}{a})} \frac{\beta(\psi)}{b_b} \frac{a}{b_b} \left(1 - \cos(\theta_v)\, \underbrace{\Psi_{K_{Lu}}(\psi) \bar{\mu}_\infty \left(\frac{b_b}{a}\right)^{-1}}\right) + f_L(\psi, \lambda) \left(1 - \tilde{b}_b^{-1}\right) + \tilde{b}_b^{-1} \Big]^{-1}$$

average cosine of downwelling light field (E_d/E_{od})

phase function in backward direction

absorption over backscattering

coefficients related to diffuse attenuation of radiance in viewing direction

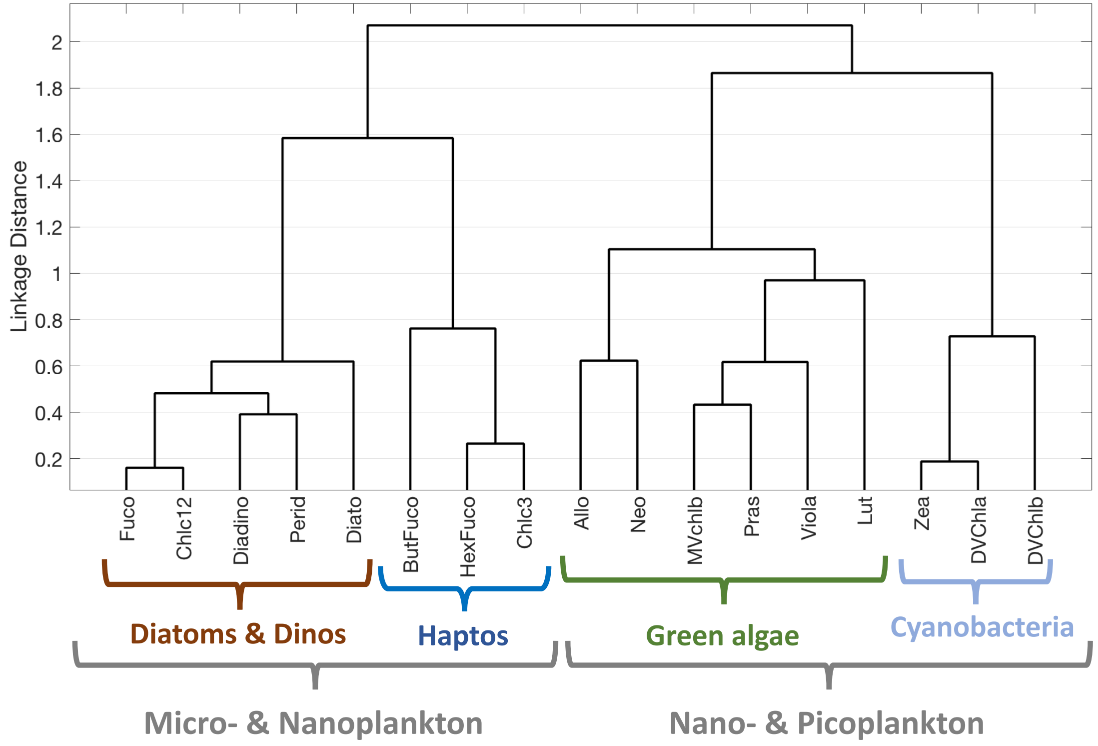
(Twardowski and Tonizzo 2017)

shape function for upwelling component of path radiance

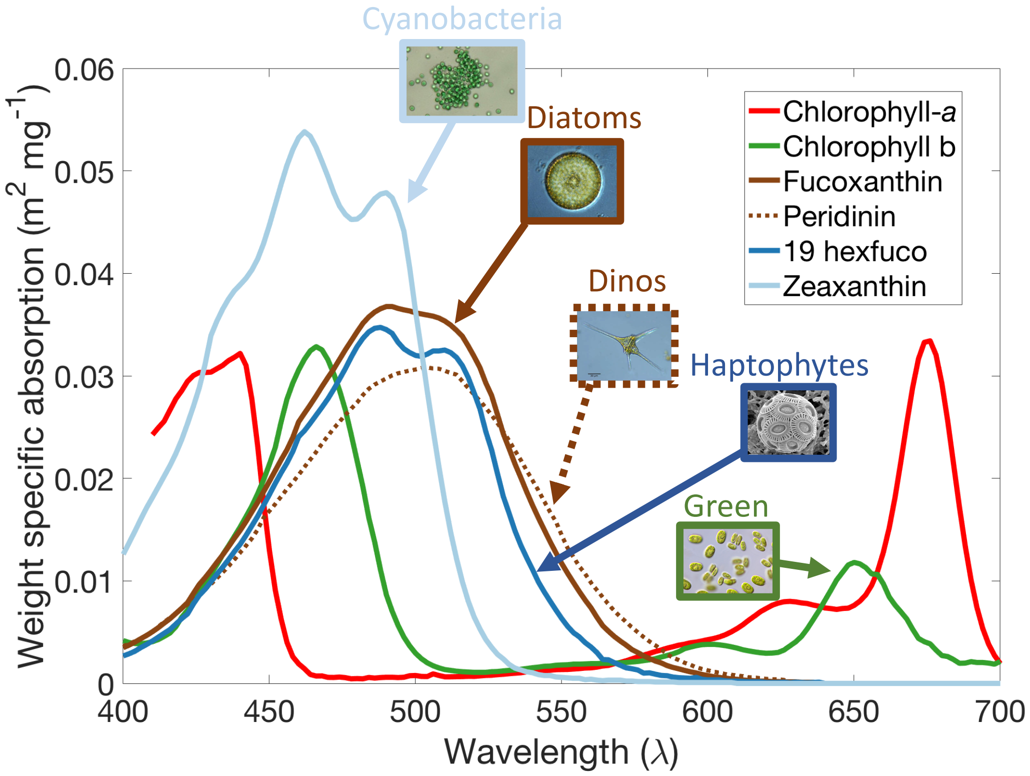
backscattering ratio b_b/b

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

Spectral derivative methods for estimating phytoplankton pigment concentrations

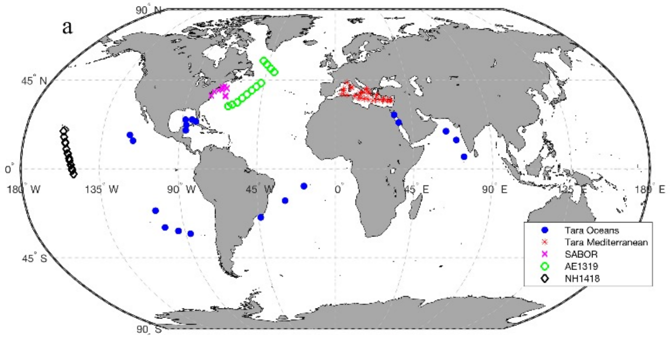


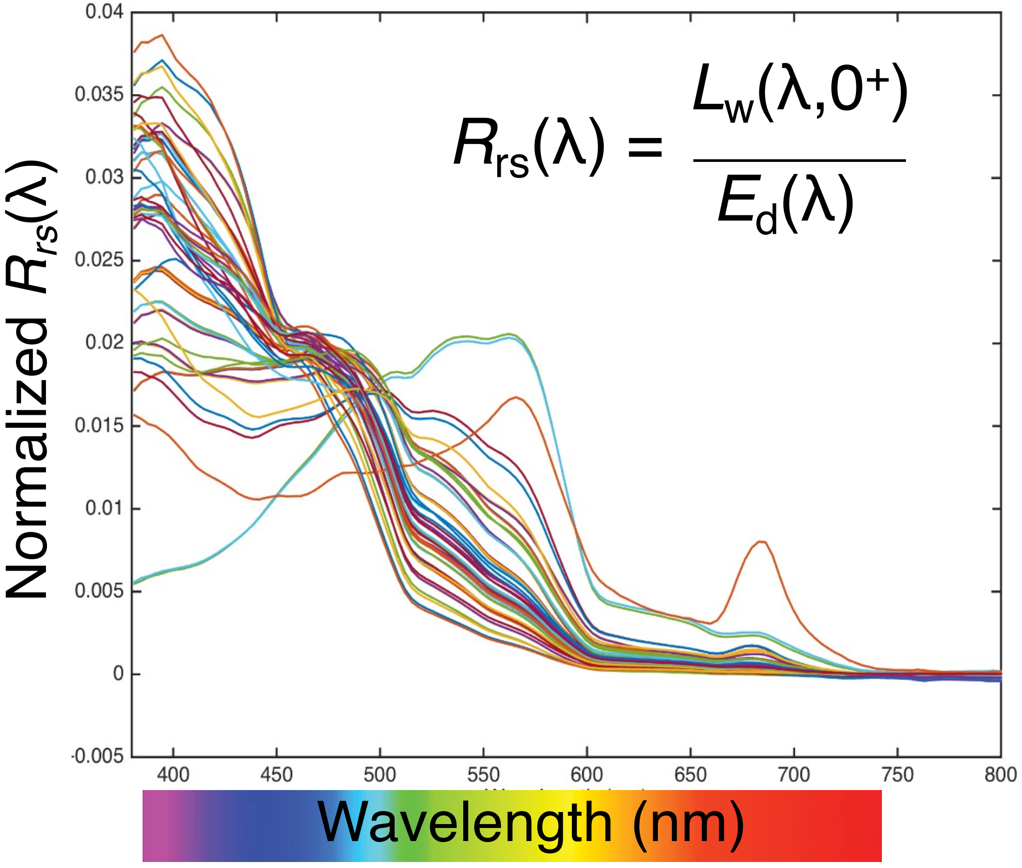
Kramer & Siegel JGR-Oceans [2019]

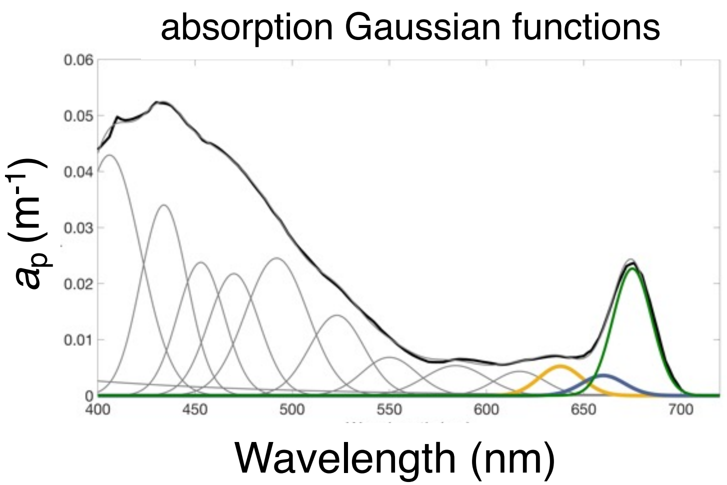


- Large degree of covariability among pigments
- Limits number of PFT groups can be retrieved using **HPLC pigments**

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







Chase et al. 2017, JGR-Oceans

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

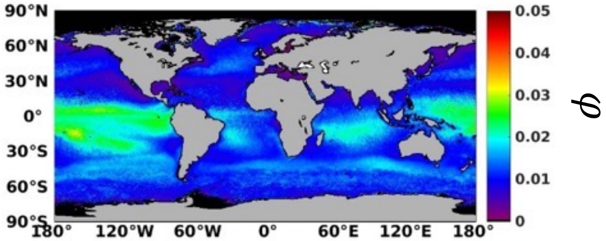
<u>Team members:</u>

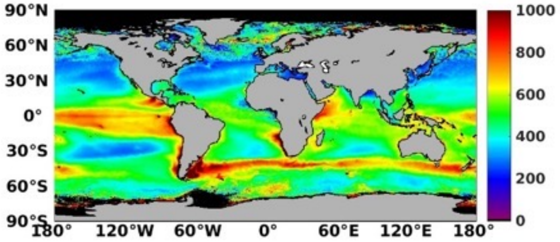
Toby Westberry (PI)

Mike Behrenfeld (Co-I)

Jason Graff (Co-I)

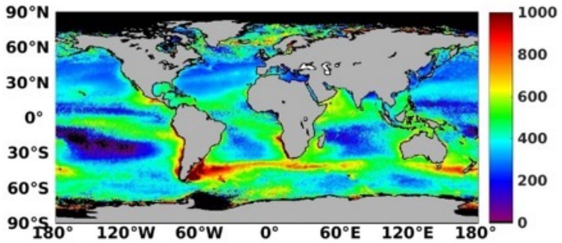
Keywords: Phytoplankton, photosynthesis, primary production, biomass, physiology, photoacclimation, fluorescence, growth rate





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

∫ΔNPP = 10.9 Pg C



Testing PACE Terrestrial Ecosystem Productivity Algorithms Using HICO

K. Fred Huemmrich, Petya P.K. Campbell, University of Maryland Baltimore County - kfhuemm@gmail.com

Used HICO data to test potential PACE terrestrial algorithms for productivity

Require robust algorithms that work across vegetation types due to PACE's large pixels

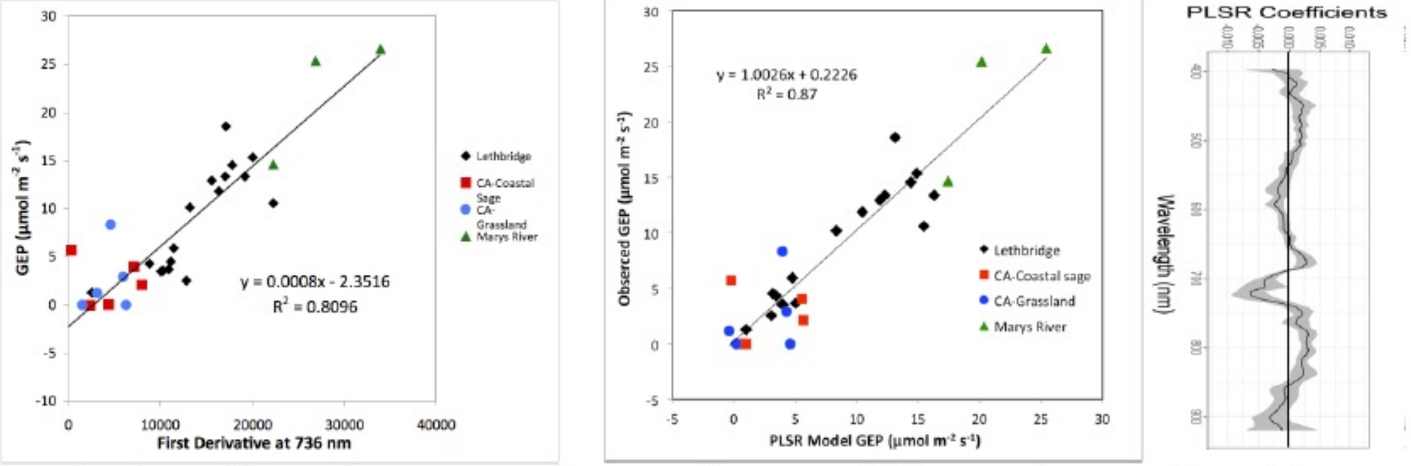
- most land pixels will likely be mixtures

Examined four different sites with flux towers measuring productivity. Sites included grass, shrubs, and forest covers

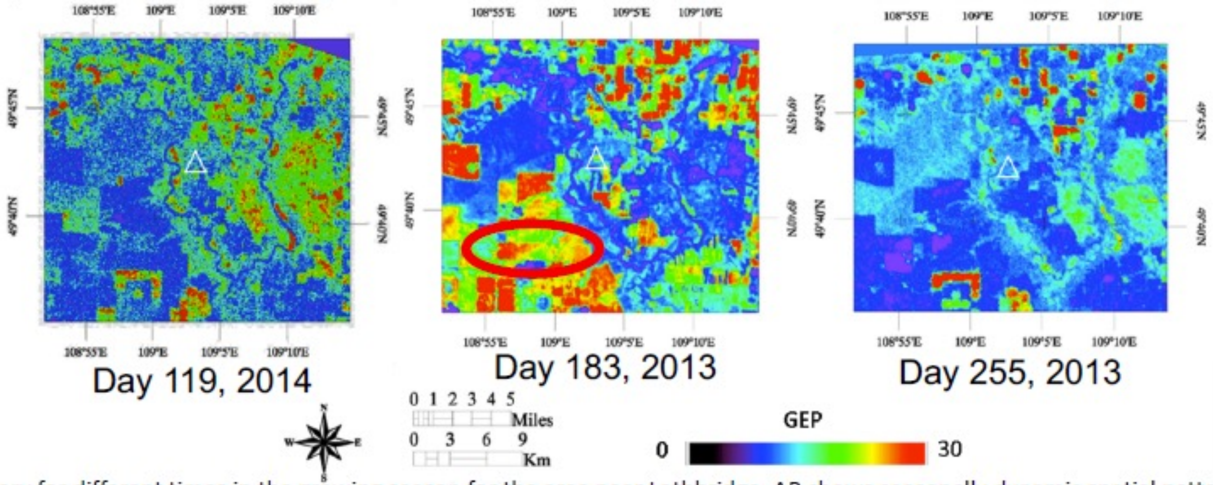
Multiple approaches were successful

Further studies are required to determine optimal approaches for PACE that describe diverse vegetation types

This work may be advanced by leveraging SBG activities such as the reprocessed imaging spectrometer data by SISTER project (SBG Space-based Imaging Spectroscopy and Thermal PathfindER)



Two examples of successful approaches to retrieve GEP from HICO reflectances are: left figure uses descriptions of spectral shape, in this case first derivatives of spectral reflectance at 736 nm, and right figure uses statistical approaches such as Partial Least Squares Regression (PLSR) (the figure to the far right shows the coefficients for each spectral bands from the PLSR calculation).

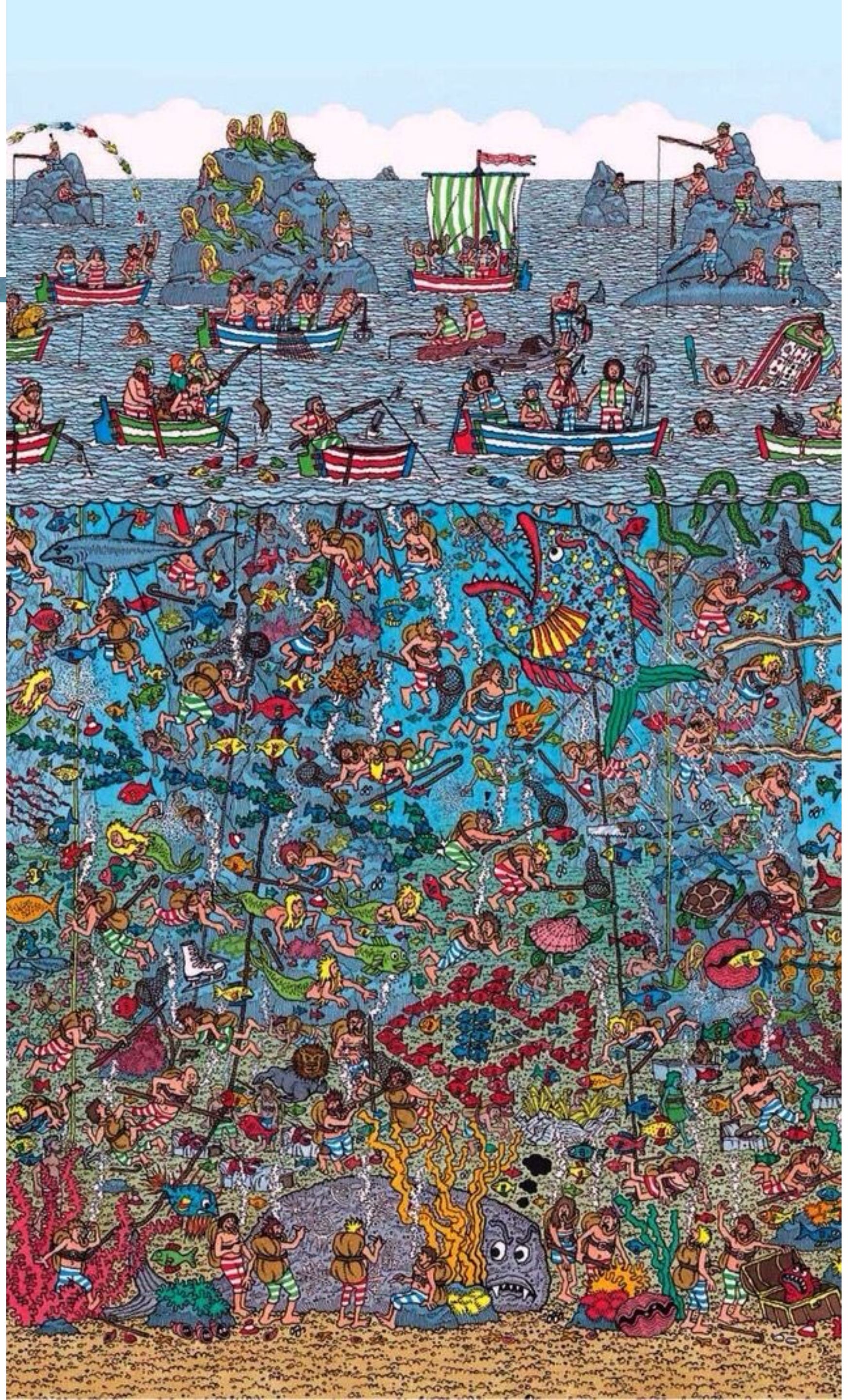


HICO imagery for different times in the growing season for the area near Lethbridge, AB shows seasonally dynamic spatial patterns of GEP. Further, the reflectance-based algorithm describes both between and within field variability in GEP as indicated by the variability in the circled field in the midsummer (center) image. In visible color images this field is uniformly green. The triangle marks the location of the flux tower.

Reference: Huemmrich, et al. (2017) ISS as a Platform for Optical Remote Sensing of Ecosystem Carbon Fluxes: A Case Study Using HICO." IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 10(10) : 4360-4375, DOI 10.1109/JSTARS.2017.2725825

PACE SAT and Validation

- Draft Validation Plan is currently being updated
- Validation:
  - hyperspectral radiometry and polarimetry
  - required atmospheric and aquatic products
  - within 12 months of launch
- Variety of sub-orbital validation data
  - airborne campaigns (PACE-PAX)
  - autonomous measurements
  - other validation needs
- SAT will provide recommendations to the PACE Validation Science Team.
- Innovative ideas about how to best validate satellite missions – biggest bang for buck



VALIDATION CONSIDERATIONS

Spatial Domain	All pixels
Temporal Domain	All images
Product Suite	All products
Latency	Immediate
Cost	Free

Subset

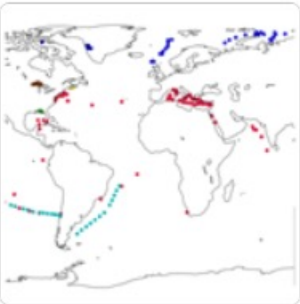
Hyperspectral Data is ***critically needed*** for algorithm development and validation

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

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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[4]Universities Space Research Association, Columbia, MD 20771, USA
[5]School of Marine Sciences, University of Maine, Orono, ME 04469, USA
[6]Ocean Ecology Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
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[8]Marine Physical Laboratory, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093, USA
[9]Naval Research Laboratory, Washington, DC 20375, USA
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[13]Earth Research Institute, University of California, Santa Barbara, CA 93106, USA

Correspondence: Kimberly A. Casey (kimberly.a.casey@nasa.gov, kcasey@usgs.gov)

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

Relevant Hyperspectral Databases (Dierssen et al. 2021)

Field and Culture Data		
Casey, K. A., Rousseaux, C. S., Gregg, W. W., Boss, E., Chase, A. P., Craig, S. E., et al. (2020). *Earth System Science Data*, *12*(2), 1123–1139. https://doi.org/10.5194/essd-12-1123-2020. https://doi.pangaea.de/10.1594/PANGAEA.902230.	Field, Global	A global compilation of in situ aquatic high spectral resolution inherent and apparent optical property data for remote sensing applications
Carpenter, Dierssen, Hochberg, Lee. 2014-2017. The Coral Reef Airborne Laboratory (CORAL) database. https://doi.org/10.5067/SeaBASS/CORAL/DATA001 https://airbornescience.jpl.nasa.gov/campaign/coral	Field, Pacific Reefs	In situ IOP and AOP data collected over Pacific coral reefs in conjunction with PRISM hyperspectral imagery
Knaeps et al. (2018). The SeaSWIR dataset. https://doi.org/10.1594/PANGAEA.886287	Field, Regional	Hyperspectral marine reflectances, total suspended matter, and turbidity measurements gathered at three turbid estuarine sites.
Behrenfeld et al., 2014-2017. North American Aerosol and Marine Ecosystem Study (NAAMES). https://doi.org/10.5067/SeaBASS/NAAMES/DATA001	Field, North Atlantic	Four cruises in North Atlantic with AOPS, IOPs, associated with phytoplankton and aerosol data.
Siegel et al. 2018-2020. Ocean EXPORTS https://doi.org/10.5067/SeaBASS/EXPORTS/DATA001	Field, Pacific & Atlantic	Data on export and fate of upper ocean net primary production coupled to IOP and AOP measurements.
Marine Biodiversity Observation Network (MBON) Data Portal. https://mbon.ioos.us/	Field, Regional	Biodiversity time series of flora and fauna along coastal zones with ancillary data.
Mortelmans et al. (2019). Lifewatch Flanders Marine Institute Observatory Data. In prep for Reflectance https://doi.org/10.14284/393	Field, Coastal North Sea	Monthly phytoplankton pigment, suspended matter, turbidity, and recently hyperspectral radiometry

Vanderwoude et al. (2020). NOAA GLERL Great Lakes Harmful Algal Bloom Database Doi: In prep	Field, Great Lakes	Monthly sampling of Great Lakes phytoplankton composition and hyperspectral optics
Bracher et al. 2020. Coupled phytoplankton composition and radiometry from Atlantic Ocean. https://doi.org/10.1594/PANGAEA.913536	Field, Atlantic	Phytoplankton pigment concentration, groups, and radiometric measurements in the Atlantic Ocean.
Bagniewski, W. et al. (2010). North Atlantic Bloom Experiment 2008. https://www.bco-dmo.org/project/2098	Field, Atlantic	Phytoplankton dynamics, profiled hyperspectral reflectance with autonomous optical backscatter, attenuation, radiance
Dekker, Anstee, In prep. Digital Earth Australia. Australian Shallow Waters Spectral Library https://ozcoasts.org.au/management/library/	Field, Australia	Spectral library repository for aquatic ecosystem substratum and substratum cover types
Clementson and Wojtasiewicz (2019). Australian National Algae Culture Collection https://doi.org/10.1016/j.dib.2019.104020	Culture	Dataset on the in vivo absorption characteristics and pigment composition of various phytoplankton species
Voss et al. NOAA Marine Optical Buoy (MOBY) https://www.star.nesdis.noaa.gov/socd/moby/filtered_spec/	Field, Hawaii	Hyperspectral water-leaving reflectance
Joyce, K. 2020. Shared Drone Spectroscopy https://www.geonadir.com/	Field, Global	Public repository for drone data including hyperspectral datasets

Simulated Databases

Simulated and Derived Data		
Craig, Susanne E; Lee, Zhongping; Du, Keping (2020). National Aeronautics and Space Administration, PANGAEA, https://doi.org/10.1594/PANGAEA.915747.	Simulated, Global	Top of Atmosphere, Hyperspectral Synthetic Dataset for PACE (Phytoplankton, Aerosol, and ocean Ecosystem) Ocean Color Algorithm Development.
Gregg, W. W., & Rousseaux, C. S. (2017). Simulating PACE Global Ocean Radiances. *Frontiers in Marine Science*, *4*. https://doi.org/10.3389/fmars.2017.00060	Simulated, Global	Dynamic simulation of global water-leaving radiances at 1 nm spectral resolution using an ocean model containing multiple ocean phytoplankton groups, etc.
Bracher et al. 2017. Phytoplankton composition from 2002-2012 in world ocean https://doi.org/10.1594/PANGAEA.870486	Derived, Global	Global monthly mean surface chlorophyll a for diatoms, coccolithophores and cyanobacteria from SCIAMACHY data

Loisel and Stramski Developing a new simulated dataset for PACE.

Simulated Imagery on PACE website

Simulated Ocean Color Imagery

Simulated OCI Instrument Model

Simulated GMAO

Simulated PyToast

Simulated Polarimetry Imagery

Simulated SPEXone data

AirHARP Proxy Data

OceanData Home ▸ directaccess ▸ PACE ▸

Filename
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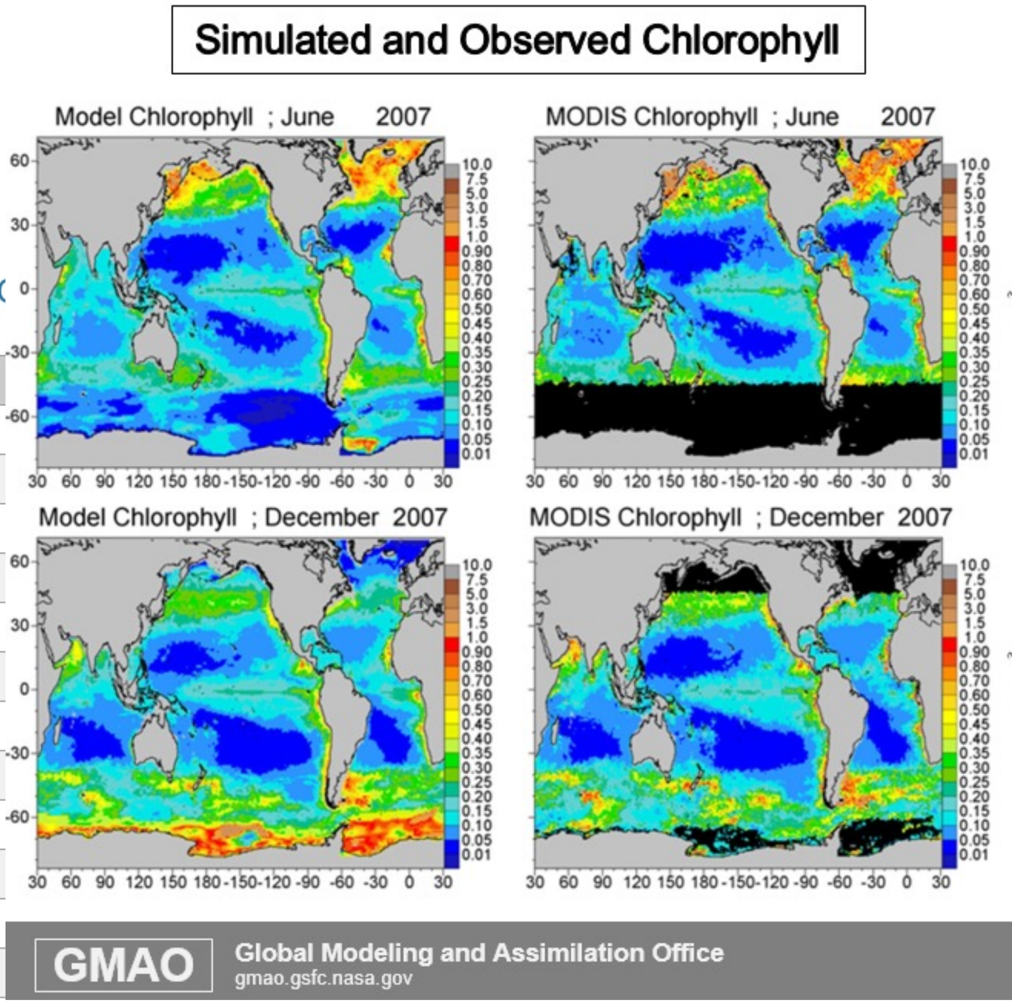
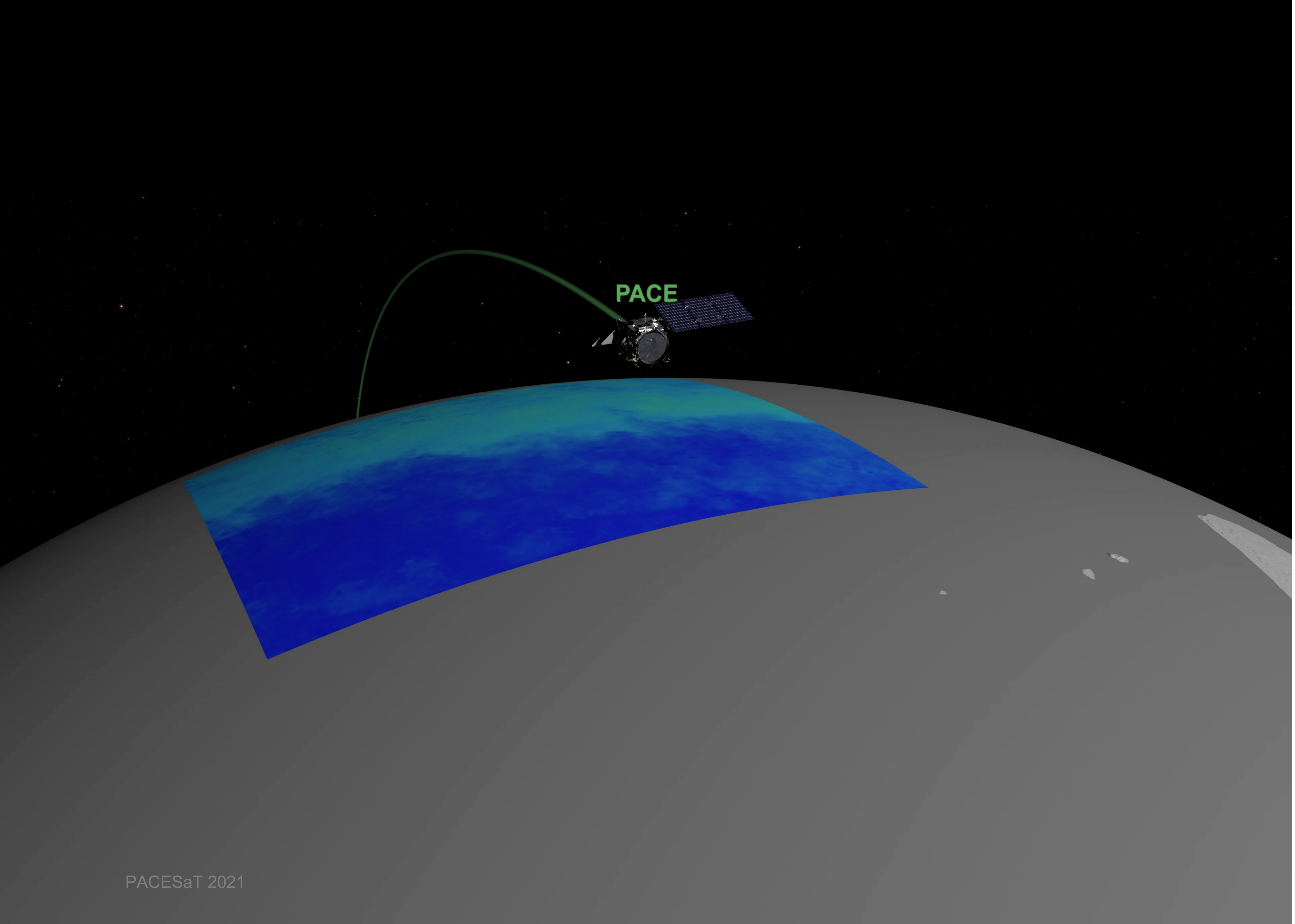


Fig. 7. A host of new applications will be available with better discrimination of pelagic and benthic biodiversity promised by hyperspectral imagery.

Dierssen et al. 2021



Questions

PACE Applications Updates

Natasha Sadoff

NASA Goddard Space Flight Center/SSAI

natasha.sadoff@nasa.gov

PACE Applications & Early Adopter Program

Leveraging Science to Advance Society

Natasha Sadoff [1,2], Erin Urquhart[1,2]

[1]NASA GSFC, [2]SSAI

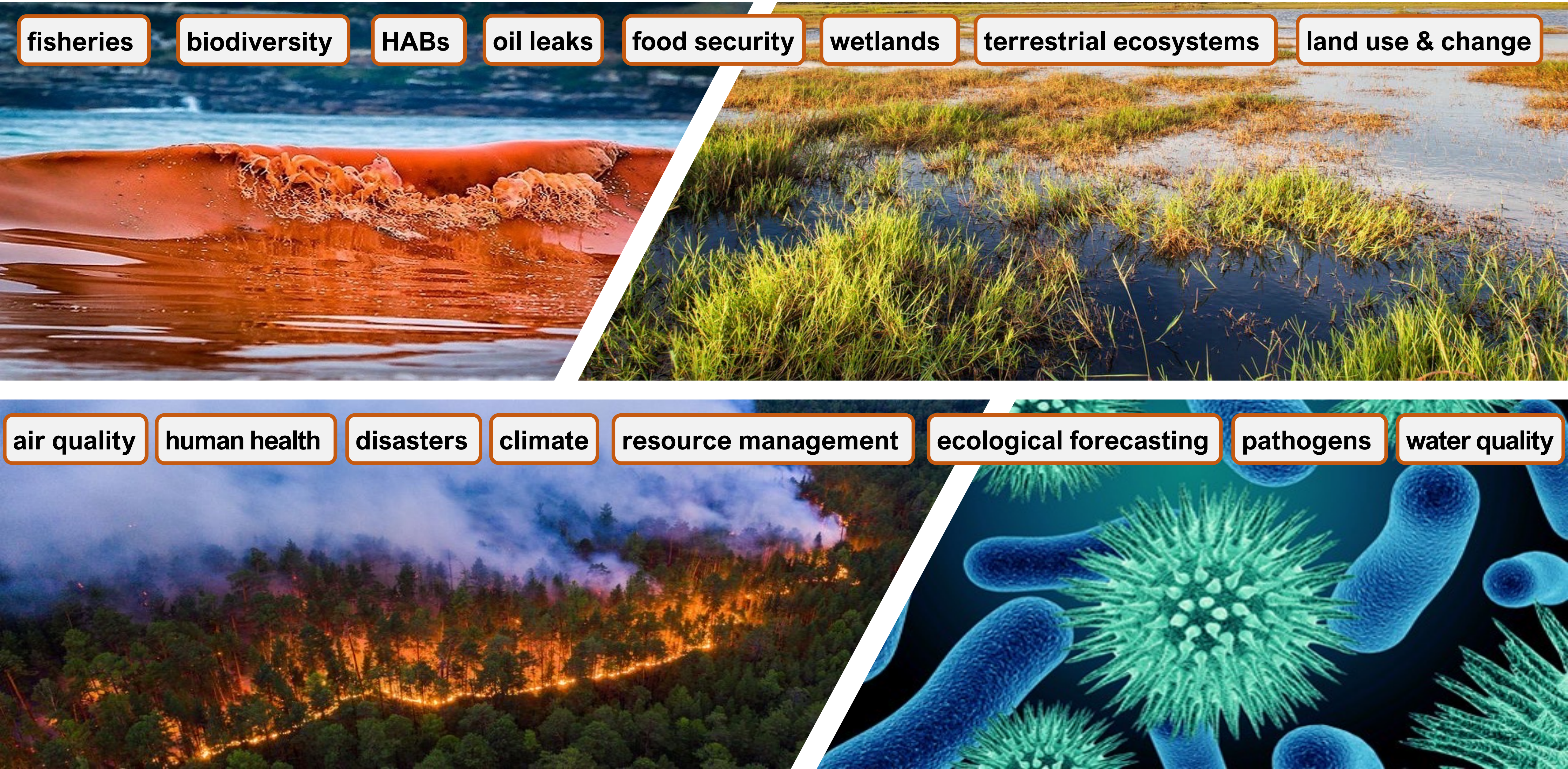
NASA and the PACE Mission Perspective: What is an Application?

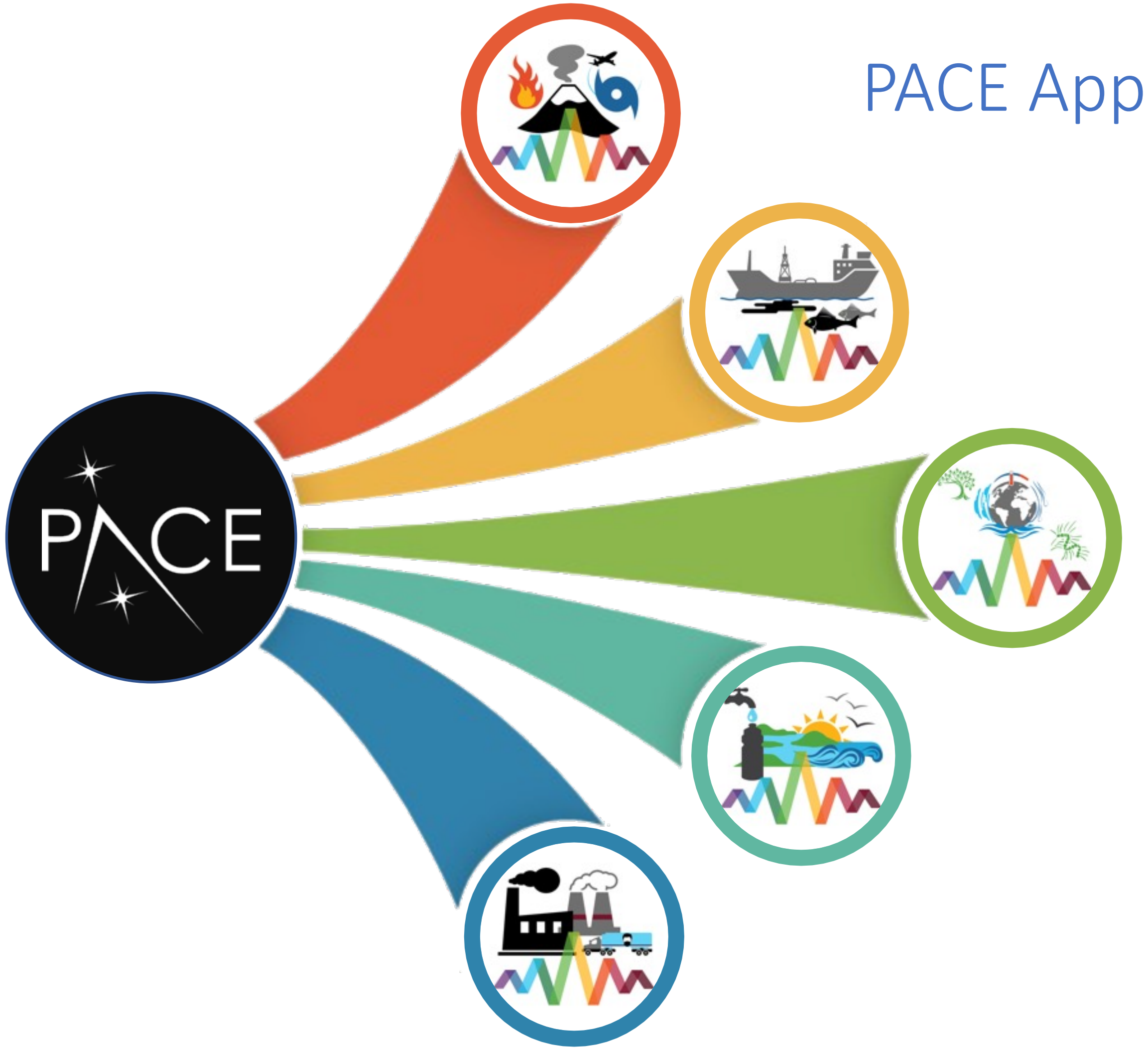
- **Applications** are innovative uses of NASA PACE data products to complement and improve *decision-making activities and provide practical solutions to meet societal needs.*

- **Applied Research** provides *fundamental knowledge* of how PACE data products may be scaled & integrated into *users'* policy, business, and management activities to improve decision-making.

- **End-user communities** include
  - Individuals & groups
  - Public & private sectors
  - National & international organizations
  - Local & global scales

PACE: Interdisciplinary applied science objectives





PACE Applications Program


PACE Applications Plan

PACE

Ver. 1.2

July 2019

Edited by:
Maria Tzortziou [1], Ali Omar [2], Woody Turner [3], Jeremy Werdell [4], Antonio Mannino [5], and Annette de Charon [6]

[1] NASA HQs PACE Deputy Program Applications Lead - Oceans, [2] NASA HQs PACE Deputy Program Applications Lead - Atmosphere, [3] NASA HQs PACE Program Applications Lead, [4] NASA PACE Project Scientist, [5] NASA PACE Deputy Project Scientist - Oceans, [6] PACE Project Communications Team.

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

- *Address community user needs* & concerns with PACE data products
- *Grow relevance* & sustainability of PACE
- *Demonstrate the societal value* & utility of PACE

The goal of the PACE Applications Program is to foster new partnerships and out-of-the-box thinking that will generate inventive solutions that aid society.

PACE Applications Program (*a year in review*)

https://pace.oceansciences.org/app_workshops_02.htm

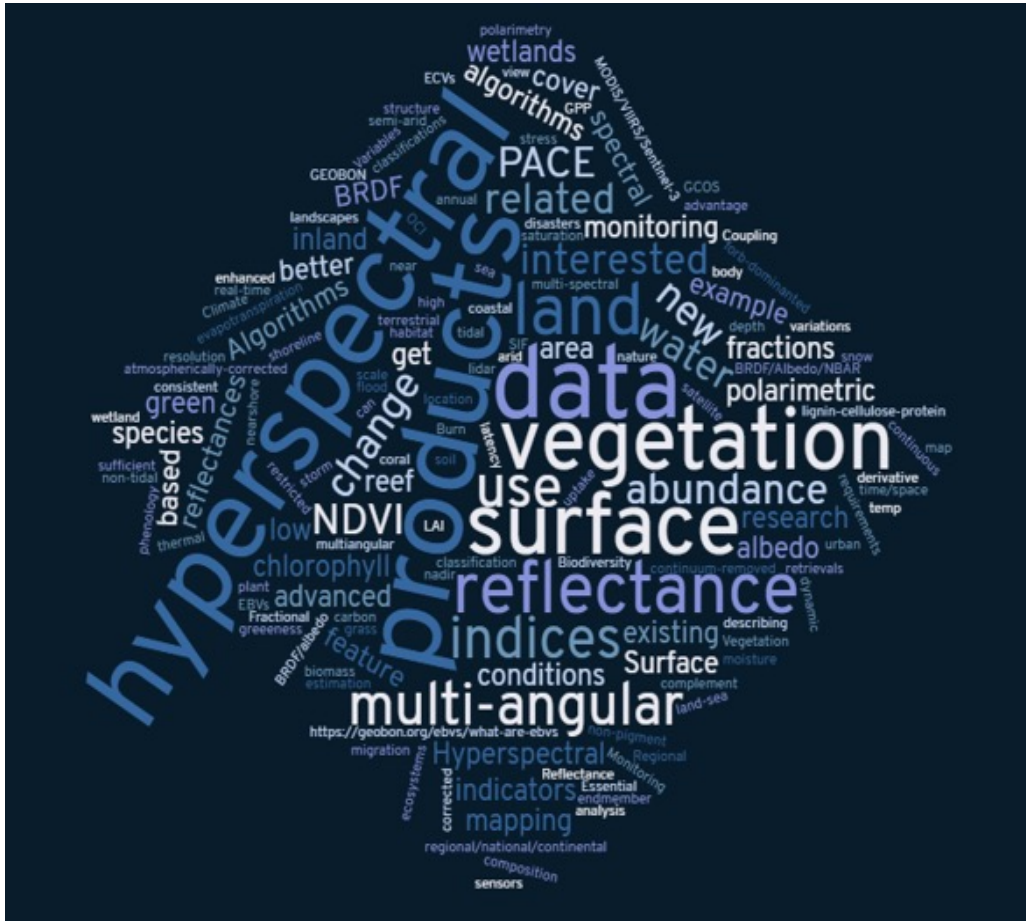
PACE Applications Program (*a year in review*)

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

2021 PACE Terrestrial-land Community Assessment

SurveyMonkey

Q13: What exploratory PACE products might you be interested in? *(Terrestrial Community Survey, 2021; Urquhart, Sadoff et al.)*



More on the Focus Session: Pursuing Data Accessibility, Usability, Actionability

- Reflecting on how data or products will be used and for what purpose – the user experience is different for different users.
- Using illustrative user personas to collectively identify what **accessibility, usability, and actionability** mean or looks like to different user groups, including researchers, scientists, policy-makers, or the private sector.
- Recognizing that individual users have different goals, pain points and frustrations, and ideal experiences or must haves related to:
  - *Data format, quality, processing, latency; user/stakeholder engagement or outreach; training and capacity building; identifying complementary missions and data*

This is Tom

Occupation: Water Quality Manager

Age: 59

Location: Tampa, FL

Water Resources

Ecological Forecasting

Bio/ Backstory:

Tom has worked at Florida DEP for 25yrs. He manages a team of over 60ppl. He has a masters in Marine Biology and is passionate about the environment and recreational fishing. Most of his work has focused on Gulf Coast water quality, focusing on harmful algal blooms, fecal coliforms, and associated recreational beach safety. Tom plans to retire in the next 5-7yrs.

Goals

- Provide accurate, up-to-date info. on coastal HAB and bacteria conditions.
- Effectively coordinate with other teams/managers on the conditions & risks

Technical Characteristics

- Remote Sensing Knowledge
- Computing Power
- Machine Learning & Classification
- Data Pre-processing Ability

Pain Points / Frustrations

- Limited computing/processing resources for processing satellite data
- Coastal cloud inference reducing data consistency, reliability, and dependability
- Difficulty communicating risk conditions to citizens and decision-makers
- Often doesn't understand the limitations of science data
- Lack of daily (24-48hr) imagery in coastal recreation areas

Ideal Experience / Must Have

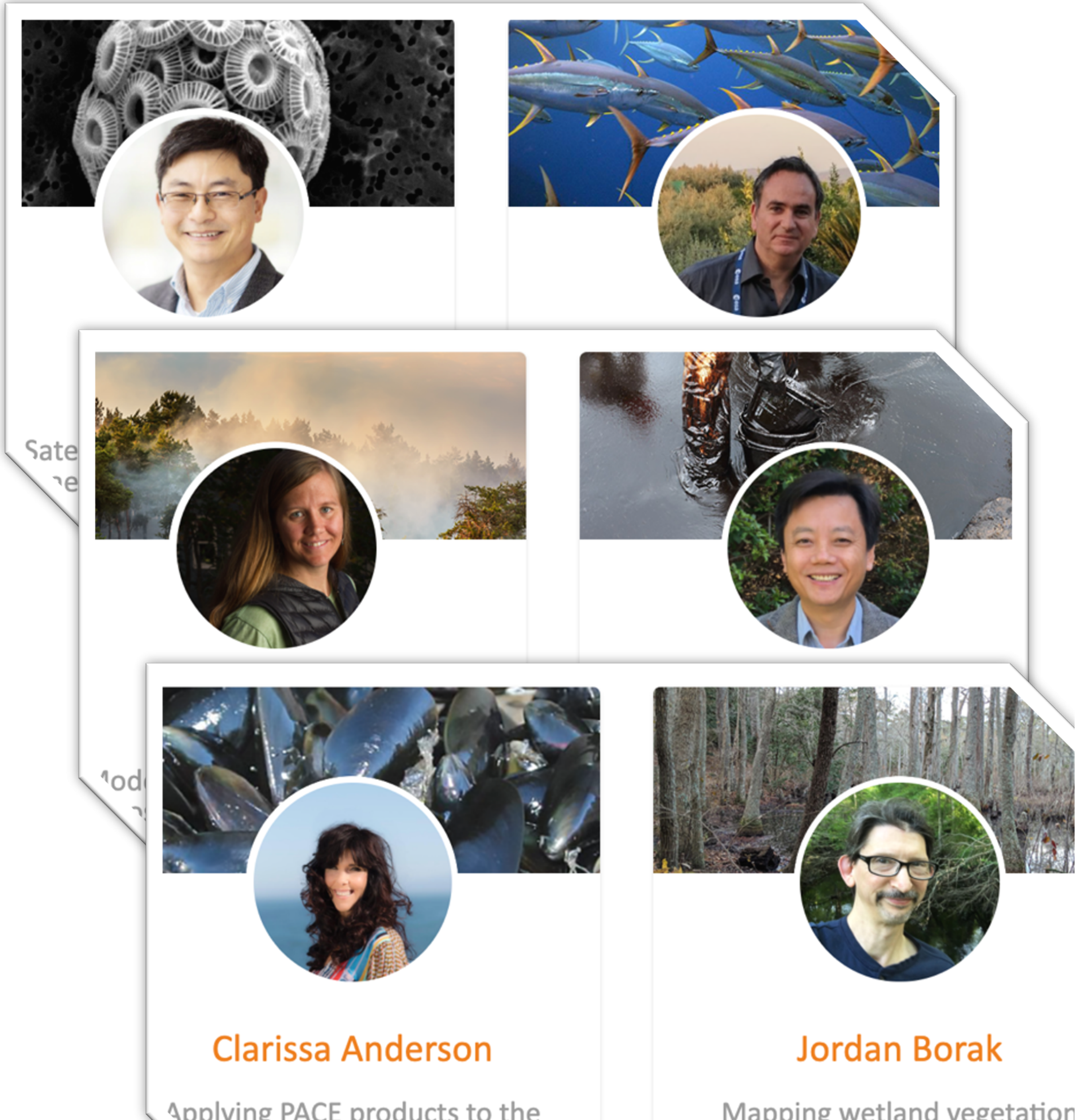
- Easy source of information to convey risk & safety about beach & recreational conditions
- Free, and/or cheap, access to data for multiple locations
- Routine data notifications
- Data that is delivered routinely, daily would be ideally for management (low latency products)
- Quality assured data with pixel level uncertainty estimates
- Binary HAB risk maps
- Near-future HAB forecasting

PACE Early Adopter Program

The PACE Early Adopter program promotes applied science and applications research designed to scale and integrate PACE data into policy, business, and management activities that benefit society and inform decision making.

Goals:

- Expand the user communities with tangible and potential applications that would benefit from the use of PACE data
- Facilitate feedback on PACE data products pre-launch
- Accelerate the use and integration of PACE products into applications post-launch by providing specific support to Early Adopters who commit to engage in pre-launch applied research



Early adopters + PACE SAT member = Goal

 +  = Monitoring and Fisheries Applications in Central America

 +  = Sustainable Aquaculture Site Selection

 +  = Detecting and Differentiating Oil Slicks

 +  +  = Fisheries and aquaculture decision support tool for the South African coast

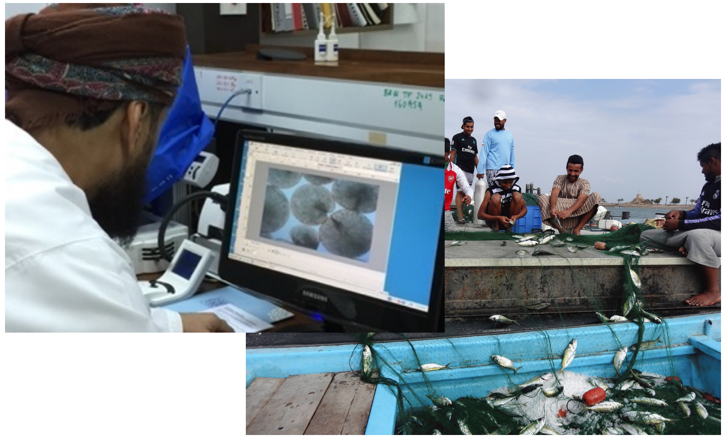
PACE Early Adopter Program

Joaquim Goes

Decision and Information System for Coastal waters of Oman (DISCO) - an integrative tool for managing coastal resources experiencing climate change »

Application: Harmful Algal Bloom (HAB), hypoxia, and fish kill forecasting decision support tool (DST) for the coastal waters of Oman

Significance: Over the past decade and half, the Sultanate of Oman has been experiencing massive outbreaks of HABs attributable to the warming trend and the onshore influx of hypoxic waters. DISCO, including PACE data inputs, will allow extended applications in analyses of industrial effluent discharge and seawater intake, environmental assessment, biodiversity, aquaculture, optimum water properties for fisheries, contaminant tracking, and other areas with implications for livelihoods and local, national, and regional economies.



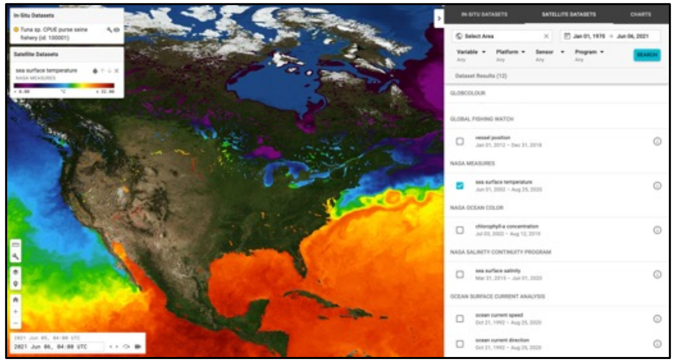
How PACE can help: The availability of hyperspectral PACE OCI data will help accelerate the process of developing green Noctiluca specific ocean color algorithms for coastal waters of Oman. We have also seen a connection between aerosol plumes and green Noctiluca bloom outbreaks.

Stakeholders: Government ministries and the private sector (desalination plants, aquaculture, oil refineries, shipbuilding, tourism) in Oman and others around the Arabian Sea.

https://pace.oceansciences.org/people_ea.htm?id=83

Vardis Tsontos

Applying PACE products to Earth Observation (EO) Applications and Oceanographic Data Management- CEOS COVERAGE »



The CEOS COVERAGE visualization toolkit

Application: Oceanographic data management and visualization toolkit

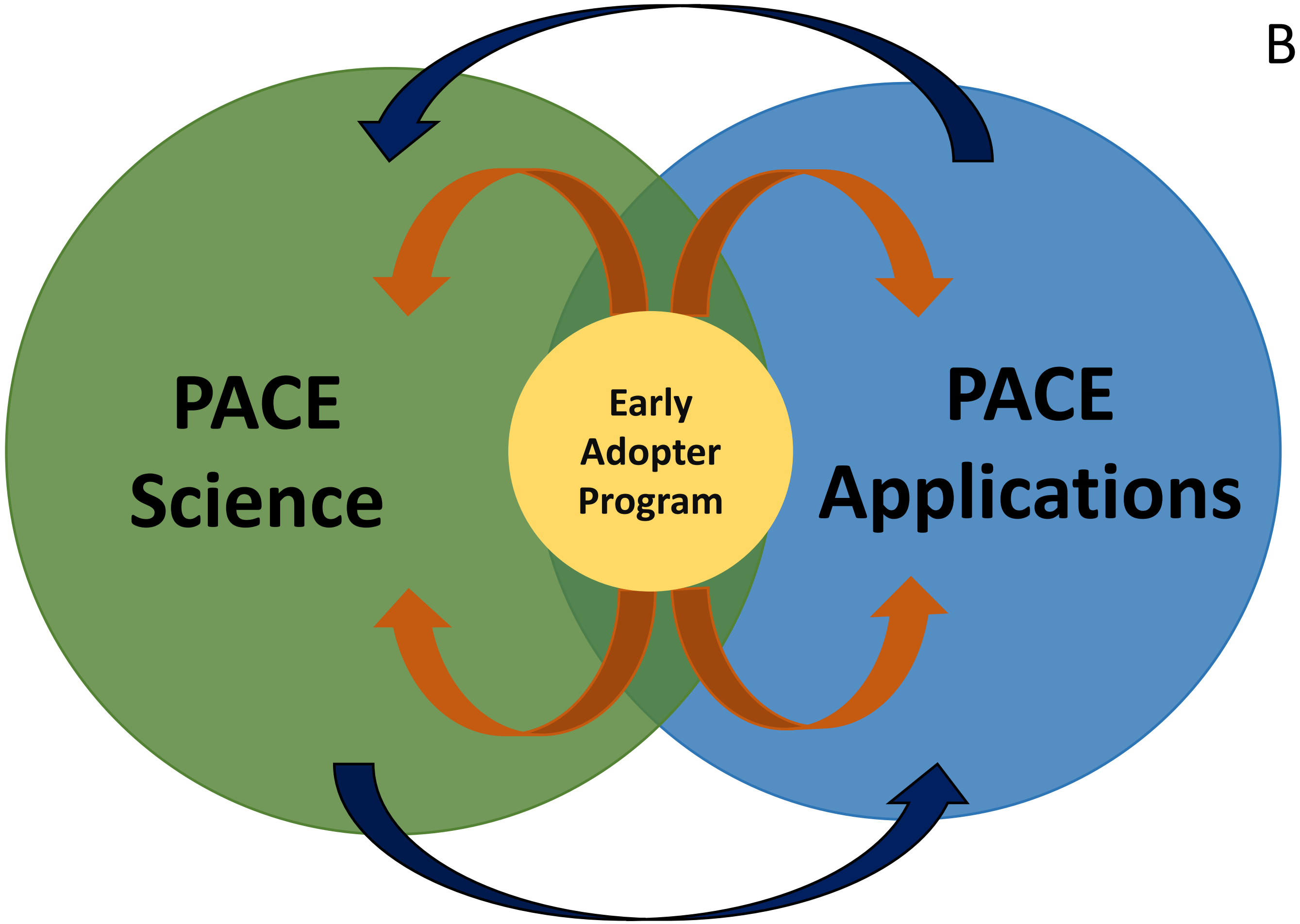
Significance: COVERAGE seeks to expand the accessibility of EO data for the oceans to a broader community of users with a particular emphasis on less expert remote sensing users and biological applications communities. COVERAGE will facilitate improved understanding and decision in key areas including population and biodiversity responses to environmental variability and climate, species habitat characterization and utilization, etc.

How PACE can help: COVERAGE is anticipating the needs and necessary data infrastructures for improved end-user access to the increasing data volumes coming from the next generation NASA ocean satellite missions. The increased quantity of PACE hyperspectral data will serve as a test bed of value-added data services that will seamlessly integrate with other oceanographic data streams to support ocean applications.

Stakeholders: GEO-Marine Biodiversity Observation Network; GEO-Blue Planet; GOOS-AniBOS; Sargasso Sea Commission; Inter-American Tropical Tuna Commission

https://pace.oceansciences.org/people_ea.htm?id=81

PACE Early Adopter Program: *We're looking for new teams!*



Benefits of joining the Early Adopter team:

- Direct engagement with the NASA PACE Project
- Partnership with the PACE Science and Application Team and other EAs
- Participation in events, including workshops, focus sessions, and tutorials
- Priority access to pre-launch simulated and proxy PACE data
- PACE web presence, project promotion and advocacy at external events

Apply here: https://pace.oceansciences.org/app_adopters.htm

Closing Thoughts!

PACE Applications are a *measure of mission success* to NASA, used to advocate and justify continued support for the mission

Pre-launch applied science from PACE Early Adopters provides feedback & guidance to the mission, *saving time & resources post-launch*

Early engagement between data producers & data users builds partnerships to *advance applications for decision-making*

PACE will have several *marine applications* close to NASA ARL 9 by the time it's on orbit, but **we're still looking for new EAs and innovative applications!**

How can PACE Applications help you??

Erin Urquhart & Natasha Sadoff
PACE-applications@oceancolor.gsfc.nasa.gov
https://pace.gsfc.nasa.gov

Break

We will return at 3:00p ET (noon PT)

Joe Salisbury
University of New Hampshire
joe.salisbury@unh.edu

GLIMR Updates

Geostationary Littoral Imaging and Monitoring Radiometer (GLIMR): Observing Coastal Ocean Processes & Hazards from Space at Hourly Frequency

J. Salisbury
UNH

A. Mannino
NASA GSFC
Ocean Ecology Laboratory

Credits:
Jeff Puschell, Ryan Vandermeulen, Maria Tzortziou
GLIMR Team

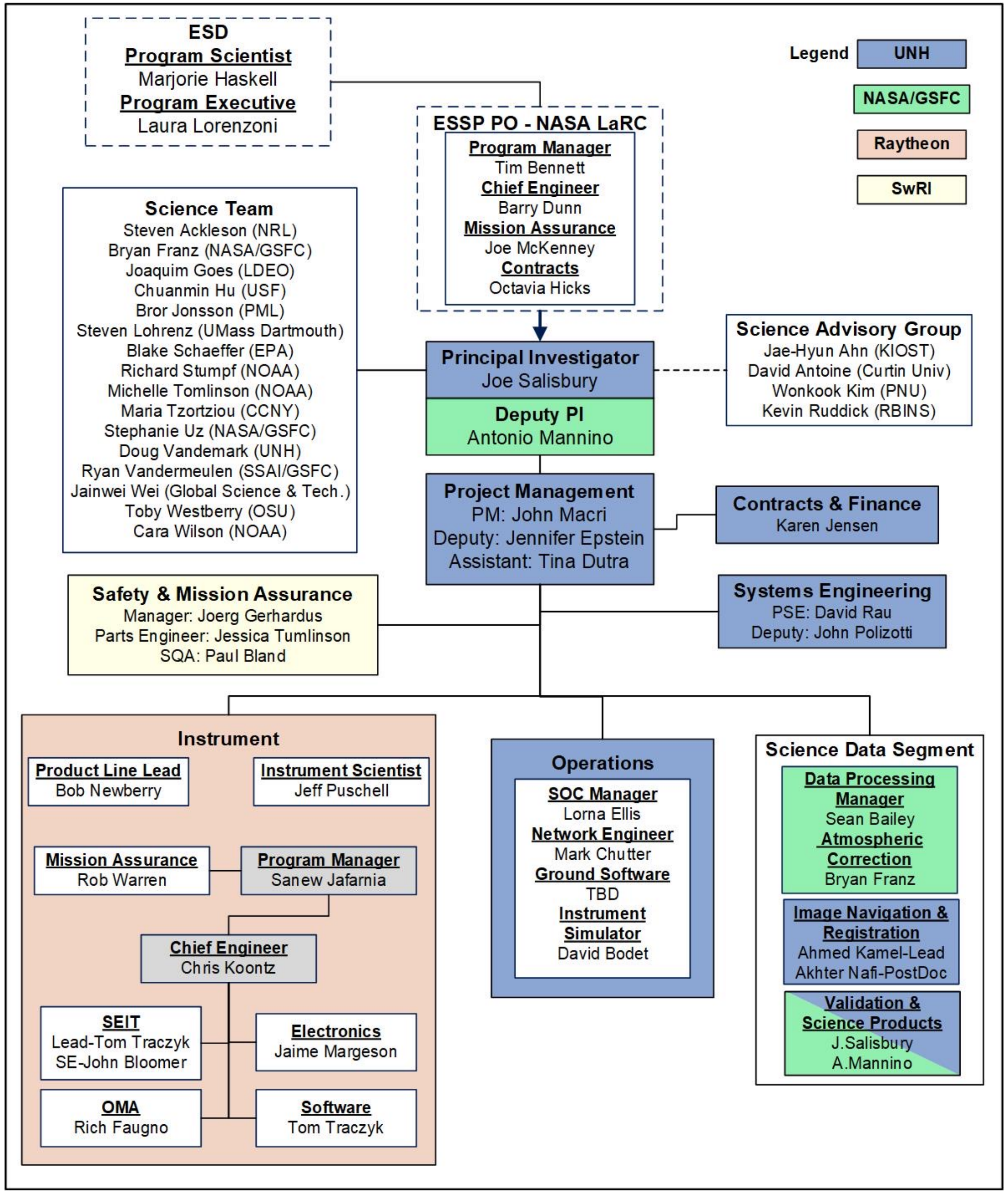
GLIMR

Geostationary
Littoral
Imaging and
Monitoring
Radiometer

- Earth Venture Instrument (EVI): a NASA program for PIs to propose a satellite instrument to accomplish a scientific investigation
- NASA announced GLIMR EVI-5 selection on Aug. 1, 2019
- Project start May 17, 2021
- Launch TBD – 2026/2027
- Budget cap ~$108M

Management and Sci-Ops: UNH (Salisbury, PI)
Deputy PI: Antonio Mannino (GSFC)
Instrument: Raytheon Intelligence and Space
Safety Mission & Assurance: Southwest Research Institute
Science Data Segment: Ocean Ecology Lab (GSFC)
GLIMR Science & Applications Team: (various institutions)
NASA Program Office: ESSP PO (LaRC)

Org Chart



ESD
Program Scientist
Marjorie Haskell
Program Executive
Laura Lorenzoni
Legend
UNH
NASA/GSFC
Raytheon
SwRI
ESSP PO - NASA LaRC
Program Manager
Tim Bennett
Chief Engineer
Barry Dunn
Mission Assurance
Joe McKenney
Contracts
Octavia Hicks
Science Team
Steven Ackleson (NRL)
Bryan Franz (NASA/GSFC)
Joaquim Goes (LDEO)
Chuanmin Hu (USF)
Bror Jonsson (PML)
Steven Lohrenz (UMass Dartmouth)
Blake Schaeffer (EPA)
Richard Stumpf (NOAA)
Michelle Tomlinson (NOAA)
Maria Tzortziou (CCNY)
Stephanie Uz (NASA/GSFC)
Doug Vandemark (UNH)
Ryan Vandermeulen (SSAI/GSFC)
Jainwei Wei (Global Science & Tech.)
Toby Westberry (OSU)
Cara Wilson (NOAA)
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Joe Salisbury
Deputy PI
Antonio Mannino
Science Advisory Group
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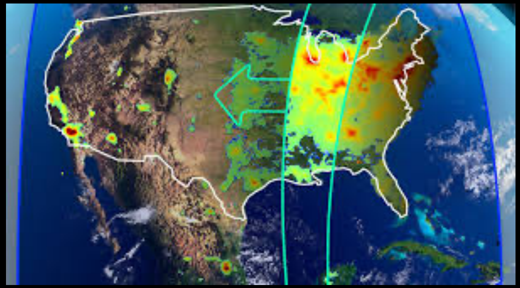
David Antoine (Curtin Univ)
Wonkook Kim (PNU)
Kevin Ruddick (RBINS)
Project Management
PM: John Macri
Deputy: Jennifer Epstein
Assistant: Tina Dutra
Contracts & Finance
Karen Jensen
Safety & Mission Assurance
Manager: Joerg Gerhardus
Parts Engineer: Jessica Tumlinson
SQA: Paul Bland
Systems Engineering
PSE: David Rau
Deputy: John Polizotti
Instrument
Product Line Lead
Bob Newberry
Instrument Scientist
Jeff Puschell
Mission Assurance
Rob Warren
Program Manager
Sanew Jafarnia
Chief Engineer
Chris Koontz
SEIT
Lead-Tom Traczyk
SE-John Bloomer
Electronics
Jaime Margeson
OMA
Rich Faugno
Software
Tom Traczyk
Operations
SOC Manager
Lorna Ellis
Network Engineer
Mark Chutter
Ground Software
TBD
Instrument
Simulator
David Bodet
Science Data Segment
Data Processing
Manager
Sean Bailey
Atmospheric
Correction
Bryan Franz
Image Navigation &
Registration
Ahmed Kamel-Lead
Akhter Nafi-PostDoc
Validation &
Science Products
J.Salisbury
A.Mannino

GLIMR's Evolution from GEO-CAPE

- GLIMR science and applications emerged from GEO-CAPE
- GEO-CAPE originated in the 2007 Earth Science Decadal Survey
- Air Quality & Ocean Color Mission
- ~11 years of mission studies
- Despite acknowledging very high priority science, the 2018 ESAS DS recommended pursuing GEO-CAPE science objectives through Earth Venture opportunities

Joe Salisbury (PI) - University of New Hampshire



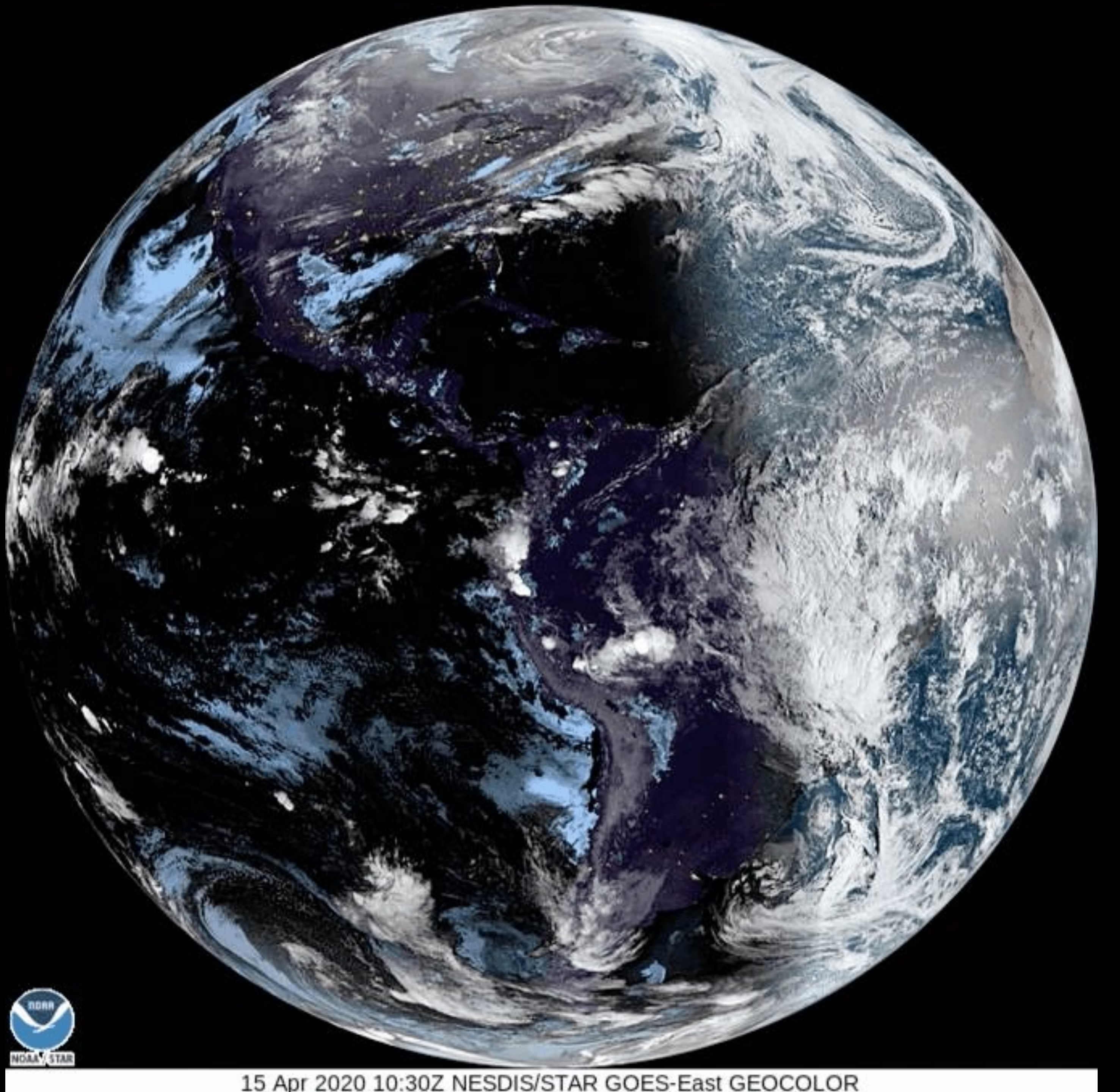
TEMPO (EVI-1)
Tropospheric Emissions: Monitoring of Pollution
Kelly Chance (PI)
Smithsonian Institution

GeoCarb (EVM-2)
Geostationary Carbon Cycle Observatory
Berrien Moore (PI)
Oklahoma University

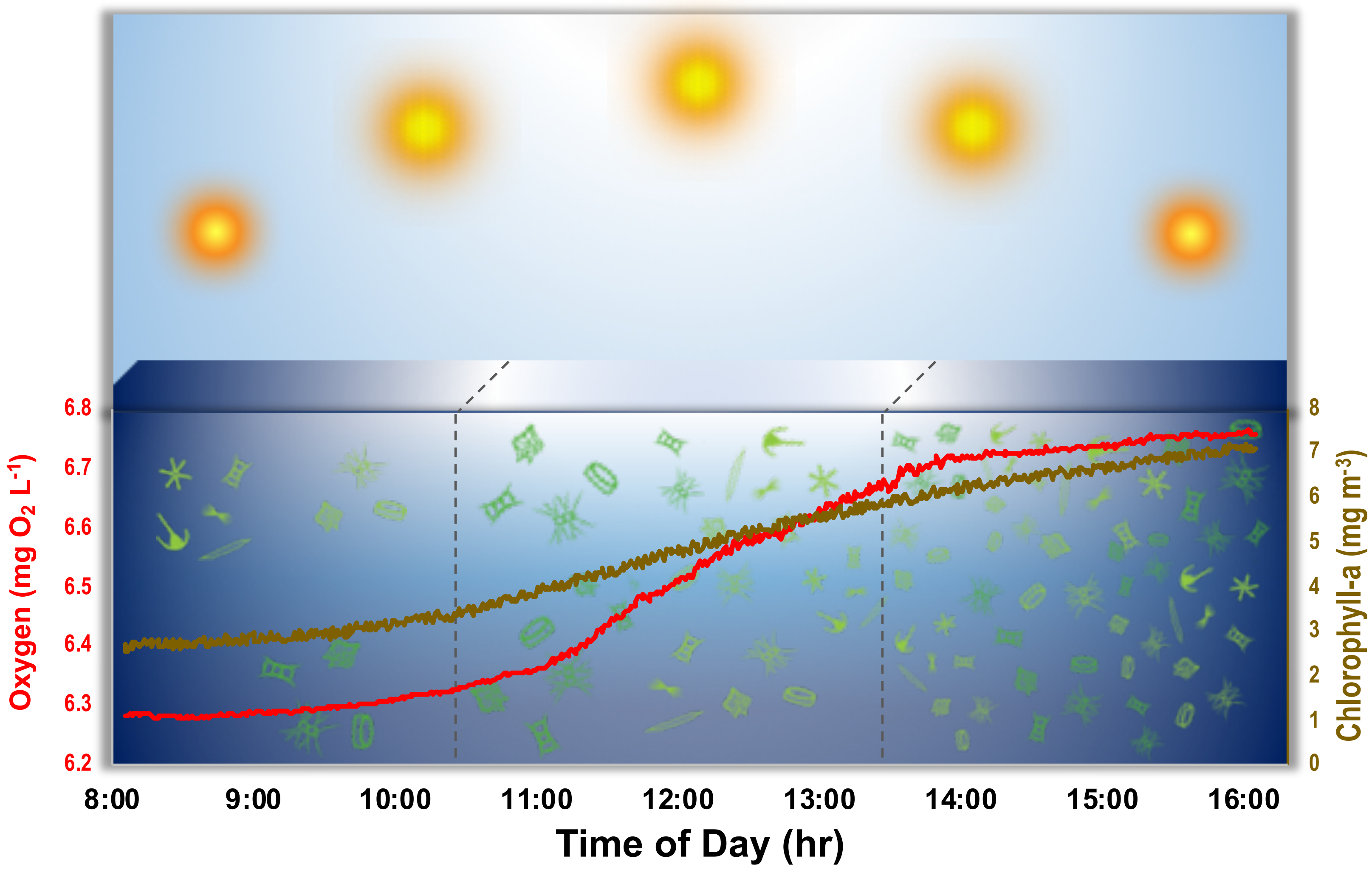
Benefits of Geostationary

- Viewing same areas of the earth throughout the day enables high-frequency time series
- “Stare” at any location (iFOV) to achieve required SNR
- Scan between cloudy periods of the day

GOES-16 Full Disk Animation – 15-16



GLIMR Science Overview

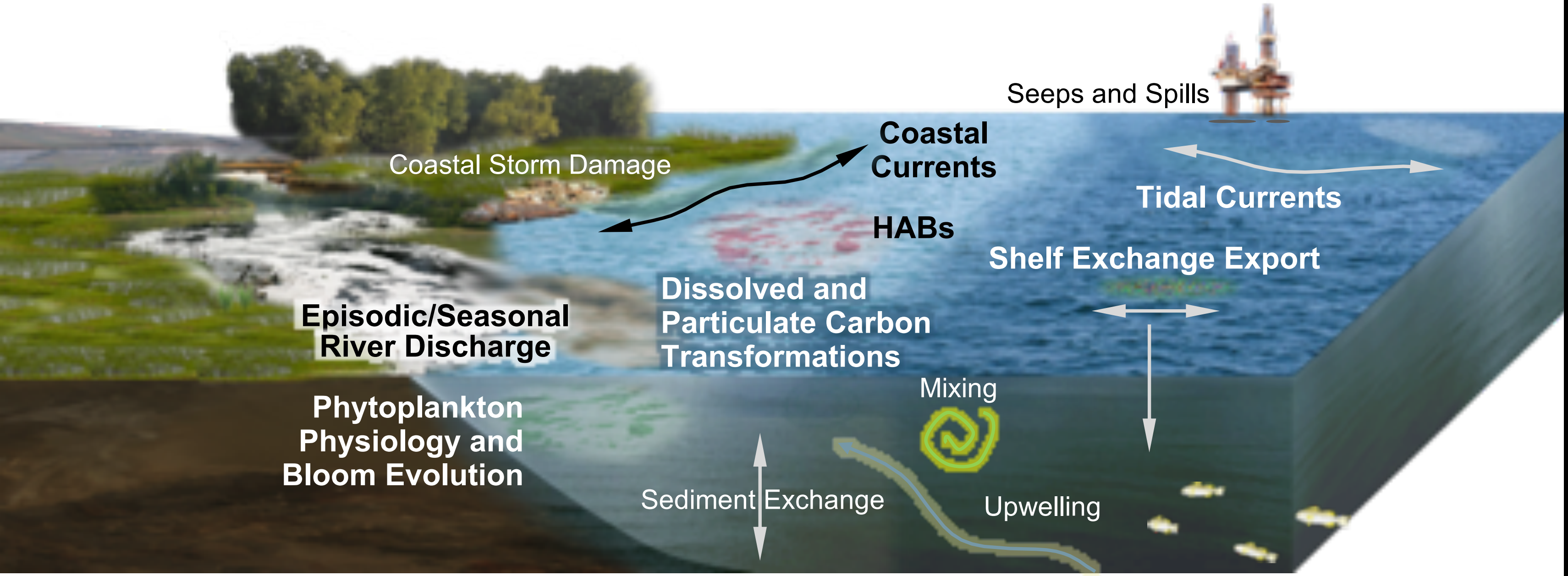


Phytoplankton Growth and Physiology

Understanding processes contributing to rapid changes in phytoplankton growth rate and community composition.

Short Term Coastal Processes

GLIMR Science Overview



Phytoplankton Growth and Physiology

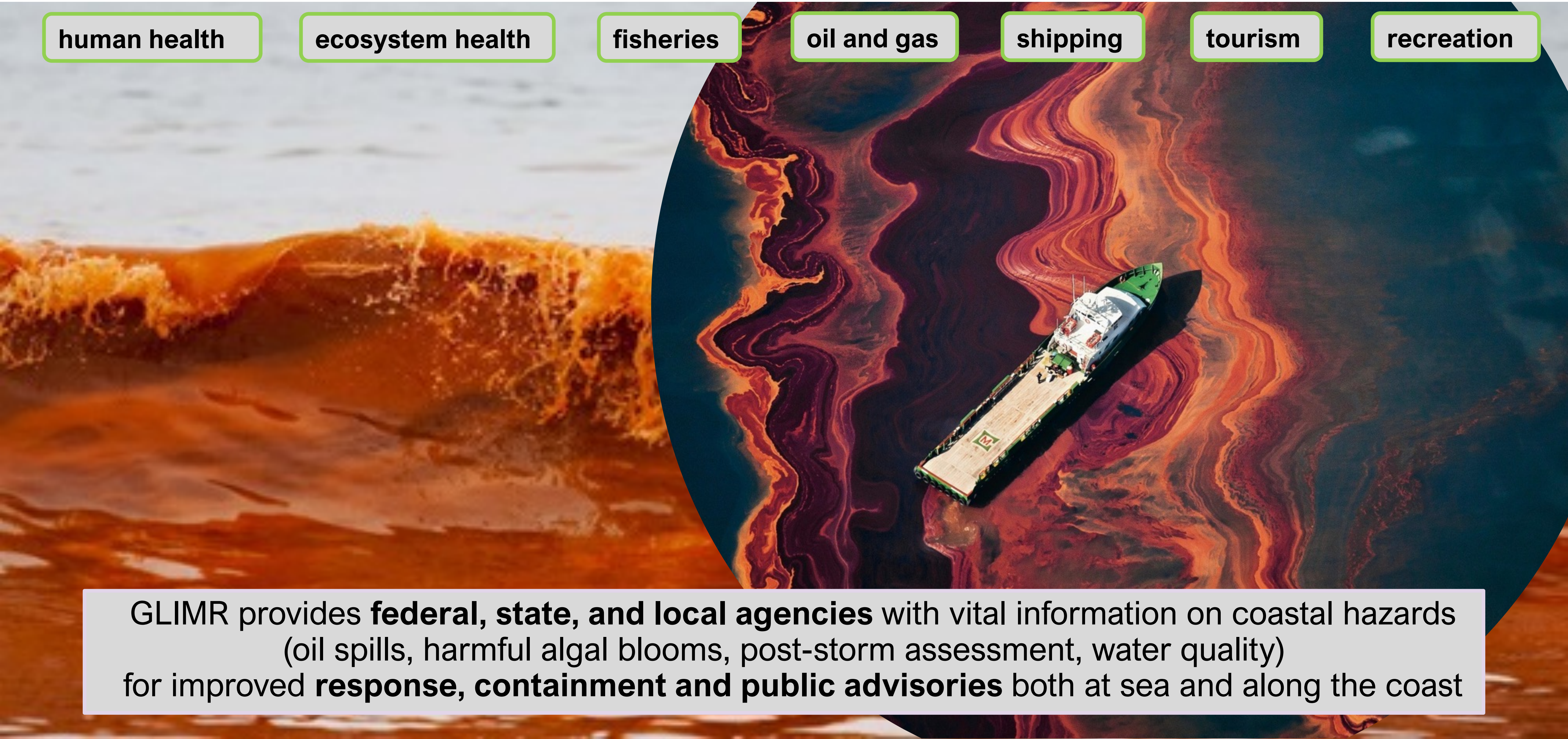
Understanding processes contributing to rapid changes in phytoplankton growth rate and community composition.

Short Term Coastal Processes

Investigate how high frequency fluxes of sediments, organic matter, and other materials between and within coastal ecosystems regulate the productivity and health of coastal ecosystems.

GLIMR: Applied Science Foci

Targeting the formation, magnitude, and trajectory of **harmful algal blooms** and **oil spills**.



human health | **ecosystem health** | **fisheries** | **oil and gas** | **shipping** | **tourism** | **recreation**

GLIMR provides **federal, state, and local agencies** with vital information on coastal hazards (oil spills, harmful algal blooms, post-storm assessment, water quality) for improved **response, containment and public advisories** both at sea and along the coast

Applications of GLIMR

Key Data Products

- Phytoplankton species/functional group separation
- Better estimate of phytoplankton biomass given several scenes a day (surface expression changes throughout the day)
- Monitoring bloom patchiness and movement throughout the day
- Better bloom detection around clouds due to multiple scenes a day

Applications supported

- Phytoplankton community structure/HAB Monitoring
- Aquaculture management and planning
- Frontal analysis for fisheries applications
- Addressing water clarity/quality issues

Courtesy of Shelly Tomlinson (NOAA)

GLIMR's unprecedented measurement capabilities (*in toto*)

Hyperspectral

- 340-1040 nm
- <10 nm resolution
- ~5 nm sampling

High Temporal

- ~hourly scans of Gulf of Mexico (6x/day)
- 2x/day other regions
- 3x/day HAB target sites

High Spatial

- 300 m GSD nadir
- ~328 m Gulf of Mexico
- <500 m over coastal CONUS

High SNR

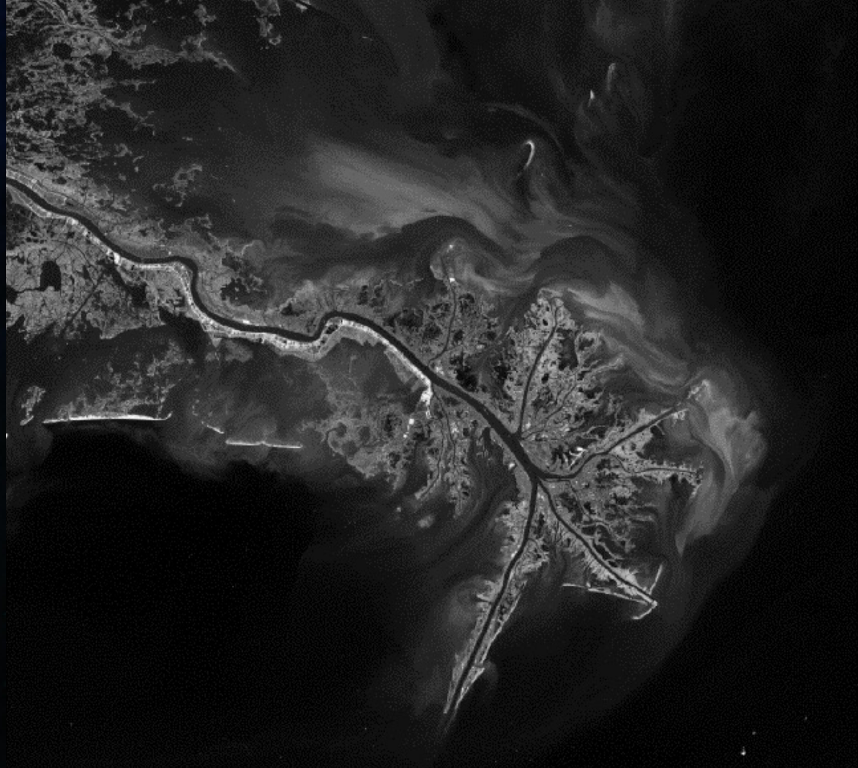
Requirements at Ocean Ltyp

- > 420, UV
- > 1000, 400-580 nm
- > 750, 580-650 nm
- > 580, 650-890 nm

GLIMR's Spatial Resolution

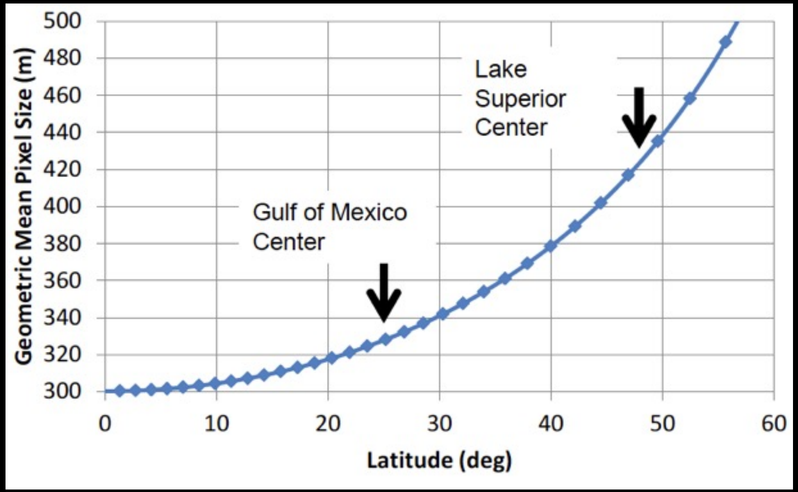
GOES ABI (1 km)

GLIMR Spectrometer (328 m)



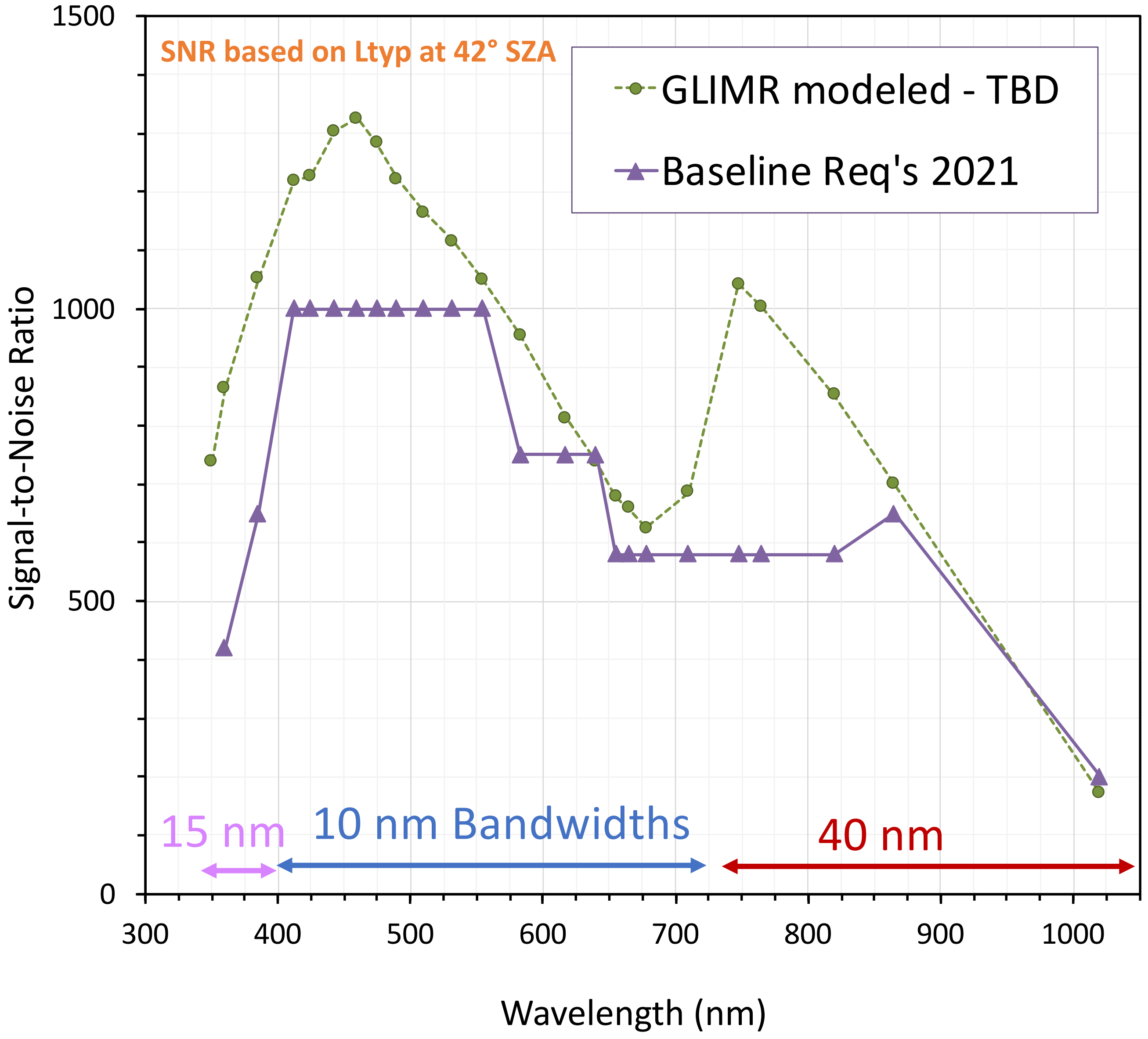
GLIMR Landmark Imager (~150 m)

Spatial resolution finer than 500 m is required to resolve spatial dynamics of phytoplankton blooms, suspended sediments and exchange of material across the land-sea interface.



Simulated from Landsat data
Credit: Jeff Puschell

GLIMR SNR Requirements & Modeled Performance



GLIMR offers exceptional sensitivity (SNR) to quantify sub-diurnal changes. This requirement is particularly important for coastal waters because of their low UV and blue reflectance compared to the open ocean.

- Effective spectrometer dwell time can be increased or decreased to optimize SNR and scan time required per scene.

How GLIMR images

Spectrometer

- Slit (nadir): 1 pixel E-W (300 m) x 3072 N-S (1.47° FOV or ~920 km)
- 0.76 seconds effective dwell time per iFOV
  - aggregate of many snapshots
  - variable/tunable gain
- Continuous scan (11 urad/sec)
  - ~70 min to scan Gulf of Mexico at Ltyp

Landmark Imager

- 2D-imager with 133 m GSD nadir: 680 km E-W (0.5°) x 340 km N-S (0.25°)
- Collects sub-frames at 10-40 Hz for multiple landmarks simultaneously from Landsat Ground Control Points
- Continuous imaging of landmarks by LMI enables INR and spectrometer data geolocation (can view stars between scans)

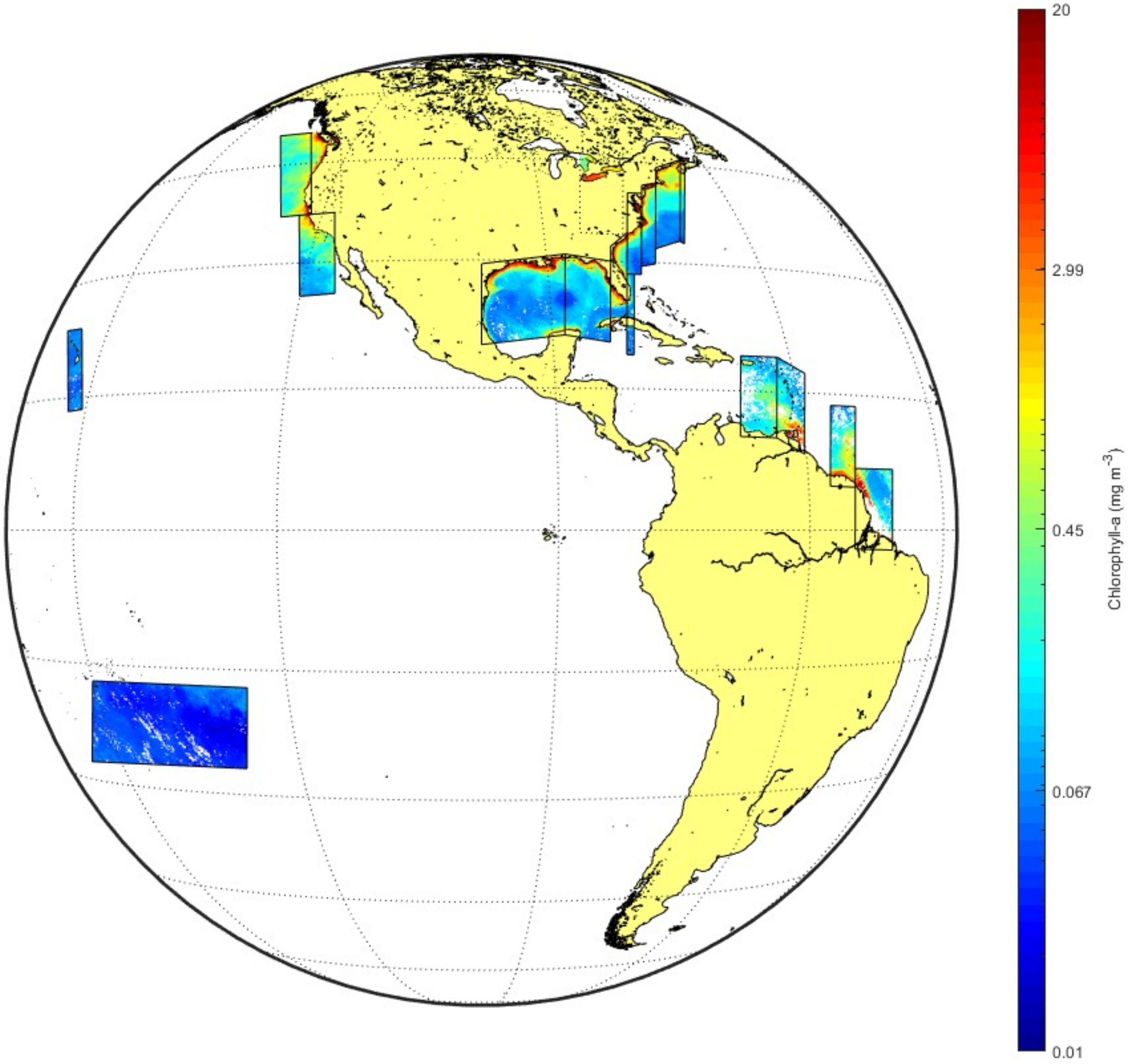
Day-in-the-life of GLIMR

Primary Science Scans

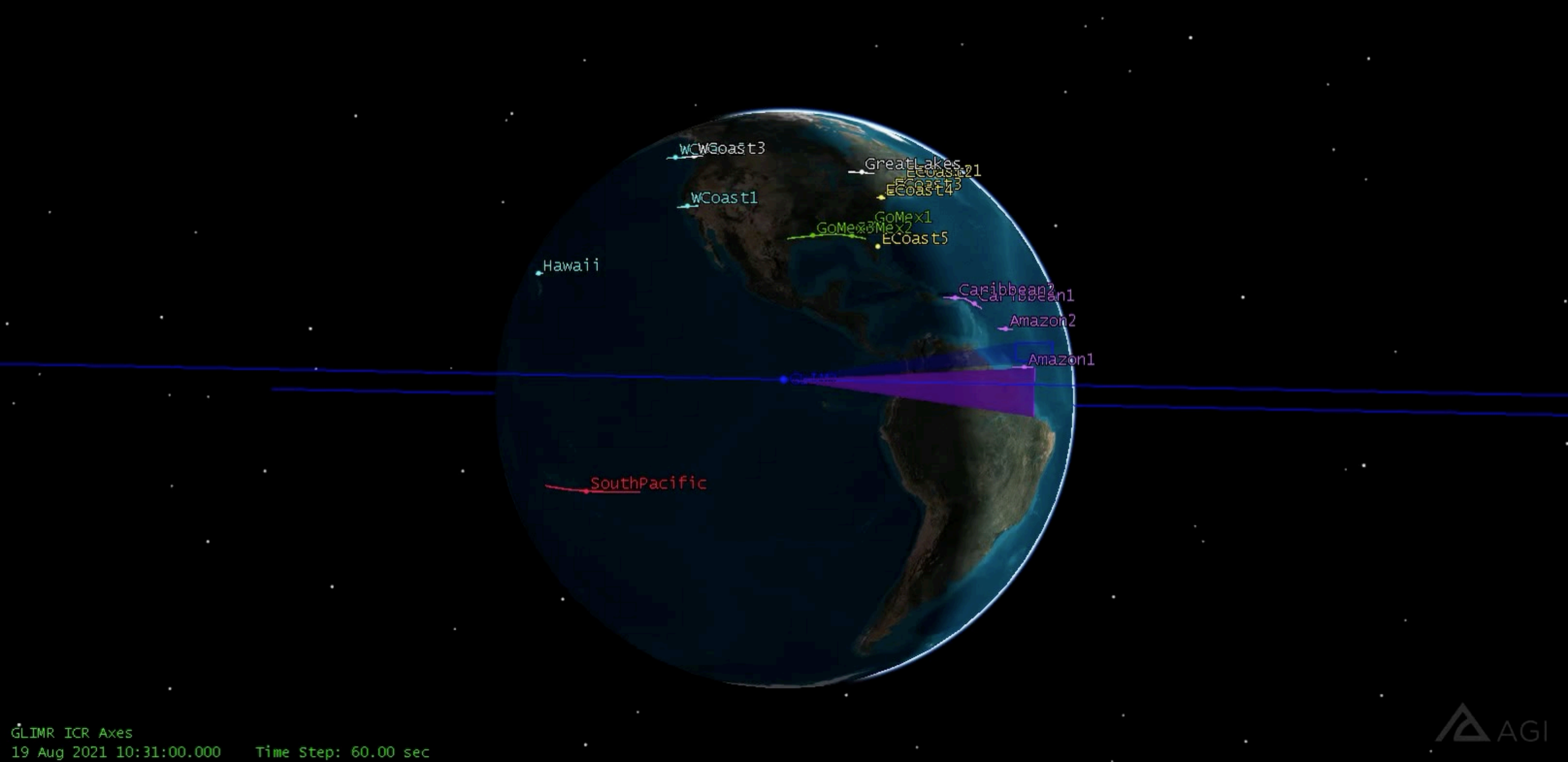
- 6 times/day Gulf of Mexico
- 2x/day US East Coast
- 2x/day US West Coast
- 2x/day Amazon River plume ROI
- 2x/day Caribbean Sea ROI
- 3x/day other HAB target sites

Primary Calibration Scans

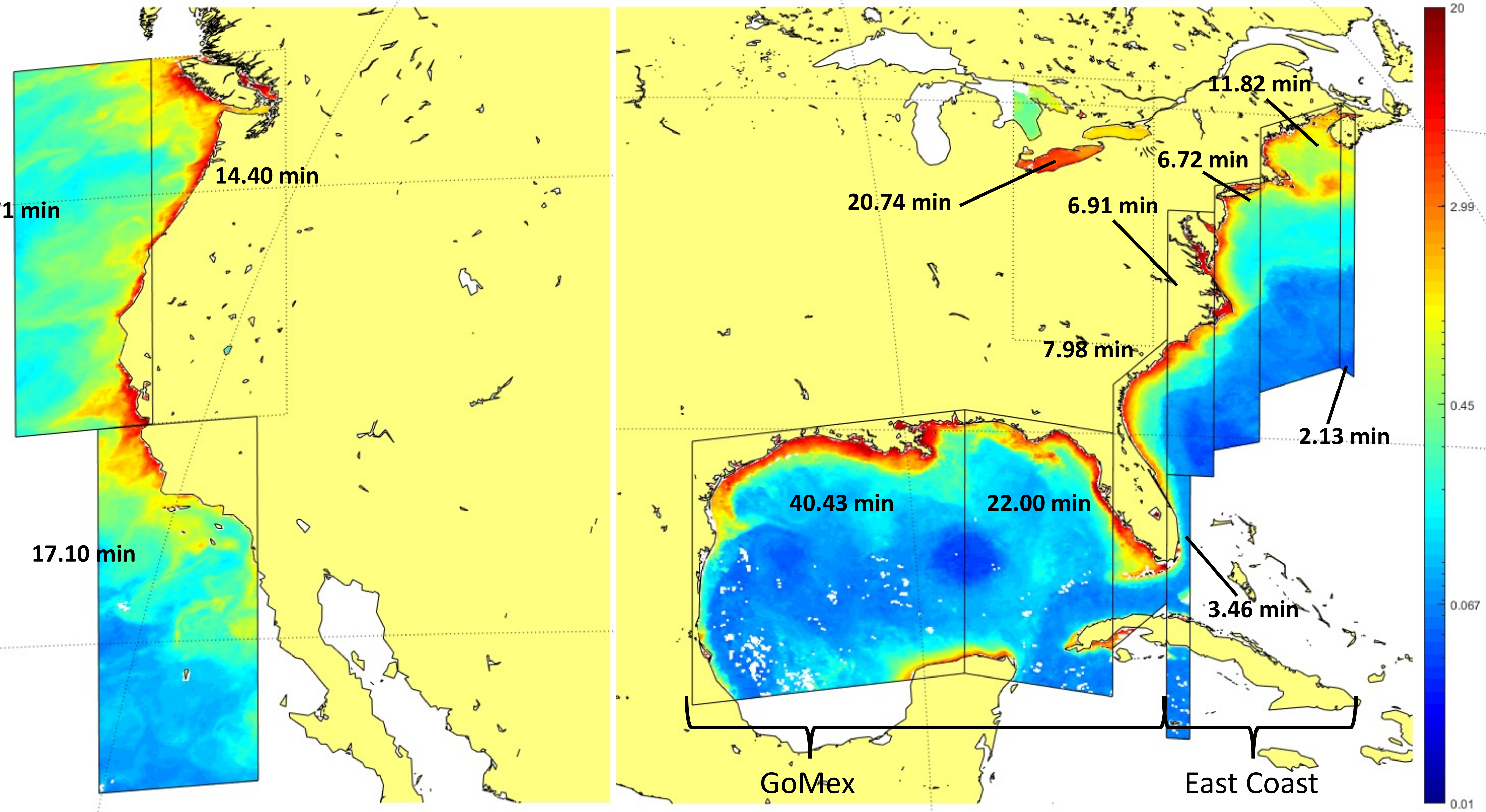
- 2x/day South Pacific clear waters
- 3x/day coincident with PACE's OCI for cross-calibration
- 1/month Lunar calibration



A day in the life of GLIMR from 95W



GLIMR Science Regions - preliminary



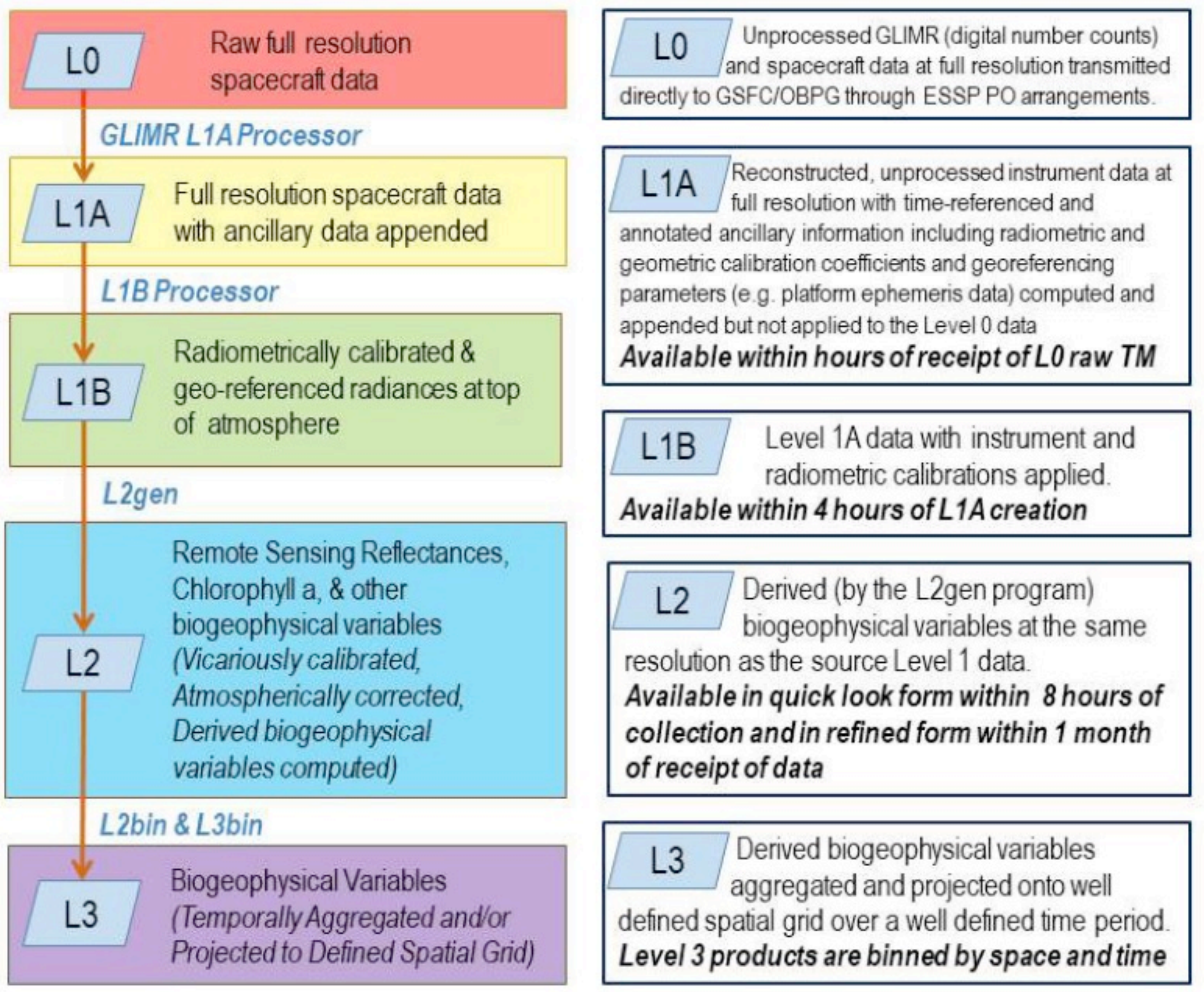
Planned GLIMR Data Products

"PACE-like" Ocean Color Products
Remote sensing reflectance (360 to 720nm every 15 or 10 nm @ 5 nm steps)
Spectral diffuse attenuation coefficients
Apparent visible wavelength
Spectral absorption coefficients (a_t, a_p, a_{ph}, a_{cdm}, a_g) and backscatter coefficients (380 to 680 nm)
CDOM Spectral slope coefficients
Chlorophyll-*a*
Phytoplankton pigments
Phytoplankton community composition
Daily and instantaneous PAR
Fluorescence line height
Euphotic depth
Particulate organic carbon
Dissolved organic carbon
Suspended particulate matter
Particle size distribution

Rates and Flux Products
Net primary production (NPP)
Net community production of POC
Fluxes of SPM, POC and DOC
Surface Ocean Currents

Applied Science Products
HAB detection index
Karenia brevis cell count index
Mycrocystis cell count index
Floating algae biomass
Water type classification
Petroleum detection and thickness
Oil density
Absorbing aerosol index

OBPG Science Data Processing



GLIMR will emulate PACE by example

20+ years of ocean color data processing heritage


Thank You

NASA Earth System Observatory (ESO) - Surface Biology & Geology (SBG)

Kevin Turpie

University of Maryland, Baltimore County

kturpie@umbc.edu




SBG Overview

Description

- *Earth surface geology and biology*, ground/water temperature, snow reflectivity, active geologic processes, vegetation traits, and algal biomass as described by the 2017 Earth Science and Applications from Space (ESAS) Decadal Survey.

Priorities

- Terrestrial vegetation physiology, functional traits, and health
- Inland and coastal aquatic ecosystems physiology, functional traits and health
- Snow and ice accumulation, melting, and albedo
- Active surface changes (eruptions, landslides, evolving landscapes, hazard risks)
- Effects of changing land use on surface energy, water, momentum, and C fluxes
- Managing agriculture, natural habitats, water use/quality, and urban development

Implementation

- Hyperspectral imagery in the visible and shortwave infrared; multi- or hyperspectral imagery in the thermal IR.
- Global coverage and change detection.
- Cost constraint is $650M
- Now in Pre-Phase A. MCR and KDP-A expected mid to late CY22.

NASA's Earth System Observatory Core and associated aquatic missions in the late 2020s

SOLID EARTH
Aerosols — ATMOS
Gases — SBG
Surface Deformation — NISAR
Surface Composition
and Geologic Hazards — SBG

WATER CYCLE
Precipitation — ATMOS
Ice Mass Evolution - NISAR
Snow Albedo and Melt — SBG
Total water storage - MC

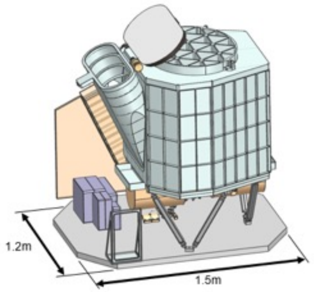
ECOSYSTEMS AND NATURAL RESOURCES
Boundary Layers — ATMOS
Ecosystem Structure — NISAR
Vegetation Type/Physiology — SBG

LAND-SEA CONTINUUM
Phytoplankton, Organic Matter, Sediment — SBG,GLIMR, PACE
Boundary layers-ATMOS

Notional Architecture to Study During Pre-Phase A

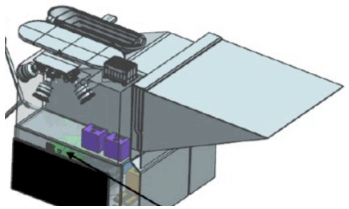
VSWIR Satellite

- Hyperspectral instrument(s) (10 nm, 380-2500nm)
- Observation swath of 185 km
- Global coverage; Revisit ~16 days
- 6000 cross-track samples (~30 m GSD*)
- VSWIR 632 km Sun-Sync Orbit, 10:45 local time



TIR Satellite

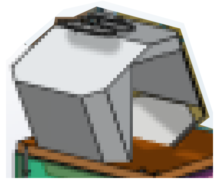
- Thermal instrument(s) (multi or hyperspectral)
- Observation swath of 935 km (~60 m GSD*)
- Global coverage; Revisit ~3 days
- TIR 665 km Sun-Sync Orbit, 13:30 local time



* - 1 km over open ocean

VSWIR Smallsat Pathfinder

- Narrow swath constellation pathfinder
- Observation swath of < 20 km
- Fly leading or trailing VSWIR



SBG Collaborating Missions

COMMUNITY ENGAGEMENT

WORKING GROUPS OF THE SBG RESEARCH AND APPLICATIONS TEAM

ALGORITHMS

Kerry Cawse-Nicholson
Kerry-Anne.Cawse-Nicholson@jpl.nasa.gov

- State-of-Research Algorithms
- Representative Data Products

APPLICATIONS

Stephanie Schollaert Uz
stephanie.uz@nasa.gov

- Representative applications
- Applications supportability

CAL/VAL

Kevin Turpie
kturpie@umbc.edu

- Cal/Val Infrastructure
- Connecting Engineering to Science

MODELING

Ben Poulter
benjamin.poulter@nasa.gov

- Observation System Simulation Experiments (OSSE)
- Uncertainty Quantification

SBG Algorithm Working Group Candidate Algorithm Classes

SBG Algorithm Class	SBG Algorithm Products (examples)
CORE Algorithms	
Earth Surface Temperature and Emissivity	Land Surface Temperature* and Emissivity
VSWIR Reflectance	Land and Water Reflectances, BRDF Corrections, Albedo
Cover Classifications	Cloud, Water, Land Cover, Plant Functional Types, etc.
PRODUCT Algorithms	
Terrestrial Ecosystems	
Vegetation Traits	Nitrogen, LMA, Chlorophyll, Canopy water
Evapotranspiration	ET*, Evaporative stress index
Proportional Cover	GV, NPV, Substrate, Snow/Ice, Burned Area
Geology/Earth Surface	
Substrate Composition	Mineral type*, Fractional abundance*, Soil types and constituents
Volcanic Gases and Plumes	SO2, Volcanic ash
High Temperature Features	Volcanic temperature anomalies (lava temperature), Forest fires
Aquatic and Coastal Ecosystems	
Water Biogeochemistry	Pigments, CDOM, Suspended particulate matter
Water Biophysics	Diffuse light attenuation, Inherent optical properties, Euphotic depth, PAR
Aquatic Classification	Phytoplankton functional types, Floating vegetation, Benthic cover, Wetlands
Snow and Ice	
Snow albedo	Albedo, Grain size, SSA, Light absorbing particles, Fractional cover

**Leverages ECOSTRESS and EMIT algorithms*

Aquatic Studies Group (ASG)

Founding Chair: Kevin Turpie   **Co-Chair**: Liane Guild

- **ASG (aka AquaRS) is a community of practice for the coastal and inland aquatic remote sensing community, compiling community input regarding science and applications to formulate recommendations to NASA.**
- Currently, over 130 participants, affiliated with **international** and **domestic** institutions, including government, university, research or application organizations.
- To join, please contact Kevin Turpie (kturpie@umbc.edu).

Recent SBG Activities:

Calibration and Instrument Performance	Studied baseline needs for various aquatic observation
Aquatic Algorithms	~90 algorithms provided to the SBG Algorithm Working Group
Coastal Mask	Static command of spatial resolution over the ocean
Special Observations	Dynamic command of spatial resolution over the ocean
Glint Mitigation ⚠	Examining tilt and algorithmic reduction strategies

Aquatic Cross-Mission Exchange (ACME)

Moderator: Kevin Turpie

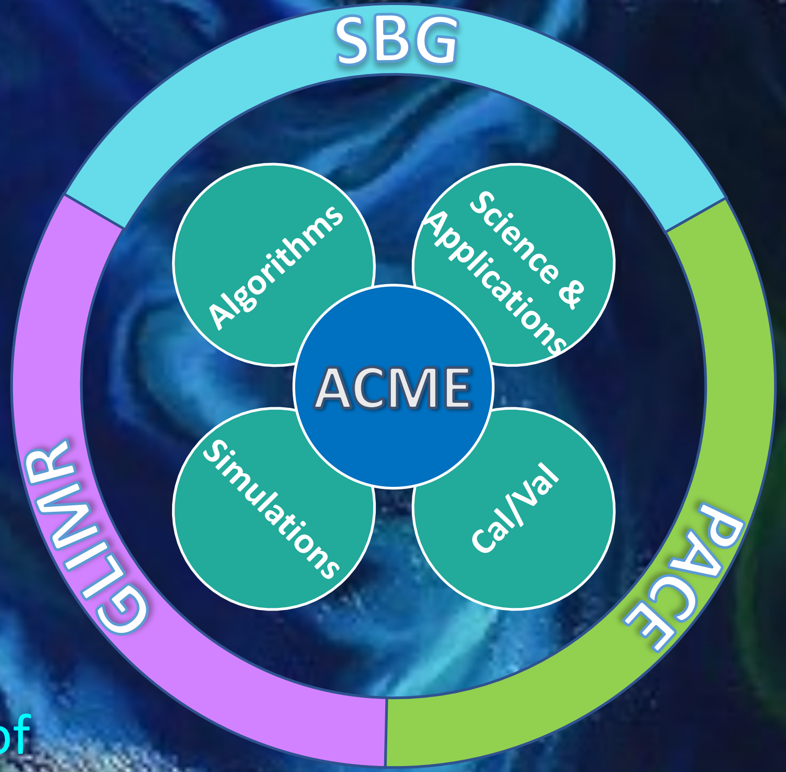
Purpose: To identify shareable resources, mutually beneficial opportunities, overlapping activities and find ways to synergize efforts across aquatic missions in order to reduce risk, save cost and better our support of the research and applications needs of the aquatic remote sensing communities.

Ocean Science Meeting 2022 Feb 27 – Mar 4
Honolulu, Hawaii

Joint Town Hall Proposal Submitted

Joint Science Session (Currently 27 abstracts submitted)

CB04 PACE, GLIMR and SBG: Synergy across Future NASA Missions for Hyperspectral Remote Sensing of Coastal and Inland Waters



MEMBER MISSIONS

Surface
Biology and Geology

PACE

Phytoplankton, Aerosols, Clouds and ocean Ecology

GLIMR

Geostationary Littoral Imaging and Monitoring Radiometer

Summary

- The project is currently in Pre-Phase A, with MCR and KDP-A probably in mid 2022.
- The current architecture consists of two free flying, polar-orbit platforms, one with a VSWIR imaging spectrometer and one with a TIR imager and a small VNIR camera (ASI).
- A constellation concept pathfinder mini-sat will also be deployed.
- To improve temporal sampling, SBG expects to harmonize its data products with collaborating missions: CHIME, LSTM, TRISHNA.
- Efforts have been underway to develop simulations, algorithms and ground system work flow, applications, and build cal/val capacity.
- The aquatic coastal and inland science and application communities are interested and involved (e.g., ASG, ACME).
  - Ocean Science Meeting 2022: watch for joint activities for SBG, PACE and GLIMR
  - A coastal mask product is being created for planning marine acquisitions.
  - An approach is needed for glint, but the process is currently stymied.

ACCP/AOS Updates

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ATMOSPHERE

EARTH SYSTEM OBSERVATORY

National Aeronautics and Space Administration

NASA

Atmosphere Observing System (AOS)

(Formerly known as ACCP)

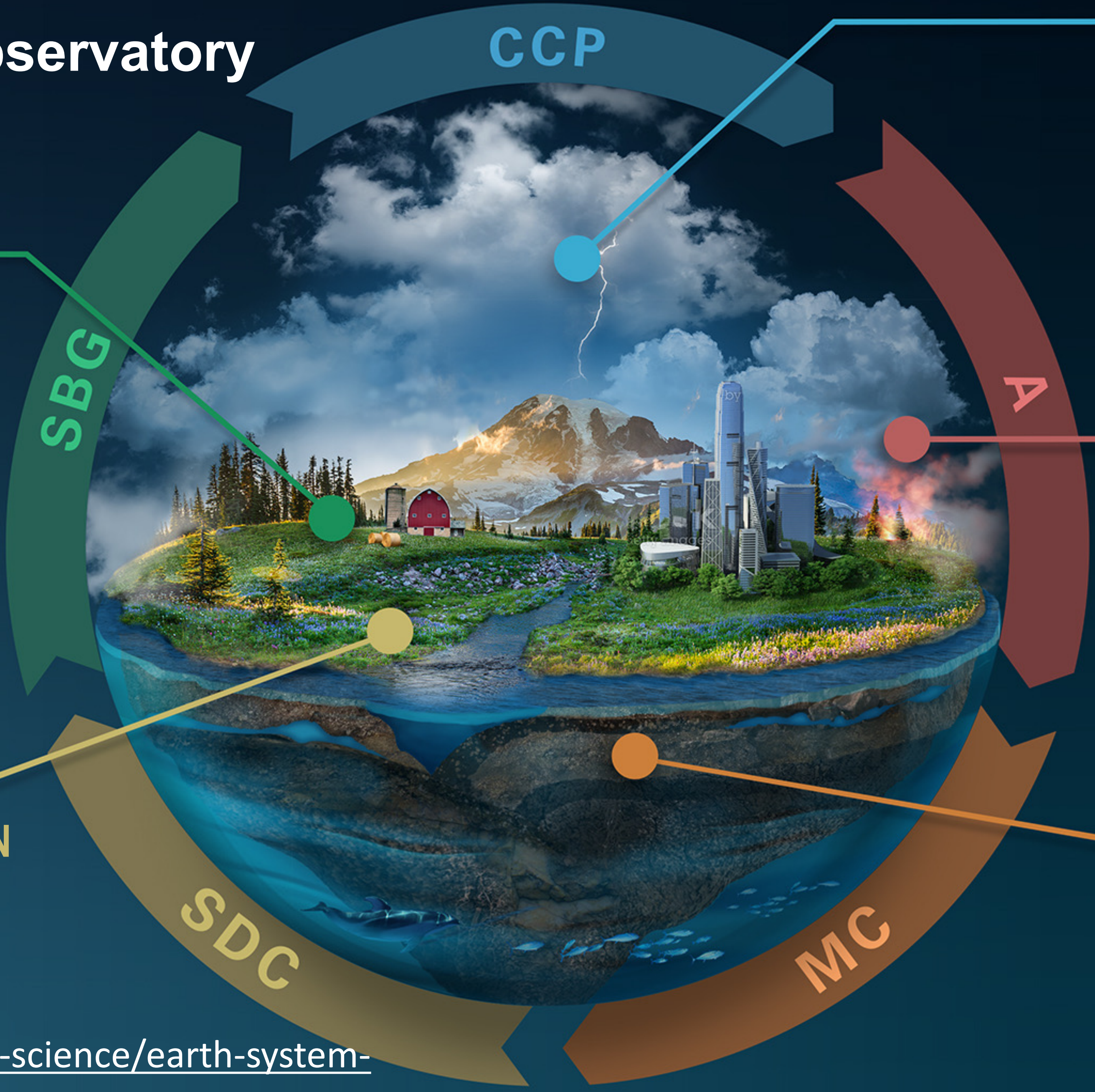
Update for the OCRT 28 October 2021

Chris Hostetler, NASA LaRC, chris.a.hostetler@nasa.gov

With inputs from Scott Braun, Amir Ibrahim, Kirk Knobelspiesse, Emmanuel Boss, Mike Behrenfeld, Snorre Stamnes, Brian Cairns, Kerry Meyer, Bill Cook, Jacek Chowdhary and others….

Earth System Observatory

Interconnected Missions



CLOUDS, CONVECTION AND PRECIPITATION

Water and Energy in the Atmosphere

SURFACE BIOLOGY AND GEOLOGY

Earth Surface & Ecosystems

AEROSOLS

Particles in the Atmosphere

SURFACE DEFORMATION AND CHANGE

Earth Surface Dynamics

MASS CHANGE

Large-scale Mass Redistribution

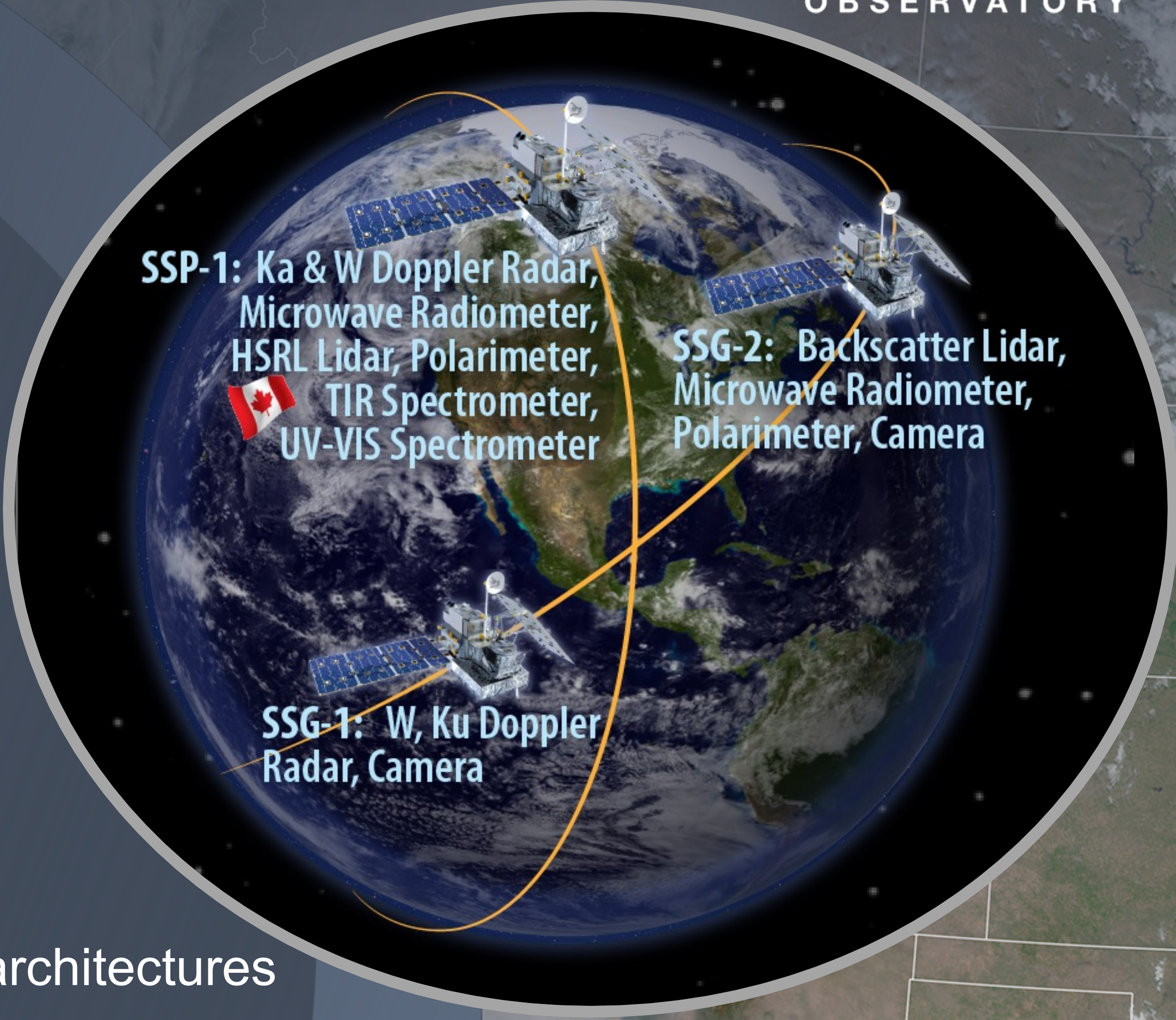
https://science.nasa.gov/earth-science/earth-system-observatory

AOS: One Observing System, Two Synergistic Segments

EARTH SYSTEM OBSERVATORY

Science

- To better understand and predict how microscopic particles and moisture interact in the atmosphere to fuel severe storms, affect air quality, impact the Earth's radiation budget, and influence our changing climate



Constellation Approach

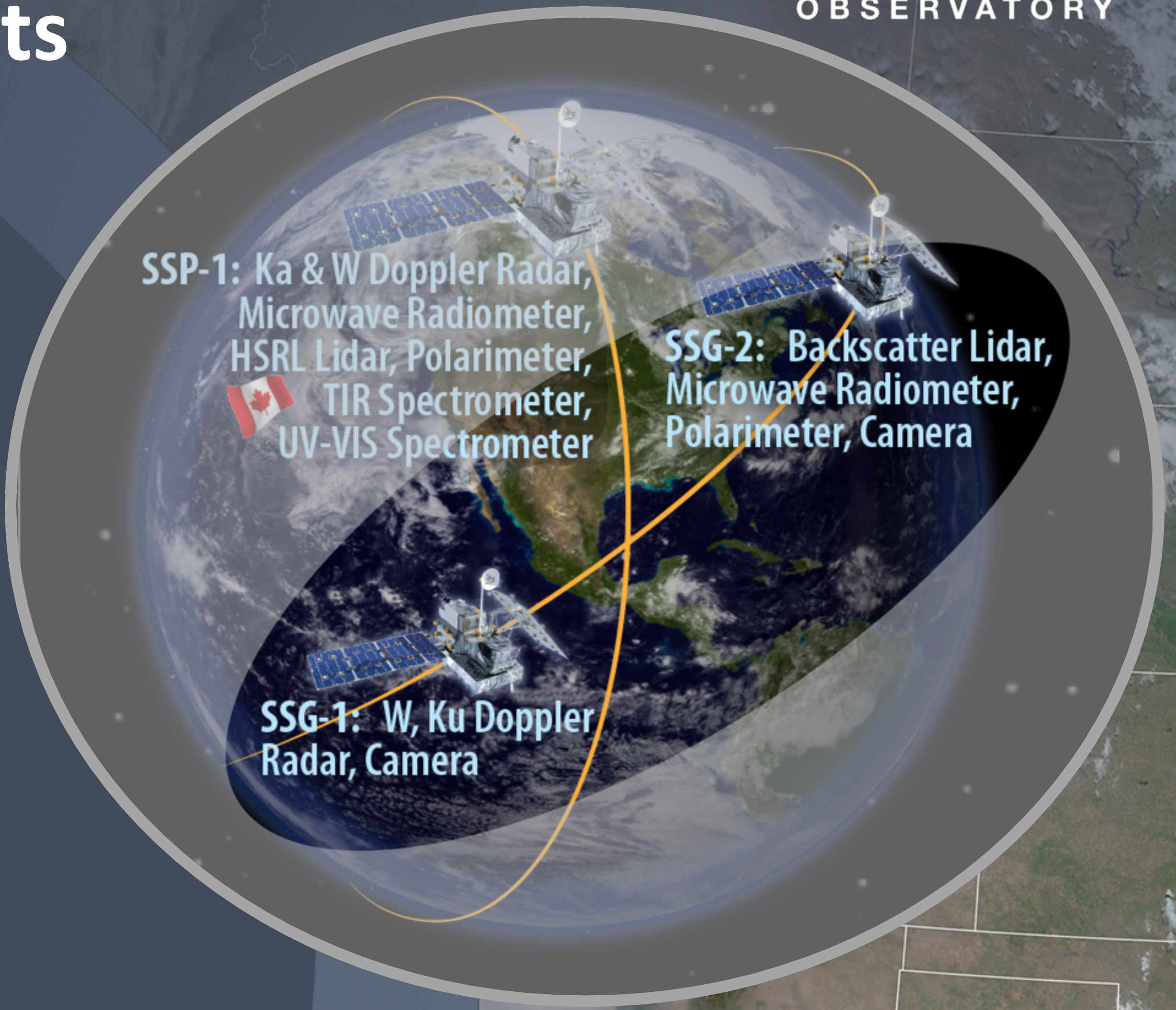
- Includes both Polar and Inclined orbits
- Recommendation based on exploration of ~100 architectures
- Architecture presented here is pre-decisional and subject to descopes

EARTH SYSTEM OBSERVATORY

AOS: One Observing System, Two Synergistic Segments

Inclined Orbit (2028 launch)

- Targets diurnally varying convective clouds to explore connections between vertical air motion and cloud/precipitation processes
- Explores the dynamics of evolving low clouds and aerosol plumes
- Provides insight on sub-daily processes that influence the distribution of aerosols and their linkage to clouds-precipitation



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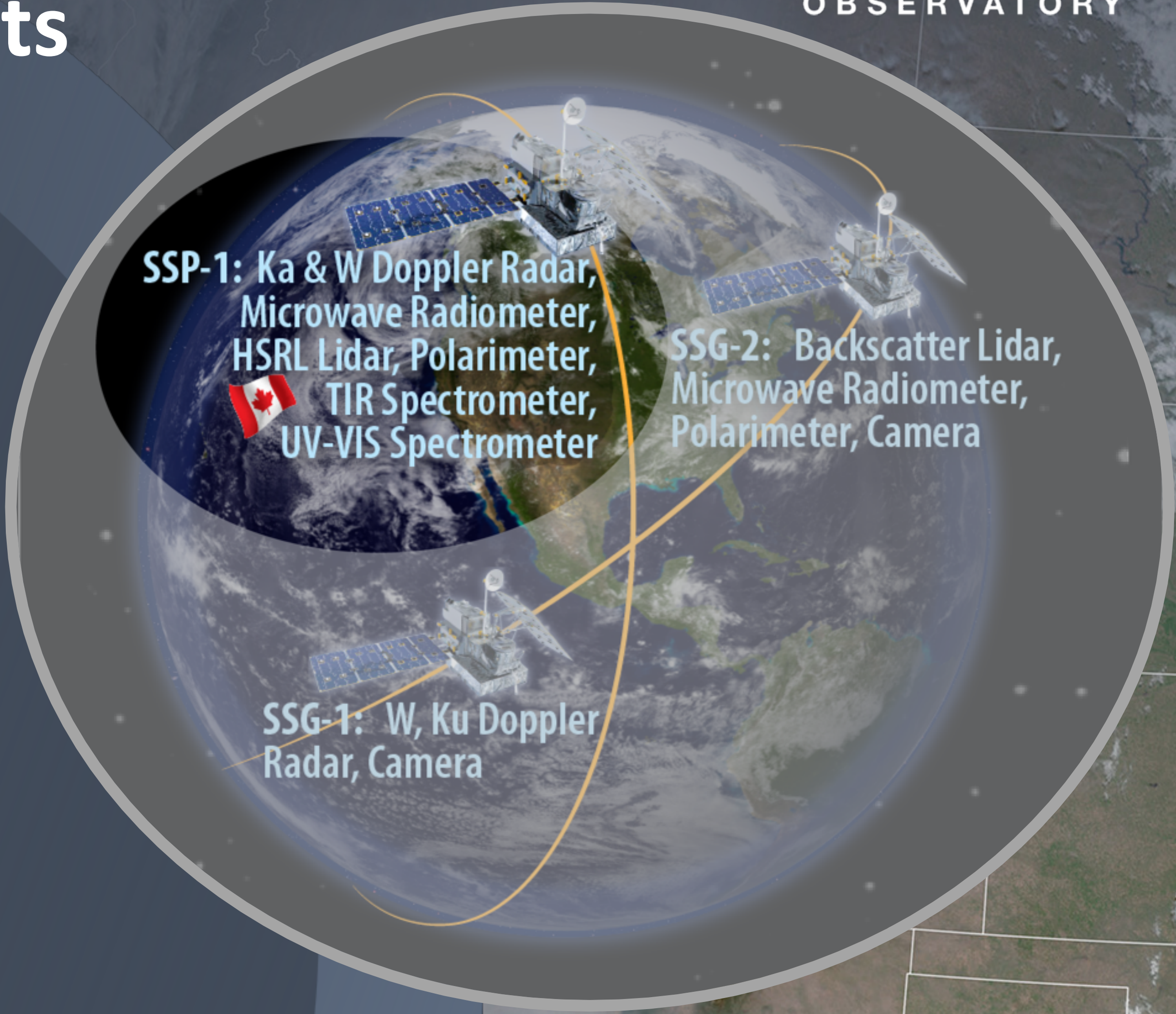
AOS: One Observing System, Two Synergistic Segments

EARTH SYSTEM OBSERVATORY

Polar Orbit (2030 launch)

- Advances understanding of how clouds and aerosols interact with each other and radiation to influence Earth's energy and water cycles
- Provides critical measurements on aerosol properties that will aid AQ forecasts
- Emphasizes processes critical to aerosol forcing, cloud feedbacks, and AQ

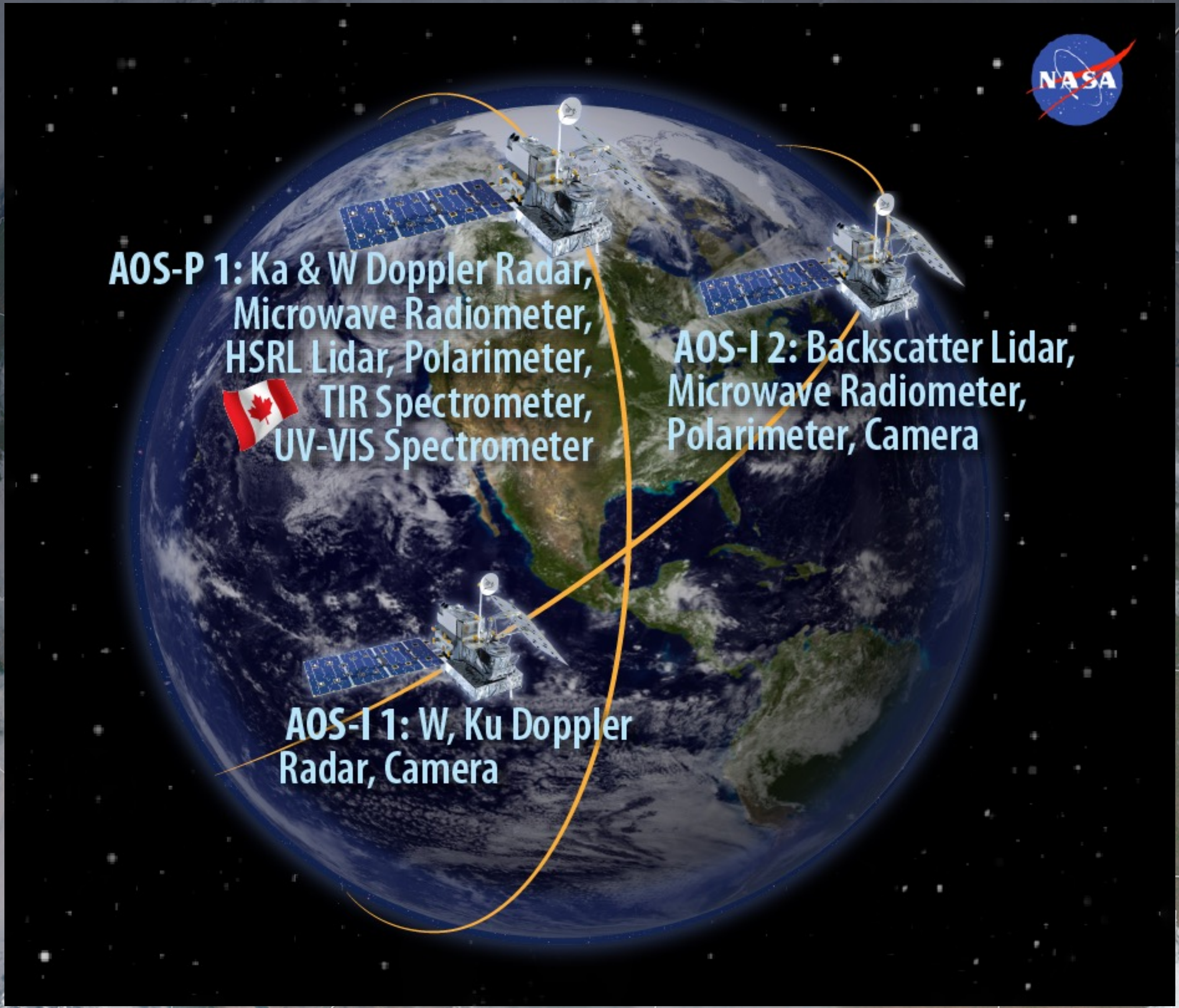


AOS relevance to ocean remote sensing

Polar Orbit
- ➢ Microwave radiometer
- ➢ TIR spectrometer
- ➢ **UV-VIS spectrometer**
- ➢ **Polarimeter**
- ➢ **High-spectral-resolution lidar**

Inclined Orbit
- ➢ Satellite 1:
  - Radar: W-band &
  - Ku-band with Doppler
  - Camera (1st of a pair)
- ➢ Satellite 2:
  - Microwave radiometer
  - Camera (2nd of a pair)
  - Elastic backscatter lidar
  - **Polarimeter**

Note: ocean measurements are not driving any AOS mission or instrument requirements



Spectrometer relevance to ocean remote sensing

EARTH SYSTEM OBSERVATORY

- Better spectral coverage than MODIS and VIIRS
  - Enhanced spectral capabilities enable separation of absorption into components: algal, non-algal, and CDOM
- SNR, dynamic range, etc. similar to MODIS and VIIRS
  - Designed for aerosols and clouds, so SNR may be an issue for things like fluorescence line height (TBD)
- Radiometric accuracy can be improved in post processing
- Swath << MODIS, VIIRS, OCI

Parameter	Current baseline requirements (thresholds are lower)
Spectral coverage	350 – 2400 nm
Channel bandwidth	5 nm
Pixel size at nadir	≤ 300 m
Swath	≥ 300 km
Absolute spectral radiometric uncertainty	≤ 3%
Radiometric stability	<1%
Channel-to-channel radiometric uncertainty	<1%
SNR, dynamic range, NEdL, NeDT	Similar to MODIS and VIIRS

Polarimeter relevance to ocean remote sensing

EARTH SYSTEM

- Likely to have MODIS-like spectral bands for ocean color retrievals
- Multiple view angles increases effective SNR
- Deployed on both inclined and polar orbits

Parameter	Current baseline requirements (thresholds are lower)	
Spectral coverage	Number of bands	View angles
360 – 390 nm	1	10
410 – 870 nm	3	10
670 – 870 nm	1	60
1000 – 2260 nm	3	10
Channel bandwidth	TBD	
Pixel size at nadir	≤ 500 m	
Swath	≥ 300 km	
Absolute spectral radiometric uncertainty	≤ 3%	
Radiometric stability	<1%	
Degree of linear polarization uncetainty	.005	
Dynamic range	Resolve reflectance ≤ $2x10^4$	
SNR	> 300 for reflectance = 0.1	

Why should you care about polarimetry?

EARTH SYSTEM OBSERVATORY

- Provides far better atmospheric correction than possible with a radiometer/spectrometer
- Multi-angle capability ensures observation outside of sun glint (and provides the ability to characterize the wind speed that drives it)
- Multi-angle, polarimetric observations provide other dimensions of information to characterize the ocean hydrosols, e.g.,
  - Relative scattering contribution between organic and inorganic particles
  - A measure of beam attenuation as demonstrated in Ibrahim et al 2016.
  - Potential to retrieve bulk microphysical properties of hydrosols, e.g., refractive index and the particle size distribution as demonstrated from POLDER-2 in Loisel et al 2008.
  - Reduce ambiguity in inherent optical property retrievals, e.g., improve scattering and backscattering retrievals in complex waters as in Chami and Platel 2007.
  - Improve the Bidirectional Reflectance Distribution Function (BRDF) correction from the multi-angular observations to derive the ocean reflectance as being developed for PACE e.g., He et al. 2017
- Several groups working on coupled atmosphere-ocean retrievals using polarimeter data (PACE/HARP2, PACE/SPEXone) which can be applied to AOS

Lidar relevance to ocean remote sensing

EARTH SYSTEM OBSERVATORY

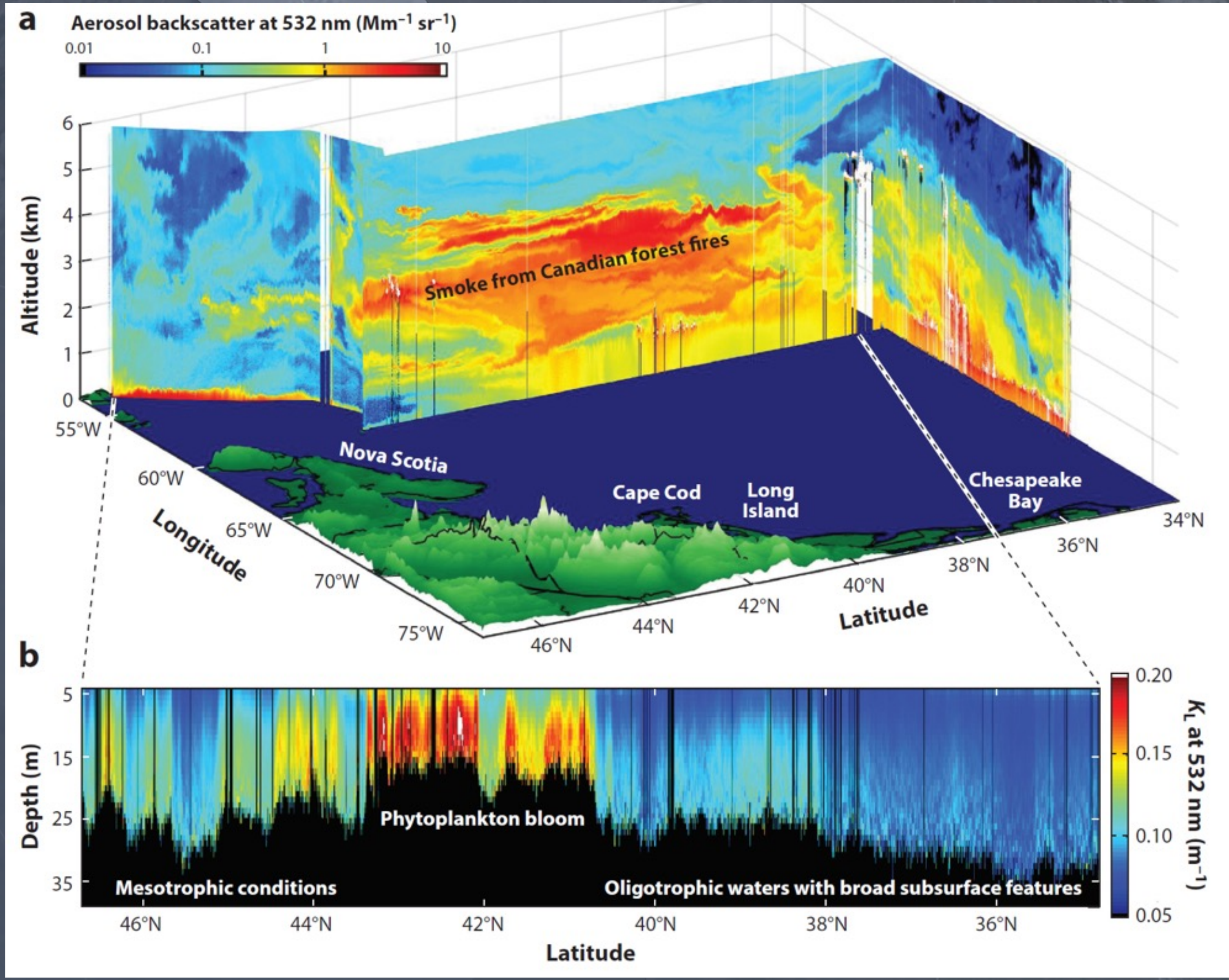
- Backscatter lidar employs technique similar to CALIOP on CALIPSO, but dynamic range may preclude CALIOP-like ocean measurements
- High-spectral-resolution lidar (HSRL) employs more advanced technology
  - Enables independent retrieval of
    - Particulate backscatter
    - Diffuse attenuation coefficient
  - High vertical resolution
  - Dynamic range and transient response required to capture ocean signal

Parameter	Current baseline requirements (thresholds are lower)
Backscatter Lidar	**Inclined orbit**
Wavelength	532 nm
Polarization sensitive	yes
Vertical resolution	30 m
Dynamic range	May saturate on ocean surface reflection
High-Spectral-Resolution Lidar	**Polar Orbit**
Wavelength	532 nm
Polarization sensitive	yes
Vertical resolution	1 m
Dynamic range	Unlimited for ocean surface and subsurface

Why should you care about lidar?

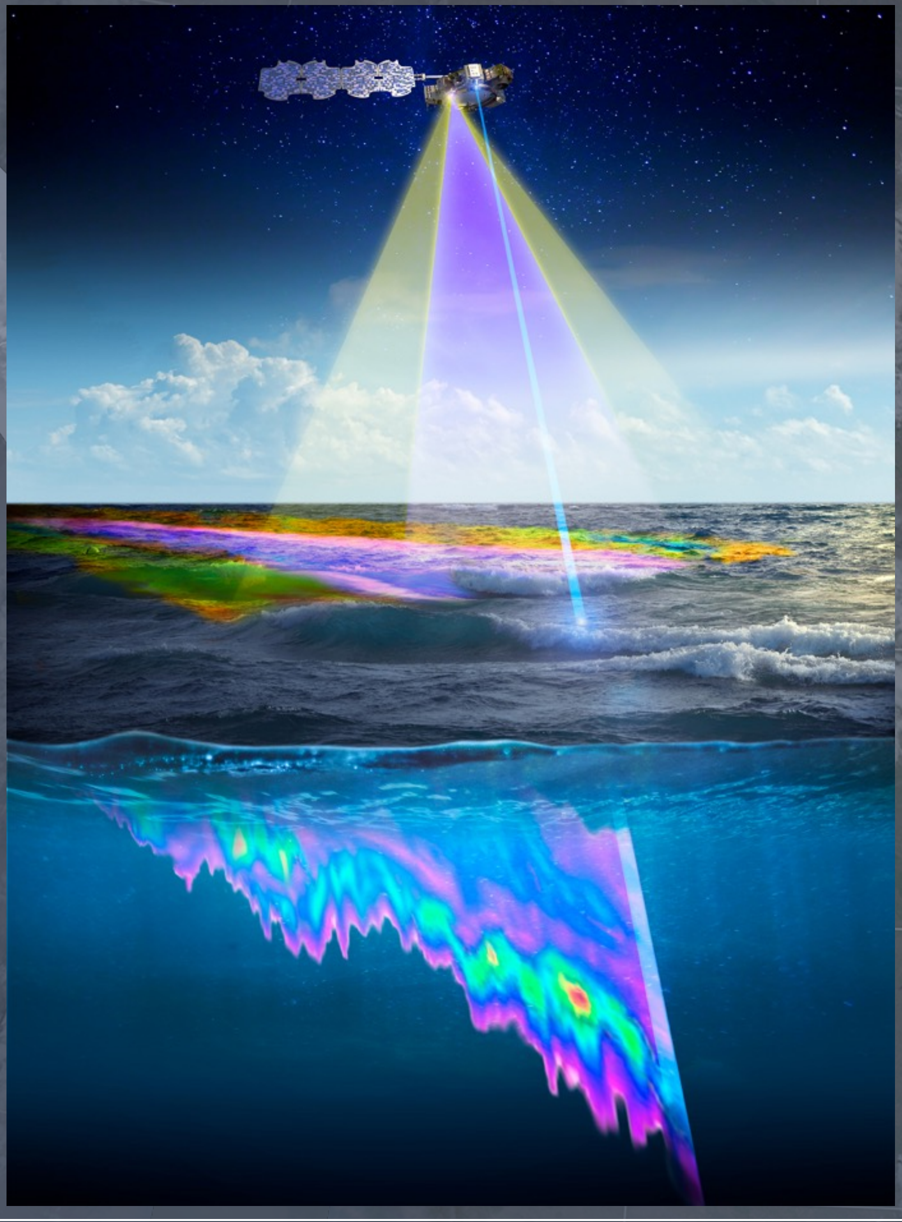
EARTH SYSTEM OBSERVATORY

- Lidar has been unequivocally shown to provide new science
- Provides measurements in scenes that are difficult for ocean color
  - Night as well as day
  - At high wintertime latitudes
  - In small holes in broken cloud systems (immune to cloud shadowing and 3-D side scatter)
  - Through dense aerosol layers and optically thin clouds (for HSRL implementations)
- Can provide depth-resolved measurements to ~3 optical depths (with appropriate design)
- Can be employed in synergistic joint retrievals with polarimeter and spectrometer



Summary

- Current baseline capabilities indicate that AOS spectrometer and polarimeter will enable advanced ocean property retrievals
- AOS passive sensors lack the swath of MODIS, VIIRS, and OCI
- However, AOS has a potential added capability – an ocean profiling high-spectral-resolution lidar
- AOS has the potential to provide the first global 3-D view of the near-surface ocean
- Complimentary/joint retrievals between lidar, polarimeter and spectrometer likely to enable new science
- Matchups with PACE would provide an independent means to assess/improve PACE retrievals



NOTE: AOS is in Pre-Phase A. The current baseline mission is subject to descopes which may eliminate instruments or reduce capabilities.

Some references on application of polarimetry and lidar to ocean remote sensing (not comprehensive)

EARTH SYSTEM OBSERVATORY

- Polarimeter papers

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- Lidar papers

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- Lidar + Polarimeter papers

  - Jamet, C., Ibrahim, A., Ahmad, Z., Angelini, F., Babin, M., Behrenfeld, M.J., Boss, E., Cairns, B., Churnside, J., Chowdhary, J. and Davis, A.B., 2019. Going beyond standard ocean color observations: lidar and polarimetry. Frontiers in Marine Science, 6, p.251.
  - Neukermans, G., Harmel, T., Galí, M., Rudorff, N., Chowdhary, J., Dubovik, O., Hostetler, C., Hu, Y., Jamet, C., Knobelspiesse, K. and Lehahn, Y., 2018. Harnessing remote sensing to address critical science questions on ocean-atmosphere interactions. Elementa: Science of the Anthropocene, 6.
  - Stamnes, S., Hostetler, C., Ferrare, R., Burton, S., Liu, X., Hair, J., Hu, Y., Wasilewski, A., Martin, W., Van Diedenhoven, B. and Chowdhary, J., 2018. Simultaneous polarimeter retrievals of microphysical aerosol and ocean color parameters from the "MAPP" algorithm with comparison to high-spectral-resolution lidar aerosol and ocean products. *Applied optics*, *57*(10), pp.2394-2413.

NASA Ocean Biology & Biogeochemistry Future Directions

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Grand Challenges

- ***Global Biosphere*: ** In the face of compounding stressors from natural variability, climate warming, and direct human impacts, how will global ocean ecosystems change in the future and how will these changes impact life on our planet as a system of systems?
- ***Elements of Life*: ** How will the ocean's role in climate regulation and the biogeochemical cycling of elements change in the future and what are the ramifications of these changes on ecosystems, resource sustainability, and human welfare?
- ***Interface Habitats*: ** How do natural processes and human activities govern the diversity, function, and resilience of interface habitats and how can their services and value to humanity be safeguarded and sustained for future generations?

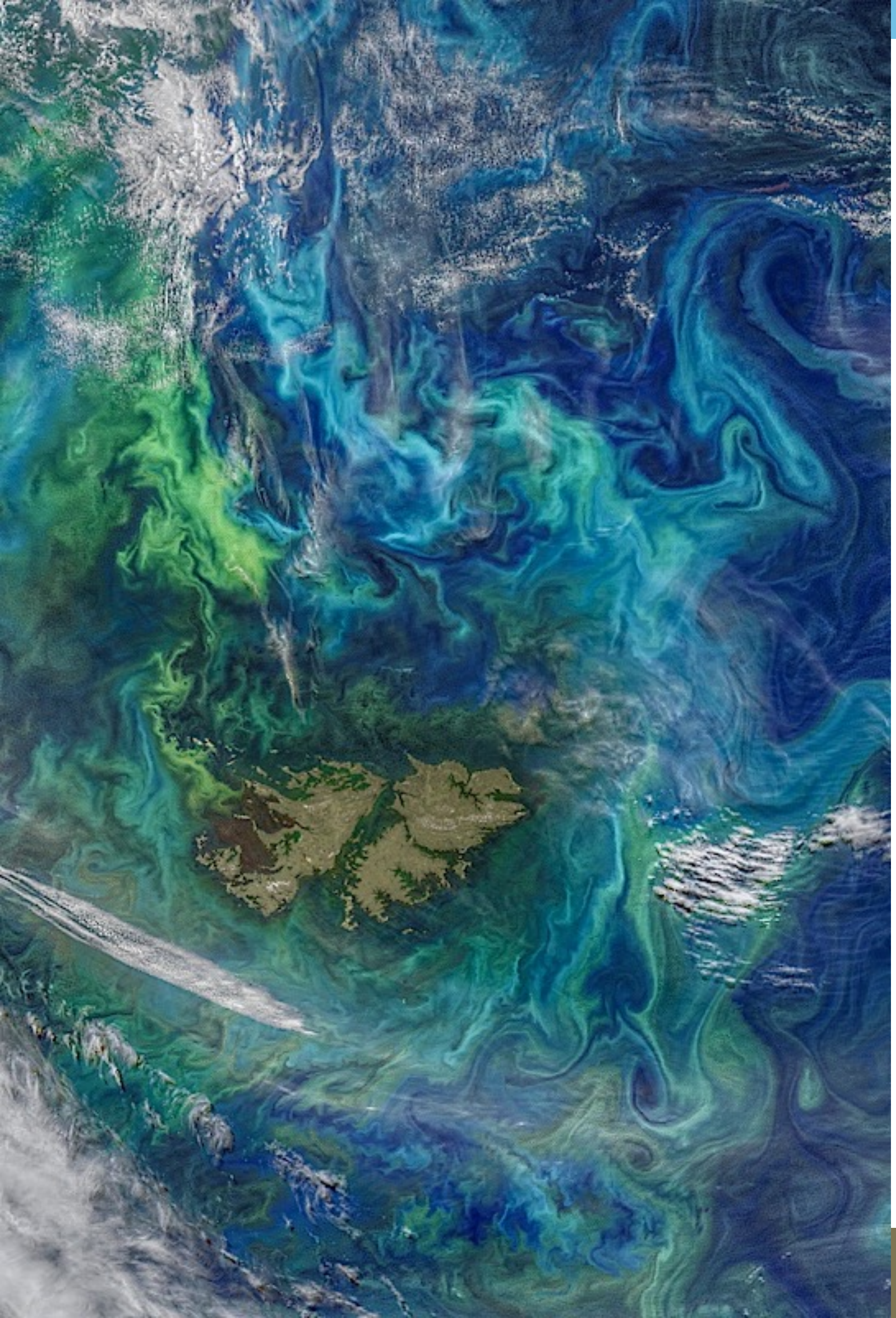
Grand Challenges (cont'd)

- ***Transient Events*****:** How can we best understand and respond to transient events in the marine environment to facilitate preparation, mitigation, and recovery by affected communities?
- ***Leveraging Ocean Data and Models*****:** How can we leverage advanced data harmonization, synthesis, and mining strategies to maximize the value of remote, in situ, autonomous, and modeled ocean data across the international community to better understand ocean biogeochemistry, ecosystems and their dynamic processes?

NASA Ocean Biology & Biogeochemistry: ***Advanced Science Plan***

- This Plan will frame the next decade (and beyond) of ocean biology and biogeochemistry research
- We want to hear initial reactions!

Please post in the chat or raise your hand.
You may also email either of us in the coming days.
(laura.lorenzoni@nasa.gov or joel.scott@nasa.gov)



OCRT 2022!!

- For the 2022 OCRT meeting, we are planning for a hybrid meeting with an in-person component.
- Look for a survey from us to…
  - Gauge interest
  - Scope potential locations (US: East Coast, West Coast, Central, etc)
  - Volunteer space/facilities if you are inclined to host
- We will be following all Federal, NASA, and local policies, guidelines, and ordinances to ensure the safety of you and our community.

Thank you!

- To our presenters,
- To our attendees,
- To all of YOU in the Ocean Color and Ocean Biology & Biogeochemistry communities!