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 policies 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.
• 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. Turple/UMBC
- 3:30-3:40 ACCP/AOS – Chris Hostetler/LaRC
- 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
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)
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
• 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).

SeaWIFS

MOBY timeseries, nLw(412)

OLCI/S3A and MODIS/Aqua

Deep Water Rrs

Deep Water Chl

Clear Water Rrs

Clear Water Chl
Annual Mean Chlorophyll Concentration for 2018

VIIRS

JPSS-1

SNPP

MODIS

Aqua

Terra
Annual Mean Chlorophyll Concentration for 2019

VIIRS

JPSS-1

SNPP

MODIS

Aqua

Terra
Annual Mean Chlorophyll Concentration for 2020

VIIRS
- JPSS-1
- SNPP

MODIS
- Aqua
- Terra
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)
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

Δ~2%
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
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 $C_{\text{cyano}}$ for inland waterbodies.
L2 files
L3-binned files
L3 standard mapped images (SMI)

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 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

• Introduction
• FSG Activities
• \textit{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.
**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

- HPLC Pigment Analysis
- SeaBASS Data Quality Evaluation
- Field Campaigns
- Field Measurement Protocols
- Gain and Sustain New Measurement Expertise
- Conduct Research
- Community Training & Advice
- Develop Software Tools
- Round Robins
- Lab Experiments
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

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

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SeaBASS QA/QC subject matter experts

- **Aimee:** pigments, particle absorption, PCC, PSD
- **Joaquin:** NPP, POC, CDOM abs., ac-s
- **Mike/Chelsea:** CDOM and particle abs., DOC, POC, SPM
- **Scott & Harrison:** radiometry, underway and profile absorption, attenuation, backscatter, VSF, particle size distribution
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

Vol. 1.0
Absorption (particles)
Nov. 2018

Vol. 2.0
Beam Attenuation
April 2019

Vol. 3.0
Radiometry for Validation
Dec. 2019

Vol. 4.0
Inline Flow-Through IOPs
Nov. 2019

Vol. 6.0
Particulate Organic Carbon
August 2021

Status of Protocols – CDOM Absorption

- 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

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

Vol. 5.0
CDOM Absorption

Authors
Status of Protocols – Primary Productivity

Vol. 7.0 Aquatic Primary Productivity

Contributors
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

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

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
Status of Protocols – more radiometry

- 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

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
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

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

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

Rigorous glint correction and quality control

Dirk Aurin
NASA/GSFC Code 616
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.
Thank You

Questions / Follow-up
antonio.mannino@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

http://seabass.gsfc.nasa.gov
SeaBASS News and Updates: Team is growing!

The extended SeaBASS team includes many others:

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

Chris Proctor
SeaBASS manager

Inia Soto Ramos
Data manager

David Norris
Developer

Noah Vegh-Gaynor
Developer

Violeta Sanjuan Calzado
NOMAD lead
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_WHOL – 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?

New SeaBASS Experiment?
- Short & Long name
- Project PIs
- Brief description
- Start/End Dates
- Website links

NO

New SeaBASS user?

Request SFTP account

NO

Submit Data
- Contact us about new data types
- Format your data
- Check for any special data requirements
- FCHECK
- Upload data via SFTP

Email us!

Wait for DOI Landing Page

YES

Email us!

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

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

Jeremy Werdell
PACE Project Scientist

OCRT, October 2021
outline

brief background & observatory overview
mission update
science teams & community engagement
resources
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 km² at nadir
- ± 20° 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
**Update**

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

---

<table>
<thead>
<tr>
<th>HARP-2</th>
<th>SPEXone</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV-NIR range</td>
<td>Continuous from 385-770 nm in 5 nm steps</td>
</tr>
<tr>
<td>SWIR range</td>
<td>None</td>
</tr>
<tr>
<td>Polarized bands</td>
<td>All</td>
</tr>
<tr>
<td>Number of viewing angles [degrees]</td>
<td>Continuous from 385-770 nm in 15-45 nm steps</td>
</tr>
<tr>
<td>Number of viewing angles [degrees]</td>
<td>10 for 440, 550, 870 nm; 60 for 670 nm [spaced over 114°]</td>
</tr>
<tr>
<td>Number of viewing angles [degrees]</td>
<td>5 [-57°, -20°, 0°, 20°, 57°]</td>
</tr>
<tr>
<td>Swath width</td>
<td>±47° [1556 km at nadir]</td>
</tr>
<tr>
<td>Swath width</td>
<td>±4.5° [106 km at nadir]</td>
</tr>
<tr>
<td>Global coverage</td>
<td>2 days</td>
</tr>
<tr>
<td>Global coverage</td>
<td>30+ days</td>
</tr>
<tr>
<td>Ground pixel</td>
<td>3 km</td>
</tr>
<tr>
<td>Ground pixel</td>
<td>2.5 km</td>
</tr>
<tr>
<td>Heritage</td>
<td>AirHARP, Cubesat</td>
</tr>
<tr>
<td>Heritage</td>
<td>AirSPEX</td>
</tr>
</tbody>
</table>

---

**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.
**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!*

---

**Schedule Diagram**

- **Phase A**: OCI PDR, Spacecraft PDR, Mission PDR, OCI CDR, Mission CDR & LV Award
- **Phase B**: OCI & Spacecraft I&T, Observatory I&T
- **Phase C**: Launch Readiness Date (LRD) Jan. 2024
- **Phase D**: Post Pandemic (not yet Approved)
- **Phase E**: Decommission

**Timeline**

- CY16
- CY17
- CY18
- CY19
- CY20
- CY21
- CY22
- CY23
- CY24
- CY25
- CY26
- CY27

**Key Dates**

- June 16, 2016: Phase A
- July 13, 2017: Phase B
- August 2019: Phase C
- October 2021: Phase D
- June 2023: Phase E

*Launch – 27 mos.*
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
Ocean Color Instrument (OCI)

Engineering Test Unit Optical Module Assembly

11/06/19 – 12/11/19
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
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- 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
• 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)
FY22 is an incredibly important year for PACE!
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

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

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
Plankton, Aerosol, Cloud, ocean Ecosystem
PACE Science and Application Team Updates

Heidi Dierssen
PACE Science & Application Team Lead
University of Connecticut
heidi.dierssen@uconn.edu
PACE Science and Applications Team (SAT)

Plus Streaming Totals: 75 Cities 195 Unique IP Addresses

Credit OskarLandi
GOALS of Team

**Algorithm production**
- implemented as Standard, Provisional, Test or Special

**Algorithm documentation**
- to be available online

**Algorithm implementation**
- with project team

Partnerships with end-users through Early Adopters Program.

Communication to the public with news and updates on PACE research.
Table 1. Required Ocean Color Instrument (OCI) ocean color data products.

<table>
<thead>
<tr>
<th>Data Product</th>
<th>Baseline Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-leaving reflectances centered on (±2.5 nm) 350, 360, and 385 nm (15 nm bandwidth)</td>
<td>0.0057 or 20%</td>
</tr>
<tr>
<td>Water-leaving reflectances centered on (±2.5 nm) 412, 425, 443, 460, 475, 490, 510, 532, 555, and 583 (15 nm bandwidth)</td>
<td>0.0020 or 5%</td>
</tr>
<tr>
<td>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)</td>
<td>0.0007 or 10%</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Data Product</th>
<th>Range</th>
<th>Baseline Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total aerosol optical depth at 380 nm</td>
<td>0.0 to 5</td>
<td>0.06 or 40%</td>
</tr>
<tr>
<td>Total aerosol optical depth at 440, 500, 550 and 675 nm over land</td>
<td>0.0 to 5</td>
<td>0.06 or 20%</td>
</tr>
<tr>
<td>Total aerosol optical depth at 440, 500, 550 and 675 nm over oceans</td>
<td>0.0 to 5</td>
<td>0.04 or 15%</td>
</tr>
<tr>
<td>Fraction of visible aerosol optical depth from fine mode aerosols over oceans at 550 nm</td>
<td>0.0 to 1</td>
<td>±25%</td>
</tr>
<tr>
<td>Cloud layer detection for optical depth &gt; 0.3</td>
<td>NA</td>
<td>40%</td>
</tr>
<tr>
<td>Cloud top pressure of opaque (optical depth &gt; 3) clouds</td>
<td>100 to 1000 hPa</td>
<td>60 hPa</td>
</tr>
<tr>
<td>Optical thickness of liquid clouds</td>
<td>5 to 100</td>
<td>25%</td>
</tr>
<tr>
<td>Optical thickness of ice clouds</td>
<td>5 to 100</td>
<td>35%</td>
</tr>
<tr>
<td>Effective radius of liquid clouds</td>
<td>5 to 50 μm</td>
<td>25%</td>
</tr>
<tr>
<td>Effective radius of ice clouds</td>
<td>5 to 50 μm</td>
<td>35%</td>
</tr>
<tr>
<td><strong>Atmospheric data products to be derived from the above</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water path of liquid clouds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water path of ice clouds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short-wave Radiative Effect</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 $E_a(0^+, \text{PAR})$
  - Downwelling Irradiance $E_a(0^+, \lambda)$
- Irradiance Below Water Surface:
  - Downwelling Irradiance $E_a(0^-, \lambda)$
  - Scalar Irradiance $E_a(0^-, \lambda)$
- Surface Index of Refraction
- Bidirectional Reflectance Function (BRDF)
- Whitecap Fraction/Factor
Properties

- Spectral Light Penetration
  - Downwelling Attenuation $K_d(\lambda)$, $K_d$(PAR)
  - Scalar Attenuation $K_o(\lambda)$
- 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
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

Aerosols
Clouds
Surface Physics
Wet Biophysics
Shallow Habitats
Phyto-Plankton Dynamics
Floating Matter

Clouds
Surface Physics
Wet Biophysics
Shallow Habitats
Phyto-Plankton Dynamics
Floating Matter
# PACE SAT Algorithms

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Last Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unified algorithm for aerosol characterization from OCI</td>
<td>Remer</td>
</tr>
<tr>
<td>Radiative Transfer Simulator and Polarimetric Inversion for PACE</td>
<td>Zhai</td>
</tr>
<tr>
<td>Retrievals of the Ocean Surface Refractive Index</td>
<td>Ottaviani</td>
</tr>
<tr>
<td>Joint polarimetric aerosol and ocean color retrievals with deep learning</td>
<td>FastMAPOL</td>
</tr>
<tr>
<td>Algorithms to obtain inherent optical properties of seawater</td>
<td>Stromski</td>
</tr>
<tr>
<td>The PACE-MAPP collaborative algorithm project</td>
<td>Stamnes</td>
</tr>
<tr>
<td>Freshwater Hyperspectral HABs Algorithms</td>
<td>Shuchman</td>
</tr>
<tr>
<td>Retrieving water quality indicators via MDNs</td>
<td>Pahlevan</td>
</tr>
<tr>
<td>Chi factor and BRDF</td>
<td>Zhang</td>
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<tr>
<td>PACE UV Retrieval of Oceanic and Atmospheric Data products</td>
<td>Chowdhary</td>
</tr>
<tr>
<td>Spectral Derivative Methods for Quantifying Phytoplankton Pigments for PACE</td>
<td>Siegel</td>
</tr>
<tr>
<td>Topic</td>
<td>Author</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>-------------------------</td>
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<tr>
<td>Inversion algorithm for PACE</td>
<td>ZTT Model</td>
</tr>
<tr>
<td>MAIAC Processing of OCI Over Land: Aerosol Chemical Speciation</td>
<td>Go (Lyapustin)</td>
</tr>
<tr>
<td>HARP2 Level 1 Data Processing Plan</td>
<td>Xu</td>
</tr>
<tr>
<td>Remote sensing of cloud properties using PACE SPExOne and HARP-2</td>
<td>van Diedenhoven</td>
</tr>
<tr>
<td>Phytoplankton Algorithms and Data Assimilation: Preparing a Pre-launch Path to Exploit PACE Spectral Data</td>
<td>Rousseaux</td>
</tr>
<tr>
<td>PACE implementations for optically shallow waters</td>
<td>Barnes</td>
</tr>
<tr>
<td>A toolbox for the diagnostic assessment of spectral behavior</td>
<td>AVW</td>
</tr>
<tr>
<td>Radiative products for PACE</td>
<td>Boss</td>
</tr>
<tr>
<td>Support for PACE OCI Cloud Products</td>
<td>Meyer</td>
</tr>
<tr>
<td>Hyperspectral algorithms for OCI atmospheric correction and UV penetration</td>
<td>Krotkov</td>
</tr>
<tr>
<td>Net Primary Production for PACE OCI</td>
<td>NPP PACE, PhytoC</td>
</tr>
<tr>
<td>Machine learning approaches for predicting phytoplankton community composition from ocean color</td>
<td>Westberry</td>
</tr>
<tr>
<td>SpexONE - Aerosols</td>
<td>remoTAP</td>
</tr>
<tr>
<td></td>
<td>Hasekamp</td>
</tr>
</tbody>
</table>
Standard Semi-analytical Formulation

\[ r_{TS,00} = \sum_{i=1}^{2} g_i \left( \frac{b_b}{a + b_b} \right)^i \]

Backscattering over absorption

Proportionality factor
Bidirectionalality of incoming and reflected light

\[ b_b = b_{b,\text{water}} + b_{b,\text{large part}} + b_{b,\text{small part}}. \]

\[ a = a_{\text{water}} + a_d + a_g + a_{ph}. \]

ZTT (Zaneveld-Twardowski-Tonizzo) model

\[ r_{TS}(\theta_s, \theta_v, \phi, V, a, b_b, \beta) \approx r_{TS,\text{Raman}}(\theta_s', a, b_b) \]

+ \frac{1}{\bar{a}(\theta_s, \theta_v, \frac{b_b}{a})} \left( 1 - \cos(\theta_v) \Psi_{Kz\mu}(\psi) \bar{b}_b(a - b_b)^{-1} \right) f_L(\psi, \lambda) \left[ 1 - \left( \frac{b_b}{a} \right)^{-1} + \left( \frac{b_b}{a} \right)^{-1} \right]^{-1}

Water Raman contribution (Westberry et al. 2013)

Average cosine of downwelling light field (\( E_d/E_{od} \))
Phase function in backward direction
Absorption over backscattering
Shape function for upwelling component of path radiance

Coefficients related to diffuse attenuation of radiance in viewing direction (Twardowski and Tonizzo 2017)
Backscattering ratio \( b_d/b \)
Spectral derivative methods for estimating phytoplankton pigment concentrations

- Large degree of covariability among pigments
- Limits number of PFT groups can be retrieved using HPLC pigments
Chase et al. using Gaussian Functions to estimate Phytoplankton Pigments

\[ R_{rs}(\lambda) = \frac{L_w(\lambda,0^+) \cdot \text{absorption Gaussian functions}}{E_d(\lambda)} \]
A Net Primary Production (NPP) algorithm for application to PACE OCI

Team members:
Toby Westberry (PI)
Mike Behrenfeld (Co-I)
Jason Graff (Co-I)

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

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

\[ \int \Delta NPP = 10.9 \text{ Pg C} \]
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.

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

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

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

\(^1\)Earth Sciences Division, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
\(^2\)U.S. Geological Survey, Reston, VA 20192, USA
\(^3\)Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
\(^4\)School of Marine Sciences, University of Maine, Orono, ME 04469, USA
\(^5\)Ocean Ecology Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
\(^6\)Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882 USA
\(^7\)Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093, USA
\(^8\)Marine Physical Laboratory, Washington, DC 20375, USA
\(^9\)NASA Research Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
\(^10\)CNRS and Sorbonne Universities, Laboratoire d’Océanographie de Villefranche (LOV), 06230 Villefranche-sur-mer, France
\(^11\)Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711, USA
\(^12\)Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada
\(^13\)Earth Research Institute, University of California, Santa Barbara, CA 93106, USA

**Correspondence:** Kimberly A. Casey (kcasey@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)

<table>
<thead>
<tr>
<th>Field and Culture Data</th>
<th>Field, Global</th>
<th>A global compilation of in situ aquatic high spectral resolution inherent and apparent optical property data for remote sensing applications.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field, Pacific Reefs</td>
<td>In situ IOP and AOP data collected over Pacific coral reefs in conjunction with PRISM hyperspectral imagery.</td>
<td></td>
</tr>
<tr>
<td>Knaeps et al. (2018). The SeaWiFS dataset. <a href="https://doi.org/10.1594/PANGAEA.886287">https://doi.org/10.1594/PANGAEA.886287</a>.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field, Regional</td>
<td>Hyperspectral marine reflectances, total suspended matter, and turbidity measurements gathered at three turbid estuarine sites.</td>
<td></td>
</tr>
<tr>
<td>Field, North Atlantic</td>
<td>Four cruises in North Atlantic with AOPS, IOPs, associated with phytoplankton and aerosol data.</td>
<td></td>
</tr>
<tr>
<td>Field, Pacific &amp; Atlantic</td>
<td>Data on export and fate of upper ocean net primary production coupled to IOP and AOP measurements.</td>
<td></td>
</tr>
<tr>
<td>Field, Regional</td>
<td>Biodiversity time series of flora and fauna along coastal zones with ancillary data.</td>
<td></td>
</tr>
<tr>
<td>Mortelmans et al. (2019). LifeWatch Flanders Marine Institute Observatory Data. In prep for Reflectance <a href="https://doi.org/10.14594/993">https://doi.org/10.14594/993</a>.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field, Coastal North Sea</td>
<td>Monthly phytoplankton pigment, suspended matter, turbidity, and recently hyperspectral radiometry.</td>
<td></td>
</tr>
<tr>
<td>Vanderwoude et al. (2020). NOAA GLERL Great Lakes Harmful Algal Bloom Database <a href="https://doi.org/10.1594/PANGAEA.913536">https://doi.org/10.1594/PANGAEA.913536</a>.</td>
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<tr>
<td>Field, Australia</td>
<td>Spectral library repository for aquatic ecosystem substratum and substratum cover types.</td>
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<tr>
<td>Field, Hawaii</td>
<td>Hyperspectral water-leaving reflectance.</td>
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<tr>
<td>Field, Global</td>
<td>Public repository for drone data including hyperspectral datasets.</td>
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Simulated Databases

<table>
<thead>
<tr>
<th>Simulated and Derived Data</th>
<th>Simulated, Global</th>
<th>Top of Atmosphere, Hyperspectral Synthetic Dataset for PACE (Phytoplankton, Aerosol, and ocean Ecosystem) Ocean Color Algorithm Development.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Craig, Susanne E; Lee, Zhongping; Du, Keping (2020). National Acronautics and Space Administration, PANGAEA, <a href="https://doi.org/10.1594/PANGAEA.915747">https://doi.org/10.1594/PANGAEA.915747</a></td>
<td></td>
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</tr>
</tbody>
</table>

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

---

**Filename**

<table>
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<td>PACE_OCI_SIM.20190321T002000.L1B.V7.nc</td>
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<td>PACE_OCI_SIM.20190321T014000.L1B.V7.nc</td>
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<td>PACE_OCI_SIM.20190321T014500.L1B.V7.nc</td>
</tr>
</tbody>
</table>
Fig. 7. A host of new applications will be available with better discrimination of pelagic and benthic biodiversity promised by hyperspectral imagery.
Natasha Sadoff
NASA Goddard Space Flight Center/SSAI
natasha.sadoff@nasa.gov

PACE Applications Updates
PACE Applications & Early Adopter Program

*Leveraging Science to Advance Society*

Natasha Sadoff \(^1\), Erin Urquhart \(^1,2\)

\(^1\)NASA GSFC, \(^2\)SSAI
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

- fisheries
- biodiversity
- HABs
- oil leaks
- food security
- wetlands
- terrestrial ecosystems
- land use & change
- air quality
- human health
- disasters
- climate
- resource management
- ecological forecasting
- pathogens
- water quality

Images: Water landscape, wetland, forest fire, bacteria
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.

- **Address community user needs & concerns with PACE data products**
  
  - **Grow relevance & sustainability of PACE**
  
  - **Demonstrate the societal value & utility of PACE**
PACE Applications Program (a year in review)

https://pace.oceansciences.org/app_workshops_02.htm
PACE Applications Program (a year in review)

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, policymakers, 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 |

Bio/ Backstory:
Tom has worked at Florida DEP for 25yrs. He manages a team of over 600pl. 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
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
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
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
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](https://pace.oceansciences.org/app_adopters.htm)
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)
GLIMR Updates

Joe Salisbury
University of New Hampshire
joe.salisbury@unh.edu
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
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)
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
Benefits of Geostationary GOES

- 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 April 2020
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.

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

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

**High SNR**
*Requirements at Ocean Ltyp*
- > 420, UV
- > 1000, 400-580 nm
- > 750, 580-650 nm
- > 580, 650-890 nm
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.
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
# Planned GLIMR Data Products

## "PACE-like" Ocean Color Products

<table>
<thead>
<tr>
<th>Product</th>
<th>Details</th>
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<tbody>
<tr>
<td>Remote sensing reflectance</td>
<td>(360 to 720 nm every 15 or 10 nm @ 5 nm steps)</td>
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<tr>
<td>Spectral diffuse attenuation coefficients</td>
<td></td>
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<tr>
<td>Apparent visible wavelength</td>
<td></td>
</tr>
<tr>
<td>Spectral absorption coefficients ($a_D$, $a_P$, $a_{Ph}$, $a_{cdm}$, $a_g$) and backscattering coefficients</td>
<td>(380 to 680 nm)</td>
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<tr>
<td>CDOM Spectral slope coefficients</td>
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<tr>
<td>Chlorophyll-$a$</td>
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<tr>
<td>Phytoplankton pigments</td>
<td></td>
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<tr>
<td>Phytoplankton community composition</td>
<td></td>
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<tr>
<td>Daily and instantaneous PAR</td>
<td></td>
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<tr>
<td>Fluorescence line height</td>
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<tr>
<td>Euphotic depth</td>
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<tr>
<td>Particulate organic carbon</td>
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<tr>
<td>Dissolved organic carbon</td>
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<tr>
<td>Suspended particulate matter</td>
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<td>Particle size distribution</td>
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## Rates and Flux Products

<table>
<thead>
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<th>Details</th>
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<tr>
<td>Net primary production (NPP)</td>
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<tr>
<td>Net community production of POC</td>
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<tr>
<td>Fluxes of SPM, POC and DOC</td>
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<tr>
<td>Surface Ocean Currents</td>
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## Applied Science Products

<table>
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<tr>
<td>HAB detection index</td>
<td></td>
</tr>
<tr>
<td>Karenia brevis cell count index</td>
<td></td>
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<tr>
<td>Mycrocystis cell count index</td>
<td></td>
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<tr>
<td>Floating algae biomass</td>
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<tr>
<td>Water type classification</td>
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<tr>
<td>Petroleum detection and thickness</td>
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<tr>
<td>Oil density</td>
<td></td>
</tr>
<tr>
<td>Absorbing aerosol index</td>
<td></td>
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</tbody>
</table>
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
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

LSTM (2)
ESA TIR

LIGHT:
VSWIR platform in an AM orbit carrying a wide-swath VSWIR imager.

HEAT:
TIR platform in a PM orbit with a wide-swath thermal imager and a VNIR camera.

TRISHNA (1)
CNES/ISRO TIR

CHIME (2)
ESA VSWIR

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

*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:

<table>
<thead>
<tr>
<th>Calibration and Instrument Performance</th>
<th>Studied baseline needs for various aquatic observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquatic Algorithms</td>
<td>~90 algorithms provided to the SBG Algorithm Working Group</td>
</tr>
<tr>
<td>Coastal Mask</td>
<td>Static command of spatial resolution over the ocean</td>
</tr>
<tr>
<td>Special Observations</td>
<td>Dynamic command of spatial resolution over the ocean</td>
</tr>
<tr>
<td>Glint Mitigation</td>
<td>Examining tilt and algorithmic reduction strategies</td>
</tr>
</tbody>
</table>
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
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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Earth System Observatory

Interconnected Missions

CLOUDS, CONVECTION AND PRECIPITATION

Water and Energy in the Atmosphere

AEROSOLS

Particles in the Atmosphere

MASS CHANGE

Large-scale Mass Redistribution

SURFACE BIOLOGY AND GEOLOGY

Earth Surface & Ecosystems

SURFACE DEFORMATION AND CHANGE

Earth Surface Dynamics

https://science.nasa.gov/earth-science/earth-system-observatory
AOS: One Observing System, Two Synergistic Segments

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
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
AOS: One Observing System, Two Synergistic Segments

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

- 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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Current baseline requirements (thresholds are lower)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral coverage</td>
<td>350 – 2400 nm</td>
</tr>
<tr>
<td>Channel bandwidth</td>
<td>5 nm</td>
</tr>
<tr>
<td>Pixel size at nadir</td>
<td>≤ 300 m</td>
</tr>
<tr>
<td>Swath</td>
<td>≥ 300 km</td>
</tr>
<tr>
<td>Absolute spectral radiometric uncertainty</td>
<td>≤ 3%</td>
</tr>
<tr>
<td>Radiometric stability</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Channel-to-channel radiometric uncertainty</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>SNR, dynamic range, NEdL, NeDT</td>
<td>Similar to MODIS and VIIRS</td>
</tr>
</tbody>
</table>
Polarimeter relevance to ocean remote sensing

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Current baseline requirements (thresholds are lower)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral coverage</td>
<td>Number of bands  View angles</td>
</tr>
<tr>
<td>360 – 390 nm</td>
<td>1  10</td>
</tr>
<tr>
<td>410 – 870 nm</td>
<td>3  10</td>
</tr>
<tr>
<td>670 – 870 nm</td>
<td>1  60</td>
</tr>
<tr>
<td>1000 – 2260 nm</td>
<td>3  10</td>
</tr>
<tr>
<td>Channel bandwidth</td>
<td>TBD</td>
</tr>
<tr>
<td>Pixel size at nadir</td>
<td>≤ 500 m</td>
</tr>
<tr>
<td>Swath</td>
<td>≥ 300 km</td>
</tr>
<tr>
<td>Absolute spectral radiometric uncertainty</td>
<td>≤ 3%</td>
</tr>
<tr>
<td>Radiometric stability</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Degree of linear polarization uncertainty</td>
<td>.005</td>
</tr>
<tr>
<td>Dynamic range</td>
<td>Resolve reflectance ≤ 2x10^4</td>
</tr>
<tr>
<td>SNR</td>
<td>&gt; 300 for reflectance = 0.1</td>
</tr>
</tbody>
</table>
Why should you care about polarimetry?

- 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
  - 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

- 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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Current baseline requirements (thresholds are lower)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Backscatter Lidar</strong></td>
<td>Inclined orbit</td>
</tr>
<tr>
<td>Wavelength</td>
<td>532 nm</td>
</tr>
<tr>
<td>Polarization sensitive</td>
<td>yes</td>
</tr>
<tr>
<td>Vertical resolution</td>
<td>30 m</td>
</tr>
<tr>
<td>Dynamic range</td>
<td>May saturate on ocean surface reflection</td>
</tr>
<tr>
<td><strong>High-Spectral-Resolution Lidar</strong></td>
<td>Polar Orbit</td>
</tr>
<tr>
<td>Wavelength</td>
<td>532 nm</td>
</tr>
<tr>
<td>Polarization sensitive</td>
<td>yes</td>
</tr>
<tr>
<td>Vertical resolution</td>
<td>1 m</td>
</tr>
<tr>
<td>Dynamic range</td>
<td>Unlimited for ocean surface and subsurface</td>
</tr>
</tbody>
</table>
Why should you care about lidar?

- 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)

- **Polarimeter papers**

- **Lidar papers**

- **Lidar + Polarimeter papers**
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!