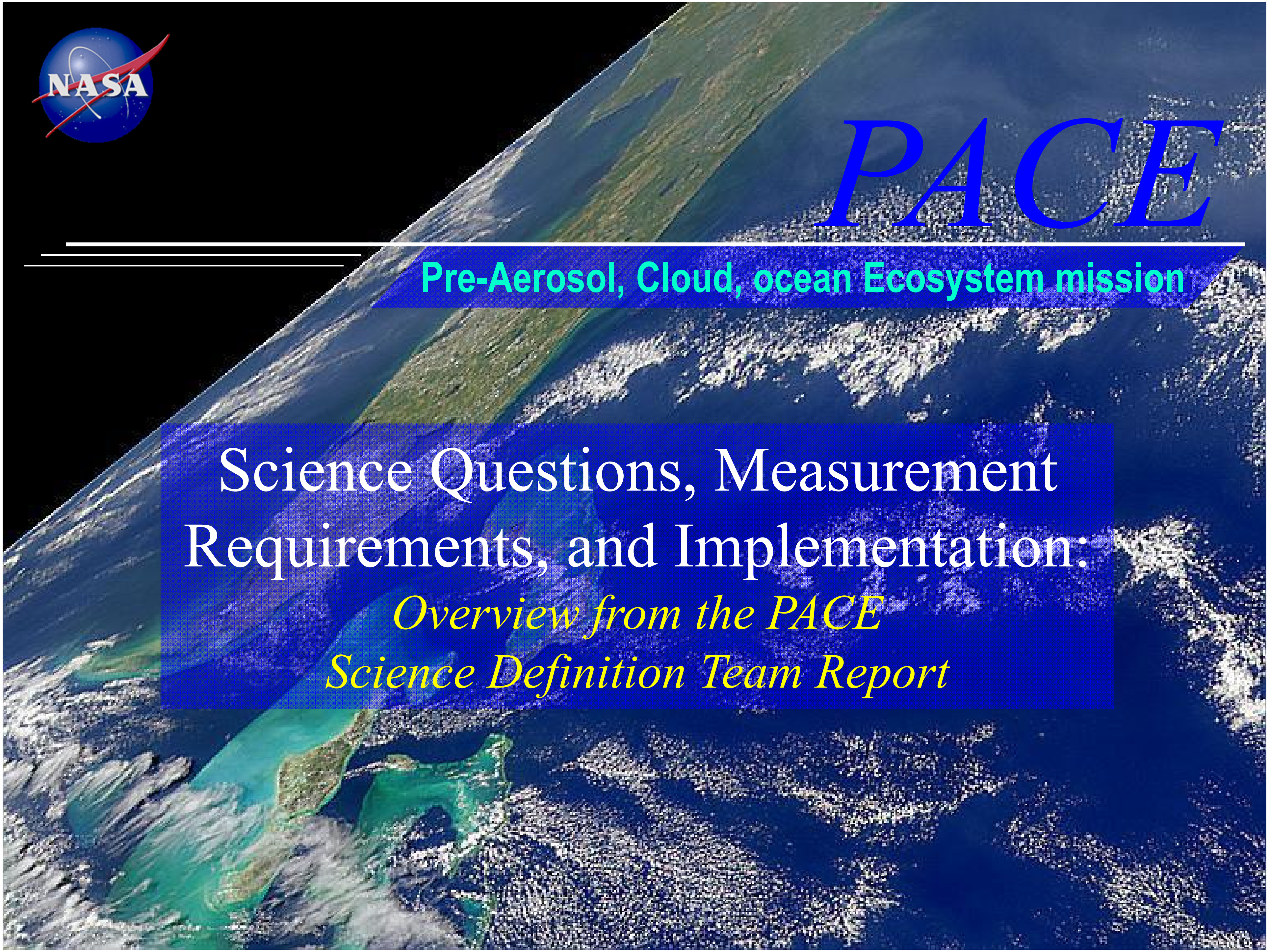

PACE

Pre-Aerosol, Cloud, ocean Ecosystem mission

Science Questions, Measurement Requirements, and Implementation:

Overview from the PACE Science Definition Team Report

PaCE

Pelagic and Coastal Ecosystems mission

Science Questions, Measurement Requirements, and Implementation:

Overview from the PACE Science Definition Team Report

Disclaimer: The material presented here does not represent any official view of NASA or PACE mission management regarding the goals or approaches of the PACE mission. This material summarizes recommendations from the PACE Science Definition Team (SDT). Some, all, or none of these recommendations may be adopted by NASA for developing the official scope and objectives of the PACE mission and for preparing an Announcement of Opportunity (AO). All of the material presented here is described in detail (~250 pages) in the publically-available SDT report, which is open for comment during the month of August.

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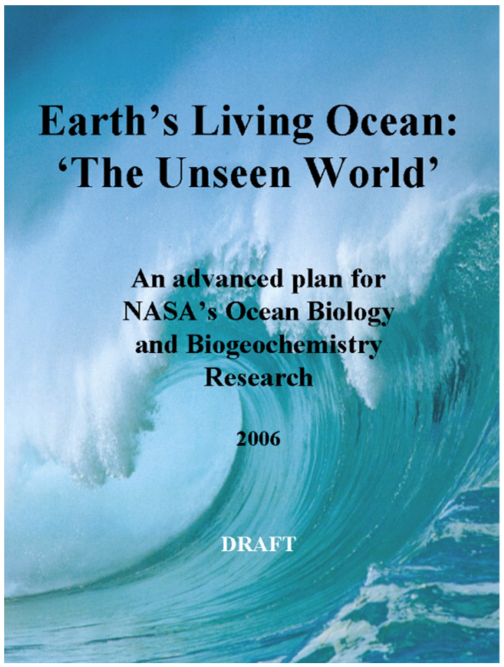
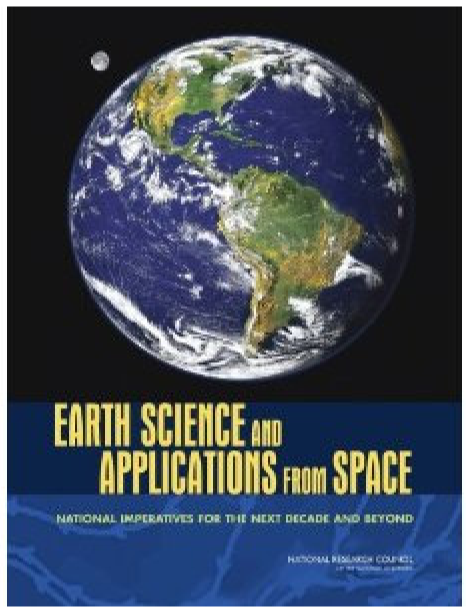
NASA Ocean Biology & Biogeochemistry Advanced Plan



ACE Ocean Science Team



Lots of 'lessons learned' from heritage sensors/missions

Overarching Science Questions

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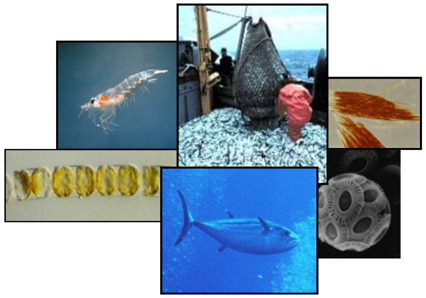
Pelagic and Coastal Ecosystems mission



- What are the standing stocks, compositions, and productivity of ocean ecosystems? How and why are they changing?

- How and why are ocean biogeochemical cycles changing? How do they influence the Earth system?

- What are the material exchanges between land and ocean? How do they influence coastal ecosystems and biogeochemistry? How are they changing?

- How do aerosols influence ocean ecosystems and biogeochemical cycles? How do ocean biological and photochemical processes affect the atmosphere?

- How do physical ocean processes affect ocean ecosystems and biogeochemistry? How do ocean biological processes influence ocean physics?

- What is the distribution of both harmful and beneficial algal blooms and how is their appearance and demise related to environmental forcings? How are these events changing?

- How do changes in critical ocean ecosystem services affect human health and welfare? How do human activities affect ocean ecosystems and the services they provide? What science-based management strategies need to be implemented to sustain our health and well-being?

Approach

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Pelagic and Coastal Ecosystems mission

SQ-1 Ocean Ecosystems:
- Quantify phytoplankton biomass, pigments, and optical properties
- Assess key phytoplankton groups (e.g., calcifiers, nitrogen fixers, carbon export)
- Estimate particle size distribution and productivity using bio-optical modeling, chlorophyll fluorescence, and ancillary data on ocean physical properties (e.g., SST, MLD, etc.)
- Validate retrievals from pelagic to near-shore environments

SQ-2 Ocean Biogeochemical Cycles:
- Quantify phytoplankton biomass, functional groups, POC, PIC, DOC, PSD and productivity
- Validate retrievals from pelagic to near-shore environments.
- Assimilate observations in biogeochemical models to assess key properties (e.g., air-sea CO_2 flux, export)

SQ-3 Land-Ocean Interactions:
- Quantify concentrations and physical/optical properties of particles & dissolved material
- Validate retrievals from coastal to estuarine environments.
- Compare observables with ground-based and model-based land-ocean exchange in the coastal zone, physical properties (e.g., winds, SST, SSH, etc), and circulation.

SQ-4 Atmosphere-Ocean Interactions:
- Quantify ocean photobiochemical and photobiological processes and atmospheric aerosols
- Combine ocean and atmosphere observables with models and other remotely retrieved fields (e.g. temperature and wind speed) to evaluate (1) air-sea exchange of particulates, dissolved materials, and gases and (2) impacts on aerosol , cloud, and biological properties
- Validate retrievals from pelagic to near-shore environments

Approach (cont.)

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SQ-5 ***Bio-physical Interactions***:

- Compare observed ecosystem properties with measured physical ocean properties (e.g., winds, SST, SSH, OOI assets) and model-derived physical fields (e.g., ML dynamics, horizontal divergence)
- Estimate ocean radiant heating and assess feedbacks
- Validate from pelagic to near-shore environments

SQ-6 ***Algal Blooms and Consequences***:

- Measure biomass, pigments, and abundance of key phytoplankton groups, including harmful algae
- Quantify bloom magnitudes, durations, and distributions
- Assess inter-seasonal and inter-annual variations
- Compare variability to changing environmental/physical properties
- Validate retrievals from pelagic to near-shore environments

***SQ-7: Human Dimensions*:**

- Establish close linkages between science, operational, and resource management communities early in the planning phases of PACE and maintain feedbacks throughout mission life.
- Engage management and operational communities fully in science planning efforts
- Estimate the social and economic impacts of ocean ecology, including biodiversity, biogeochemical processes, and biological and chemical stocks and fluxes
- Understand the applications of PACE products for water quality assessments and pollution identification.
- Implement strong education and capacity building programs addressing national & international needs.

Targeted Ocean Retrievals

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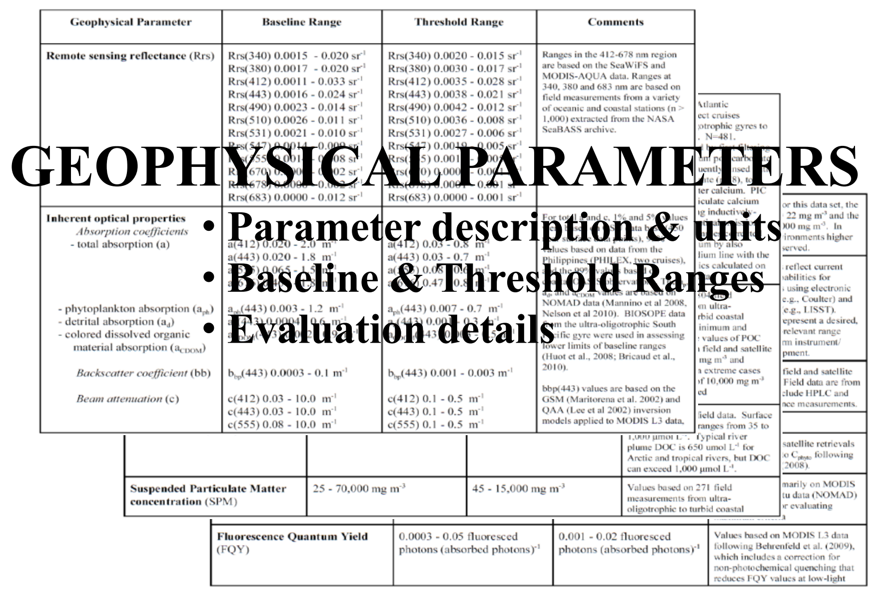
- Normalized water-leaving radiances
- Chlorophyll-a
- Diffuse attenuation coefficient (490 nm)

- Inherent optical properties
- Spectral K_d
- Euphotic depth
- Spectral remote sensing reflectance
- Particulate organic carbon concentration
- Primary production
- Calcite concentration
- Colored dissolved organic matter
- Photosynthetically available radiation
- Fluorescence line height
- Total suspended matter
- Trichodesmium concentration
- Particle size distributions & composition
- Phytoplankton carbon
- Dissolved organic matter/carbon
- Physiological properties
- Phytoplankton pigment absorption spectra
- Export production
- Functional/Taxonomic groups



Targeted Ocean Retrievals

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Measurement Class	Geophysical Parameters
Core Optical Variables	
radiometric quantities	$L_u(z,\lambda)$, $L_i(\lambda)$, $L_{sky}(\lambda)$, $E_d(z, \lambda)$, $E_s(\lambda)$, PAR(z)
apparent optical properties (AOPs)	$K_d(\lambda)$, K_{PAR}, Z_{eu}
inherent optical properties (IOPs)	$a(z,\lambda)$, $a_p(z,\lambda)$, $a_{ph}(z, \lambda)$, $a_d(z, \lambda)$, $a_{CDOM}(z, \lambda)$, $b_b(z, \lambda)$, $c(z, \lambda)$
Biogeochemical State Variables & Processes (Secondary Variables)	
phytoplankton pigment concentrations	Chl, accessory pigments, carotenoids, etc.
phytoplankton characteristics	C_{phyto}, taxonomic/functional groups, chlorophyll fluorescence
particle population characteristics	SPM, POC, PIC, PSDs, $\beta(z, \lambda)$
photobiochemical characteristics	DOC, CDOM fluorescence, MAAs, phycobili proteins
production	NPP, NCP, nutrients
Synthesis & Modeling Variables (Tertiary Variables)	
Fluxes & ecosystems	C export, air-sea CO_2 exchange, land-ocean material exchange

Measurement Requirements

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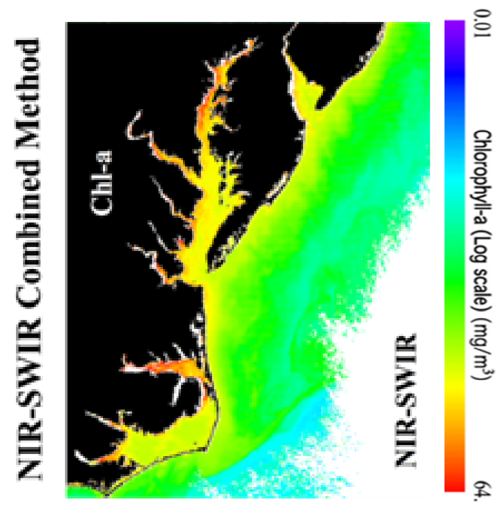
- ATMOSPHERIC CORRECTIONS
  - Spectral anchoring with UV band (~350 nm)
  - Open ocean bands in NIR [748 (10 nm bw), 820 (15 nm), 865 (40 nm)]
  - Turbid water SWIR [1230 (20 nm), 1640 (40 nm), 2130 (50 nm)]

  - This is one of the important areas of overlap between PACE aerosol and ocean science communities



Wang, M. and W. Shi (2007) *Optics Express,* **15**, 15722-15733.

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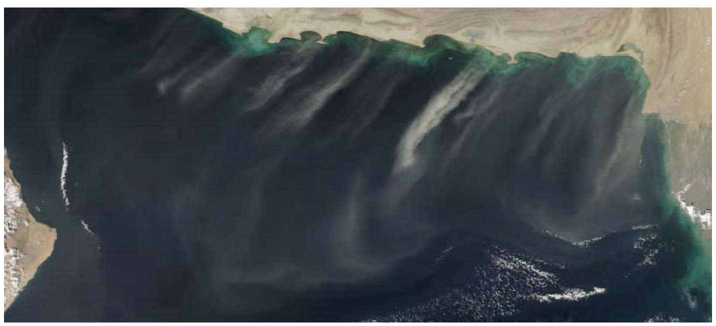

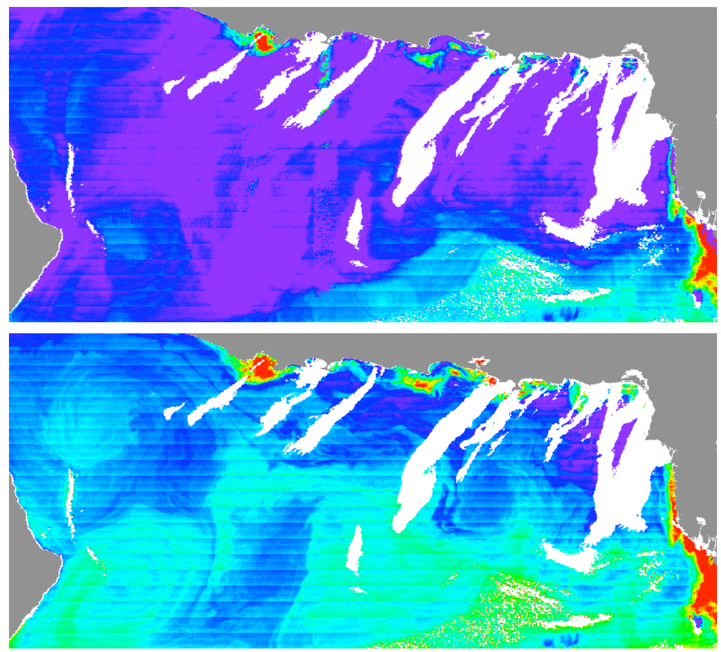

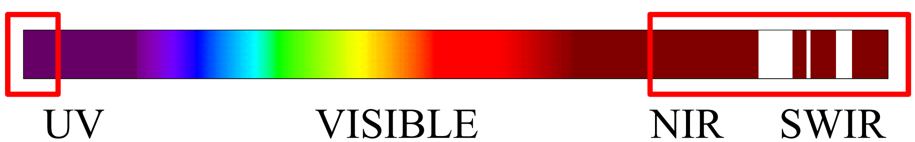

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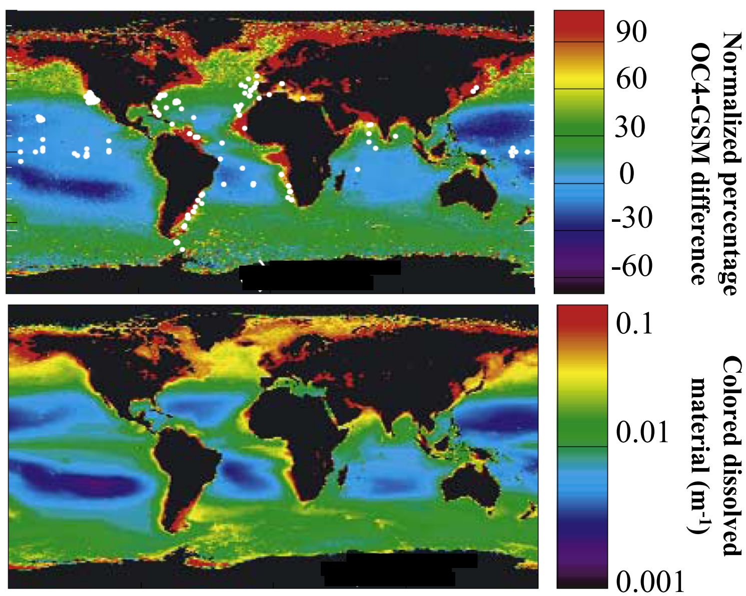
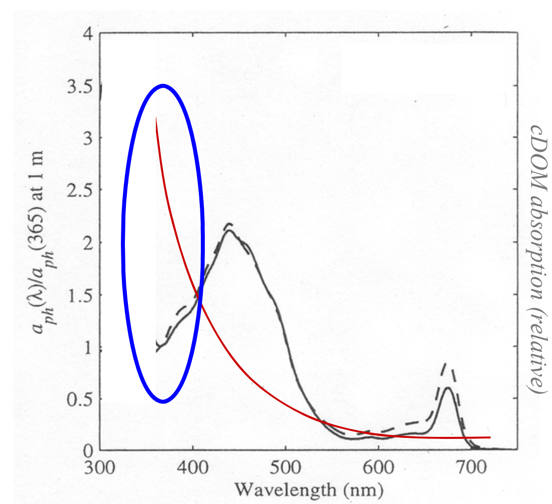
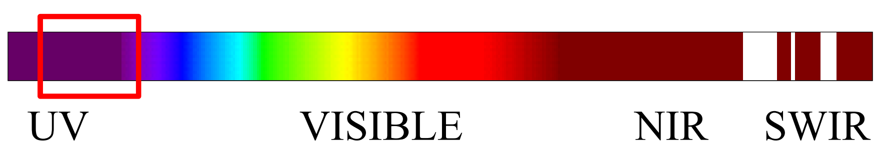
Measurement Requirements

- ATMOSPHERIC CORRECTIONS
- CDOM / SEPARATION FROM PIGMENT ABSORPTION
  - Current uncertainty impacts NPP assessment by 16 Gt y^{-1} (total ~50 Gt y^{-1})
  - Near UV bands [360 (15 nm),380 (15 nm)]







Siegel et al., GEOPHYSICAL RESEARCH LETTERS, VOL. 32, L20605, doi:10.1029/2005GL024310, 2005

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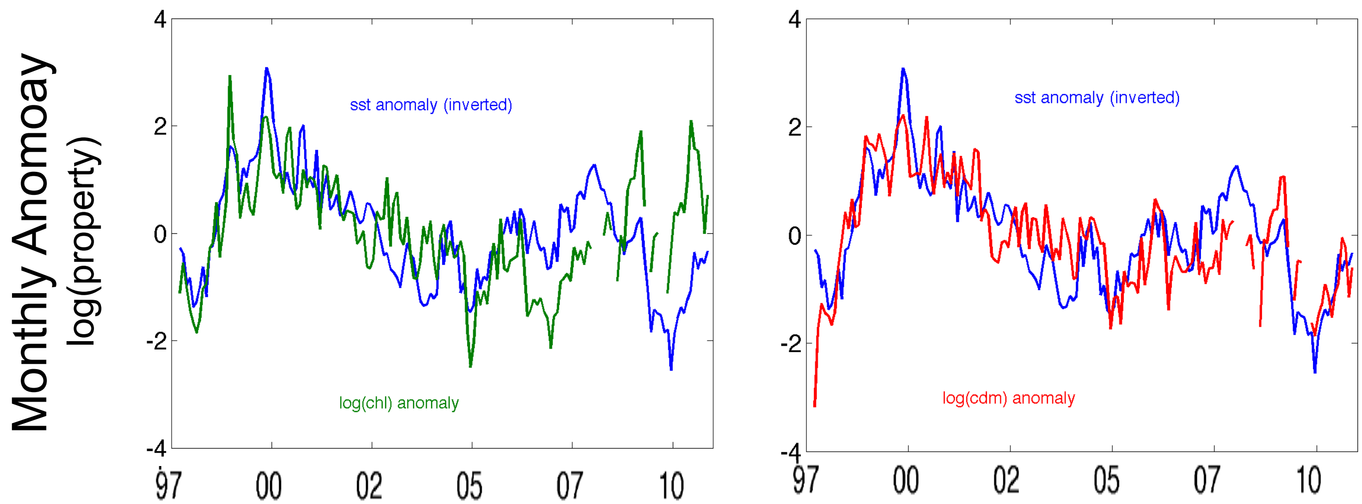

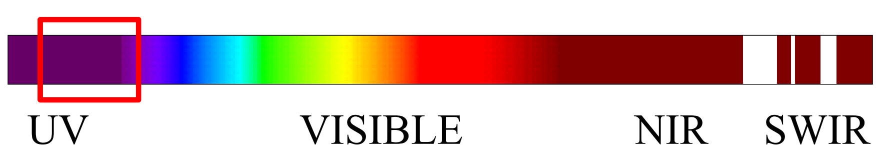

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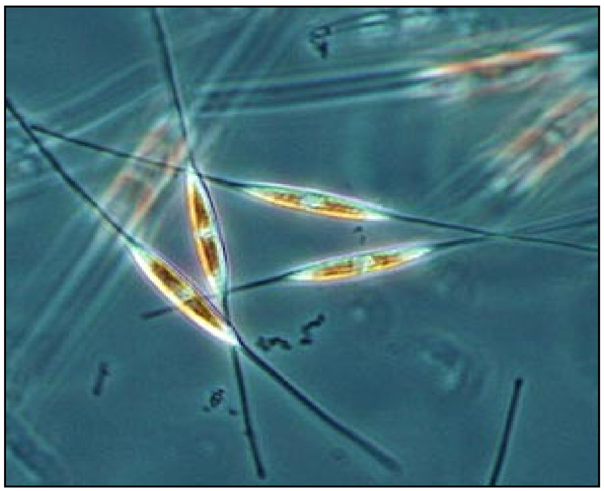
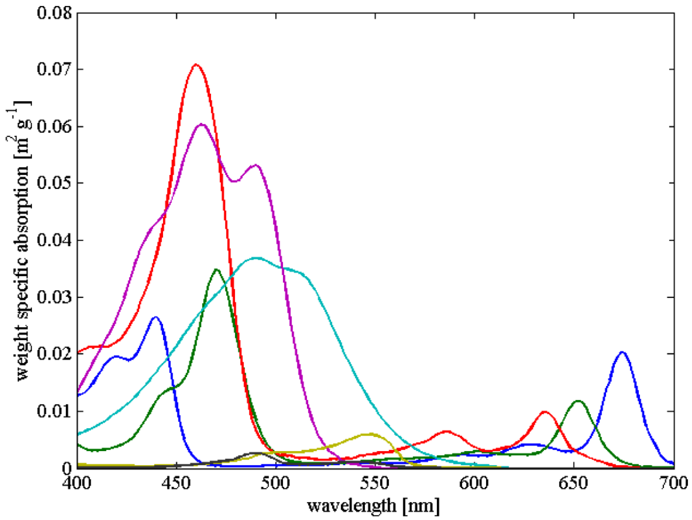
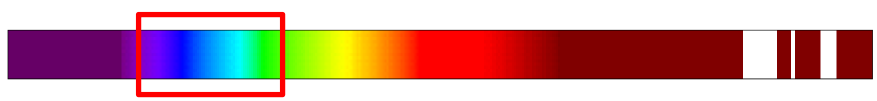
Measurement Requirements

PaCE
Pelagic and Coastal Ecosystems mission

- ATMOSPHERIC CORRECTIONS
- CDOM-PIGMENT SEPARATION
- PHYTOPLANKTON ABSORPTION SPECTRA
    - Productivity keyed to total pigment absorption, not simply chlorophyll concentration
    - Assess both the amplitude and breadth of absorption spectra
    - 15 nm resolution in blue-green region







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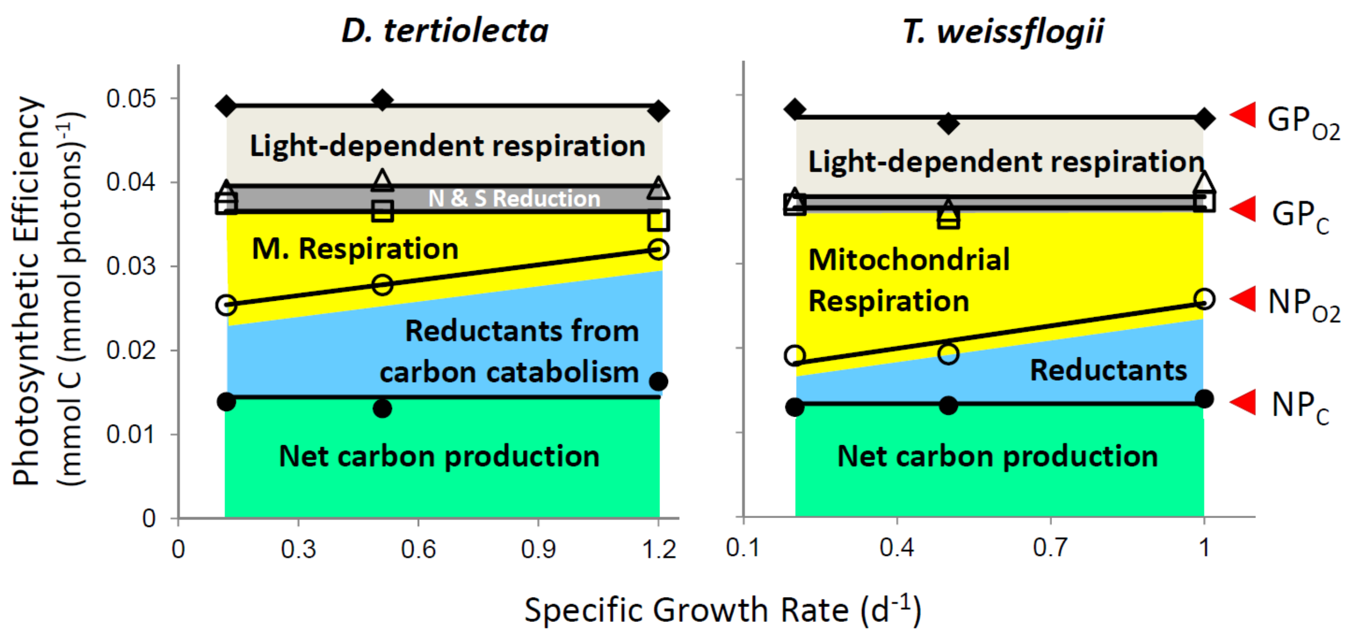

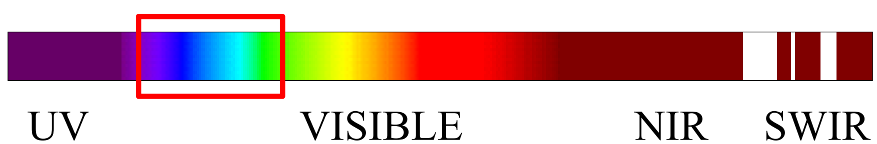

Measurement Requirements

PaCE
Pelagic and Coastal Ecosystems mission

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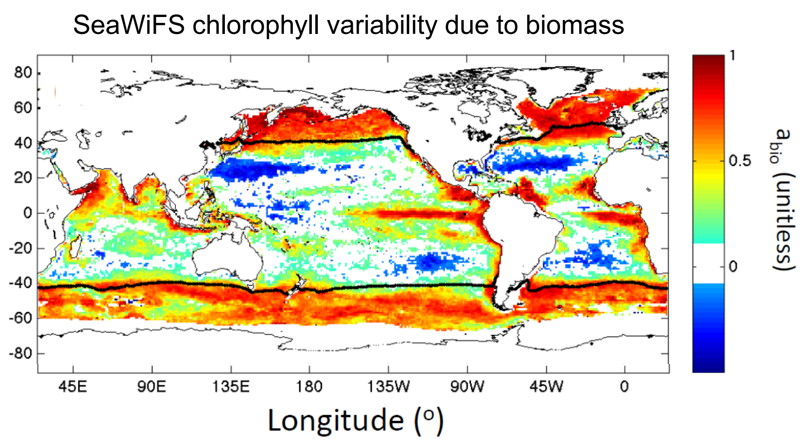
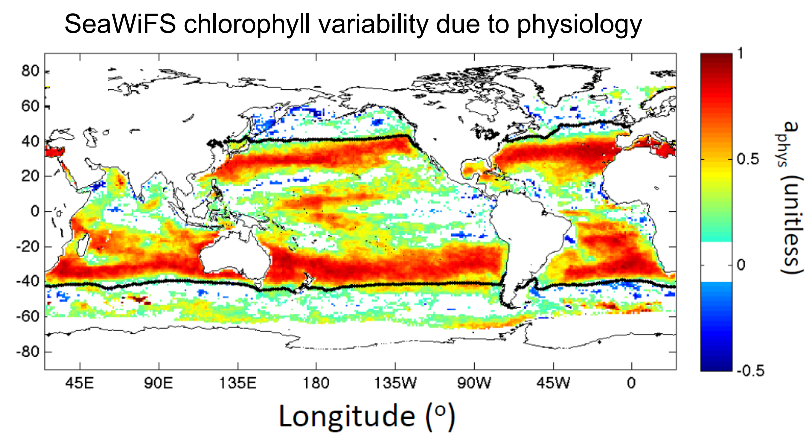
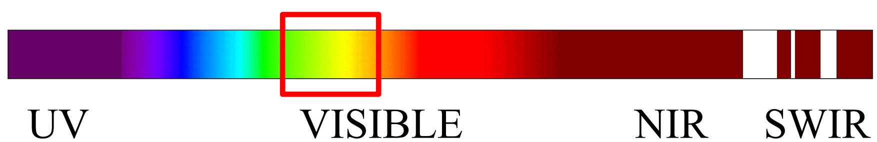
- PHYTOPLANKTON CARBON; TOTAL PARTICULATE CARBON
  - Chlorophyll is not biomass
  - Carbon stocks related to particulate scattering coefficients ***and*** spectral slope
  - 15 nm bands in the region of minimum pigment absorption







Siegel et al., *in review*

Measurement Requirements

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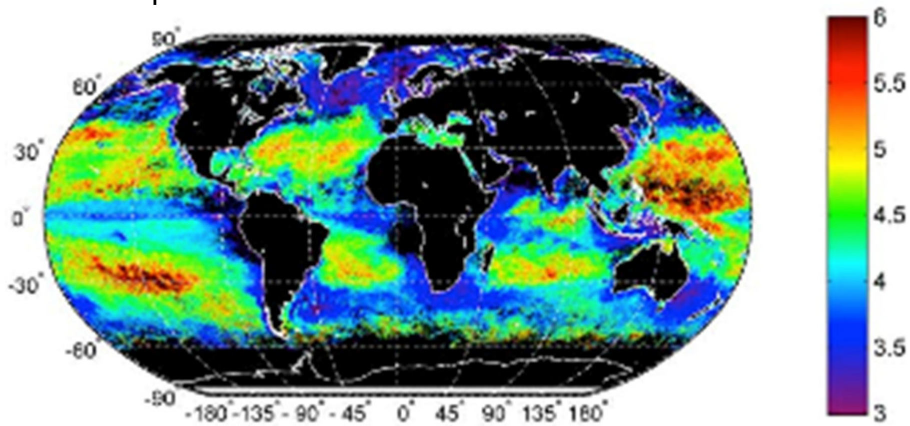
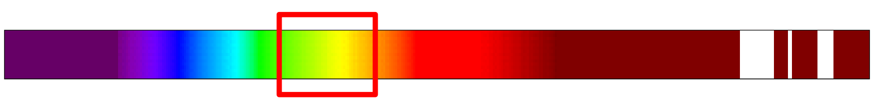
Slope of the Particle Size Distribution





Kostadinov et al., 2009

Measurement Requirements

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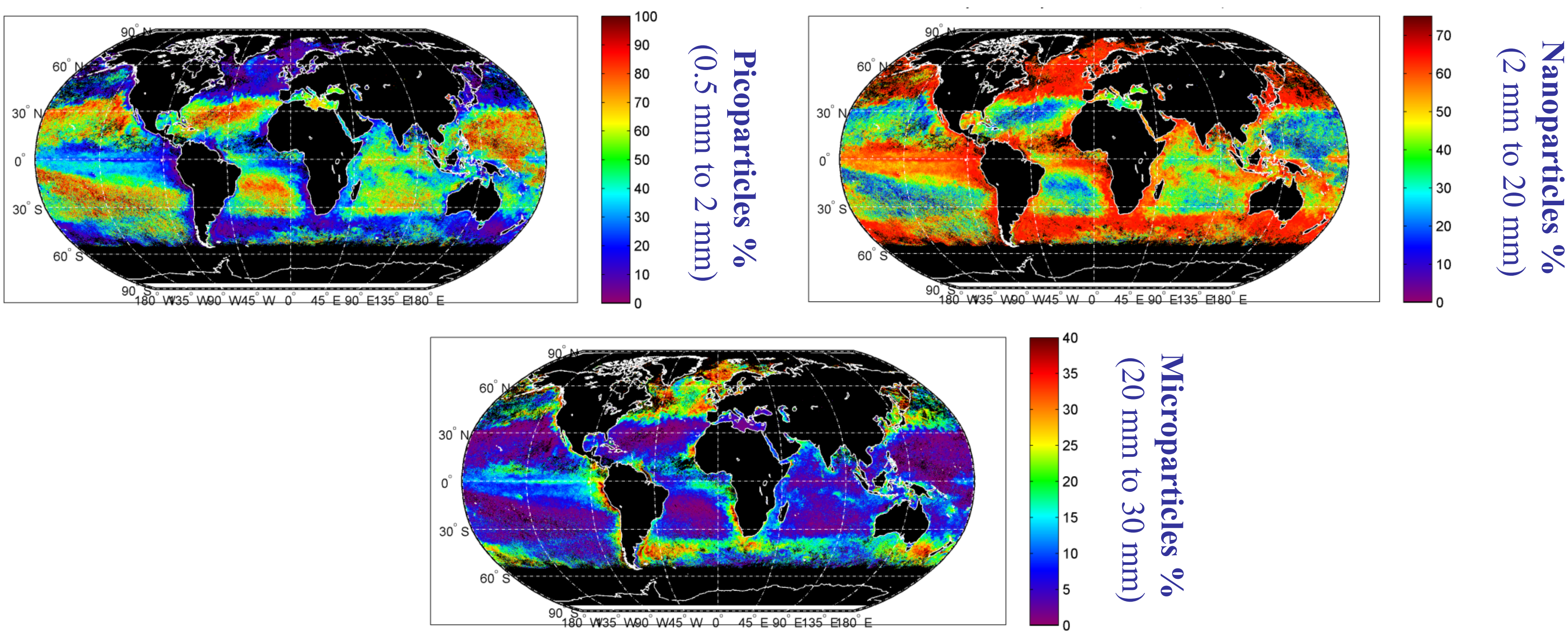

Tihomir Kostadinov *et al*

Measurement Requirements

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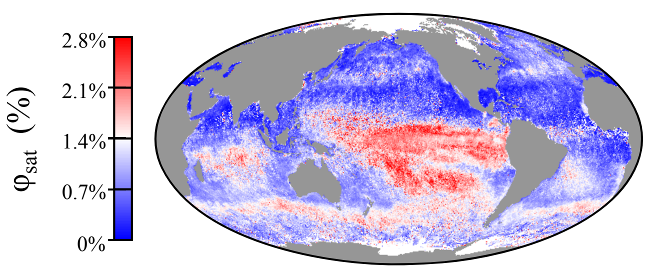
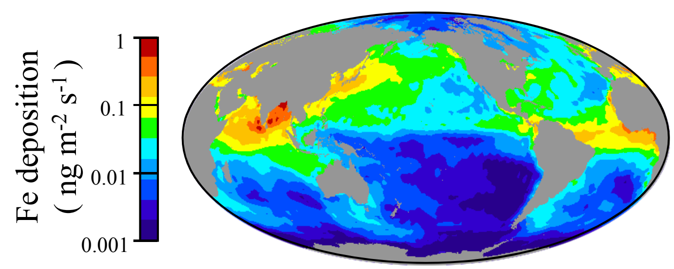
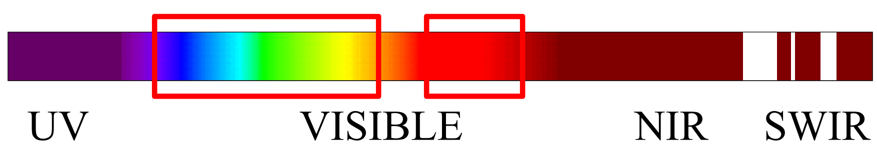
- PHYTOPLANKTON/TOTAL PARTICULATE CARBON
- PHYTOPLANKTON PHYSIOLOGY
    - How do we interpret observed chlorophyll trends?
    - How do we account for unique nutrient effects?
    - What are the ecological responses to atmospheric nutrient deposition?
    - Ratio of pigment absorption to phytoplankton carbon - general light and nutrient effects
    - Chlorophyll fluorescence quantum yield [665 (10 nm), 678 (10 nm), 710 (15 nm)] – detection of iron-stressed populations







Behrenfeld et al. *Biogeosciences* 6, 779-794, 2009.

Measurement Requirements

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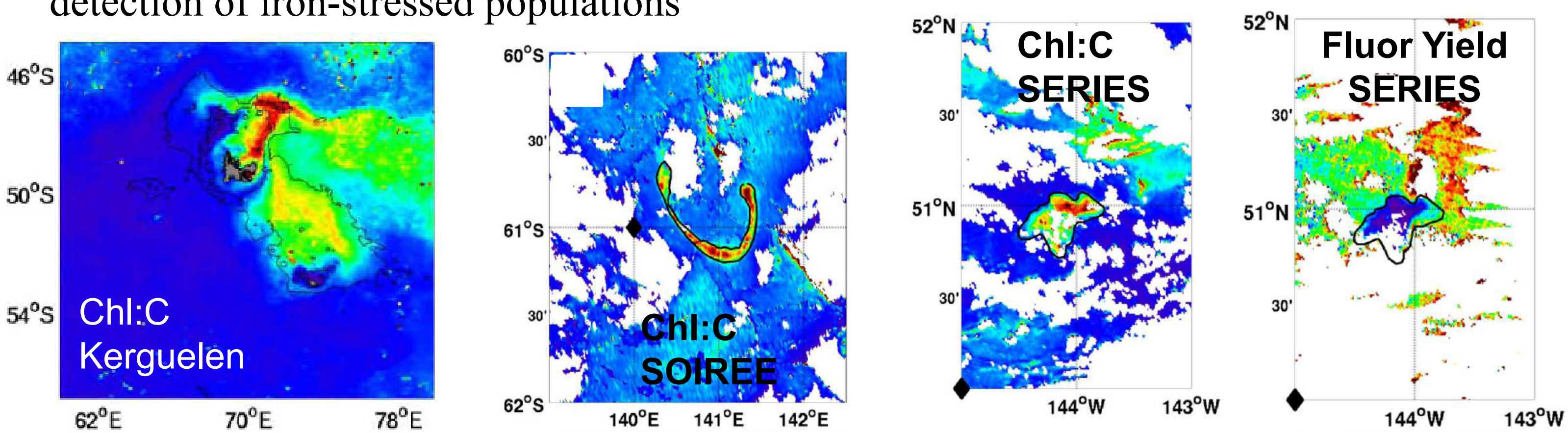

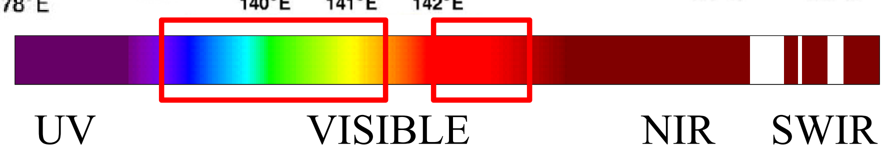

Westberry et al. 2012

Measurement Requirements

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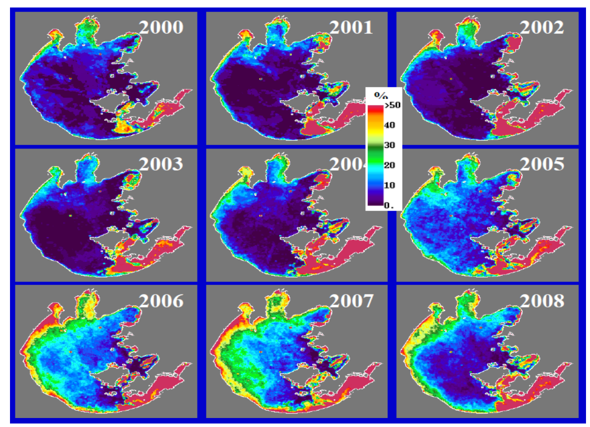
- EUTROPHIC WATERS / HARMFUL ALGAL SPECIES
    - How are bloom events changing? Duration, extent, timing, composition?
    -‘Red-edge’ algorithms for pigment stocks (red-NIR band differences)
    - Near-UV and/or 710 nm band for HABs



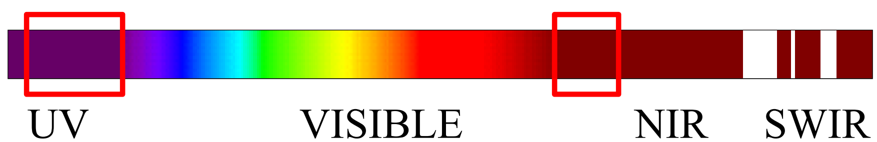


Image & data from Chuanmin Hu, Univ. South Florida

Measurement Requirements

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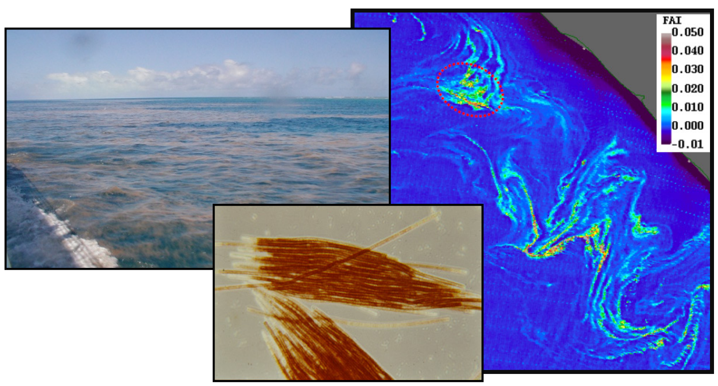
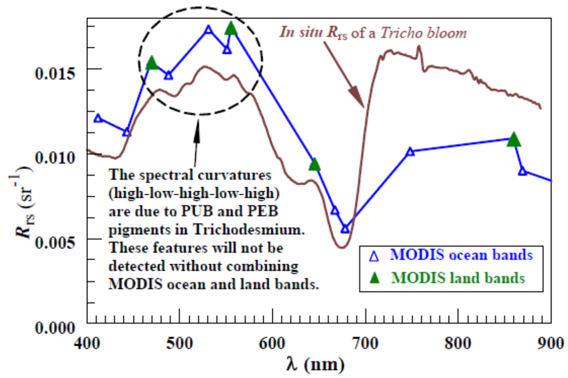
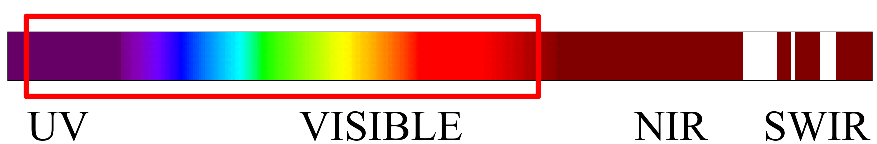
  - How is it changing? What detail can we derive from space?
  - ‘Multi-band’ approaches for targeted organism
  - ‘Hyperspectral’ (5 nm) derivative analysis for multiple broad groups







Measurement Requirements

PaCE
Pelagic and Coastal Ecosystems mission

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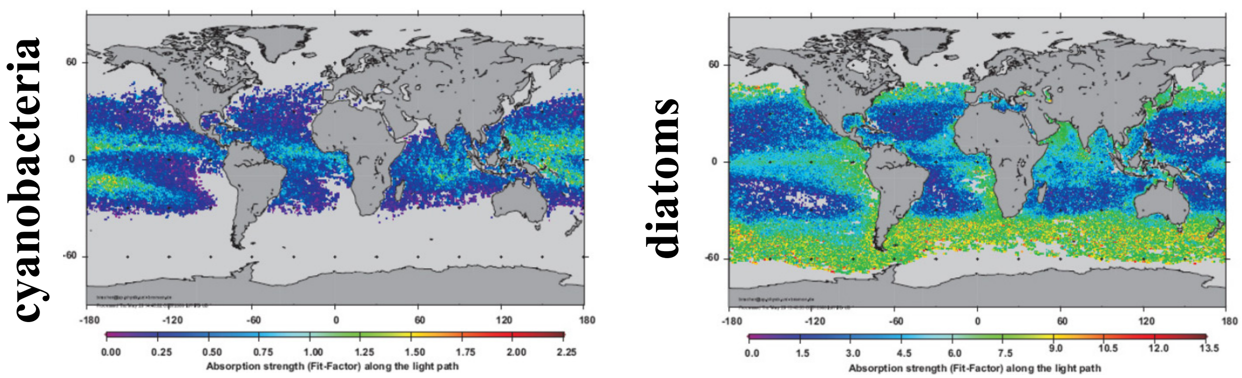

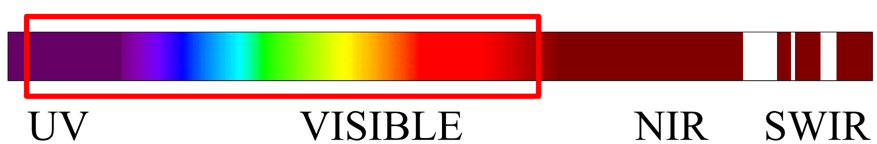

Measurement Requirements

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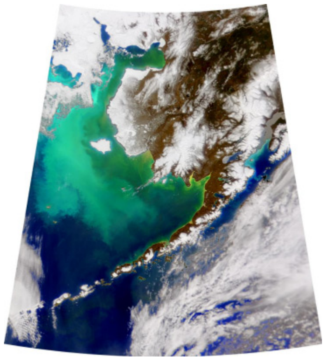

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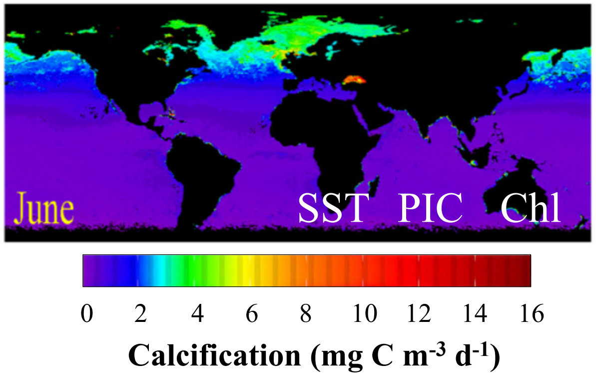
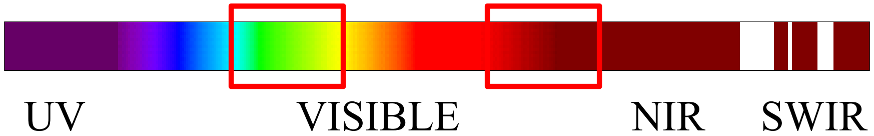
- PHYTOPLANKTON FUNCTIONAL GROUPS
- PARTICULATE INORGANIC CARBON
    - Calcifying organisms play a key role in carbon export and surface carbon chemistry
    - Complication of POC from backscattering coefficients
    - Green, Red, NIR bands for open ocean and coastal waters

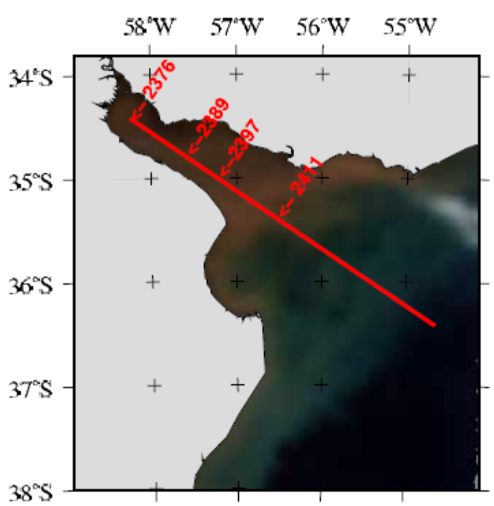




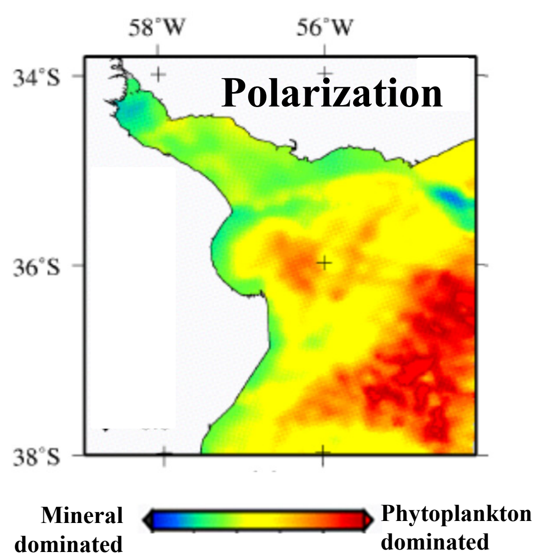
Measurement Requirements

PaCE
Pelagic and Coastal Ecosystems mission

- ATMOSPHERIC CORRECTIONS
- CDOM-PIGMENT SEPARATION
- PHYTOPLANKTON ABSORPTION SPECTRA
- PHYTOPLANKTON/TOTAL PARTICULATE CARBON
- PHYTOPLANKTON PHYSIOLOGY
- EUTROPHIC WATERS / HARMFUL ALGAL SPECIES
- PHYTOPLANKTON FUNCTIONAL GROUPS
- PARTICULATE INORGANIC CARBON
- LAND-OCEAN MATERIAL EXCHANGE
  - Distinguishing mineral and biotic particles through polarization properties



Rio de la Plata



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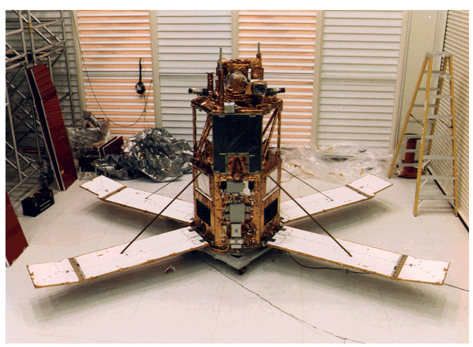
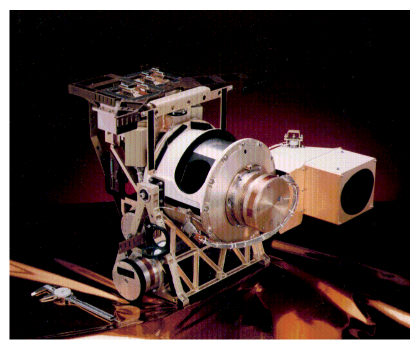
- PARTICULATE INORGANIC CARBON
- LAND-OCEAN MATERIAL EXCHANGE
- HERITAGE OCEAN COLOR BANDS
    - Flexible reconstruction: 412, 443, 490, 510, 532, 555, 665, 678, 710, 765, 865 nm





Threshold Requirements

PaCE
Pelagic and Coastal Ecosystems mission

PACE multispectral band specifications. SNR-spec is the minimum value at L_{typ}. Radiances are in mW/cm^2 str.

High spectral resolution range (5 nm)

'aggregate band' list

λ	Band Width (nm)	Spatial Resol. (km^2)	L_{typ}	L_{max}	SNR-Spec
350	15	1	7.46	35.6	300
360	15	1	7.22	37.6	1000
385	15	1	6.11	38.1	1000
412	15	1	7.86	60.2	1000
425	15	1	6.95	58.5	1000
443	15	1	7.02	66.4	1000
460	15	1	6.83	72.4	1000
475	15	1	6.19	72.2	1000
490	15	1	5.31	68.6	1000
510	15	1	4.58	66.3	1000
532	15	1	3.92	65.1	1000
555	15	1	3.39	64.3	1000
583	15	1	2.81	62.4	1000
617	15	1	2.19	58.2	1000
640	10	1	1.90	56.4	1000
655	15	1	1.67	53.5	1000
665	10	1	1.60	53.6	1000
678	10	4	1.45	51.9	2000
710	15	1	1.19	48.9	1000
748	10	1	0.93	44.7	600
820	15	1	0.59	39.3	600
865	40	1	0.45	33.3	600
1245	20	1	0.088	15.8	250
1640	40	1	0.029	8.2	180
2135	50	1	0.008	2.2	15

L_{typ} = typical top-of-atmosphere clear sky ocean radiances

Threshold Requirements

PaCE
Pelagic and Coastal Ecosystems mission

Orbit	• sun-synchronous polar orbit • equatorial crossing time between 11:00 and 1:00 • orbit maintenance to ±10 minutes over mission lifetime
Global Coverage	• 2-day global coverage to solar zenith angle of 75^o • mitigation of sun glint • multiple daily observations at high latitudes • view zenith angles not exceeding ±60^o • mission lifetime of 5 years
Navigation and Registration	•pointing accuracy of 2 IFOV and knowledge equivalent to 0.1 IFOV over the full range of viewing geometries (e.g., scan and tilt angles) • pointing jitter of 0.01 IFOV between adjacent scans or image rows • spatial band-to-band registration of 80% of one IFOV between any two bands, without resampling • simultaneity of 0.02 second • characterization of all detectors and optical components through monthly lunar observations through Earth-viewing port
Instrument Performance Tracking	• characterization of instrument performance changes to ±0.2% within the first 3 years and maintenance of this accuracy thereafter for the duration of the mission • monthly characterization of instrument spectral drift to an accuracy of 0.3 nm • daily measurement of dark current and observations of a calibration target/source, with knowledge of daily calibration source degradation to ~0.2%
Instrument Artifacts	• Prelaunch characterization of linearity, RVVA, polarization sensitivity, radiometric and spectral temperature sensitivity, high contrast resolution, saturation, saturation recovery, crosstalk, radiometric and band-to-band stability, bidirectional reflectance distribution, and relative spectral response • overall instrument artifact contribution to TOA radiance of <0.5% • characterization & correction for image striping to noise levels or below • crosstalk contribution to radiance uncertainties 0.1% at L_{typ} • polarization sensitivity of ≤1% and knowledge of polarization sensitivity to ≤ 0.2% • no detector saturation for any science measurement bands at L_{max} • RVVA of <5% for the entire view angle range and by <0.5% for view angles that differ by less than 1^o • Stray light contamination < 0.2% of L_{typ} 3 pixels away from a cloud • out-of-band contamination of <0.01 for all multispectral channels • radiance-to-counts relationship characterized to 0.1% over full dynamic range (L_{typ} to L_{max})

Threshold Requirements

PaCE
Pelagic and Coastal Ecosystems mission

Spatial Resolution	• Global spatial coverage of 1 km x 1 km (±0.1 km) along-track
Atmospheric Corrections	• retrieval of $[r_w(l)]_N$ for open-ocean, clear-water conditions and standard marine atmospheres with an accuracy of the maximum of either 5% or 0.001 over the wavelength range 400 – 710 nm • two NIR atmospheric correction bands comparable to heritage, one of which is centered at 865 nm • NUV band centered near 350 • SWIR bands centered at 1240, 1640, and 2130 nm
Science Spectral Bands	• 5 nm spectral resolution from 355 to 800 nm • complete ground station downlink and archival of 5 nm data.
Signal-to-noise	• SNR at L_{typ} of 1000 from 360 to 710 nm; 300 @ 350 nm; 600 @ NIR bands; 250, 180, and 15 @ 1240, 1640, & 2130 nm
Data Reprocessing	• full reprocessing capability of all PACE data at a minimum frequency of 1 – 2 times annually.

PACE Threshold-mission Ocean Science Traceability Matrix (STM)

Science Questions

1 What are the standing stocks, compositions, and productivity of ocean ecosystems? How and why are they changing?

2 How and why are ocean biogeochemical cycles changing? How do they influence the Earth system?

3 What are the material exchanges between land & ocean? How do they influence coastal ecosystems and biogeochemistry? How are they changing?

4 How do aerosols influence ocean ecosystems & biogeochemical cycles? How do ocean biological & photochemical processes affect the atmosphere?

5 How do physical ocean processes affect ocean ecosystems & biogeochemistry? How do ocean biological processes influence ocean physics?

6 What is the distribution of both harmful and beneficial algal blooms and how is their appearance and demise related to environmental forcings? How are these events changing?

7 How do changes in critical ocean ecosystem services affect human health and welfare? How do human activities affect ocean ecosystems and the services they provide? What science-based management strategies need to be implemented to sustain our health and well-being?

Approach

Approach	Maps to Science Question
Quantify phytoplankton biomass, pigments, optical properties, key groups (functional/HABS), & estimate productivity using bio-optical models, chlorophyll fluorescence, & ancillary physical properties (e.g., SST, MLD)	1 4 2 5 3 6
Measure particulate &dissolved carbon pools, their characteristics & optical properties	2 3
Quantify ocea & photobiolog	
Estimate parti distribution (P	
Assimilate PA biogeoche key properties carbon export	
Compare PAC and model dat land-ocean ex (e.g., winds, SST, SSH), and circulation (ML dynamics, horizontal divergence, etc)	5 6
Combine PACE ocean & atmosphere observations with models to evaluate ecosystem-atmosphere interactions	4
Assess ocean radiant heating and feedbacks	5
Conduct field sea-truth measurements & modeling to validate retrievals from the pelagic to near-shore environments	1 4 2 5 3 6
Link science, operational, & resource management communities. Communicate social, economic, & management impacts of PACE science. Implement strong education & capacity building programs.	7

Seven Focused Ocean Science Questions

Measurement Requirements

- water leaving radiance at 5 nm resolution from 355 to 800 nm
- 10 to 40 nm wide atmospheric correction bands at 350, 865, 1240, 1640, & 2130 nm, plus one additional NIR band
- characterization of instrument performance changes to ±0.2% in first 3 years & for remaining duration of the mission
- monthly characterization of instrument spectral drift to 0.3 nm accuracy
- daily measurement of dark current & a calibration target/source with its degradation known to ~0.2%
- Prelaunch characterization of linearity, RVVA, polarization sensitivity, radiometric & spectral temperature sensitivity, high contrast resolution, saturation, saturation recovery, crosstalk, radiometric & band-to-band
- istribution, & relative spectral response
- tion to TOA radiance of < 0.5%
- nage striping to noise levels or below
- ncertainties of 0.1% at L_{typ}
- ty to ≤ 0.2%
- ce measurement bands at L_{max}
- le range & < 0.5% for view angles
- f L_{typ} 3 pixels away from a cloud
- for all multispectral channels
- 0.1% over full dynamic range
- 1 km (±0.1 km) along-track
- latitudes
- ±60°
- Standard marine atmosphere, clear-water $[r_w(l)]_N$ retrieval with accuracy of max[5% , 0.001] over the wavelength range 400 – 710 nm
- SNR at L_{typ} for 1 km² aggregate bands of 1000 from 360 to 710 nm; 300 @ 350 nm; 600 @ NIR bands; 250, 180, and 50 @ 1240, 1640, & 2130 nm

Implementation Requirements

Vicarious Calibration: Ground-based R_{rs} data for evaluating post-launch instrument gains. Features: (1) Spectral range = 350 - 900 nm at ≤ 3 nm resolution, (2) Spectral accuracies ≤ 5%, (3) Spectral stability ≤ 1%, (4) Deploy = 1 yr prelaunch through mission lifetime, (5) Gain standard errors to ≤ 0.2% in 1 yr post-launch, (6) Maintenance & deploy centrally organized, & (7) Routine field campaigns to verify data quality & evaluate uncertainties ***Product Validation***: Field radiometric & biogeochemical data over broad possible dynamic range to evaluate PACE science products. Features: (1) Competed & revolving Ocean Science Teams, (2) PACE-supported field campaigns (2 per year), (3) Permanent/public archive with all supporting data

Ocean Biogeochemistry-Ecosystem Modeling

- Expand model capabilities by assimilating expanded PACE retrieved properties, such as NPP, IOPs, & phytoplankton groups & PSD's
- Extend PACE science to key fluxes: e.g., export, CO_2, land-ocean exchange

Platform Requir'ts

2-day global coverage to solar zenith angle of 75°

Sun-synchronous polar orbit with equatorial crossing time between 11:00 and 1:00

Maintain orbit to ±10 minutes over mission lifetime

Mitigation of sun glint

Mission lifetime of 5 years

Storage and download of full spectral and spatial data

Monthly lunar observations at constant phase angle through Earth observing port

Pointing accuracy of 0.2° over full range of viewing geometries, with knowledge to 0.01°

Pointing jitter of 0.001° between adjacent scans or image rows

Spatial band-to-band registration of 80% of one IFOV between any two bands, without resampling

Simultaneity of 0.02 second

Other Needs

Capability to reprocess full data set 1 – 2 times annually

Ancillary data sets from models missions, or field observations:

Measurement Requirements
(1) Ozone
(2) Water vapor
(3) Surface wind velocity and barometric pressure
(4) NO_2

Science Requirements
(1) SST
(2) SSH
(3) PAR
(4) UV
(5) MLD
(6) CO_2
(7) pH
(8) Ocean circulation
(9) Aerosol deposition
(10) run-off loading in coastal zone

PACE Threshold-mission Ocean Science Traceability Matrix (STM)

Ocean Spectrometer
- UV/Vis high spectral resolution
- Fluorescence capability
- NIR & SWIR bands
- Sensor tilt
- Climate quality data focus

Additional requirements beyond the sensor itself …

Supporting Datasets for Science

Science Questions

1 W… co… oc… wl…

2 Ho… bi… Ho… sy…

3 W… be… th… and biogeochemistry? How are they changing?

4 How do aerosols infl… ecosystems & biogeo… cycles? How do ocea… & photochemical pro… the atmosphere?

5 How do physical ocean processe… affect ocean ecosystems & biogeochemistry? How do ocea… biological processes influence ocean physics?

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Approach (Maps to Science Question)

Approach	Maps to Science Question
Estimate particle abundance, size …	1, 3
… carbon export, pH, etc.)	
Compare PACE observations with field … (e.g., winds, SST, SSH), and circulation (ML dynamics, horizontal divergence, etc)	…, 6
Combine PACE ocean & atmosphere observations with models to evaluate ecosystem-atmosphere interactions	4
Assess ocean radiant heating and feedbacks	5
Conduct field sea-truth measurements & modeling to validate retrievals from the pelagic to near-shore environments	1, 4, 2, 5, 3, 6
Link science, operational, & resource management communities. Communicate social, economic, & management impacts of PACE science. Implement strong education & capacity building programs.	7

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- …ions at high latitudes
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… health and welfare? How do human activities affect ocean …

Approach

Approach	Maps to Science Question
Quantify phytoplankton biomass, pigments, optical properties, key groups (functional/HABS), & estimate productivity using bio-optical models, chlorophyll fluorescence, & ancillary physical properties (e.g., SST, MLD)	1, 4, 2, 5, 3, 6
Measure particulate &dissolved carbon pools, their characteristics & optical properties	2, 3
Quantify ocean photobiochemical & photobiological processes	2, 4
Estimate particle abundance, size distribution (PSD), & characteristics	1, 3
Assimilate PACE observations in ocean biogeochemical model fields to evaluate key properties (e.g., air-sea CO_2 flux, carbon export, pH, etc.)	2, 4
Compare PACE observations with field- and model data of biological properties, land-ocean exchange, physical properties (e.g., winds, SST, SSH), and circulation …	3, 4, 5
… the pelagic to near-shore environments	2, 5, 3, 6
…	7

Field validation and calibration, new measurements, process studies, and algorithm development are central to mission and thus required in flight project budget

Models are essential for achieving PACE science objectives

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- RVVA of < 5% for entire view angle range & < 0.5% for view angles differing by less than 1°
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(7) pH
(8) Ocean circulation
(9) Aerosol deposition
(10) run-off loading in coastal zone

Measurement Goals

PaCE
Pelagic and Coastal Ecosystems mission

Accuracy: Retrieval of normalized $[r_w(l)]_N$ for open-ocean, clear-water conditions and standard marine atmospheres with an accuracy of the maximum of either 10% or 0.002 over the wavelength range of 350 – 395 nm
Aerosol heights: Identified approach or measurement capacity for evaluating/measuring aerosol vertical distributions and type for improved atmospheric corrections.
Atmospheric correction: SWIR atmospheric correction band at 2130 nm with a SNR of 100.
Coverage: 1-day global coverage; Coverage to a solar zenith angle >75^o
Crossing time: Noon equatorial crossing time (±10 min)
Instrument artifact: Overall instrument artifact contribution to TOA radiance retrievals of <0.2%.
Navigation and Registration: pointing knowledge of 0.05 IFOV; band-to-band registration of 90% of one IFOV; simultaneity of 0.01 second
Nitrogen dioxide: Identified approach for characterizing NO_2 and ozone concentrations at sufficient accuracy for improving atmospheric corrections
Mission lifetime: 10 years
Performance changes: Characterization of instrument performance changes to ±0.1% within 3 years and maintenance of this accuracy thereafter
Saturation: No detector saturation for any science measurement bands up to 1.2 × L_{max}
Signal-to-noise: SNR for bio-optical science bands and/or atmospheric correction bands greater than those specified for mission threshold requirements
Spatial resolution: Spatial resolution of 1 km^2 (±10%) at all scan angles; Along-track spatial resolution of 250 m x 250 m to 500 m x 500 m for inland, estuarine, coastal, and shelf area retrievals for all bands or a subset of bands.
Spectral coverage: 5 nm spectral coverage from 800 to 900 nm
Spectral subsampling: ~1-2 nm resolution from 655 to 710 nm for refined characterization of the chlorophyll fluorescence spectrum
Water vapor: Spectral measurement band centered at 820 nm or 940 nm to determine water vapor content


PACE
Pre-Aerosol, Cloud, ocean Ecosystem mission
...Final Comments...