The NASA PACE Mission

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HyspIRI Aquatic Sciences Workshop

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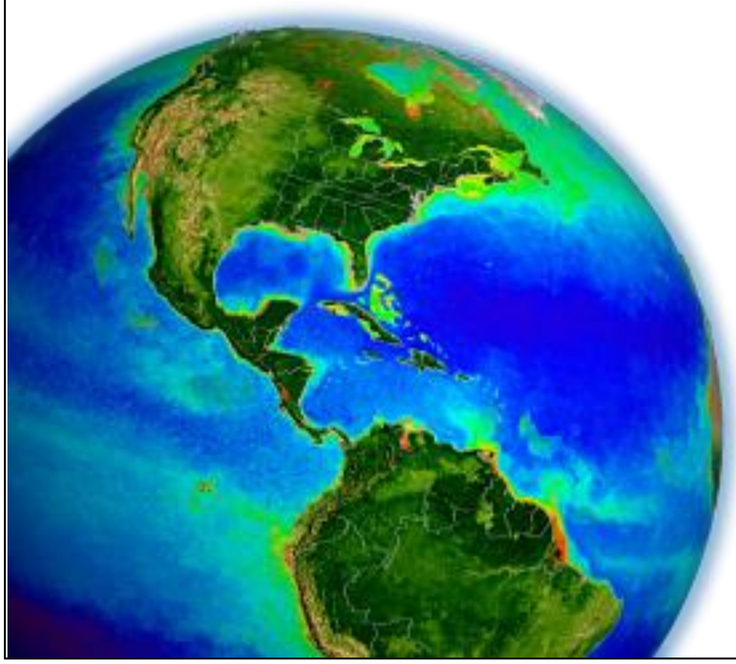
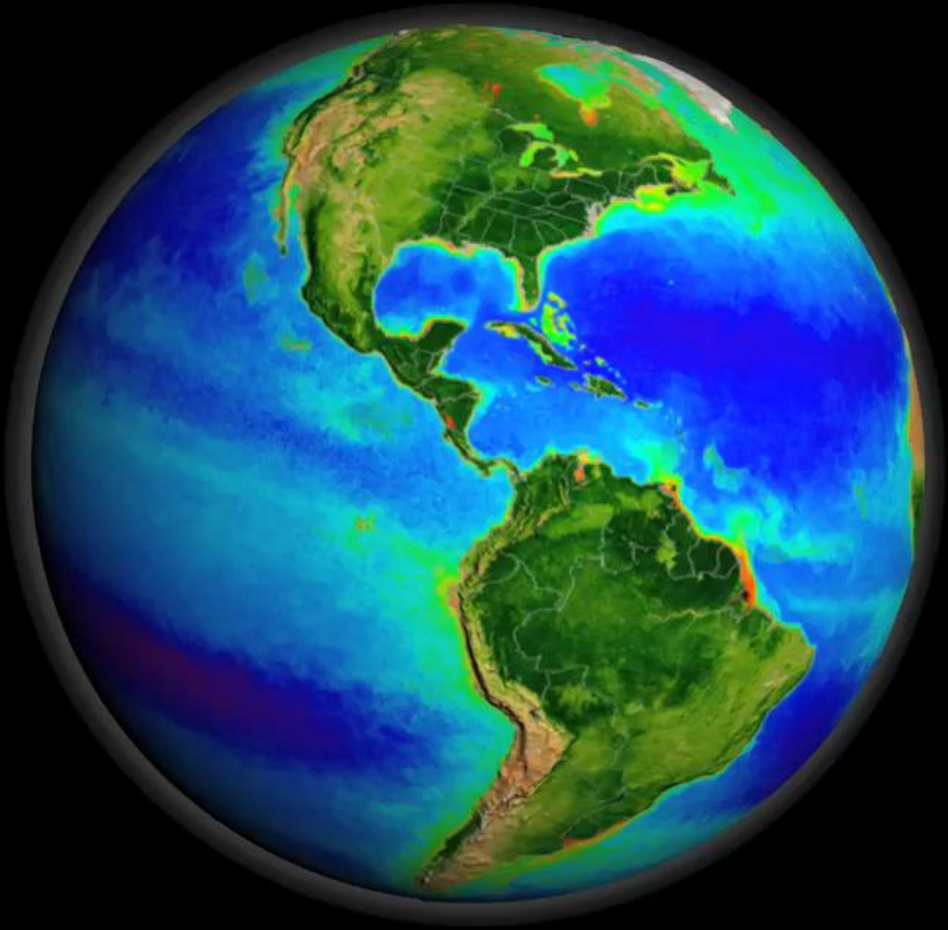




PACE ocean science questions

Pre-Aerosol, Clouds, and ocean Ecosystem (PACE) Mission Science Definition Team Report

b.1. Threshold Ocean Science Questions

The threshold ocean science questions (SQ) addressed by the OCI option are listed below. The SQ are addressed by the ocean science instrument (OCI) and the mission requirements, as specified in Appendices I and II of this summary.

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

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

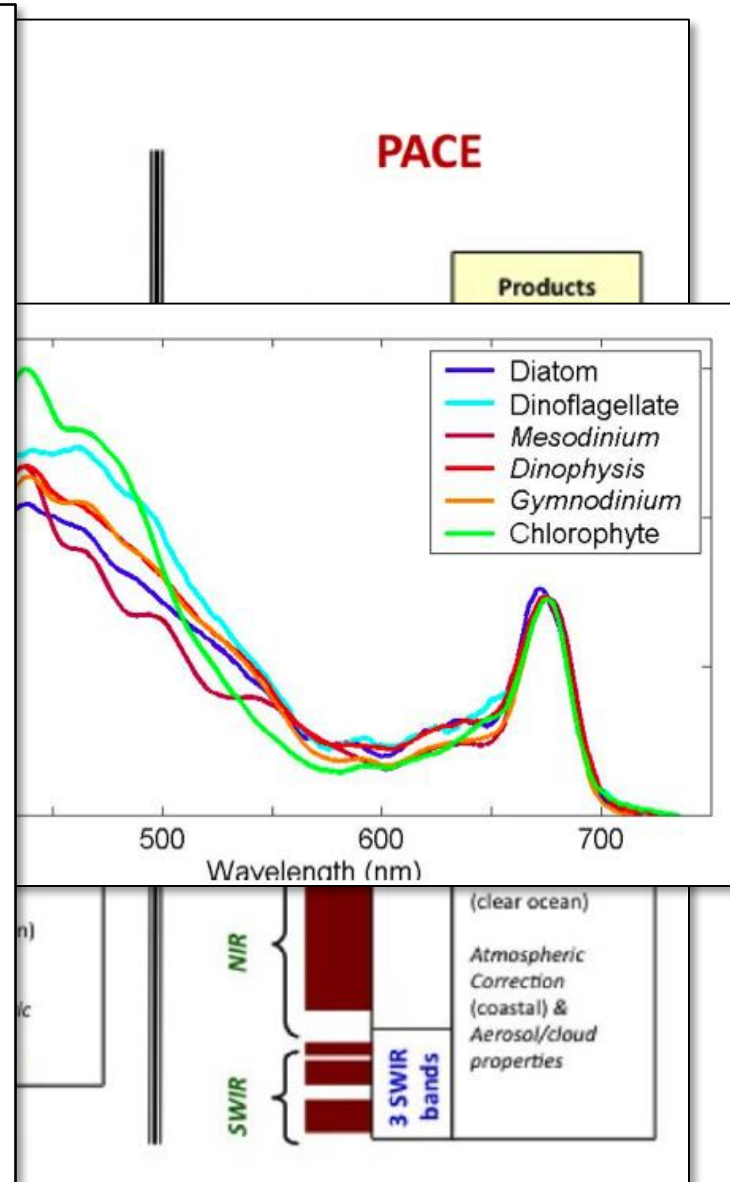
SQ-3: What are the material exchanges between land and ocean? How do they influence coastal ecosystems and biogeochemistry? How are they changing?

SQ-4: How do aerosols influence ocean ecosystems and biogeochemical cycles? How do ocean biological and photochemical processes affect the atmosphere?

SQ-5: How do physical ocean processes affect ocean ecosystems and biogeochemistry? How do ocean biological processes influence ocean physics?

SQ-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?

SQ-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?



PACE coastal ocean & terrestrial science questions

CSQ-1: What is the distribution of habitat and ecosystems and the variability of biogeochemical parameters at moderate scales (250-500 m) and what is the impact on coastal (estuarine, tidal wetlands, lakes) biodiversity and other coastal ecosystem services?

CSQ-2: What is the connectivity between coastal, shelf, and offshore environments?

CSQ-3: How does the export of terrestrial material affect the composition of phytoplankton functional types in coastal waters, and how do these in turn affect the cycling of organic matter?

CSQ-4: How do moderate scale processes (sedimentation, photodegradation, respiration) affect the cycling of terrigenous organic material in the coastal environment?

TSQ-1: What are the structural and biochemical characteristics of plant canopies? How do these characteristics affect carbon, water, and energy fluxes?

TSQ-2: What are the seasonal patterns and shorter-term variations in terrestrial ecosystems, functional groups, and diagnostic species? Are short-term changes in plant biochemistry the early signs of vegetation stress and do they provide an indication of an increased probability of serious disturbances?

TSQ-3: What are the global spatial patterns of ecosystem and biodiversity distributions, and how do ecosystems differ in their composition? Can differences in the response of optical signals to environmental changes improve the ability to map species, characterize species diversity, and detect occurrence of invasive species?

the PACE SDT report also presents atmospheric science questions

the PACE mission

organization

directed to GSFC (Dec 2014)

PACE science staff:

Project Scientist: J. Werdell
Deputy PS Oceans: A. Mannino
Deputy PS Atmos: B. Cairns
OC Instrument Sci: G. Meister
Program Scientist: P. Bontempi
Deputy PS Atmos: H. Maring
Applied Sciences: W. Turner

ocean color science data processing by GSFC OBPG

mission elements

GSFC will build the ocean color instrument

options for the optional 2^{nd} instrument (polarimeter): JPL provided, contributed, procured (not GSFC)

mission overview

$805M "design to cost" cost capped mission
includes: project team, spacecraft, launch vehicle, instruments, 3 years of mission ops, calibration/validation, science data processing, mission science

notional launch 2022-2023; 3 years Phase E

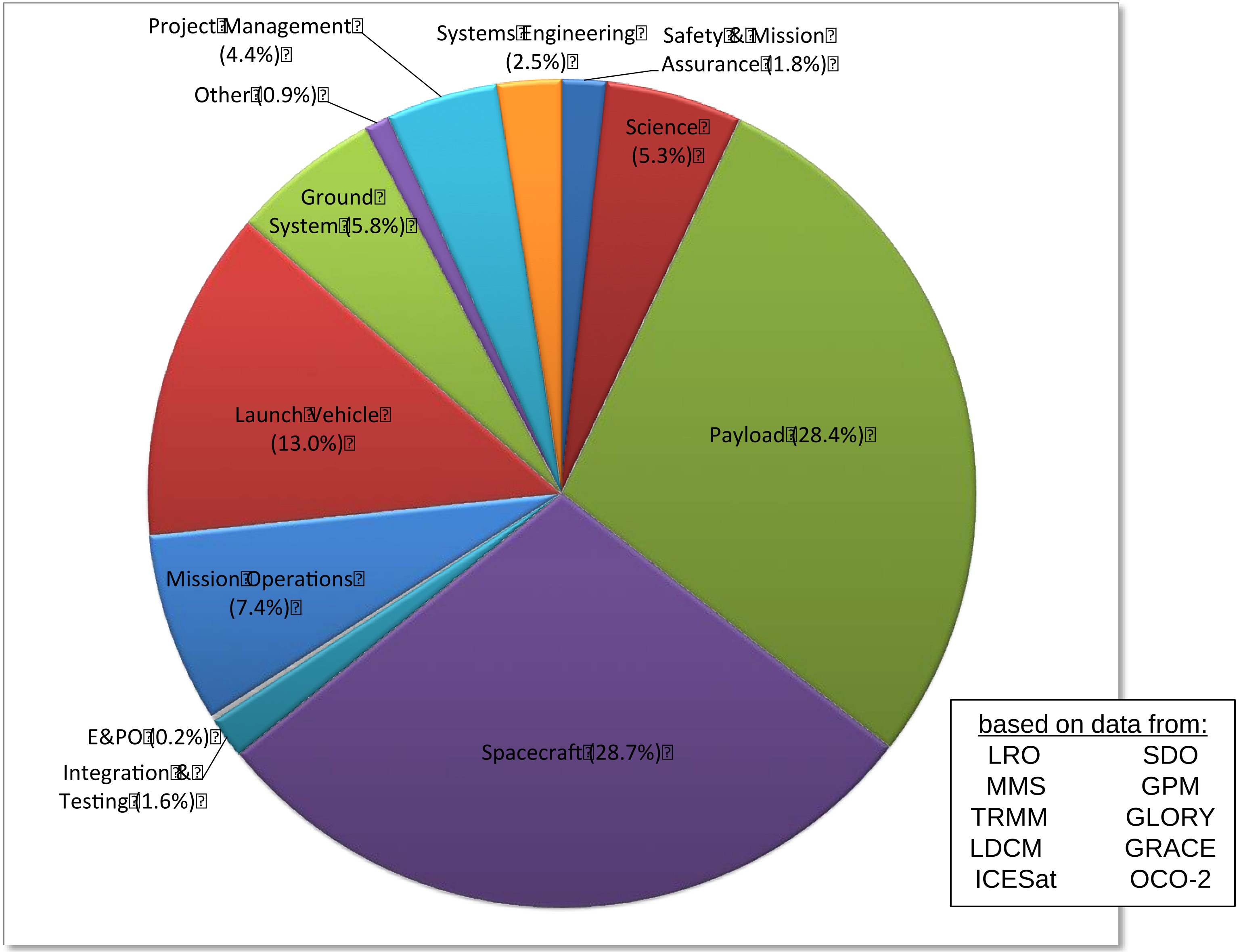
sun synchronous polar orbit @ ~650 km

ROSES-funded science teams (2014-2017)

algorithms: 24 members focusing on atmospheric correction & inherent optical properties

vicarious calibration: 3 teams developing radiometric systems & focusing on risk reduction

a typical mission budget



courtesy Bill Sluder, PACE Deputy Project Manager for Resources

noteworthy & upcoming events

Jan 2015:	PACE kickoff meeting held at HQ
Apr-May:	two RFIs released for spacecraft
May:	HQ delivered threshold OCI instrument requirements
now:	Pre-phase A trade studies being identified
Jun-Aug:	OCI Instrument Design Laboratories @ GSFC complementary polarimeter studies conducted
Aug-Sep:	Technical, Management, & Cost Review
Nov-TBD:	Mission Concept Review Key Decision Point A meeting first Acquisition Strategy Meeting

the PACE ocean color instrument: threshold requirements

Earth surface spatial resolution of 1 km^2 at nadir

sun synchronous, polar orbit w/ equatorial crossing time near local noon

2-day global coverage to solar zenith ≤ 75^o and sensor zenith ≤ 60^o

spectral range from 350-800 nm @ 5 nm resolution

plus: an atmospheric correction band @ 865 nm
plus: (roughly) 940, 1230, 1378/1880, 1640, 2130, & 2250 nm

normalized water-leaving reflectance accuracies in open ocean of

20% or 0.004 for 350-395 nm
5% or 0.001 for 400-600 nm
10% or 0.002 for 600-800 nm

tilt to mitigate Sun glint

lunar calibration through Earth view port with illumination of all detectors

image striping artifacts < 0.5% & correctable to noise levels

the PACE ocean color instrument: threshold requirements

Atmospheric Aerosol Measurements

a) Aerosol Optical Depth
   a. UV at 0.05 or 30% (total)
   b. VIS at 0.05 or 15% (total) over land
   c. VIS at 0.03 or 10% (total) over ocean
b) Fraction of Total Visible Optical Depth contributed by the fine mode aerosol over dark water to ±0.25.

Cloud Measurements

Cloud Layer Detection of 5-10% at a cloud optical depth of ~0.3 with dependence on surface type as a partial continuation of MODIS and VIIRS

a) Cloud Top Pressure
   a. Low cloud when optically thick and/or over dark surface at ≤50 hPa
   b. High cloud at >50 hPa.
b) Cloud Water Path as a function of optical depth, effective radius and surface
   a. ~30% for liquid clouds
      ~50% for ice clouds
c) Optical Thickness as a function of optical depth, effective radius, wavelength and surface
   a. ~20% for liquid clouds with small sub-pixel heterogeneity
      ~30% for ice clouds
d) Effective Radius with upper layer weighting
   a. ~20% for liquid clouds with small sub-pixel heterogeneity
      ~30% for ice clouds

Shortwave Radiative Effect at ~10 Wm^{-2} TOA

the PACE ocean color instrument: IDL studies @ GSFC

(1) hyperspectral pushbroom (Jun)

multiple camera system (implies multiple detectors per scan line)
spectrograph @ 5 nm resolution
$\pm 52^o$ cross track FOV
spatial resolution of 250 & 500 m^2

(2) multispectral scanner (Jul)

rotating telescope with ~40 spectral bands (~5-10 nm wide in VIS)
filter radiometer systems with multiple detectors per scan line
$\pm 58^o$ cross track FOV
spatial resolution of 260 & 500 m^2

(3) hyperspectral scanner (Aug)

rotating telescope with 1 detector per scan line
spectrograph @ 5 nm resolution
$\pm 52^o$ cross track FOV
spatial resolution of 350 & 500 (& 1000) m^2

common features of all runs include:

spectral resolution from 350-900 nm, plus SWIR
SNR as specified in PACE SDT (~1000 in VIS at 1 km^2)

the PACE ocean color instrument: trade studies

a variety of configurations can be envisions for the mission payload … but, the funding framework is “design-to-cost”

need to conduct focused studies on measurement trades / feasibility /risk to optimize science returns from the mission

examples of trade considerations:

cost	spectral resolution
risk	spatial resolution
schedule	data rates
TRL	data volume
mass	SNRs
power	pre-launch calibration
striping	post-launch calibration

examples of desired studies:

spectral subsampling @ 1-2 nm (e.g., over the chlorophyll fluorescence peak)

spatial resolution to 250 m

hyperspectral < 350 & to 900 nm

spectral resolution < 5 nm

data latency & direct broadcast

the PACE polarimeter

per the HQ letter of direction, 4 options exist:

(1) no polarimeter

(2) polarimeter directed to JPL

(3) polarimeter competed

(4) polarimeter contributed

desired threshold instrument capabilities currently being iterated upon with HQ

ongoing ST discussions

possible RFI

JPL
Jet Propulsion Laboratory
California Institute of Technology

esa
European Space Agency

SRON
Netherlands Institute for Space Research

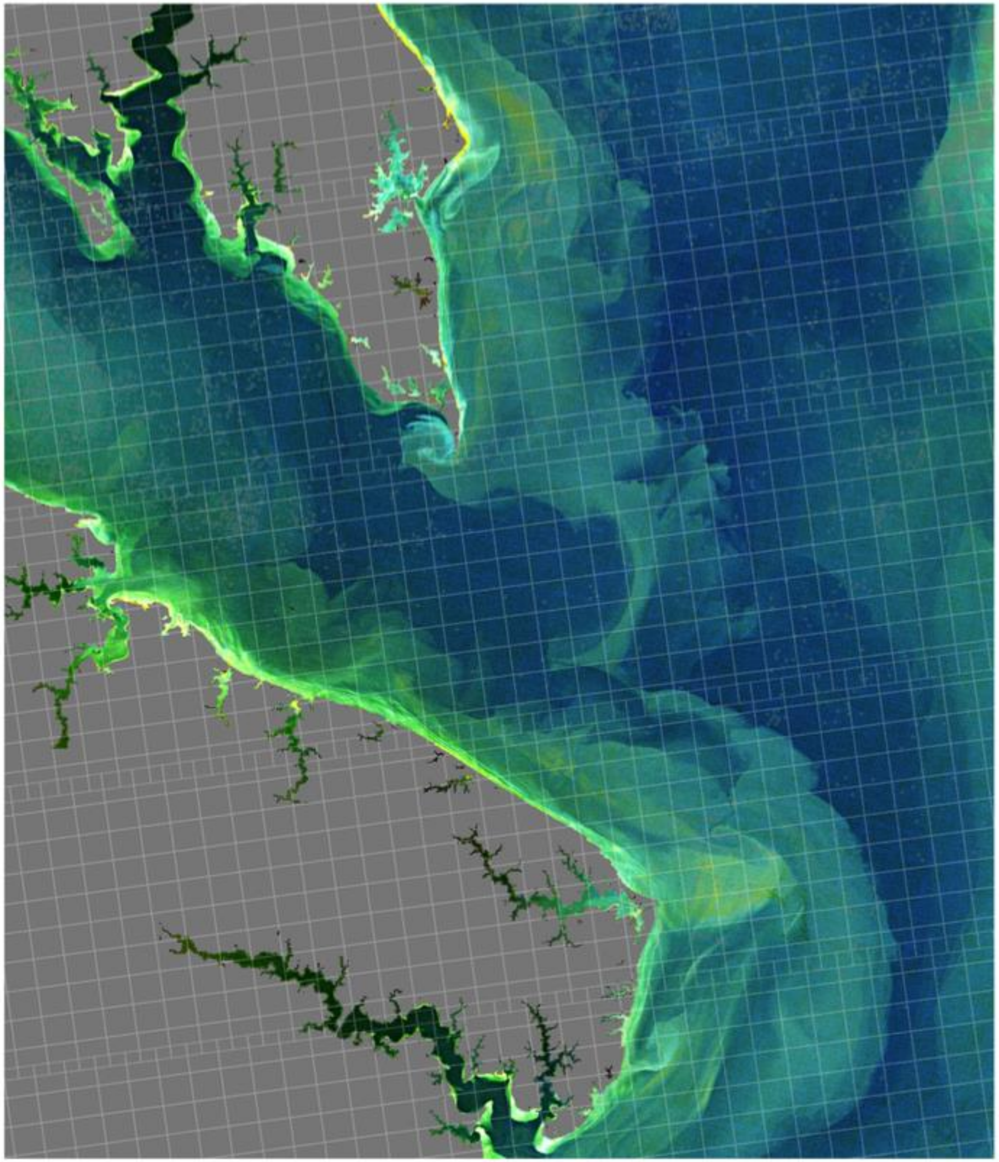
a second coastal ocean color instrument?

50-100 m spatial resolution

just an idea

TBD:
- multi- or hyperspectral
- coverage & scheduling
- swath
- SNRs
- TRL
- mass, power

possible RFI



OLI on Landsat-8; from Franz, Bailey, Kuring, & Werdell (2015), J. Appl. Rem. Sens.

current PACE science teams

PACE Science Team (2014-2017; announced Sep 2014)

24 members, including 2 Applied Sciences reps & 2 GSFC liaisons
2 teams: atmospheric correction & inherent optical properties

teams charged with:
- reporting on consensus state-of-the-art
- advancing hyperspectral methods
- developing related software
- identifying current limitations (research, modeling, tech)

PACE Vicarious Calibration (2014-2017; announced Jul 2014)

3 groups selected

tasked with developing radiometric systems for vicarious calibration
- risk reduction; not vicarious calibration system development