PACE Town Hall

2016 Ocean Sciences Meeting

22 Feb 2016

What is PACE?

PACE provides a strategic climate continuity mission that will collect many global measurements essential for understanding marine and terrestrial biology, biogeochemistry, ecology, and cloud and aerosol dynamics.

Pre-***A***erosols, ***C***louds, and ocean ***E***cosystems

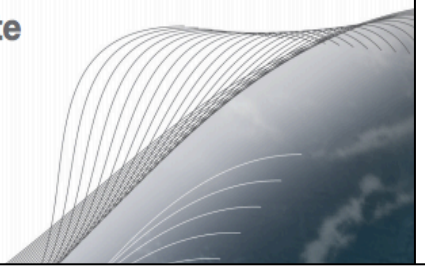
Plankton

global continuous spectroradiometric measurements from the UV to SWIR to enable ocean color & cloud/aerosol studies & continuity of their multi-decadal data records … plus, multi-angular photopolarimetry to support advanced cloud/aerosol/ ocean color research.

Responding to the Challenge of Climate and Environmental Change:

NASA's Plan for a Climate-Centric Architecture for Earth Observations and Applications from Space

June 2010

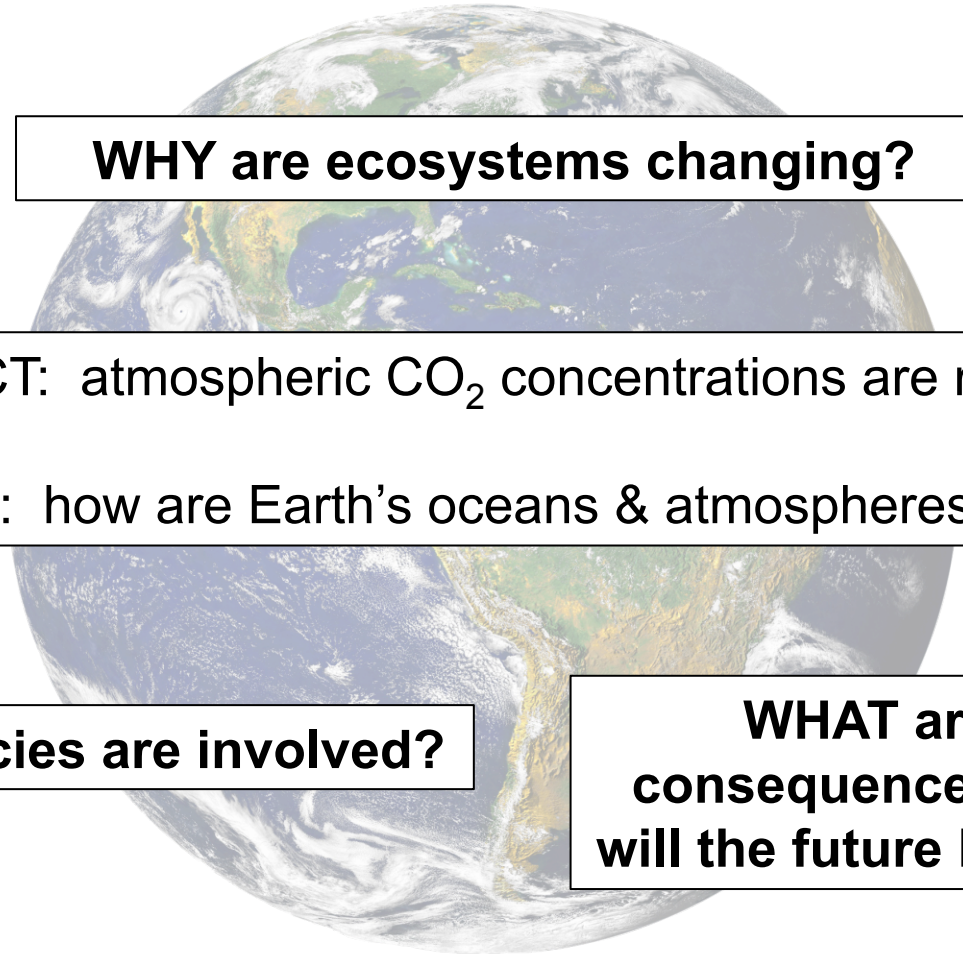


Climate Continuity Missions: The FY2011 budget request allows NASA to address important scientific needs for continuity of key climate observations.

- Refurbishment of the SAGE-III instrument and of a hexapod pointing platform, and accommodation studies for a flight opportunity on the ISS as early as 5/2014, if transportation to the ISS can be arranged;
- Development of a GRACE Follow-on mission (with a launch in 2016) as a gap-filler between the operating GRACE and the recommended higher-capability GRACE-II Decadal Survey Tier 3 mission.
- Development of an ocean color and clouds/aerosols polarimetry mission (launch in 2018) to bridge between existing on-orbit missions and the future, more capable ACE Tier 2 mission.

Overarching science questions

PACE is focused on global ecosystem structure, physics, health, & carbon dynamics to resolve reasons & consequences of change in today's oceans & atmospheres to predict and prepare for tomorrow's Earth



WHY are ecosystems changing?

FACT: atmospheric CO_2 concentrations are rising.

QUESTION: how are Earth's oceans & atmospheres responding?

WHICH species are involved?

WHAT are the consequences & HOW will the future Earth look?

PACE advanced science questions

What are the standing stocks & compositions of ocean ecosystems? How & why are they changing?

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

How do physical ocean processes affect ocean ecosystems? How do ocean biological processes influence ocean physics?

What is the distribution of both harmful & beneficial algal blooms & how is their appearance & demise related to environmental forcing?

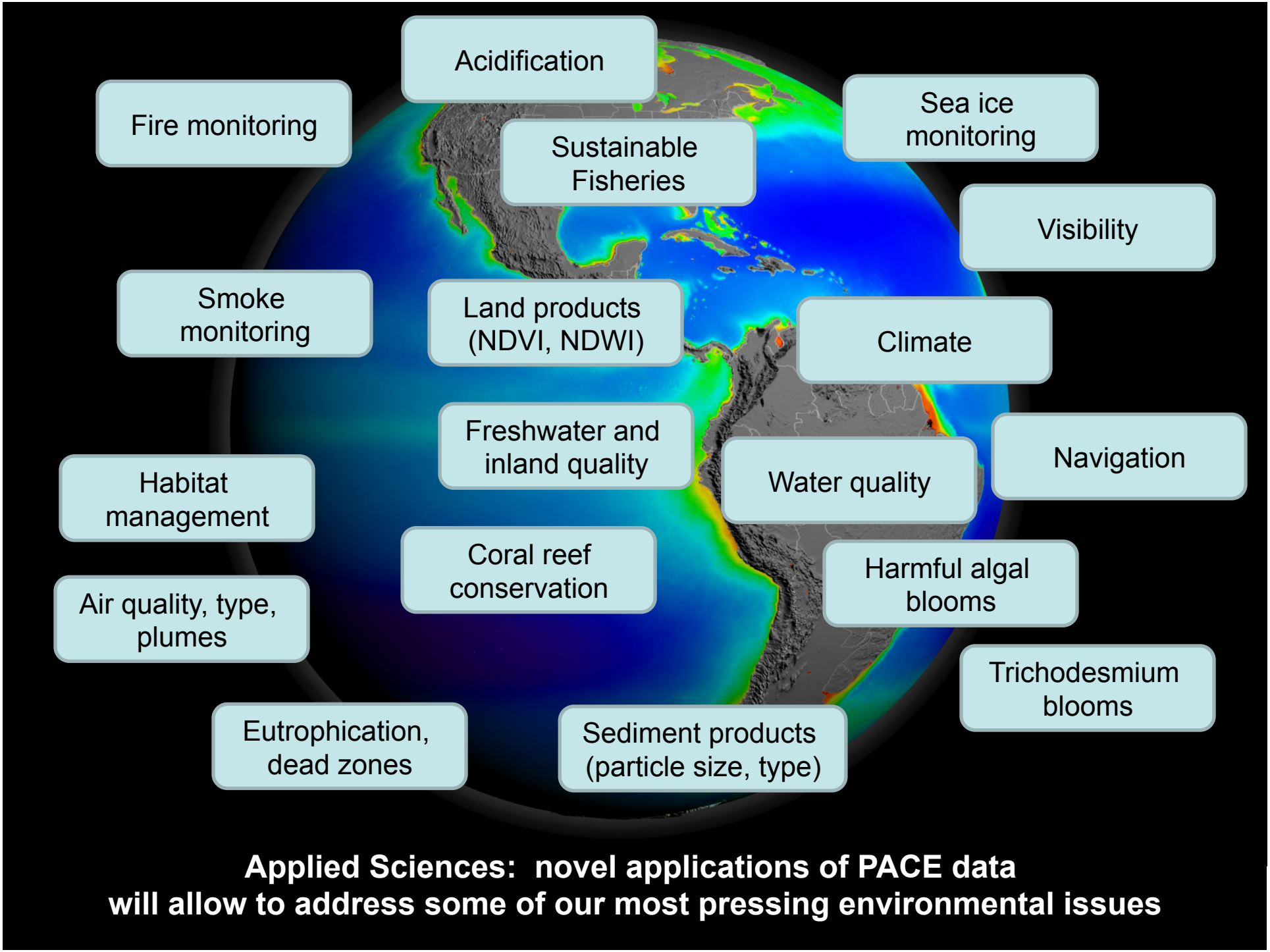
How do changes in critical ocean ecosystem services affect human health & welfare? What science-based management strategies need to be implemented to sustain our health & well being?

What are the long-term changes in aerosol & cloud properties & how are these properties correlated with inter-annual climate oscillations?

What are the magnitudes & trends of direct radiative forcing & its anthropogenic component?

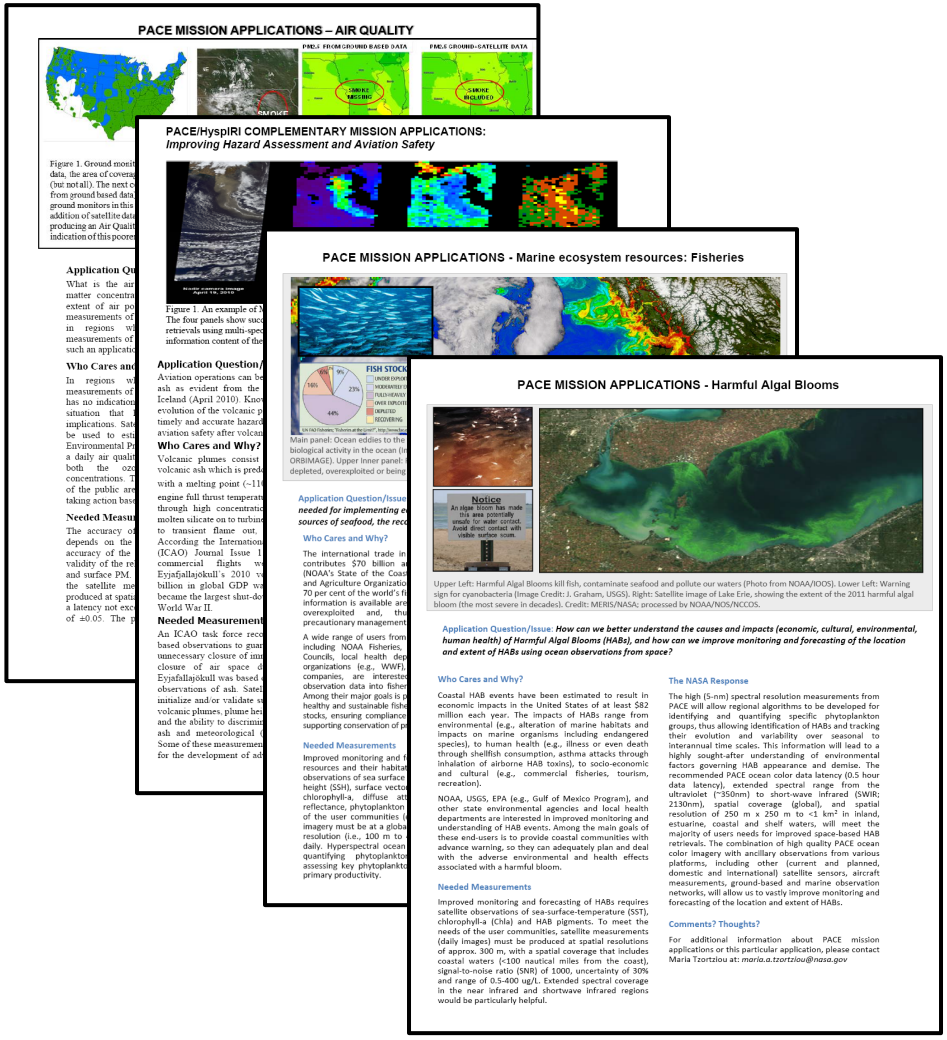
How do aerosols influence ocean ecosystems & biogeochemical cycles?
How do ocean biological & photochemical processes affect the atmosphere?

Please see also the 2012 PACE Science Definition Team Report


Acidification
Fire monitoring
Sea ice monitoring
Sustainable Fisheries
Visibility
Smoke monitoring
Land products (NDVI, NDWI)
Climate
Freshwater and inland quality
Navigation
Habitat management
Water quality
Coral reef conservation
Harmful algal blooms
Air quality, type, plumes
Trichodesmium blooms
Eutrophication, dead zones
Sediment products (particle size, type)
Applied Sciences: novel applications of PACE data
will allow to address some of our most pressing environmental issues

Fire monitoring | Fisheries | Sea ice | Eutrophication | Acidifcation | Harmful algal blooms | Climate

PACE Applications White Papers



PACE Applications Traceability Matrix

developed with input from the user community

PACE Application Questions & Concepts

What is the air quality forecast of particulate matter (PM) predicted from PACE measurements of the aerosol optical depth (AOD) in regions where there are no direct measurements of PM?

The EPA produces a daily air quality index which comprises both the ozone and PM concentrations. In regions where there are no direct measurements of particulate matter, satellite measurements of AOD can be used to estimate PM.

Application Readiness Level: *3*
Applied Sciences Category: *Public Health and Air Quality*
Potential Host Agency: *EPA (James Szykman)*

Mission Data Product: Aerosol Optical Depth
Spatial resolution: <1 km
Latencies: <1 hour

Projected Mission Performance: AOD within +/- 0.02 at a horizontal resolution of 250 m
Ancillary Measurements: Aerosol vertical distributions, Surface PM concentrations (at a few locations)

What is the volcanic ash concentration during and after a volcanic eruption? Is there an impact on air quality as a result of a volcanic material deposited in coastal/populated regions?

Measurements collected to support PACE atmospheric corrections in coastal regions may be used to quantify the concentration of material associated with volcanic eruptions. These data may be useful in enabling prudent ash-related aviation hazard mitigation policies and advisories.

Application Readiness Level: *3*
Applied Sciences Category: *Disaster Mitigation, Public Health and Air Quality*
Potential Host Agency*: FAA, EPA, NOAA, International Civil Aviation Organization, Volcanic Ash Advisory Centers (Shobha Kondragunta, NOAA)*

Mission Data Product: Aerosol Optical Depth
Spatial resolution: <1 km
Latencies: <1 hour

Projected Mission Performance: AOD within +/- 0.02 at a horizontal resolution of 250 m
Ancillary Measurements: Aerosol vertical distributions, Sulfur dioxide concentrations

How do exchanges across the land-ocean interface influence carbon and nutrient loadings, water quality, and ecosystem dynamics in coastal waters?

The EPA Safe and Sustainable Water Resources Research Program aims at developing core indicators of water resource integrity and sustainability as well as indicators of key drivers and pressures across a range of spatial and temporal scales for use in integrated assessments. Integration of satellite observations with field measurements and modeling tools is needed to demonstrate assessment of sustainability and integrity of water resources.

Application Readiness Level: *3*
Applied Sciences Category: *Water Resources, Oceans, Coasts, Great Lakes, Ecosystems and Human Health*
Potential Host Agency: *EPA (Blake Schaeffer)*

Mission Data Products: Chl-*a*, K_D (water quality)
Spatial resolution: Estuaries: ≤250 m Coastal Waters: ≤500 m
Coverage: Minimum distance: 5.5 km Maximum distance: 22 km
Latencies: 0.5-12 hours

Projected Mission Performance: 0.5 hour data latency, direct broadcast of 5 nanometer resolution data, spatial resolution of 1 km²(+/-10%) at all angles across track. Along track spatial resolution of 250 m² to <1 km² for inland, estuarine, coastal and shelf area retrievals for all bands or a subset of bands.
Ancillary Measurements: Aerosols (spectral shape, vertical distribution), NO_2, O_3 concentrations for atmospheric correction

How are the productivity and biodiversity of coastal ecosystems changing, and how do these changes relate to natural and anthropogenic forcing, including local to regional impacts of climate variability?

PACE satellite-derived optics and biogeochemical variables may be assimilated into operational seasonal-to-interannual computer models. As a result, PACE data may improve model skills and forecasting capabilities of the Global Ocean Data Assimilation System / Coupled Forecast System (GODAS/CFS) and Real-Time Ocean Forecast System (RTOFS).

Application Readiness Level: *3*
Applied Sciences Category: *Ecological Forecasting*
Potential Host Agency: *NOAA (Paul DiGiacomo, Cara Wilson)*

Mission Data Products: Chl-*a*, K_{PAR}, K_{490}
Spatial resolution: 1 km
Temporal resolution: Daily
Coverage: Global
Latencies: 12 hours

Projected Mission Performance: 0.5 hour data latency, direct broadcast of 5 nanometer resolution data, spatial resolution of 1 km²(+/-10%) at all angles across track. Along track spatial resolution of 250 m² to <1 km² for inland, estuarine, coastal and shelf area retrievals for all bands or a subset of bands.
Ancillary Measurements: Aerosols (spectral shape, vertical distribution), NO_2, O_3 concentrations for atmospheric correction

How can PACE help with oil spill monitoring and response?

NOAA's subsurface oil monitoring program uses various modeling and observational approaches (airborne, shipborne, ground-based, space-based measurements) to track oil spills: where the oil is going on the surface and under the sea, and what the consequences are to local communities, wildlife and the marine environment (e.g., Deepwater Horizon/BP Oil Spill).

Application Readiness Level: *3*
Applied Sciences Category: *Disasters, Water Resources*
Potential Host Agency: *NOAA (Paul DiGiacomo, Cara Wilson)*

Mission Data Product: Visible/true color imagery
Spatial resolution: <300 m
Temporal resolution: 1 hr
Coverage: Coastal waters: <185 km 50N - 10N 106 W- 60W
Latencies: 0.5-1 hours

Projected Mission Performance: 0.5 hour data latency, direct broadcast of 5 nanometer resolution data, spatial resolution of 1 km²(+/-10%) at all angles across track. Along track spatial resolution of 250 m² to <1 km² for inland, estuarine, coastal and shelf area retrievals for all bands or a subset of bands.
Ancillary Measurements: Aerosols (spectral shape, vertical distribution), NO_2, O_3 concentrations for atmospheric correction

ARL 3: **Proof of Application Concept (Viability Established)** - Feasibility studies to assess the potential viability of and provide a proof-of-concept for the application have been conducted

Habitat management, Coral reefs | Freshwater /Inland Water quality | Air quality, type, plumes | Sediment products (particle size, type) | Land products (NDVI, NDWI)

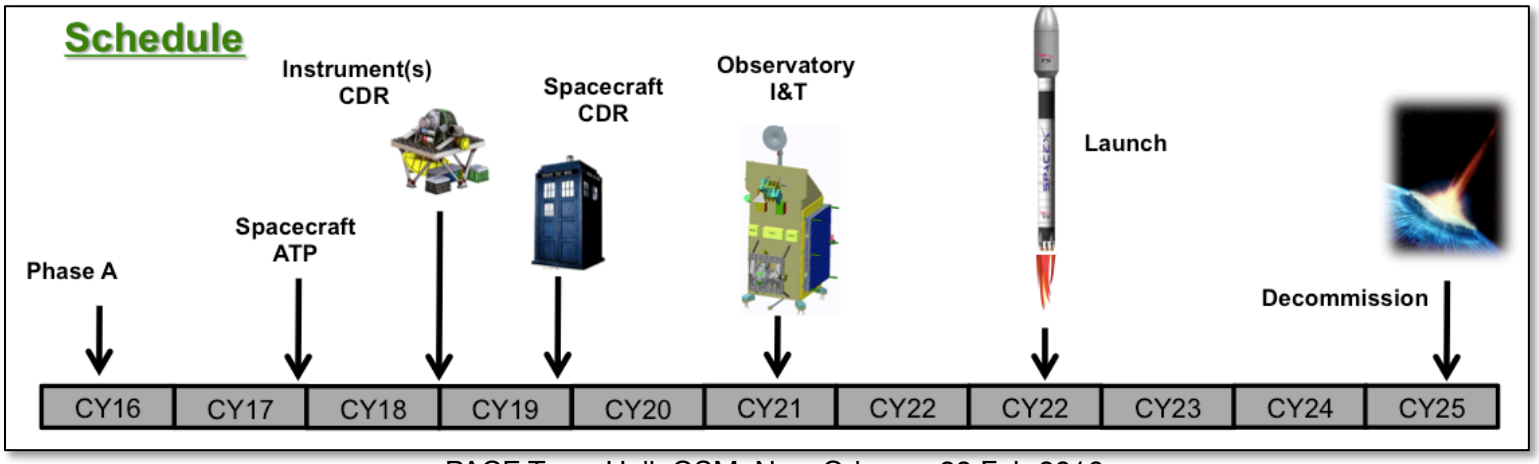
The PACE mission

HQ/ESD letter of direction in Dec 2014

- Mission management directed to NASA GSFC
- Ocean color instrument (OCI) to be built at GSFC
- Polarimeter is a second (optional) instrument
  - contributed or procured
  - directed to JPL
- Science data processing directed to GSFC Ocean Biology Processing Group

Mission characteristics

- $805M “design-to-cost” cost-capped mission
  - project team, spacecraft, launch vehicle, instruments, 3 years of mission ops, calibration/validation, science data processing, mission science
  - 65% cost confidence
- Class C (short duration, minimum risk)
- 3 year mission; 10 years of fuel
- Sun synchronous polar orbit
- 98^{o} inclination at ~675 km altitude



The PACE Ocean Color Instrument (OCI)

	Mission Threshold Req.	SDT Threshold	SDT Goal
Earth surface spatial resolution	1 km^2 at nadir	1 km^2 at nadir	*1 km^2 to edge of scan; 250 – 500 m^2 at nadir*
Orbit	Sun synchronous, polar orbit w/ equatorial crossing time near local noon	Sun synchronous, polar orbit w/ equatorial crossing b/w 11:00 & 13:00	Sun synchronous, polar orbit w/ equatorial crossing @ noon
Global coverage	2-day to solar zenith ≤ 75° & sensor zenith ≤ 60°	2-day to solar zenith ≤ 75° & sensor zenith ≤ 60°	1-day with solar zenith > 75°
Instrument tilt	Yes	Yes	Same as threshold
Lunar calibration	Through Earth view port w/ illumination of all detectors	Through Earth view port w/ illumination of all detectors	Same as threshold
Image artifacts	Striping artifacts ≤ 0.5% and correctable to noise levels	Total artifact contribution to TOA < 0.5% & *striping ≤ 0.1%* of calibrated TOA	Total artifact contribution to *TOA < 0.2%*
Accuracy / precision	20% or 0.004 for 350-395 nm 5% or 0.001 for 400-600 nm 10% or 0.002 for 700-900 nm	5% or 0.001 for 400-710 nm	*10% or 0.002* for 350-395 nm
Mission duration	3 years w/ 10 years of fuel	5 years	10 years
UV-VIS-NIR	350-800 nm @ 5 nm	350-800 nm @ 5 nm	350-900 nm @ 5 nm
SWIR	940, 1380, 2130, 2250 nm	940, 1380, 2130, 2250 nm + 1240, 1640 nm	Same as threshold

colors show differences b/w SDT report & HQ requirements: can meet or exceed; *unknown*; may/will not meet

PACE standard data products

Discipline	Data Product
ocean color	water-leaving reflectance: 350-395 nm
	water-leaving reflectance: 400-600 nm
	water-leaving reflectance: 600-800 nm
	concentration of chlorophyll-a
	diffuse attenuation coefficient: 490 nm
	concentration of particulate inorganic carbon
	concentration of particulate organic carbon
	photosynthetically available radiation
	total absorption: 350-700 nm
	phytoplankton absorption: 350-700 nm
	non-algal + CDOM absorption: 350-700 nm
	particulate backscattering: 350-700 nm

Required data product

Additional data products

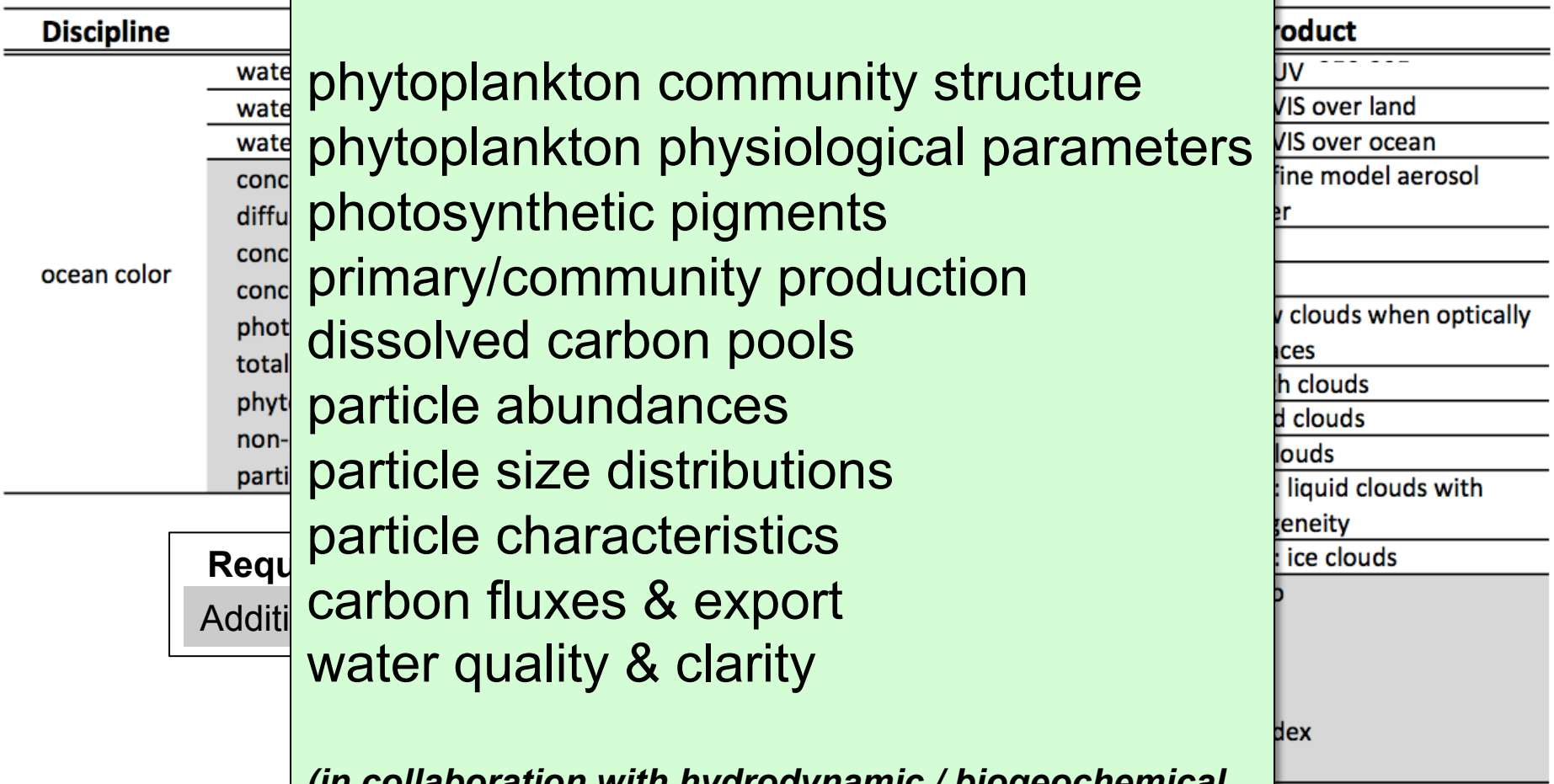
Discipline	Data Product
aerosols	aerosol optical depth: UV
	aerosol optical depth: VIS over land
	aerosol optical depth: VIS over ocean
	aerosol optical depth: fine model aerosol fraction over dark water
clouds	cloud layer detection
	cloud top pressure: low clouds when optically thick or over dark surfaces
	cloud top pressure: high clouds
	cloud water path: liquid clouds
	cloud water path: ice clouds
	cloud optical thickness: liquid clouds with small sub-pixel heterogeneity
	cloud optical thickness: ice clouds
polarimetric	single scattering albedo
	aerosol layer height
	effective radius
	real refractive index
	imaginary refractive index
	radiometry

PACE standard data products

PACE target (ocean) data products

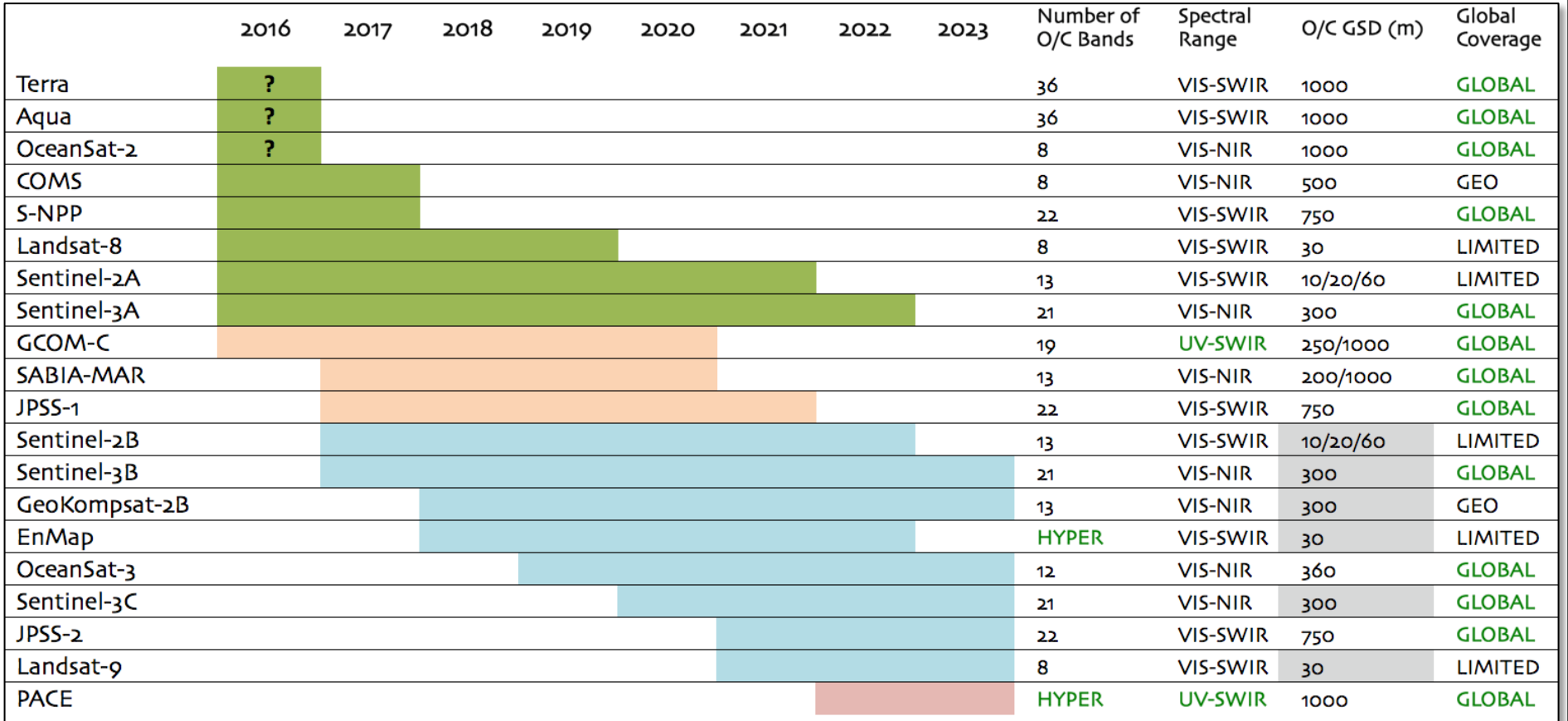
phytoplankton community structure
phytoplankton physiological parameters
photosynthetic pigments
primary/community production
dissolved carbon pools
particle abundances
particle size distributions
particle characteristics
carbon fluxes & export
water quality & clarity

(in collaboration with hydrodynamic / biogeochemical models & other observing systems)



Where does PACE fit in?

Schedule & capabilities of ocean color sensors in the pre-PACE & PACE eras



	2016	2017	2018	2019	2020	2021	2022	2023	Number of O/C Bands	Spectral Range	O/C GSD (m)	Global Coverage
Terra	?								36	VIS-SWIR	1000	GLOBAL
Aqua	?								36	VIS-SWIR	1000	GLOBAL
OceanSat-2	?								8	VIS-NIR	1000	GLOBAL
COMS									8	VIS-NIR	500	GEO
S-NPP									22	VIS-SWIR	750	GLOBAL
Landsat-8									8	VIS-SWIR	30	LIMITED
Sentinel-2A									13	VIS-SWIR	10/20/60	LIMITED
Sentinel-3A									21	VIS-NIR	300	GLOBAL
GCOM-C									19	UV-SWIR	250/1000	GLOBAL
SABIA-MAR									13	VIS-NIR	200/1000	GLOBAL
JPSS-1									22	VIS-SWIR	750	GLOBAL
Sentinel-2B									13	VIS-SWIR	10/20/60	LIMITED
Sentinel-3B									21	VIS-NIR	300	GLOBAL
GeoKompsat-2B									13	VIS-NIR	300	GEO
EnMap									HYPER	VIS-SWIR	30	LIMITED
OceanSat-3									12	VIS-NIR	360	GLOBAL
Sentinel-3C									21	VIS-NIR	300	GLOBAL
JPSS-2									22	VIS-SWIR	750	GLOBAL
Landsat-9									8	VIS-SWIR	30	LIMITED
PACE									HYPER	UV-SWIR	1000	GLOBAL

color legend: LAUNCHED; PLANNED; NO PACE OVERLAP; PLANNED; PACE OVERLAP; PACE

see also www.ioccg.org/sensors

Enhanced features for climate science

High-spatial resolution in the PACE era

A PACE polarimeter?

Rationale for prioritization	Priority	Minimum Capability	Enhanced Capability
PACE is a climate-science mission. Global polarimetry will: (1) Reduce uncertainties in aerosol characterizations for input into global climate forcing (e.g., IPCC) models; and (2) Improve ocean color atmospheric correction, thus improving understanding of global ocean ecosystems and carbon cycles	1a	**% ground coverage of OCI Swath** Not specified *Target: 50%*	**% ground coverage of OCI Swath** Not specified *Target 90%*
	1b	**Swath width** ±15-25°	**Swath width** ±30°
The utility of the measurements degrades when uncertainties exceed 1%	2	**DOLP uncertainty** <0.01	**DOLP uncertainty** <0.005
Spectral resolution, number of polarized bands, and angular range (# of scattering angles) all dictate what derived products can be produced	3a	**Spectral channels** >4 over 400-1600 nm + 2200 nm only if sparse angular sampling	**Spectral channels** Minimum + 940 nm or O2 A-band and 1378 or 1880 nm
	3b	**Angular range** ±50° at satellite in all bands	**Angular range** ±55° at satellite in all bands
Multiangular capabilities enhance the ability to estimate many cloud and aerosol properties	4a	**Number of angles** 5-6 for clouds	**Number of angles** ~50 for cloud bows
	4b	**Number of angles** 4 for aerosols	**Number of angles** 10 for aerosols
4 km is adequate for climate science		**Pixel size / Spatial resolution** 5 km	**Pixel size / Spatial resolution** 1 km
All concepts meet the radiometric and SNR requirements		**Radiometric uncertainty** 5%	**Radiometric uncertainty** 3%
		SNR Not specified	**SNR** Not specified

Enhanced capabilities identified based on recent work in the peer reviewed literature.
The minimum capability follows those for 3MI, which was featured in the PACE SDT.

A PACE polarimeter?

Rationale for prioritization	Priority	Minimum Capability	Enhanced Capability
PACE is a climate-science mission. Global polarimetry will: (1) Reduce uncertainties in aerosol characterizations for input into global climate forcing (e.g., IPCC) models; and (2) Improve ocean color atmospheric correction, thus improving understanding of global ocean ecosystems and carbon cycles	1a	**% ground coverage of OCI Swath** Not specified *Target: 50%*	**% ground coverage of OCI Swath** Not specified *Target 90%*
	1b	**Swath width** ±15-25°	**Swath width** ±30°
The utility of the measurements degrades when uncertainties exceed 1%	2	**DOLP uncertainty** <0.01	**DOLP uncertainty** <0.005
Spectral resolution, [illegible] scattering angles) all			**ectral channels** um + 940 nm or O2 d and 1378 or 1880 nm
			ngular range at satellite in all bands
Multiangular capabilities enhance the ability to estimate many cloud and aerosol properties		5-6 for clouds	**mber of angles** 50 for cloud bows
	4b	**Number of angles** 4 for aerosols	**Number of angles** 10 for aerosols
4 km is adequate for climate science		**Pixel size / Spatial resolution** 5 km	**Pixel size / Spatial resolution** 1 km
All concepts meet the radiometric and SNR requirements		**Radiometric uncertainty** 5%	**Radiometric uncertainty** 3%
		SNR Not specified	**SNR** Not specified

In collaboration with HQ/ESD, the Project is exploring several acquisition strategies, including instrument concepts from JPL, Netherlands SRON, ESA/asdf, others

Enhanced capabilities identified based on recent work in the peer reviewed literature.
The minimum capability follows those for 3MI, which was featured in the PACE SDT.

Other capabilities for the PACE payload: not required, but under study

A high spatial resolution (~100 m) spectroradiometer to study coastal/inland ecosystems & cloud microphysics

- Request for Information to industry released in Jul 2015
- 9 responses from industry, 3 from academia/government

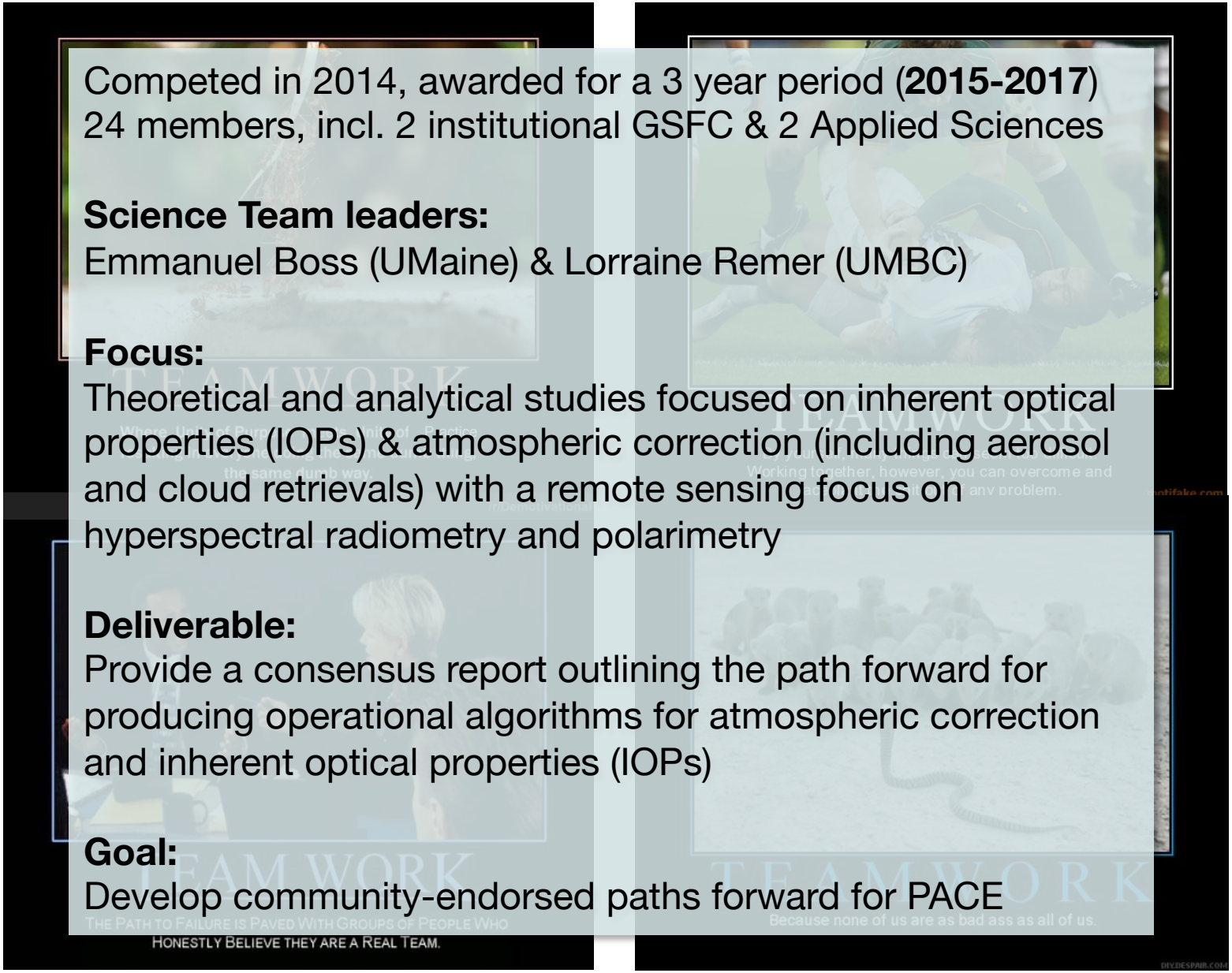
Support for NASA Earth Venture class instruments

- http://science.nasa.gov/about-us/smd-programs/earth-system-science-pathfinder/

Direct broadcast communications capabilities

- http://directreadout.sci.gsfc.nasa.gov/

The first PACE Science Team



Competed in 2014, awarded for a 3 year period (**2015-2017**)
24 members, incl. 2 institutional GSFC & 2 Applied Sciences

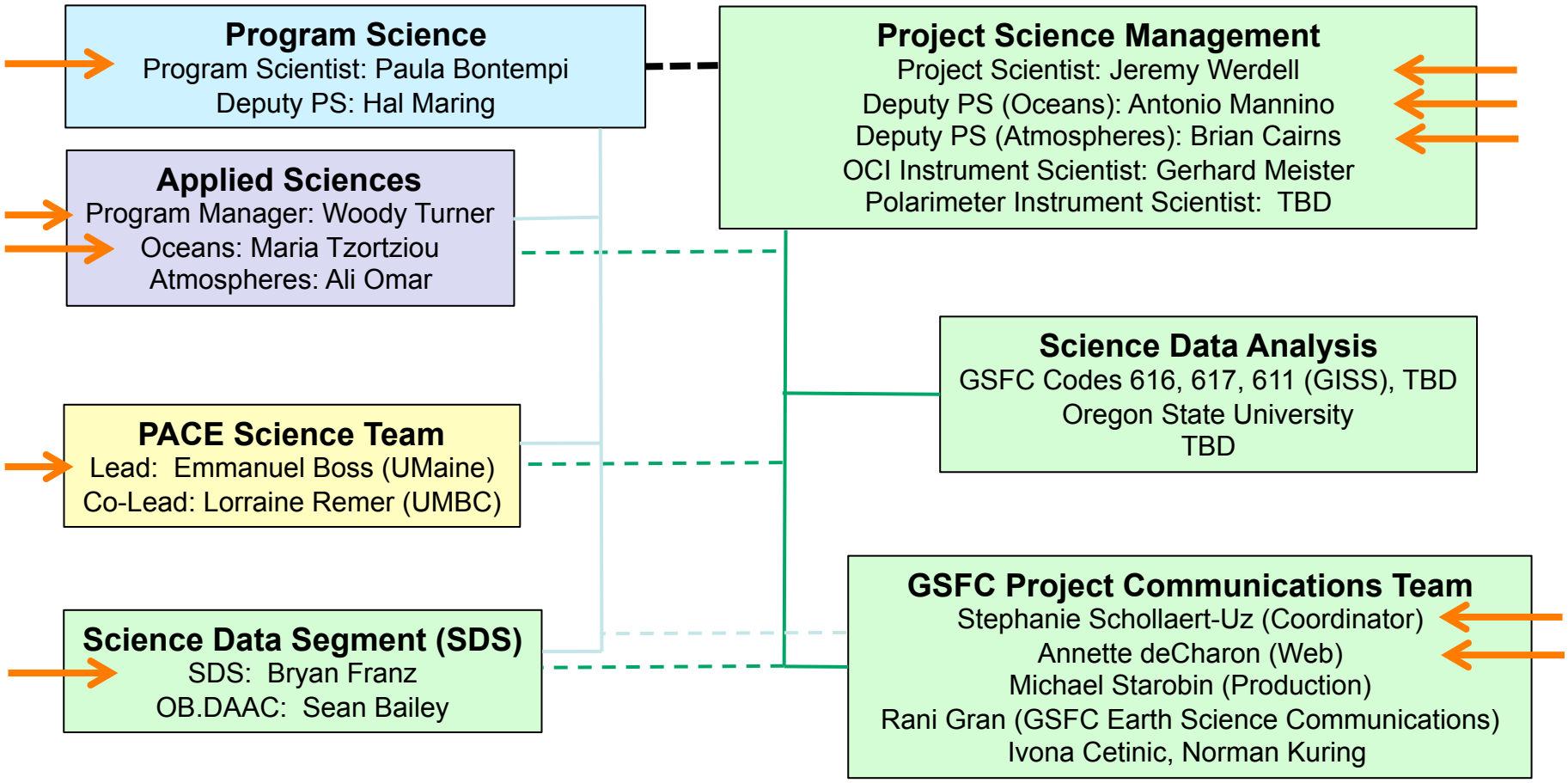
Science Team leaders:
Emmanuel Boss (UMaine) & Lorraine Remer (UMBC)

Focus:
Theoretical and analytical studies focused on inherent optical properties (IOPs) & atmospheric correction (including aerosol and cloud retrievals) with a remote sensing focus on hyperspectral radiometry and polarimetry

Deliverable:
Provide a consensus report outlining the path forward for producing operational algorithms for atmospheric correction and inherent optical properties (IOPs)

Goal:
Develop community-endorsed paths forward for PACE

Who is here from PACE?



PACE at the Ocean Sciences Meeting

EC21B: Present and Future Coastal and Inland Aquatic Remote Sensing for Science and Societal Benefit I

SESSION

Tuesday, February 23, 2016 08:00 AM - 10:00 AM

Ernest N. Morial Convention Center - 222

Christine Lee et al. POSTER

EC34D-1221: Application synergies between the NASA Pre- Aerosol Cloud and ocean Ecosystem (PACE) and Hyperspectral Infrared Imager (HysplRI) missions

Defining Priorities for NASA in Ocean Ecology and Biogeochemistry: 2017–2027

TOWN HALL

Synopsis

The next Decadal Survey for Earth Science, due out in 2017, will establish the observational needs and priorities for NASA, USGS and NOAA and will help guide the development of future space-based missions. NASA's Ocean Biology and Biogeochemistry Program is facilitating the development of a pre-Decadal Survey report that will identify the most pressing science questions and gaps in our understanding of ocean carbon-climate-ecosystem processes and prioritize new technology, modeling, and instrument/mission needs for the next decade. This townhall will engage the ocean community in reviewing and commenting on the OBB pre-Decadal Survey report.

Thursday, February 25, 2016 12:45 PM - 01:45 PM

Ernest N. Morial Convention Center - 211-213

2016 OCEAN SCIENCES MEETING

AGU • ASLO • The Oceanography Society

21–26 February • New Orleans, Louisiana, USA

ME51A: Frontiers in Ocean Color Remote Sensing: Science and Challenges I

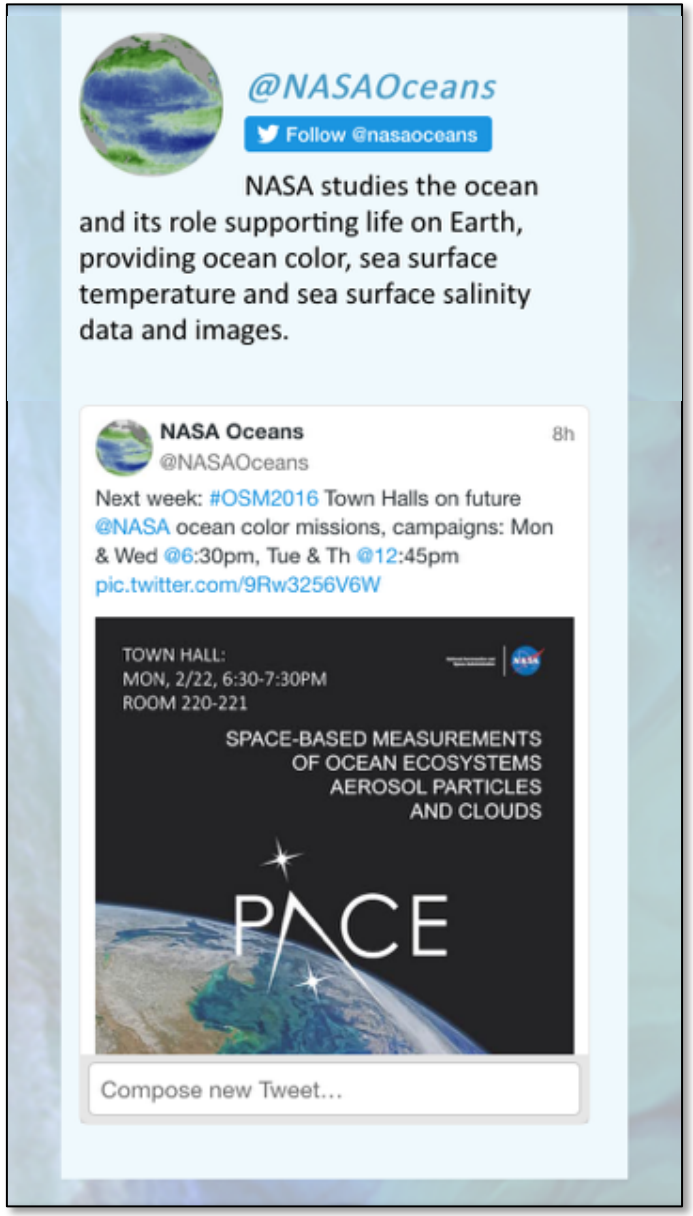
SESSION

Friday, February 26, 2016 08:00 AM - 10:00 AM

Ernest N. Morial Convention Center - RO2

Visit PACE online or through social media

pace.gsfc.nasa.gov



Community-driven philosophy