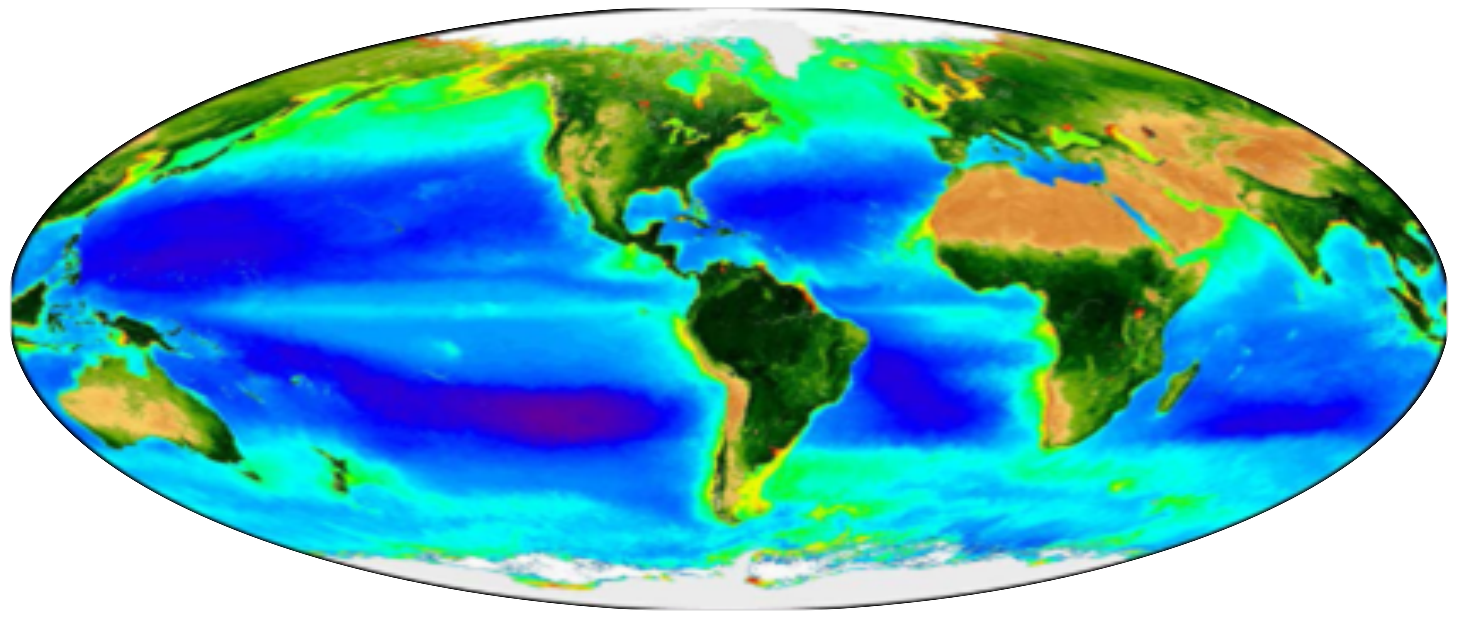
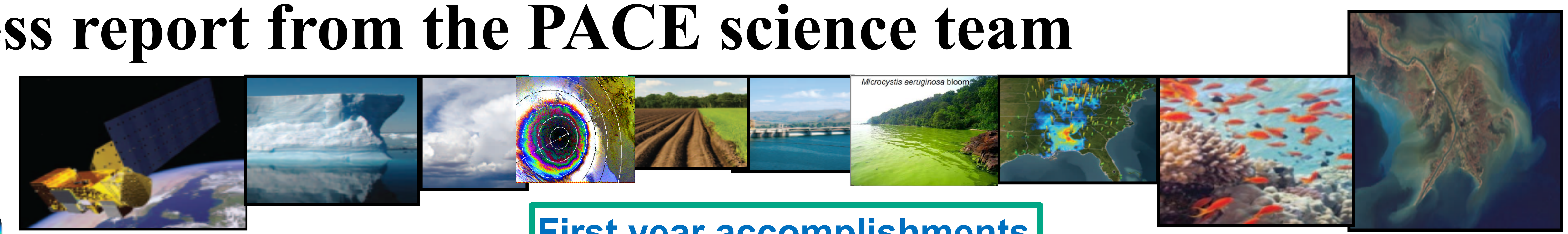
PACE ST-1: Emmanuel Boss (lead), Lorraine Remer (Co-lead), Steven Ackleson, Jacek Chowdhary, Susanne Craig, Heidi Dierssen, Bryan Franz, Robert Frouin, Bo-Cai Gao, Olga Kalashnikova, ZhongPing Lee, Stephane Maritorena, Greg Mitchell, Ali Omar, Steve Platnick, Collin Roesler, Cecile Rousseaux, Dariusz Stramski, James Sullivan, Michael Twardowski, Maia Tzortziou, Jeremy Werdell, Xiaodong Zhang. GSFC: Jeremy Werdell (Project Scientist), Antonio Mannino (Deputy PS for Ocean), Brian Cairns (deputy PS for atmosphere), Gerhard Meister (PACE OCI instrument Scientist), Andre Dress (Project Manager).

PACE SDT: Carlos Del Castillo (Chair), Steve Platnick (Deputy), David Antoine, Barney Balch, Mike Behrenfeld, Emmanuel Boss, Brian Cairns, Jacek Chowdhary, Ardino DaSilva, David Diner, Oleg Dubovik, Bryan Franz, Robert Frouin, Watson Gregg, Fred Huemmrich, Ralph Kahn, Alexander Marshak, Steve Massie, Charles McClain, Cameraon McNaughton, Gerhad Meister, Greg Mitchell, Frank Muller-Karger, Jeffery Puschell, David Siegel, Menghua Wang, Jeremy werdell.

Progress report from the PACE science team





Background

The **PACE (Plankton, Aerosol, Clouds and ocean Ecosystem)** mission is a strategic Climate Continuity mission, included in NASA's 2010 plan: *"Responding to the Challenge of Climate and Environmental Change: NASA's Plan for a Climate-Centric Architecture for Earth Observations and Applications from Space"*. On a polar orbit, PACE will make climate-quality global measurements that are essential for understanding ocean biology, biogeochemistry, ecology, aerosol and cloud properties, and determining how the ocean and atmosphere's role in global biogeochemical cycling, ocean ecology and perturbations to Earth's energy balance both affects and is affected by climate change.

With advanced global remote sensing capabilities PACE is expected to: 1. provide high quality observations which will contribute substantialy for both basic science and research as well as application and 2. Extend the current time-series of climate quality data to enable detection of long-term trends.

The PACE Science Team 1 (2014-2017)

The PACE science team has been selected in ROSES 2014 and has a three year span. A new science team will be assembled as part of a ROSES 2017 call.

Charge of the first PACE Science Team: collaboratively address inversion for in-water optical properties, and atmospheric characterization, including atmospheric correction.

Science Team goals:
•Achieve consensus about, and develop community-endorsed paths forward for the PACE sensor(s) for the full spectrum of IOP and atmospheric measurements, algorithms and retrievals.
• Identify gaps in knowledge, research and in technologies that should be filled to maximize the utility of PACE and contribute to it.

In addition, the ST is called upon to provide advise on imager and polarimeter specifications (e.g. we had a series of webminars to learn about new/available technologies, their attributes and the science they will facilitate).

While th members of the team each have been funded to accomplish *specific* science goals, here we highlight some of the team's collaborative accomplishments from its first year.

First year accomplishments

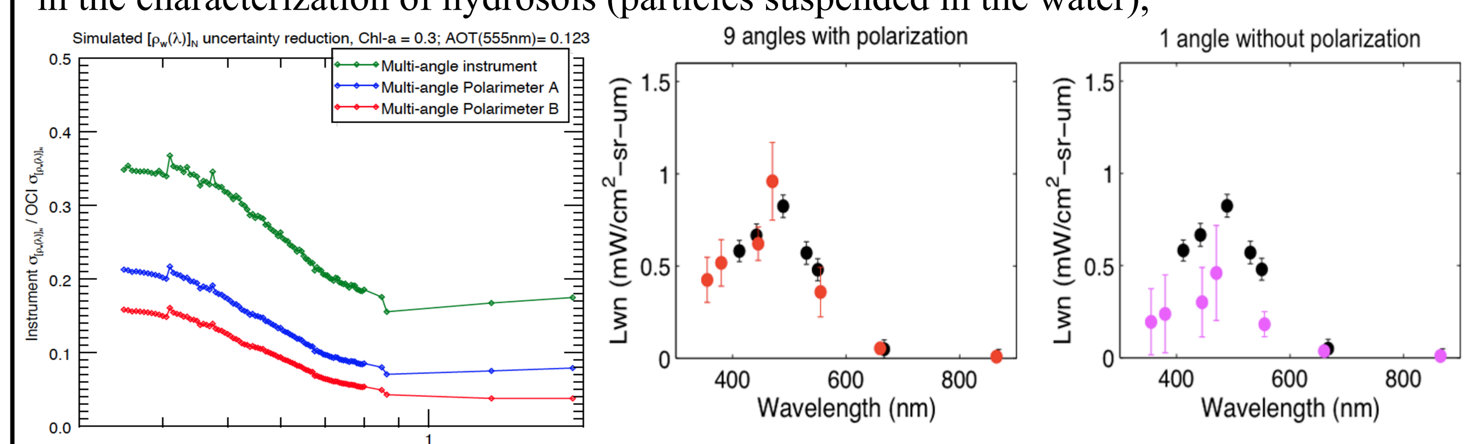
Polarimetry Report (Lead: L. Remer)

The PACE Science Team strongly endorses the inclusion of a polarimeter in the PACE mission. This consensus opinion is based on the following three reasons:

(1) There are specific atmospheric products related to both clouds and aerosols that can only be obtained with a multi-angle polarimeter

(2) Multi-angle polarimetry will reduce uncertainty in derivation of normalized water leaving radiance and provide more accurate atmospheric correction. (See figures.)

(3) Preliminary theoretical and observational studies that show that polarimetry can aid in the characterization of hydrosols (particles suspended in the water),



Ratio of uncertainty in normalized water leaving reflectance ($[\rho_w(\lambda)]_N$) between theoretical instruments having multi-angle and polarimetric capability and those measuring only radiometry at one view angle per target.

Left above. Colored symbols are atmospheric correction results derived from high altitude aircraft observations at 9 angles; 7 wavelengths; and with polarization. Right above. Colored symbols are results derived without angular and polarization information. In both, black symbols are measurements from SeaPRISM near sea surface.

Synthetic hyper-spectral IOP-AOP dataset (Lead: Z. Lee)

•**Objective:** Create a free-of-measurement-error hyperspectral (350-800 nm, 5 nm resolution) dataset for algorithm test and evaluation.

•**General rules:**

- Representative to commonly encountered waters.
- Consistent with up-to-date knowledge.

•**Approach:** create an IOP dataset, and feed it to Hydrolight to generate corresponding AOP spectra.

$$b_b(\lambda) = b_{bw}(\lambda) + b_{b-ph}(\lambda) + b_{b-dm}(\lambda)$$

$$a(\lambda) = a_w(\lambda) + a_{ph}(\lambda) + a_y(\lambda) + a_d(\lambda)$$

synthesized; constants; from measurements

•720 a_{ph} spectra (from >4000 SeaBASS spectra): 12 "groups" (separated by a_{ph}(440) value), and ~3 a_{ph} shapes within each "group".

$$a_y(\lambda) = a_y(440)e^{-S_y(\lambda-440)};\ a_y(440) = p_1 \times a_{ph}(440) \qquad a_d(\lambda) = a_d(440)e^{-S_d(\lambda-440)};\ a_d(440) = p_2 \times a_{ph}(440)$$

$$b_{b-ph}(\lambda) = 0.01 \times \left(c_{ph}(\lambda) - a_{ph}(\lambda)\right) \qquad b_{b-dm}(\lambda) = p_5 \times a_{ph}(440) \times \left(\frac{440}{\lambda}\right)^{p_6} \qquad c_{ph}(\lambda) = p_3 \times a_{ph}(440) \times \left(\frac{440}{\lambda}\right)^{p_4}$$

•Value of p_1, S_y, p_2, S_d, p_3, p_4, p_5, and p_6 are determined semi-randomly (within ranges from field observations) as in IOCCG Report #5.

In-situ dataset (Lead C. Rousseaux)

•**Objective:** To create a high quality, diverse and extensive database of existing hyperspectral inherent and apparent optical properties (IOP/AOP) data both polarized and non-polarized) for the validation of remote sensing products and the development of algorithms for the PACE mission

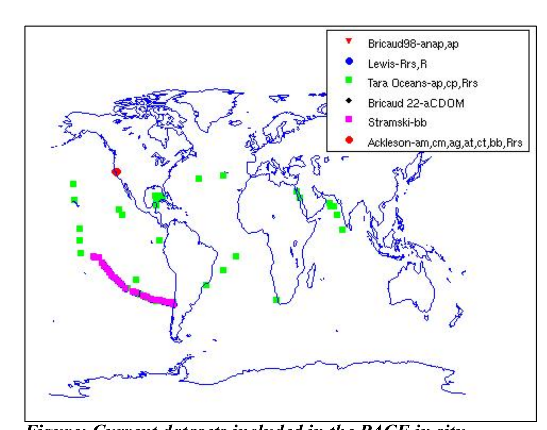


Figure: Current datasets included in the PACE in situ hyperspectral database

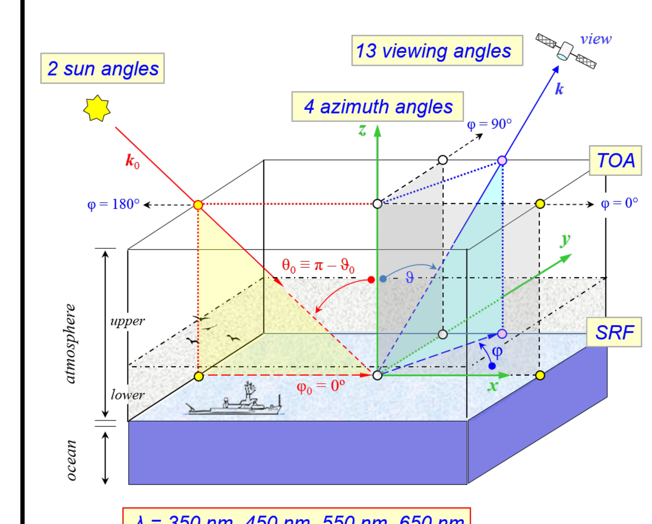
Variables of interest:
Sea Surface Temperature
Temperature MLD
Water Temperature
Salinity
Depth of measurment
Radiometry
Total absorption coefficient (aw+ap+ag)
Absorption coefficient of particles
Absorption coefficient of non algal detritus
Absorption coefficient of phytoplankton
Absorption coefficient of Gelbstoff + particles
Absorption coefficient of Gelbstoff
Total Backscattering Coefficient
Backscattering coefficient of particles
Beam attenuation coefficient of particles (ap+bb)
Beam attenuation coefficient
Attenuation coefficient of Gelbstoff+particles
Volume Scattering Function
Fluorescence of CDOM
Fluorescence of Chlorophyll

•**Outcome:** A database of hyperspectral IOP and AOP data covering a range of ecosystems to be used for the validation of PACE products and algorithms. This database will be published with every contributor as co-author in ~2017. Please contact Cecile S. Rousseaux (Cecile.S.Rousseaux@nasa.gov) and Emmanuel Boss (Emmanuel.Boss@maine.edu) for to contribute your data to this database or for any questions, recommendations or comments.

Intercomparision of polarized RT codes (Lead: J. Chowdhary)

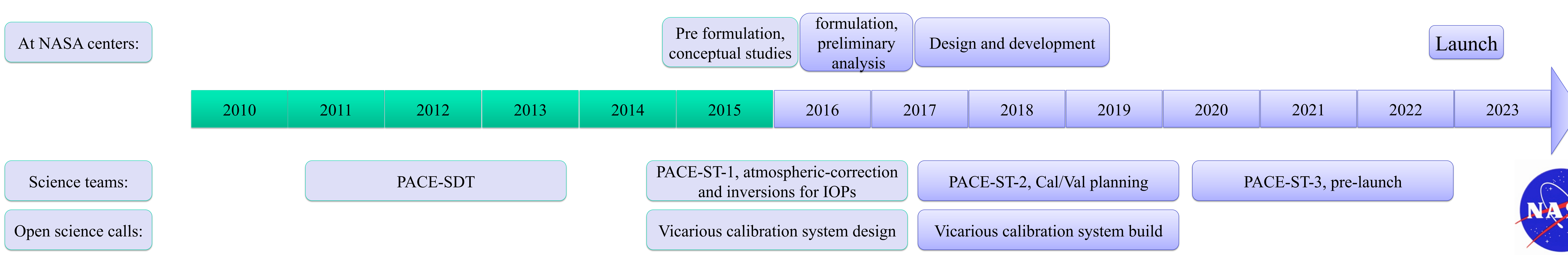
• **Objective:** The high measurement accuracy (0.2%-0.5%) of modern polarimeters deployed over oceans requires matching improvements in validating the simulation accuracy for polarized light scattered in atmosphere-ocean system (AOS) models

• **Set-up:** 5 AOS models, 104 scattering geometries, 2 altitudes, 4 wavelengths:



models	Ocean Body	Ocean Surface	Atmosphere
AOS-I	none	rough • Gaussian isotropic • No foam or shadowing	molecular • Pure Rayleigh scattering
AOS-II	pure water • Pure Rayleigh scattering	rough • Gaussian isotropic • No foam or shadowing	none
AOS-III	pure water • Pure Rayleigh scattering	rough • Gaussian isotropic • No foam or shadowing	molecular • Pure Rayleigh scattering
AOS-IV	pure water & hydrosol • Pure Rayleigh scattering • Detritus-Plankton mix	rough • Gaussian isotropic • No foam or shadowing	molecular • Pure Rayleigh scattering
AOS-V	pure water & hydrosol • Pure Rayleigh scattering • Detritus-Plankton mix	rough • Gaussian isotropic • No foam or shadowing	molecular & aerosol • Pure Rayleigh scattering • Fine-mode aerosol

• **Results:** Using 3 independently written RT codes that were based on 2 different methods, we obtained thus far for AOS-I to AOS-III agreement within 10^{-6} for Stokes parameters I, Q, U. This is 1-2 orders of magnitude better than previous comparisons, and leads to an <0.1% accuracy in degree of linear polarization.



PACE applications: Ali Omar, Maria Tzortziou NASA Head Quarters: Paula Bontempi, Hal Maring, Betsy Edward, Widdy Turner (applications)