PACE Inherent Optical Properties – Gaps Matrix

IOPs	State of the art	What is felt is needed for PACE
CDOM	Lab measurements spanning the full PACE spectrum. In situ limited to 410-750nm	In-situ spanning UV<->NIR instrumentation
ap	Lab measurements spanning the full PACE spectrum. Issues with sample stability in the UV. In-situ limited to 410-750nm. Significant uncertainty due to scattering correction, particularly where inorganic particles abound.	In-situ UV<->NIR instrumentation with reduced uncertainties compared to existing technology. Laboratory studies focused on a_phi in UV.
cp, bp	In situ sensors limited to 410-750nm (can also be used in the lab).	In-situ spanning UV<->NIR instrumentation at <5nm resolution Understanding of uncertainties arising from pumping water through instruments in different environments.
VSF, back-scattering	Commercial: near forward VSF at one wavelength (LISST). One or three angles in the back direction at a few wide bands (ECO-VSF, Eco-bb, Hydroscat). Prototypes: High angular resolution from 10-170degrees at one or a few wavelengths. New commercial sensor exists (LISST-VSF) but has not been vetted.	Need in-situ instrumentation from spanning UV<->NIR, with high angular resolution (<=10degrees).
Polarized IOPs	New commercial sensors for S11, S12 and S22 at a single wavelength exist (LISST-VSF, LISST-STOKES) but has not been vetted.	Need in-situ instrumentation spanning from UV<->NIR, with high angular resolution (<=10degrees).
Water optical properties	Papers by Pope and Fry, 1997, Lee et al., 2015, Mason et al, 2016.	Raman emission as function of T & S, depolarization ratio, Absorption values in the UV (current uncertainties ~0.002m^-1) including the influence of various inorganic compounds.

Scalar irradiance	PAR only	Hyper-spectral (UV-VIS-NIR) scalar radiometer.
Lu(0-)	Most often extrapolated from sub-surface measurement resulting in large uncertainties in red and NIR that are too large for validation studies.	Improved methods/measurement platform for Lu(0-) in red and NIR.

Other gaps:

Radiative transfer codes	Hydrolight – unpolarized, ocean only. Fully spectral and vector RT of ocean+atmosphere exist with Zhai, Chowdhary, Kattawar, Chami.	Commercial or open-source polarized ocean only RT code to increase understanding of the effects of polarization on scalar radiance fields, facilitate closure studies and inversion developments.
Codes for single particle models	Available codes for: Mie, coated spheres, spheroids and coated spheroids, simplified models of aggregates based on the above. Some groups have data for more complicated shapes but codes are not widely available.	More realistic models of oceanic particles to improve our understanding on how their microphysical properties affect the IOPs we measure.
Characterization of particle microphysical properties	Measurements for bulk properties (PSD, organic fraction, pigments). Early phase of single-particle imaging (size, scattering, fluorescence). Flow-cytometry.	High throughput single particle property analysis to better understand how IOPs relate to suspended particles covering particles from sub-micron to mm.
Measurement protocols	SeaWiFS era Protocols. Some (e.g. absorption) have been updated. Some are in review.	A full suite of community agreed protocols for ALL relevant in-situ measurements.

To improve inversion algorithms:

- Infrastructure for computationally demanding inverse algorithms.
- Comprehensive in-situ datasets with UV-NIR hyperspectral reflectance, IOPs and biogeochemical variables, and other environmental properties (e.g., temperature, salinity, MLD, depth, lat, lon, etc.).
- Research on how polarimetry could help improve inversions.
- Research on how PACE capabilities could be used to improve inversion of biogeochemical variables.
- Studies of other variables (e.g. lon, lat, temperature, MLD, distance from shore, depth) that could inform inversion algorithms.

Quantify system uncertainty:
Increased assessment and quantification of uncertainty budgets, including those associated with the satellite instrument, sub-pixel variability, atmospheric correction algorithms, bi-directional reflectance characterizations and simplified AOP-IOP relationships, in-water algorithms, and in-situ and laboratory measurements, so that efforts can target reduction of the largest sources of uncertainty.

For PACE validation:
A community definition of a “minimal” list of in situ observations for the purpose of PACE validation program.

To maximize PACE science:
There is a strong need for a national program supporting basic research in ocean optics in the US.