INTRODUCTION

The “NASA Ocean Optics Protocols for Satellite Ocean Color Validation” are community-vetted protocols that were first synthesized as part of the Sensor Intercomparison and Merger for Biological and Interdisciplinary Studies (SIMBIOS). This standard set of protocols, when followed explicitly, provides community-wide measurement consistency and accuracy that are necessary for minimizing measurement and data processing errors in multi-mission satellite algorithm development and validation. The protocols are living documents with topics separated into different volumes so each could be revised independently as standards and technology improve over time. However, the last revision to the protocols was in 2003 and, as such, they are due for an update. One of the overarching goals of the NASA Ocean Ecology Laboratory Field Support Group (FSG) is the revision and distribution of community-vetted protocols for in situ data collection, processing and analysis. To this end, the NASA FSG hosted an absorption workshop June 11-13, 2014 at NASA Goddard Space Flight Center that brought together an international collaboration of spectral absorption experts to produce the ultimate deliverable: a revised version of the Inherent Optical Properties Protocol (Revision 4, Vol. IV, 2003) that includes both liquid and filter pad techniques for measuring *ap*(*λ*).

THE WORKSHOP

The workshop participants (Table 1) focused on spectral particle absorption (*ap*(*λ*)) and updating the protocols used to separate *ap*(*λ*) into its individual components *aφ*(*λ*) and *ad*(*λ*). Each chapter of the 2003 protocol was assessed and updates, additions and reorganization of the protocol were addressed where necessary. A subset of the participants presented their expertise, updates to current methods and introduced new methods that have been developed since the publication of the last protocol.

1) Collin Roesler: Transmission Method

2) Eurico D’Sa: QFT measurements with an Ultrapath (Ultrapath QFT Measurement)

3) Dariusz Stramski and Rick Reynolds: Spectrophotometric measurements of particulate absorption coefficient with center-mounted samples in the integrating sphere

4) Rüdiger Röttgers: PSICAM measurements of particulate absorption in seawater

5) Mike Twardowski: ac device absorption measurements

6) Emmanuel Boss: Underway and Mooring sampling methods

7) Chris Proctor: SeaBASS Validation: Absorption

8) Aimee Neeley: Methods Unite: a method intercomparison

Of particular interest was to include methods and instrumentation that were developed after the publication of the 2003 protocol. Here, only a summary of the updates will be addressed. The rest of the updates will be available in the updated protocol to be released January 2015/February 2015.

INSTRUMENT UPDATES

1) IS method: filter pad absorption samples are placed in the center of a Spectralon-coated 150 mm cavity. The sphere is part of a diffuse reflection accessory that houses it’s own detector. The purpose of using the sphere is that it reduces the scattering error, i.e. the light that is lost when it is scatter within and out of the filter fibers.

2) PSICAM- Point Source integrating-cavity absorption meter (Kirk 1997; Rottgers and Doerffer, 2007): the cavity is made of a white, highly reflective material that reduces scattering errors. A central, diffuse light source is contained within the sphere. The effective pathlength of photons within the sphere is very long, increasing measurement sensitivity.

3) ac-s: The ac-s is a hyperspectral absorption and attenuation meter. It employs dual 25-cm pathlength flow cells. The light source is a collimated beam from a tungsten lamp, which passes through a linear variable filter. The absorption side has a reflecting tube and a large area diffuse detector, whereas the attenuation side has a non-reflective tube and a collimated detector. The instrument provides an 80+ wavelength output from approximately 400–730 nm with approximately 4 nm steps.

PROTOCOL UPDATES

1) *Sample collection*

A subset of blanks should be collected coincident with field samples and treat them as samples. It was suggested that 100 ml of ultrapure water should be filtered through the samples to remove potential contamination. Then the filter should be soaked in 0.2 μm filtered seawater and stored the same as the samples. These blanks should be measured and treated through the extraction process during sample analysis. Roesler (1998) hypothesized that if the same amount of water is filtered through the blank filter as through the sample filter, β can be assumed to be 2.0 (Kirk 1997). Additionally, filtering volumes should result in range of optical density 0.1 to 0.4 absorbance units.

2) *Satellite validation*

    Knowledge of the structure of the water column helps scientists in the field make good choices about what depths and how many samples to take water measurements. Approximately 90% of the light they measure comes from the first optical depth. Therefore, if the water column isn't homogeneous (e.g. if there is a subsurface *Ca* maximum within the first optical depth), then satellite validation requires multiple in-water measurements to be as accurate as possible. Post-measurement calculations (e.g. the optical-weighting calculations) are ideally made using attenuation coefficients derived from field measurements (coincident or relatively-coincident optics measurements; Chris Proctor, pers. comm. and Werdell and Bailey 2005).

Therefore, it has been recommended that in order to successfully sample for satellite validation, it must meet the following criteria:

1. Ideally sampling for filter pad analysis should occur coincident with optics measurements
2. The researcher should sample at multiple depths particularly in the first optical depth in order to characterize what the satellite ’sees’

3) *Deployment Strategies*

With increasing use of underway sampling and moorings to augment our repository of *in situ* data, particularly important for satellite validation, the addition of optics instrumentation has become attractive. However, biofouling, detector drift and degradation of the light sources are legitimate concerns for long-term deployment. Some strategies have been developed to counteract these issues (Slade et al. 2010) and will be further described in the protocol.

4) *Reporting Guidelines*

The participants proposed to generate a community log sheet to be included in the data submission to streamline uniformity. When submitting to SeaBASS include good documentation on data processing methods. Also provide optical density data with other metadata, such as volume filtered, so that the data can be reprocessed by the NASA OBPG if warranted.

Table 1: NASA Goddard Absorption Workshop Participants. Those with a \* indicate that they were not able to attend the workshop but will participate in editing the updated protocol.

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| Participants | Affiliation |
| Aimee Neeley | NASA Goddard Space Flight Center, Greenbelt, MD |
| Brian Schieber | Scripps Institution of Oceanography, La Jolla, CA |
| Emmanuel Boss | University of Maine, Orono, Maine |
| Rick Reynolds | Scripps Institution of Oceanography, La Jolla, CA |
| Dariusz Stramski | Scripps Institution of Oceanography, La Jolla, CA |
| Collin Roesler | Bowdoin College, Brunswick, Maine |
| Rüdiger Röttgers | Helmholtz-Zentrum Geesthacht , Centre for Materials and Coastal Research, Germany |
| Annick Bricaud | Laboratoire d'Océanographie de Villefranche, France |
| Marcel Babin\* | Universite Laval, Quebec |
| Eurico D’Sa | Louisiana State University, Baton Rouge, LA |
| Mike Twardowski | WetLabs, Inc, Narragansett, RI |
| Scott Freeman | NASA Goddard Space Flight Center, Greenbelt, MD |
| Mike Novak | NASA Goddard Space Flight Center, Greenbelt, MD |
| Antonio Mannino | NASA Goddard Space Flight Center, Greenbelt, MD |
| Chris Proctor | NASA Goddard Space Flight Center, Greenbelt, MD |
| Jeremy Werdell | NASA Goddard Space Flight Center, Greenbelt, MD |
| Mary Jane Perry\* | University of Maine, Orono, Maine |

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