<u>Splinter Session 8</u>: System Vicarious Calibration

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Program and Objectives

The Splinter Session aimed at:
i. *Summarizing the state-of-art on satellite ocean color vicarious calibration, and*
ii. *Discussing the need for advances in support of future missions*.

The state-of-art was summarized through a general introduction by the co-chairs, and targeted talks on current system vicarious calibration schemes applied to global missions and requirements for *in situ* data to support the system vicarious calibration of forthcoming ocean color missions. Three talks were presented:

1. *A general overview of the methods currently applied by the NASA Ocean Biology Processing Group to SeaWiFS and MODIS with focus on constraints for* in situ *reference data* delivered by Jeremy Werdell (NASA-GSFC);
2. *A general overview of the method currently applied by ESA for MERIS with focus on the dual source of* in situ *reference data* delivered by Constant Mazeran (ACRI-ST); and,
3. *An introduction to requirements for system vicarious calibration of future ocean color sensors with reference to sources of* in situ *data* delivered by Carlos Del Castillo (Johns Hopkins University).

Introduction

The general introduction to the Splinter Session summarized the rationale for the vicarious calibration of satellite ocean color sensors and reminded the audience of the legacy constraints for *in situ* measurements and sites supporting the process. In particular, it was recalled that the indirect calibration of satellite ocean color sensors, so called *System Vicarious Calibration***,** relies on the use of highly accurate *in situ* measurements of $L_w(\lambda)$ and the application of the radiative transfer code and models embedded in the atmospheric correction scheme. This solution leads to the calibration of the entire system, i.e., the sensor plus the atmospheric correction algorithm, and forces the satellite-derived $L_w(\lambda)$ to match on average that from the *in situ* source. The temporal calibration of the satellite instrument is considered independently before the system vicarious calibration.

Accuracy specifications for the calibration of the space sensor are imposed by the target uncertainties for the satellite-derived $L_w(\lambda)$ (see (National Research Council, 2011). That is, if one assumes a maximum acceptable uncertainty of 5% in $L_w(\lambda)$ and that $L_w(\lambda)$ is 10% of $L_T(\lambda)$, the uncertainty in top-of-atmosphere $L_T(\lambda)$ must be lower than 0.6%. The allowed uncertainty in $L_T(\lambda)$ decreases to approximately 0.3% when $L_w(\lambda)$ is 5% of $L_T(\lambda)$. These uncertainty values can only be achieved through system vicarious calibration, largely to account for uncertainties in the atmospheric correction process. The uncertainties achieved through system vicarious calibration are expected to be strictly valid for the specific “observation” conditions that characterized the indirect calibration process.

It was noted that when system vicarious calibration coefficients determined from different *in situ* data sets exhibit (spectral) biases as low as 0.3-0.6%, their interchangeability in the generation of derived data products should be considered with caution. In fact, radiometric products resulting from the application of the different system vicarious calibration coefficients may exhibit (spectral) differences (i.e., biases) of the order of the uncertainties considered acceptable. This suggests that *in situ* measurements and sites supporting system vicarious calibration of satellite ocean color sensors need to be carefully evaluated accounting for the actual application of satellite data products, recognizing that the downstream creation of CDRs imposes the most stringent conditions.

Finally, legacy constrains for vicarious calibration measurements and sites were listed. Early indications included (Gordon 1998):

1. Cloud free, very clear, maritime atmosphere (τ_a<0.1 in the visible) to maximize the capability of correctly determining the aerosol type;
2. Horizontally uniform $L_w(\lambda)$ over spatial scales of a few kilometers to minimize effects of non-homogeneity in the field of view;
3. Oligotrophic-mesotrophic waters to minimize uncertainties *in situ* measurement of $L_w(\lambda)$ in the blue spectral region; and,
4. Coincident aerosol measurements as an aid to the validation of aerosols retrieval in the system vicarious calibration process.

Additional more recent indications included (Clark et al. 2003):

5. Hyper-spectral measurements to comply with any ocean color spectral band spectral response;
6. Fully characterized *in situ* radiometers to minimize measurement uncertainties; and,
7. SI traceability to ensure production of absolute radiometric quantities with defined uncertainties.

Contributions from invited talks

Two of the invited talks illustrated state-of-art system vicarious calibration method(s) relying on the vicarious calibration of visible (VIS) bands with respect to near infrared (NIR) bands using highly accurate *in situ* VIS data and assuming space sensor sensitivity decay with time is independently addressed. The talks were specifically focused on NASA and ESA system vicarious calibration schemes relying on *in situ* measurements from MOBY (Clark et al. 2003) and BOUSSOLE (Antoine et al. 2008), and confirmed the robustness of the approaches currently applied by both agencies (which largely overlap).

The talk on requirements for system vicarious calibration focused on PACE and indicated the need for *in situ* measurements satisfying the following requirements:

1. Spectral range from 340-900 nm at ≤ 3 nm resolution;

2. Radiometric uncertainties ≤ 5% including contributions from instrument calibrations and data processing steps (with SI traceability);
3. Temporal radiometric stability ≤ 1% per deployment (with SI traceability);
4. Continuous deployment beginning one-year pre-launch and extending throughout the life of the mission; and,
5. Sufficient data acquisition rates to reduce vicarious gain standard errors to ≤ 0.2% within one year of launch.

Discussion

The discussion following the talks was supported by a series of seed questions that led to the following recommendations and conclusions

<u>Recommendations and Conclusions</u>

Recommendations from the Splinter Session on System Vicarious Calibration:

1. The current VIS and NIR method for system vicarious calibration of satellite ocean color sensors, which rely on the vicarious calibration of VIS bands with respect to NIR bands with the application of highly accurate *in situ* VIS data, is considered a robust approach over clear waters and should be considered for the forthcoming missions.

2. The importance of involving National Reference Laboratories in the characterization of field radiometers and SI traceability of measurements is essential. Still, the evaluation of new *in situ* platforms (i.e., gliders, AWS, …), in addition to existing bio-optical buoys, is recommended.

3. The analysis of legacy constraints for *in situ* measurements and sites supporting system vicarious calibration suggests that spatial homogeneity of the measurement site(s) is an essential requirement. The constraint on the aerosol optical thickness lower than 0.1 in the visible could be likely “relaxed” as long as the atmospheric conditions are well characterized. It is additionally recommended that the availability of supplementary atmospheric measurements at the vicarious measurement site(s) (e.g., vertical characterizations of the atmospheric components) are of potential aid to system vicarious calibration.

4. The use of commercial systems to support system vicarious calibration imposes the generation of *in situ* traceable measurements through fully characterized hyperspectral systems. This requires comprehensive characterizations of commercial hyperspectral systems whose performances often need thorough verification.

5. The standardization of system vicarious calibration is a necessary strategy for the generation of CDRs from multiple satellite instruments. Current system vicarious calibration exercises involving NASA and ESA sensors appear to indicate that the lack of standardization between institutions (not only for the system vicarious calibration process) may lead to significant differences in derived satellite data products not compatible with the creation of CDRs from independent missions. However, standardization using current technologies should consider that forthcoming advanced systems like PACE may benefit from additional measurement capabilities (e.g., polarization) with respect to current space sensors.

6. The short time available for the Splinter Session on System Vicarious Calibration has not provided the capability to comprehensively address all specific elements of relevance for the forthcoming satellite ocean color missions. It is then expected that results from the Splinter Session are the start for additional international actions aiming at detailing specific requirements and methods for System Vicarious Calibration of new missions like PACE and Sentinel-3.

References

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