System Vicarious Calibration: The Session

Co-Chairs: Giuseppe Zibordi (EC-JRC) and Jeremy Werdell (NASA-GSFC)

The Splinter Session on "**System Vicarious Calibration**" aimed at:

i. ***Summarizing the state-of-art on satellite ocean color vicarious calibration***
ii. ***Discussing the need for advances in support of future missions***.

System Vicarious Calibration is *the indirect calibration of the space sensor relying on the use of highly accurate in situ measurements of* L_w *and the application of the RT 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 algorithms* (Gordon 1998). Expected top-of-atmosphere calibration uncertainties are 0.3-0.5%, leading to uncertainties of 3-5% in L_w.

These uncertainties are expected to be strictly valid for the "measurement" conditions which characterize the "system vicarious calibration" process.

System Vicarious Calibration: Rationale

By assuming a maximum acceptable uncertainty of 5% in L_w determined from top-of-atmosphere L_T, if L_w is 10% of L_T, then the uncertainty in L_T needs to be lower than 0.6% (=5% x 10/90). The allowed uncertainty in L_T decreases to approximately 0.3% if L_w is 5% of L_T.

This can only achieved through "system vicarious calibration" mostly because of the inaccuracy of the atmospheric correction process.

*If vicarious calibration factors determined from independent in situ data sets exhibit (spectral) biases as low as 0.3-0.6%, their application may introduce a (spectral) **bias** of the order of the uncertainty considered acceptable for the derived radiometric data products.*

This suggests that in situ data sources for vicarious calibration of satellite ocean color sensors need to be carefully evaluated accounting for the actual application of satellite data products (recognizing that the creation of CDRs imposes the most stringent conditions).

System Vicarious Calibration: Constrains

Legacy constrains for vicarious calibration data/sites

- Early indications on the appropriateness of *in situ* data/sites included (Gordon 1998):
  1. Cloud free, very clear, maritime atmosphere (τ_a<0.1 in the visible);
  2. Horizontally uniform L_w over spatial scales of a few kms;
  3. Oligotrophic-mesotrophic waters (to minimize *in situ* measurement errors of L_w in the blue);
  4. Coincident aerosol measurements.

- Additional main indications suggested (Clark et al. 2003):
  5. Hyper-spectral measurements to cover any ocean color spectral band;
  6. Fully characterized *in situ* radiometers;
  7. SI traceable measurements.

System Vicarious Calibration: Talks

- ***General overview of the method currently applied by NASA-OPBG with focus on constrains for in situ reference data*** (Jeremy Werdell, NASA GSFC)
- ***General overview of the method currently applied by ESA for MERIS with focus on the dual source of in situ reference data*** (Constant Mazeran, ACRI-ST)
- ***Requirements for system vicarious calibration of future ocean color sensors with reference to sources of in situ data*** (Carlos Del Castillo, Johns Hopkins University)

System Vicarious Calibration: Discussion

Is there any need for revising the current VIS and NIR method?

(e.g., is there any alternative to the current method(s) relying on the vicarious calibration of VIS bands with respect NIR bands, using highly accurate in situ VIS data, and assuming space sensor sensitivity decay with time is accounted for elsewhere?)

The talks, focused on NASA and ESA "system vicarious calibrations" relying on MOBY and BOUSSOLE data, showed the robustness of the methods.

No alternative method was proposed except the "provocative" recommendation of performing the system vicarious calibration directly relying on chlorophyll concentration, if chlorophyll is the needed product for the generation of CDRs .

System Vicarious Calibration: Discussion

***Which are the requirements for traceability, uncertainty, temporal continuity, and data rate of in situ reference data*?**

(e.g., is there any community consensus on the specifications for in situ reference measurements, implying consensus on measuring instruments and methods?)

The talk on requirements for "system vicarious calibration" focusing on PACE, indicated:

1) Spectral range from 340-900 nm at ≤ 3 nm resolution
2) Total spectral radiometric uncertainties ≤ 5% including contributions from all instrument calibrations and data processing steps (with NIST traceability)
3) Temporal spectral radiometric stability ≤ 1% per deployment (with NIST traceability)
4) Continuous deployment beginning one year pre-launch and extending throughout the life of the PACE mission
5) Sufficient data acquisition rates to reduce vicarious gain standard errors to ≤ 0.2% within one year of launch.

The discussion remarked the importance of involving National Reference Laboratories in the characterization and calibration of field radiometers.

It was suggested to evaluate new in situ platforms (i.e., gliders, AWS) in addition to buoys. It was also asked if system vicarious calibration could not rely on "burst" measurements performed with small in situ systems deployed for limed time during the various ocean color missions. The main motivation appeared to be a minimization of costs justified by relatively inexpensive instrumentation and non continuous operations.

A related comment clarified that current running costs for continuous field deployments (i.e., MOBY) are not explained by the continuous deployment, but rather the continuous effort in characterizing and improving the measurement system.

It was stated that the continuative operation of at least one measuring system is an element undoubtedly warrantying consistency across successive satellite ocean color missions.

It was finally recommended to report uncertainties related to system vicarious calibration in absolute terms and not in percent only.

System Vicarious Calibration: Discussion

Is there any evidence that legacy environmental constrains of measurement data/site(s) could be relaxed?

(e.g., is it assured that relaxation of constrains for some environmental quantities can still allow for the determination of vicarious calibration coefficients suitable for climate investigations?)

The spatial homogeneity of the measurement site was stated to be an essential requirement.

It was reaffirmed that the constrain on the aerosol optical thickness lower than 0.1 in the visible could be likely " relaxed".

It was however recommended that the availability of additional atmospheric measurements at the vicarious measurement sites (e.g., vertical characterizations of the atmospheric components) could be a potential additional aid to system vicarious calibration.

System Vicarious Calibration: Discussion

Is there any evidence that requirements for field instrument(s) and method(s) could be somehow relaxed?

(e.g., by recognizing the major effort to assure the characterization of measuring systems like MOBy, is it assured that that relaxation of requirements for field instrument(s)/method(s) can still allow for the determination of vicarious calibration coefficients suitable for climate investigations?)

The discussion restated the extreme importance of in situ hyperspectral systems in support of system vicarious calibration.

Additionally some strong recommendation was made on the need for a comprehensive characterization of commercial hyperspectral systems whose performances still require a throughout verification.

System Vicarious Calibration: Discussion

Is there any need for standardizing the "system vicarious calibration" process across the various space missions devoted to the generation of CDR's?

(e.g., isn't that the need for generating CDRs by combining data products from fully independent space missions imposes the standardization of the vicarious calibration process for the various space sensors?)

The standardization of system vicarious calibration is considered a needed strategy for the generation of CDR's. However, it was also seen as a potential limitation for the indirect calibration of forthcoming advanced systems like PACE benefitting of additional measurement capabilities with respect to current space sensors.

Still current system vicarious calibration exercises involving NASA and ESA sensors, appear to indicate that le lack standardization (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.

System Vicarious Calibration: Discussion

Is it conceivable to generate regional products relying on relaxed requirements for the system vicarious calibration?

(e.g., by recognizing that current operational schemes are targeted to oligotrophic-mesotrophic waters, is there any general vicarious calibration strategy that can be suggested for regional applications not requiring the delivery of climate quality data?)

This topic for discussion remained "a topic for discussion".