Ocean Colour Vicarious Calibration
Community requirements for future infrastructures

IOCS 2017 - Breakout Workshop#3
Part II: Discussion on community requirements for any future SVC programme
High level scientific and technical requirements

15:05 – 15:25 Approach to define requirements (uncertainty, stability)
15:25 – 15:45 Requirements on the SVC process and site
15:45 – 16:00 Sources of uncertainty and example of quantified budget
What approach to define requirements?

1. Requirements on the SVC infrastructure are driven by the uncertainty budget of the gains (e.g. to reach 0.5% TOA)
   - Requirements are **not directly** defined by applications
   - Existing infrastructures provide **guidance**

2. Justification for the gain uncertainty (e.g. 0.5% TOA) are driven by requirements on OC products:
   - **Open ocean, climate applications**: 5% on Lw in the blue
   - **Coastal applications**: unknown. Effort should focus on AC

3. Focus on **System Vicarious Calibration** and on **standard** atmospheric correction (Gordon & Wang)

\[
\frac{u(L_w^{\text{cal}})}{L_w^{\text{cal}}} = u(\bar{g}) \left/ \left( \frac{t_g t_{up} L_w^{\text{cal}}}{L_t} \right) \right\} \rightarrow 5\% \text{ for } L_w \text{ with } t L_w / L_t = 10\% \text{ requires } u(\bar{g}) = 0.5\%
\]
What quality required in OCR?

4. **Commonly accepted radiometric uncertainty requirement** for CDRs: 5% (k=1) in the blue-green for open ocean (Gordon 1987, GCOS 2011)

5. Long-term stability is key attribute for CDRs, but **which requirement on stability?**
   - 0.5% per decade from GOCS 2011
   - 1% from Ohring et al. 2004: "somewhat arbitrary" by simple rule of “1/5”
   - Predicted change from numerical model (S. Dutkiewicz): 1% per decade for most of the ocean

6. **What metric to assess stability?**
   - Ohring 2004: *Stability is measured by the maximum excursion of the short-term-average measured value of a variable under identical conditions over a decade*
   - Zibordi et al. 2015: \( \frac{\sigma_{\bar{g}}}{\bar{g}} / \sqrt{N_y} \)
What requirements on the SVC process?

- What justification in the Level-1 calibration for one unique $\overline{g}(\lambda)$?
  - Characterisation and monitoring of sensor SRF (including out-of-band)
  - Correction for ageing. Use of lunar or on-board device for verification.
  - Across-track relative calibration. E.g. OLCI on-board diffuser and BRDF characterisation; what for scanner?
  - Non-linearity correction

- What requirement on the $L_w^t$ in the VIS, in terms of SVC process?
  - Choice of water type (meso/oligo) only driven by the uncertainty budget

$$\sigma_g = \sqrt{\left(\frac{\sigma_{L_{WN}^t}}{L_{WN}^t}\right)^2 + \left(\frac{\sigma_C}{C_Q}\right)^2 t_g t_s C_s C_Q L_{WN}^t L_t}$$

  Mesotrophic waters may minimize $L_w^t/L_t$ but increase $\sigma_{L_w^t}$ and $\sigma_C$

  - Calibration in radiance or reflectance: use of $L_{WN}^t$ or $L_{WN}^t/E_s^t * F_0$ ?

- How to evaluate various SVC options? Assess global impact of SVC?
  - Need high-quality validation dataset (Fiducial Reference Measurements)
What requirements at the SVC site?

- **Assuming a low uncertainty in** $L_w^t$ **is achieved (cf. full unc. budget):**
  - **Temporal stability?** An ideal external calibration source is one that is nearly constant in time and able to be viewed from different orbit configurations (Ohring 2004)
  - **Spatial homogeneity?** To be assessed by in situ measurements
  - **Characterisation of water IOPs?** Depth-extrapolation, BRDF correction

- **What atmospheric measurement (used for site selection & QC)?**
  - Need characterisation by dedicated space mission for aerosol (not OC mission) + field measurement (LIDAR, AERONET) at least during one year
  - During operation, monthly measurement of AOT($\lambda$)

- **Can multiple sites be used? What requirement on the “super-site”?**
  - Redundancy is recommended from a metrology point of view (weighted average gains) + limit impact of any failure + maximise # of match-ups
  - Requirements: strict equivalence in terms of uncertainty, traceability, protocols, observation conditions. Statistical proof of equivalence of gains
Sources of uncertainty

- Completeness of the uncertainty sources?

<table>
<thead>
<tr>
<th>OC-VCAL ID</th>
<th>Uncertainty source</th>
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<tbody>
<tr>
<td>OC-VCAL-RD-14</td>
<td>Spectral resolution</td>
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<tr>
<td>OC-VCAL-RD-15</td>
<td>Spectral calibration</td>
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<td>OC-VCAL-RD-16</td>
<td>Stray-light</td>
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<tr>
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<td>Radiometric calibration &amp; stability</td>
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<tr>
<td>OC-VCAL-RD-18</td>
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<tr>
<td>OC-VCAL-RD-19</td>
<td>Immersion factor</td>
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<td>OC-VCAL-RD-22</td>
<td>Polarisation sensitivity</td>
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<td>OC-VCAL-RD-24</td>
<td>Noise characterisation</td>
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<tr>
<td>OC-VCAL-RD-25</td>
<td>Environ. conditions (like-to-like rule)</td>
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<tr>
<td>OC-VCAL-RD-26</td>
<td>Shading</td>
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<td>OC-VCAL-RD-27</td>
<td>BRDF</td>
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<td>OC-VCAL-RD-28</td>
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<td>OC-VCAL-RD-29</td>
<td>Surface propagation</td>
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<td>OC-VCAL-RD-30</td>
<td>Data reduction</td>
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<td>OC-VCAL-RD-31</td>
<td>Other effects</td>
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<tr>
<td>OC-VCAL-RD-32</td>
<td>Total uncertainty on in situ Lw</td>
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Gain computation

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<td>Spectral integration to satellite SRF</td>
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<td>BRDF correction to satellite geometry</td>
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<tr>
<td>OC-VCAL-RD-41-42-43</td>
<td>Match-up process</td>
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<tr>
<td>OC-VCAL-RD-44</td>
<td>Individual gains (Eq. 23)</td>
</tr>
<tr>
<td>OC-VCAL-RD-44</td>
<td>Averaging (Eq. 22)</td>
</tr>
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</table>

In situ radiometer (Lw)

Lw post-processing and match-up
### Uncertainty budget - Example

- **Examples to be discussed**
  - Random and systematic components in the averaging: \[ \sigma_g^2 = \left( \frac{\sigma_{g_{\text{rand}}}}{\sqrt{N}} \right)^2 + (\sigma_{g_{\text{syst}}})^2 \]

#### Table: Uncertainty Budget

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<td>Total uncertainty on in situ Lw</td>
<td>3.25% 2.61% 3.25%</td>
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<td></td>
<td>Total uncertainty on post-processed in situ Lw for match-up</td>
<td>6.04% 2.81% 6.04%</td>
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<td>0.14% 0.06% 0.20%</td>
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<tr>
<td></td>
<td>Total uncertainty on mission average gain</td>
<td>0.15% 0.15% 0.21%</td>
<td>0.15% 0.15% 0.21%</td>
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In this example: \[ t_g t_C Q L_w \]

\[ = 5\% \text{ at } 400, 412 \]

\[ = 7\% \text{ at } 443 \]
Operational requirements

16:00 – 16:10 Field operation and maintenance
16:10 – 16:20 Data access and timelines
16:20 – 16:30 Service operation & science
Field operation & maintenance

- What rotation?
  - Frequency of rotation of 4 to 6 months (max)
  - Maybe limited to some component of the structure
  - Continuity between deployment

- What routine maintenance?
  - Divers for cleaning and checking anomalous measurements

- What autonomous field operation?
  - Store all measured data (optical + platform + environmental)
  - Continuous transmission to the lab
Data access and timelines

• What access?
  • Data publicly and freely available on a website
  • Documentation on measurement protocols, field operation, quality level
  • Raw data, Lw data, history of calibration
  • Automated graph
  • Open source code to process raw data to Lw
  • Rigorous version management system
  • Levels of data quality (cf. AERONET-OC)
  • Different levels of uncertainty depending on levels of data quality
  • Sampling strategy programmed according to LEO/GEO acquisition

• What latency?
  • For early phase of mission: quick delivery (one week)
  • With reduced quality for NRT monitoring: daily or weekly
  • With highest quality for SVC (after post-calibration): after several months
Service operation & science

- What type of operation is required?
  - **Operational component** for SVC. For Copernicus: rely on Service Level Agreement (SLA)
  - **Evolutionary and science component**. Research activity possibly funded by other programmes

- What requirements to run a sustainable SVC service?
  - Service aligned on the mission lifetime (e.g. Copernicus)
  - Long-term funding. Cost driven by the characterisation, calibration and maintenance, not the equipment.
  - Contingency funding in case of emergency
  - Sustainable team with demonstrated experience, training, redundancy of PI
  - Joint development and operation with a NMI
Programmatic steps and international activities

16:30 – 16:40 International harmonisation
16:40 – 16:50 Programmatic steps
International harmonisation

• What could be the required actions for international harmonisation?
  • Link with CEOS and IOCCG, in particular INSITU-OCR
  • Create an IOCCG task force and or Working Group
  • Harmonisation in infrastructure? Intercomparison in Lu measurement with a dedicated transfer instrument (with similar radiometric quality)
  • Harmonised protocols
  • Consistent uncertainty budget assessment (metrology)
  • Data and code sharing
  • Training
Programmatic steps

- In US: next steps after the ROSES call?
- In Asia and Oceania:
  - Plans for GOCI-II (KIOST)?
  - Plans for the Kavaratti buoy in Arabian Sea (ISRO)?
  - Buoy off Australia?
- In Europe:
  - Conclusions of FRM4SOC workshop:
    - Two sites in Europe, including BOUSSOLE
    - Long-term investment is critical (initial purchase and installation but also adequate funding for on-going operations in terms of updates/ upgrades, maintenance, and consistent staffing that develops and retains expertise
  - What should be the next steps towards a SVC programme?
    - Step1: Scientific, technical and operational requirements (EUMETSAT report)
    - Step2: Preliminary design, project plan and costing
    - Step 3: Technical definition, specifications, detailed design
    - Step 4: Development, testing and demonstration in the field
    - Step 5: Operation
Conclusion
Message to decision-makers

- How to justify SVC with a self-explanatory image?

Impact of vicarious calibration on chlorophyll-a concentration, as measured by MERIS over the Med Sea in April 2008. The relative change (in %) is due to disabling vicarious calibration.
Coordinated message to IOCS

- **Goal:** identify ONE highest priority for SVC, captured in a single sentence, to be discussed during the final IOCS Q&A session with space agencies

- **Suggestion:**

  Main priority for operational SVC is to ensure sustainable resources (people and infrastructure) along the complete lifetime of current and future OC missions