International Ocean Colour Science Meeting 2017

Advancing Global Ocean Colour Observations

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)

$\frac{u(\overline{L_w^{cal}})}{\overline{L_w^{cal}}} = u(\bar{g}) / \left(\frac{t_g t_{up} \overline{L_w^{cal}}}{L_t} \right)$ → 5% for L_w with tL_w/L_t=10% requires u($\bar{g}$)=0.5%

What quality required in OCR?

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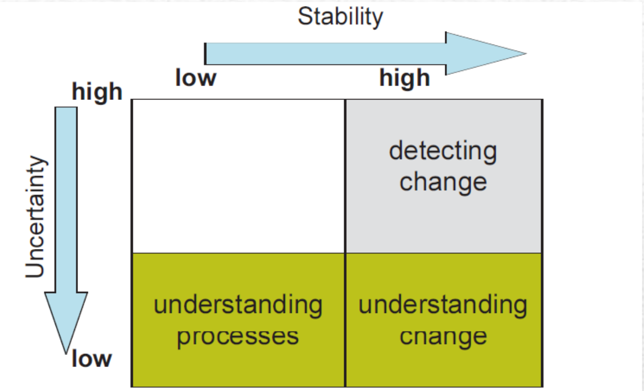
- **Commonly accepted radiometric uncertainty requirement** for CDRs: 5% (k=1) in the blue-green for open ocean (Gordon 1987, GCOS 2011)



Uncertainty and stability requirement for CDR. From Ohring et al. 2004

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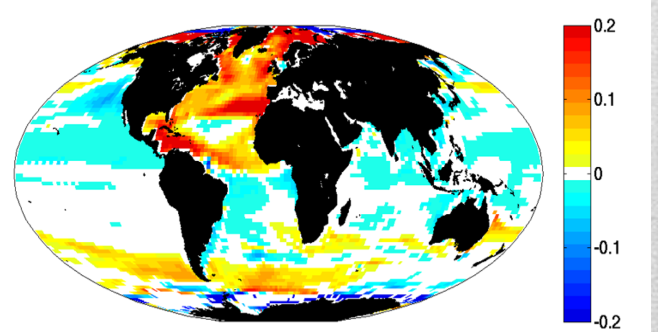
- Long-term stability is key attribute for CDRs, but **which requirement on stability?**
  - 0.5% per decade from GOCS 2011
  - 1% from Ohring et al. 2004: "*somewhat arbitrary*" by simple rule of "1/5"
  - Predicted change from numerical model (S. Dutkiewicz): 1% per decade for most of the ocean



Predicted change in rrs(475) per year [%] over the 21st century. From Dutkiewicz 2016

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- **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: $\left(\sigma_{\bar{g}}/\bar{g}\right)/\sqrt{N_y}$

What requirements on the SVC process?

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- **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

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- **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

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

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

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

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- **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 assess by in situ measurements
  - **Characterisation of water IOPs?** Depth-extrapolation, BRDF correction

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- **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(λ)

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- **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

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Sources of uncertainty

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- **Completeness of the uncertainty sources?**

In situ radiometer (Lw)

Lw post-processing and match-up

Gain computation

OC-VCAL ID	Uncertainty source
In situ Lw measurement	
OC-VCAL-RD-14	Spectral resolution
OC-VCAL-RD-15	Spectral calibration
OC-VCAL-RD-16	Stray-light
OC-VCAL-RD-17	Radiometric calibration & stability
OC-VCAL-RD-18	Angular response
OC-VCAL-RD-19	Immersion factor
OC-VCAL-RD-20	Thermal stability
OC-VCAL-RD-21	Dark current
OC-VCAL-RD-22	Polarisation sensivity
OC-VCAL-RD-23	Non-linearity response
OC-VCAL-RD-24	Noise characterisation
OC-VCAL-RD-25	Environ. conditions (like-to-like rule)
OC-VCAL-RD-26	Shading
OC-VCAL-RD-27	BRDF
OC-VCAL-RD-28	Depth-extrapolation
OC-VCAL-RD-29	Surface propagation
OC-VCAL-RD-30	Data reduction
	Other effects
Total uncertainty on in situ Lw	
In situ Lw post-processing and match-up	
OC-VCAL-RD-39	Spectral integration to satellite SRF
OC-VCAL-RD-40	BRDF correction to satellite geometry
OC-VCAL-RD-41-42-43	Match-up process
Total uncertainty on post-processed in situ Lw for match-up	
SVC gains	
OC-VCAL-RD-44	Individual gains (Eq. 23)
OC-VCAL-RD-44	Averaging (Eq. 22)

Uncertainty budget - Example

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

OC-VCAL ID	Uncertainty source	rel_unc(400) rand.	rel_unc(400) syst.	rel_unc(412) rand.	rel_unc(412) syst.	rel_unc(443) rand.	rel_unc(443) syst.
In situ Lw measurement							
OC-VCAL-RD-14	Spectral resolution		0.50%		0.50%		0.50%
OC-VCAL-RD-15	Spectral calibration		0.10%		0.10%		0.10%
OC-VCAL-RD-16	Stray-light		0.75%		0.75%		0.75%
OC-VCAL-RD-17	Radiometric calibration & stability		2.00%		2.00%		2.00%
OC-VCAL-RD-18	Angular response						
OC-VCAL-RD-19	Immersion factor	0.05%		0.05%		0.05%	
OC-VCAL-RD-20	Thermal stability	0.30%		0.30%		0.30%	
OC-VCAL-RD-21	Dark current						
OC-VCAL-RD-22	Polarisation sensivity	0.20%		0.20%		0.20%	
OC-VCAL-RD-23	Non-linearity response		0.10%		0.10%		0.10%
OC-VCAL-RD-24	Noise characterisation						
OC-VCAL-RD-25	Environ. conditions (like-to-like rule)	0.50%		0.50%		0.50%	
OC-VCAL-RD-26	Shading		1.00%		1.00%		1.00%
OC-VCAL-RD-27	BRDF	0.30%		0.30%		0.30%	
OC-VCAL-RD-28	Depth-extrapolation	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%
OC-VCAL-RD-29	Surface propagation	0.25%		0.25%		0.25%	
OC-VCAL-RD-30	Data reduction	3.00%		3.00%		3.00%	
	Other effects						
Total uncertainty on in situ Lw		3.25%	2.61%	3.25%	2.61%	3.25%	2.61%
In situ Lw post-processing and match-up							
OC-VCAL-RD-39	Spectral integration to satellite SRF		0.20%		0.20%		0.20%
OC-VCAL-RD-40	BRDF correction to satellite geometry	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%
OC-VCAL-RD-41-42-43	Match-up process	5.00%		5.00%		5.00%	
Total uncertainty on post-processed in situ Lw for match-up		6.04%	2.81%	6.04%	2.81%	6.04%	2.81%
SVC gains							
OC-VCAL-RD-44	Individual gains (Eq. 23)	0.30%	0.14%	0.30%	0.14%	0.42%	0.20%
OC-VCAL-RD-44	Averaging (Eq. 22)	0.04%	0.14%	0.04%	0.14%	0.06%	0.20%
Total uncertainty on mission average gain		0.15%		0.15%		0.21%	

In this example:

$\frac{t_g t C_Q L_w^t}{L_t}$=5% at 400, 412

= 7% 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

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

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

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

Data access and timelines

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- **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

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- **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

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- **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

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Programmatic steps and international activities

16:30 – 16:40 International harmonisation

16:40 – 16:50 Programmatic steps

International harmonisation

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- **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

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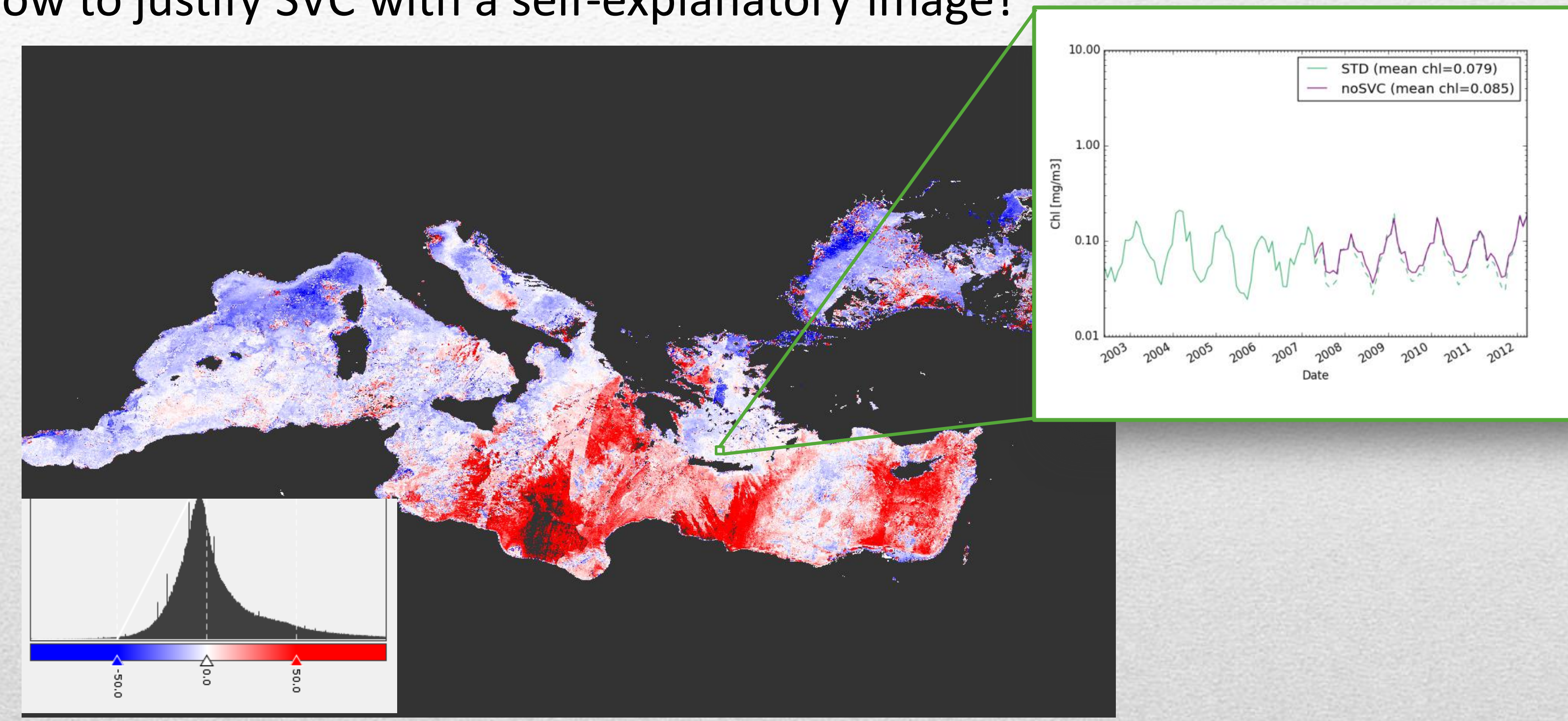
- **In US: next steps after the ROSES call?**
- **In Asia and Oceania:**
  - Plans for GOCI-II (KIOST)?
  - Plans for the Kavaratti buoy in Arabian Sea (ISRO)?
  - Buoy off Australia?
- **In Europe:**
  - **Conclusions of FRM4SOC workshop:**
    - Two sites in Europe, including BOUSSOLE
    - Long-term 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

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