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Lessons Learned from Operation of On-Board Calibration Devices on Sentinel-2 MSI and Sentinel-3 OLCI

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CCVS Project Overview

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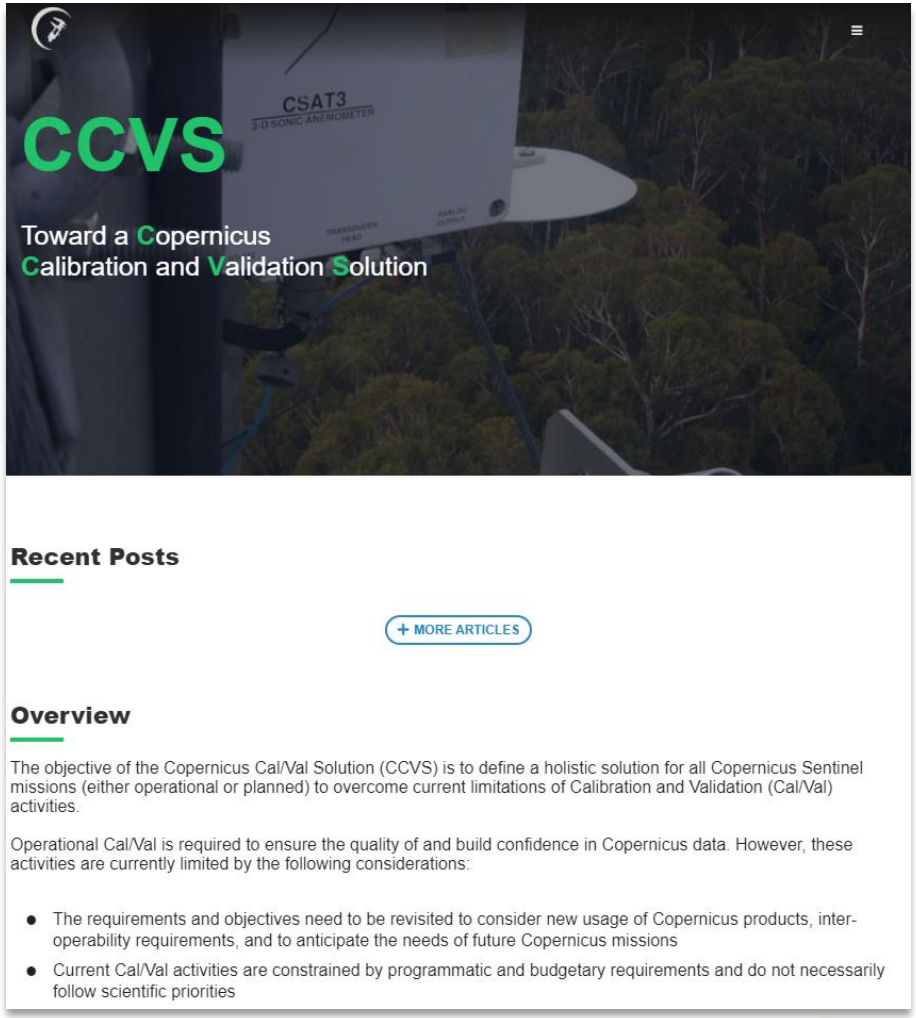
- Copernicus Cal/Val Solution (CCVS) is a H2020 R&D project funded by the European Union
- Objective: *"To define a holistic solution for all Copernicus Sentinel missions (either operational or planned) to overcome current limitations of Calibration and Validation (Cal/Val) activities."*
- Kick-Off 02/12/2020
- 2-year project
  - Phase 1 (completed): Analysis and state of the art
  - Phase 2 (in progress): Elaboration of a new Cal/Val Solution
- More info on https://ccvs.eu



On-Board Calibration Sources for Sentinel optical missions

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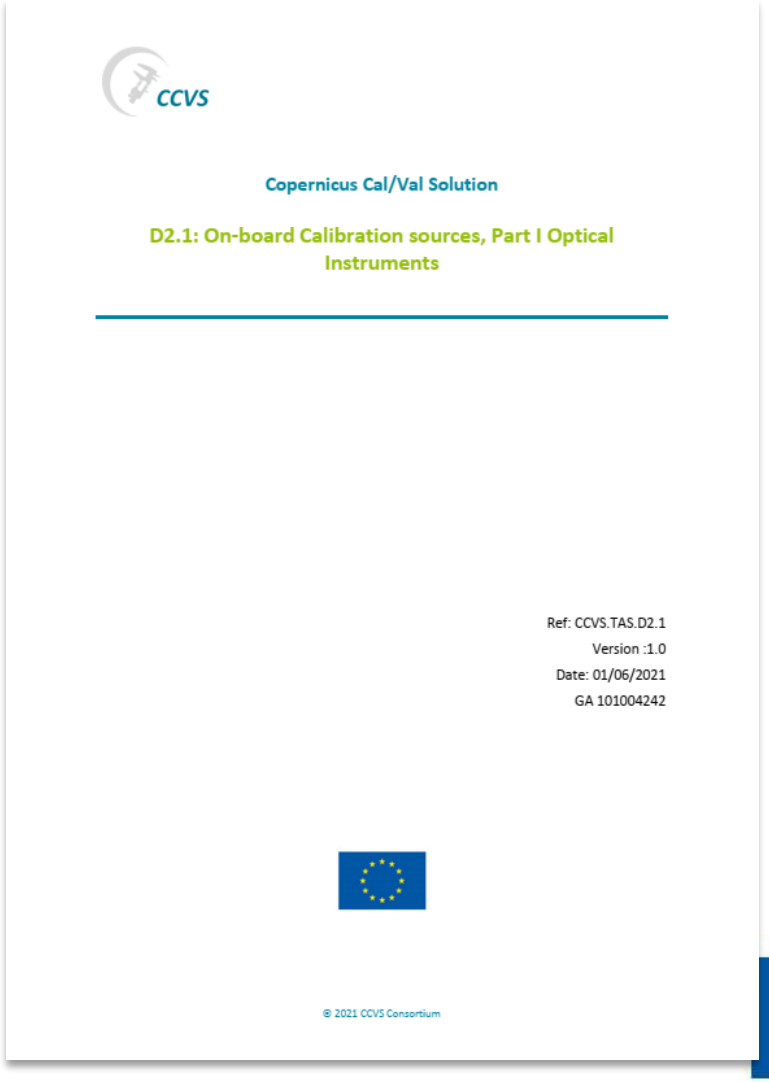
- As part of the state-of-the-art analysis, a review of On-Board Calibration sources for optical instruments has been prepared
- Activity coordinated by Thales Alenia Space
- Document available on-line from the ccvs.eu website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Copernicus Cal/Val Solution

D2.1: On-board Calibration sources, Part I Optical Instruments

Ref: CCVS.TAS.D2.1
Version :1.0
Date: 01/06/2021
GA 101004242

On-Board Calibration Sources for Sentinel optical missions

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Contents : 4 main sections

- **On-board calibration sub-systems**
  - ✓ Calibration sub-system per mission
  - ✓ Calibration frequency, operational constraints, lifetime
- **On-board calibration sources**
  - ✓ Solar diffuser, White Light Sources, LED, Tunable laser diodes, Black bodies
  - ✓ Characteristics, on-ground characterization and associated measurement uncertainties, lifetime
  - ✓ Alternatives and perspectives

	Optical missions			Atmospheric Composition missions		
	Sentinel 2	Sentinel 3 OLCI	Sentinel 3 SLSTR	Sentinel 4	Sentinel 5P	Sentinel 5
Solar diffuser(s)	Y	Y	Y	Y	Y	Y
White Light Source	-	-	-	Y	Y	Y
LED(s)	-	-	-	Y	Y	Y
Tuneable laser diodes	-	-	-	-	Y	Y
Blackbody	-	-	Y	-	-	-
Shutter	-	Y	-	-	Y	Y

On-board calibration sources for Sentinel optical missions

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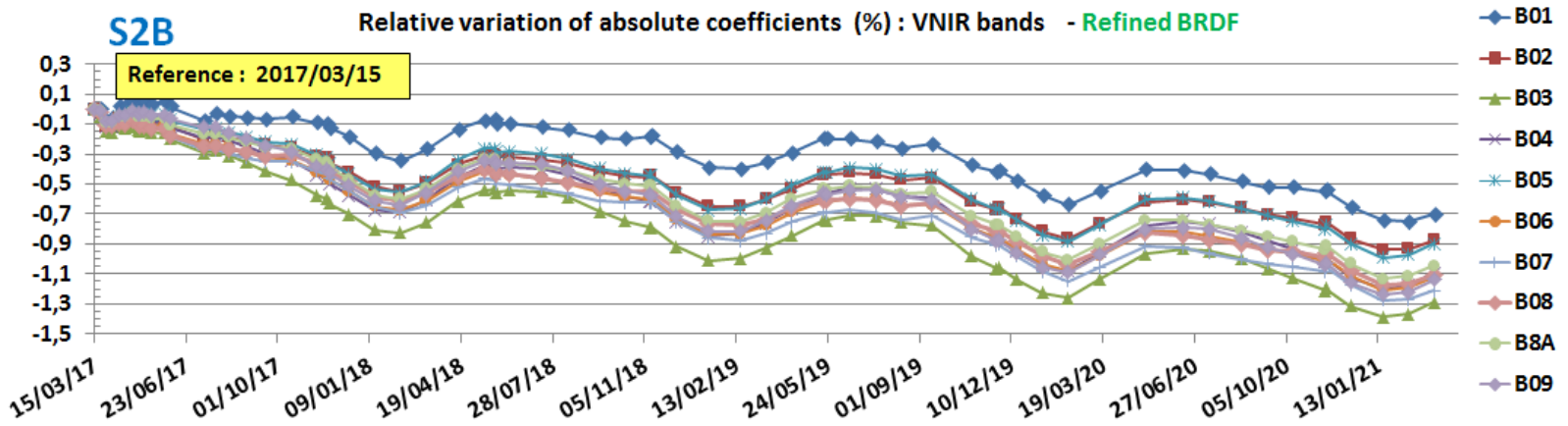
- **Presentation of the document**
  - **Pre-flight Instrument characterization/calibration**
    - ✓ Detector calibration
    - ✓ Spectral calibration
    - ✓ Radiometric calibration
    - ✓ Geometric calibration
  - **User feedback and recommendations**
    - ✓ Sentinel 2
    - ✓ Sentinel 3 OLCI & SLSTR
    - ✓ Sentinel 5P TROPOMI

	Calibration , correction and monitoring
Solar Diffuser	Absolute radiometric calibration Relative gains calibration (equalisation) Defective pixel identification
White Light Source	Pixel Response Non Uniformity
LED	Linearity calibration Defective pixel identification Monitoring of the Full Well Capacity Monitoring of diffuser degradation
Tuneable laser diode	Spectral response function stability calibration Spectral localisation Straylight monitoring
Blackbody	Absolute radiometric Calibration Relative gains calibration (equalisation) Defective pixel identification
Shutter	Dark calibration

- **First conclusion :**
  - **User feedback on radiometric calibration with solar diffuser**
    - ✓ Observation of seasonal artefacts due to BRDF inaccuracies
      - For OLCI and TROPOMI, corrected through characterization with yaw maneuvers



    - ✓ Gap in absolute radiometric calibration performed on-ground and performed in-flight on the different missions as well as on different models on the same mission
      - ~2.5% between OLCI-A and B
      - ~1.1% between MSI-A and B

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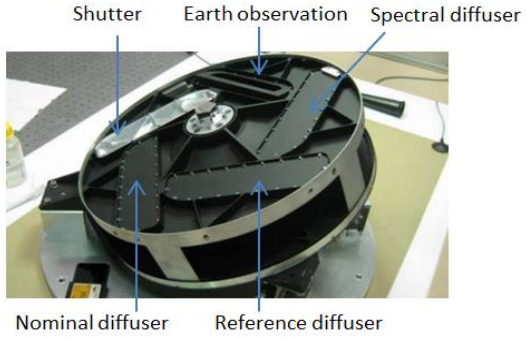
- **First conclusion :**
  - **Based on available data, the other on-board calibration sources perform as expected**
    - ✓ Sentinel 3 SLSTR blackbodies
    - ✓ Sentinel 3 OLCI spectral diffuser
    - ✓ Sentinel 5P calibration sources : LEDs, WLS and tuneable laser diodes



OLCI calibration wheel with solar diffusers and spectral diffuser (TAS)

On-board calibration sources for Sentinel optical missions

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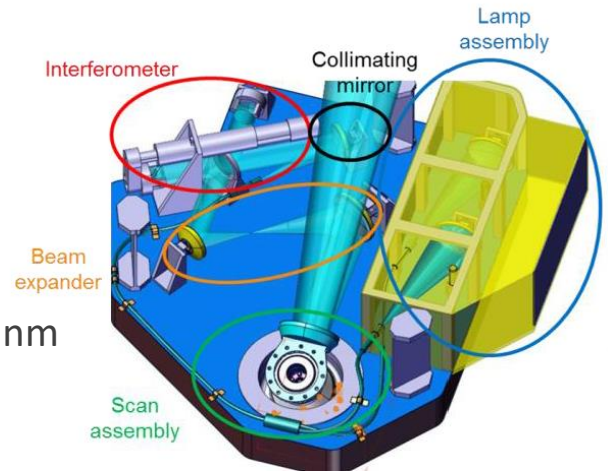

- **First conclusion : Promising ideas / Innovation to be developed**
  - **Promising technologies**
    - ✓ Spectral calibration
      - Broad range source, 270-2400 nm (Garnier et al ICSO 2021) with high accuracy 0.5 nm
    - ✓ Thermal infrared radiometric calibration
      - High performance black coating (high emissivity on a large spectral range)
      - Flat black bodies
      - Traceability to International System of Unit through embedded Phase Change Cells (Smith et al 2020)
  - **Alternatives**
    - ✓ to Solar diffuser: neutral density lens inserted in the optical path (MTG –FCI)
    - ✓ to large dimension calibration source at instrument entrance: calibration source of reduced dimension inserted close to an intermediate pupil plane
      - Small dimension black bodies in MTG-FCI and IRS

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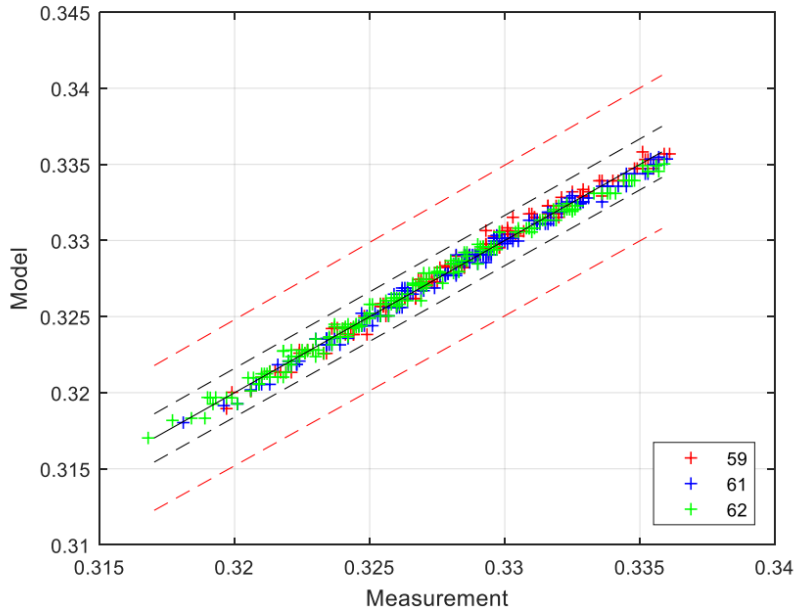
- **First conclusion : Technologies to be improved/developed**
  - **Enhancement of the on-ground characterization of the on-board sources**
    - ✓ Absolute and relative diffuser BSDF characterization consolidation: increase source power to improve SNR and reduce integration time
    - ✓ Instrument end-to-end test
      - provides calibration of the full chain
      - implies strong constraints in terms of AIT, costly and often on the critical path of the instrument
  - **Ageing model and ageing monitoring of the on-board sources**
    - ✓ For future mission of longer lifetime, the calibration source ageing will be further studied and consolidated



Comparison between modelled and measured diffuser BRDF for MSI model 4 @ 705 nm (credits CSL)

On-board calibration devices for Sentinel optical missions

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- **First conclusions : best practices to be generalized**
  - **Traceability of the on-board sources measurement uncertainties and budget**
    - ✓ Available to ESA and Prime contractors generally not published (exception of S3-SLSTR and S5P-TROPOMI)
    - ✓ Should be provided to the MPC and users
- **First conclusions : recommendation of on-ground / in-flight repartition**
  - **Generalization of yaw maneuvers for relative radiometric calibration of diffuser solar angle dependence**
    - ✓ Better accuracy in flight than on ground (relative only)
    - ✓ Shall be limited to the essential angular range to avoid diffuser(s) early ageing
    - ✓ Implies constraints in terms of platform agility and instrument thermal architecture
  - **Limitation of the on–ground instrument line-of-sight geometrical tests to 'good health test'**
    - ✓ Better accuracy in flight than on ground

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- Sentinel Optical missions implement a large range of on-board calibration devices
  - Globally help meeting instrument radiometric performance requirements (with a few exceptions)
  - Good consistency and temporal stability
  - No reliability issue so far
- However some shortcomings are identified
  - Discrepancies between units in the same family
  - Angular response characterisation artifacts for diffusers
- Best practices to be generalized
  - Instrument-level characterization tests (if possible) for radiometry
  - Make characterization error budget available, ideally with standardized methodology
  - Implement in-flight characterization procedure (yaw manoeuvres) for relative radiometry (temporal/in-field)
- New technologies to be developed
  - BSDF characterization, flat/small blackbodies, phase-change cells…

Announcement

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- CCVS workshop 13/15th October 2021 (afternoon)

- Registration and abstract submission now open
  - Seize the opportunity to contribute to the cal/val solution for future Copernicus mission

Objectives:

The CCVS workshop will be a multi-disciplinary forum adressing the main components of the Copernicus program: atmospheric composition, optical observations, altimetry and radard imaging. It will:

- Present an overview of existing calibration and validation sources for the cal/val of sentinel misions;
- Identify gaps and limitations;
- Propose improvements, synergies and innovations for the future.

Audience:

The workshop is open to international experts on calibration and validation, in-situ measurement, as well as users of Sentinel products interested in quality aspects.

Technical solution:

The workshop will use the Worksup platform, allowing parallel virtual poster sessions, networking, and live chat. the platform can be accessed from a web browser, mobile, or tablet. No download is required.

Format:

The workshop will combine:

- Invited presentations by stakeholders of the Copernicus program, cal/val and in-situe measurement experts;
- Round tables addressing workshop objectives;
- Contributed presentations and virtual posters.

It will be organized in three afternoons: