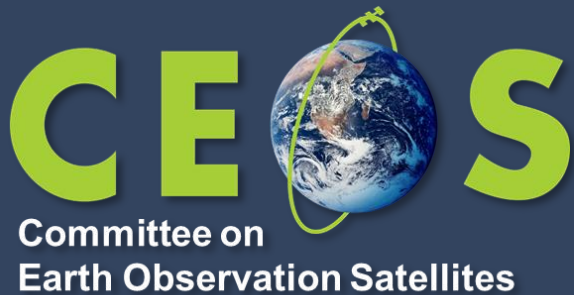


WGCV AGSG

Atmospheric Composition Cal/Val Updates



Jean-Christopher Lambert (BIRA-IASB)

Agenda Item 2.10

AC-VC #21 / ACSG Joint Meeting 2025

Takamatsu, Japan, 9-13 June 2025

Working Group on Calibration and Validation (WGCV) *(talk 2.09 by M. Thankappan)*

Several AO domains, Atmospheric Composition SG since 2001 *(this talk)*

WGCV activities relevant to atmospheric composition

- Pre-flight/in-flight calibration, SI-Traceable Satellites *(6.08 Shiomi, 2.11 Fox, 5.03 August)*
- Cal/Val best practices and protocols *(2.06 Keppens, 2.13 Koopman)*
- Support to Cal/Val networks: RadCalNet, HYPERNETS, TIRCALNET, FRM programmes, infrastructures... *(many updates in AC-VC thematic sessions)*
- CEOS-FRM Maturity Assessment Framework *(2.12 Castracane)*
- Interoperability framework: vocabulary, architecture, interfacing, quality, policy
- Collaboration with WMO, CGMS-GSICS, ISO/OGC, IMEO
- CEOS-ARD certification, VH-RODA, New Space engagement
- CEOS Cal/Val Portal

- ❖ Best practices: vicarious calibration, DCC, ISO 19159, PICS, Rayleigh Scattering, SNO/SONO, GEO/LEO...
- ❖ SWIR Cal/Val for GOSAT-1/2, OCO-2/3 & TROPOMI *(talk 6.08 by Kei Shiomi)*
 - Regular OCO-GOSAT-TROPOMI Calibration Meetings
 - Vicarious calibration & campaigns website at JAXA https://www.eorc.jaxa.jp/GOSAT/GHG_Vical/index.html
 - Match-up database for SWIR and TIR sounders *(talk 1.02 by Hiroshi Suto)*
- ❖ SI-Traceable Satellites (SITSat) Task Team *(talk 2.11 by Nigel Fox)*
- ❖ Collaboration with CGMS-GSICS
 - WGCV participation in GSICS annual meetings
 - Pre-flight Optical Sensors Calibration Workshop, ESA/ESTEC, 2024/11

❖ Community practices

- Peer-reviewed articles, ISO 19124-1 ⇒ Cal/Val Resources document
- Aerosol, Cloud & Precipitation Profile Validation (ACPPV)

CV-22-01

Talk 2.13 Koopman

❖ Tropospheric ozone datasets harmonization and validation

VC-20-01

Talk 2.06 Keppens

❖ Support to validation of constellations

GHG-TT, VC-20-02/03/04

❖ CEOS-FRM – Atmospheric composition engagement

CV-23-01

Talk 2.12 Castracane

❖ CINDI-3 intercomparison campaign

CV-24-01

Talk 3.22 Van Roozendaal

❖ Tracking evolving needs, gaps and issues

General discussion Thursday 5pm

Validation Protocol for Aerosols and Cloud Profiles

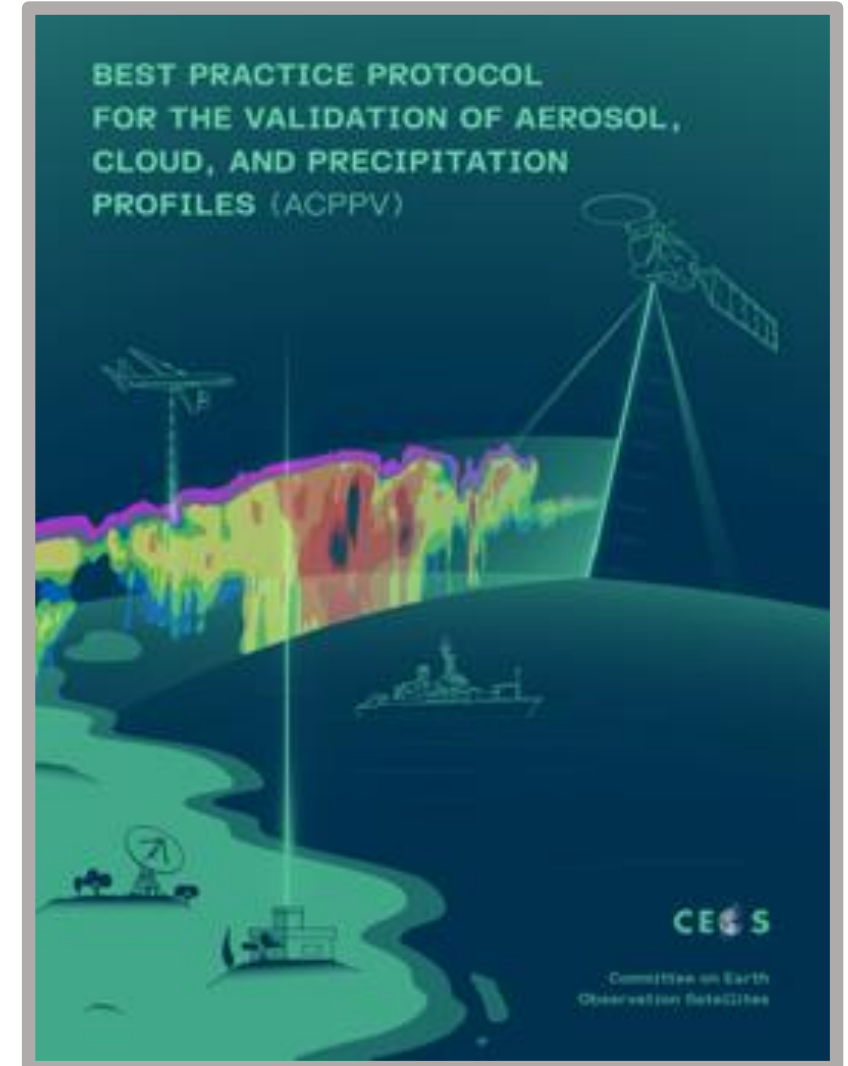


See presentation 2.13 by Rob Koopman

- ❖ Community effort: NOAA, NASA, ESA, DLR, JAXA, NILU, many universities (FI, US, DE, GR...), 51 affiliations
- ❖ 16 lead authors, 70+ co-authors
- ❖ Reviewed by WGCV and endorsed in Oct. 2024

Content

- Validation needs for space profilers
- Survey of validation measurements
- Correlative metadata and data format
- Guidance for the validation of lidar and aerosol products
- Guidance for the validation of Radar, cloud and precipitation products
- Statistical validation
- Near-real-time validation through monitoring in NWP data assimilation
- Gaps and challenges



Frameworks and Protocols

Cross-EO domains validation framework,
standardized in ISO/TS 19124-1

Round-robin protocol for nadir profilers incl.
AK-based information content analysis and QIs

Vertical state harmonization incl. tropospheric
column representativeness and error propagation
of data harmonization

Error budget closure of validation incl. 2D/3D
representativeness and co-location mismatch
errors

AGU PUBLICATIONS

Reviews of Geophysics

REVIEW ARTICLE
10.1002/2017RG000562

Validation practices for satellite-based Earth observation data across communities

Key Points:

- First review of EO validation approaches across different Geoscience communities
- Validation approaches depend on the intermittency and inhomogeneity

Alexander Loew^{1,2}, William Bell³, Luca Brocca⁴, Claire E. Bulgin⁵, Jörg Burdanowitz⁶, Xavier Calbet⁷, Reik V. Donner⁸, Darren Ghent⁹, Alexander Gruber¹⁰, Thomas Kaminski¹¹, Julian Kinzel¹², Christian Klepp¹³, Jean-Christopher Lambert¹⁴, Gabriela Schaeppman-Strub¹⁵, Marc Schröder¹², and Tijl Verhoelst¹⁴

Atmos. Meas. Tech., 8, 2093–2120, 2015
www.atmos-meas-tech.net/8/2093/2015/
doi:10.5194/amt-8-2093-2015
© Author(s) 2015. CC Attribution 3.0 License.

Atmospheric Measurement Techniques

Round-robin evaluation of nadir ozone profile retrievals: methodology and application to MetOp-A GOME-2

A. Keppens¹, J.-C. Lambert¹, J. Granville¹, G. Miles², R. Siddans², J. C. A. van Peet³, R. J. van der A³, D. Hubert¹, T. Verhoelst¹, A. Delcloot⁴, S. Godin-Beekmann⁵, R. Kivi⁶, R. Stübi⁷, and C. Zehner⁸

Atmos. Meas. Tech., 12, 4379–4391, 2019
https://doi.org/10.5194/amt-12-4379-2019
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Atmospheric Measurement Techniques

Harmonization and comparison of vertically resolved atmospheric state observations: methods, effects, and uncertainty budget

Arno Kennens, Steven Compernelle, Tijl Verhoelst, Daan Hubert, and Jean-Christopher Lambert

Atmos. Meas. Tech., 8, 5039–5062, 2015
www.atmos-meas-tech.net/8/5039/2015/
doi:10.5194/amt-8-5039-2015
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Atmospheric Measurement Techniques

Metrology of ground-based satellite validation: co-location mismatch and smoothing issues of total ozone comparisons

T. Verhoelst¹, J. Granville¹, F. Hendrick¹, U. Köhler², C. Lerot¹, J.-P. Pommereau³, A. Redondas⁴, M. Van Roozendaal¹, and J.-C. Lambert¹



Ground-based networks design

There is a need for R&D on *network design*, in particular for emerging measurement networks, but also for FRM-tailoring and sustainability of the existing networks.

Cal/Val
requirements =>
objective gap
analysis criteria
for Cal/Val
infrastructures

- ❖ Range of measurand
- ❖ Geographical coverage, types of atmospheric states (or regimes)
- ❖ Range and sampling of main influence quantities (SZA, T profile, surface albedo, aerosols, clouds...)
- ❖ Assessment of the spatio-temporal representativeness of measurements at a given location – requiring also assessment of spatio-temporal variability at that location => complementarity of airborne campaigns and modelling
- ❖ Co-location of instruments at 'supersites', e.g., SWIR with UVVIS, atmospheric composition and ancillary data (incl. surf. albedo) for in-depth validation of retrieval algorithms, validation of attribution proxies (simultaneous measurements of CO₂, NO₂, HCHO, SIF, smoke AOD)...

<http://ccvs.eu>



Cal/Val Resources Document



<https://calvalportal.ceos.org/web/guest/hyperspectral-calval-resources>

CEOS Cal/Val Portal
Hyperspectral Cal/Val Resources

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Hyperspectral Cal/Val Resources: Introduction

The "Hyperspectral Cal/Val Resources" document was created following the request made to the CEOS for guidance on Cal/Val hyperspectral reference instrumentation for: land, coastal and open ocean measurements with the aim of having a coordinated global network for all satellite missions with hyperspectral sensors on board.

A spaceborne hyperspectral imaging sensor is an advanced spaceborne optical sensor that captures high spectral resolution images of the Earth's surface in many contiguous bands across the electromagnetic spectrum, typically between the visible to shortwave infrared ranges. The data collected by spaceborne hyperspectral imaging sensors are used in a wide range of applications, including environmental monitoring, agriculture, forestry, and non-renewable resources exploration and extraction. The list of hyperspectral missions is growing rapidly with new missions being launched by countries around the world.

In general Cal/Val activities for a Hyperspectral Mission will include the elements (Methods, Protocols and standards; Network and Instruments; Campaign; Intercomparison exercises and Cal/Val Analysis) sketched in the figure below:

Please download the Hyperspectral Cal/Val Resources document by CEOS WGCV available [here](#)

Additional material is available below

The WGCV-S2 presentation "Hyperspectral Cal/Val Resources" is available [here](#)

Plan for an Atmospheric Composition Cal/Val Resources document

- Frameworks, protocols, guidelines
 - ✓ Generic validation process, terminology
 - ✓ Metrics, data comparison error budget
- End-to-end validation from L1B and L2 to L3
- FRMs and other validation measurements
 - ✓ Monitoring networks
 - ✓ Campaigns
 - ✓ Supersite concepts
 - ✓ CEOS-FRM maturity
- Cross-satellite validation
- Alternative retrievals
- Tools, databases and services
- Mission-specific resources

See 2.12 talk by Paolo Castracane
<https://calvalportal.ceos.org/web/guest/frms-assessment-framework>

CEOS-FRM Maturity Assessment Framework version 1 (2023)



remote sensing

Open Access Communication



Order Article

Fiducial Reference Measurements (FRMs): What Are They?

by Philippe Goryl^{1,*}, Nigel Fox², Craig Donlon³ and Paolo Castracane⁴

Self-assessment					Independent assessor
Nature of FRM	FRM Instrumentation	Operations/ sampling	Data	Metrology	Verification
Descriptor	Instrument Documentation	Automation level	Data completeness	Uncertainty Characterisation	Guidelines adherence
Location/ availability of FRM	Evidence of traceable calibration	Measurand sampling	Availability and Usability	Traceability Documentation	Utilisation/Feedback
Range of sensors	Maintenance plan	ATBDs on processing/software	Data Format	Comparison/calibration of FRM	Metrology verification
Complementary observations	Operator expertise	Guidelines on transformation to satellite Pixel	Ancillary Data	Adequacy for intended class of sensors	Independent <u>Verification</u>
FRM CLASSIFICATION					A B C D (to be selected)



Self-assessment pilots



BREWER NO₂

Self-assessments published in Remote Sensing Special Issue



See 2.12 talk by Paolo Castracane

CEOS-FRM Version 2

- ❖ V1 applicable to a measurement \Rightarrow classification
- ❖ V2: additional column characterizing 'completeness of validation capacity' achieved by network deployment of the same instrumentation, centralized processing, and timeliness; not a classification criteria
- ❖ Not meant to be applicable to multi-species/multi-instruments/GHG-AQ-synergy supersite concepts
- ❖ Intended to be applied systematically

Completeness, coverage and distribution
Validation capacity
Geographical coverage
Temporal sampling
Centralized data, processing, quality assessment and adherence to community standards
Timeliness

Cal/Val Needs for the Constellations



Air Quality



PM 2.5



GHG



GHG Constellation Roadmap V2 – Annex C – L2VAL-03

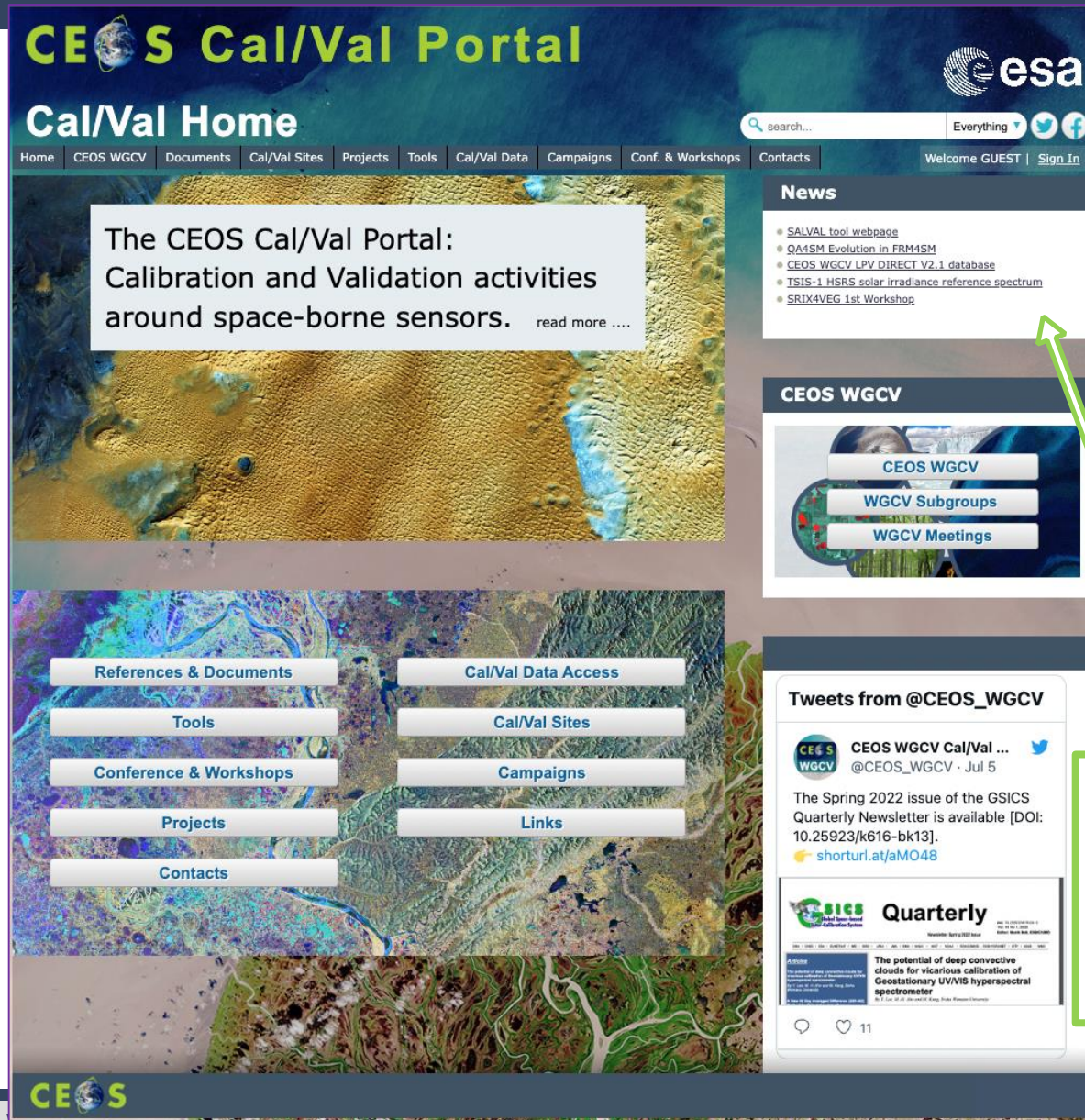
- To track L2 validation Capabilities, Evolving Needs and Gaps in the ground-based L2 validation system
- To explore a more operational framework for delivering its products to support evolving GHG mission needs

Extension to other thematic domains

- Ozone: ongoing collaboration with WMO GAW
- Air Quality: C CVS gap analysis; AGU 2024 update talk, ESA LPS25 session

➤ AC-VC / ACSG General Discussion Th 17:00-17:30

- 5.01 – Tracking need, gaps and issues'
- 5.02 – 'WMO ET on Network Design and Evolution'



The screenshot shows the CEOS Cal/Val Portal homepage. At the top, there's a header with the CEOS logo and 'Cal/Val Home'. Below this is a navigation bar with links: Home, CEOS WGCV, Documents, Cal/Val Sites, Projects, Tools, Cal/Val Data, Campaigns, Conf. & Workshops, and Contacts. A search bar and social media icons are also present. The main content area features a large banner with the text 'The CEOS Cal/Val Portal: Calibration and Validation activities around space-borne sensors.' and a 'read more' link. To the right, there's a 'News' section with a list of recent updates, including 'SALVAL tool webpage', 'QA4SM Evolution in FRM4SM', 'CEOS WGCV LPV DIRECT V2.1 database', 'TSIS-1 HSRS solar irradiance reference spectrum', and 'SRX4VEG 1st Workshop'. Below the news is a 'CEOS WGCV' section with links to 'CEOS WGCV', 'WGCV Subgroups', and 'WGCV Meetings'. At the bottom, there's a 'Tweets from @CEOS_WGCV' section showing a tweet about the Spring 2022 issue of the GSICS Quarterly Newsletter. A green arrow points from the 'News' section to the text on the right.

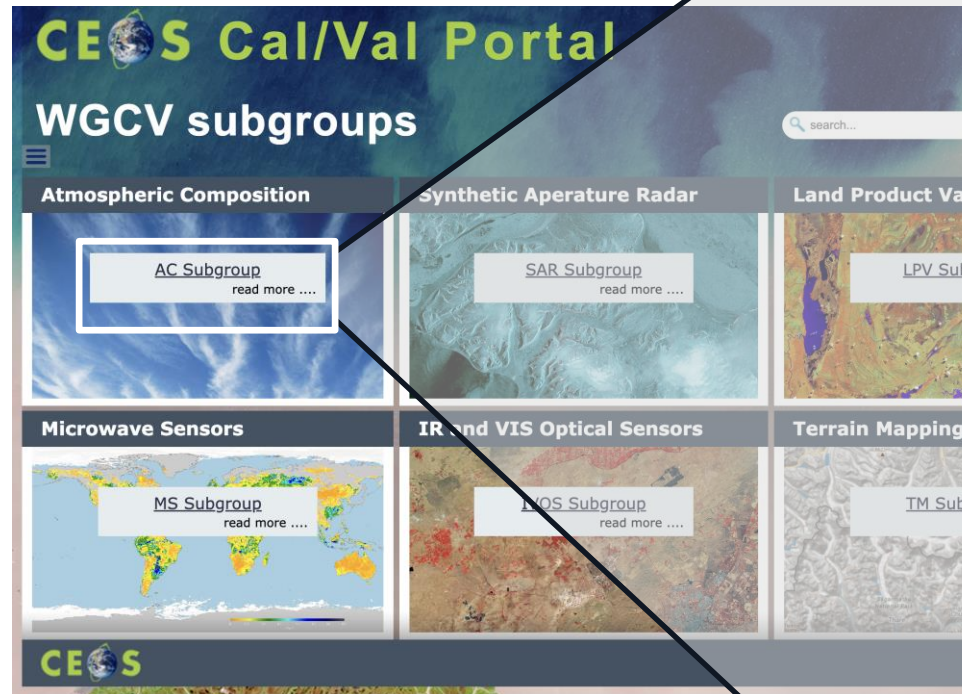
Atmospheric updates in development

- ❖ Registry of Cal/Val practices
- ❖ Registry of Cal/Val networks
- ❖ Registry of Cal/Val resources
- ❖ Advertisement of campaigns


The Third Cabauw Intercomparison of DOAS-like Instruments (CINDI-3)

We are pleased to announce the Third Cabauw Intercomparison of DOAS-like Instruments (CINDI-3), that will take place in Cabauw (The Netherlands) during four weeks from May 21 until June 22, 2024.

CINDI-3 is a community-wide intercalibration campaign of ground-based UV-Visible DOAS instruments measuring the atmospheric column and profile of NO₂ and O₃, complemented by mobile-DOAS observations and an exhaustive range of measurements of aerosols, NO₂, O₃ and other UV-Visible trace gases of interest like HCHO, CHOCHO, HONO, BrO and H₂O. The campaign also includes an airborne component for the characterization of the



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- WGClimat
- WGCV

Contact Us

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- SAR
- MSSG
- LPV
- IVOS
- | ACSG

Meetings

Current Activities

WGCapD

ACSG

The Atmospheric Composition Subgroup

The ACSG Mission is to ensure the accurate and traceable calibration of remotely-sensed atmospheric composition radiance data and validation of higher level products for application to atmospheric composition, land, ocean, and climate research.

Terms of Reference

Approved at the 15th CEOS Plenary meeting in November, 2001, the objectives of this subgroup, beyond those of the WGCV, are to:

- Promote international collaboration and technical exchange to ensure the efficient use and maintenance of calibration/validation resources required for atmospheric composition and other missions
- Verify accurate scientific products by encouraging an end-to-end approach to the calibration and validation of Level 1 and Level 2 data products, and any subsequent re-calibration and reprocessing using established best practice procedures
- Ensure that validation sensors are calibrated to traceable national standards, with documented statements of accuracy and repeatability
- Encourage interaction between calibration scientists and data users to enable a better understanding of data uncertainties and user requirements
- Recommend a network of validation sites and to encourage continuous observation and quality control of data through the use of standard procedures and inter-comparison
- Develop comprehensive data validation methods that employ ground, aircraft, balloon, and satellite measurements and with models
- Specify a comprehensive, consistent and quality-controlled multi-mission validation database in an accepted format and employing user-friendly tools

Action Plan

To accomplish its objectives, this subgroup initiates and supports the process of approaching agencies, through CEOS, for partial sustained support for ground validation networks and the maintenance of these networks between missions. It also actively pursues long-term data validation archival and retrieval across present and future mission applications. The subgroup meets regularly to review and coordinate upcoming validation activities, discuss results, and pursue its main objectives, which are reviewed and updated as necessary. Whenever possible, the ACSG makes every effort to add to the membership of this subgroup by including relevant agencies and organisations that are not yet represented.

Chair

[Dr. Jean-Christopher Lambert](#)
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CEOS has endorsed a number of test sites that are used for calibration and validation activities (coloured). The sites have been grouped according to WGCV's subgroup's domain and divided by applications, see the tree diagram below. In addition, there are other reference sites that are also used for EO calibration or validation.

AC subgroup	IVOS subgroup			LPV subgroup	MS subgroup	SAR subgroup
AC networks	Land Sites	Other Methods	Ocean Sites	LPV Supersites	MSSG test Sites	Targets Database
ACTRIS	PICS	ROLO	MOBY	ISMN		
AERONET	RadCalNet	GIRO	BOUSSOLE	NEON		
AGAGE	Sensor Characterization	LIME	AERONET-OC	TERN		
COCCON	MTF Ref. Dataset	FRM4STS		ICOS		
CONTRAIL	USGS Catalogue			BSRN		
GAW	HYPERNETS			SURFRAD		
GRUAN				FLUXNET		
HATS				NPN		
IAGOS				PEP		
NDACC				PEN		
MPLNET				EnviroNet		
PGN				KIT		
SHADOZ				ForestGeo		
SolRad-Net				ForestPlots		
TCCON						
TOLNet						

coloured

CEOS endorsed Cal/Val sites

white

Reference Networks

NDACC

Network for the Detection of Atmospheric Composition Change

Satellite Working Group

BIRA-IASB

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HOME

The objective of the NDACC Satellite Working Group is to foster exchanges and collaboration among atmospheric scientists involved in the NDACC and in atmospheric composition satellite missions. This website is a guide to ground-based researchers, space agencies and other interested parties to practical information on satellite missions relevant to NDACC and to satellite validation resources.

Illustration: Low Earth Orbit and Geostationary (LEO+GEO) satellite constellation for air quality monitoring (image courtesy: CEOS).

CONTACTS

For further questions or suggestions, please send an e-mail to: acc_satellites at aeronomie.be

or contact the Co-Chairs of the NDACC Satellite Working Group:

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Ibaraki 305-8506

Japan

2023-2029

TEMPO (hourly)

2024-2042

Sentinel-4 (hourly)

2020-2031

GEMS (hourly)

Sentinel-5P (once per day)

2017-2027

Sentinel-5 (once per day)

2024-2044

OMPS (once per day)

2011-2038

EMI GaoFen-5 (once per day)

2018-2028



General discussion on requirements and practices

later this morning

- ❖ WGCV-ACSG and AC-VC collaboration
- ❖ Systematic application of CEOS-FRM V2
- ❖ Input to Cal/Val Portal update
- ❖ Atmospheric Composition Cal/Val Resources document

Gaps, evolving needs, and issues

- ❖ Operational validation capacity
- ❖ Tracking gaps for validation systems and networks

today 15:10 - 2.24

Thursday 17:00 - 5.01