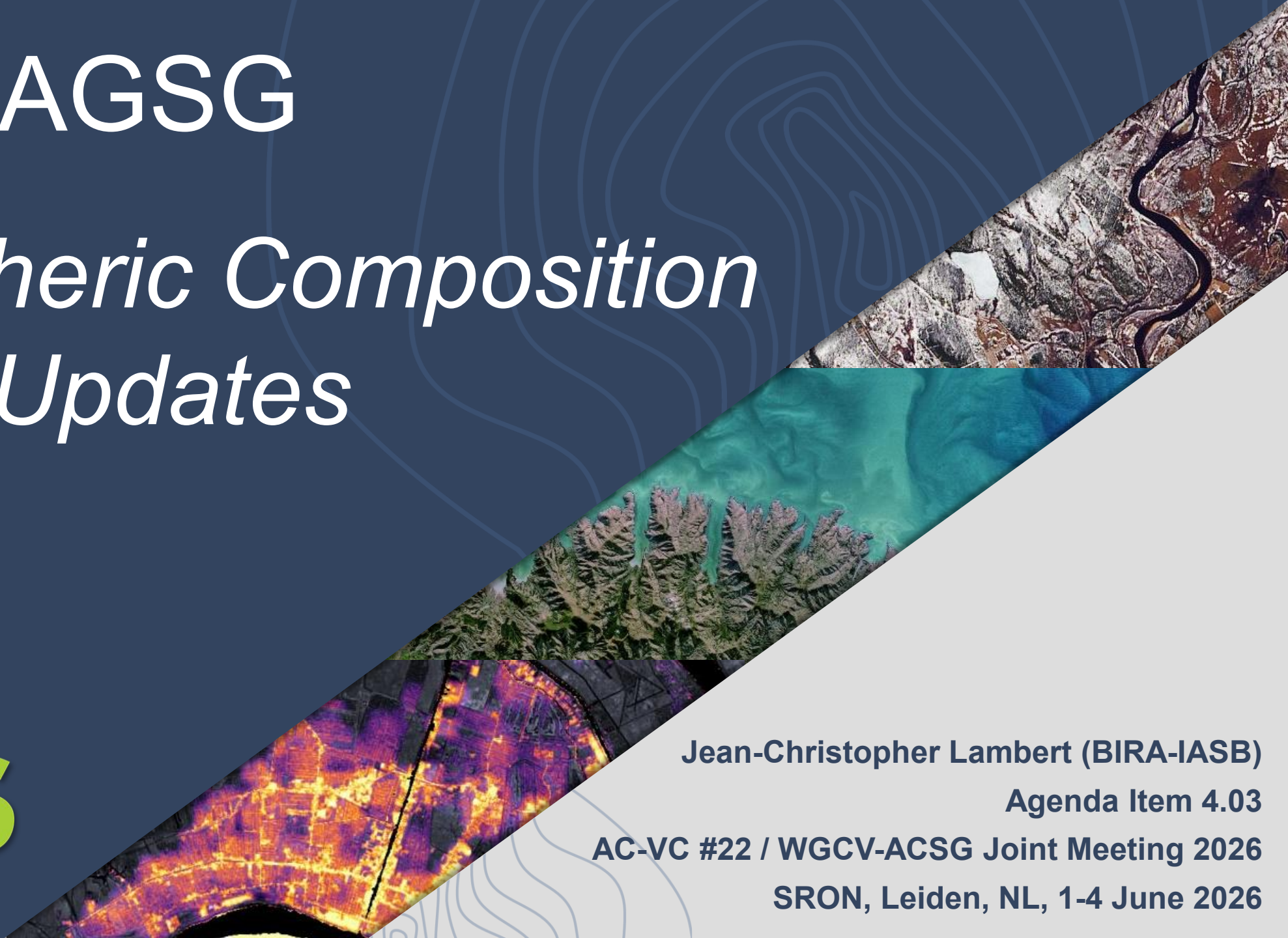
WGCV AGSG

Atmospheric Composition Cal/Val Updates



Committee on Earth Observation Satellites

Jean-Christopher Lambert (BIRA-IASB)

Agenda Item 4.03

AC-VC #22 / WGCV-ACSG Joint Meeting 2026

SRON, Leiden, NL, 1-4 June 2026

Terms of Reference

Approved at the 15th CEOS Plenary in November 2001, the objectives of the *Atmospheric Composition Sub Group* (ACSG), beyond those of the *Working Group on Calibration and Validation* (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

L1B Calibration and Validation

- Best practices: vicarious calibration, DCC, ISO 19159, PICS, Rayleigh Scattering, SNO/SONO, GEO/LEO…
- Vicarious calibration and calibration validation
  - SWIR/NIR GHG and AQ sensors *(talk 4.04 by H. Suto)*
  - UV/Vis/NIR O_3 and AQ sensors *(talk 4.05 by M. Coldewey-Egbers)*
  - Vicarious calibration & campaigns website at JAXA https://www.eorc.jaxa.jp/GOSAT/GHGs_Vical/index.html
  - Potential role of radiometric calibration networks ? *(talks 4.06 by M. Bouvet & 4.07 by K. Ruddick)*
- FRM Satellites (FRMsat) Task Team *(talk 4.08 by N. Fox)*
- WGCV collaboration with CGMS-GSICS *(talk 4.09 by L. Flynn)*
  - WGCV participation in GSICS annual meetings
  - Pre-flight Optical Sensors Calibration Workshop, ESA/ESTEC, 2024/11

CINDI-3 (May 21 – June 21, 2024)

CV-24-01

Cabauw, The Netherlands

UV-Vis intercalibration campaign organized as part of NDACC and ACTRIS CREGARS Topical Center, with additional ESA support.

Overview

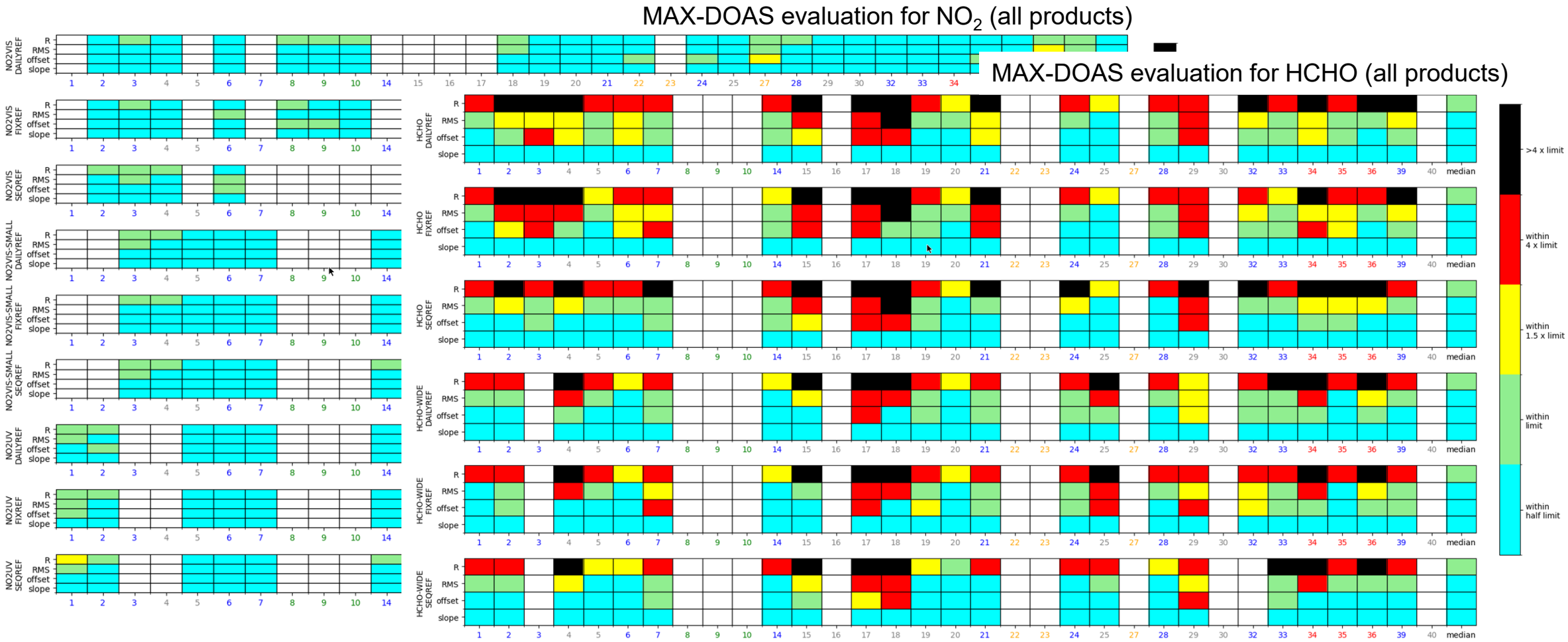
- 35+ UV-VIS MAX-DOAS instruments intercompared, from 16 countries
- 60+ instruments deployed
- 100+ participants
- FRM4DOAS central processing applied to 50% of participating instruments
- Airborne deployment for NO_2 mapping and profiling
- Data analysis in progress


CINDI-3: ~30 research institutes, companies and international organisations
CINDI-3
Third Cabauw INtercomparison of DOAS-type Instruments
Copyright © Free Vector Maps.com
NASA
UNIVERSITY OF TORONTO
LOA
LABORATOIRE D'OPTIQUE ATMOSPHÉRIQUE
CNR ISAC
BIRA-IASB
Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment
iup
MAX-PLANCK-INSTITUT FÜR CHEMIE
esa
BK SCIENTIFIC
Airyx
DIFFERENT THINKING. BETTER MEASURING.
SciGlob
LATMOS
PGN
THE UNIVERSITY OF SUWON
USW
RAL Space
VIRGINIA TECH
THE UNIVERSITY OF MELBOURNE
UNIVERSIDADE DE ÉVORA
Australian Government
Bureau of Meteorology
UNIVERSIDAD DE LA REPÚBLICA URUGUAY
NDACC
UNAM
INTA
LUFTBLICK
EARTH OBSERVATION TECHNOLOGIES
1958
PUKYONG NATIONAL UNIVERSITY
NILU
ACTRiS

CINDI-3 – Progress in 2025

Analysis of semi-blind intercomparison completed → Friedrich *et al*, 2026

(ESA report available from FRM4DOAS website and paper in preparation for AMT)



CINDI-3 – Publication plan

To appear in AMT/ ACP (thematic collection)

Subject	Lead Author	Planned date of submission
Campaign overview	Karin Kreher	Q4 2026
Semi-blind intercomparison of **NO_2, HCHO, O_3 and O_4** slant columns	Martina Friedrich	Q4 2026
Intercomparison of **glyoxal** retrievals	Kai Krause	Q3 2026
Cloud bottom altitude retrieval from MAX-DOAS	Udo Friess	Q2 2027
Intercomparison of **BrO** retrievals	Michel van Roozendael	Q2 2027
Synergistic **aerosol** retrieval using Pandora and CIMEL sunphotometer	Elena Lind	Q3 2026
Imaging DOAS NO_2 measurements during CINDI-3	Cedric Busschots	Q3 2026
Airborne NO_2 measurements during CINDI-3	Frederik Tack	Q3 2027
O_3 retrieval intercomparison	Chengzhi Xing	Q4 2026
Tomographic reconstruction of NO_2 fields using CINDI-3 data	Manuel Henning	Q2 2026

CEOS-FRM Maturity Assessment Framework

- Cross-domain WGCV activity **(CV-23-01)**

See talk 4.11 by P. Castracane

- Active participation of Atmospheric Composition
  - Reviews, test cases, feedback
  - Cross-EO exchanges (WGCV, ESA FRM Workshop 2026/05)

See talk 4.12 by J.-C. Lambert

- Dedicated sub-session later this morning:

		CEOS Fiducial Reference Measurements		
4.11	11:25	CEOS-FRM maturity assessment framework & tool v2	Paolo Castracane (ESA/STARION)	10
4.12	11:35	CEOS-FRM assessments for atmospheric composition	Jean-Christopher Lambert (BIRA-IASB)	10
4.13	11:45	First feedback on CEOS-FRM and way forward	All	10

CEOS Working Group on Calibration and Validation

CEOS-FRM Maturity Assessment Framework

See talk 4.11 by Paolo Castracane

https://calvalportal.ceos.org/web/guest/frms-assessment-framework

Criteria

Metrology

Data comparability

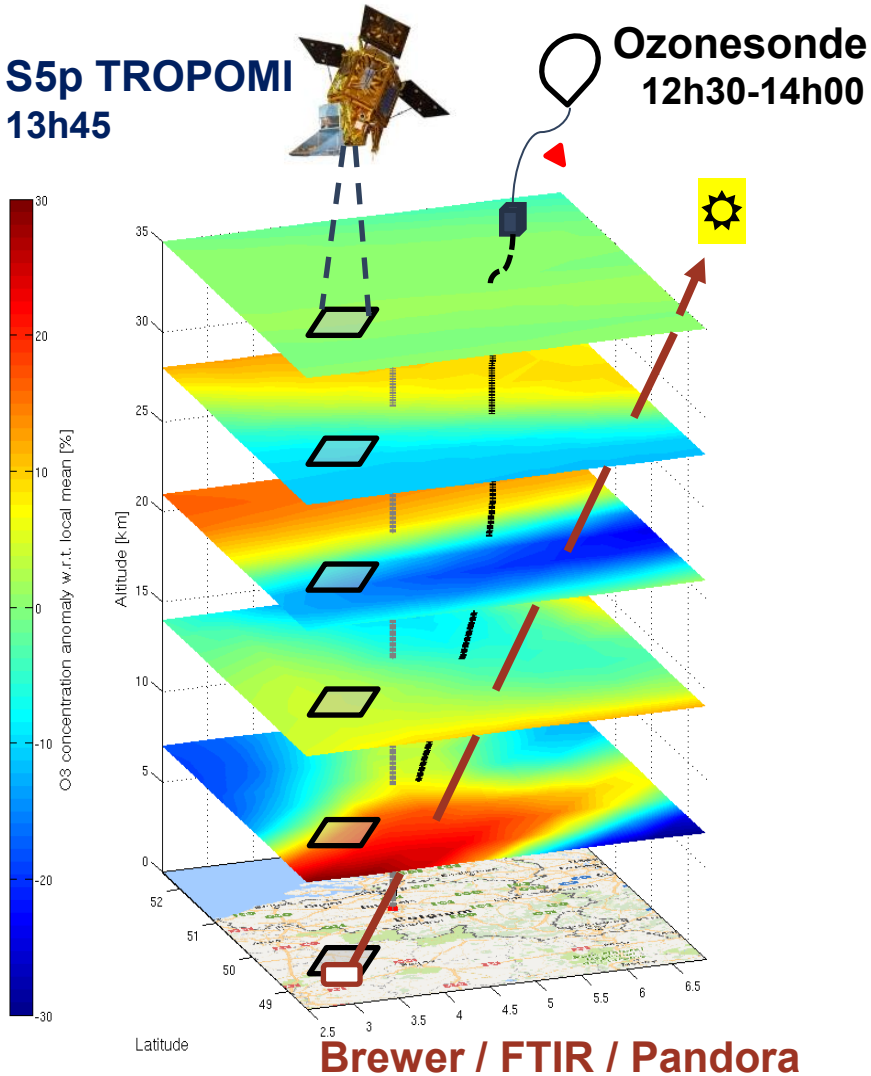
Validation capacity

Self-Assessment						Independent Assessor
Nature of FRM	FRM Instrumentation	Operations/ Sampling (single instrument)	Data	Metrology	Completeness, coverage and distribution	Verification
Descriptor	Instrument documentation	Automation level	Data completeness	Uncertainty characterisation	Validation capacity	Guidelines adherence
Location/ availability of FRM	Evidence of traceable calibration	Measurand sampling/ representativeness	Availability and Usability	Traceability documentation	Geographical coverage Temporal sampling	Utilisation/ Feedback
Range of sensors	QA Maintenance	ATBDs on processing/software	Data format	Comparison/ calibration of FRM	Centralized data, processing, quality assessment and adherence to community standards	Metrology verification
Complementary observations	Operator expertise	Guidelines on transformation to satellite sensor	Ancillary data	Adequacy for class of instrument/ measurand	Timeliness	Independent verification
					FRM CLASSIFICATION	A B C D

CEOS FRM

CEOS Working Group on Calibration and Validation

Data Comparability ⇨ Representativeness



$$|m_1 - m_2| < k\sqrt{u_1^2 + u_2^2}$$

Loew *et al.*, RG 2017
ISO/TS 19124-1:2023

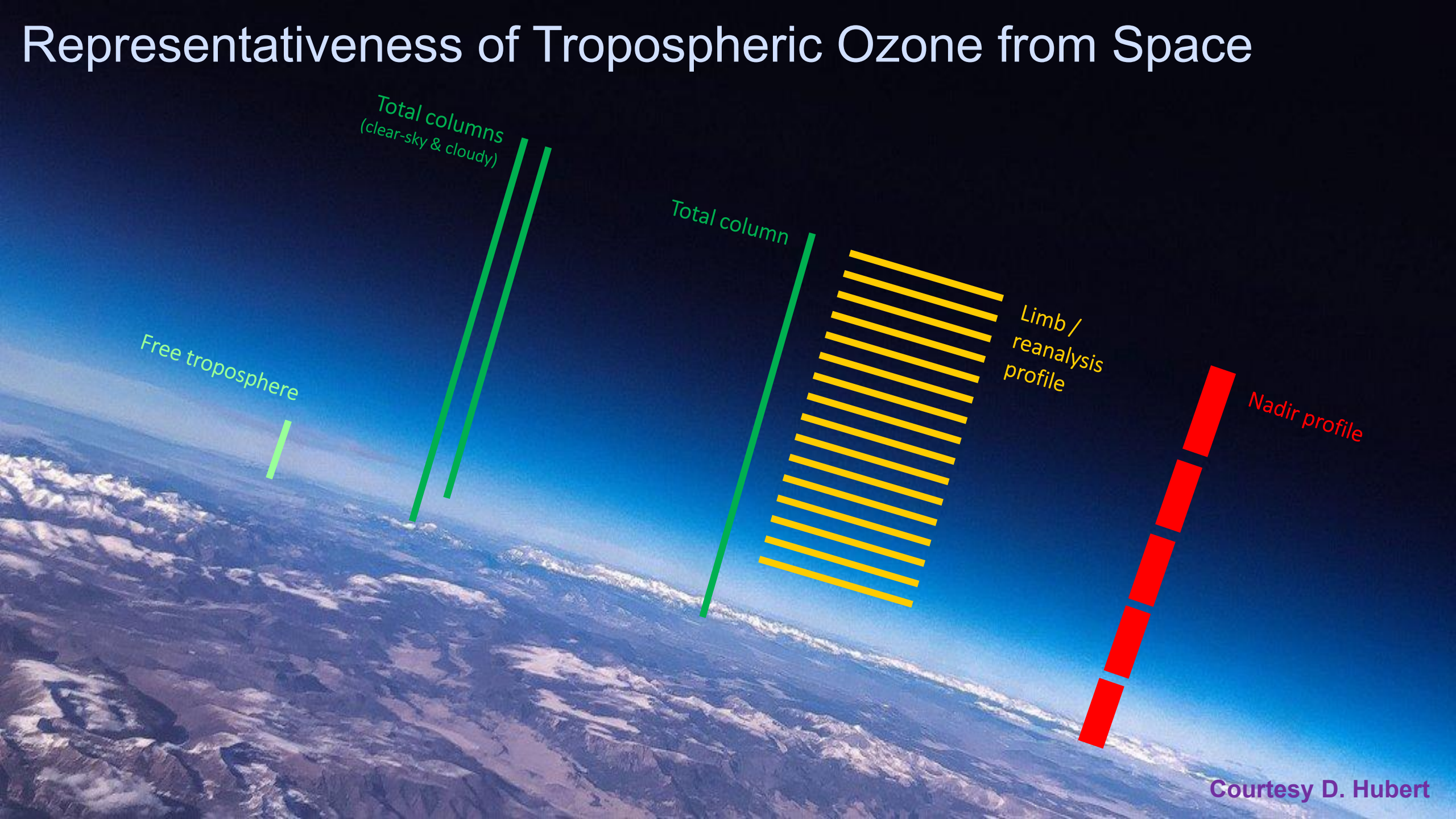
Verhoelst *et al.*, AMT 2015

$$|m_1 - m_2| < k\sqrt{\sigma^2 + u_1^2 + u_2^2}$$

Mismatch uncertainty:

- Combination of spatiotemporal **co-location** mismatch and **smoothing** differences of atmospheric variability and gradients
- Random and systematic components
- Some irreducible part remains after optimization of co-location criteria.

Representativeness of Tropospheric Ozone from Space



TOAR-II / Satellites

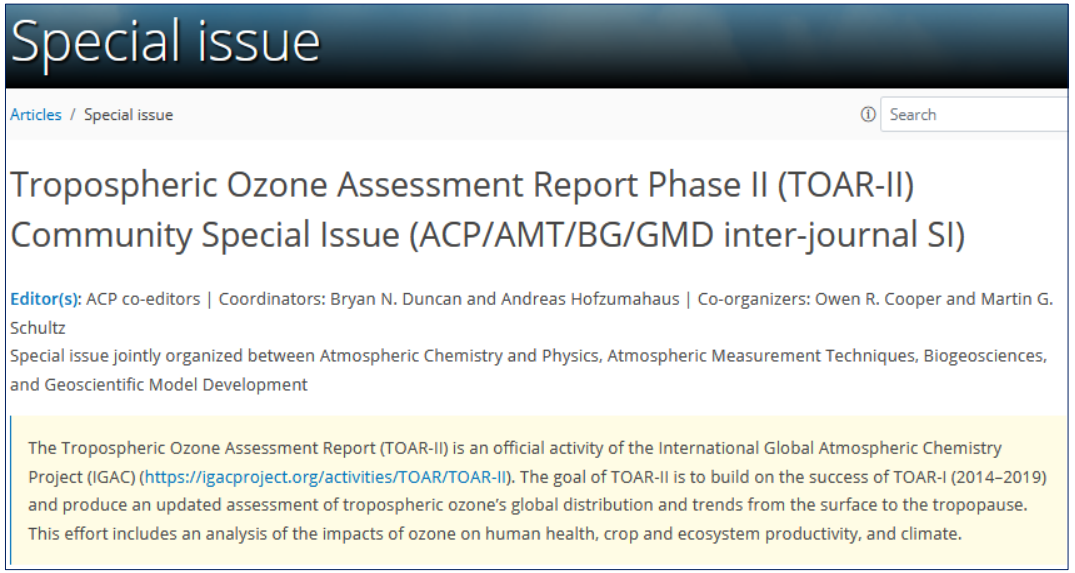
IGAC TOAR-II Community Special Issue in Copernicus journals

(58 papers published)

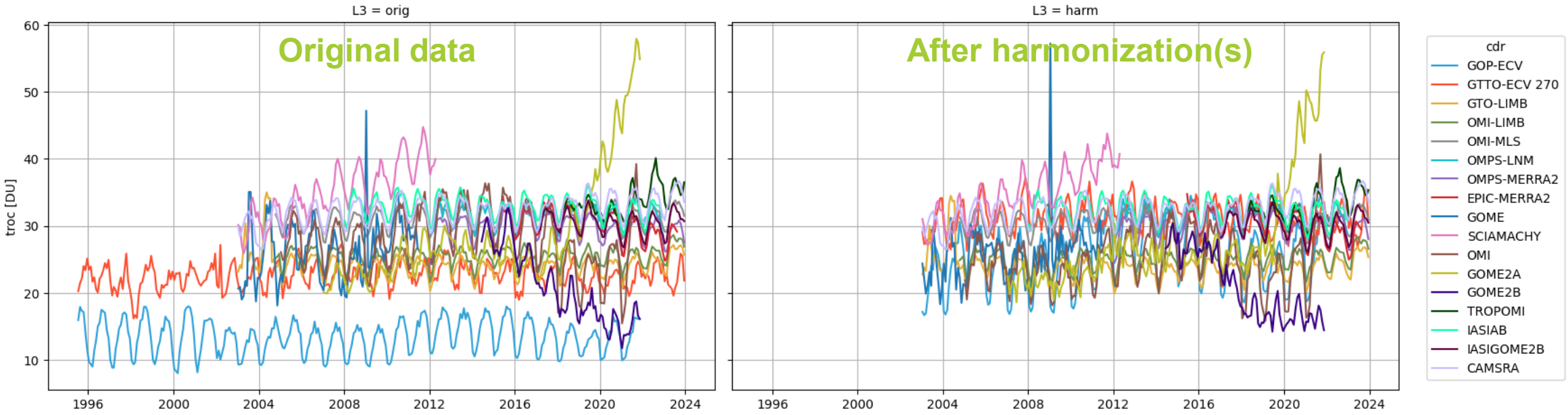
Satellite contribution: 21 papers in total

- **Intercomparison & harmonization** (5 published) ⇨ **VC-20-01 contribution**
- Satellite O_3 trend (8)
- Reanalysis (3)
- Satellite O_3 precursors trends (1)
- Other analyses: CoViD-19 period, O_3 production rates, O_3 Radiative Forcing, model evaluation (4)

https://acp.copernicus.org/articles/special_issue1256.html



TOAR-II / Satellite Data Harmonization



- Harmonization themes: (i) Vertical representation & units, (ii) Top-of-troposphere definition, (iii) Surface pressure, (iv) Spatial sampling, (v) Temporal sampling, (vi) A-priori information sources, (vii) A-priori information (effective) contributions (vertical smoothing)
- Satellite O_3 data harmonization reduces dispersion between datasets by about ~10-40 %.
- Residual discrepancies between harmonized satellite data ⇨ other sources of uncertainty

Keppens et al., AMT 2025

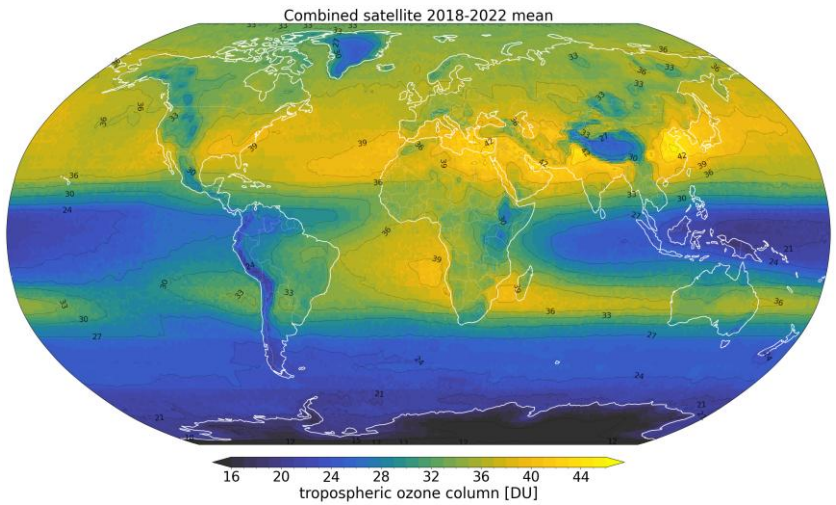
TOAR-II Satellite Assessment

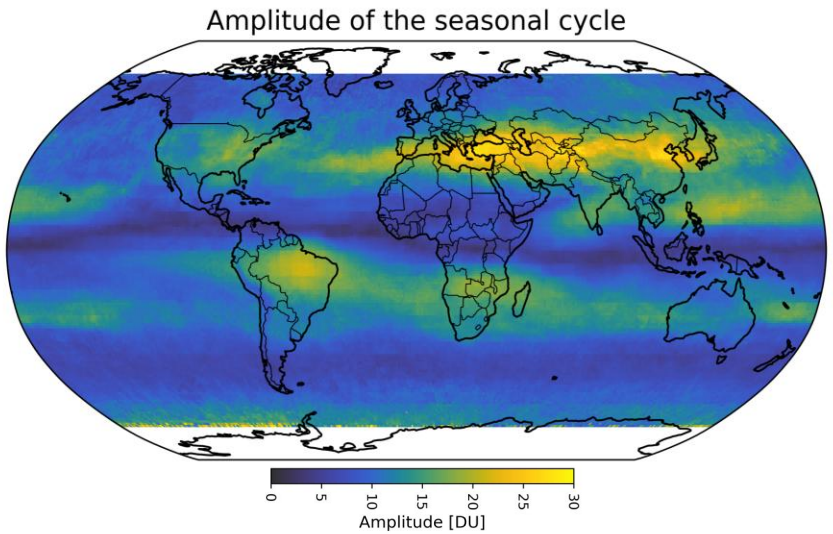
TOAR-II Satellite Assessment combines 15 harmonized records.

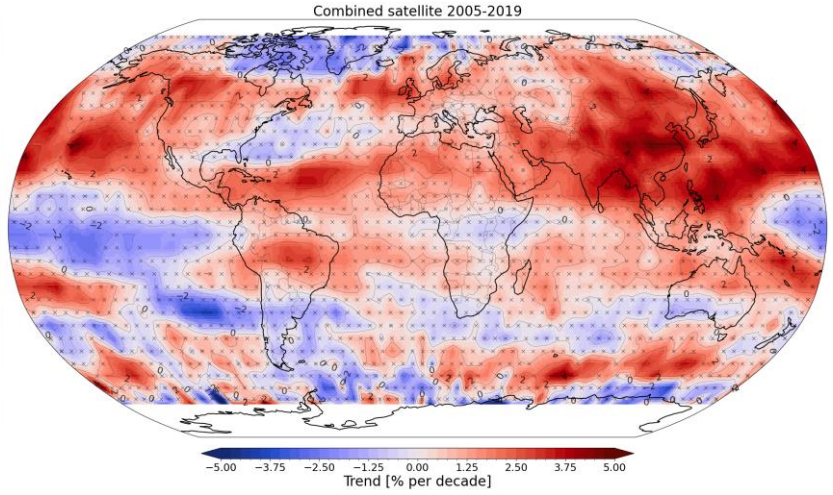
D. Hubert, K. Miyazaki et al., *Philos. Trans. R. Soc. A* (in press)

Significant advances since TOAR-I

Maps of present-day mean & seasonal cycle, long-term trend and episodic events are more finely resolved, more accurate, and have more robust uncertainty estimates.







Validation Capacity ⇨ Network Design and Evolution

WMO GAW gap analysis and monitoring strategies

- Critical review of observing capabilities (GAW Report No 307, 2025)
- GAW Global Ozone Monitoring Strategy just submitted to BAMS

  ⇨ Includes satellite validation needs and CEOS-FRM concept

NDACC network evolution strategy

- Peer-reviewed paper including satellite validation strategies and viewpoint of stakeholders (incl. CEOS and space agencies)

GHG Roadmap v2 Annex C – Tracking needs, gaps and issues

- EUMETSAT CO2M Cal/Val Support project incl. TCCON, COCCON & NDACC

“Cal/Val Supersite” concepts

Presented and discussed at : CEOS AC-VC-21 / WGCV-ACSG Joint Meeting 2025, Takamatsu, JP (2025/06)
WMO GAW Scientific Advisory Groups on Ozone, UV and Greenhouse Gases, Geneva, CH (2025/07)
NDACC Steering Committee Meeting 2025, Virginia Beach, VA (2025/10)
CEOS WGCV-56, Sioux Falls, SD (2026/04) ⇨ cross-domain discussions

Staggered approach to satellite validation, from producer to user service

1. ‘*Traceability validation*’: in-depth, end-to-end validation of L1-to-L2 retrieval diagram elements and associated uncertainties; R&D nature, cross-domain, cross-constellation harmonization
2. ‘*End-product validation’*: global, long-term production of L1 & L2 data quality indicators over entire domain of application; may have operational needs
3. ‘*Product-to-service validation’* connecting space, surface, modelling and user applications; multi-constituent/multi-theme; likely both R&D and operational

Tiered approach to Cal/Val network design and evolution

Tier 1: High CEOS-FRM classes; full suite of retrieval and influence quantities; may include L1 related data, e.g., from RadCalNet & HYPERNETS

Tier 2: High-to-mid CEOS-FRM classes; classical L2 product validation, L2/3/4 CDRs

Tier 3: Mid-to-low CEOS-FRM classes; global, first-order, statistical mass

CEOS Cal/Val Portal

https://calvalportal.ceos.org

Atmospheric updates in development

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

Your input is welcome !

Cal/Val Discussion Topics for Today

Topical discussions

- Vicarious calibration and calibration validation 10:35 (4.10)
- Feedback on CEOS-FRM and way forward 11:45 (4.13)

General discussion on requirements and evolving needs noon

- White Paper on GEO-AQ validation needs: Status of recommendations
- Input to Cal/Val Portal update, emerging needs…
- WGCV-ACSG and AC-VC collaboration