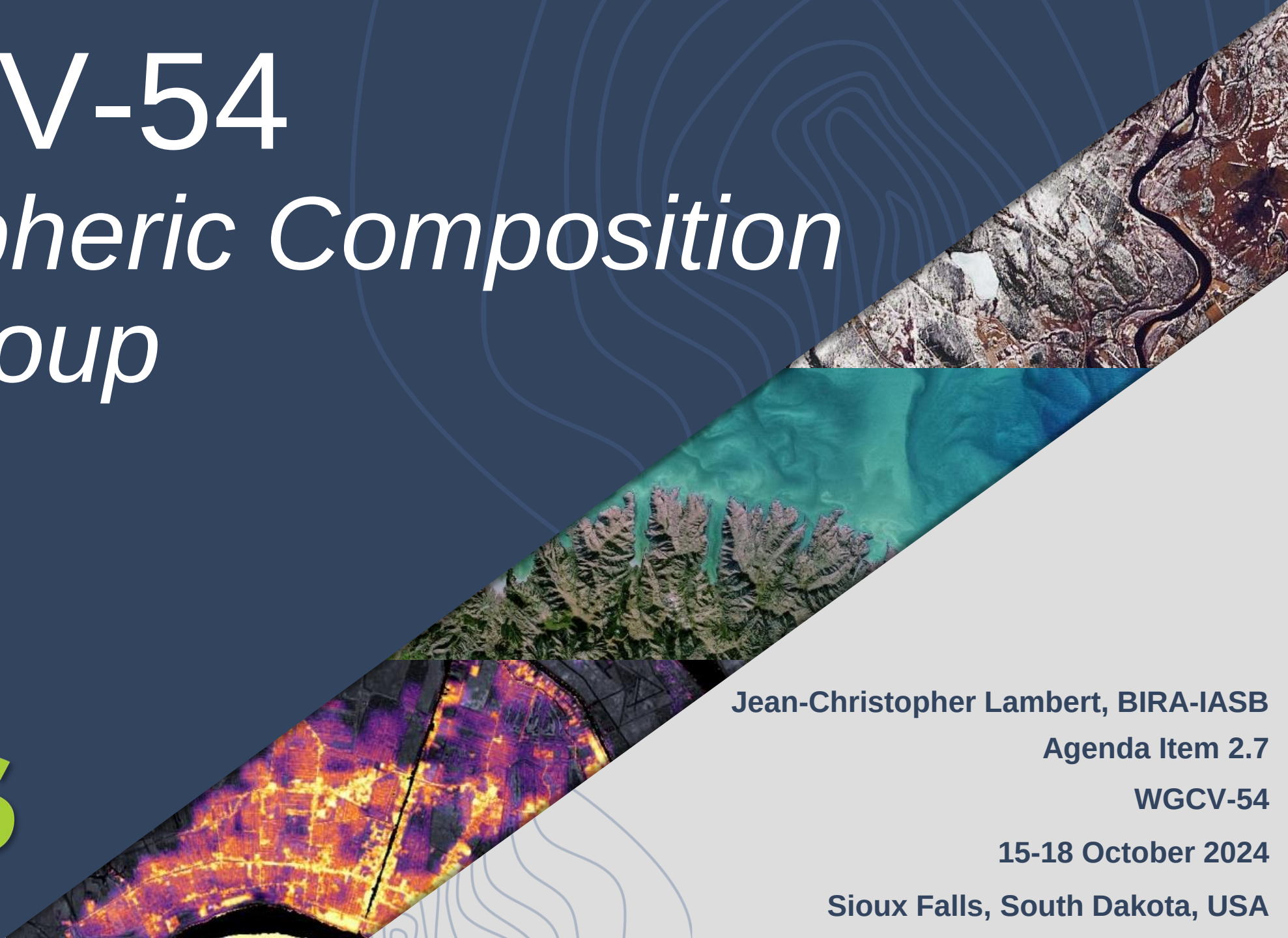
WGCV-54

Atmospheric Composition Sub Group



Jean-Christopher Lambert, BIRA-IASB

Agenda Item 2.7

WGCV-54

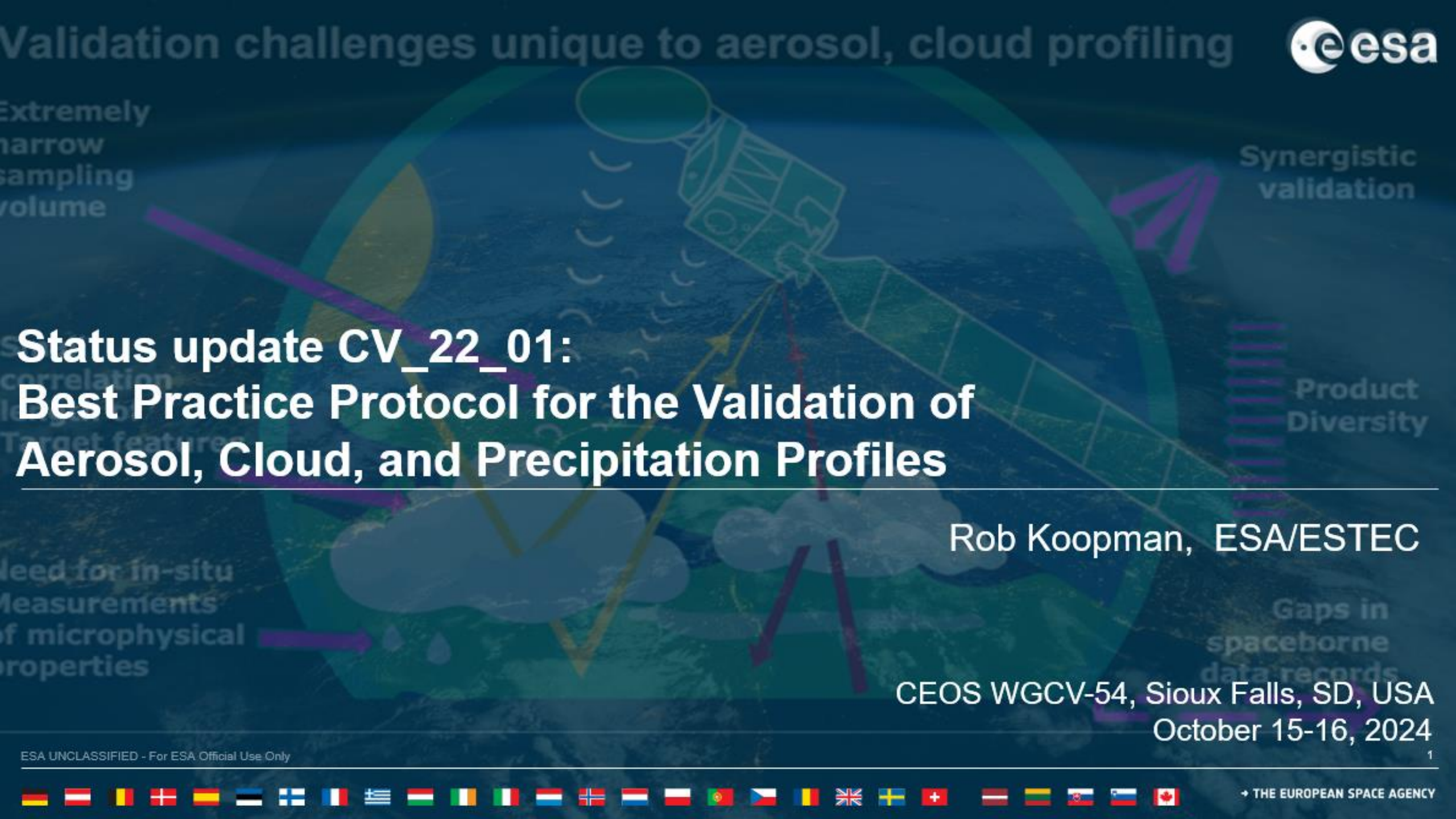
15-18 October 2024

Sioux Falls, South Dakota, USA

CEOS
Committee on
Earth Observation Satellites

Atmospheric Composition Updates

- Aerosol, Cloud & Precipitation Profile
  - Aerosol, Cloud & Precipitation Profile Validation Protocol — CV-22-01
  - EarthCARE validation campaign
- Tropospheric ozone datasets harmonization and validation — VC-20-01
- GHG Cal/Val highlights
- Air Quality Constellation validation — VC-20-02/03/04
- CINDI-3 campaign — CV-24-01
- CEOS-FRM – Atmospheric composition — WGCV-53-ACT-14 / CV-23-01

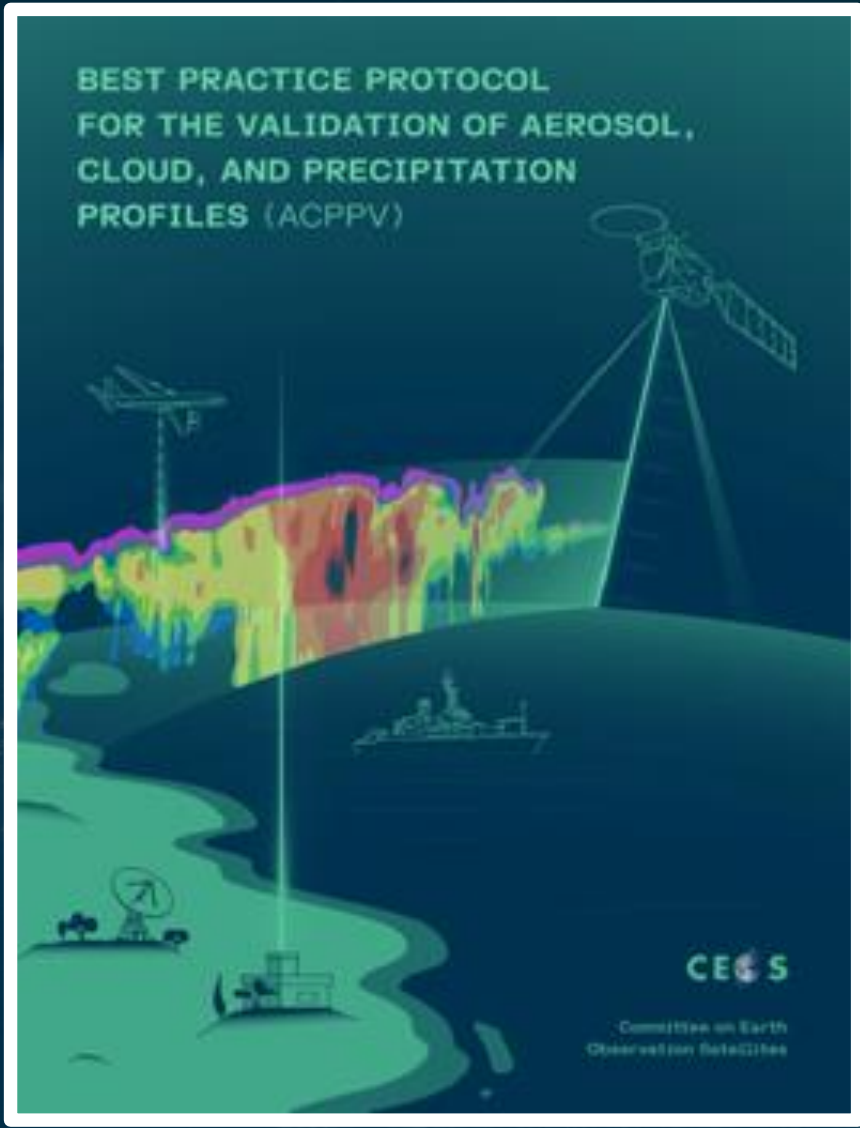


Status update CV_22_01: Best Practice Protocol for the Validation of Aerosol, Cloud, and Precipitation Profiles

Rob Koopman, ESA/ESTEC

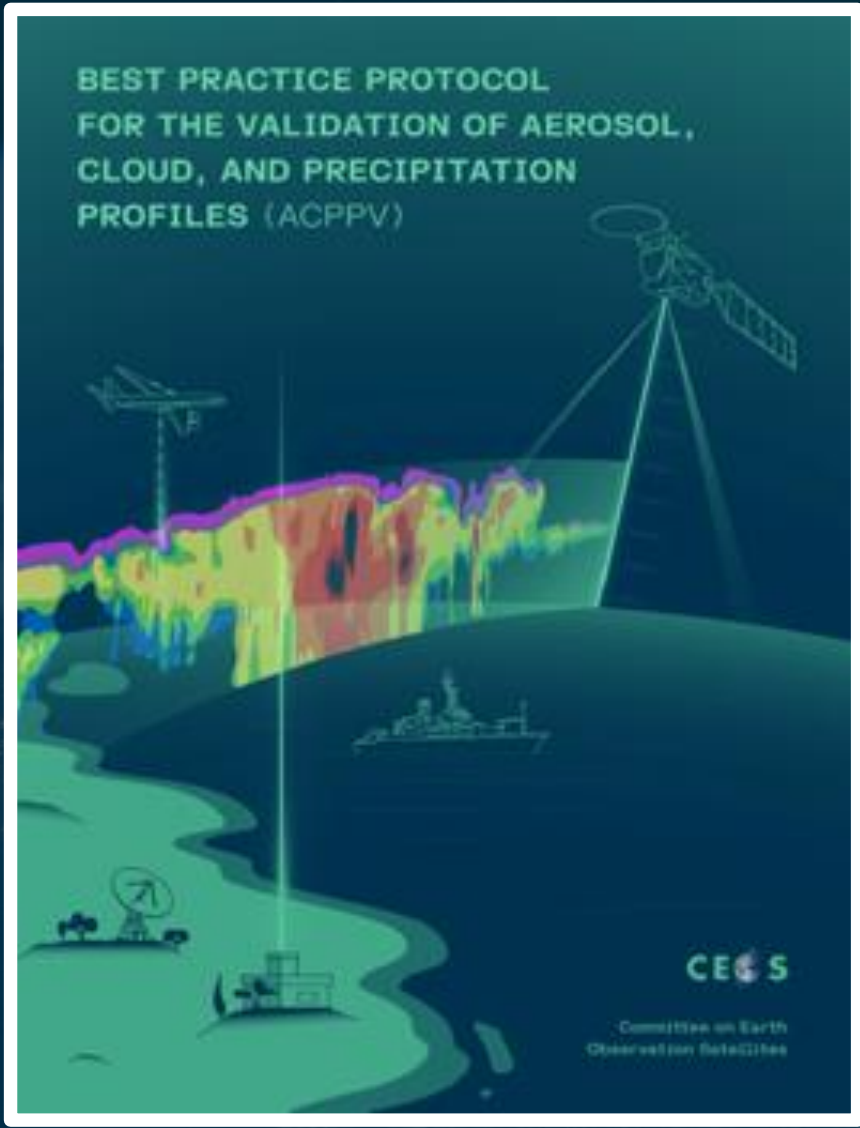
CEOS WGCV-54, Sioux Falls, SD, USA
October 15-16, 2024

CV-22-01 Activity Status



- February 2024: draft circulated within the EarthCARE validation team (250+ scientists)
- Review feedback taken on board in an update which is considered the final version prior to CEOS review
- This document was provided to J.-C. Lambert on **21 September 2024** and distributed to initiate **CEOS review/endorsement process**.
- Authors and editors are on standby to take into account any CEOS feedback.
- Intention for further updates based on EarthCARE lessons learned, in preparation for AOS, Aeolus-2, and further high-resolution profiling missions

CV-22-01 Activity Status



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 system
- Gaps and challenges

EarthCARE Validation Status (ESA products)

Rob Koopman, Stephanie Rusli, Jonas von Bismarck,
Timon Hummel, Montserrat Pinol Solé

CEOS WGCV-54, Sioux Falls, SD, USA
October 15-16, 2024

1. ESA Validation-Related Activities

ECVT
EarthCARE Validation team

- 43 EarthCARE Cal/Val Projects
- Knowledge transfer (algoritms, instruments)
- Prepare observation planning & correlative data handling
- Organise validation analysis
- Foster interaction with funding sources
- Facilitate interaction with algorithm teams, instrument experts, and peers through interactive validation portal

- **Organisation of pre-/post-launch campaigns**
- **Securing collocated airborne datasets**
- Validation Data Centre for correlative data

Pre-/post-launch and correlative measurements

National Agencies

Validation bi-laterals with several agencies to address funding

ESA-JAXA joint Scientific Validation Implementation Plan

ESA-NASA Joint Programme Planning Group (campaigns, best practices) and AOS, PACE etc.

Pilot to support cal/val of Atmospheric satellite missions

Various

Consultation with domains/communities to solicit further contributions

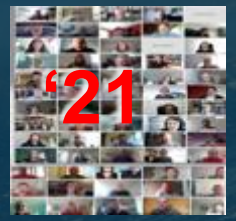
Collaboration Coordination

Methods and approaches

- **Fiducial Reference Measurement** developments for lidars (eVe, EMORAL) and radars (FRM4RADAR)
- Development of **suborbital to orbital signal converters** for radar, lidar, imager
- **best practice convergence (**collaboration of EarthCARE, CALIPSO, Cloudsat, Aeolus, and AOS scientists)

2. ESA validation preparations

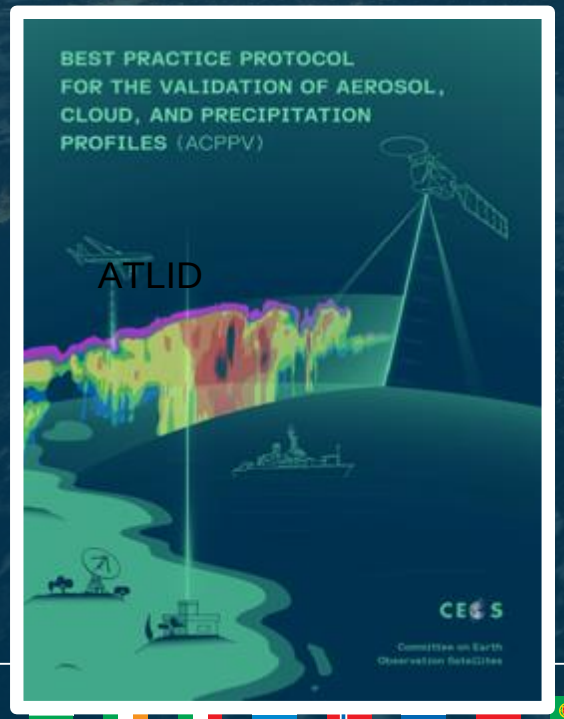
Pre-Launch Validation Workshops



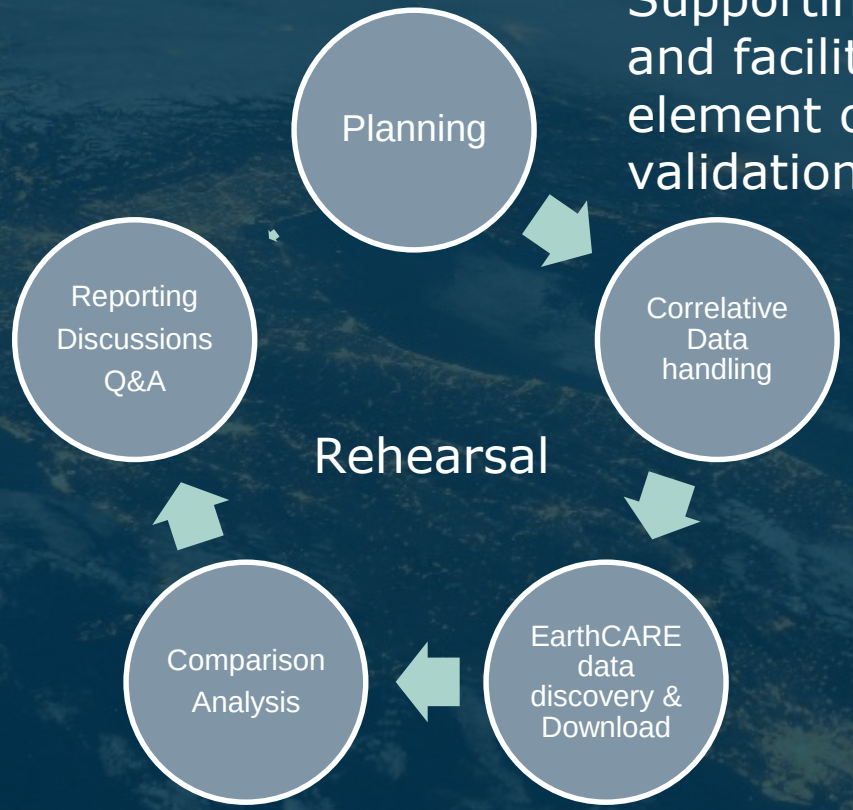
Supporting PIs

Securing datasets and analyses

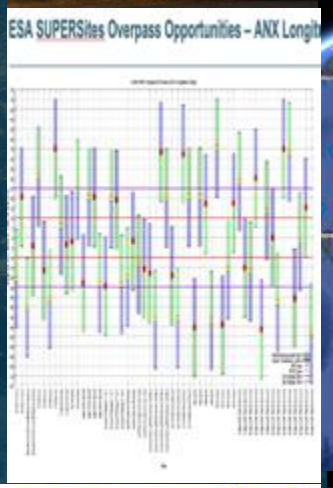
Studies, Community convergence

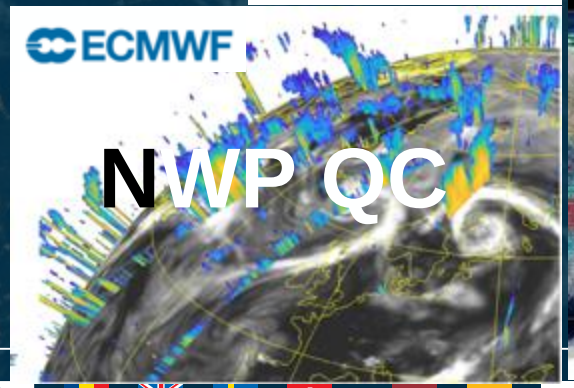


Adaptation and development of Supporting tools and facilities for each element of the validation workflow



3. ESA Product Validation Approach





Plan is documented in **EarthCARE Scientific Validation Implementation Plan**

– Issue 2.0 Released 23 Sep 2024

4. Correlative measurements status

- Ground-based, shipborne, and airborne measurements all underway
  - Correlative instruments for BBR and MSI related single sensor (L1, MSI L2) and BM-RAD synergy products are underway since 26 July (this includes also ground-based radars and lidars validating MSI cloud products)
  - Correlative measurements for CPR and ATLID (L1, and L2) and for the full synergy suite are underway since 9 and 10th of August respectively, including the first underflight on 11 August
  - Many of the network stations involved in EarthCARE validation have begun dedicated measurements, including CloudNet, Earlinet (example below), LALINET, ADNET, others have collected routine data (MPLNET, E-PROFILE)

ATMO ACCESS - EU project

- 53 Stations (mostly ACTRIS) participating, of which 28 are observing routinely. Includes EARLINET (lidar, most 355 and Depol) and CLOUDNET stations.
- ATMO ACCESS project encompasses 2 prelaunch rehearsals, intercalibration with other networks/systems, bespoke data processing, and dedicated observation campaign during EarthCARE Commissioning Phase and until February 2025, with fast delivery. Intercalibration with MPLNET is ogoing, and will also be performed with eVe, EMORAL and BASTA

5. Airborne campaigns overview

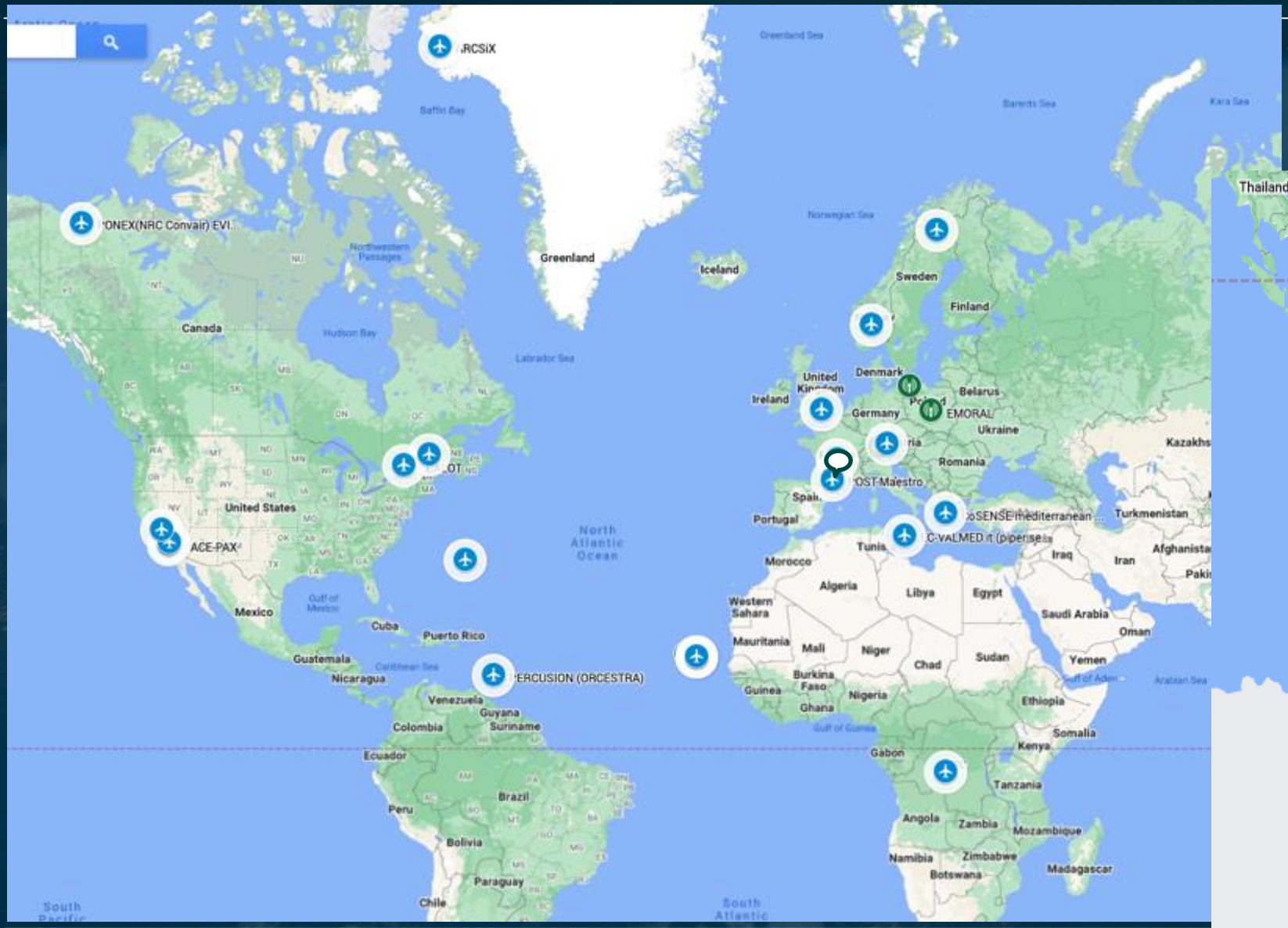
- Collaborations ongoing with large number (22 and counting) of airborne campaigns, often complemented with ground and/or ship-based instruments. National scientific institutions (mainly Europe and Canada) and NASA
- Campaigns are a mix of dedicated validation campaigns and collaborative piggybacking campaigns
- Strong synergies with NASA PACE mission: reciprocal EarthCARE and PACE underflights during ORCESTRA and PACE PAX campaigns, complemented by science projects with synergistic retrievals
- 41 underflights of 33 EarthCARE orbits have already been performed between 11 August and 10 October 2024 with many more to follow during the EarthCARE lifetime:
    - These underflights were performed by 7 Aircraft involved in 6 Campaigns, including tandem and triple underflights.
    - The airborne payloads included 5 lidars, 3 imagers, 1 polarimeter, 3 radars, and 4 different in-situ sampling suites, complemented by several ground-based and ship-borne instruments
- https://blogs.esa.int/campaignearth/category/earthcare/

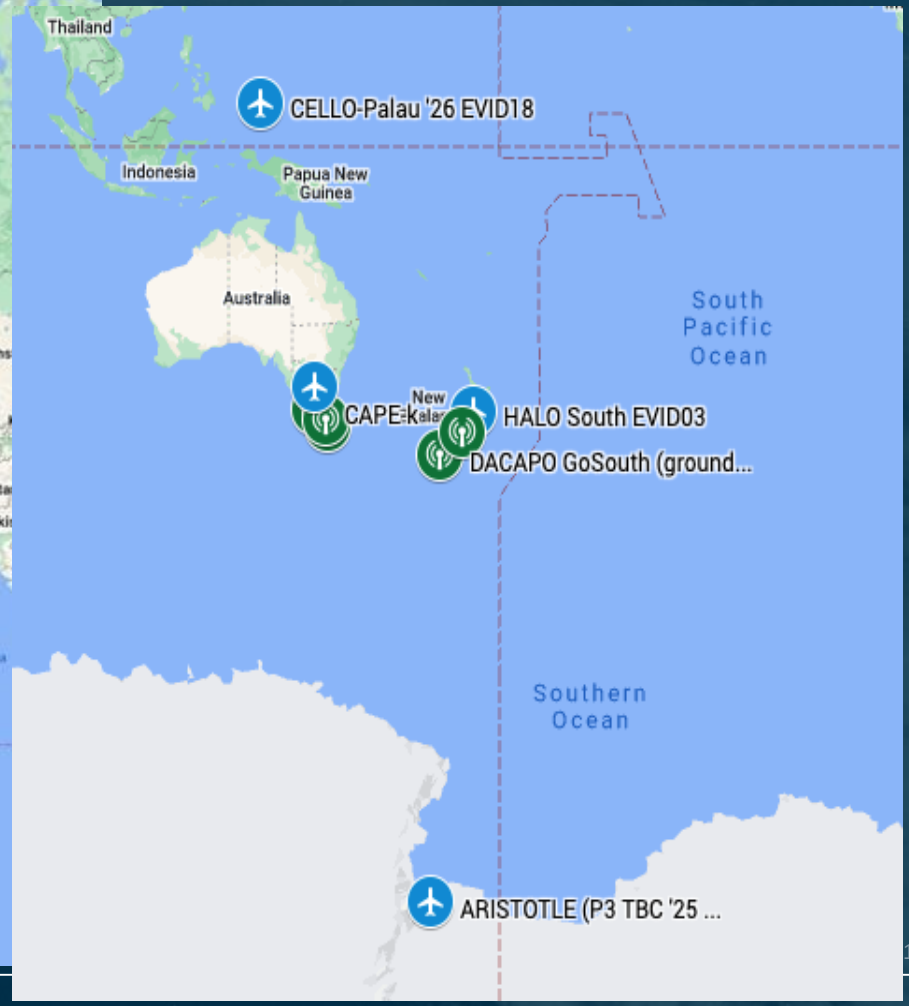
5. Airborne campaigns overview

2024		2025		2026	
PERCUSION (ORCESTRA)	Cape Verde, Barbados, Germany	GLOVE	USA	PONEX	Canadian Arctic
MAESTRO (ORCESTRA)	Cape Verde	POST-Maestro	France	CELLO-Palau	Palau
CELLO(ORCESTRA)	Cape Verde	CELLO-ARCTIC	Norway/Romania		
ARCSiX	Arctic				
BAIVEC	France	Tentative:			
PACE-PAX	USA	HALO South	New Zealand		
ECALOT	Canada	CARINA	Australia	Tentative:	
WhyMSIE	USA	Bermuda HSRL-2	Bermuda	CoSENSE	Mediterranean
Tentative:		ARISTOTLE	Antarctica	NURTURE -	Canada
VERIFY	UK	Piper Seneca	Mediterranean	BACCOPA	Africa

5. Airborne campaigns overview

Many airborne campaigns are combied with ground and or marine component





Outlook

- Pre-operational Data release to **validation teams**
  - Level1 available
  - Level 2 staggered release between October ‘24 and February ‘25

- Validation analysis (intercomparisons) reporting at **workshops** aligned with **public release**:

- Operational data **public release** (for both ESA and JAXA products)
  - Level 1 by **January 2025** (1st In-Orbit Validation Workshop, online)
  - Level 2a and 2-sensor L2B by **March 2025** (2nd In-Orbit Validation Workshop, Frascati)
  - 3- and 4-sensor L2B products by **December 2025** (2025 Science and Validation Workshop, Tokyo)

Questions ? ⇨ Rob.Koopman@esa.int

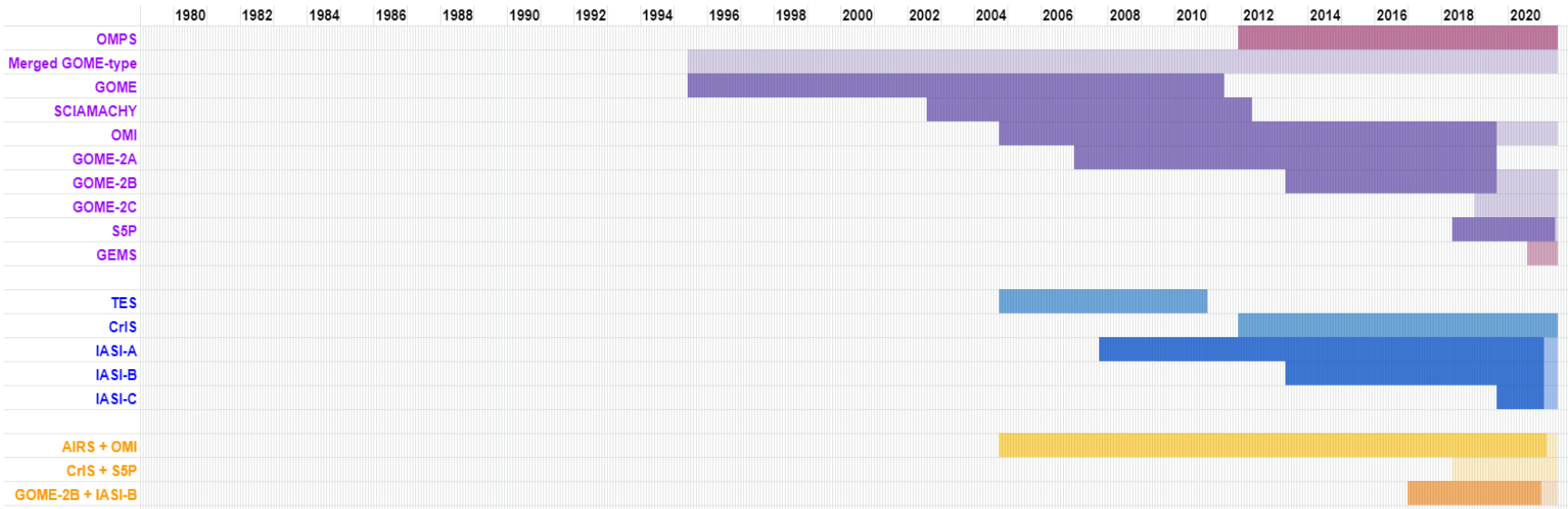
Tropospheric Ozone Activity

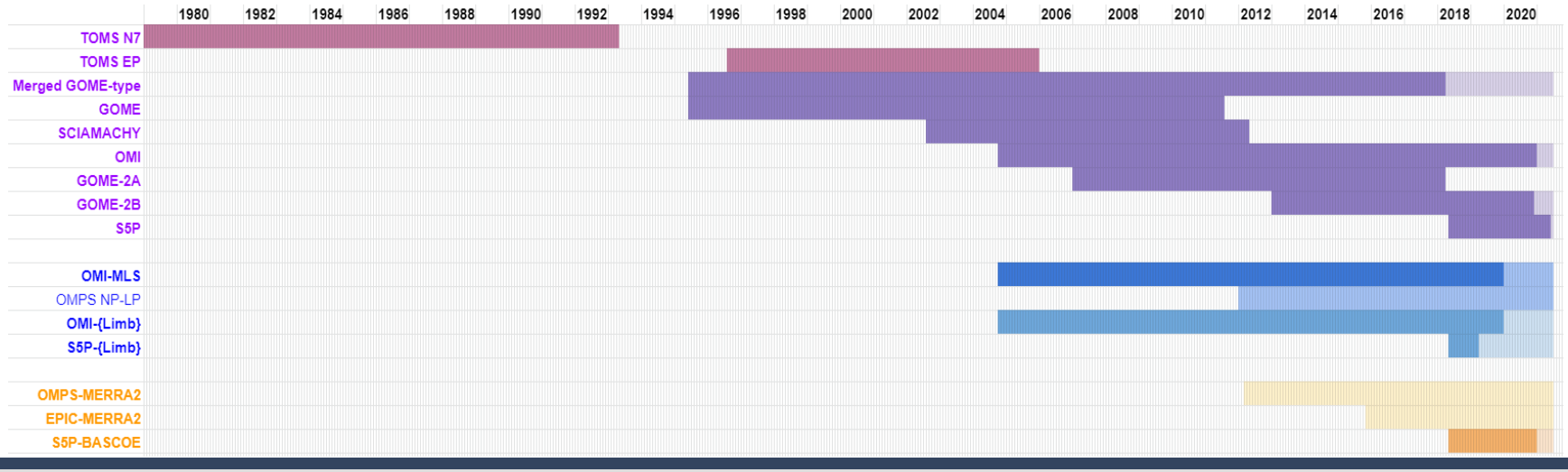
VC-20-01

- VC-20-01: Tropospheric ozone data validation and harmonization (Lead DLR, Co-Leads BIRA-IASB & NASA)
- TOAR-II Community Special Issue in progress https://acp.copernicus.org/articles/special_issue1256.html
- Community papers deadline November 30.
  12 satellite-based papers/preprints so far, out of 28 in total
- Summary papers come after, in 2025, including constellation wide assessment using cross-harmonized satellite data anchored to HEGIFTOM

Tropospheric Ozone Datasets

VC-20-01





SATELLITE DATASETS

Optimal Estimation retrievals

→ vertical profile at pixel level or at pixel-cluster level

- UV-VIS
- TIR
- Synergy UV-VIS+TIR

Residual techniques

→ partial column calculated as difference between total and pseudo-stratospheric columns, often gridded in time & space

- Cloud-free TC minus above Convective Cloud TC
- Nadir TC minus Limb PROF
- Nadir TC minus Reanalysis PROF

Tropospheric Ozone Datasets

TOAR-II Focus Working Group: HEGIFTOM

Major Deliverable:

Quality assessed ozone data sets from established ground-/air-based instruments, whereby each measurement gets also an ***uncertainty*** and a ***quality flag***, with ***representativeness*** and ***instrumental drifts*** characterized and evaluated

Harmonization and
Evaluation of
Ground-based
Instruments for
Free
Tropospheric **O**zone
Measurements

TOAR tropospheric ozone assessment report Phase II

WG HEGIFTOM

https://igacproject.org/hegiftom-focus-working-group

HEGIFTOM Core Group

Roeland Van Malderen (Co-Chair: roeland@meteo.be & Sondes),
Herman Smit (Co-Chair: h.smit@fz-juelich.de & Sondes),
Romain Blot (IAGOS), Corinne Vigouroux & James Hannigan (FTIR),
Thierry Leblanc (LIDAR), Irina Petropavlovskikh (Brewer/Dobson Umkehr)
Michel Van Roozendael (MAX-DOAS), Alexander Cede & Thomas Hanisco (Pandora),
Owen Cooper, TOAR-II SSC-Liaison Member

Tropospheric Ozone Datasets

Ground-based Free Tropospheric Ozone Measuring Platforms

Instrument/Platform	Time period	Coverage/Network	Groups in HEGIFTOM
Ozonesondes	1965 - present	**> 50 Sites** worldwide (GAW/WOUDC, NDACC, SHADOZ)	RMI (Belgium), FZJ (Germany), ECCC (Canada), NOAA (USA), NIWA (NZ), NASA (USA)
MOZAIC/IAGOS	1994 - present	Cruise altitude (10-12 km) & Airports worldwide **(100-250 Airports)**	CNRS (France) & KIT (Germany
FTIR	1995 - present	NDACC, **13-15** sites having more than 10 years of data	BIRA (Belgium), NCAR (USA), AEMET (Spain)
Lidar		NDACC, TOLNET **(9-10 Sites)**	NASA (USA), LATMOS (France), UAH (USA)
Umkehr (Dobson & Brewer)	1956 - present	WOUDC (> Sites), NEUBrew, EUBrew **(14 Sites)**	NOAA (USA), MeteoSwiss (Switzerland), BoM (Australia), NIWA (New Zealand), OHP (France), AEMET (Spain), Univ. Thessaloniki (Greece)
MAX-DOAS	2010-present	**5-10 sites** NDACC and associated sites	BIRA (Belgium)
Pandora	2012 - present	**> 40 sites** at 2020, Pandonia Global Network (PGN)	NASA (USA), VTU (USA), LuftBlick (Austria)

TOAR tropospheric ozone assessment report Phase II

WG HEGIFTOM

GHG Cal/Val Highlights

- Details: see WGCV-54 item 2.6 on GHG Val/Val (this morning)
- L1 calibration
  - VICAL GHG Cal/Val website
  - Match-up database for SWIR and TIR sounders
- L2 GHG networks:
  - Several actions in progress or in elaboration (see item 2.6)
  - EUMETSAT ITT for CO2M product validation methods, reference data provision and processing, incl. TCCON, COCCON and NDACC
  - EUMETSAT ITT for Pandora NIR development

GHG Cal/Val Highlights

- Cal/Val updates in CEOS-CGMS Greenhouse Gas Roadmap v2
  - incl. WGCV related and coordination with AC-VC, Cal/Val networks role and challenges, Global Mapper/Facility Scale (New Space), emissions/fluxes validation challenges
  - Annexe C – Implementation Actions – Cal/Val as a living document
- Facility scale L2/emissions/fluxes validation
  - JPL/ESA/NASA collaboration with commercial operators (GHGSat, CCMs…)
  - IMEO Cal/Val Testing WG
  - Continued work on '*Common Practices for Quantifying, Reporting, Validating, and Assessing Facility Scale Methane Emissions Using Remote Sensing*' by Worden *et al.* and need for extension to area fluxes
- GHG Cal/Val updates at AC-VC-20 (this week in College Park, MD)

Air Quality Constellation Validation

Cal/Val coordination (VC-20-02) & plans (VC-20-03)

- L2 algorithms: Sentinel-4 L2 prototype testing on GEMS; NO_2 and HCHO algorithms round-robin studies
- International collaboration on FRMs and other validation data: collaborative airborne campaigns, Pandonia Global Network & Pandora Asian Network, CINDI-3 MAX-DOAS community campaign with participation of other networks
- Sentinel-5P MPC operational validation service (2017-2027) as pathfinder for:
  - ESA PEGASOS validation service for GEMS (2022-2024). PEGASOS to be continued and extended to TEMPO (2025-2026)
  - EUMETSAT operational validation system for Sentinel-4, Sentinel-5 and CO2M
- EUMETSAT ITT (deadline 2024/10) scientific service for CO2M product (incl. NO_2) validation methods, reference data provision and processing

Air Quality Constellation Validation

Cal/Val Announcements of Opportunities (VC-20-04)

- GEMS AO (L 2020/02) → ongoing Cal/Val activities with international participation; airborne campaigns, cross-validations
- TEMPO (L 2023/04), Mission Validation Plan, joint NASA/NOAA science field campaigns contribute to validation
- Joint ESA/EUMETSAT AO Call (closed October 11, 2024) for the Cal/Val of Sentinel-4 and -5 (first launches in 2025-2026)
  - Validation data analysis and reporting aligned with staggered release of L2 products
  - Proposed validation data must evaluate CEOS-FRM maturity level.
  - Synergies with Sentinel-5P, GEMS, TEMPO, OMPS and other validation efforts encouraged

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

Semi-blind intercalibration and intercomparison campaign with external referee

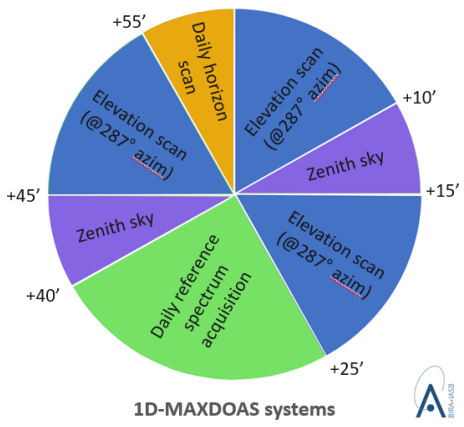
- to intercalibrate instruments and assess mutual consistency of measurements
- to get NDACC and ACTRIS-CREGARS certification for new instruments
- to assess and improve FRM maturity for validation of CEOS Air Quality and Ozone satellite constellations

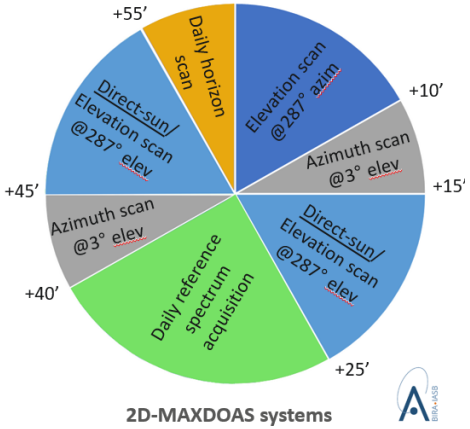
Data product	Fitting range
NO_2 (VIS range)	425 – 490 nm
NO_2 (alternative VIS range)	411 – 445 nm
NO_2 (UV range)	338 – 370 nm
O_4 (VIS range)	425 – 490 nm
O_4 (UV range)	338 – 370 nm
HCHO	324.5 – 359 nm
HONO	335 – 373 nm
CHOCHO	436 – 468 nm
O_3 (Chappuis bands)	450 – 540 nm
O_3 (Huggins bands)	320 – 340 nm

Additional species: CHOCHO and HONO

Observation protocol

Every day between 11:10:00 and 12:10. Local noon is at ~11:40





CINDI-3 (May 21 – June 21, 2024)

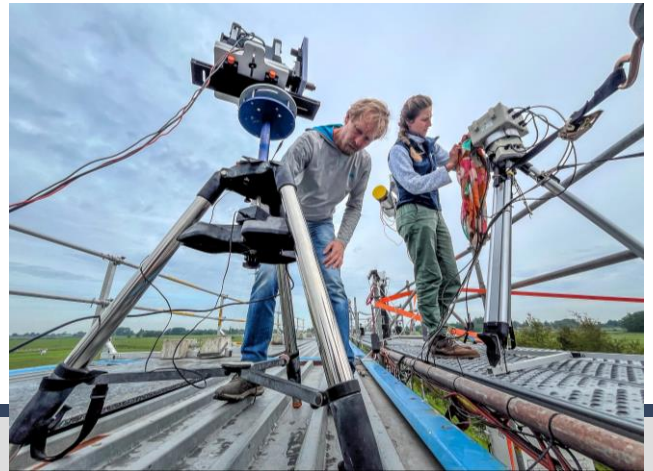
CV-24-01

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

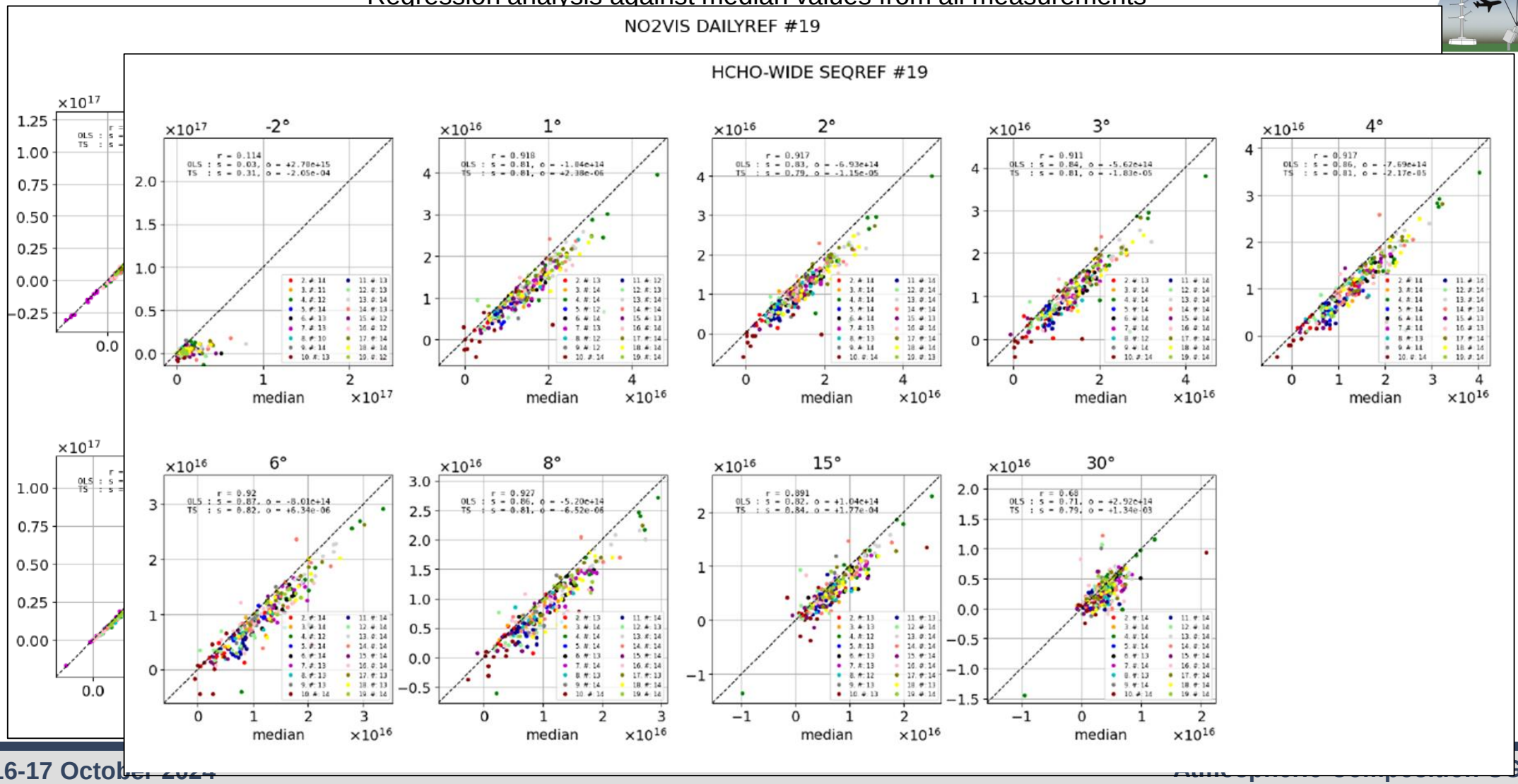


Highlights

- 35+ UV-Vis DOAS instruments of (MAX)DOAS, SAOZ and Pandora types intercompared for NO_2, HCHO, O_4, O_4, CHOCHO, HONO, BrO and O_3 slant column measurements
- In-field calibration setup by Luftblick/NASA applied to all UV-Vis instruments
- Interactive semi-blind data evaluation with daily briefs
- Comprehensive set of ancillary measurements: aerosol and tropospheric O_3 lidars, Brewer and aerosol sunphotometers, NO_2 and O_3 sondes, in-situ instruments, long-path DOAS, etc.
- Mobile measurement setup for NO_2 (carDOAS) and aerosols (MAMS)
- Airborne mapping and vertical profiling of NO_2 in Cabauw and Rotterdam area using Belgian coast-guard research aircraft (operator RBINS)
- Post-campaign data analysis in progress

Data evaluation in progress

Regression analysis against median values from all measurements



CEOS-FRM – Atmospheric composition

Current CEOS-FRM Version 1

- 2023/09: Substantial feedback on CEOS-FRM document provided by ACSG and NDACC Steering Committee
- 2024/02: FRM4DOAS and PGN test cases for CEOS-FRM tool (v1) reported at WGCV-53 ⇨ need to clarify guidelines and address CEOS-FRM v1 issues for atmospheric composition (WGCV-53-ACT-14)
- BAQUNIN Brewer NO_2 self-assessment
- 2024/10: FRM4DOAS and FRM4GHG (EM27/SUN) self-assessments published in *Remote Sensing* special issue '*Copernicus Sentinels Missions Calibration, Validation, FRM and Innovation Approaches in Satellite-Data Quality Assessment'* (SI closes 2024/11)

CEOS-FRM – Atmospheric composition

Future CEOS-FRM Version 2

- WGCV-53-ACT-14 in progress: telecon 2024/06, iterations…, proposal for additional column:
  - v1 matrix applicable to a measurement ⇨ classification
  - additional column characterizing validation capacity achieved by network deployment, centralized processing and QA/QC, timeliness
- Version 2 development in progress
- Test cases volunteering for future v2: NDACC sub-networks (DOAS, FTIR, lidars, MWR, sondes), ACTRIS-CREGARS (topical Centre for Reactive Trace Gases Remote Sensing)

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

FRMs and Other Validation Data

- ESA Living Planet Symposium 2025 (Vienna, 2025/06): cross-EO domains session *'Recent progress on uncertainty analysis for Earth Observation measurements'* open to FRM presentations
- NDACC network strategy peer-reviewed paper in good progress, including satellite validation strategies for NDACC sub-networks and viewpoint of stakeholders (incl. ACSG and several space agencies)
- NDACC Symposium 2025 Celebrating 35th Anniversary of the Network, Virginia Beach, VA, USA (2025/10)