Precursors_cci+

ESA Climate Change Initiative (CCI)



D5.3 User Workshop Report

Title	D5.3 User Workshop Report
Reference	Precursors_cci+_D5.3_UWR_01_02
Issue	01
Revision	02
Status	Final
Date of issue	09/04/2026
Document type	Deliverable

This work has received funding from the European Space Agency under Contract No 4000138243 and is the result of the cooperation between the partners of the Precursors_cci+ consortium.















Generated by KNMI

Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

	FUNCTION	NAME	DATE
LEAD AUTHOR(S)	Co-Science Leader Contributing authors	Folkert Boersma N. Kalb, M. Van Roozendael	01/10/2025
REVIEWED BY	Science Leader	M. Van Roozendael	10/10/2025
	ESA Project Officer	Simon Pinnock	04/12/2025
DISTRIBUTED TO	ESA Precursors_cci+ Consortium		

1. TABLE OF CONTENTS

2. PURPOSE AND SCOPE 4

A. PURPOSE 4
B. SCOPE 4
C. LIST OF ACRONYMS 6

3. AGENDA 8

A. AGENDA ON TUESDAY 10 JUNE 2025 8
B. AGENDA ON WEDNESDAY 11 JUNE 2025 9
C. HIGH-LEVEL SUMMARY OF DAY 1 10
D. HIGH-LEVEL SUMMARY OF DAY 2 11

4. TRANSCRIPT OF DAY 1 14

5. REFERENCES 17

Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

2. Purpose and scope

a. Purpose

The purpose of ESA's Precursors of Aerosol and Ozone ECV - CCI User Workshop is to enhance the visibility, accessibility, and impact of relevant atmospheric composition satellite data products for research and applications in climate change. The key objectives of the workshop are to:

- Inform users by providing insights into the strengths, limitations, and potential applications of ECV Precursor project data products.
- Engage with the chemistry-climate community to gather valuable user feedback, ensuring that future data developments align with scientific and operational needs.

The User Workshop took place on 10-11 June 2025 as an online meeting to allow as many as possible users to attend while minimizing travel costs. It was organized by Dr. Michel Van Roozendael (BIRA), Dr. Folkert Boersma (KNMI), and Nathalie Kalb (BIRA).

b. Scope

The scope of the User Workshop (BIRA, 2025) was to invite a selection of key producers *and* data users of satellite ECV Precursor data. The focus was on exchanging information to improve the visibility, accessibility, and impact of satellite data products for climate change research and applications, and to gather feedback from users on the data products provided.

The following list of users, split up per ECV Precursor gas have been invited:

NO_2:

Kazu Miyazaki	Kazuyuki.miyazaki@jpl.nasa.gov
Herizo Narivelo	herizo.narivelo@aero.obs-mip.fr
Jenny Stavrakou	jenny@aeronomy.be
Ronald van der A	avander@knmi.nl
Rob Roebeling	Rob.Roebeling@eumetsat.int
Suvarna Fadnavis	suvarna@tropmet.res.in
Antje Inness	antje.inness@ecmwf.int
Nicolas Bousserez	Nicolas.bousserez@ecmwf.int
Kees de Hoogh	c.dehoogh@swisstph.ch
Aris Georgoulias	ageor@auth.gr

NH_3:

Martin Van Damme	Martin.Van.Damme@ulb.be
Jianan Chen	jianan1.chen@wur.nl
Enrico Dammers	enrico.dammers@tno.nl
Tyler Wizenberg	tyler.wizenberg@tno.nl

CO:

Benjamin Gaubert	gaubert@ucar.edu
Christoph Keller	Christoph.a.keller@nasa.gov
Maarten Krol	Maarten.krol@wur.nl
Antoine Ehret	antoine.ehret@latmos.ipsl.fr
Heba Marey	hmarey@atmosp.physics.utoronto.ca
Marion Ranaivombola	marion.ranaivombola@univ-reunion.fr
Marcellin Adon	adonatma@yahoo.fr
Medhi Meziane	mehdi.meziane@meteo.fr
Nicola Zoppetti	n.zoppetti@ifac.cnr.it
Deng Yange	deng.yange@nies.go.jp
Brad Weir	Brad.weir@nasa.gov
Chayan Roychoudhury	croychoudhury@arizona.edu

HCHO:

Antje Inness	antje.inness@ecmwf.int
Vincent Huijnen	Vincent.huijnen@knmi.nl
Hervé Petetin	herve.petetin@bsc.es
Suvarna Fadnavis	suvarna@tropmet.res.in
Rokjin Park	rjpark@snu.ac.kr
Gitaek Lee	gitaek2@snu.ac.kr
Maarten van Herpen	van@acacia-ii.com
Jos de Laat	Jos.de.laat@knmi.nl
Caroline Nowlan	cnowlan@cfa.harvard.edu
Meiyun Lin	meiyun.lin@noaa.gov
Xiaomeng Jin	xiaomeng.jin@rutgers.edu
Karn Vohra	k.vohra@ucl.ac.uk
Gonzalo Abad	ggonzalezabad@cfa.harvard.edu

SO_2:

Vitali Fioletov	vitali.fioletov@ec.gc.ca
Zhen Qu	zhen.qu@colorado.edu
Can Li	can.li@nasa.gov
Nick Krotkov	nickolay.a.krotkov@nasa.gov
Ben Esse	benjamin.esse@manchester.ac.uk
Thomas Aubry	t.aubry@exeter.ac.uk

Furthermore, representatives from the CCI ozone and aerosol community were invited (Arno Keppens (O_3 CCI, BIRA), Gerrit de Leeuw and Thomas Holzer-Popp (Aerosol CCI). There were 42 participants attending the workshop. The full list of participants can be found here: https://events.spacepole.be/event/231/registrations/participants.

c. List of acronyms

AC-SAF	Satellite Application Facility on Atmospheric Composition Monitoring
ADP	Algorithm Development Plan
AK	Averaging Kernel
AMF	Air-mass factor
ATBD	Algorithm Theoretical Basis Document
BIRA-IASB	Royal Belgian Institute for Space Aeronomy
BIRA-IR	BIRA-IASB Infrared Observations Team
BIRA-SYN	BIRA-IASB Atmospheric Data Synergies Team
BIRA-UVVIS	BIRA-IASB UV-Visible Observations Team
BIRA-MOD	BIRA-IASB Tropospheric Chemistry Modelling Team
CAMS	Copernicus Atmospheric Monitoring Service
C3S	Copernicus Climate Change Monitoring Service
CCI	ESA Climate Change Initiative
CCI+	Climate Change Initiative Extension (CCI+), is an extension of the CCI over the period 2017-2024.
CDR	Climate Data Record
CEOS	Committee on Earth Observation Satellites
CMUG	Climate Modelling User Group
CO	Carbon monoxide
COBRA	COvariance-Based Retrieval Algorithm
CRDP	Climate Research Data Package
CRG	Climate Research Group
DLR	German Aerospace Centre
DOAS	Differential Optical Absorption Spectroscopy
ECMWF	European Centre for Medium-range Weather Forecast
ECV	Essential Climate Variable
ENVISAT	Environmental Satellite (ESA)
EO	Earth Observation
ESA	European Space Agency
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FCDR	Fundamental Climate Data Record
FRESCO	Fast Retrieval Scheme for Clouds from the Oxygen A band
FRM	Fiducial Reference Measurement
GCOS	Global Climate Observation System
GOME	Global Ozone Monitoring Instrument (aboard ERS-2)
GOME-2	Global Ozone Monitoring Instrument – 2 (aboard MetOp-A, -B and -C)
HRI	Hyperspectral Range Index
IASI	Infrared Atmospheric Sounding Interferometer
IGAC	International Global Atmospheric Chemistry project
IP	Implementation Plan
KNMI	Royal Netherlands Meteorological Institute
LEO	Low Earth Orbit
LUT	Look-up table
MetOp	Meteorological Operational Platform (EUMETSAT)
MOPITT	Measurement of Pollution in the Troposphere
NASA	National Aeronautics and Space Administration

NDACC	Network for the Detection of Atmospheric Composition Change
NH_3	Ammonia
NN	Neural Network
NO_2	Nitrogen dioxide
NRT	Near-Real Time
OCRA	Optical Cloud Recognition Algorithm)
OMI	Ozone Monitoring Instrument (aboard EOS-Aura)
PCA	Principal Component Analysis
QA4ECV	Quality Assurance for Essential Climate Variables
QA4EO	Quality Assurance framework for Earth Observation
R&D	Research and Development
ROCINN	Retrieval of Cloud Information using Neural Networks
SAF	Satellite Application Facility
SCIAMACHY	Scanning Imaging Absorption spectroMeter for Atmospheric CHartography
S5P	Sentinel-5 Precursor
SoW	Statement of Work
STREAM	STRatospheric Estimation Algorithm from Mainz
SZA	Solar Zenith Angle
TEMIS	Tropospheric Emission Monitoring Internet Service
TIR	Thermal Infrared spectral range
TROPOMI	Tropospheric Monitoring Instrument (aboard Sentinel-5 Precursor)
TOA	Top-of-atmosphere
TOAR-II	Tropospheric Ozone Assessment Report Phase-II
ULB	Université Libre de Bruxelles
IUP-UB	Institute of Environmental Physics, University of Bremen
UPAS	Universal Processor for UV/Vis Atmospheric Sensors
URD	User Requirement Document
UV-Vis	Ultraviolet and visible spectral range
VZA	Viewing Zenith Angle
WP	Work Package

3. Agenda

a. Agenda on Tuesday 10 June 2025

On day 1 of the workshop, in the afternoon the focus was on the consortium's progress to produce ECV Precursor data sets. Below is the agenda on that afternoon.

14:00	**Welcome and introduction** *Microsoft Teams*		14:00 - 14:20
	Climate Data Record of tropospheric NO2 columns and uncertainties *Microsoft Teams*	*Dr Folkert Boersma et al.*	14:20 - 14:40
	Climate Data Record of HCHO columns *Microsoft Teams*	*Dr Isabelle Desmedt*	14:40 - 15:00
15:00	**Climate Data Record of Glyoxal columns** *Microsoft Teams*	*Dr Thomas Danckaert*	15:00 - 15:20
	Climate Data Record of SO2 columns *Microsoft Teams*	*Dr Nicolas Theys*	15:20 - 15:40
	Break *Microsoft Teams*		15:40 - 16:00
16:00	**Merging IASI and MOPITT L3 data : a new CCI CDR CO product** *Microsoft Teams*	*Dr Maya George*	16:00 - 16:20
	Climate Data Record of NH3 columns *Microsoft Teams*	*Dr Martin Van Damme*	16:20 - 16:40
	Validation of ESA CCI Precursors data products *Microsoft Teams*	*Dr Steven Compernolle*	16:40 - 17:10
17:00	**Some insights gained while producing long-term formaldehyde satellite data records** *Microsoft Teams*	*G. Gonzalez Abad*	17:10 - 17:30
	Discussion user needs / requirements *Microsoft Teams*		17:30 - 18:00

b. Agenda on Wednesday 11 June 2025

On day 2 of the workshop, the focus was on how data users can best utilize the satellite data, and what they require from the data products. Below is the agenda for day 2.

14:00	**On the use of NO2 retrievals in the CAMS near-real time system and CAMS reanalysis**	*Dr Antje Inness*	
	Microsoft Teams		14:00 - 14:20
	Towards an emission monitoring capability in CAMS: methodology and preliminary results	*Dr Nicolas Bousserez*	
	Microsoft Teams		14:20 - 14:40
	TROPOMI NOx Emissions from across the Canadian Mining Sector	*Dr Chris McLinden*	
	Microsoft Teams		14:40 - 15:00
15:00	**Global distribution and trends of O3 precursors as seen from space**	*Dr Hervé Petetin*	
	Microsoft Teams		15:00 - 15:20
	Top-down estimates of NH3 emissions to characterise the influence on local air quality	*Prof. Eloise Marais*	
	Microsoft Teams		15:20 - 15:40
	Break		
	Microsoft Teams		15:40 - 16:00
16:00	**Understanding the variability and trends of the ESA CCI formaldehyde columns over Africa**	*Dr Trissevgeni Stavrakou*	
	Microsoft Teams		16:00 - 16:20
	Use of Ozone precursors (NO2, HCHO and CO) satellite observations to constrain emission inventories for 15 years of ... *Herizo Narivelo*		
	Long-term analysis of power plant emissions based on satellite NO2 data	*Dr Steffen Beirle*	
	Microsoft Teams		16:40 - 17:00
17:00	**Global SO2 emission inventories based on satellite data records**	*Dr Chris McLinden*	
	Microsoft Teams		17:00 - 17:20
	Discussion user needs / requirements		
	Microsoft Teams		17:20 - 18:00

c. High-level summary of Day 1

The development of long-term climate data records for the 6 trace gases NO_2, HCHO, CHOCHO, SO_2, CO and NH_3 was central on the first afternoon. For all 6 trace gases, retrieval algorithms have been improved, climate data records have been generated, both for level 2 and level 3 satellite data, and all records have at least been partly validated. Some things that stood out:

- Users generally require validated level 2 data that include uncertainty estimates and averaging kernels.
- Users express a need for simple and short documentation that explains how to use the satellite data.
- A detailed approach to consider spatial and temporal error correlations in the uncertainty propagation has been developed and applied for OMI and TROPOMI NO_2 level 3 data. Level 3 monthly mean uncertainties are significantly reduced compared to mean level 2 uncertainties, bringing the NO_2 data within GCOS requirements. A scientific paper on this is in review with Earth System Science Data (Glissenaar et al., 2025).
- The HCHO retrievals are more consistent and stable using CAMS Reanalysis a priori vertical profiles in the AMF calculation, and this also reduces the low bias in the validation exercise.
- Improved retrievals of glyoxal and SO_2 have been generated and shown to agree well with ground-based reference data.
- A merged IASI + MOPITT CO product was presented. It uses weighted averaging to combine collocated data from the two sensors, where the weighting tends to the retrieval with higher information content. The CO record was shown to agree within 10% with validation data.
- A climate data record of IASI NH_3 has been generated based on improved retrievals that now include averaging kernels and uncertainty estimates. The data show an intriguing increase in NH_3 over eastern China, possibly associated with the reduction of aerosols in the last decade there.

The open discussion with users covered various topics, including:

- whether to use climatological a priori profiles in the calculation of AMFs or profiles that change in time reflecting known changes in emissions; opinions differed (“climatological priors avoid ‘contamination’ by unrealistic emission trends” vs. “known changes in emissions result in more realistic a priori profiles”). In any case inclusion of averaging kernels makes it possible for users to recalculate AMFs according to their preference.
- Comparing the HCHO CDR from this ESA project with the CDR produced by NASA/SAO (Gonzales-Abad) was suggested as useful to evaluate both datasets.
- Level 3 (monthly mean gridded) data from the project will be made available via ESA CCI Data Portal, level 2 data available upon request with the retrieval teams.
- Validation should not only address discrepancies between the CDR and reference data but also test the reported uncertainties in the satellite data products, i.e. validate the retrieval uncertainty.
- Validation efforts should address aspects of vertical sensitivity, spatial representativeness, and long-term robustness to assess all relevant aspects of the satellite data products.

For a detailed transcript made by Microsoft CoPilot, see section 3.

d. High-level summary of Day 2

Antje Inness (ECMWF) presented the uptake of NO_2 tropospheric columns in ECMWF's CAMS near-real time and reanalysis systems. Especially over China (where model emissions have not been updated), using the satellite NO_2 data improves the atmospheric state. The recent assimilation of GEMS (geostationary) NO_2 columns is particularly powerful over China and helps to resolve the issue that assimilated NO_2 quickly 'falls back' to the modelled state owing to its short lifetime. Continuous, hourly NO_2 data keep forcing the state back to the observed 'state'.

Nicolas Bousserez (ECMWF) followed up on using satellite NO_2, CO, CO_2 and CH_4 data for updating emissions (rather than atmospheric concentrations as shown by Inness) in ECMWF's CAMS system. He highlighted the integration of various satellite data sources, including also surface concentrations to monitor emissions. Initial results appear promising, with CO_2 emissions improving somewhat from inverting (co-emitted) NO_2. One issue raised is the threat of 'circularity' when CAMS ingests satellite retrievals that are based on AMF calculations with a priori profiles coming from CAMS. This should not be an issue as long as the profiles in the model and in the retrieval are identical (and would avoid having to use the averaging kernels).

Hervé Petetin (Barcelona Supercomputing Centre) showed how satellite records of tropospheric CO, NO_2 and HCHO together help to improve our understanding of tropospheric ozone. There are no clear trends in the formaldehyde-to nitrogen dioxide ratio's (FNR) in most regions. Over India, however, the increase in tropospheric O_3 coincides with strong increases in NO_2 and HCHO over the subcontinent.

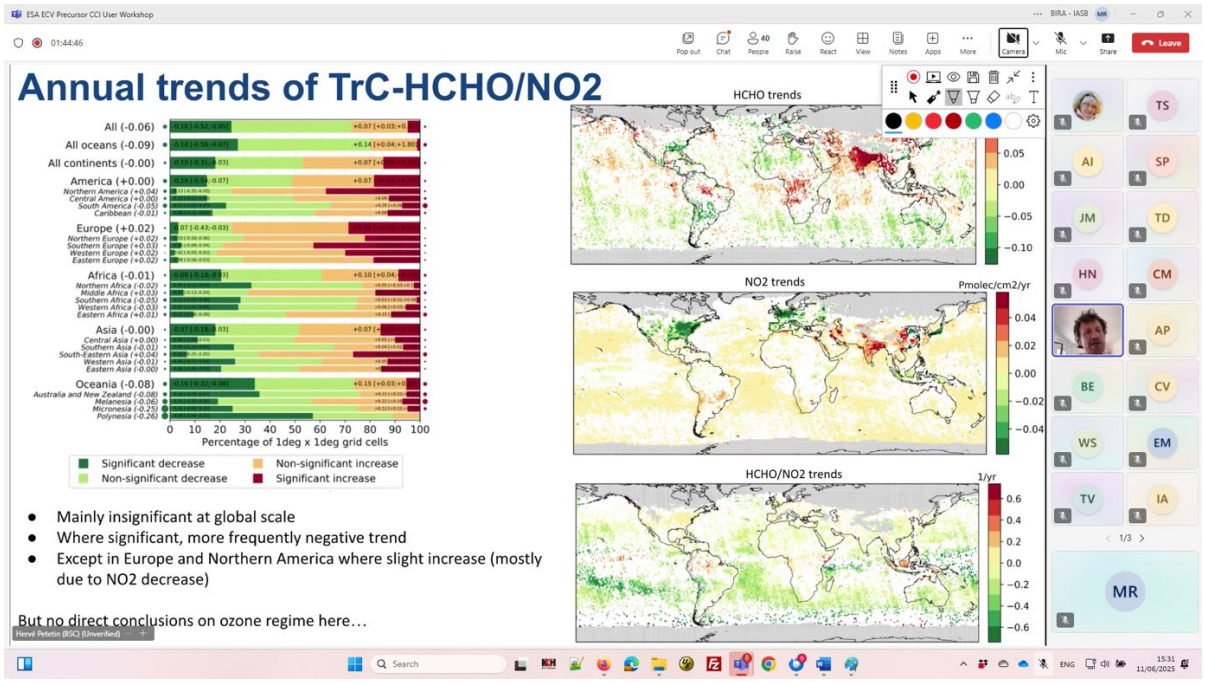


Figure 3-1. Screenshot of the presentation by Hervé Petetin on trends in the formaldehyde-to-NO_2 (FNR) ratio as indicator for photochemical ozone production.

Chris McLinden (Environment Canada) discussed the use of TROPOMI NO_2 to monitor NO_x emissions specifically from the vast Canadian mining sector. Many mines are closing, and the reductions over time correspond reasonably well with reductions reported to the national inventory. The limiting factors for detecting mining activities are interference from other nearby NO_x emissions, and noisy plumes.

Eloise Marais (University College London) presented space-based estimates of NO_x and NH_3 emissions from fires and their impact on local air quality. NO_x emissions should be high for flaming fires, NH_3 emissions for smouldering fires. Marais praised the user-friendly format of the (IASI) NH_3 data and responsiveness of the data providers. One open issue with interpreting NH_3 data is the role of nitrate aerosol evaporation which releases NH_3 back into the gas phase. This aspect requires further study in the inversion schemes.

Trissevgeni Stavrakou (BIRA) presented variability and trends in HCHO columns over Africa. Significant variability and trends, presumably reflecting trends in VOC emissions and increases from increased HCHO production from CH_4 oxidation.

Steffen Beirle (MPIC) presented a long-term analysis of power plant NO_x emissions based on TROPOMI and OMI NO_2 data. A striking finding was the decline in NO_x emissions in many regions due to the implementation of new technologies and regulations.

Chris McLinden (Environment Canada) gave a second presentation on the development of global SO_2 emission inventories based on satellite SO_2 columns. His inventory suggests a decline in global anthropogenic SO_2 emissions and a decrease in volcanic SO_2 emissions over the last decade (that could not be attributed to incoherence between sensors).

Open discussion user needs and requirements
Key points included:

(1) More attention to satellite data over snow and ice.
Retrievals should better accommodate AMF calculations over snow and ice – these are often flagged as unreliable. Specific AMF calculations, for example using the concept of effective scene albedo, could be used to unlock these valuable retrievals.

(2) the importance of (better) ground truthing.
Ground truthing can be improved by using long-term records of independent reference data, addressing issues like (mismatches in) spatial representativeness of FRM data, and vertical sensitivity. The Tropics are scarce in terms of FRM data.

(3) The need for better coverage in regions like Africa and Southeast Asia.
Users in these areas may not all be familiar with netcdf files and large data volumes, and smaller (simplified) and easily accessible data files may be of benefit to new users from these regions.

(4) The need for satellite data to inform regulatory authorities and industry (real world applications).
Most regulatory bodies traditionally rely on using surface concentrations to evaluate the effectiveness of new measures and regulation. This user-community may still need a convincing case that demonstrates how satellite data can be used to provide evidence that new rules work (or not) to reduce air pollution levels or emissions.

(5) the importance of satellite data use for inequitable exposure.
Satellite data has proven to be useful to identify which sub-populations are more affected by air pollution.

4. Transcript of Day 1

The below text has been generated by Microsoft Co-Pilot, updated by Folkert Boersma, and summarizes the presentations on Day 1.

Welcome and Introduction (14:00 - 14:20):

- Michel Van Roozendael and Simon Pinnock provided an overview of the ESA CCI programme, emphasizing the development of long-term climate data records for various trace gases. They discussed the objectives and structure of the programme, highlighting the importance of creating multi-decadal, multi-satellite global climate data records. Simon also explained the role of the Global Climate Observing System (GCOS) in defining essential climate variables (ECVs) and the need for these data sets to support climate science and policy.

Climate Data Record of Tropospheric NO_2 Columns and Uncertainties (14:20 - 14:40):

- Folkert Boersma presented the generation of climate data records for NO_2, focusing on the improvements in algorithms and uncertainty assessments. He detailed the creation of internally consistent Level 2 data sets for various sensors, including GOME, SCIAMACHY, OMI and TROPOMI. Boersma emphasized the importance of accounting for spatial and temporal correlations in uncertainty calculations and discussed the methods used to generate daily and monthly Level 3 data. He also highlighted the need for continuous validation and the inclusion of validation conclusions with the data products.

  Question: *Are there plans to extend the data to recent years?*

  Answer: Yes, it is possible to extend the data to 2025 with the current TROPOMI processing version. However, there is a need to recalculate OMI with the Coll004 level-1 data for consistency. This is planned for the Extension phase.

  Question: *Does the weighting in the temporal average introduce a problem in the monthly average?*

  Answer: The weighting is done to prevent situations where days with few pixels get equal weight to more representative days. This approach has given reasonable results, but further testing could be beneficial.

Climate Data Record of HCHO Columns (14:40 - 15:00):

- Isabelle Desmedt presented the formaldehyde data set, focusing on algorithm improvements and validation results. She discussed the reprocessing of Level 2 data sets for multiple sensors, including OMI and TROPOMI, to create a consistent climate data record. Desmedt highlighted the impact of using CAMS reanalysis profiles on the vertical columns and the improvements in temporal stability and inter-sensor consistency. She also provided examples of validation results, showing improved correlation and reduced bias compared to ground-based measurements.

  Question: *What is the impact of changing the a priori profile on the vertical column?*

  Answer: Changing the a priori profile to CAMS analysis data set resulted in an increase in the vertical column, especially over emission regions. This systematic effect justified the reprocessing of all data sets.

  Question: *How does the validation against ground-based measurements compare between OMI and TROPOMI?*

  Answer: The validation showed improved correlation and reduced bias in the version 2 Level 3 data for both OMI and TROPOMI. The slope and intercept were very close between the two sensors.

Climate Data Record of Glyoxal Columns (15:00 - 15:20):

- Thomas Danckaert discussed the glyoxal climate data record, detailing the algorithm heritage and improvements made within the CCI project. He explained the use of improved air mass factor calculations, including daily a priori vertical profiles and viewing angle-dependent surface albedo data sets. Danckaert also highlighted the improved background correction for OMI and TROPOMI, which significantly reduced striping artifacts. He presented validation results showing good agreement with reference products and ground-based measurements.

  Question: *Can you explain more about the striping corrections for the VCD?*

  Answer: The striping correction involves a wavelet decomposition approach, which first identifies persistent artifacts and then corrects the remaining stripes. This method significantly improves the quality of the data.

Climate Data Record of SO_2 Columns (15:20 - 15:40):

- Nicolas Theys presented the SO_2 data products, explaining the harmonized retrieval framework and improvements in error estimation. He discussed the use of the COBRA algorithm for spectral fitting and the computation of air mass factors for different plume heights. Theys highlighted the impact of using different a priori profiles and surface reflectance data sets on the vertical columns. He provided examples of volcanic and anthropogenic emissions and discussed the validation results, showing a low bias compared to ground-based measurements.

  Question: *How does the validation against ground-based measurements compare for SO_2?*

  Answer: The validation showed a low bias in the satellite products compared to ground-based measurements, with the bias exceeding GCOS requirements at highly polluted sites but within acceptable limits at less polluted sites.

Merging IASI and MOPITT L3 Data: A New CCI CDR CO Product (16:00 - 16:20):

- Dr. Maya George discussed the merged CO product from IASI and MOPITT, explaining the weighted averaging process and validation results. She detailed the steps taken to filter and reformat the data, including the use of a cloud detection product. George presented the merged product, highlighting its improved coverage and validation results, showing good correspondence with the NDACC platform.

Question: *How does the merged product correspond with the INDAC platform?*

Answer: The merged product showed a mean bias between -5% and 10%, with an overall bias of 3.56% and a correlation of 0.83, indicating good correspondence with the NDACC platform.

Climate Data Record of NH_3 Columns (16:20 - 16:40):
Martin Van Damme presented the ammonia climate data record, detailing algorithm improvements and validation results. He discussed the use of an artificial neural network for the retrieval and the calculation of uncertainties. Van Damme highlighted the improvements in long-term homogeneity and the calculation of total column averaging kernels. He provided examples of validation results, showing a low bias compared to ground-based measurements.

Question: *What are the trends observed in the ammonia data, and what could be the potential causes?*

Answer: The data showed a strong increasing trend in the North China Plain and moderate positive trends in Europe and central US. The trends could be driven by changes in emissions or atmospheric lifetime, such as increased SO_2 emissions or the use of certain fertilizers.

Validation of ESA CCI Precursors Data Products (16:40 - 17:10):

Steven Compernolle provided an overview of the validation approach, emphasizing the importance of long-term records and the use of various reference measurements. He discussed the compliance check with GCOS requirements and the methodology used for validation, including harmonization and vertical smoothing. Compernolle highlighted the use of different reference measurements, such as MAX-DOAS and FTIR, and the importance of sustaining long-term measurement programs for climate data validation.

Question: *How is the validation of uncertainties performed?*

Answer: The validation compares the combined prognostic uncertainties for reference and satellite data to the actual dispersion obtained. This approach helps identify any overestimation or underestimation of uncertainties.

Some Insights Gained While Producing Long-Term Formaldehyde Satellite Data Records (17:10 - 17:30):
Gonzalo Gonzalez Abad shared his experience with building climate data records in the US, discussing the challenges and strategies used. He highlighted the importance of consistent algorithms and validation against ground-based measurements. Gonzalez Abad discussed the use of different sensors and the need for corrections to ensure long-term stability and consistency in the data records. He also emphasized the importance of using a climatology for a priori profiles to avoid contamination by trends from the a priori inputs.

Question: *How do the trends in formaldehyde data compare with a priori inputs?*

Answer: The trends observed in the data are consistent with the a priori inputs, and the choice of using a climatology helps avoid contamination by trends from the a priori. However, it is important to consider the potential impact of real trends in the a priori.

Discussion User Needs / Requirements (17:30 - 18:00):
The open discussion covered various topics, including the choice of a priori profiles and the impact on trends. Participants shared their insights and experiences, discussing the pros and cons of using climatology versus reanalysis for a priori profiles. The discussion also touched on the importance of validation and the need for continuous improvement in the data products.

5. References

Glissenaar, I., Boersma, K. F., Anglou, I., Rijsdijk, P., Verhoelst, T., Compernolle, S., Pinardi, G., Lambert, J.-C., Van Roozendael, M., and Eskes, H.: TROPOMI Level 3 tropospheric NO_2 dataset with advanced uncertainty analysis from the ESA CCI+ ECV precursor project, Earth Syst. Sci. Data, 17, 4627–4650, https://doi.org/10.5194/essd-17-4627-2025, 2025.

BIRA, ESA CCI ECV Precursor User Workshop, https://events.spacepole.be/event/231/, 10-11 June 2025 (last access: 1 October 2025).