

ICAP 2026 Meeting, Bonn (Germany), 10-12 June 2026



# EarthCARE Two Years in Orbit: Overview of the Latest Aerosol Key Findings

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On behalf of: ESA and JAXA Science teams

JAXA's CPR project team

ESA EarthCARE DISC

EarthCARE Project, Flight Operations Segment, Payload and Data Ground Systems



→ THE EUROPEAN SPACE AGENCY



# ESA Earth Explorer 6: EarthCARE



**Earth Cloud Aerosol & Radiation Explorer** is the largest and most complex Earth Explorer satellite in ESA's Future EO programme.

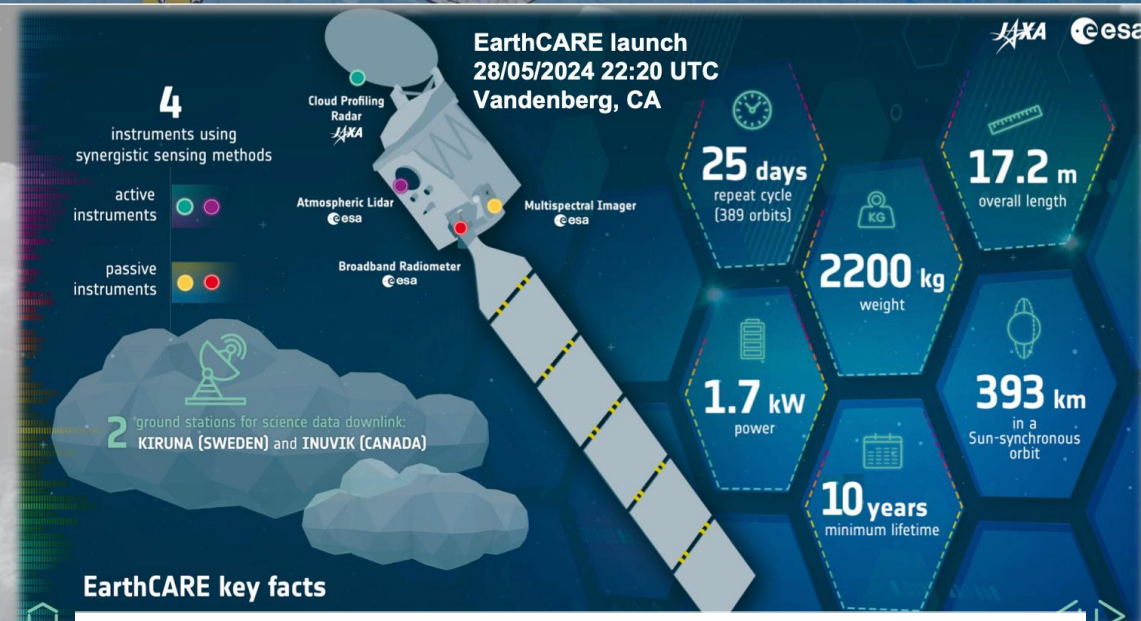
## Purpose:

- To improve our understanding of cloud, aerosol and precipitation processes and their radiative impact.
- Use synergy of active and passive instruments to provide the most accurate profiles of cloud, aerosol and precipitation.
- To perform radiative closure as part of the core mission.
- To provide near-real-time observations for assimilation into weather forecast models → **See "Recent progress on aerosol reflectance assimilation in IFS\_COMPO" by Angela Benedetti**

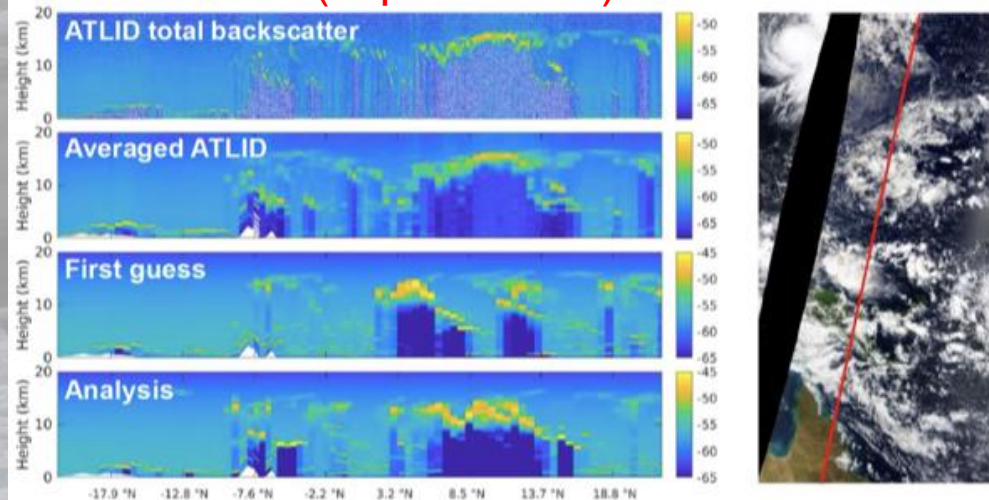
Joint venture with **JAXA**, providing the CPR radar

Space segment prime **Airbus Defence and Space DE**, with a consortium of over 75 companies

Ground segment prime **KNMI (NL)**, with a consortium of 17 companies (ESA EarthCARE Data & Innovation Science Cluster, DISC)



## Assimilation of EarthCARE radar and lidar (expectation!!)





# EarthCARE satellite and its instruments



## CPR: Cloud Profiling Radar

- First space-born Doppler cloud radar
- Frequency: 94 GHz
- Resolution: 0.65km (cross-track) x 1km (along-track), vertical 400 m

## ATLID: Atmospheric Lidar

- High spectral resolution Lidar (discriminates Mie and Rayleigh scattering components)
- UV Lidar: 355 nm, repetition rate 51 Hz, emitted energy 38 mJ
- Resolution: 30 m IFOV sampled at 100 m intervals along track, vertical 100 m

## MSI: Multi-Spectral Imager

- Push-broom scanner, cross-track observation
- 7-bands in the 0.6-12 $\mu$ m range
- Wide swath (150 km) with 500m resolution

## BBR: Broad-Band Radiometer

- Direct radiance measurements
- 2-bands: Short Wave (0.2-3.8 $\mu$ m) and Total wave (0.2-50 $\mu$ m)
- 3 direction pointing (Forward/Nadir/Backward)
- 10km resolution



## EarthCARE 2yrs in orbit: where are we?

- **Mission status**
- **Product status**
- **Emphasis of aerosol products and results**
- **Listing of major cloud-related results and other bonuses**
- **Where are we with the radiative closure?**

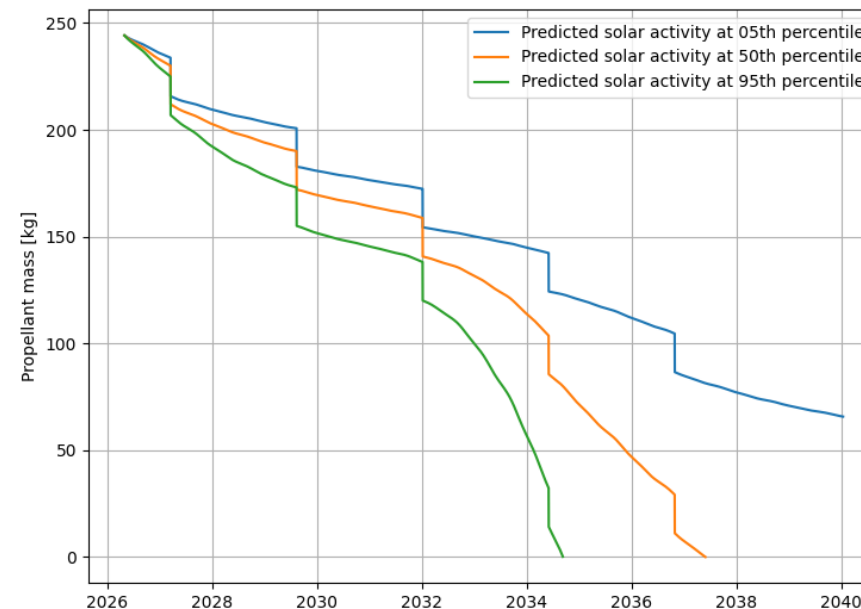


# Mission Status

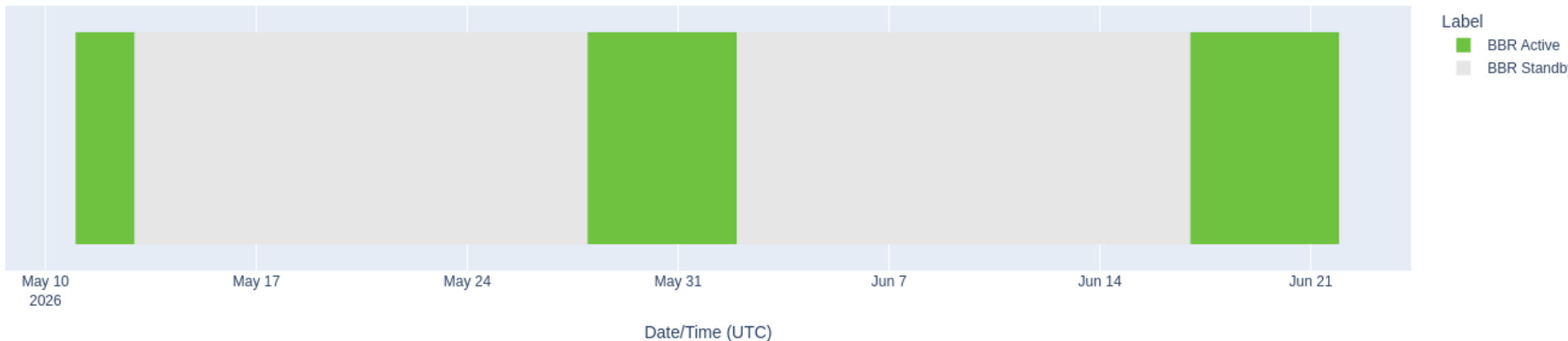


- Both the space segment and ground segment continue to perform nominally (MSI diffuser instability continues, vicarious calibration)
- Nominal lifetime is 3yrs. However, **current propellant consumption indicates a lifetime of ~10 years** (i.e., at least until 2034). This estimate is based on three different solar activity scenarios.
- BBR intermittent operations (25% cycle) started on 20 November 2025 to extend the nominal lifetime until 2029, see <https://earth.esa.int/eogateway/news/earthcare-s-bbr-instrument-life-extending-operations>
- Assessing possible changes in BBR cycle to extend its lifetime beyond 2029.

Adapted from EarthCARE SIOP-3

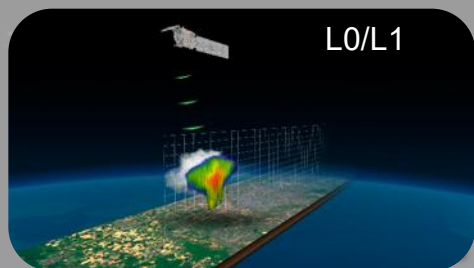


BBR Timeline: Active, Standby, and Events

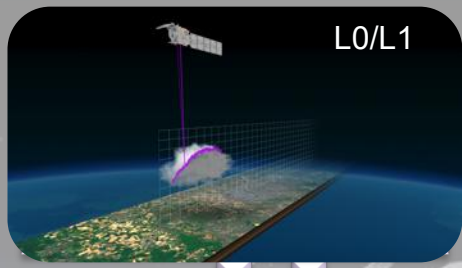




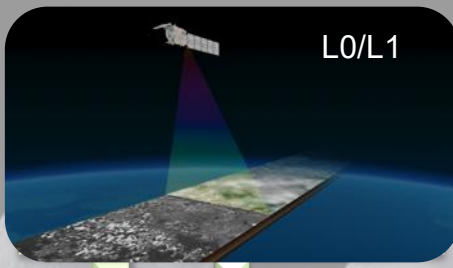
# Product Status: public release of full set of products in Dec 2025



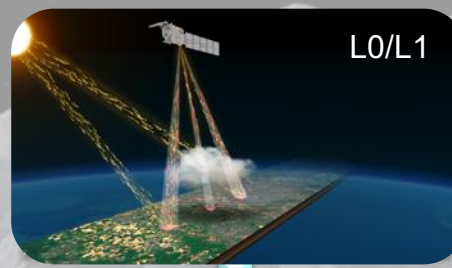
L0/L1



L0/L1



L0/L1



L0/L1

### CPR Level 2a

Radar echo product, feature mask, cloud type, liquid and ice cloud properties, vertical motion, rain and snow estimates, ...

### ATLID Level 2a

Feature mask and target classification, extinction, backscatter & depol. profiles, aerosol properties, ice cloud properties, ...

### MSI Level 2a

Cloud mask, cloud micro-physical parameters, cloud top height, aerosol parameters, ...

### BBR Level 2b

Unfiltered top-of-atmosphere radiances, short-wave and long-wave fluxes  
*Products are enhanced by using MSI*

### Synergistic Level 2b

Target classification, cloud & aerosol profiles at x-sect, ...

### 3D Scenes Construction

Expand syn. retrievals across-track using MSI; ≈40km wide

### Radiative Transfer Products

calculated radiances, fluxes, heating rate profiles

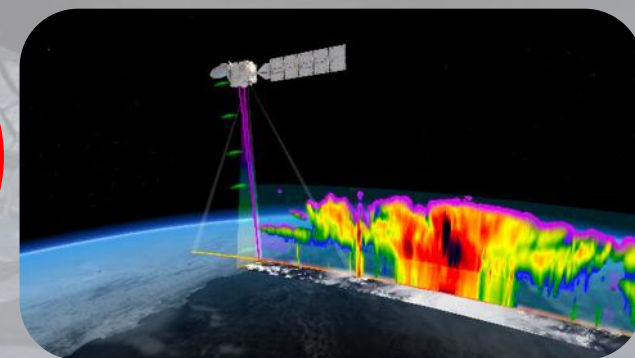
### Assessment

Comparison of calculated fluxes and radiances to BBR observations

### ESA/JAXA activities since launch (28 May 2024):

- 3 Satellite In-Orbit Performance (SIOP) meetings; 4th planned for Oct 2026
- 3 Quality Working Groups (QWG); 4th planned for Sept 2026
- 4 Science and Validation Workshops

**Three- and four-sensor synergy Products!**





# Product Status: reprocessing

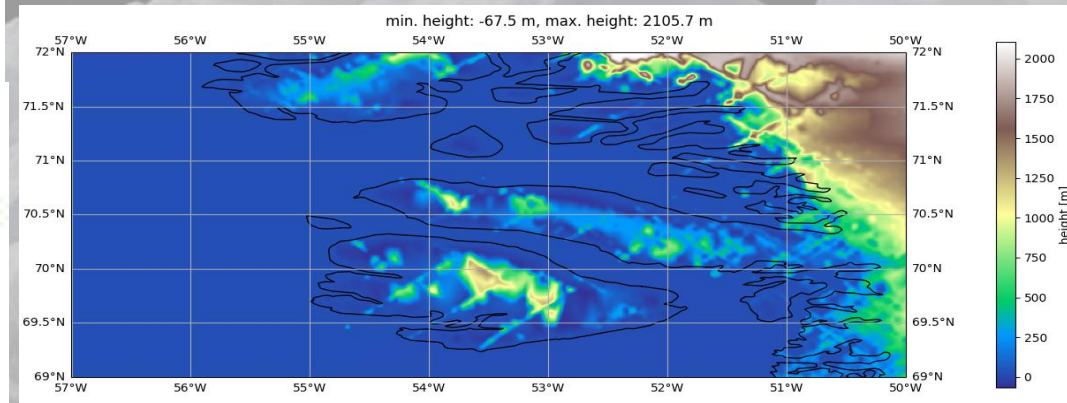


- 1st reprocessing campaign completed in Dec 2025
- 2nd reprocessing campaign planned for release by Dec 2026 (tentative schedule)

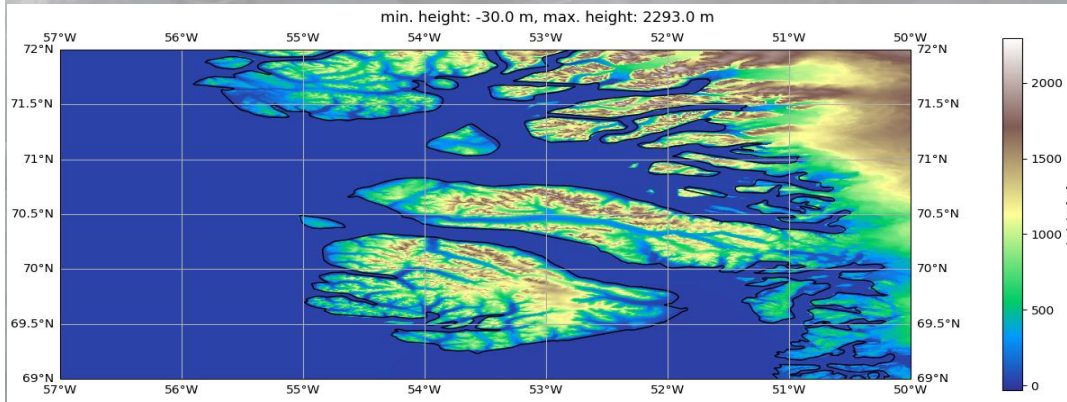
Processors	Reprocessed data													
	jun-26	jul-26	aug-26	sep-26	okt-26	nov-26	dec-26	jan-27	feb-27	mar-27	apr-27	mei-27	jun-27	jul-27
L1-ESA	CA	CA												
L1-JAXA	Repr > Nov '26													
L2a-ESA	CA	B*				CA								
L2b-ESA	CA	B*	B*			CA								
L2-JAXA	Repr > Nov '26													

- Processors updates in forward processing and 2nd reprocessing (baseline BC → CA)
- Updates include new DEM (ACE2 to AW3D30), new MSI VIS vicarious calibration, new handling of ATLID hot pixels, format changes, bug fixing (GPS outages, etc.), improved depolarization ratio, new surface BRDF and sedimentation velocity, etc.
- Updated processors:
  - **CPR:** C-L1, C-APC, C-PRO, C-CLD
  - **ATLID:** A-L1, A-FM, A-PRO, A-LAY
  - **MSI:** M-L1, M-CLD
  - **BBR:** BM-RAD
  - **Synergy:** AM-COL, BMA-FLX, AC-TC, ACM-CAP, ACM-COM, ACMB-3D, ACM-RT, ACMB-DF

ACE2 - 9 arcsec



AW3D30 - 4 arcsec



West Greenland



# Note on ATLID improvements in baseline CA

(credit: Dave Donovan & Athena A. Floutsis)

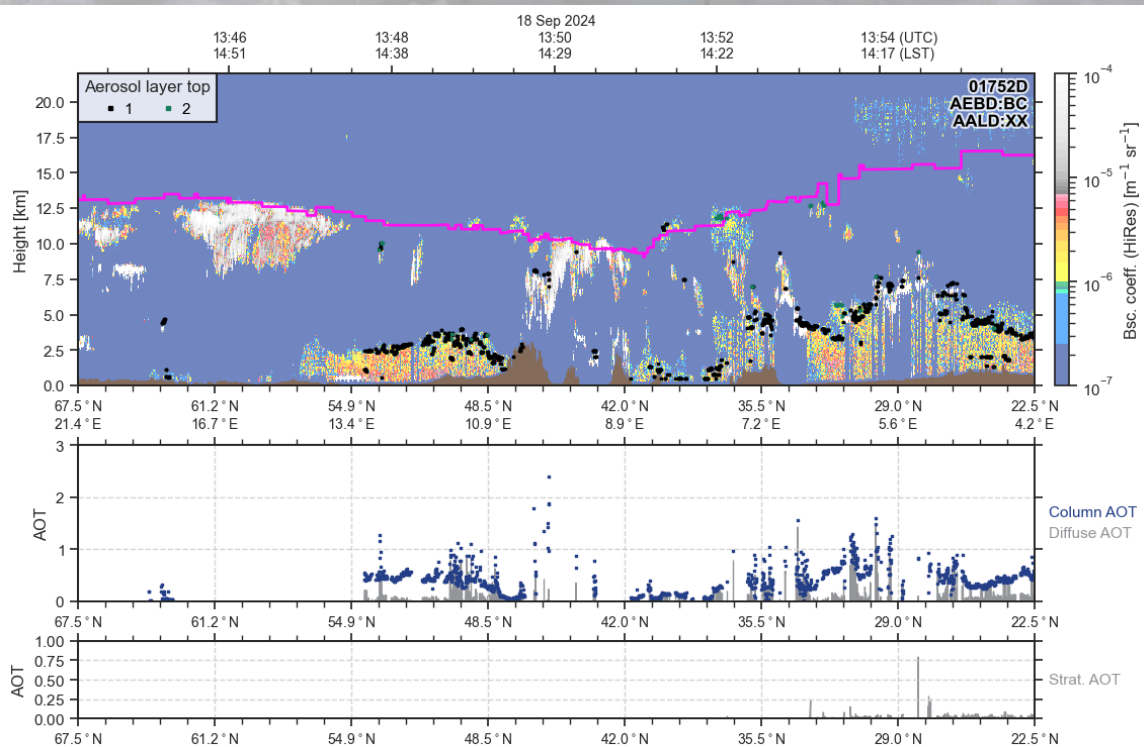
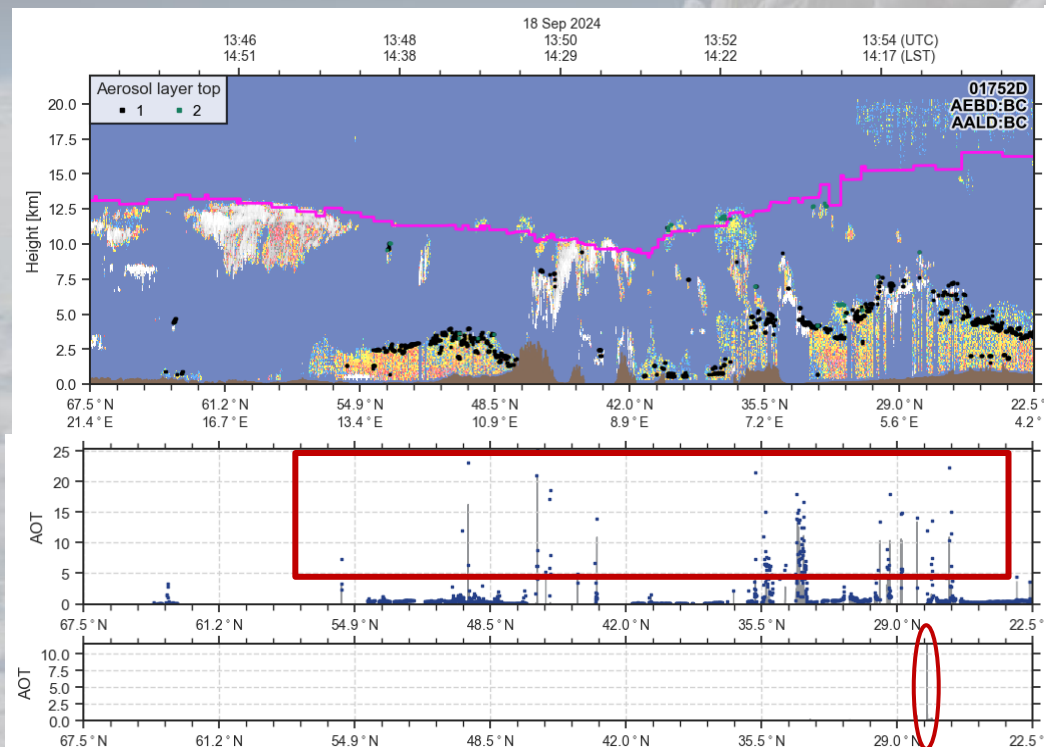


## ATLID L1

- More accurate depolarization thanks to improved characterization and correction of polarization cross-talk.
- Correction of detection chain Dark Current offset influenced by solar background → Better day-night consistency especially in cross-polar channel.
- Update handling of hot pixels (charge-transfer correction procedure).

## ATLID L2

- Improved surface detection and higher altitude performance.
- Addition of diffuse attenuation coefficient using Rayleigh channel.
- Improved particles sizes in Mie-scattering correction.
- Better cloud screening → Reduce contamination of aerosol backscatters/extinctions & MORE accurate and consistent aerosol classification.





# MSI Aerosol Optical Depth

(credit: Larisa Sogacheva, FMI)

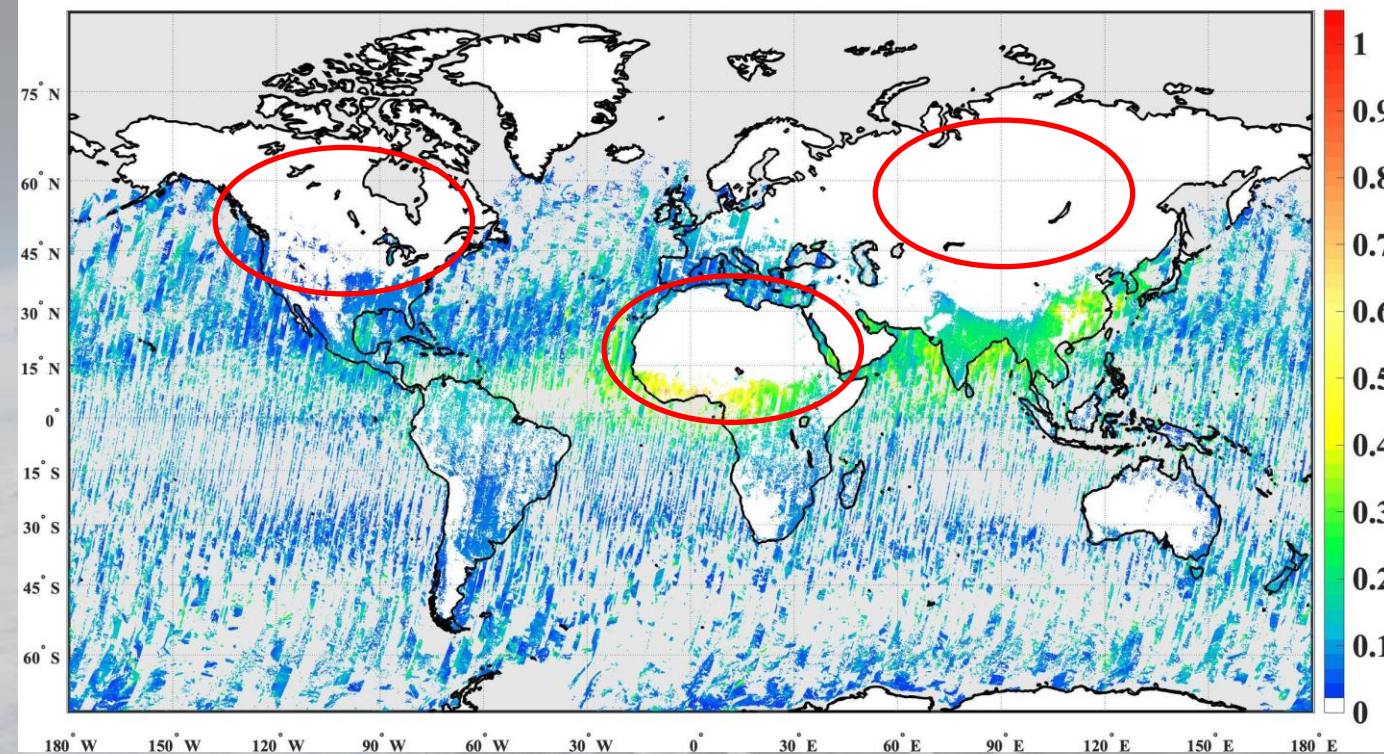


## MSI AOD@670nm

Monthly aggregates to L2 (0.1 deg)

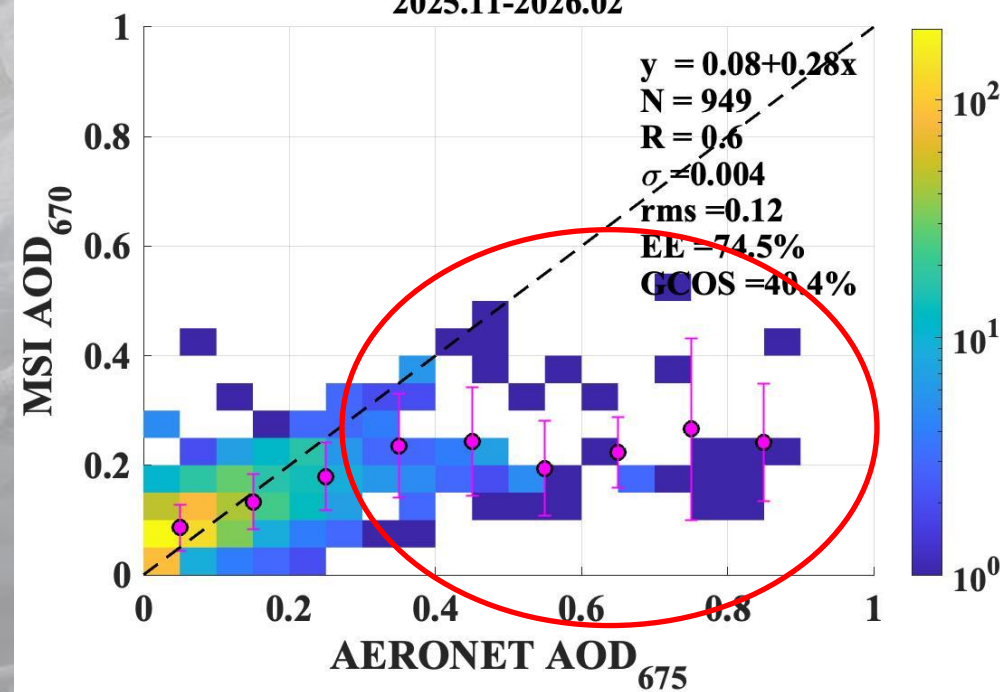
## Validation with AERONET

MSI AOD670 aod 202602



MSI AOD<sub>670</sub> BC

2025.11-2026.02



Expected improvements in baseline CA



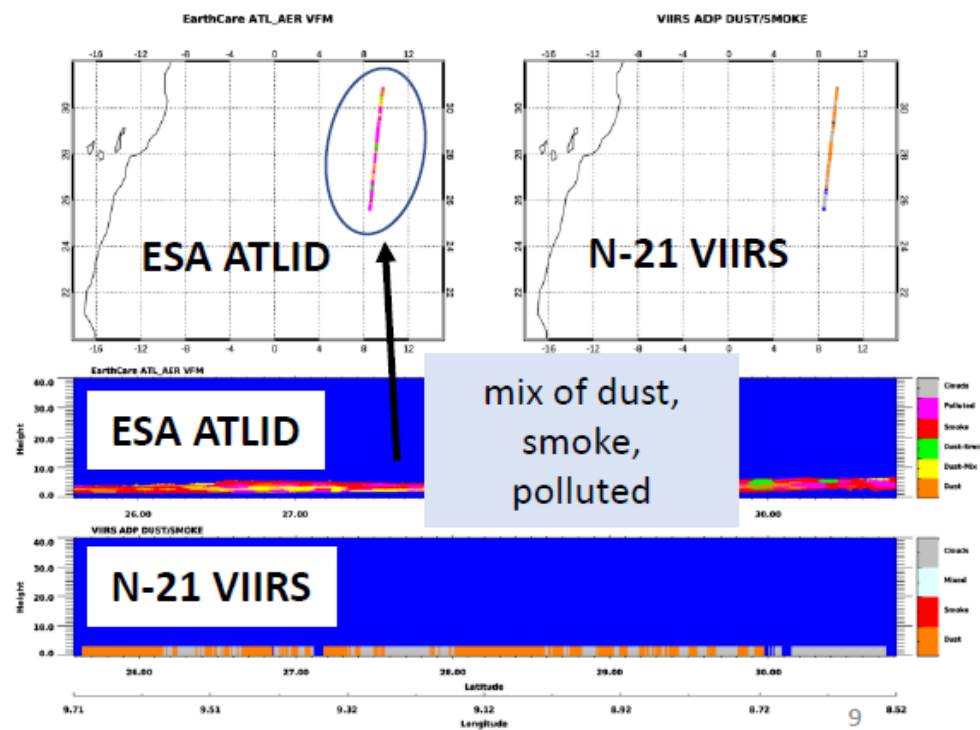
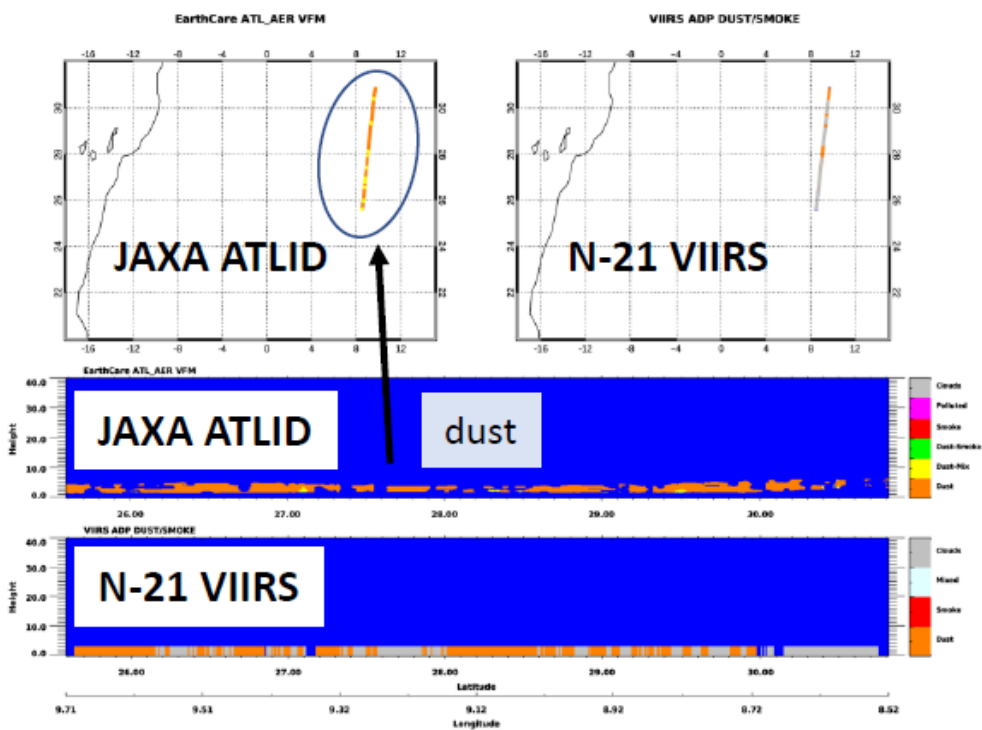
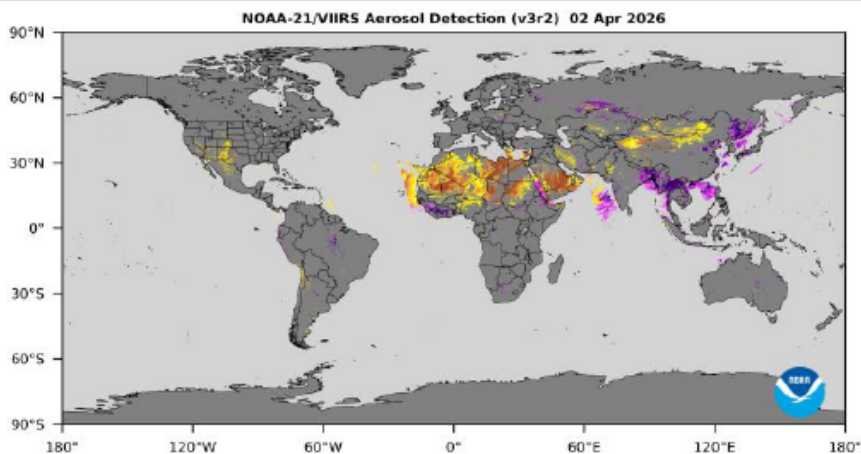
# Difference between ESA and JAXA products

(credit: Shobha Kondragunta, STC)



## Comparison of ESA/JAXA ATLID Products

- Main difference is detection in dust-dominant regions:
  - JAXA's ATLID product detects dust
  - ESA's ATLID product detects dust mixed with other aerosols





# Data Dissemination and User Support



▪ **Data dissemination** transferred to ESA MAAP since Apr 2026, see:

<https://explorer.maap.eo.esa.int>

▪ EarthCARE Product Algorithm Laboratory (**PAL**) collaborative environment linked to MAAP, see

<https://earthcare.pal.maap.eo.esa.int>

▪ 1st EarthCARE MAAP **Hackathon** held in April 2026 at ESA ESRIN, 2nd Hackathon during this Oxford Cal/Val workshop (June 2026)

**Quick Guide** added in Apr 2026 to guide the users through the extensive set of products and repeated parameters:

<https://earthcarehandbook.earth.esa.int/catalogue/index?tab=quick-guides>

Product List

Quick Guides

## EarthCARE Product Data Handbook catalogue

Browse Quick Guides

Quick Guides help you find the right EarthCARE products for your scientific needs.

Each Quick Guide focuses on a specific atmospheric or surface retrieval topic and recommends which products to use.

Use the filters to narrow down the list by product type, instrument, geometry, retrieval, or physical property, then select a Quick Guide from the list to view its content.

1. Select one or more filters to focus the list
2. Find the Quick Guide you need
3. Click a Quick Guide to read the recommendations

You can also filter Quick Guides by their name.

FILTERS

All product types ▼

All instruments ▼

All geometries ▼

All retrievals ▼

All properties ▼

Type quick guide name

Reset Filters

QUICK GUIDES

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Quality Control Reports

Quarterly Monitoring Reports

Product Availability

BBR Operations

Quality Control Disclaimers

ATLID Hot Pixel

GPS Outage

Reprocessing Quality Updates

Overpass Information

Calibration/Validation

**MAAP** Mission Algorithm and Analysis Platform IS OPEN!

<https://portal.maap.eo.esa.int>



**MAAP**

Joint access to data and algorithms



Data and computing

Data and computing

Up to date data and algorithms + Collaborative community spanning ~10 years

Ongoing improvements of “Product Availability” section at

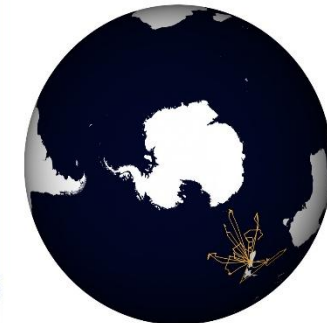
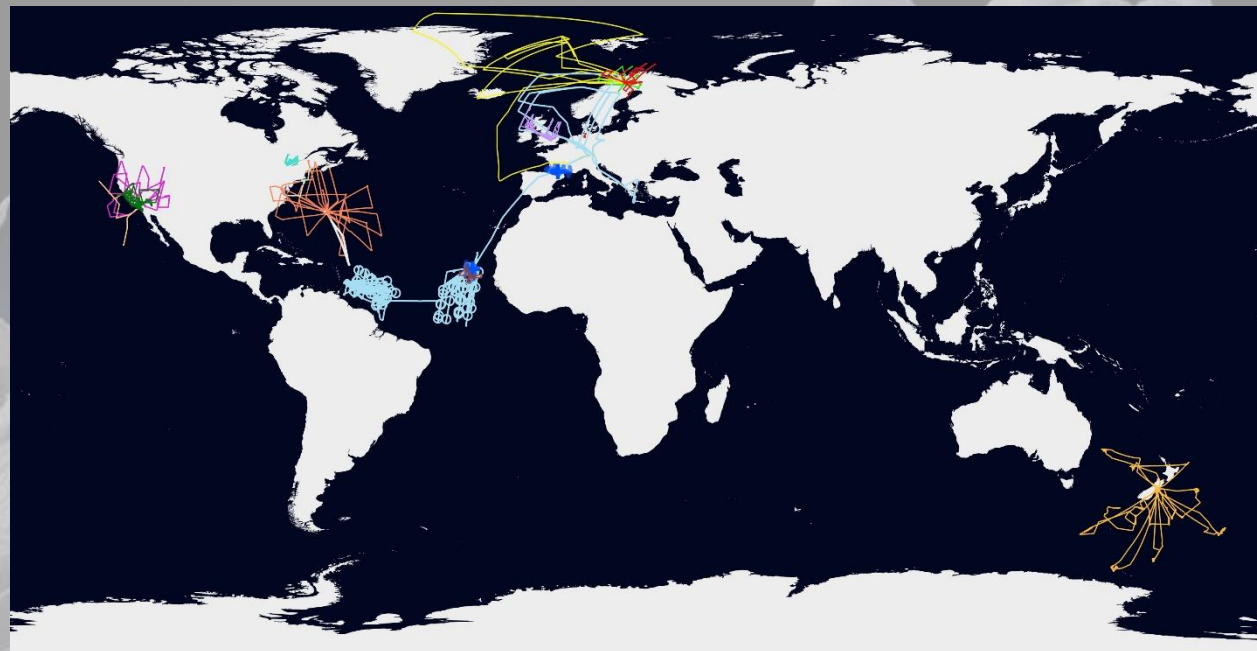
<https://earth.esa.int/eogateway/missions/earthcare/data/data-quality>



# Cal/Val Status



- Large number of **Airborne campaigns** have and will provide an abundant number of underflight comparisons.
- Additionally, several **field campaigns** combining multiple platforms to capture specific weather and aerosol regimes.
- Long-term observations of clouds, aerosols, and radiation from **ground-based sites** (e.g. Cabauw; ACTRIS, etc.) are used for routine validation.



- |              |                       |           |
|--------------|-----------------------|-----------|
| ASCCI        | ECALOT                | NightBLUE |
| ARCSIX       | GLOVE                 | PACE-PAX  |
| CELLO        | HALO                  | PERCUSION |
| CELLO ARCTIC | MAESTRO & POSTMAESTRO | VERIFY    |
| COMPEX-EC    | 100th flight          | WHyMSIE   |

Aircraft tracks to validate EarthCARE data during 2024-2025

**63** underflight during commissioning phase,  
**100** up to September 2025, **144** at present!



# EarthCARE scientific highlights



EarthCARE monthly Science Seminars started on 15 April 2026, see <https://www.earthcarescience.net/seminars>

## Upcoming seminar

Wednesday 17 June 2026  
10:00 CEST, 17:00 JST, 04:00 EDT

There will be two talks, both lasting approximately 20–25 minutes, by

1. **Yudai Ezaki** (Tohoku University): "Observation-Based Assessment of Three-Dimensional Radiative Transfer Effects with EarthCARE"
2. **Gregor Walter** (TROPOS):  
"Impact of 3D Radiative Effects on EarthCARE Retrievals"

Teams link:

Join: <https://teams.microsoft.com/meet/369076324646327?p=PGf1xJYCD11zj7f9Tj>

Meeting ID: 369 076 324 646 327

Passcode: hi3Dg3Gd

EarthCARE on LinkedIn since May 2026  
(ESA Earth Explorer page)



### ESA Earth Explorers

1,128 followers

1mo • 🌐

Spread the word: ESA's Earth Explorers are here on LinkedIn!

Check in for the latest results, data releases, operational updates, cal/val campaigns, community insights, success stories and upcoming events.

We'll also highlight how our diverse and versatile satellite missions are blazing a trail in Earth observation - often working together in unique and unforeseen ways to study all aspects of our Earth system, from deep within its core right out to the farthest stretches of the atmosphere.

A little introduction to our pioneering science missions for Earth 🗨️

<https://lnkd.in/eTyq5iBc>





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# Aerosols

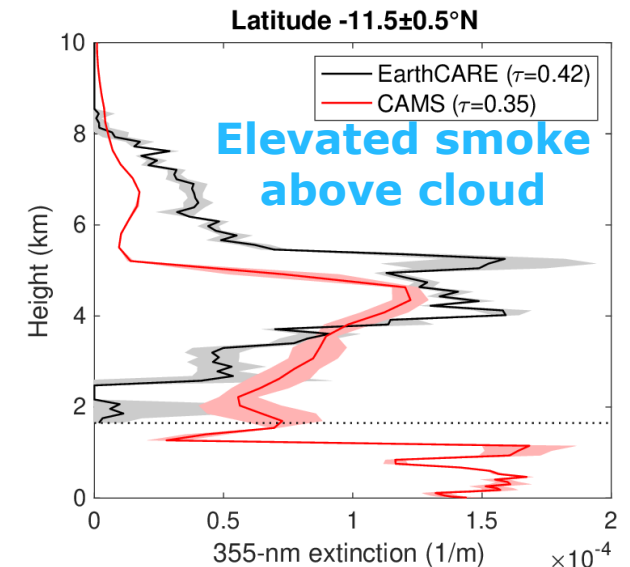
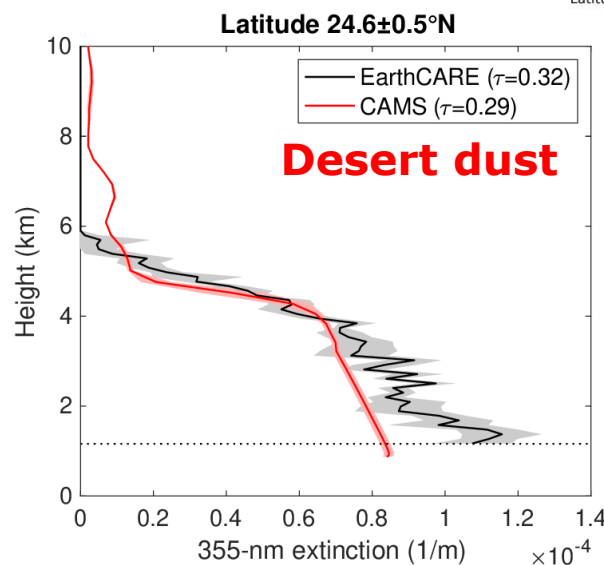
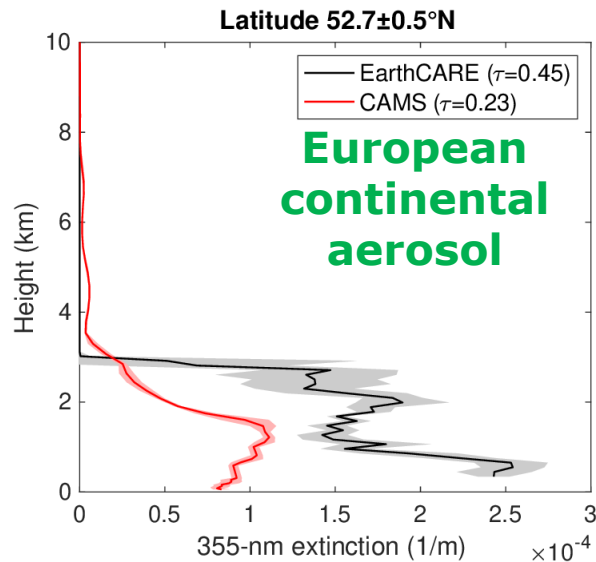
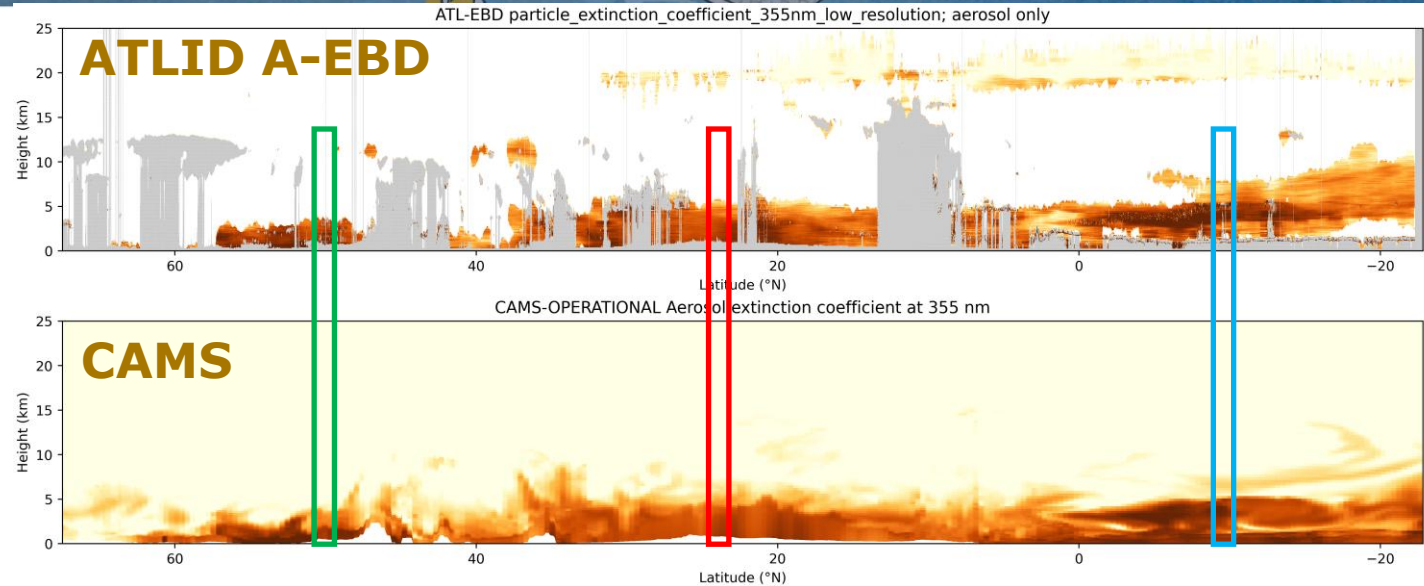
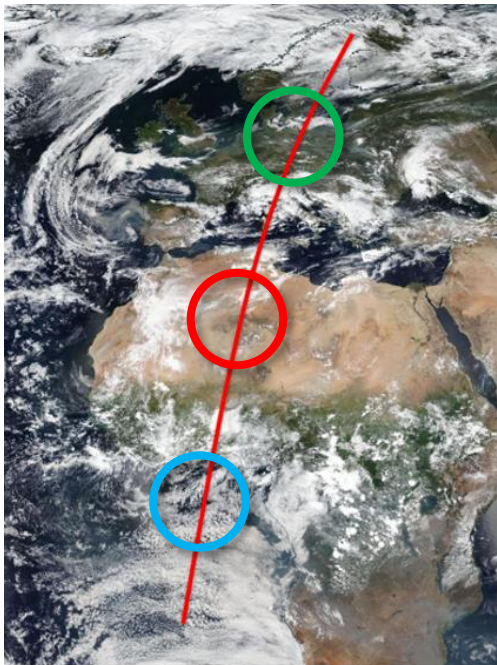


# Retrieving and comparing ATLID aerosol properties

(Credit: Peter Hill, Robin Hogan, David Donovan)



- ATLID retrieves 355-nm extinction coefficient, the classification uses measured depolarization and lidar-ratio (extinction-to-backscatter ratio)
- CAMS: ECMWF's air quality forecast including 15 prognostic aerosol variables
- *"Have never before been able to evaluate aerosol profiles globally with such resolution & accuracy."*



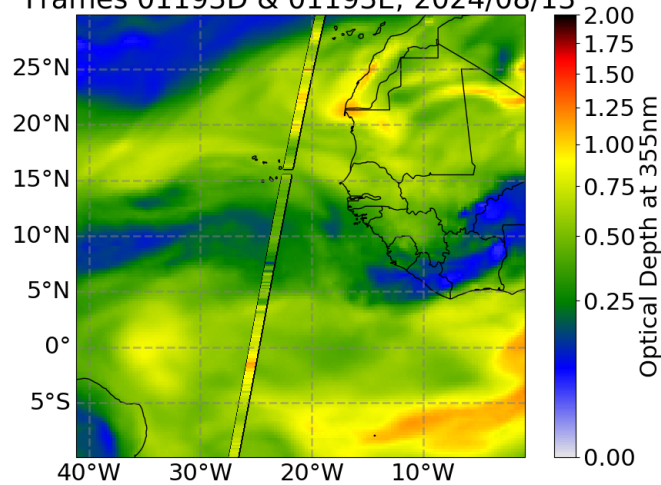
# Aerosol model evaluation, Saharan dust plume, 13 August 2024

Frames 01193D & 01193E; 13-08-2024; 15:26 - 15:50

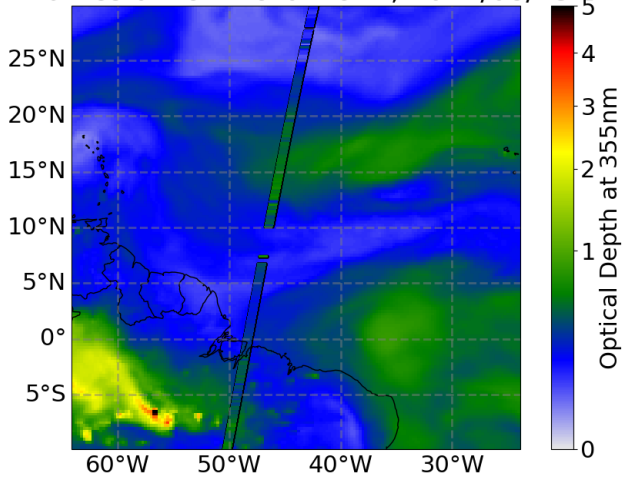
(a) Multispectral Imager channels 1-3 RGB



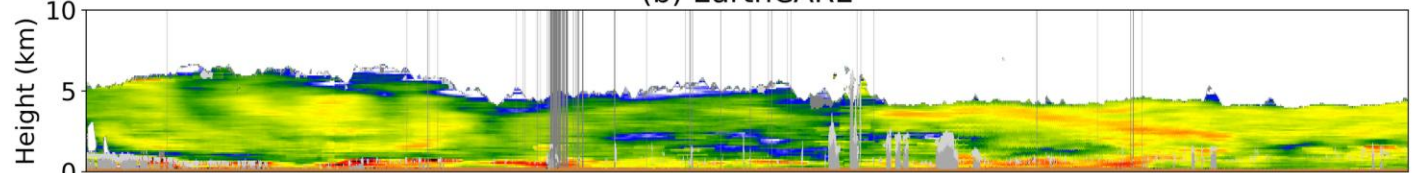
IFS-COMPO vs EarthCARE AOD  
Frames 01193D & 01193E; 2024/08/13



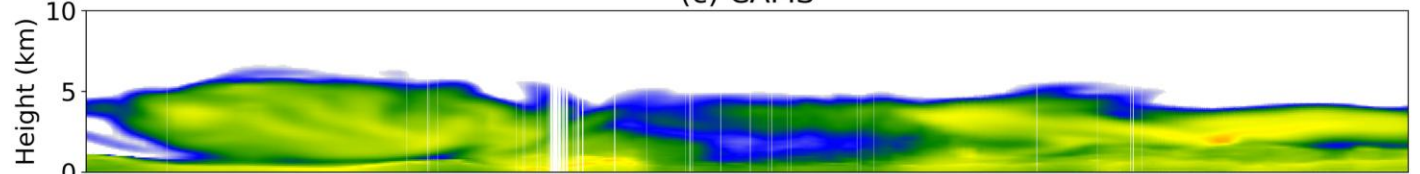
IFS-COMPO vs EarthCARE AOD  
Frames 01194D & 01194E; 2024/08/13



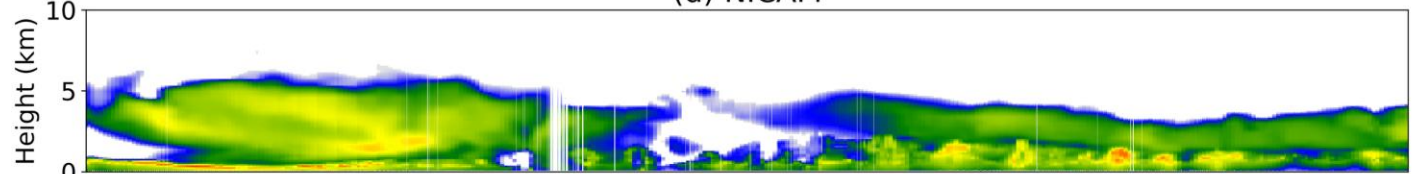
(b) EarthCARE



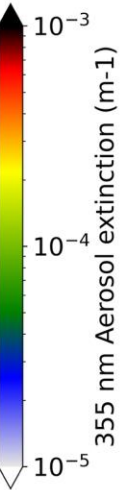
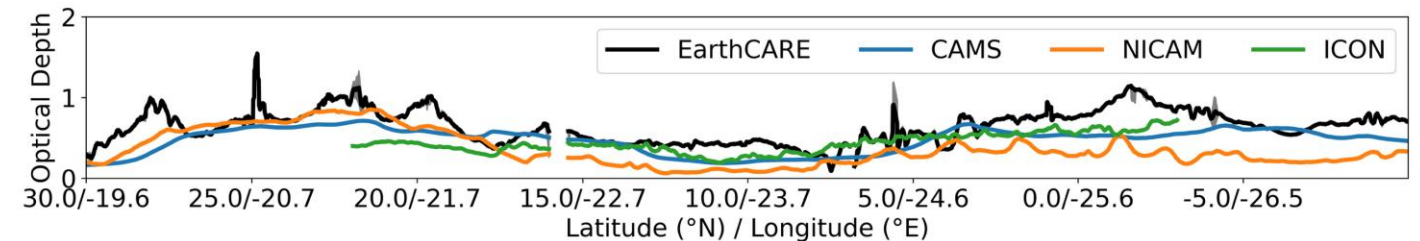
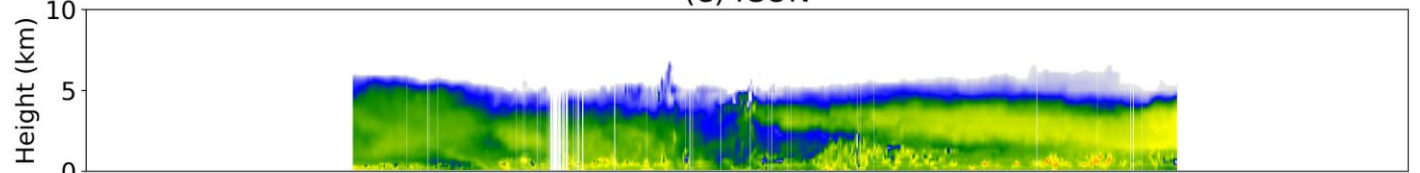
(c) CAMS



(d) NICAM



(e) ICON



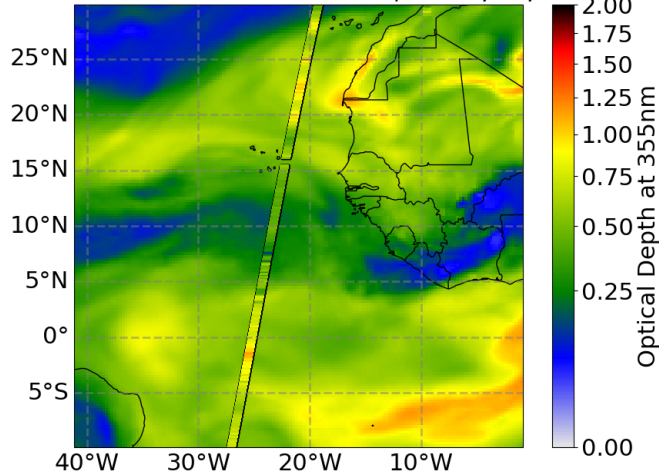
# Aerosol model evaluation, Saharan dust plume, 13 August 2024

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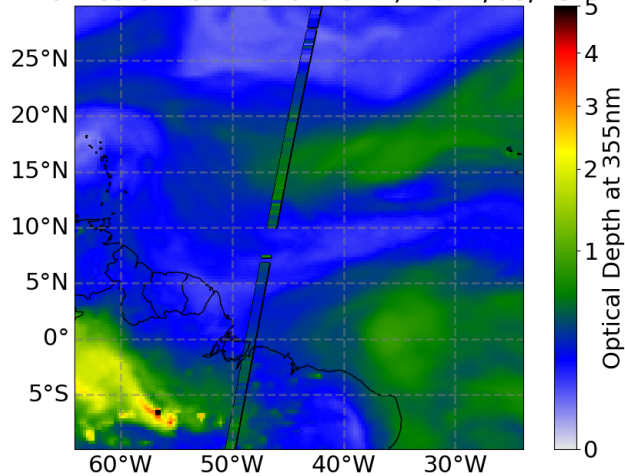
(a) Multispectral Imager channels 1-3 RGB



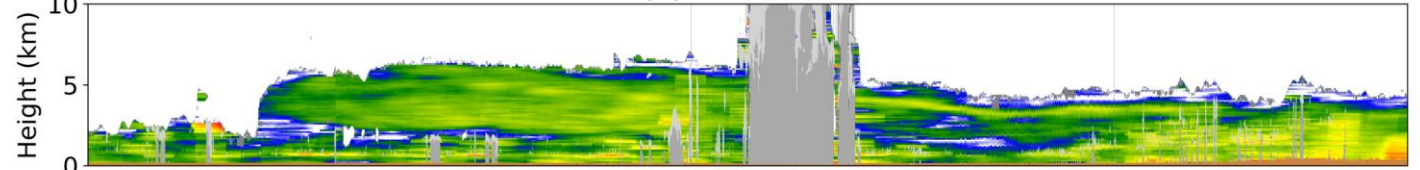
IFS-COMPO vs EarthCARE AOD  
Frames 01193D & 01193E; 2024/08/13



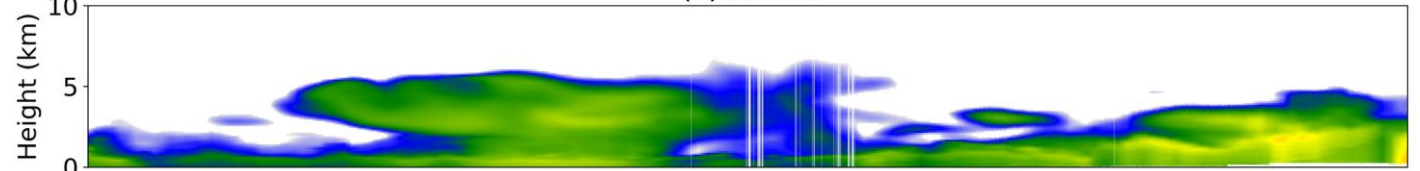
IFS-COMPO vs EarthCARE AOD  
Frames 01194D & 01194E; 2024/08/13



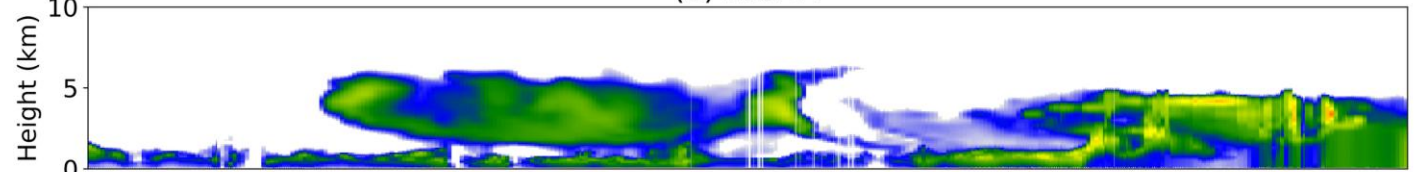
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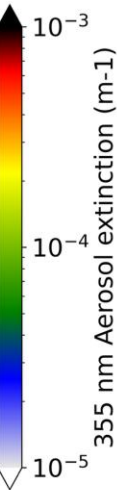
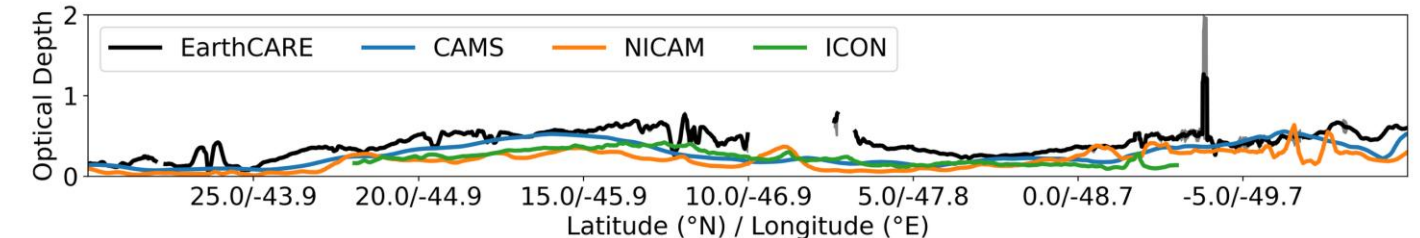
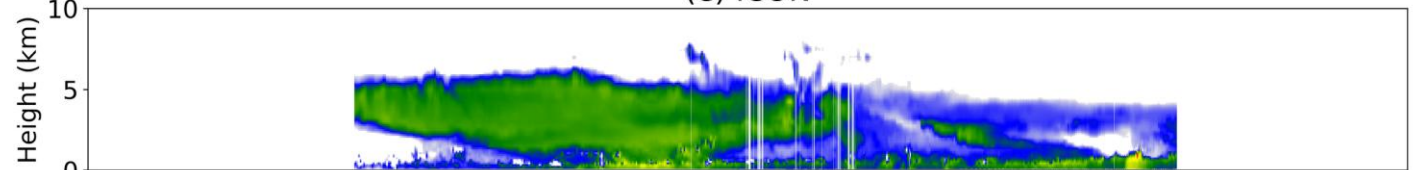
(c) CAMS



(d) NICAM



(e) ICON



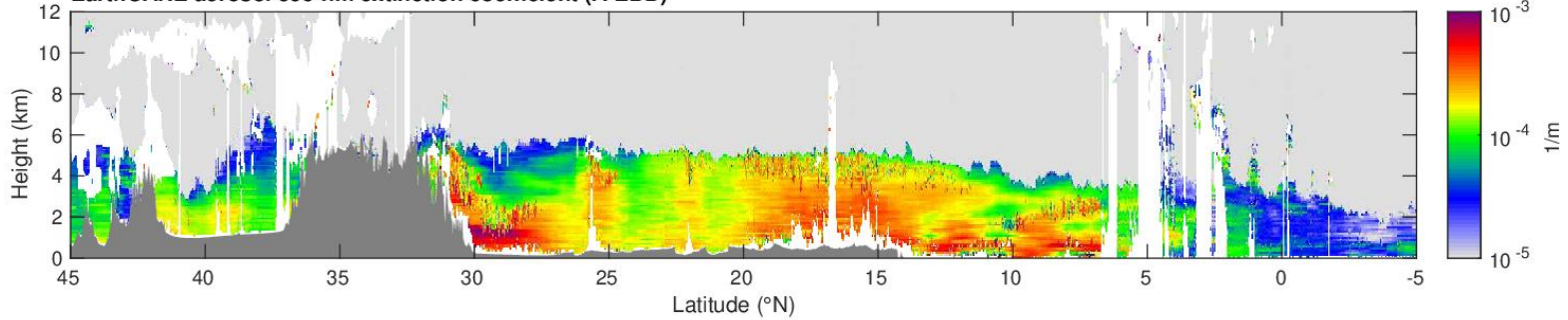
# ATLID evaluates CAMS in Indian pollution

EarthCARE natural colour image (M-RGR)

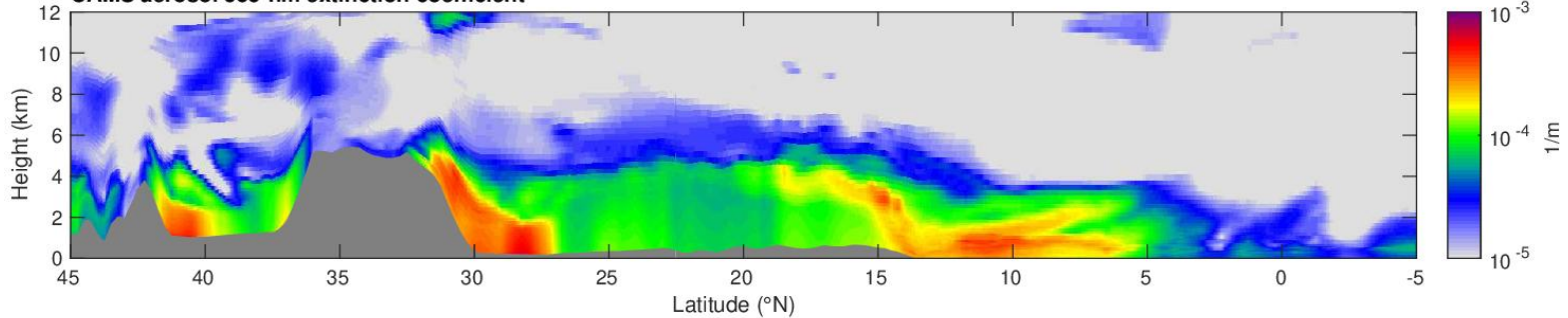
08 Apr 2025, 08:58-09:11 UTC



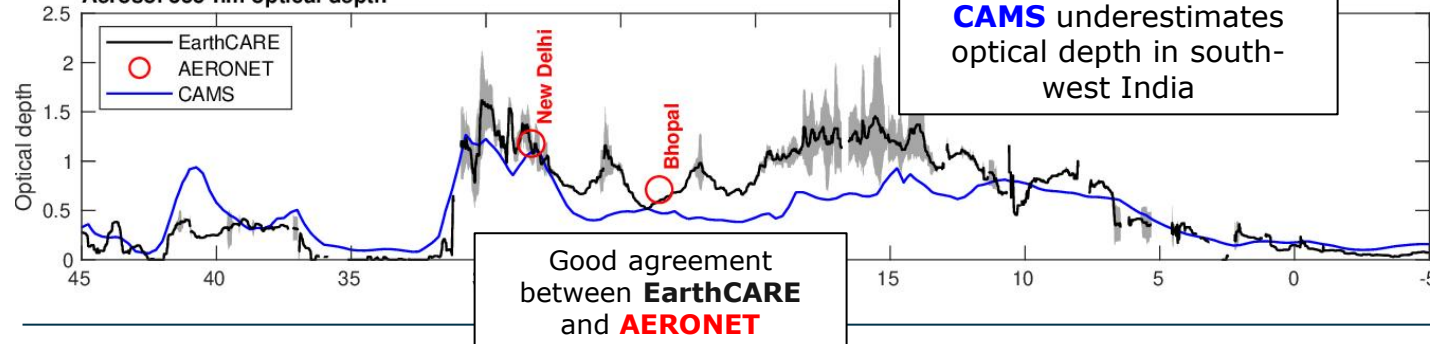
EarthCARE aerosol 355-nm extinction coefficient (A-EBD)



CAMS aerosol 355-nm extinction coefficient

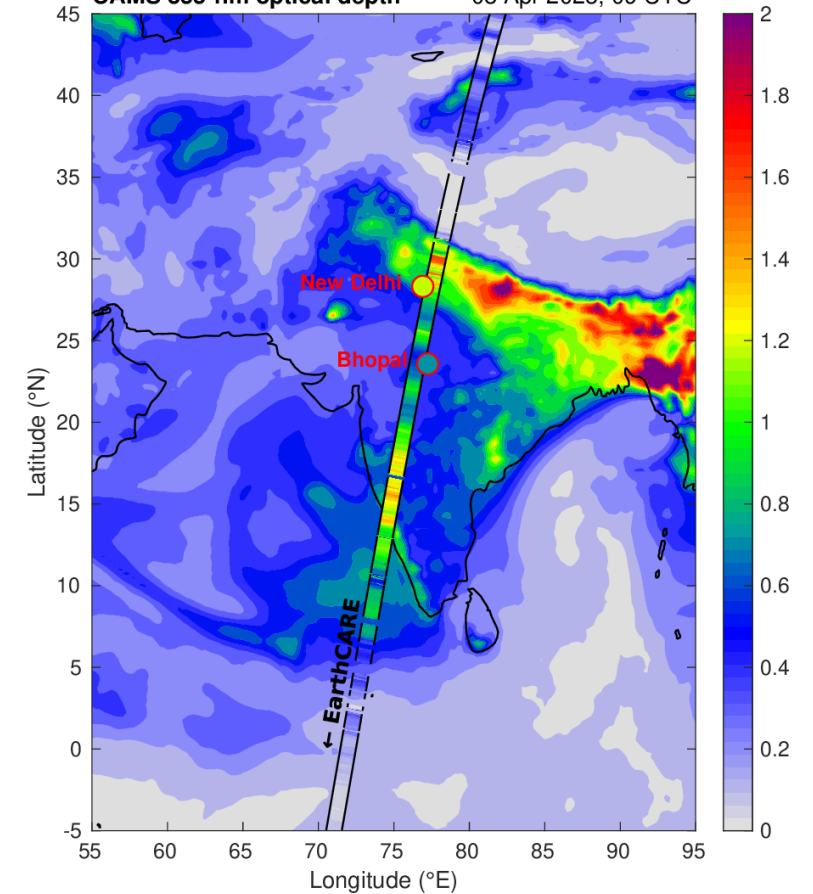


Aerosol 355-nm optical depth



- Unprecedented quantitative, global evaluation of aerosol profiles in CAMS air-quality forecasts!

CAMS 355-nm optical depth 08 Apr 2025, 09 UTC





# Climatology of dust properties

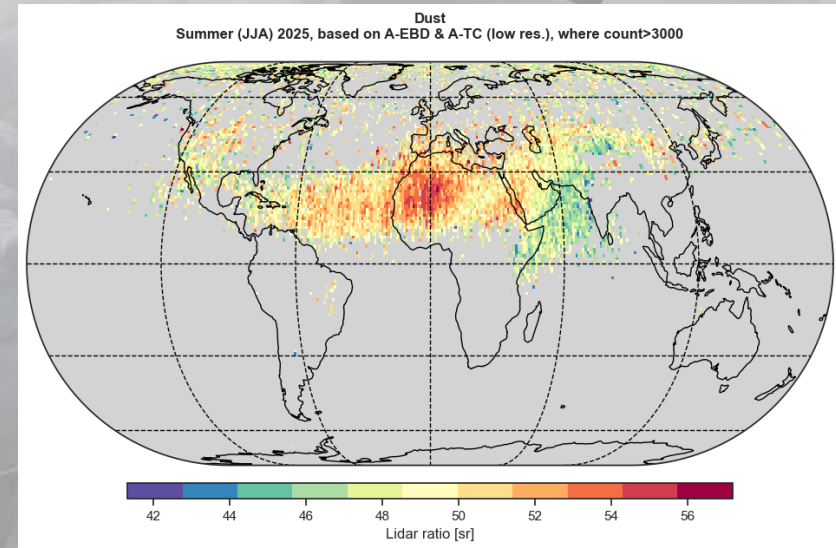
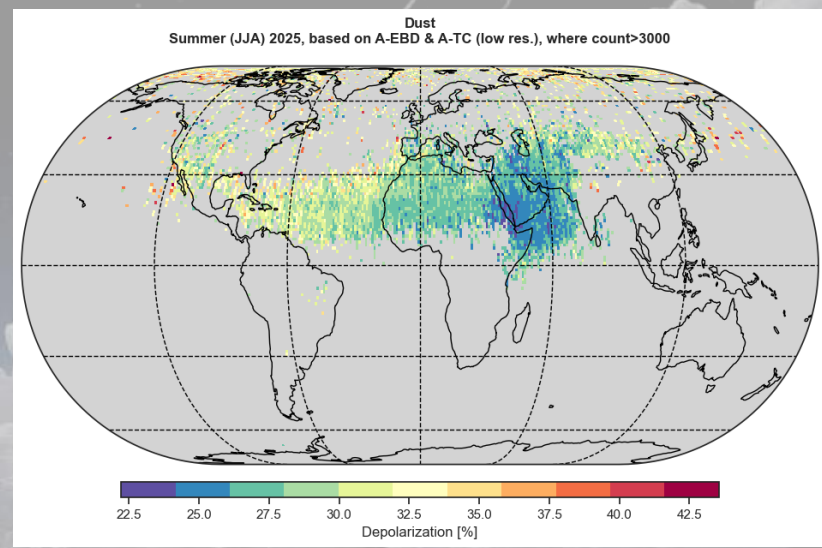
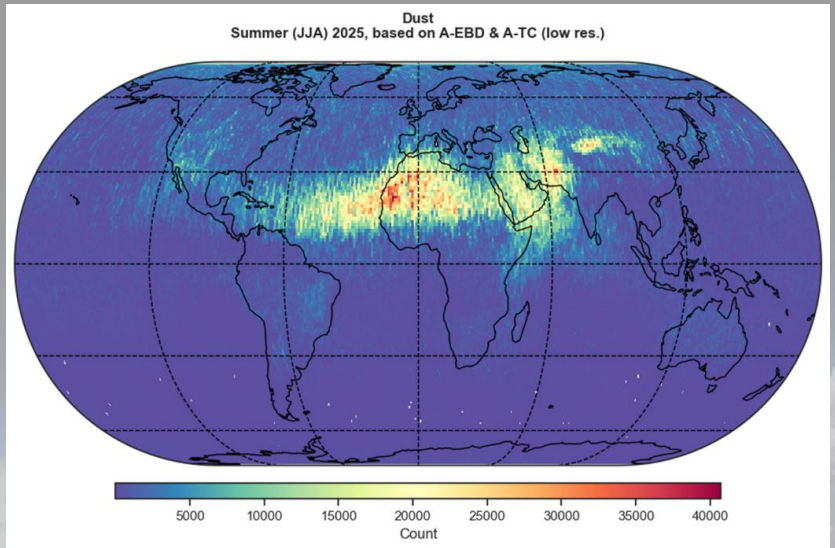
(credit Ulla Wandinger & Leonard König)



## Dust occurrence

## Depolarization

## Lidar ratio



## Global distribution of mineral dust derived from 1.5 years of ATLID data.

ATLID native resolution:

- Horizontal ~1 km
- Vertical 100 m

For the global map, all data points classified as dust were counted and allocated to 1° × 1° lat/lon grid.

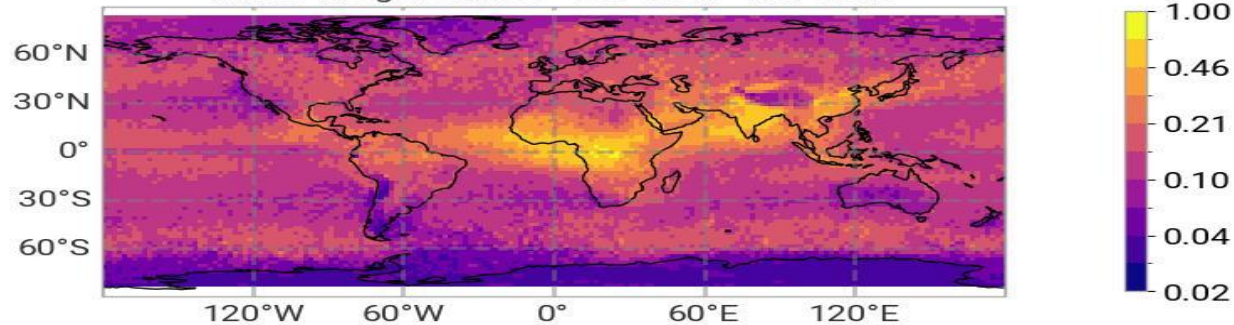
- Reveals systematic differences between sources: higher lidar ratio over Western Sahara, lower depolarization over Arabia
- What does this tell us about minerology, size and shape?
- Does it have a radiative impact? How can we incorporate it into models?

# Aerosol Global comparisons

(credit: Xumei Wang & Leonard König)

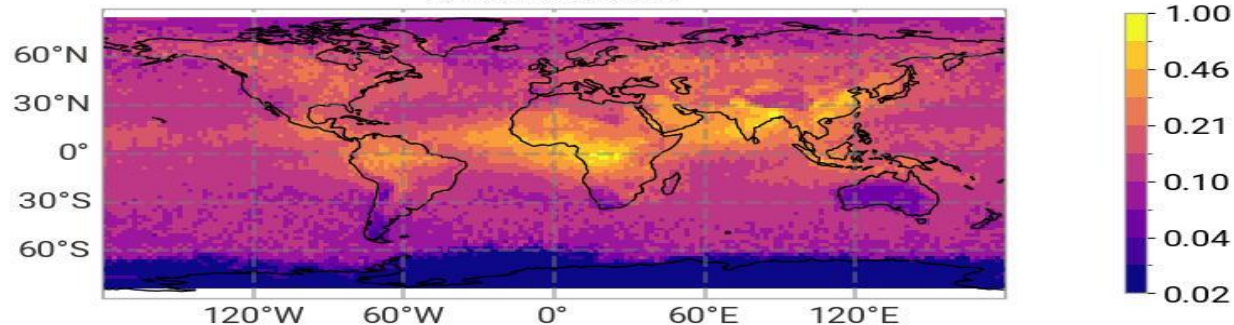


ATLID integrated AOD Dec 2024 - Nov 2025

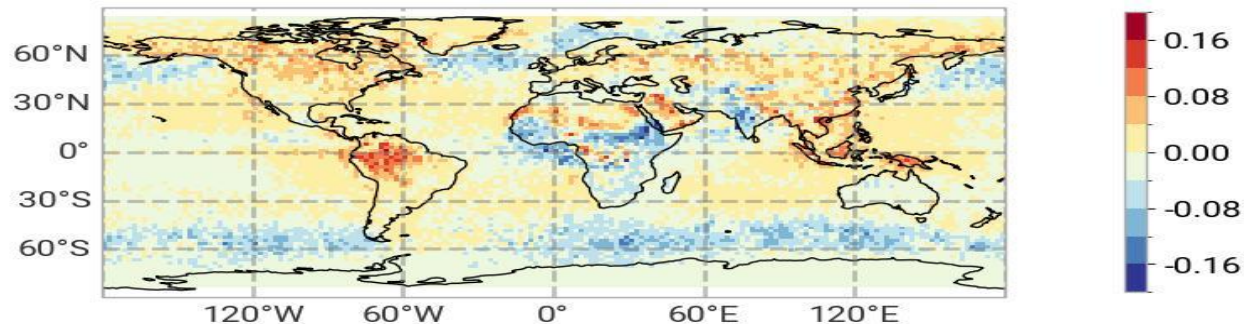


One year of ATLID retrievals allow for AOT comparison with aerosol models (CAMs)

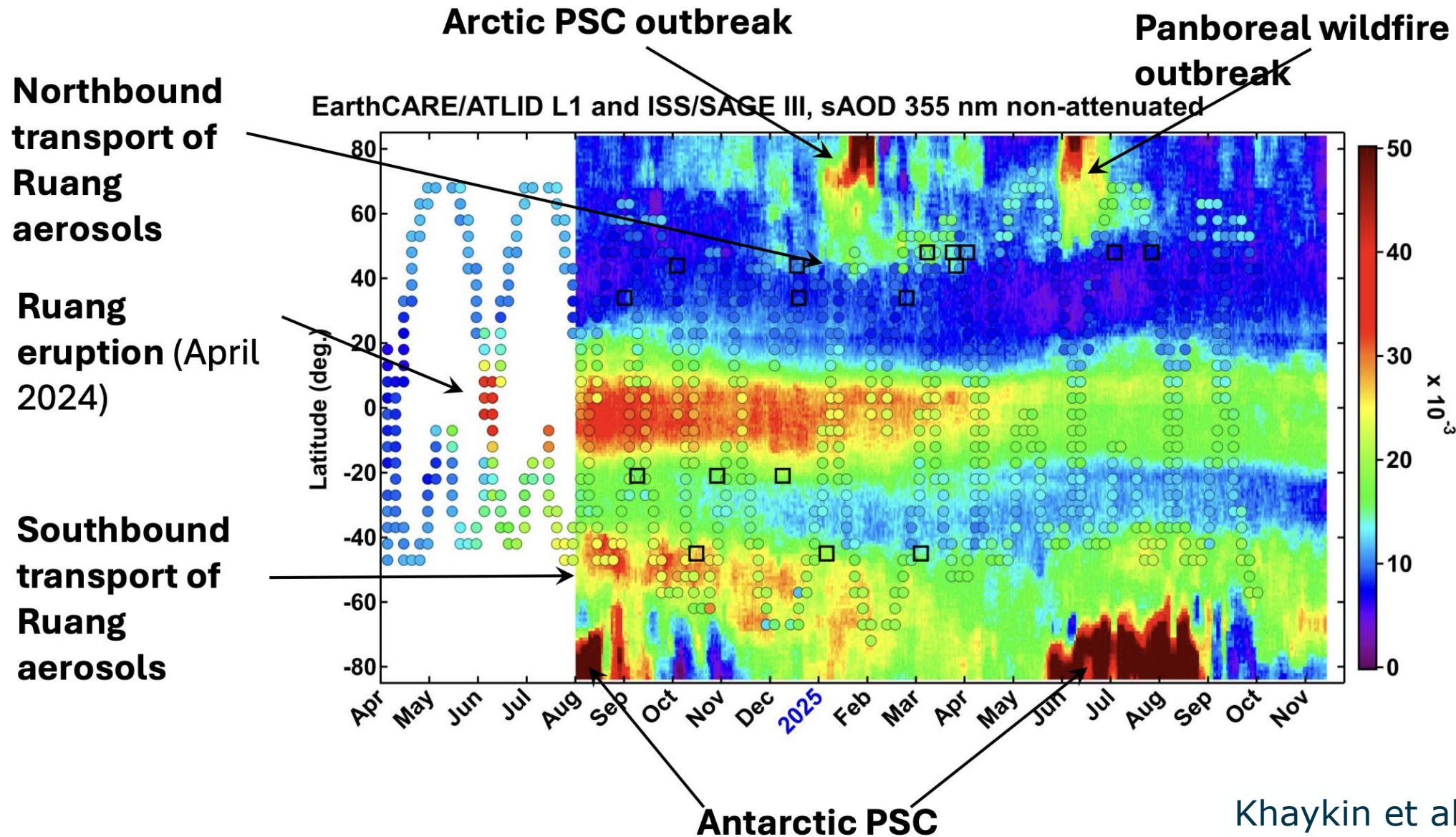
CAMS total AOD



CAMS-ATLID AOD



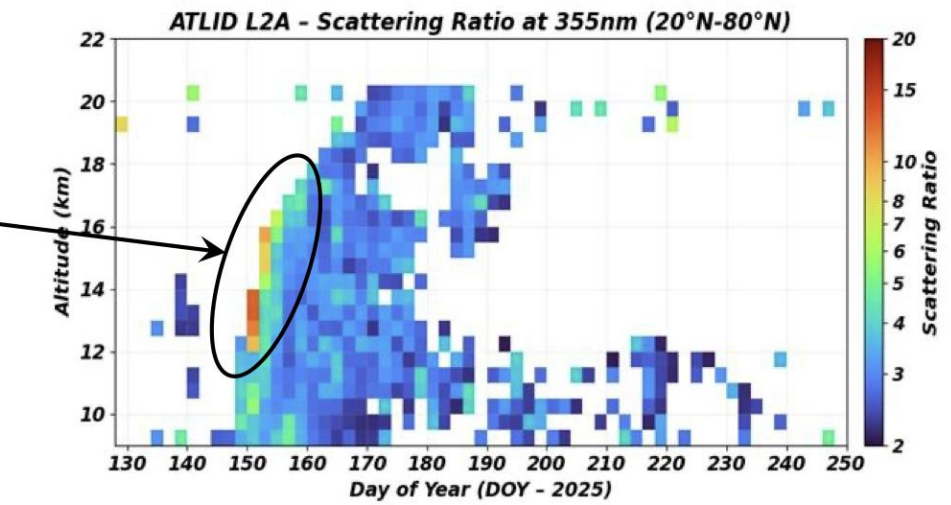
# Global variation of SAOD from ATLID



# Microphysical evolution of smoke particles from ATLID



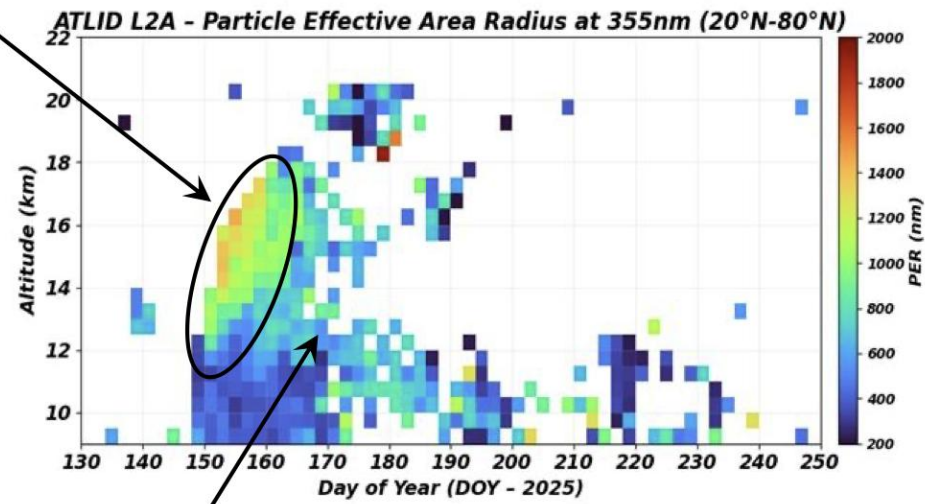
Self-lofting of high-concentrated plume up to 21 km



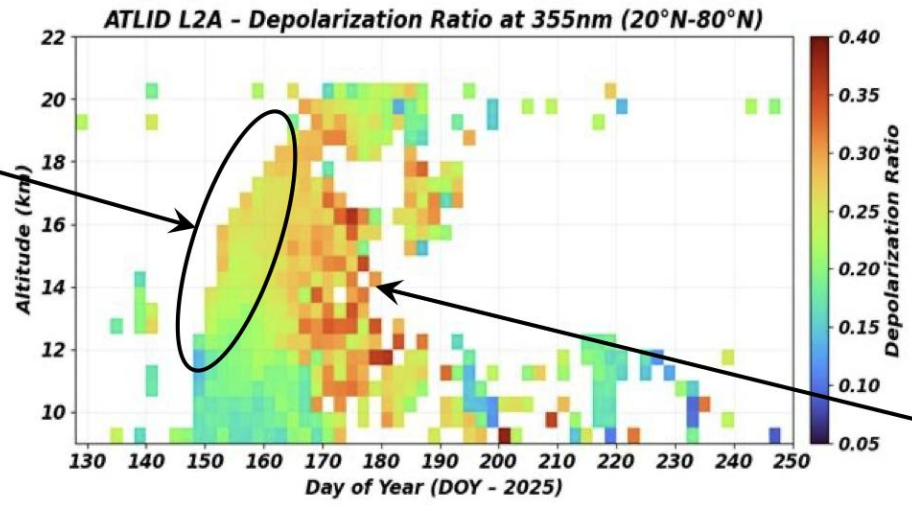
EBD data on stratospheric layers (night & day)

- ✓ Filtering on AOD>0.03, SR>2 and quality flag
- ✓ Aggregation into 1 day/500 m bins

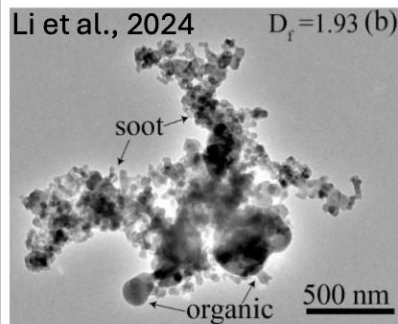
Rapid particle growth through aggregation



Depolarization growth due to aggregation



Sedimentation of large aggregates



Soares et al., in prep.

# Canadian wildfires



<https://doi.org/10.1038/s44407-025-00022-9>

## Large-scale impacts of the 2023 Canadian wildfires on the Northern Hemisphere atmosphere

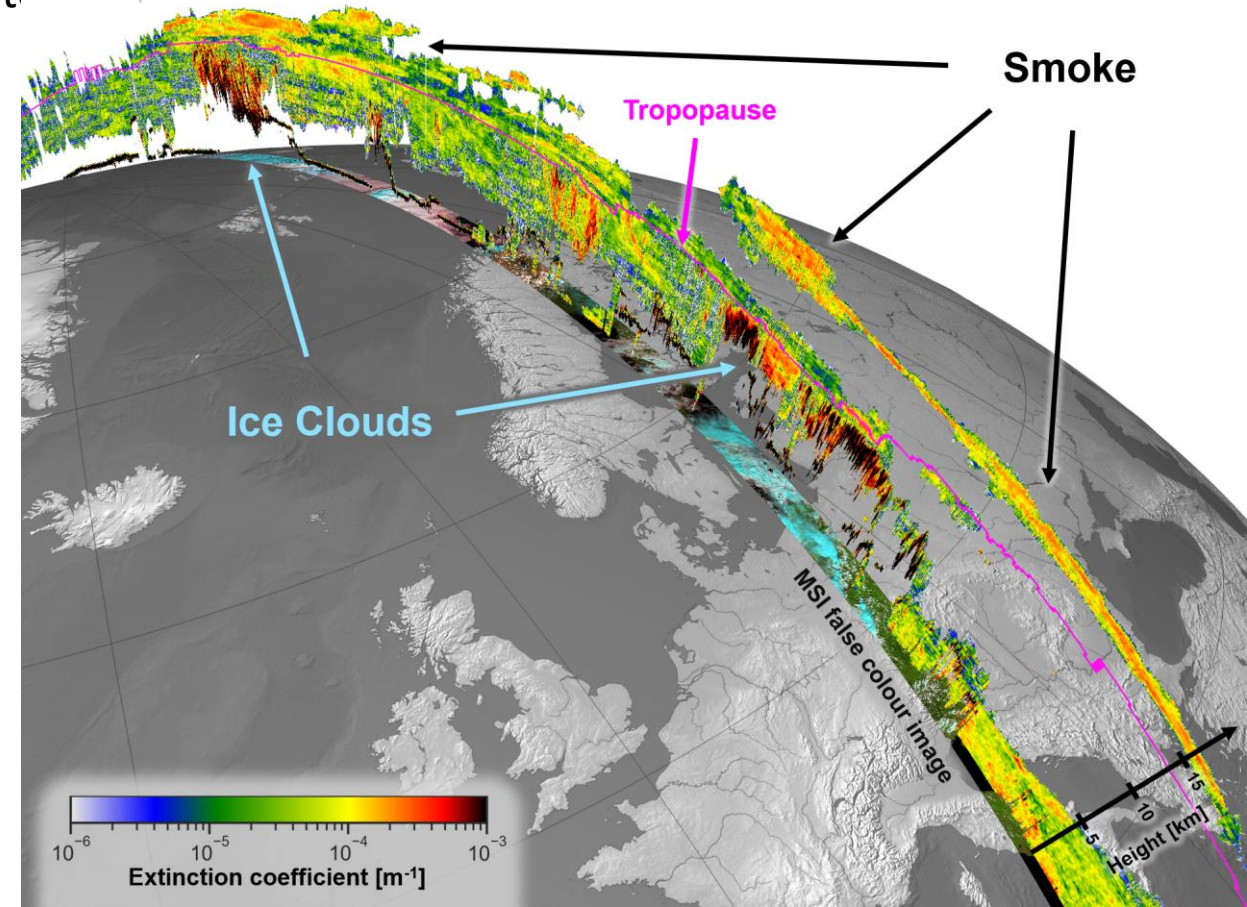
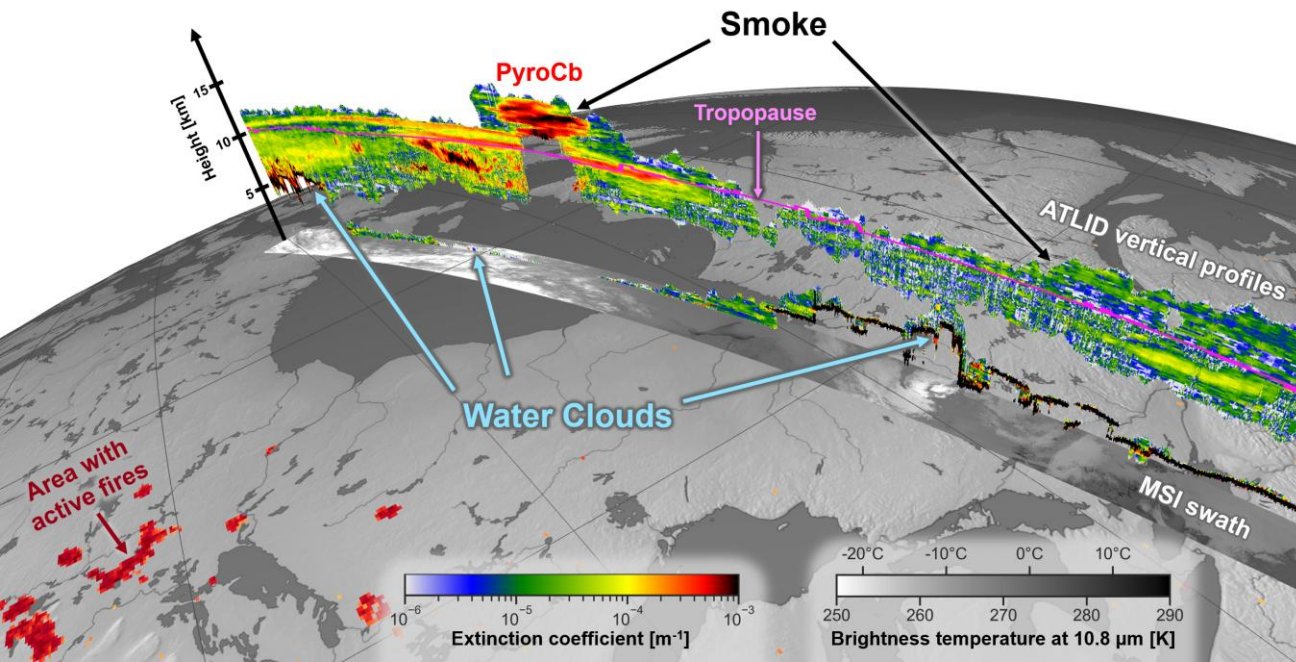
Check for updates

Iulian-Alin Roşu<sup>1,2</sup>, Răfăila-Nikola Mourgelă<sup>1,2</sup>, Matthew Kasoar<sup>2,3</sup>, Eirini Boleti<sup>1,2</sup>, Mark Parrington<sup>4</sup> & Apostolos Voulgarakis<sup>1,2,3</sup>

Climate change projections are expected to increase wildfire activity in many world regions in the coming decades because of rising mean temperatures and hydrological changes. This increase is especially pronounced in the high latitudes, and the large-scale weather impact of the resulting

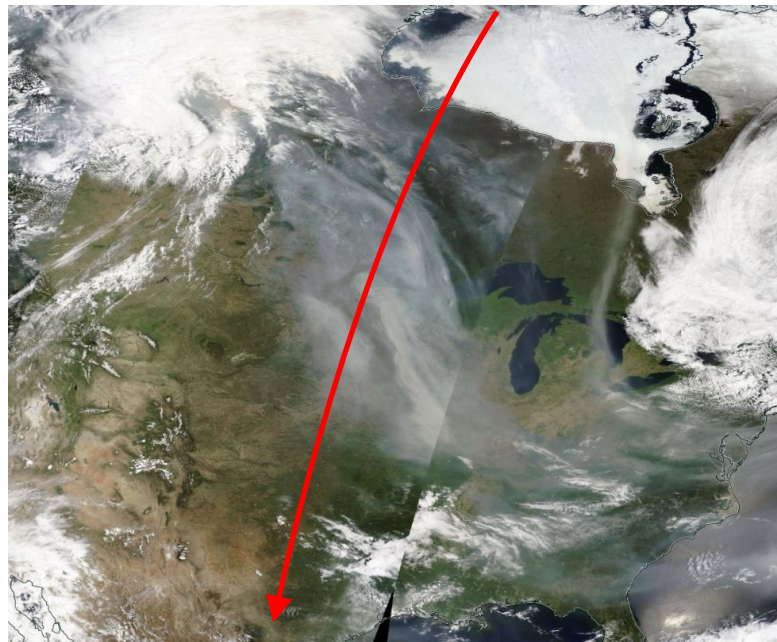
- 2025 was second only to 2023 in the intensity of the Canadian wildfires, and just ahead of 2024
- One modelling study (Rosu et al, EGU 2025) estimated that 2023 fires cooled northern hemisphere by  $\sim 1^\circ\text{C}$
- EarthCARE is perfectly placed to provide observational evidence to constrain such estimates

July Image of the month showing aerosol carried from Canada (1 June) to Europe (6 June)

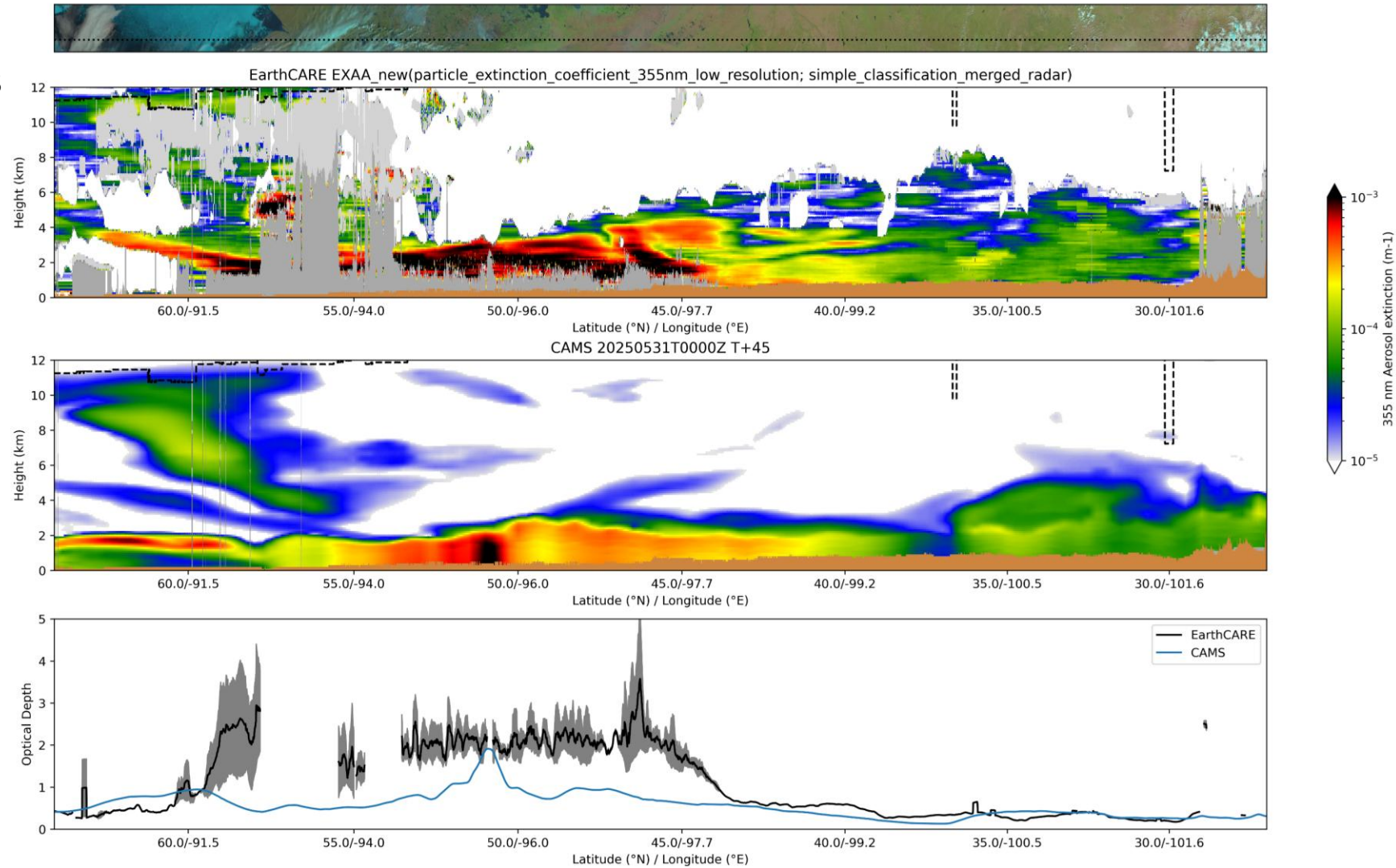


# Evaluation of CAMS aerosol forecasts (1 June 2025)

- ATLID provides an unprecedented capability to evaluate aerosol extinction in chemistry models such as ECMWF-CAMS

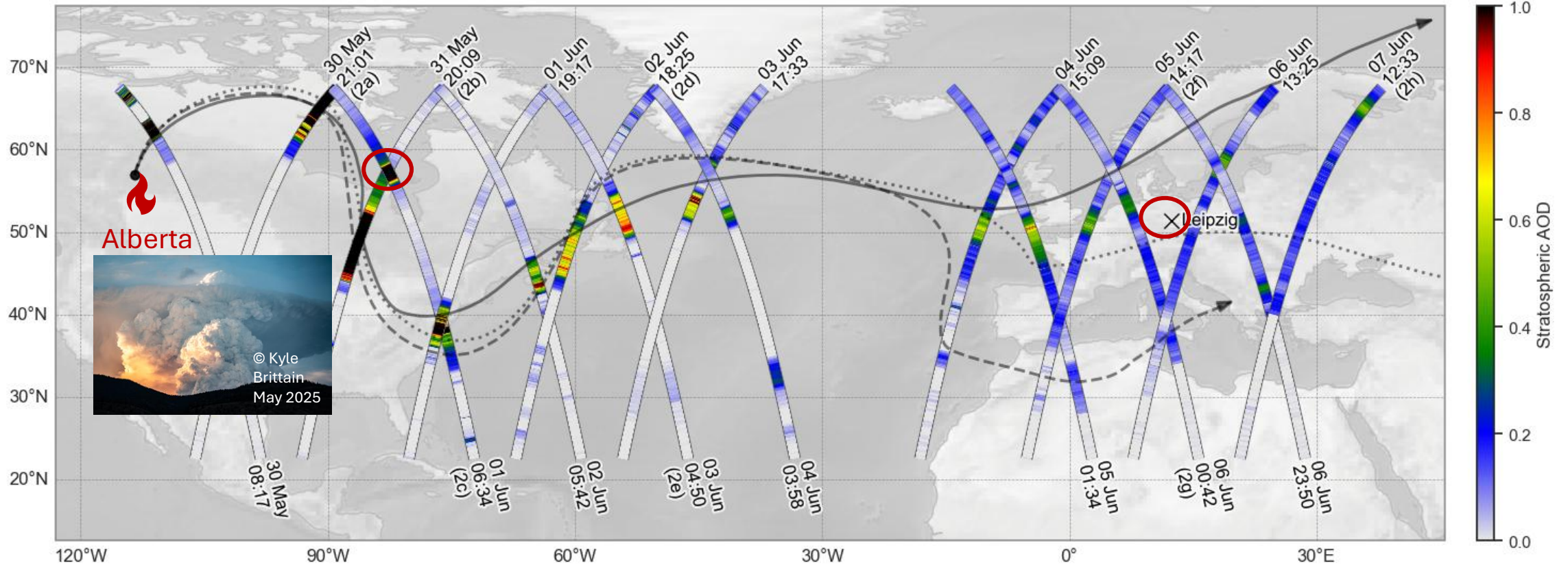


Frame 05740D; 01-06-2025; 20:49 - 21:01



# Tracking of the smoke plume towards Europe

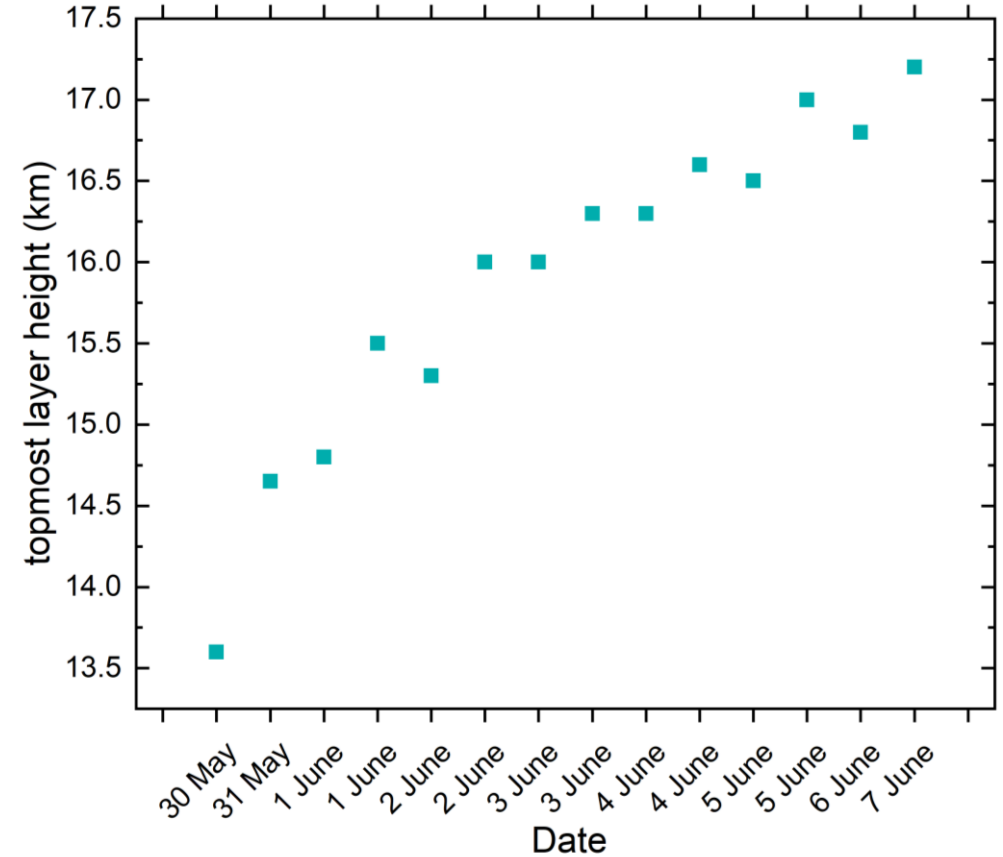
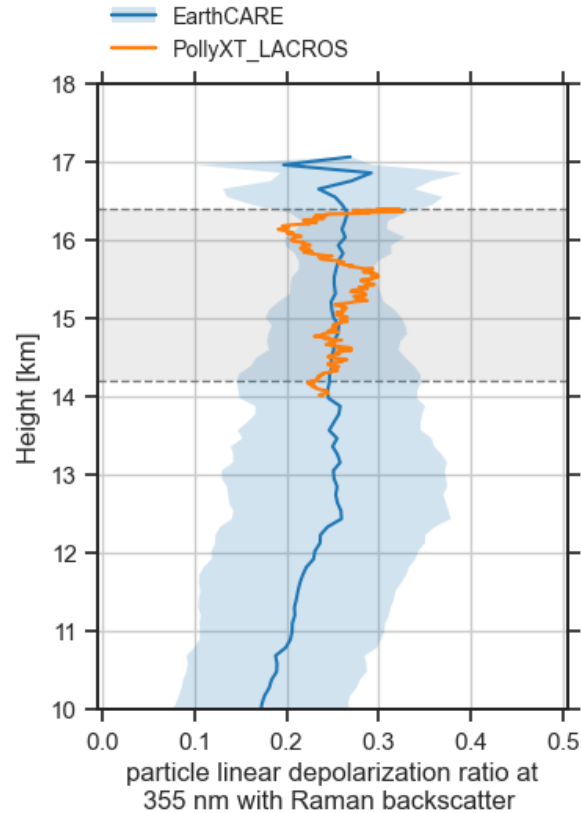
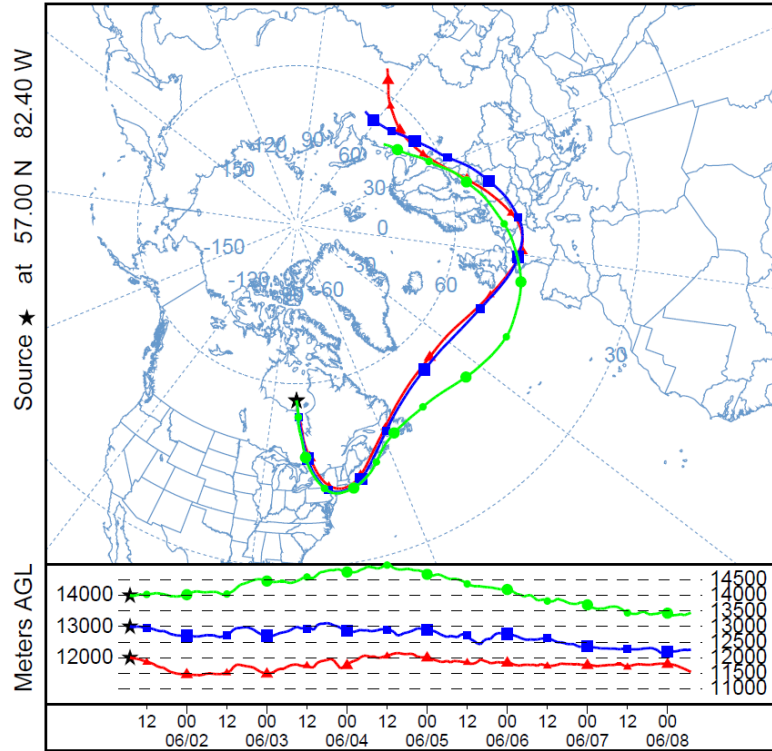
(Haarig et al. GRL 2026)



- Intense wildfires in Canada (28 May - 3 June 2025) lead to Pyrocumulonimbus
- Lifting smoke to the Upper Troposphere / Lower Stratosphere (UTLS)  $\approx 10 - 12$  km height
- Used both HYSPLIT model + ATLID to track stratospheric smoke plume
- SAOD up to 3.2 above Canada, decreasing during transport!!

# Tracking the smoke plume

(credit: Moritz Haarig)



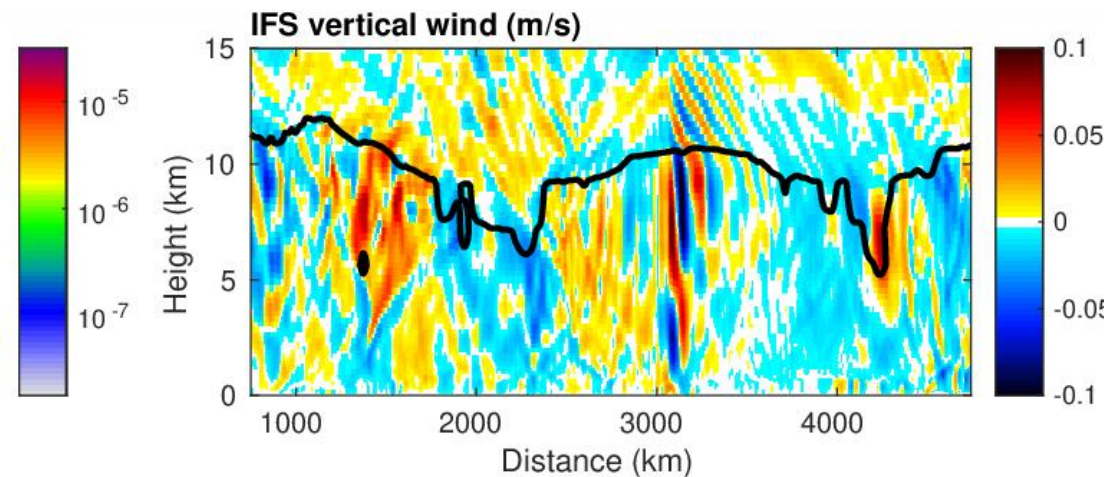
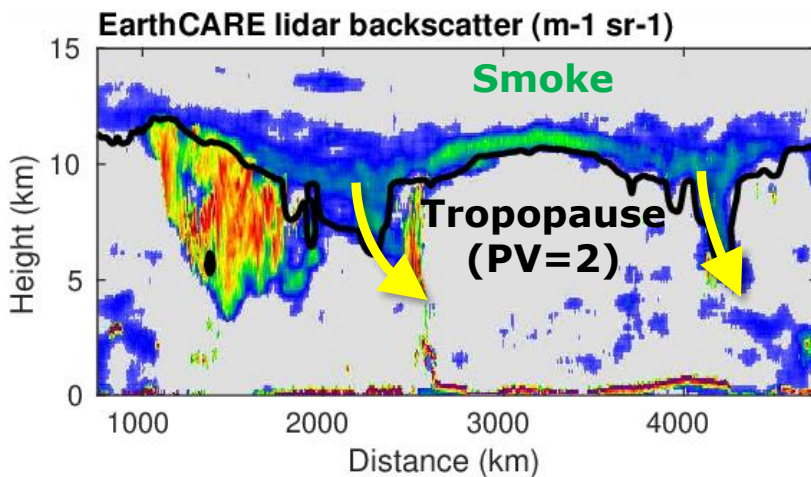
- Forward trajectories show smoke traveling across Europe
- Co-location with Leipzig lidar on 5 June:
  - (Lidar ratio:  $50 \pm 9$  sr, depolarization ratio:  $0.26 \pm 0.02$ )
- Can we estimate other optical properties?
- Analysis of multiple frames shows smoke plume rising 3.6 km in 9 days (400 m per day)

# Aerosol mixing from stratosphere to troposphere

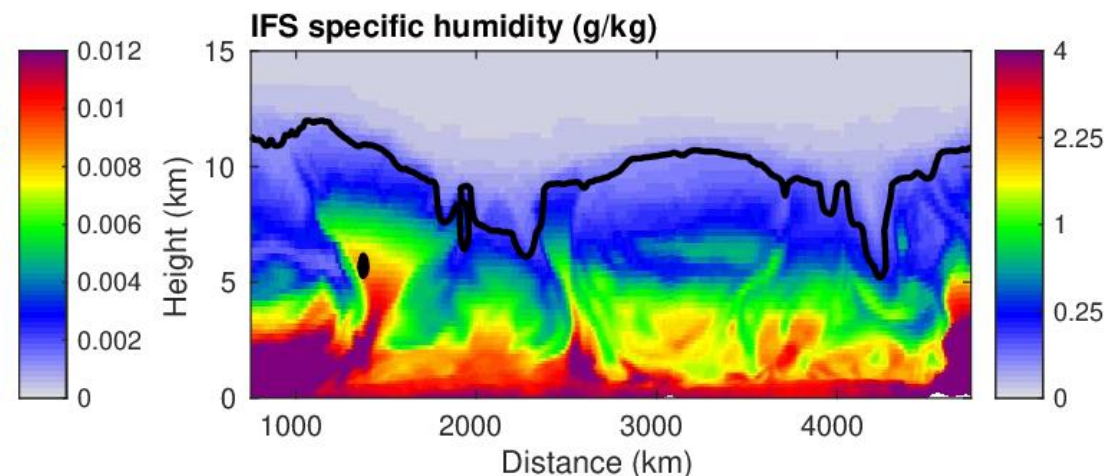
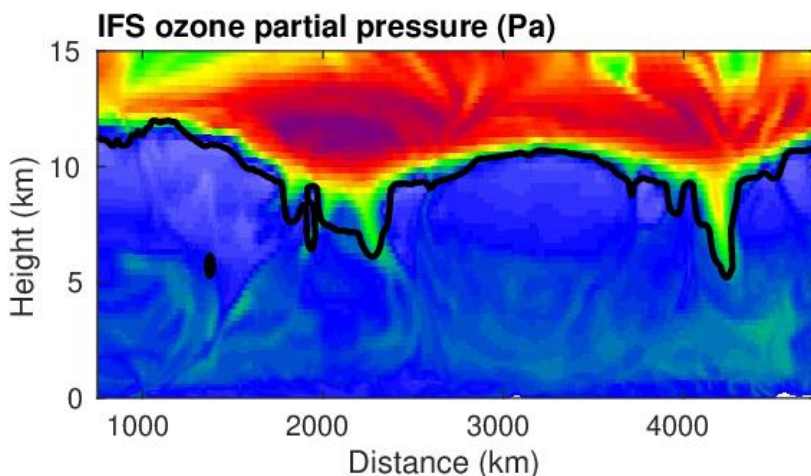
(credit: Robin Hogan)



- By July smoke is seen ubiquitously in Arctic frames just above the tropopause (PV=2 here)
- Mixing back into troposphere occurs via tropopause folds (here 1 July, 06216C), also mixing ozone and dry air



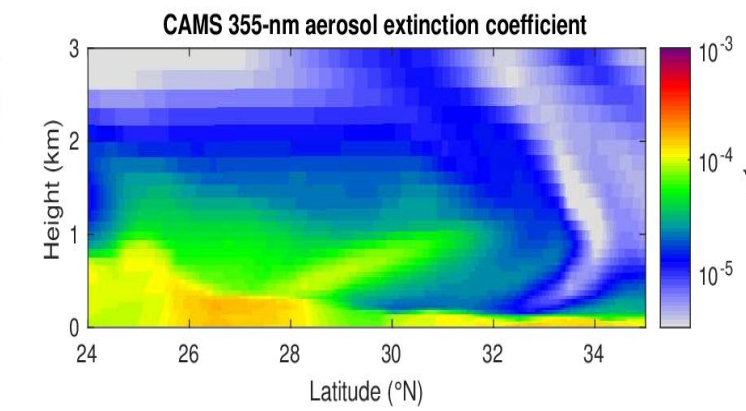
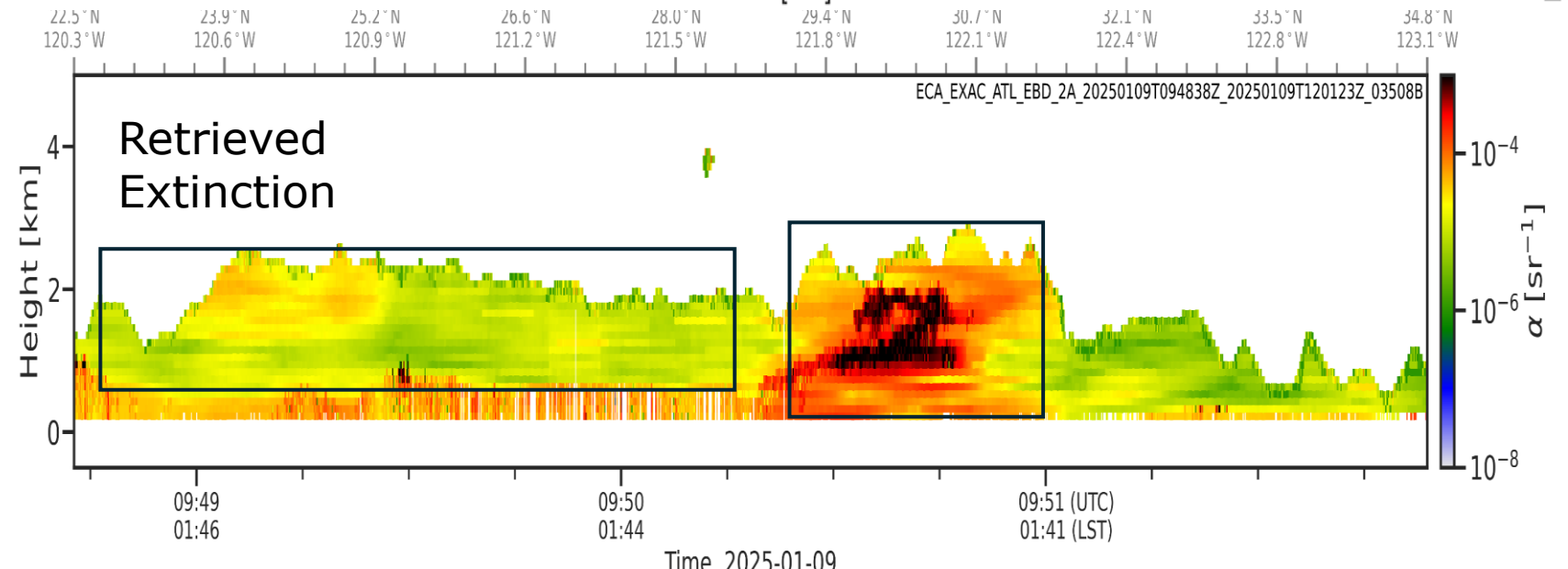
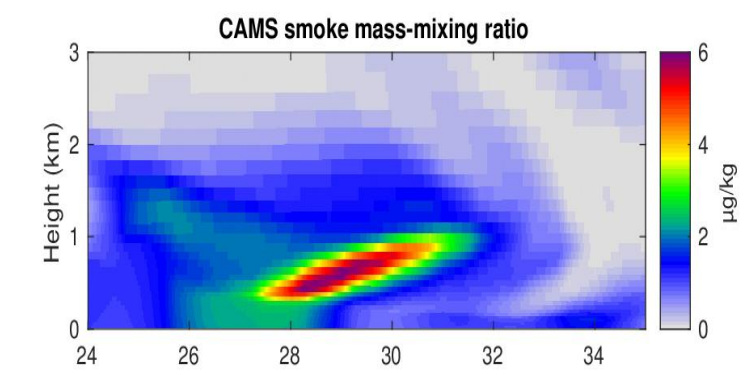
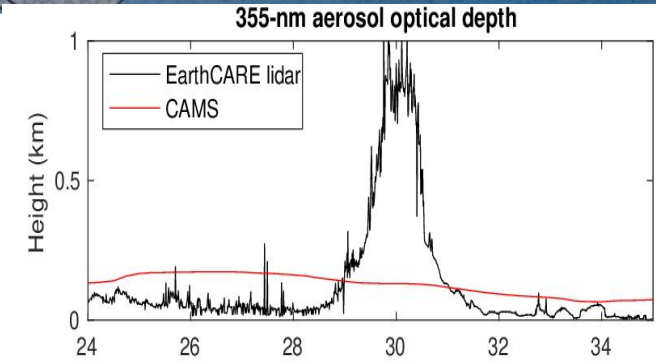
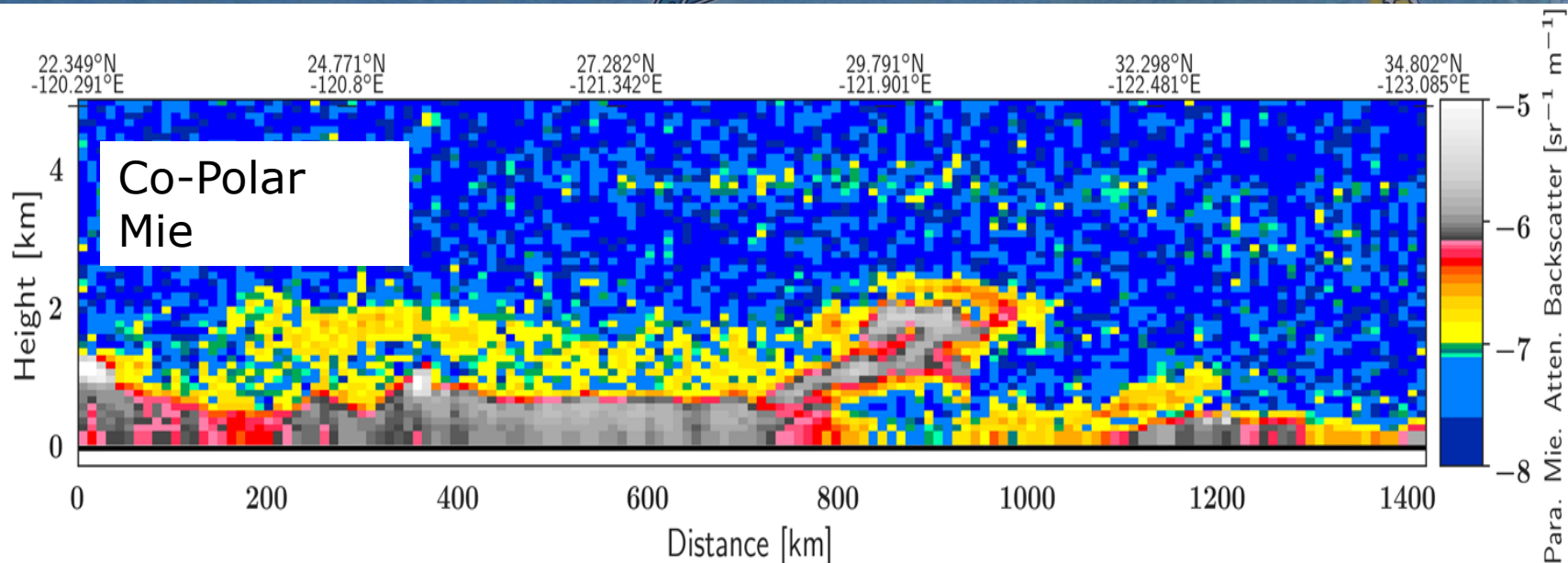
○ See Haarig et al. (GRL 2026) for a study of the lifecycle of the plume: <https://doi.org/10.1029/2025GL119977>



○ We plan an aerosol model intercomparison & evaluation with this case to test processes and to estimate the radiative and climatic impact

# Detecting smoke with the ATLID lidar

## California fires: 9 January 2025



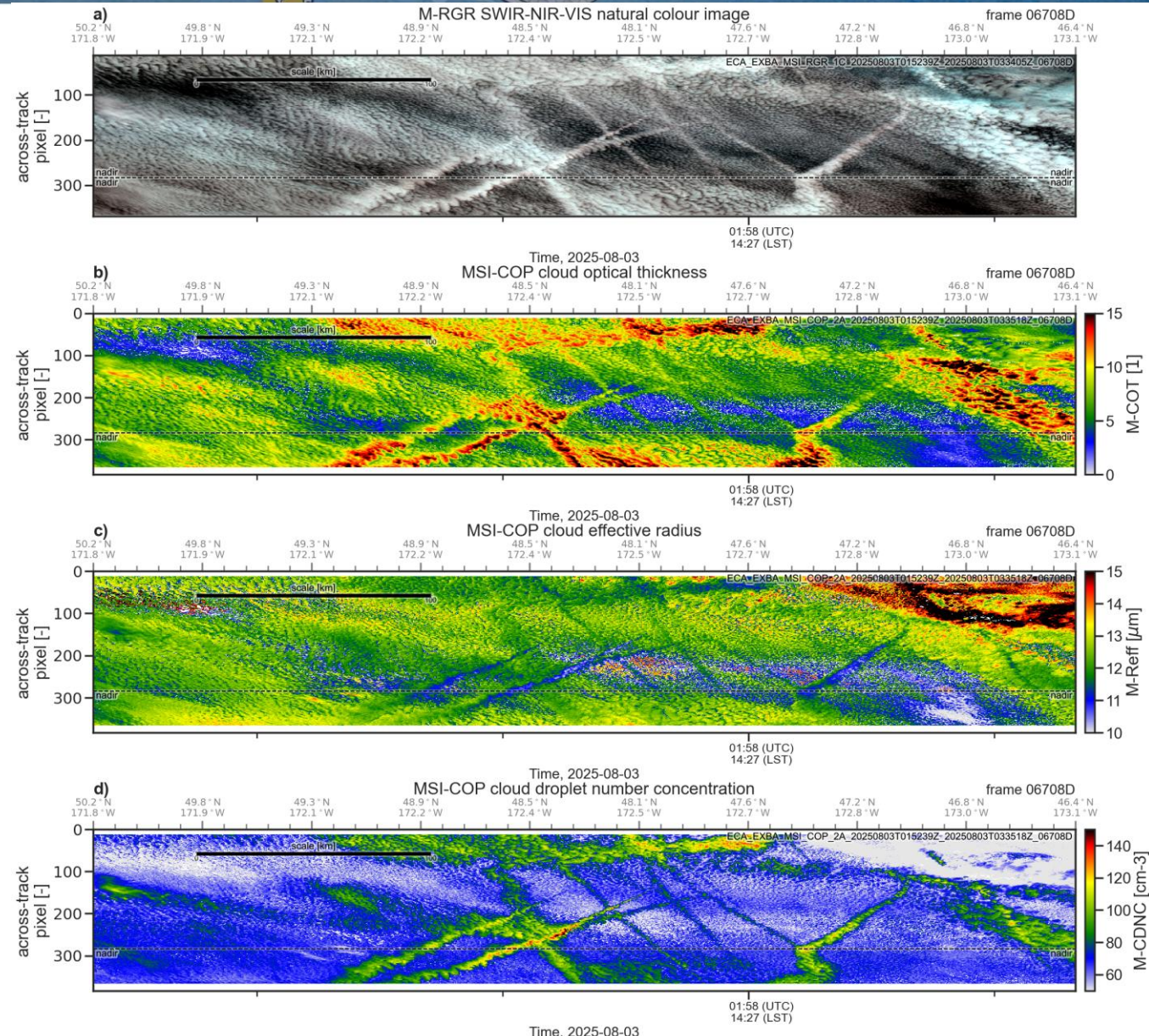
# Effects of ship emissions on clouds



*EarthCARE's MSI views on 3 August 2025, showing tracks in the clouds over ships in the Pacific Ocean*

**EarthCARE has been used to measure the effects of fumes from oceangoing vessels on clouds relative to the unperturbed background. Results:**

- Increase of the COT (panel "b")
- $R_{\text{eff}}$  (panel "c") is suppressed by about  $1\text{-}2\ \mu\text{m}$ .
- Increased (by  $\sim 30\ \text{cm}^{-3}$ ) of cloud droplet number concentration cloud (panel "d")  $\rightarrow$  **More solar radiation is reflected to space (i.e., cloud brightening) AND contributes to the net cooling of Earth's surface**



# Other results: Clouds and unexpected bonuses



- Synergistic retrievals shows increased droplet number (from increased aerosol) is related to reduced LWP.
- Global CPR observations in stratiform ice clouds reveals a pronounced slowdown in sedimentation velocities between -10°C and -20°C, consistent with the dendritic growth zone (DGZ).
- Contrail climate effects (i.e., in validation of radiative forcing estimates due to contrails that has been applied on Meteosat satellite data).
- Global 3D radiative effect (ACM-RT).
- Influence of gravity waves on cloud physics (reduced  $R_{\text{eff}}$ , increase number concentration) → How common is this globally? What's its radiative impact? Is this represented in models?
- First global statistics on insect occurrence detected from space.
- ATLID Rayleigh integrated surface returns is related to oceanic chlorophyll & diffuse attenuation coefficient.
- ATLID surface depolarization is well correlated with the vegetation index NDVI over land.

**See details at:**

<https://www.aeolus2026.org/programme>

[EarthCARE Mission Overview](#)

*Bjoern Frommknecht, ESA*

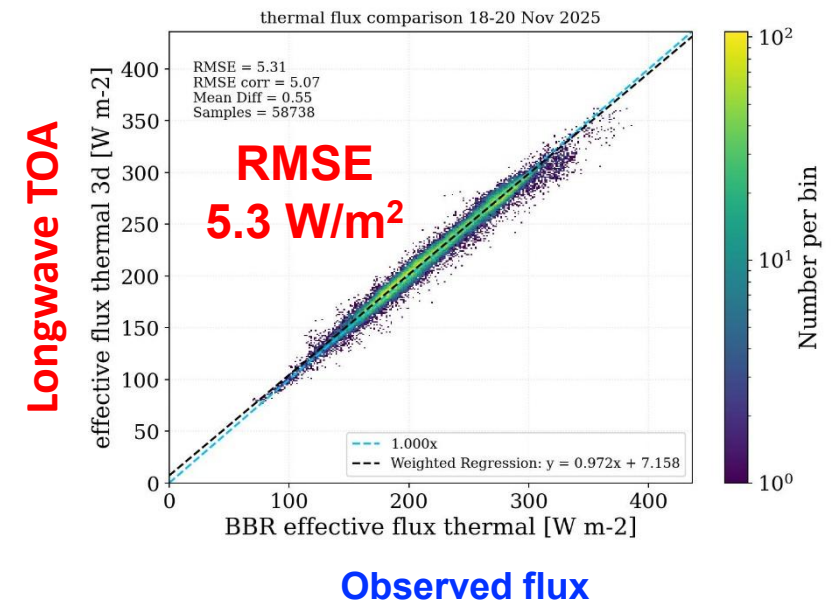
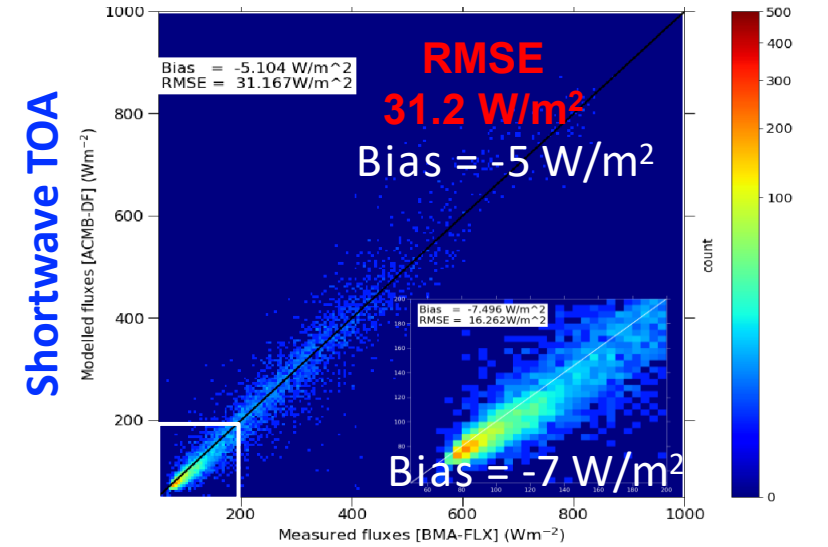
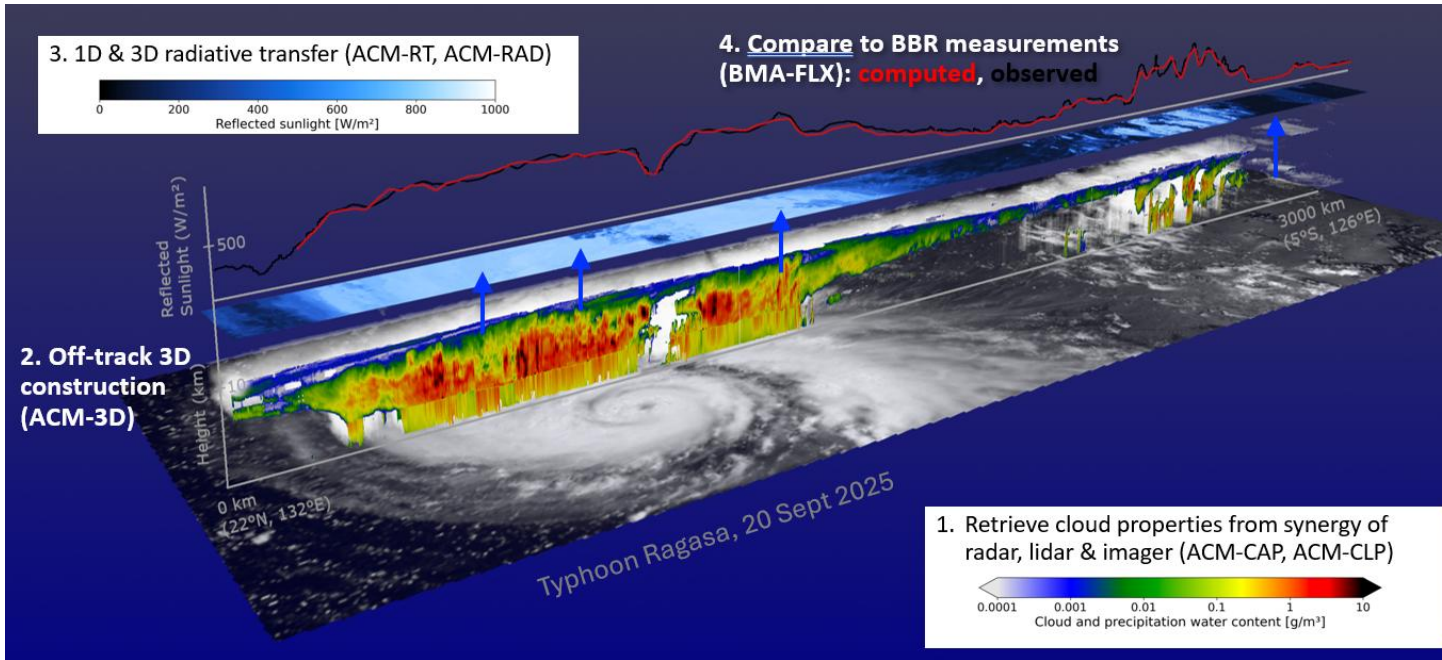
<https://www.earthcare-science-validation-2026.org/event-programme>

[EarthCARE: Global Measurements of Clouds, Aerosols, and Radiative Properties](#)

*Gerd-Jan Van Zadelhoff, KNMI*

# Status Radiative closure results

(Credit: Jason Cole & Carla Salas)



**Goal:** radiative closure within 10 W/m<sup>2</sup> [100 km<sup>2</sup>]

- Reached in the LW
- In the SW this currently reached for 48% of the cases → *Ongoing work: improve surface treatment (albedo), cloud and aerosol updates within the chain, etc.*

Thank you for  
your interest!

DISC is focusing on modelling activities, particularly the evaluation of aerosol models. Additional participants are encouraged to join model intercomparison efforts. If you are interested, please contact: [Loredana.Spezzi@esa.int](mailto:Loredana.Spezzi@esa.int)



# EarthCARE

Cloud and aerosol mission

Questions?