ESA L2 Aerosol Algorithms

Ulla Wandinger[1], David Donovan[2], Athena Floutsi[1], Moritz Haarig[1], Leonard König[1], Nicole Docter[1], Nils Madenach[1], Shannon Mason[3], Jason Cole[4], and Gerd-Jan van Zadelhoff[2]

[1]TROPOS, [2]KNMI, [3]ECMWF, [4]ECCC

TROPOS ECMWF KNMI

Environment and Climate Change Canada

EarthCARE Science and Validation Workshop 2025

1-5 December 2025 | The University of Tokyo | Tokyo, Japan

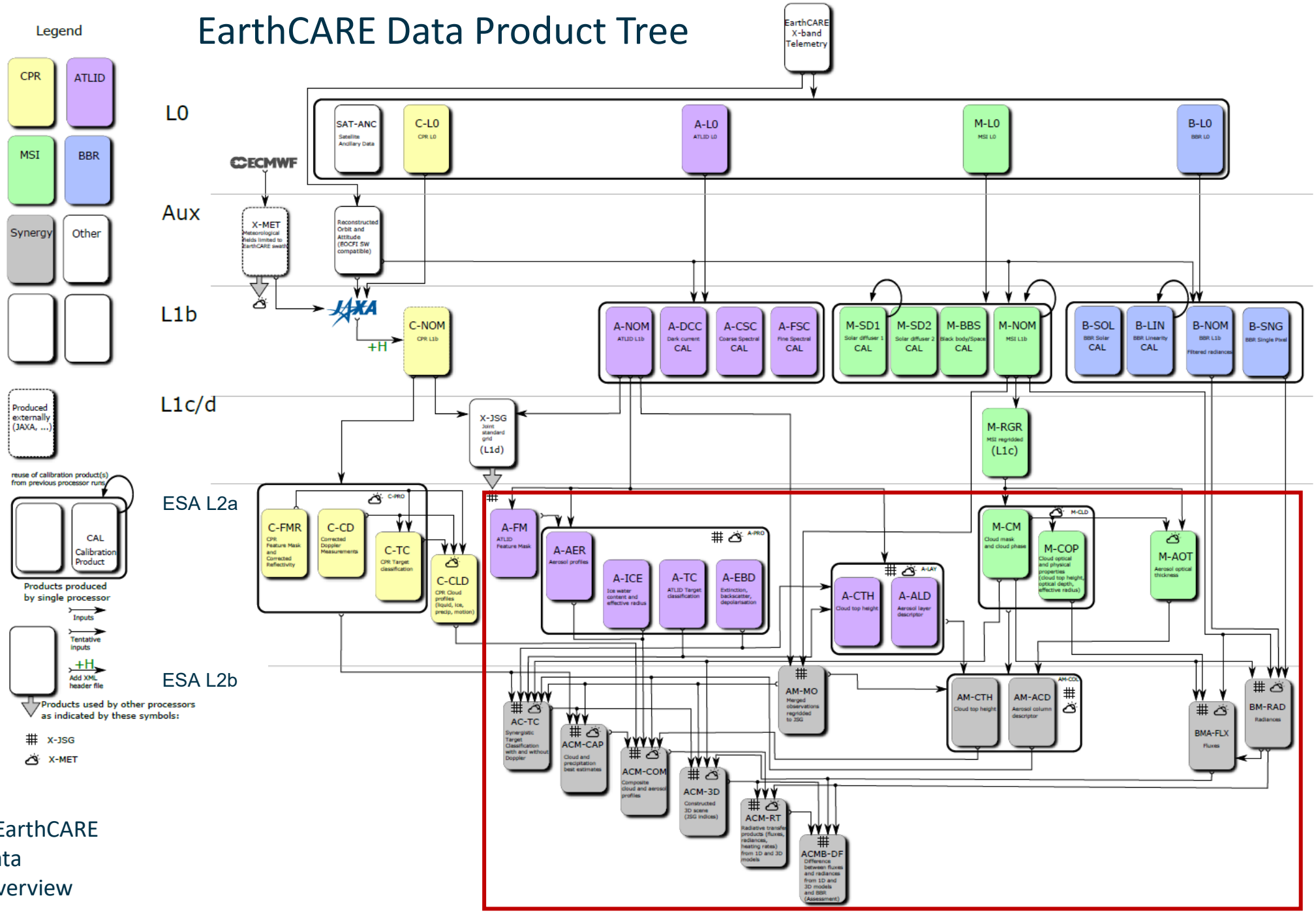
JAXA esa

Outline

- ESA Aerosol Product Chain
- Aerosol L2a and L2b Products
  - Recent improvements (baseline BA+)
  - Challenges, open issues, planned developments
  - Validation needs
- Conclusions and Remarks

TROPOS ECMWF KNMI
Environment and Climate Change Canada

EarthCARE Data Product Tree

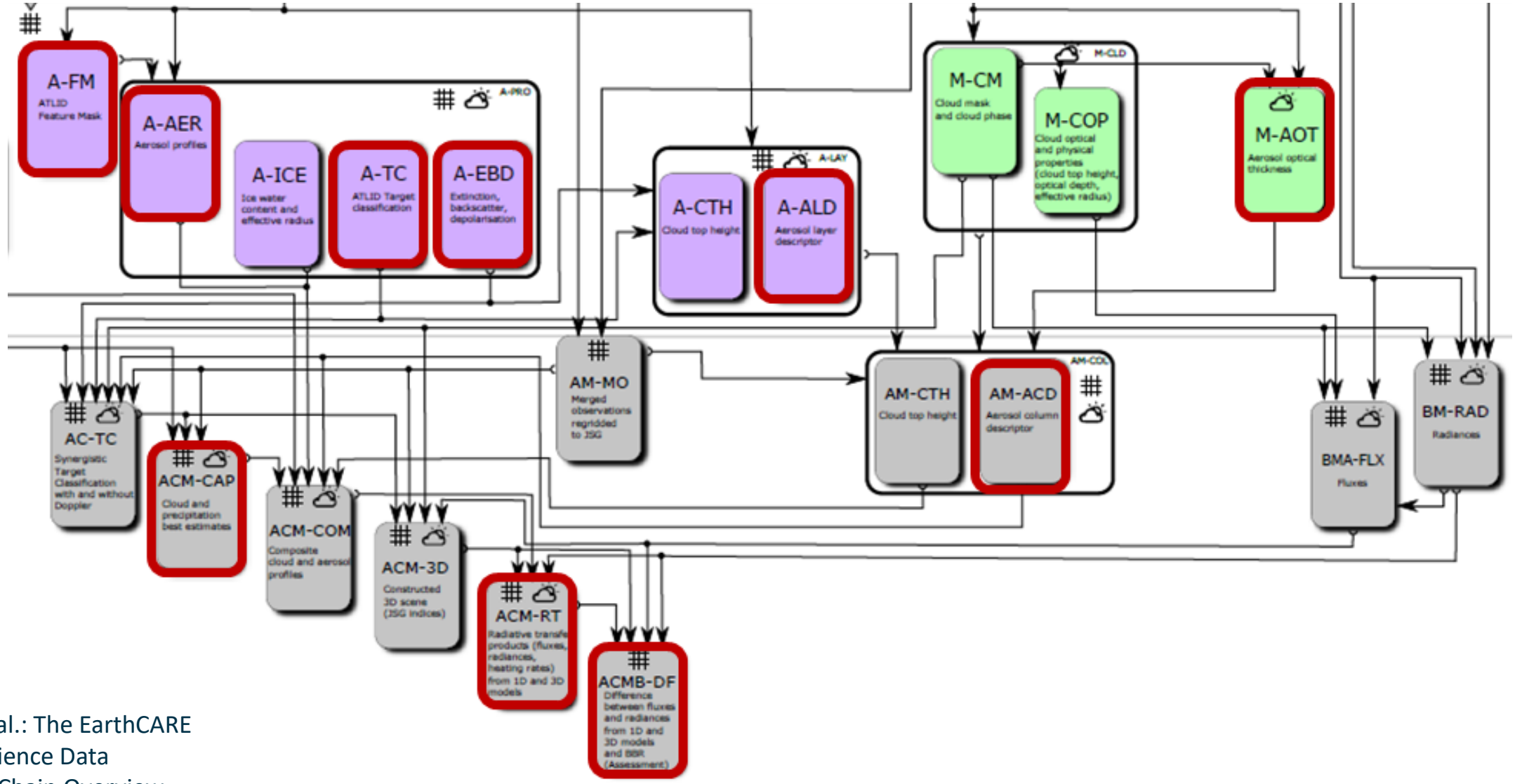


Eisinger et al.: The EarthCARE Mission: Science Data Processing Chain Overview

ESA L2 Aerosol Products

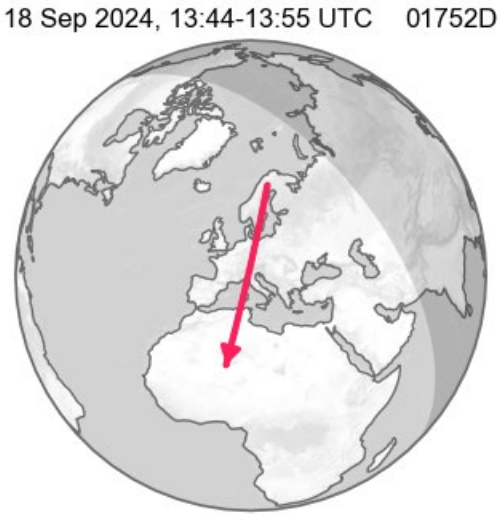
ESA L2a

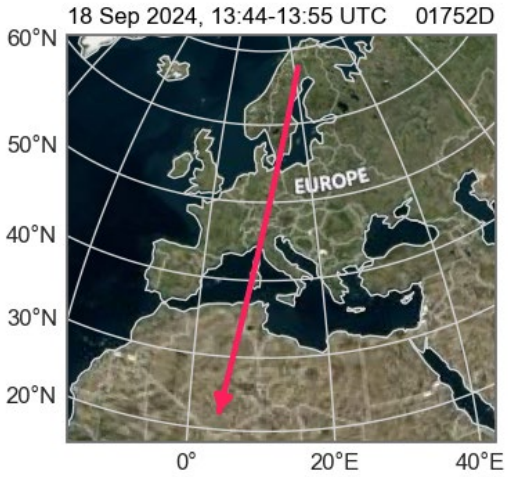
ESA L2b

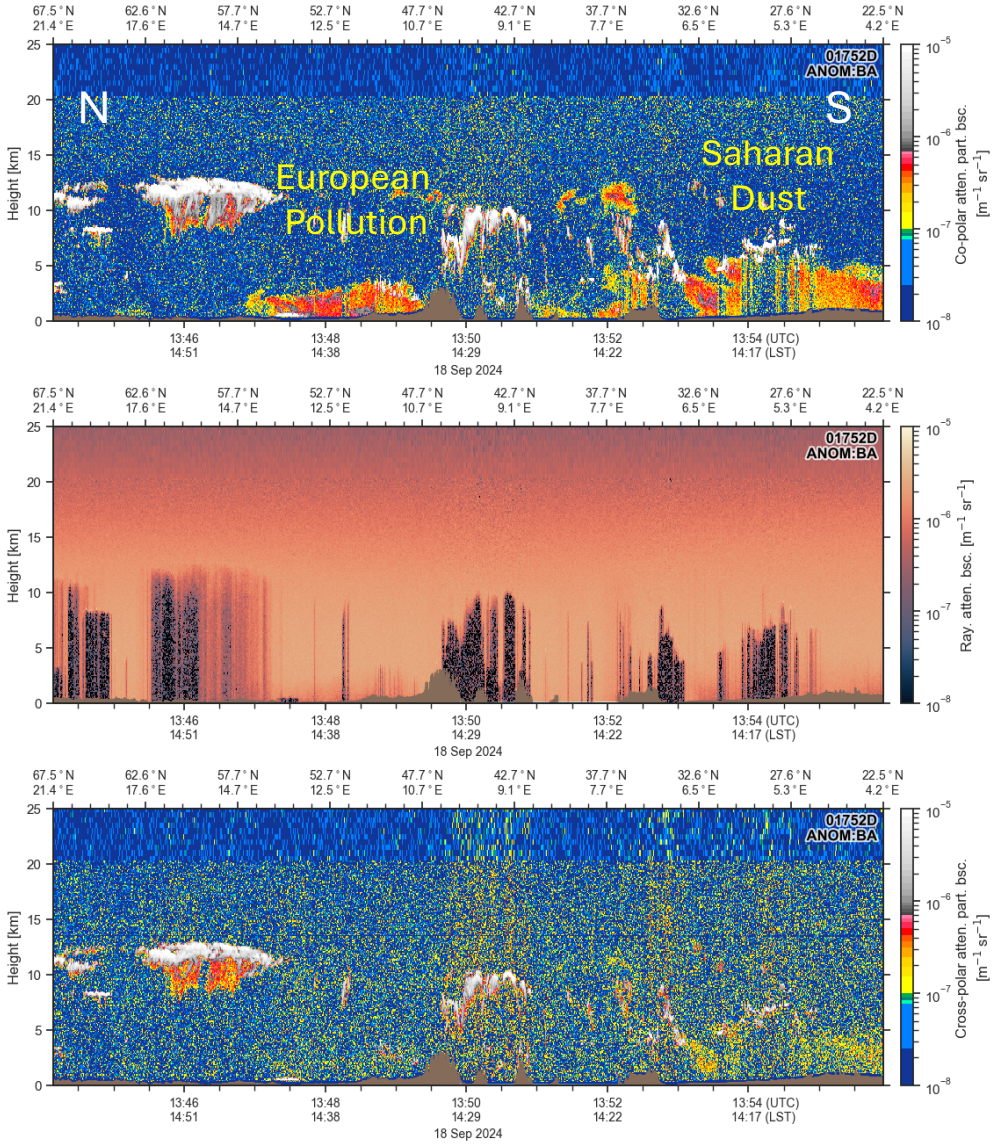


Eisinger et al.: The EarthCARE Mission: Science Data Processing Chain Overview

Demonstration Case: Frame 01752D and Baseline BA

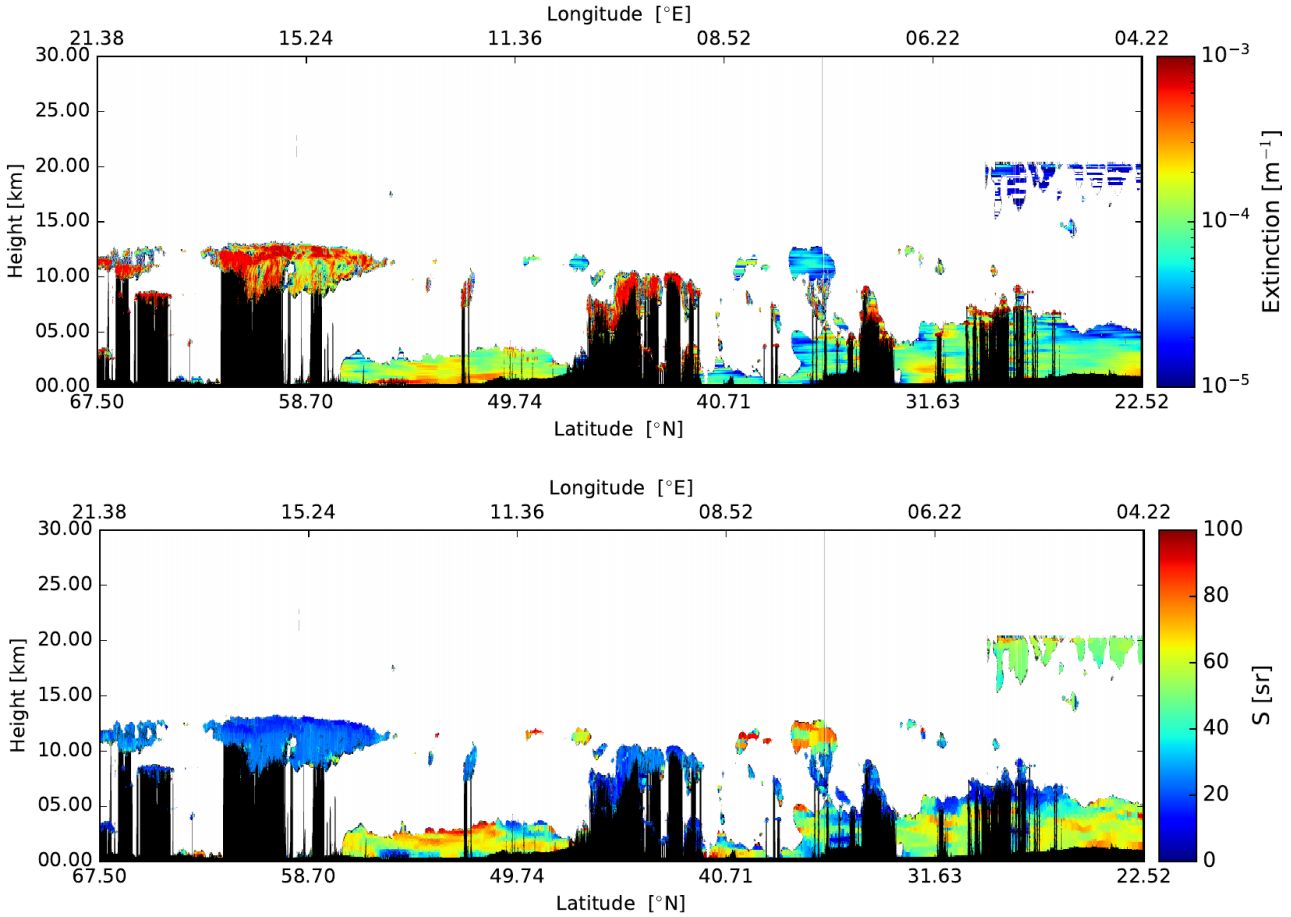






A-AER and A-EBD Extinction, Backscatter and Depolarization from ATLID

Responsible developers
David P. Donovan and Gerd-Jan van Zadelhoff (KNMI)



Recent improvements (baseline BA+)

- Improved low and medium resolution outputs
- Internal tropopause height determination improved
- Miscellaneous bug fixes

Challenges, open issues, planned developments

- QA flags should be improved
- Extinction in top regions of water clouds is likely underestimated
  - 100 meters coarse for high extinction targets
  - Use depol. to correct ?
- Cloud and aerosol regions can be overfilled (blurring effect)
  - Flagging (or removal) of “false layers” using depol. uncertainty and other error estimates

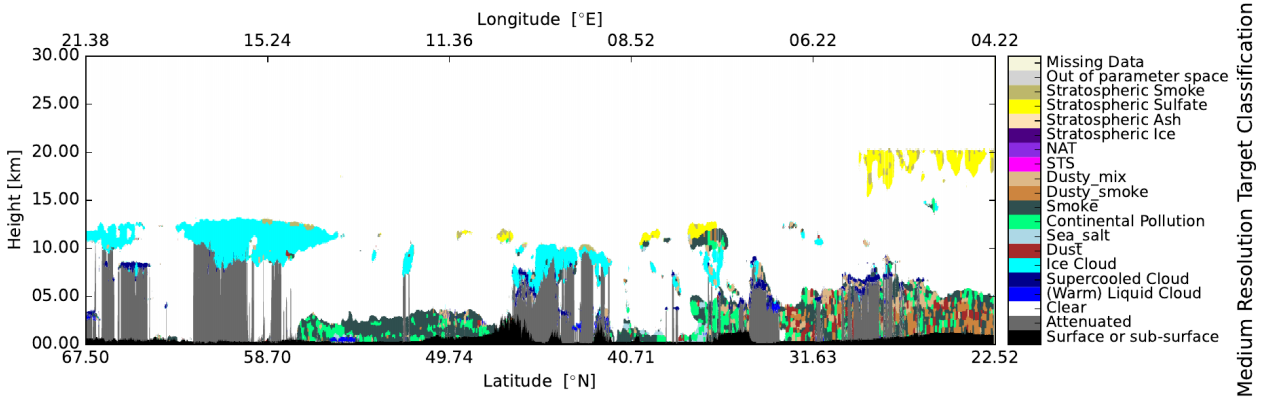
Validation needs

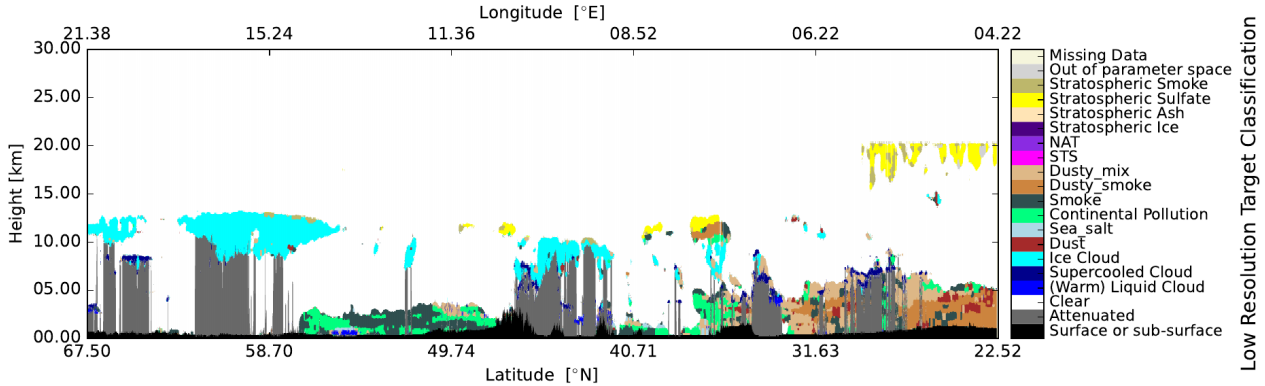
- Co-located ext, bsc, lr, depol lidar measurements
  - Close co-locations (e.g. aircraft)
  - Longer-term statistics with ground-based lidars
- AOD comparisons with, e.g., AERONET

A-TC Target Classification from ATLID

Responsible developers

David P. Donovan and Gerd-Jan van Zadelhoff (KNMI)





Recent improvements (baseline BA+)

- Improvements in A-EBD feed through to A-TC (and vice versa!)
- T, p, RH added to output
- Better cloud/aerosol discrimination

Challenges, open issues, planned developments

- QA flags should be improved
  - Should better respect the classification uncertainty
- Cloud/aerosol discrimination still needs to be improved
  - Intense smoke remains a challenge
- Smoke remains a challenge as it exhibits significant evolution in terms of S and depol.
- Stratospheric classification still has not had a whole lot of attention paid towards

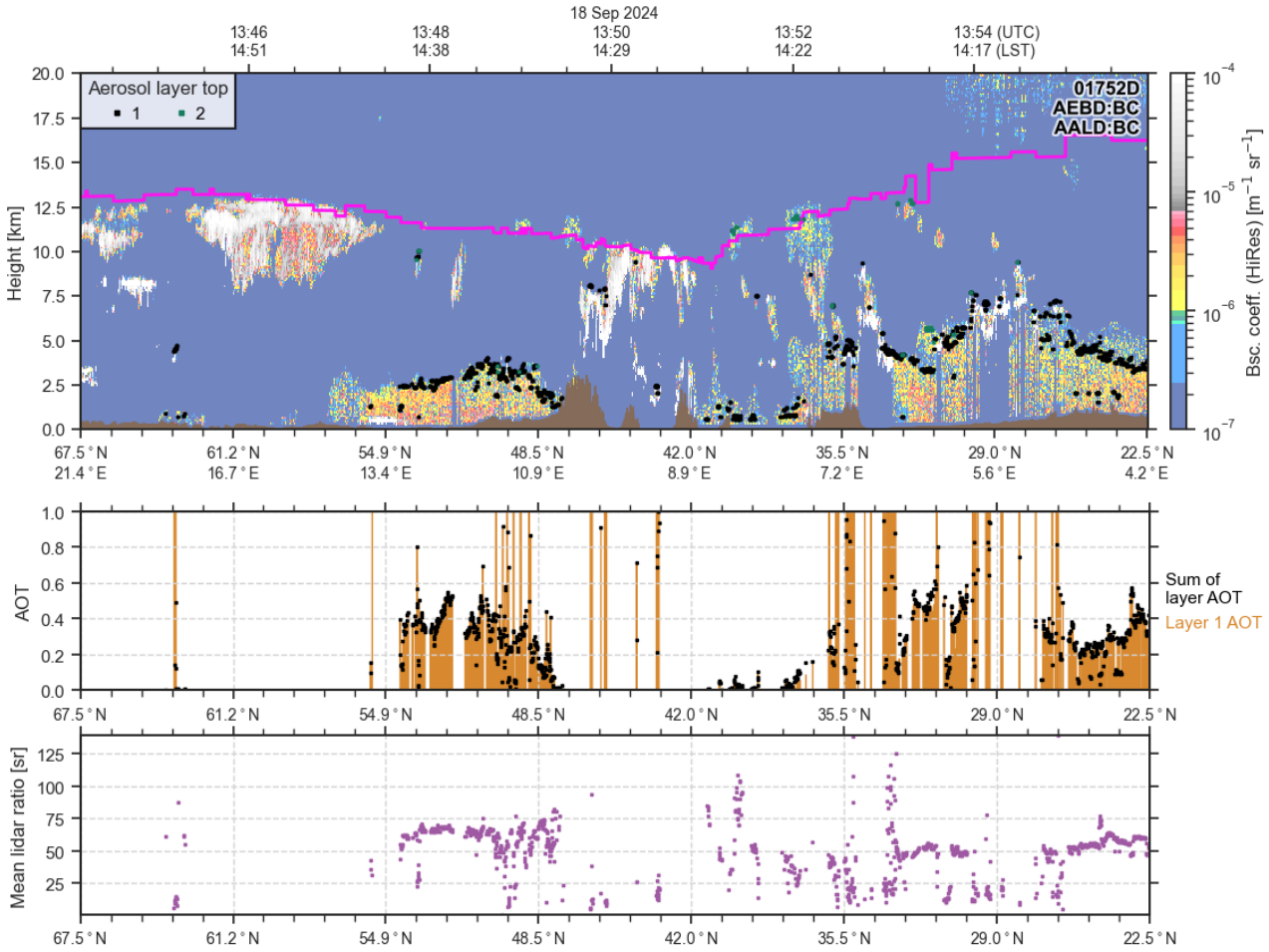
Validation needs

- Cases, cases cases !
  - Co-located high quality lidar-based S, depol and class data based up by e.g. trajectory analysis or in-situ to verify actual microphysics

A-ALD Aerosol Layer Descriptor from ATLID

Responsible developers

Athena A. Floutsi, Moritz Haarig, Ulla Wandinger (TROPOS)



Recent improvements (baseline BA+)

- Surface return no longer misidentified as CTH (baseline BB onwards)
  - Surface return was wrongly identified as CTH by A-CTH subroutine, subsequently A-ALD was only applied to very few profiles

Challenges, open issues, planned developments

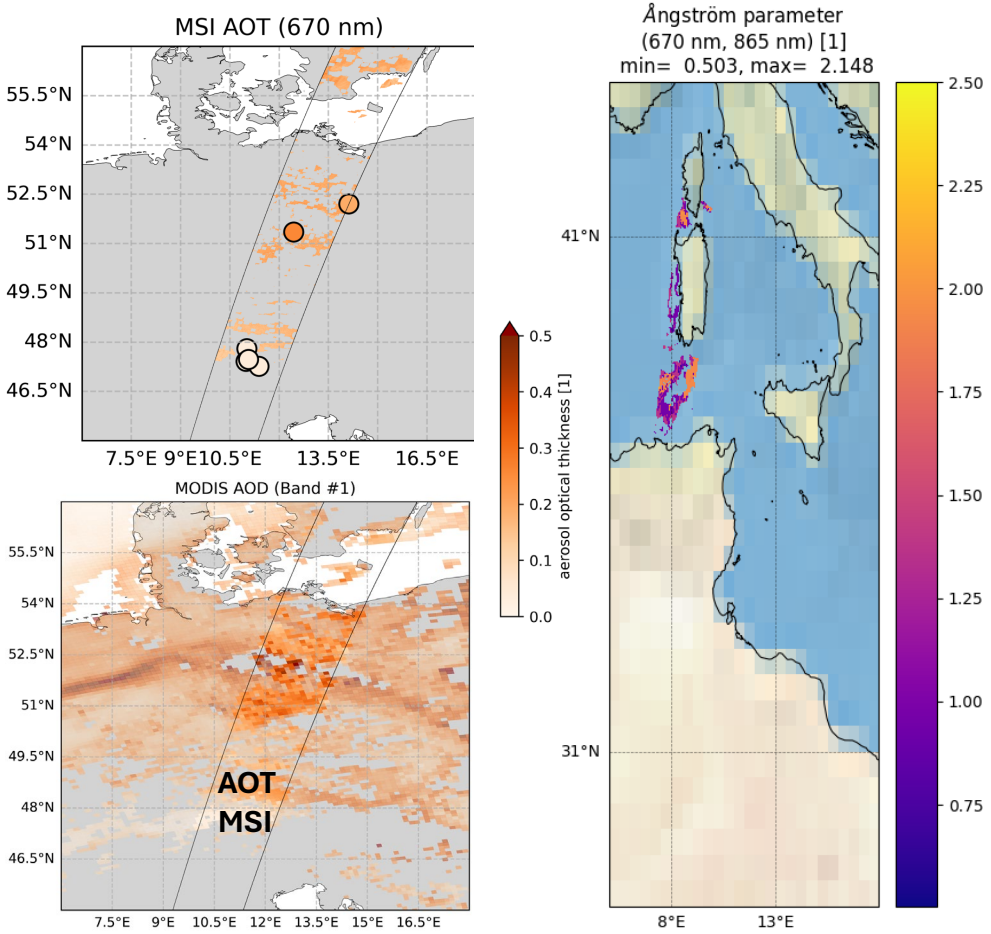
- High backscattering aerosol layers often misidentified as clouds
- Occasional misidentification of cloudy pixels within the A-ALD product
- A-ALD applied below thin cirrus and above clouds

Validation needs

- So far only AOT has been examined by cal/val teams
- Aerosol layer(s) top and base heights
- Layer-mean optical properties (ext, bsc, depol)

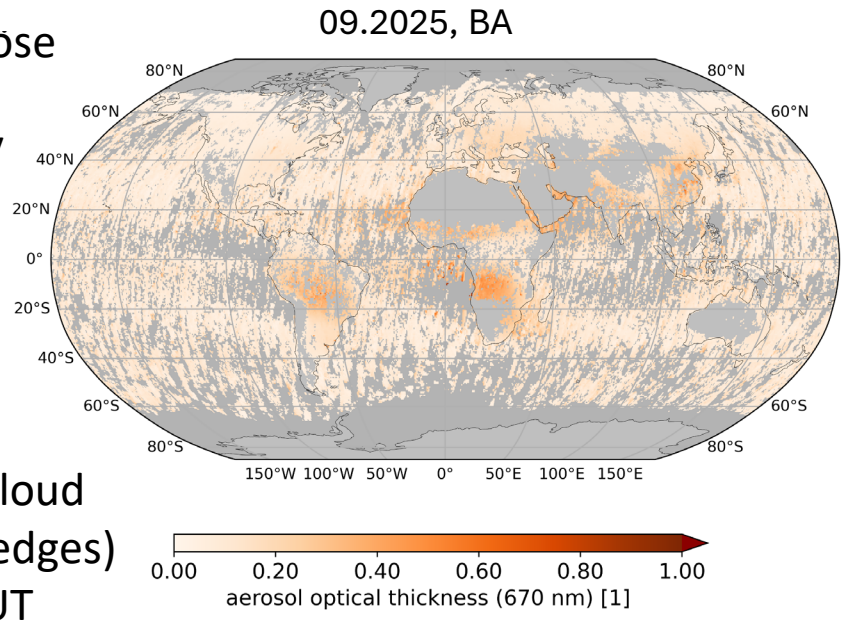
M-AOT Aerosol Optical Thickness from MSI

Responsible developers
Nicole Docter and Nils Madenach (TROPOS)



Recent improvements (baseline BA+)

- Increase # of pixel allowed close to cloud edges (10 → 5)
- First global daily and monthly composites for BA



Challenges, open issues, planned developments

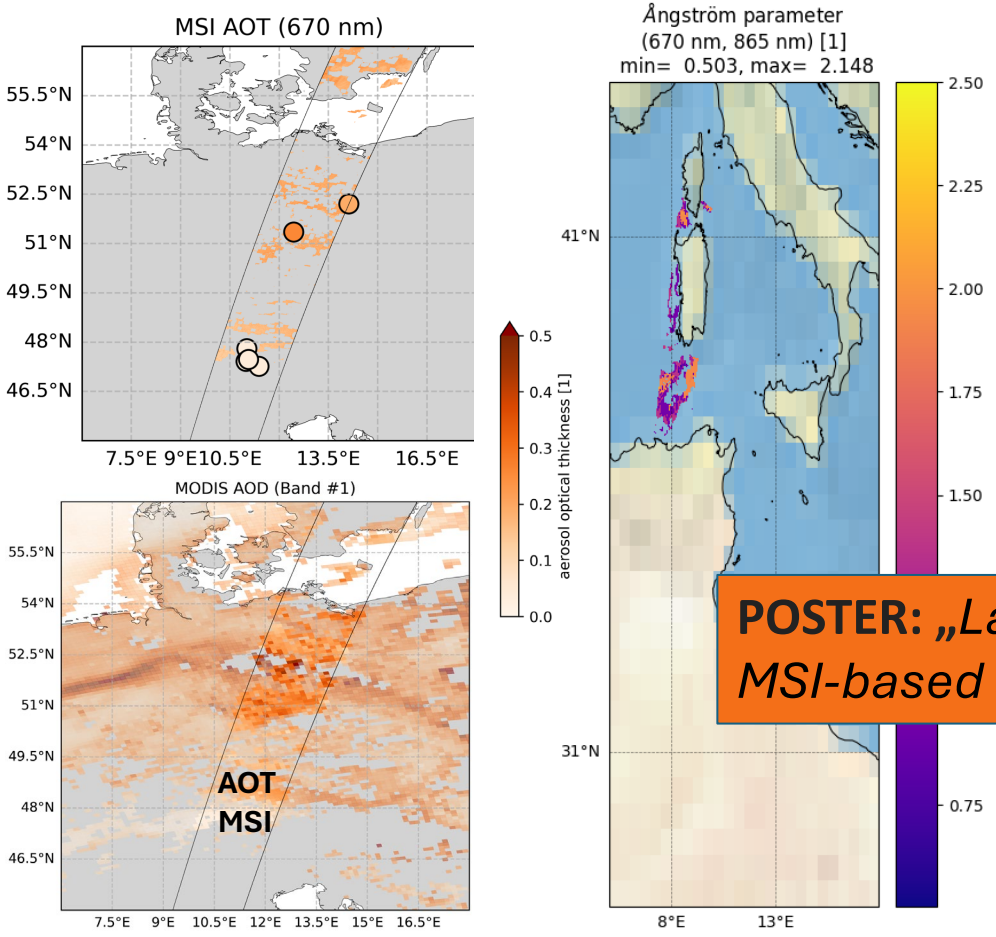
- Improvements of L1 data
- Optimization of the aerosol-cloud discrimination (i.e., at cloud-edges)
- SMILE (Docter et al., 2024) LUT updates according to updated pointing information

Validation needs

- Validation ongoing
- More validation from ground, airborne and satellite
- SMILE characterization

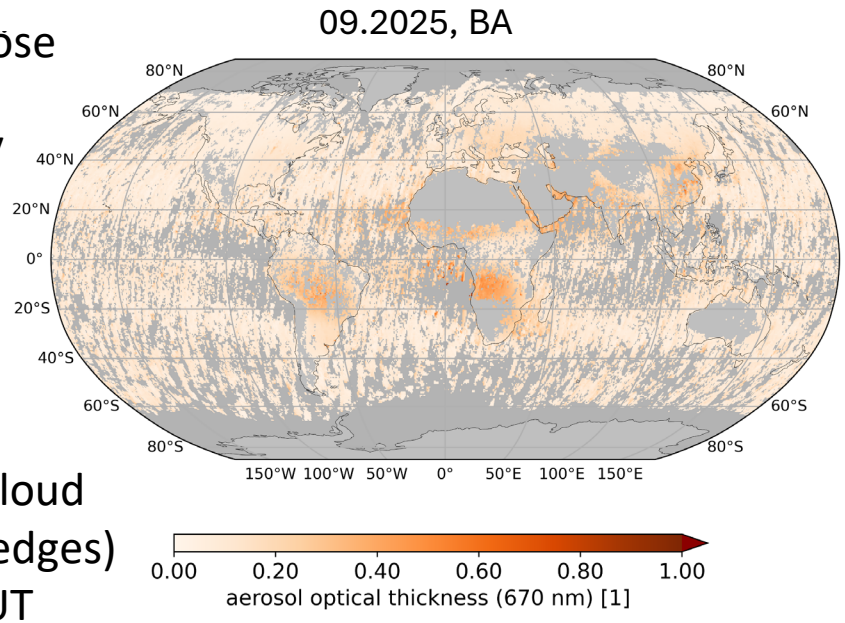
M-AOT Aerosol Optical Thickness from MSI

Responsible developers
Nicole Docter and Nils Madenach (TROPOS)



Recent improvements (baseline BA+)

- Increase # of pixel allowed close to cloud edges (10 → 5)
- First global daily and monthly composites for BA



Challenges, open issues, planned developments

- Improvements of L1 data
- Optimization of the aerosol-cloud discrimination (i.e., at cloud-edges)
- SMILE (Docter et al., 2024) LUT updates according to updated pointing information

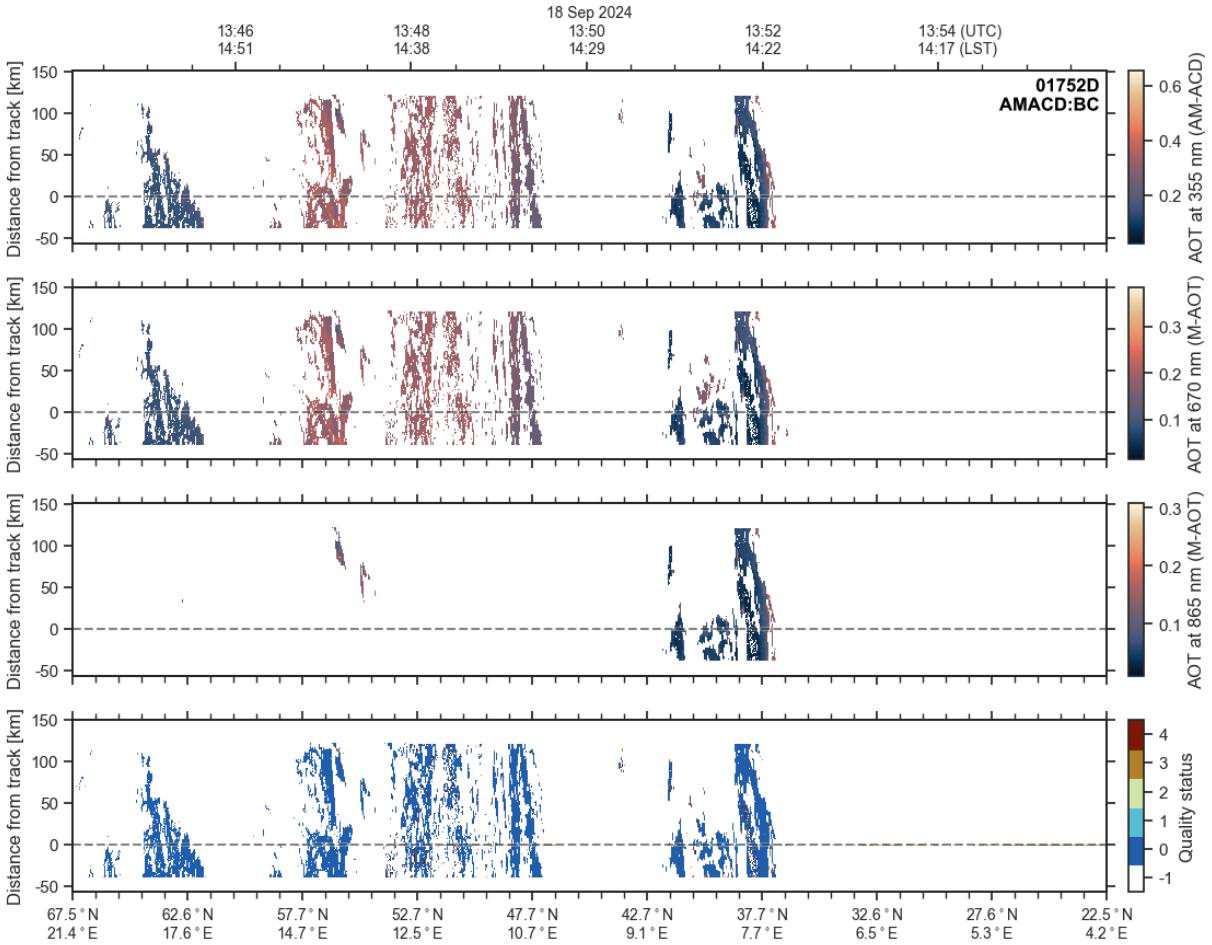
POSTER: „*Latest improvements and current status of the MSI-based aerosol product M-AOT*“ on THURSDAY Annex59

- Validation ongoing
- More validation from ground, airborne and satellite
- SMILE characterization

AM-ACD Aerosol Column Descriptor from ATLID and MSI

Responsible developers

Athena A. Floutsi, Moritz Haarig, Ulla Wandinger (TROPOS)



Recent improvements (baseline BA+)

- Improvements in reported quality status
- Minor updates to the X-JSG reading module

Challenges, open issues, planned developments

- Strongly dependent on input quality
- No feedback from cal/val community so far, makes it difficult to plan for future developments

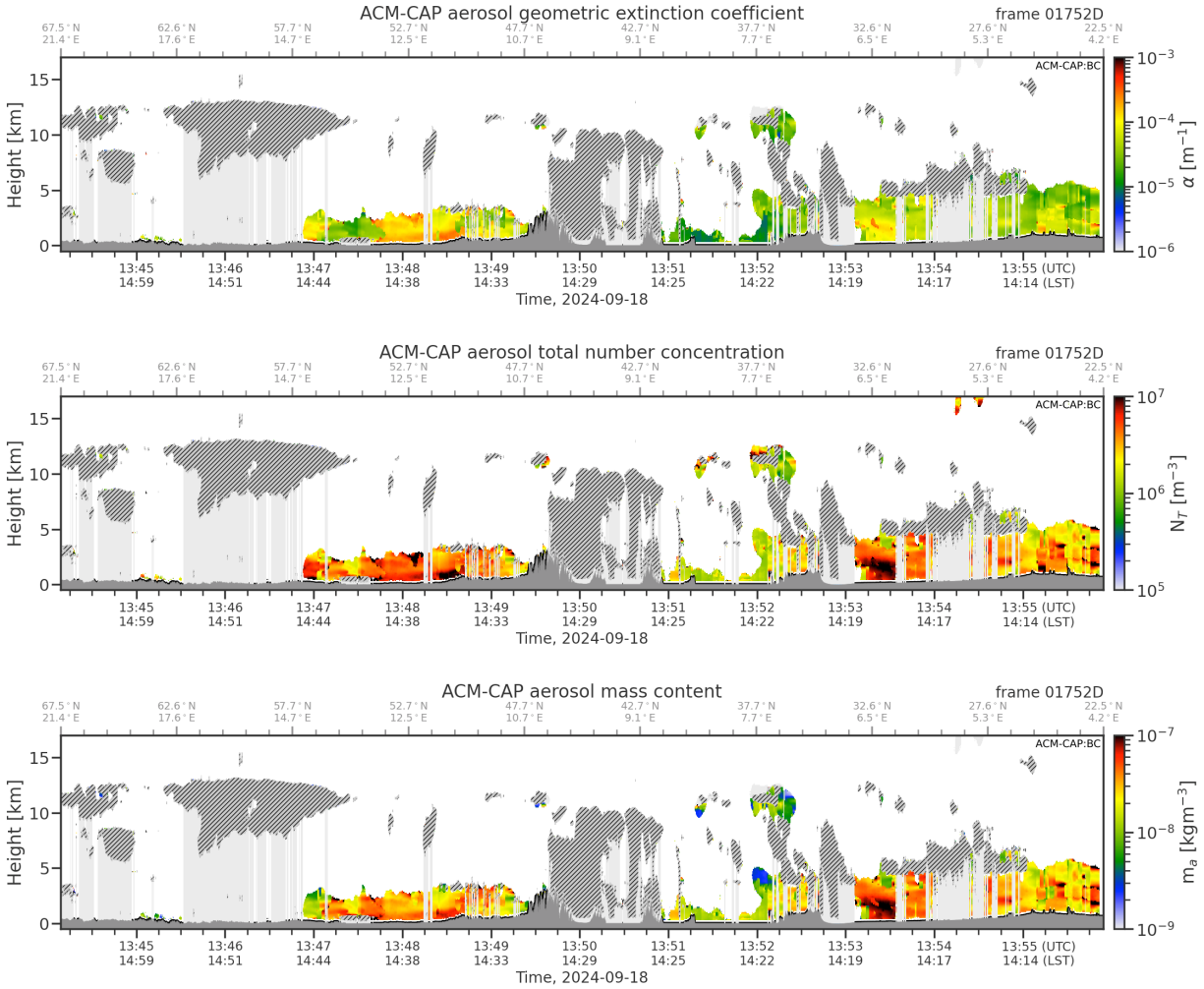
Validation needs

- AOT at 355/670/865 nm
- Ångström parameter 355/670 and 670/865 nm
- Aerosol type

ACM-CAP Cloud, Aerosol and Precipitation Products from Synergistic Retrievals

Responsible developers

Shannon Mason and Robin Hogan (ECMWF)



ACM-CAP retrieval approach

- Each aerosol class is retrieved independently based on the A-TC classification, with fixed properties based on HETEAC
- Retrieved variable is the number concentration, and the observational constraints are ATLID profiles of backscatter and MSI radiances

Recent improvements (baseline BA+)

- Chiefly due to upstream improvements in classification (A-TC) and corrected ATLID measurements (A-EBD)
- ATLID surface return is now available (A-EBD) as a constraint on total aerosol optical depth, *but is not yet used in ACM-CAP*

Challenges, open issues, planned developments

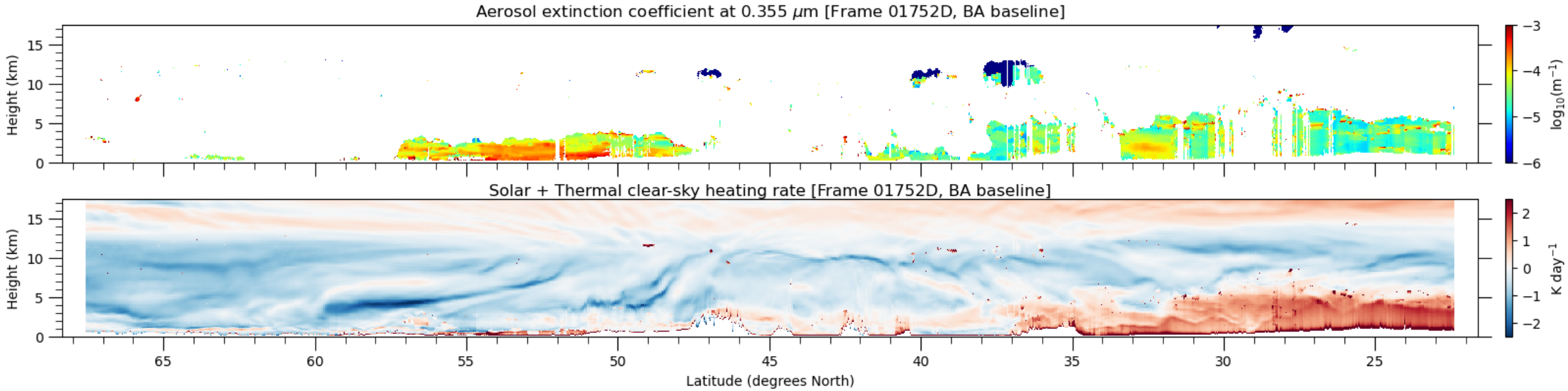
- Changes in aerosol classification and embedded clouds interrupt the Kalman smoother, causing “patchy“ retrievals
- Synergy with MSI radiances relies on the accuracy of land & ocean albedo; issues in surface properties likely affect current biases
- Stratospheric sulphates and smoke have been very frequently observed; their representation needs to be improved & validated

Validation needs

- ACM-CAP relies on the assigned aerosol class and its properties, so all validation of A-PRO and HETEAC has impacts downstream

ACM-RT Radiative Transfer Products from ATLID, CPR and MSI

Responsible developers
Jason Cole, Howard Barker, Zhipeng Qu, Meriem Kacimi (ECCC)



Recent improvements (baseline BC)

- Use A-EBD and A-TC low resolution aerosol extinction and aerosol target classification instead of ACM-CAP
- Corrected aerosol classification used in radiative transfer
- Bug-fixes in solar Monte Carlo radiative transfer model

Challenges, open issues, planned developments

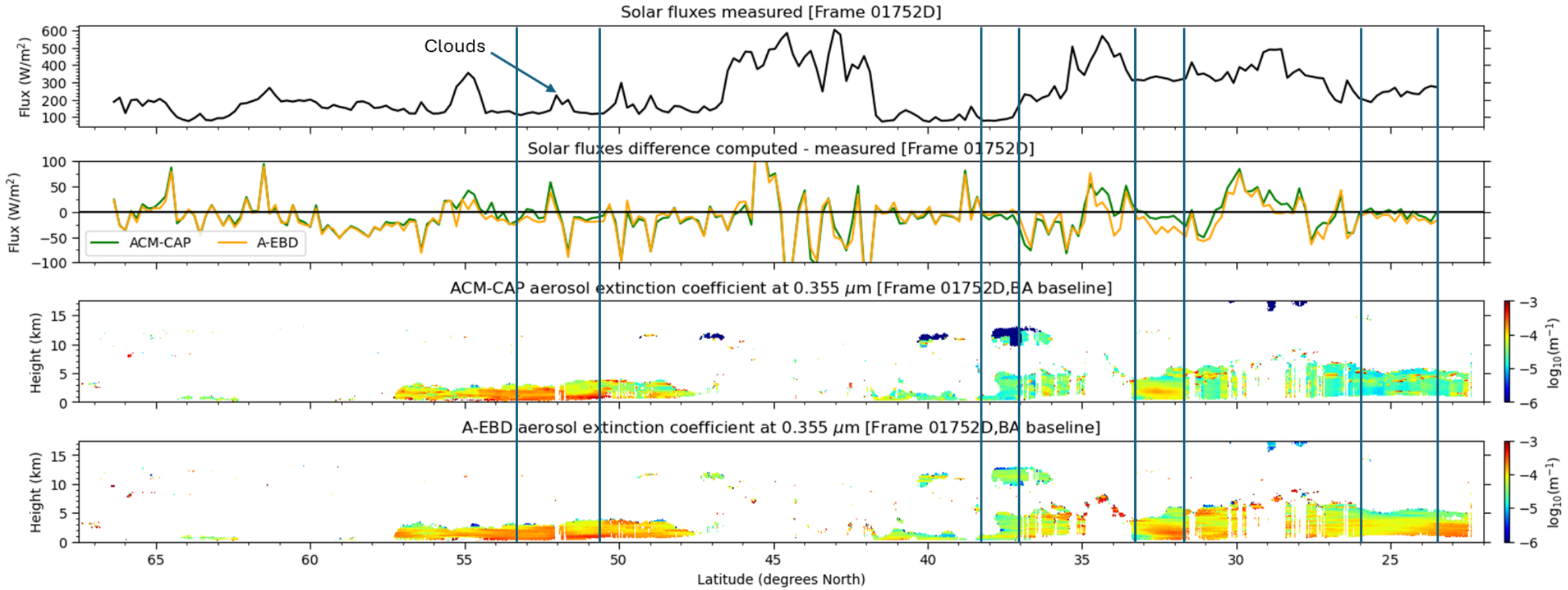
- Stratospheric aerosols in radiative transfer calculations
- Improve specification of land for solar Monte Carlo

Validation needs

- Surface and aircraft radiative closure in clear-sky
- Sensitivity studies related to aerosol optics

ACMB-DF Radiative Closure Assessment

Responsible developers
Jason Cole, Howard Barker, Zhipeng Qu, Meriem Kacimi (ECCC)



- In cloud-free portions of frame, solar fluxes from ACM-RT and BMA-FLX tend to agree within 20 W/m^2
- Effect of changing aerosol inputs is mixed for this frame, but as shown on Monday over ocean it improves closure

Conclusions and Remarks

- Baseline BA (completely reprocessed dataset) includes major improvements, particularly compared to early baselines (AC, AD)
- Consider changes and further improvements for forward-processed data beyond baseline BA

  ⇨ **Always indicate the baseline**

  ⇨ **Always check the disclaimer**

- Similar variables are available from different algorithms and with different resolution (e.g., aerosol extinction), some variables may also be derived from existing ones with own methodologies (e.g., AOT)

  ⇨ **Cross-validation of products derived in different ways is encouraged**

Thank you!

earth care

disc