How can EarthCARE contribute to long-term aerosol Climate Data Records (CDRs)

Thomas Popp, DLR-DFD – based on ESA Aerosol_cci and C3S Atmospheric Composition

Climate Data Records – next stage

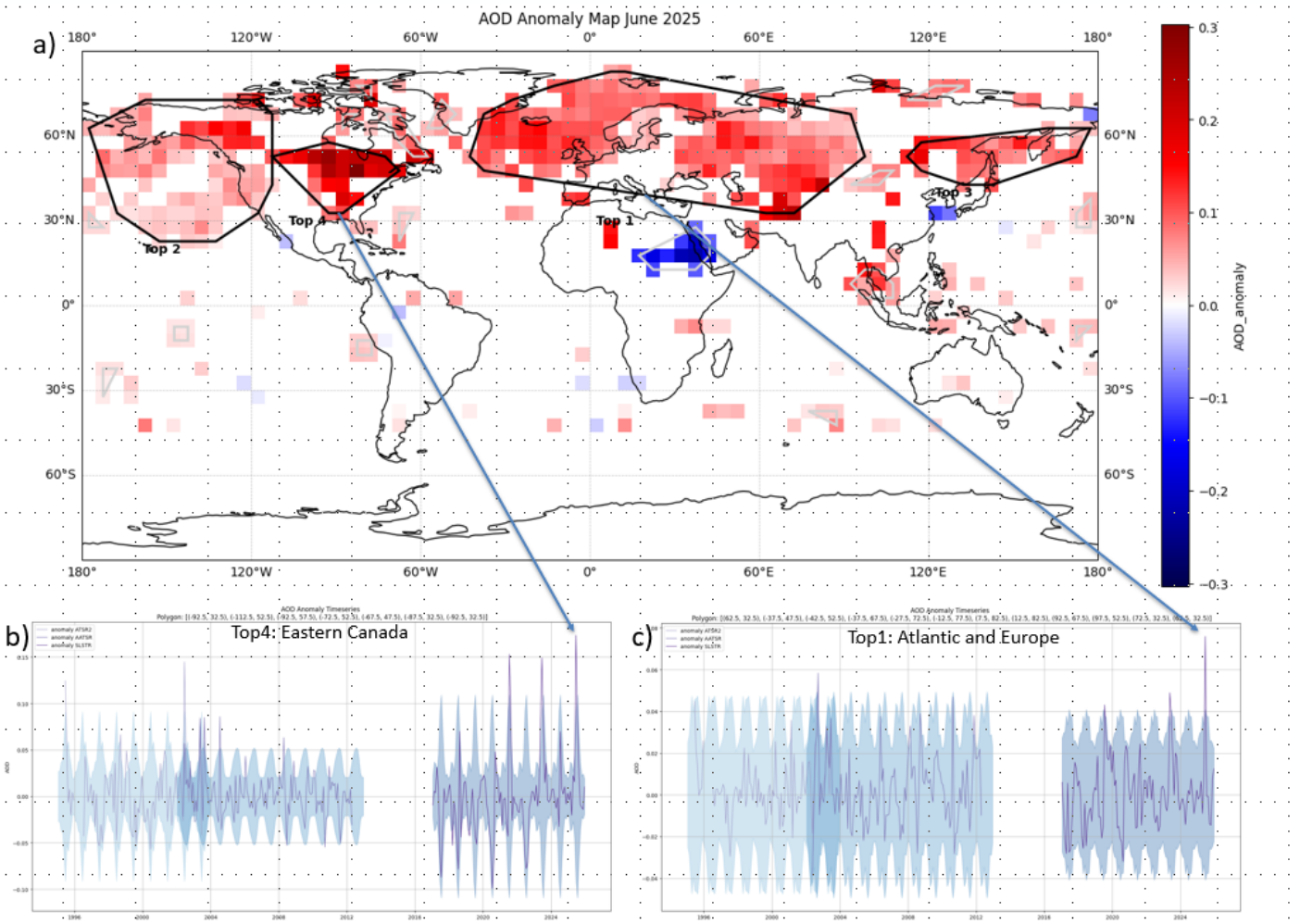
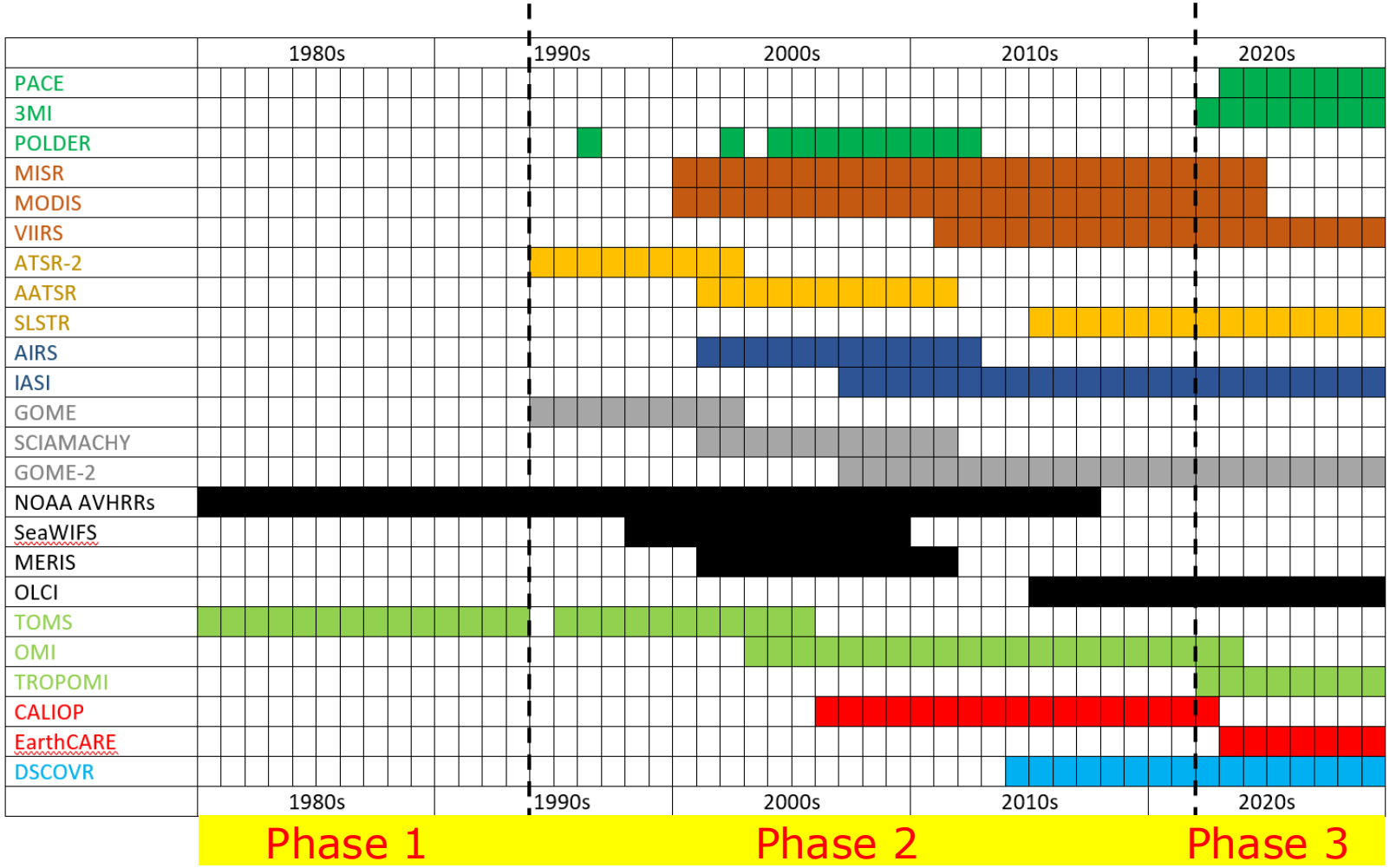


Figure 2: a) Clustered SLSTR ensemble AOD anomaly map for June 2025, outside 1.5 times the standard deviation for the years 2017 – 2025. b) Anomaly time series over Eastern Canada (cluster TOP4) and c) over the Atlantic and Europe (cluster TOP1)

Aerosol Climate Data Records: suitable polar orbiting instruments

Satellite sensor line(s) for long aerosol records (no limb sensors)



Auxiliary information used

- Pre-defined aerosol components
  - Aerosol_cci: set of 4 basic components (weakly and strongly absorbing fine mode, sea salt, dust)
    - tests of adjustments (variable dust size, smaller fine mode “extremes”)
  - EarthCARE HETEAC based on Aerosol_cci / ground-based AERONET + lidar statistics
  - Need to remain consistent / “translatable”

  ➔ Use EarthCARE typing measurements for cross-calibration of algorithms in overlapping periods

  ➔ Use EarthCARE covariances between aerosol components for new synergetic multi-sensor retrievals

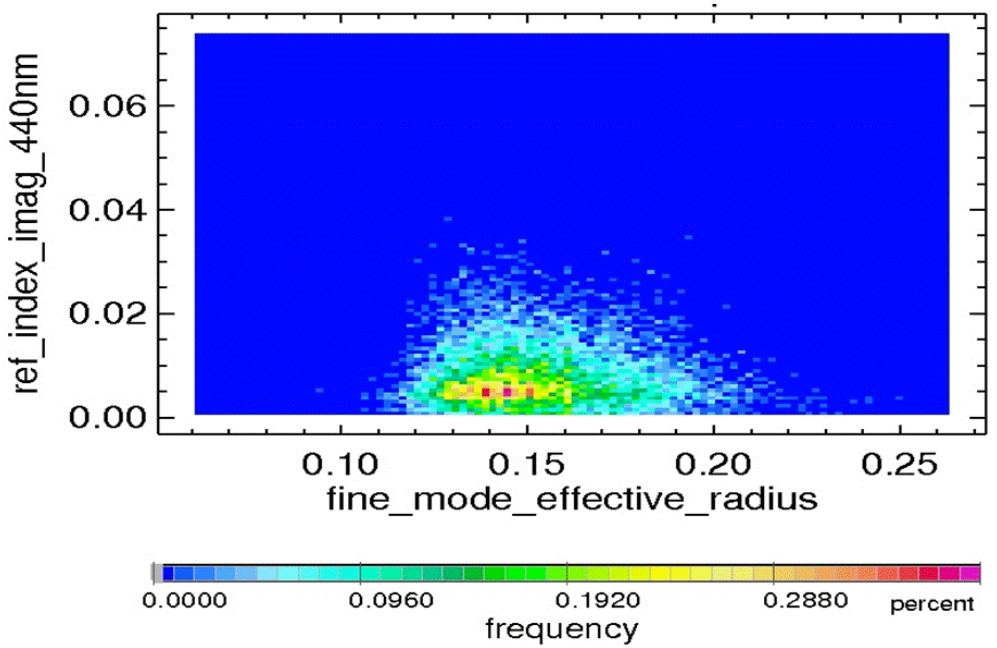
- Vertical profiles
  - Climatological profile information from ground-based lidar networks or atmospheric models

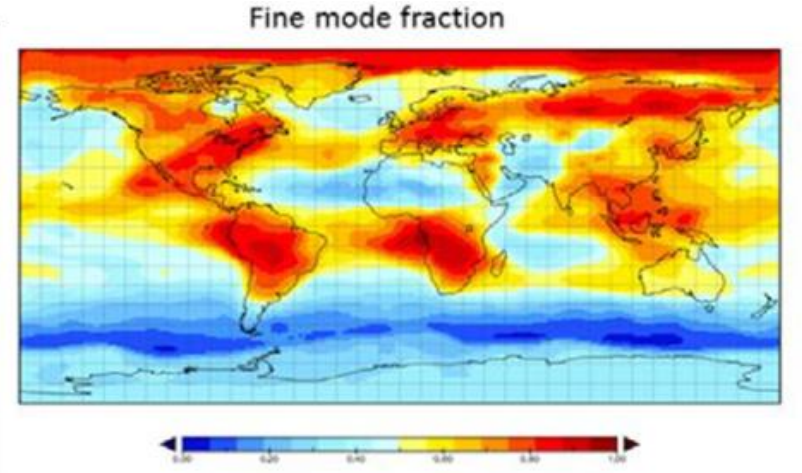
  ➔ Use globally measured EarthCARE profile (shape) climatologies

Aerosol_cci example of assumed pre-defined components in retrievals

- 4 components pre-defined
  - catch natural variety of aerosol types
  - intensive community dialogue
  - accept limitations (e.g. dust size changes)
  - Mean size from AERONET
  - Mixing maps from AEROCOM median
  - Suitable for limited information content

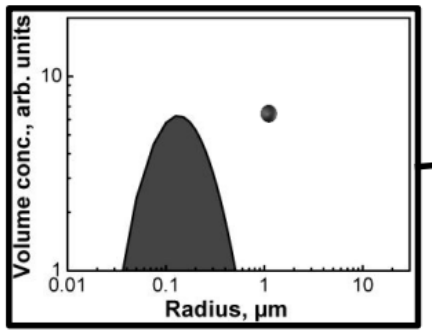
aerosol component	Refr. index, real part (55µm)	Refr. Index, imag part (.55µm)	reff (µm)	geom. st dev (σ_i)	variance (ln σ_i)	mode. radius (µm)	comments	aerosol layer height
Dust	1.56	0.0018	1.94	1.822	0.6	0.788	non-spherical	2-4km
sea salt	1.4	0	1.94	1.822	0.6	0.788	AOD threshold constraint	0-1 km
fine mode weak-abs	1.4	0.003	0.140	1.7	0.53	0.07	(ss-albedo at 0.55 µm: 0.98)	0-2 km
fine mode strong-abs	1.5	0.040	0.140	1.7	0.53	0.07	(ss-albedo at 0.55 µm: 0.802)	0-2 km





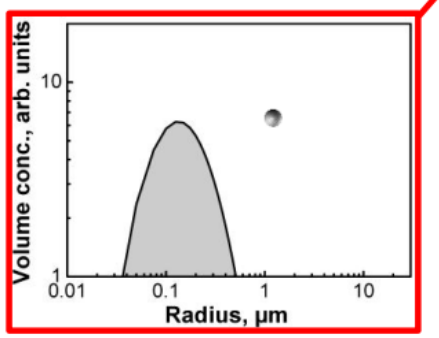
Aerosol classification model for EarthCARE

Smoke

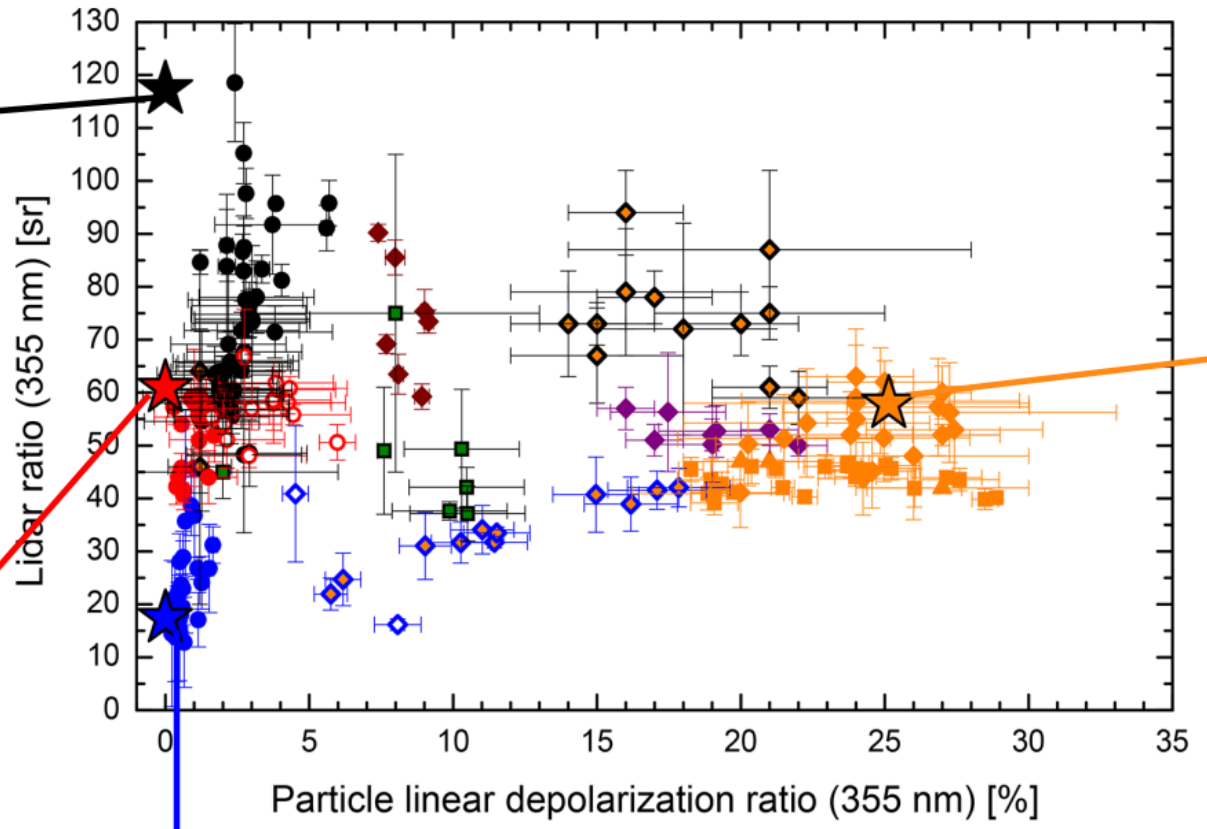


Fine mode
strongly absorbing
spherical

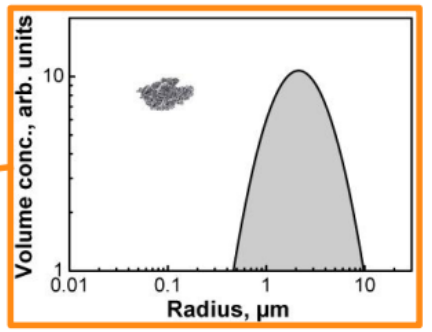
Pollution



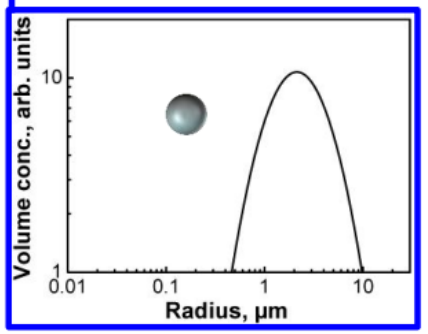
Fine mode
moderately absorbing
spherical



Dust



Coarse mode
moderately absorbing
non-spherical



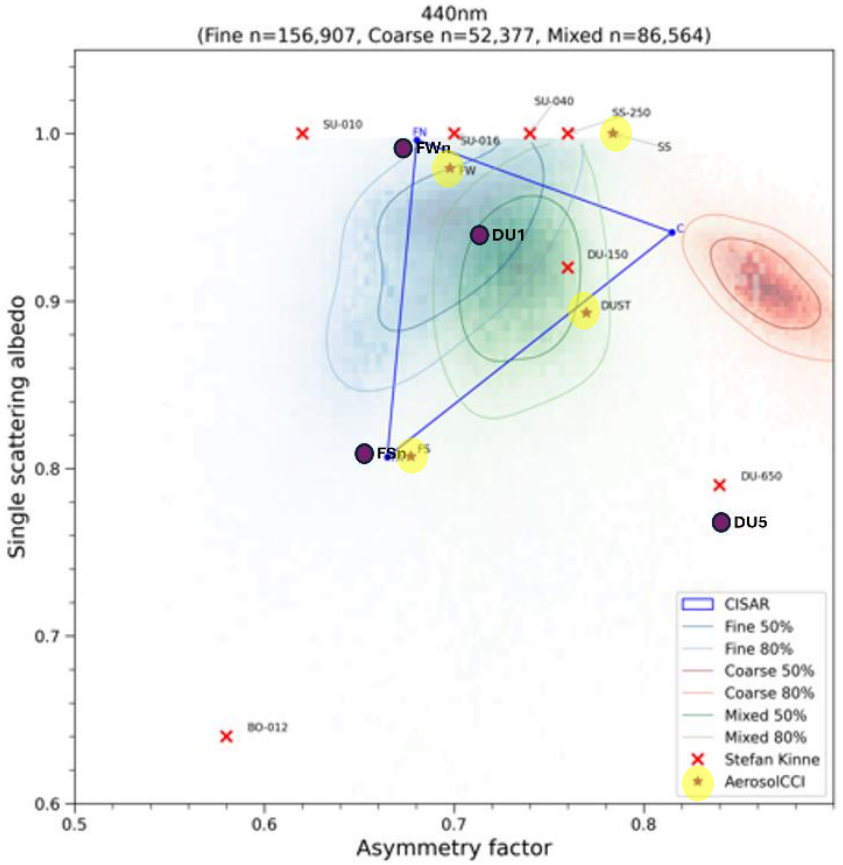
Marine

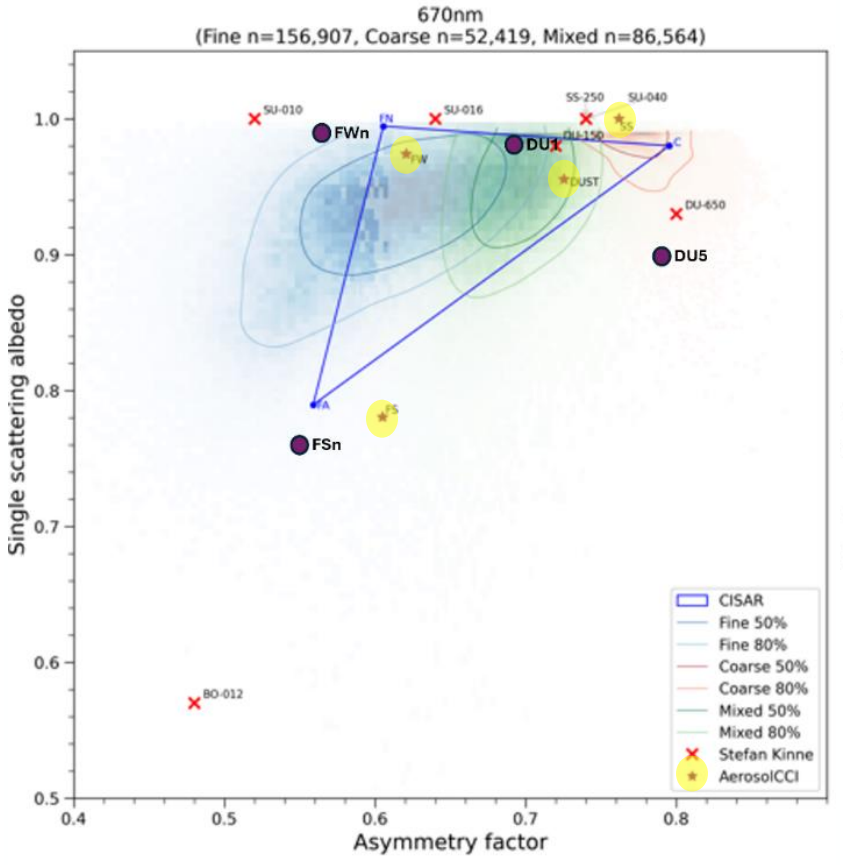
Coarse mode
non-absorbing
spherical

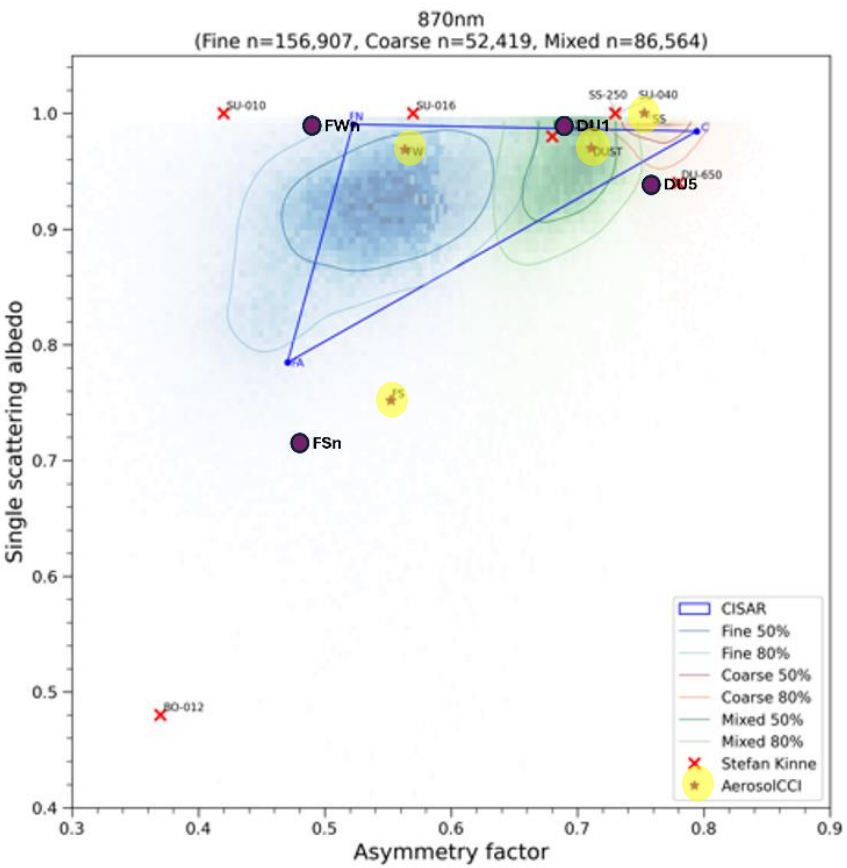
Floutsi et al., DeLiAn – a growing collection..., AMT, 2023

Wandinger et al., HETEAC – The Hybrid End-To-End Aerosol Classification model for EarthCARE, AMT, 2023

- Main tool: Aeronet fine / coarse in SSA – ASYM space



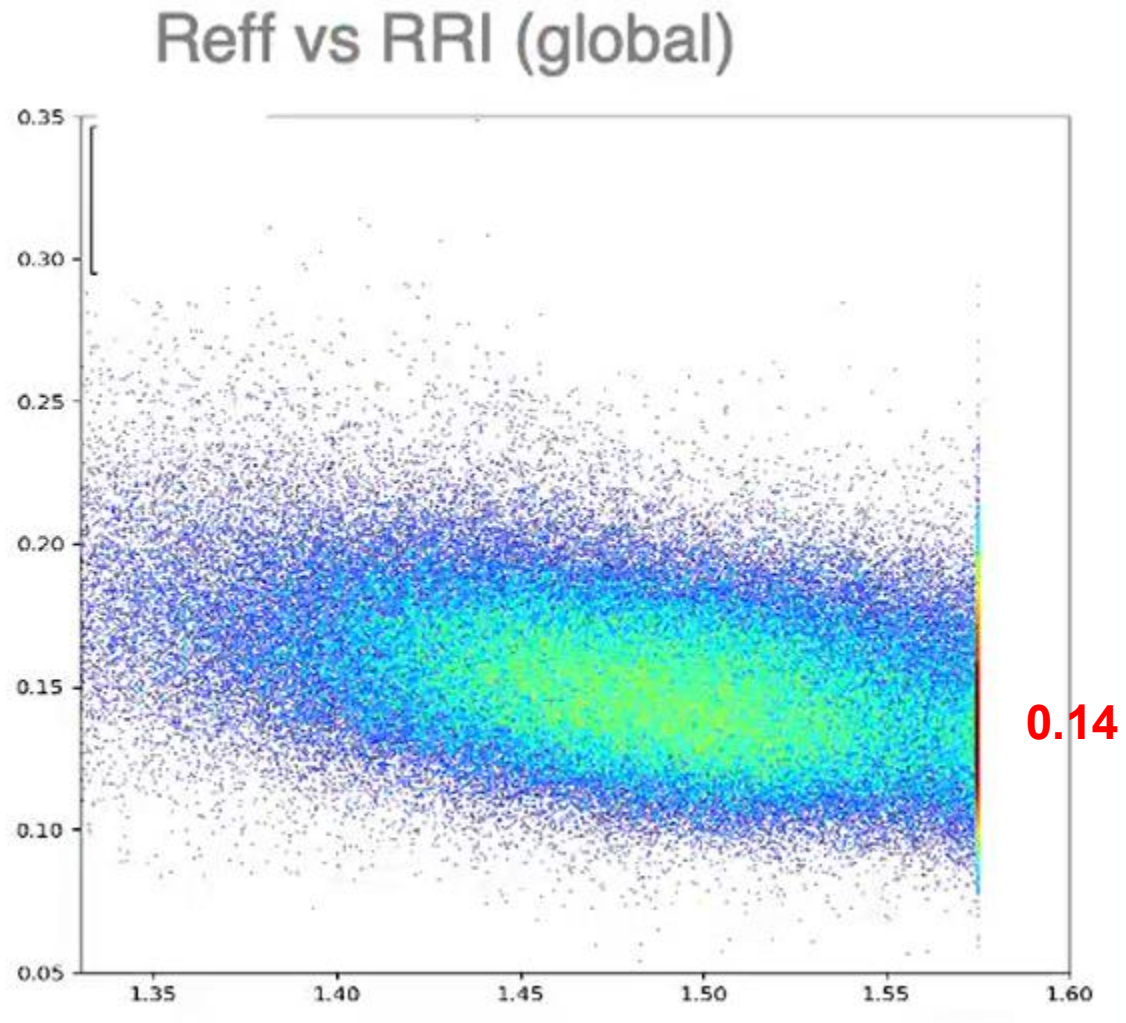


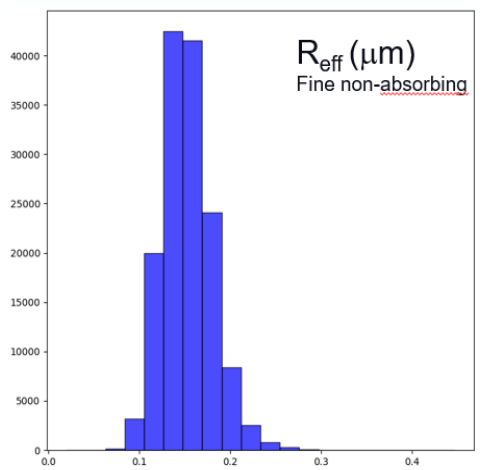


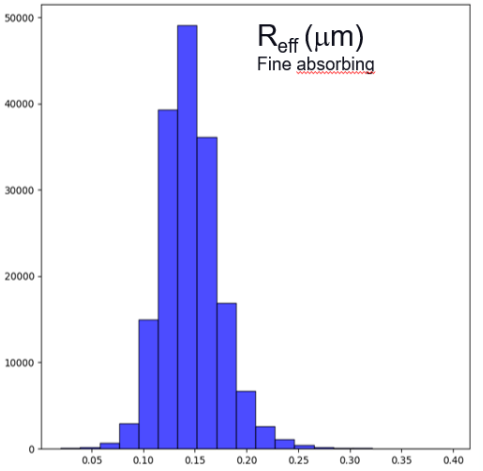
-> (slightly) extend the extreme range covered by the components: 2 dust, smaller fine mode

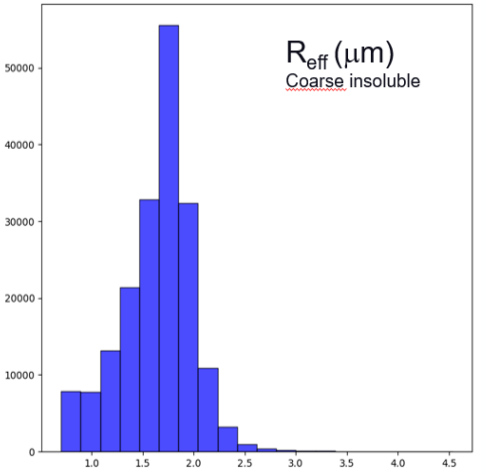
PACE SpexOne

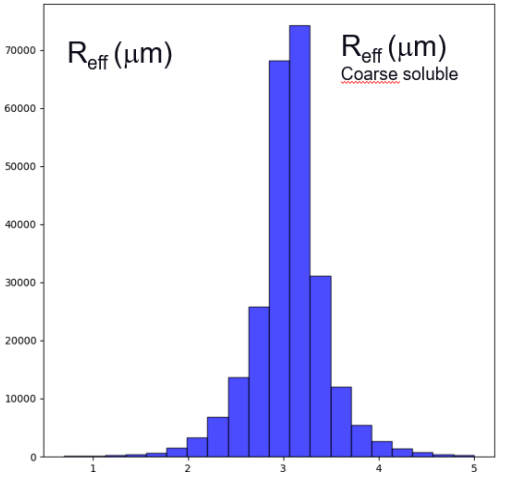
RemoTAP: REMOte sensing of Trace gas and Aerosol Products, preliminary results based on 1 year of SPEXone data







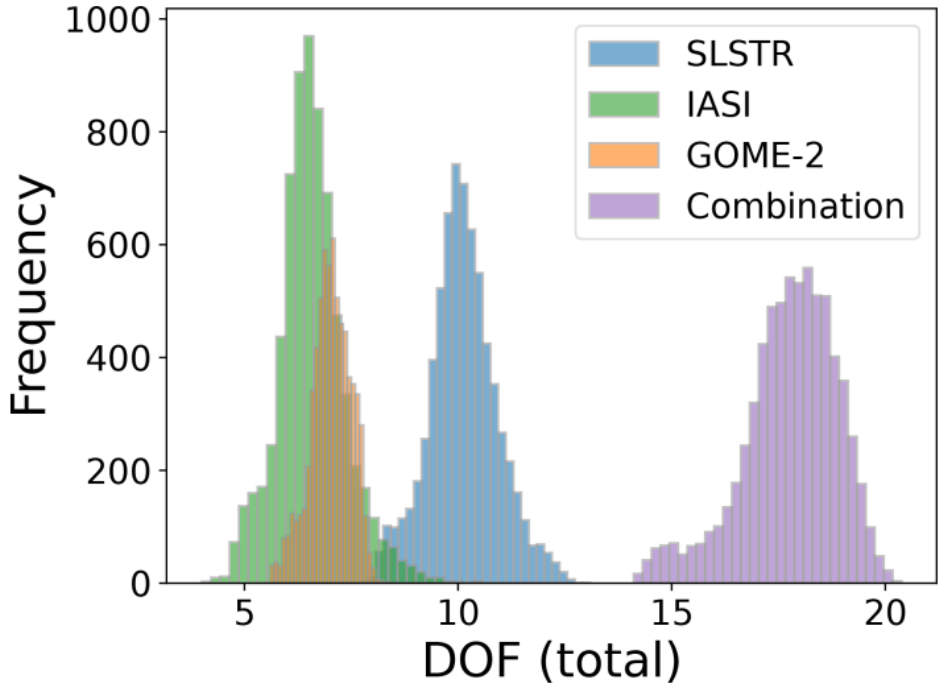


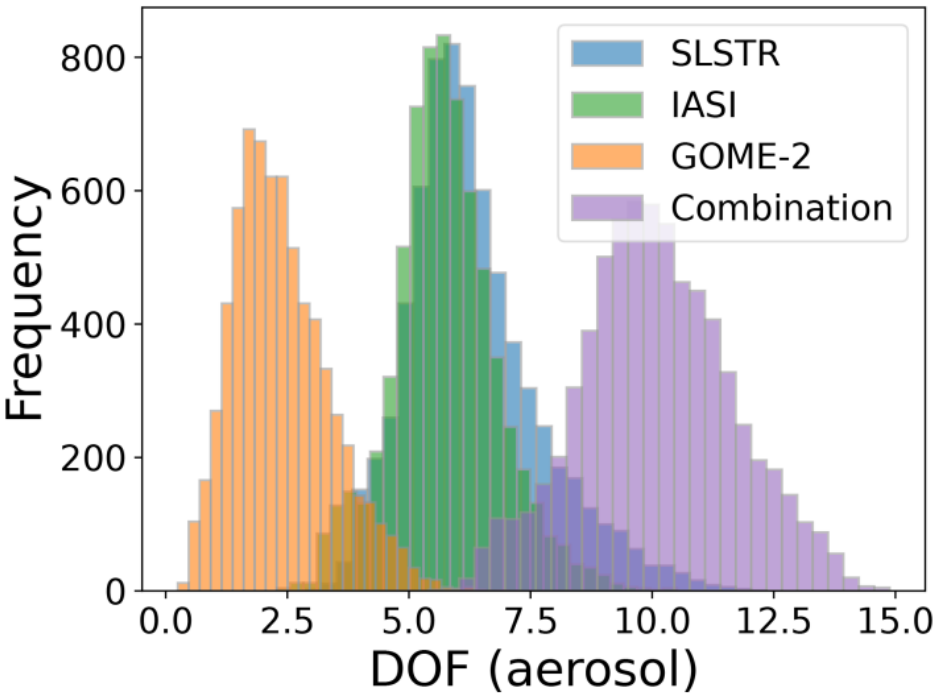


(courtesy of Otto Hasekamp)

Higher information content of synergetic retrieval ROCAS

- **Multi-sensor algorithm**
  - Optimal estimation approach SLSTR + IASI + GOME-2
  - AOD + aerosol properties
  - Exploit comprehensive information content of UV + VIS + TIR + dual view

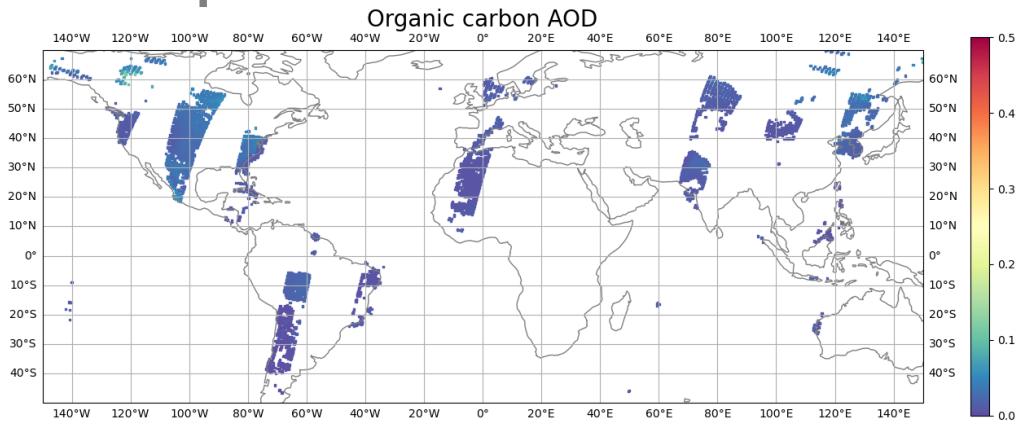




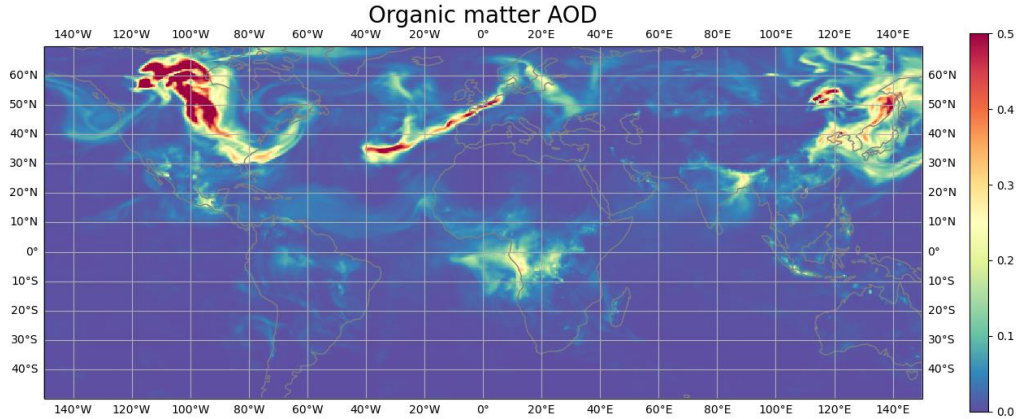
Ulrike **Stöffelmair**, Thomas Popp, Marco Vountas, and Hartmut Bösch, Satellite Aerosol Retrieval from a combination of three different Instruments: Information content analysis, accepted for publication, **AMT, 2025**

ROCAS: Retrieval Of Composition of Aerosols from Satellite
Canadian Fire June 2025 – Organic Carbon AOD

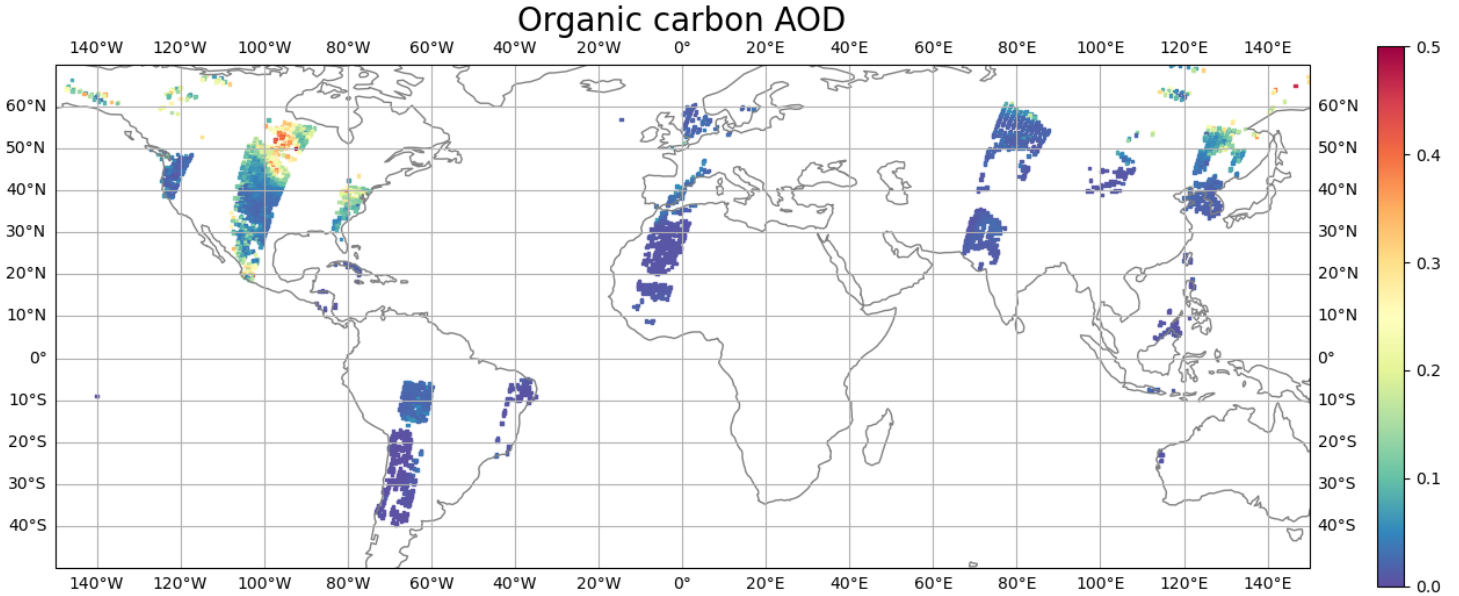
apriori:



CAMS:



Retrieved:



Synergetic algorithm for SLSTR, GOME-2, IASI

- Relies on pre-defined information from MERRA-2
  - Detailed mixing of basic sub-components
  - Vertical profiles

Courtesy of Ulrike Stöffelmair, DLR-DFD

Requirements for vertical profiles

(Not for: Modelling, process studies, radiative forcing)

1. Validation of satellite-based aerosol layer height products
2. Improving long historic aerosol climate data records from passive instruments

➔ 3D aerosol component / typing climatology - as pre-defined parameters or as a-priori information

- Parameter: extinction profiles; cloud-free
- Climatology: monthly mean vertical profile (shapes); regular grid (e.g. 1 degree), collected over several years
- Statistics: mean and median values per altitude layer, standard deviation + information on rare extreme cases
- Separated profiles for different aerosol components / types
- Separated average profile (shapes) for extreme cases (high AOD)
- Aerosol typing scheme consistent or “translatable” with aerosol component schemes used in retrievals (e.g. ACCI)
- Typing / component definitions: transparent (and best included in the products); compared to results of latest MAP-type instruments (PACE SpexOne, EPS-SG 3MI)

Conclusions

What can EarthCare contribute to long records?

- Cross-calibration of algorithms in overlapping periods
- Climatologies as apriori and pre-defined information for single-sensor and synergetic algorithms
    - Aerosol components / types (total column)
    - Climatologies of vertical extinction (average, extreme cases; cloud-free)
    - Co-variances between aerosol components
    - Mean / median climatologies + variance (for uncertainty propagation)
    - ➔ 3D aerosol typing climatology

➔ AEROCOM / AEROSAT 12-16/10/2026 Fukuoka
registration extended to 15/06/2026!
https://aerocom.met.no/events/aerocom2026

thms

- Continuous community dialogue needed