Extinction validation from Umweltforschungsstation Schneefernerhaus (UFS) – a proposal for additional validation measurements

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40 YEARS PALAS

- **EarthCare validation workshop 16/11/2023**

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DLR

Environmental Research Station Schneefernerhaus | Zugspitze

Germany‘s highest research station at 2650 m

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Schneefernerhaus

- **High altitude research station**
  for climate, bio-, hydro- and
  geospheric research as well as
  for environment and altitude medicine

- **Observatory**
  for air pollutants, greenhouse gases,
  weather and natural phenomena

- **Center for communication and meetings**
  for teaching, education and
  stustainabilitly strategies

Photo: BG UFS GmbH

www.schneefernerhaus.de

UFS target area: satellite validation

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- Satellite passive observations: large coverage
- In-situ measurements: tied to SI standards (GAW)
- Issues to link both
  - Ambient air, vertical profiles
  - Attempt of routine correction of humidity effects failed (ESA Aerosol_cci) despite of several well equipped stations (ACTRIS Super-Sites / GAW network)
- EarthCare will help close vertical profiles
- UAV ambient 3D measurements can contribute to close both gaps
  - Humidity + meteorology
  - Size distribution
  - Extinction: Scattering + Absorption
  - Low cost PM sensors

International Satellite Aerosol Science network AEROSAT

- International forum for satellite aerosol experts and users

- Requirement: systematic 3D-in-situ characterisation of aerosol types

  -> „new OPAC“
  - needs routine measurement flights over longer period
  - To reach statistically significant characterization of air masses
  - Optical properties, **mass extinction efficiency**
  - alternative flight concepts
    - Medium size aircraft with a set of instruments (Kahn et al.)
    - UAV-swarm flights with selected instruments

Kahn, R.A., T. Berkoff, C. Brock, G. Chen, R. Ferrare, S. Ghan, T. Hansico, D. Hegg, J.V. Martins, C.S. McNaughton, D.M. Murphy, J.A. Ogren, J.E. Penner, P. Pilewskie, J. Seinfeld, and D. Worsnop, 2017. SAM-CAAM: A Concept for Acquiring Systematic Aircraft Measurements to Characterize Aerosol Air Masses. Bull. Am. Meteoro. Soc. 2215-2228, doi:10.1175/BAMS-D-16-0003.1

UFS feasibility study 2016

- Requirement analysis for passive instruments

Requirement	Comment
Spatial resolution: 1km horizontal	Single pixel in satellite datasets
Spatial coverage: 10 km including valley areas	Retrieval very difficult in summit area
Temporal coverage: 1 hour	Aerosols can be regarded stable
Vertical resolution: 100m at lower end	Individual aerosol layers
Vertical coverage: 0 – 10 km (from valley ground)	Total tropospheric column
Temporal matching: ±30 min (10:00 /13:30)	AERONET experience
accuracy: < 50% of satellite AOD accuracy Size distribution 2 – 3 modes	integrated column / pixel values
Humidity condition: ambient, no drying Long-term: humig + dried (to assess humid growth)	Switch off above 90% rH (protection)
frequency: 1x per week, all seasons	Reasonable overlap with satellite data
Duration of regular observations: minimum 1 year	significant statistics
Aggregated (clustered) optical properties statistics: several years	Separate different aerosol types
Low / no cloud coverage	Contaminate satellite aerosol products
Internal consistency of all measurements	3D integration / optical closure
External consistency with station GAW in-situ measurements	Optical vs. dynamical methods
Instrument stability: caution at large temperature / humidity / pressure gradients	at layer boundaries possibly adaptive flight control
Automatization: data analysis	Cost reduction/ easy transferability
UAV emissions: zero	Avoid miss-interpretation
Data analysis: Step 1: Integration (x-y / t and z) effective column values Step 2: Integration to partial AOD values (e.g. fine mode, dust) Step 3: Tools for external users / on-demand analysis	Comparability of measurement points
Synchronisation of separate instruments < 1 sec	

Abschlussbericht

ZKL01Abt7_69452Machbarkeitsstudie „Aerosol Supersite"

Entwicklung reproduzierbarer Konzepte für innovative Satellitenvalidierung auf Basis neu-entwickelter, standardisierter UAV-In-Situ-Messungen und erweiterter LIDAR-Detektion an der UFS

Projektlaufzeit: 27.10.2015 bis 30.4.2016

Gefördert durch das Bayerische Staatsministerium für Umwelt und Verbraucherschutz

Geförderte Projektpartner: Betriebsgesellschaft Umweltforschungsstation Schneefernerhaus GmbH, Aerosol Akademie, DLR-DFD, KIT/IMK-IFU
Technologiepartner: GAT, DIALOGIS, QUANTUM Systems
Assoziierte Partner: DWD, UBA, LMU, Universität Augsburg, Helmholtz-Zentrum München, TU München, TROPOS, Leibniz Rechenzentrum (LRZ)

Projektleitung:

BG UFS GmbH – Markus Neumann

Redaktionelle Zusammenstellung Abschlussbericht:

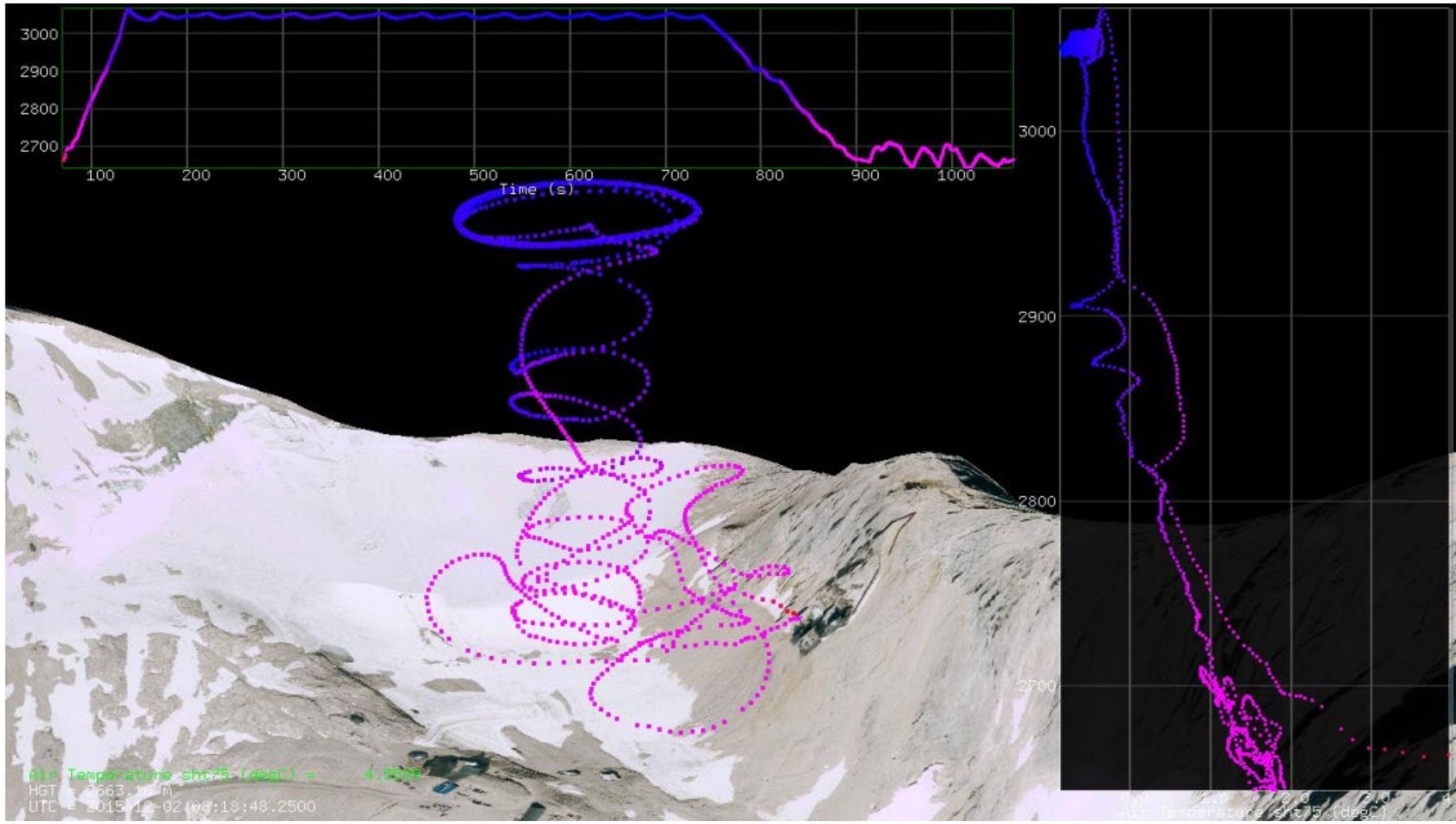
Aerosol Akademie (Wissenschaftliche Koordination) – Dr. Marcus Hank

3. Mai 2016

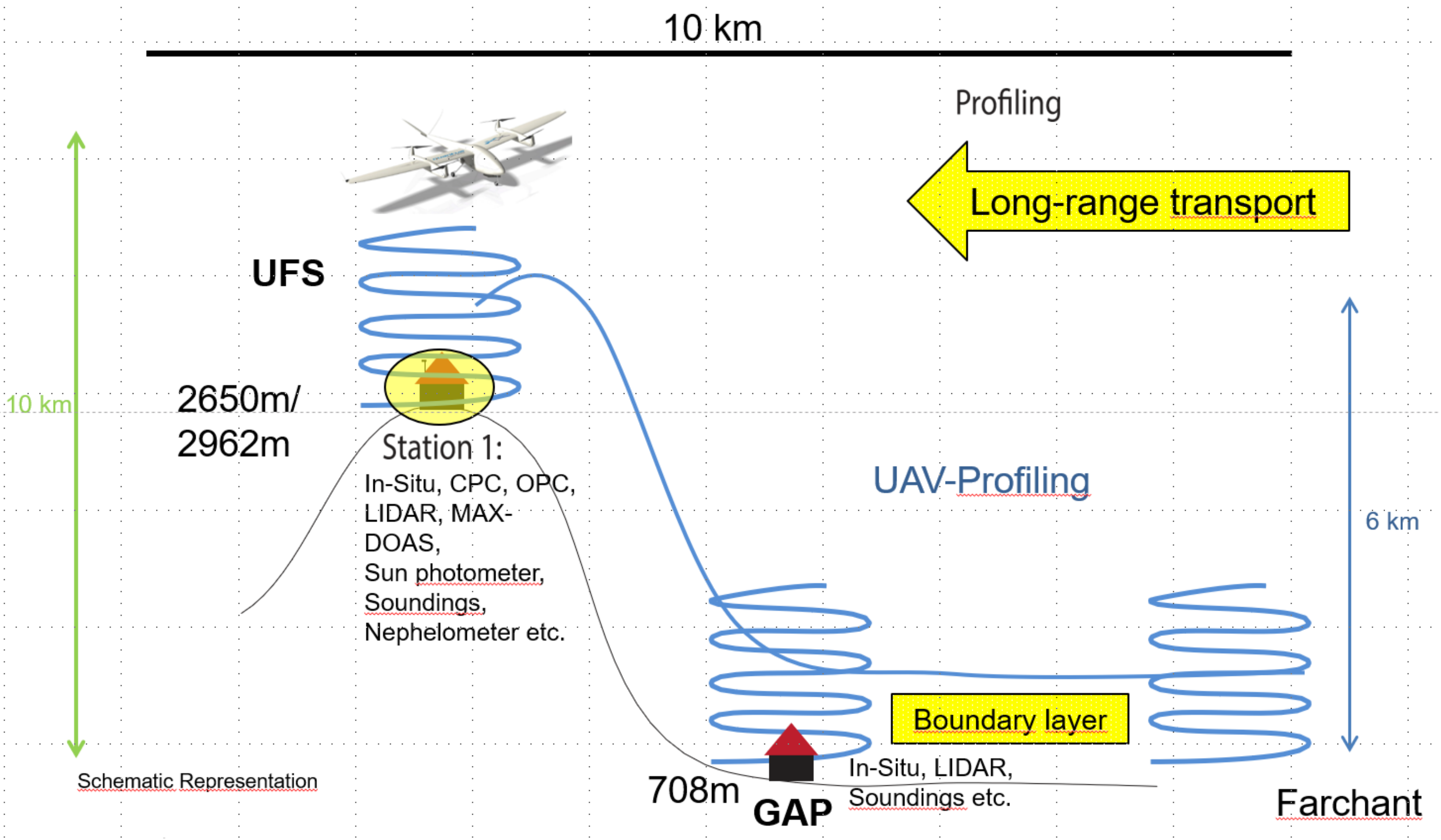
UAV flight paths at high altitude mountain stations

- Combined measurements at high + low altitudes
- Can cover significant part of the troposphere
  - Boundary layer
  - Long-range transport
  - Total column for passive instruments
  - Vertical profile for EarthCare

- Feasibility study
  - UAV test flights were made
  - With different types of UAV



UAV flight paths at high altitude mountain stations



UFS strategy

- Aim: operate regular UAV flights to measure ambient aerosol in-situ properties
- Palas wet aerosol spectrometer (adapted)
  - Tested at Sonnblick (ACTRIS campaign), Marambio and test mounted on UAV
  - Ambient size distribution / aerosol scattering
- Commercial aethalometer
  - Aerosol absorption
- Procedure for UAV flights beyond the visual line of sight in progress BVLOS
- Implementation planned from 2024

Palas aerosol spectrometer as basis

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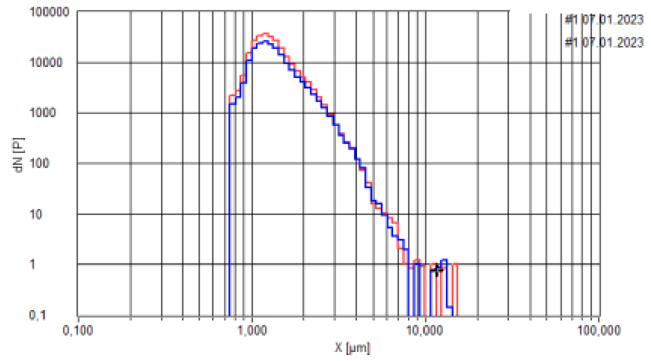
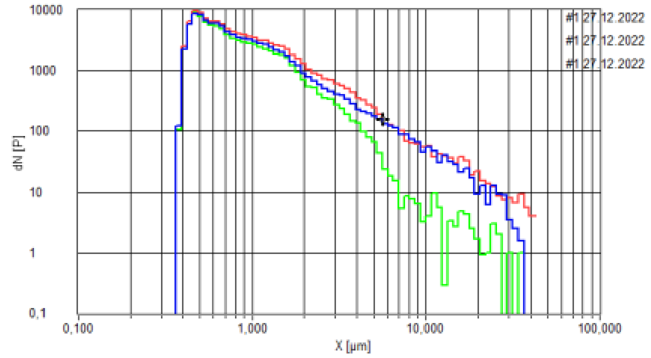
- Adaptation for wet aerosol measurements

Measuring principle	Optical light scattering on single particle
Measurement range (number concentration)	0 – 200 P/cm³
Measurement range (size)	0.6 – 40 µm 0.8 – 100 µm
Volume flow	5 l/min (full flow analysis)
Interfaces	USB, Ethernet (LAN), RS232/485, Wi-Fi
Power supply	110 – 230 V
Temperture range	-30 to +40 °C
Dimensions (W x H x D)	Approx. 600 x 1000 x 270 mm
Weight	Approx. 35 kg
Accessories	Heatable Inlet Weather Station

Aerosol background distribution



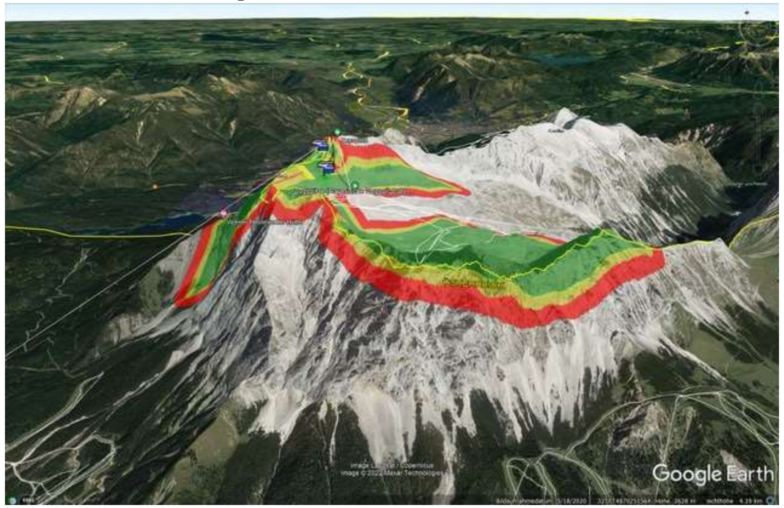
Coarse dust



Antarctic campaign (Marambio, 12/2022-3/2023)

BVLOS procedure status

- Permission for BVLOS flights has been granted in November 2023 for a separate project by the German air traffic authority (Luftfahrtbundesamt, LBA)
- The approved airspace is designed for a permafrost monitoring project in the slopes of Mt. Zugspitze (approx. 2 km², height 200m agl)
- BVLOS flights for aerosol measurements / satellite ground truthing will need a different air space and thus a separate permission
- The current BVLOS project can serve as a blueprint for future applications
- The UFS and it‘s partners will have gained considerable experience in the application procedures due to the current project



Applications / relevance

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- Satellite validation:
  - Passive radiometers: AOD + aerosol properties
  - EarthCare: extinction profiles

- Support to retrieval development
  - Statistics / climatology of optical aerosol properties

- Users
  - Roll-out to GAW stations (mountain locations)
  - Develop analysis and integration tools for users
  - Validation of EarthCare products
  - Validation + development of Copernicus products
  - Algorithm improvement for ESA CCI + Climate-Space / C3S CDRs
  - Support to retrieval experts / AEROSAT algorithm development

Summary: EarthCare validation

- Benefits from high altitude starting point
- Will be included within regular flights at UFS
- Will use CAMS forecasts for flight planning
- Validate extinction profiles in free troposphere

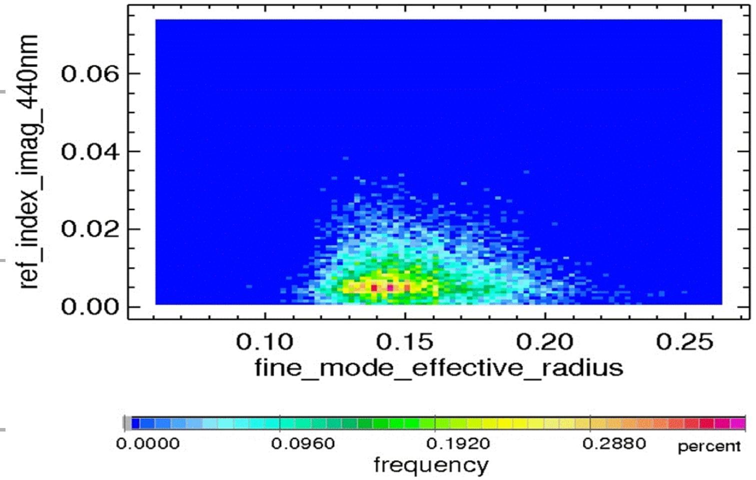
- EarthCare validation proposal needs to be worked out
  - Funding opportunity from Freistaat Bayern: infrastructure (UAV, instrument)
  - Funding for data analysis needs to be raised
  - Extended BVLOS authorization for vertical profiles needs to be obtained
    - Altitude range limited by authorities
  - Using insights of this workshop / requirements

Assumed aerosol optical properties for AOD retrieval

Table 1. Parameters describing the microphysical and optical properties of the aerosol components used in the Aerosol-cci round-robin excersizes.

Aerosol Component	Real part Refr Index (550 nm)	Im Part Refr Index (550 nm)	Reff* (μm)	Geom. st dev (σ_i)	Variance ($\ln \sigma_i$)	Geom. mean radius ($\bar{r}_{gi}$, μm)	Comments	Aerosol layer height
Dust§	1.56 (varies with wavelength)§	0.0018 (varies with wavelength)§	1.94	1.822	0.6	0.788	Non-spherical	Fixed hgt at 2-4km
Sea salt	1.4	0	1.94	1.822	0.6	0.788	AOD threshold	0-1 km
Fine mode very weak-abs	1.4	0.003	0.142	1.7				
Fine mode strong-abs	1.5	0.040	0.142	1.7				

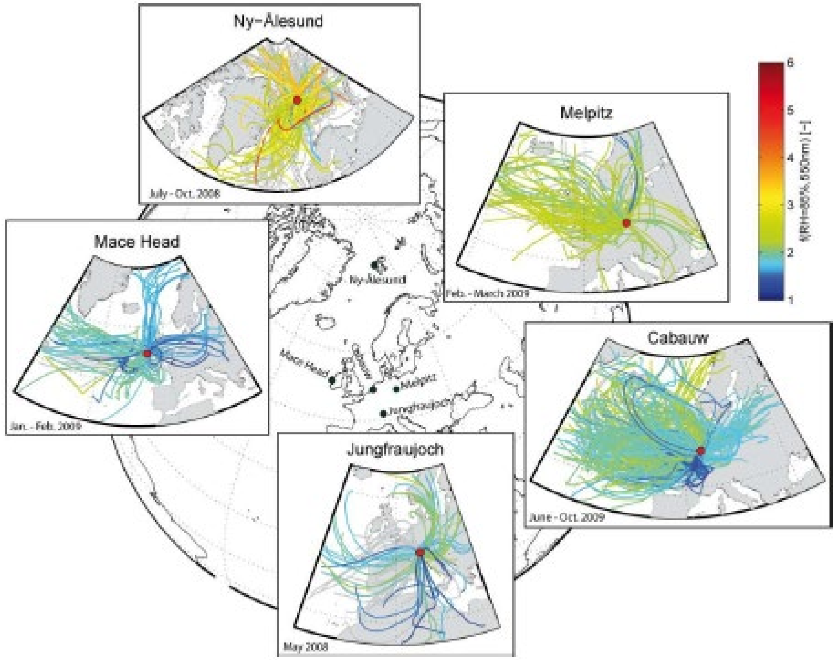
§Dubovik et al., 2002



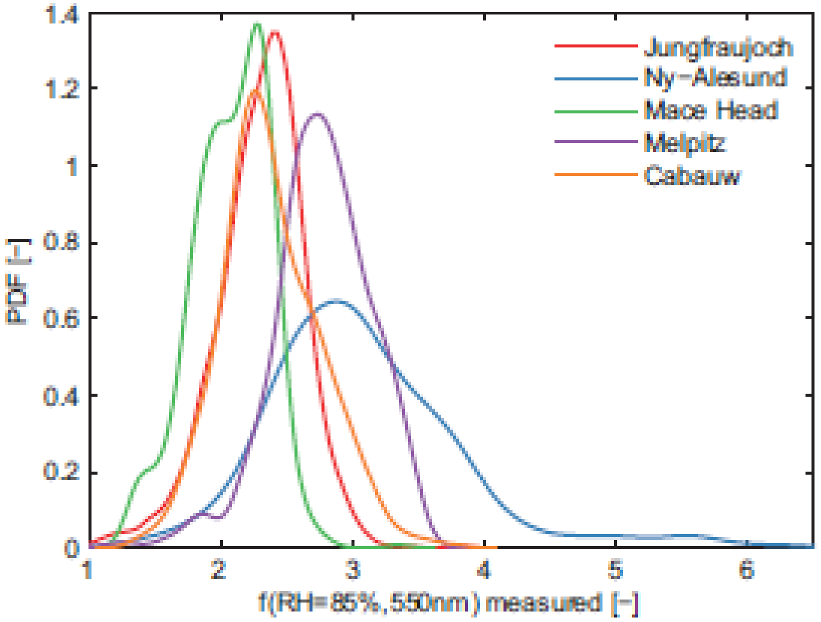
De Leeuw, Holzer-Popp, et al., RSE 2014

Case study in-situ validation of satellite aerosol products

- Several well equipped stations (ACTRIS Super-Sites / GAW network)
- Attempt of routine correction of humidity effects (ESA Aerosol_cci)



72-hour trajectories; colour: f(85%)



pdfs of (85%) for 5 stations

- Conclusion: 40% uncertainty- too large as reference