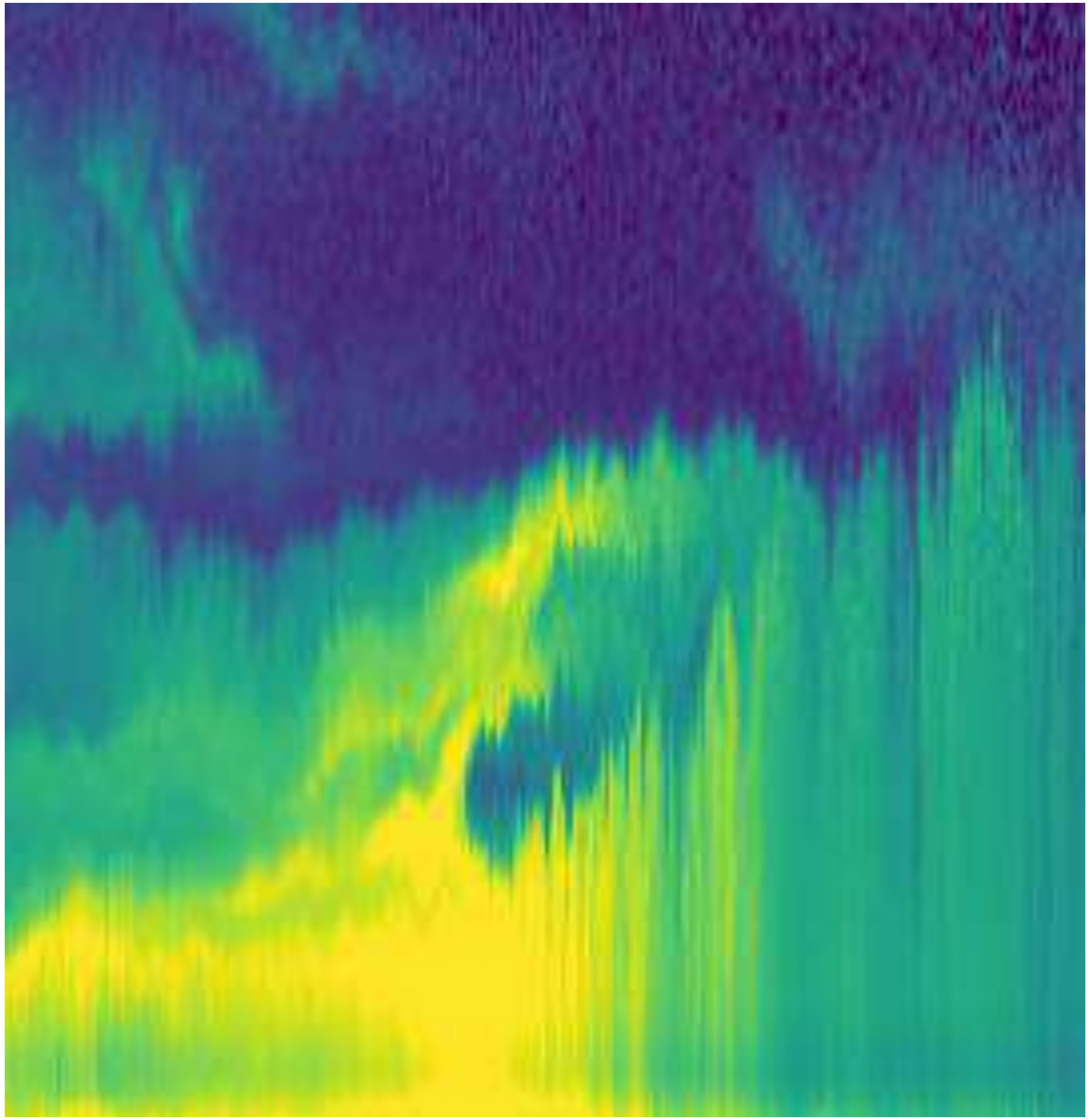


ACTRiS
CCRES

ACTRIS ALC processing for CARS and CCRES products

Overlap, artefacts, absolute calibration

Simone Kotthaus (IPSL), Melania Van Hove (IPSL), Alexander Geiss (LMU), Ina Mattis (DWD), Ewan O’Connor (FMI), Joelle Buxmann (MO), Annachiara Bellini (CNR)

CCRES Workshop, November 14- 15th, 2022

This project receives funding from the European Union’s Horizon 2020 research and innovation programme under grant agreements No 871115

Advanced ALC products

- Technological advances and algorithm development now allow for quality profile observations to be collected with automatic lidars and ceilometers (ALC)
- Overlapping interest from CCRES, CARS, and RI-URBANS
- ALC products are being derived at varying levels of operational implementation

ACTRIS CCRES

ACTRIS CARS

RI URBANS

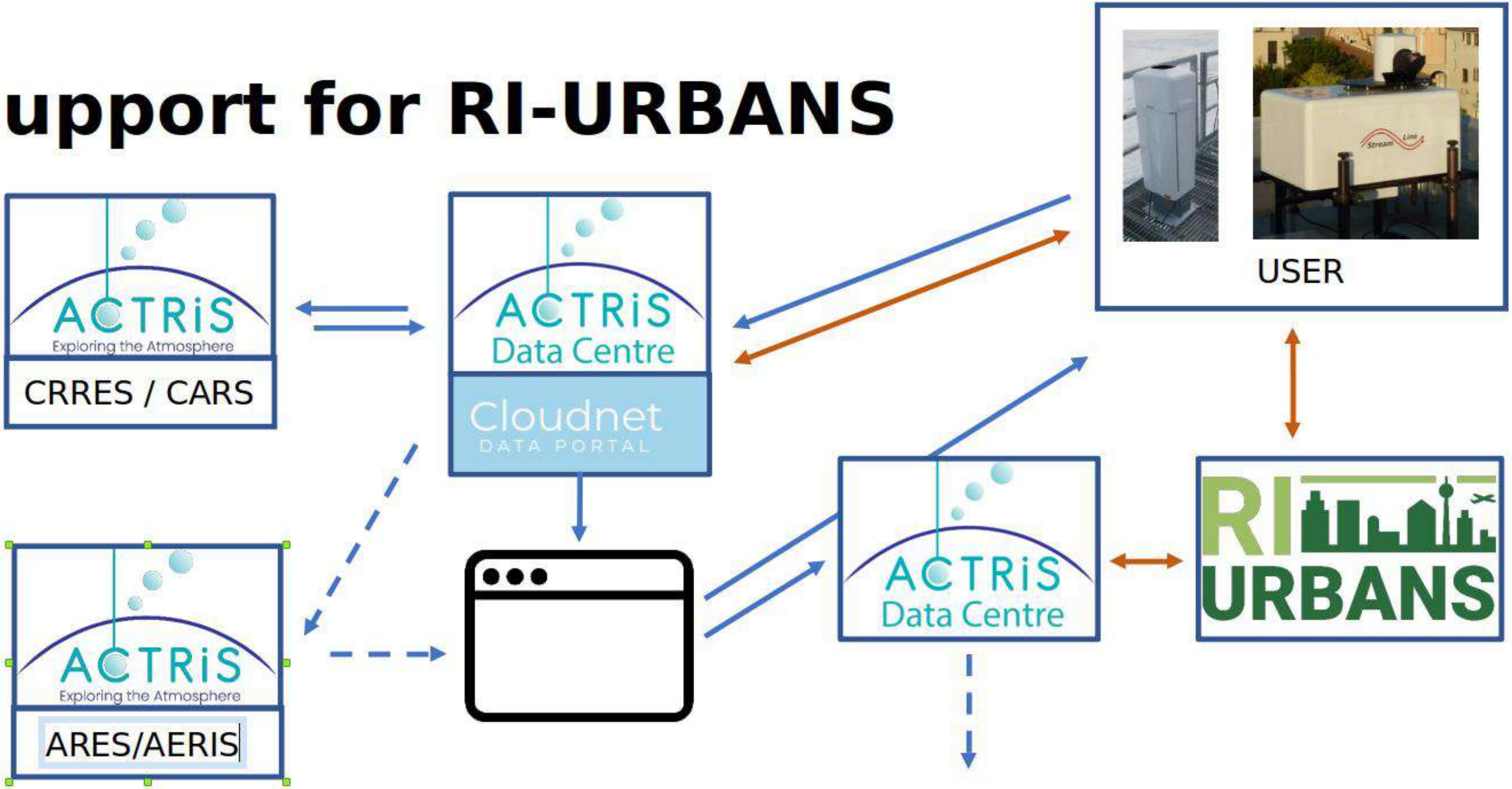
ACTRIS CCRES

CCRES perspective

- ALC SOPs formulated by CCRES
- Data processing at CLU:
  - ALC processing (implementation being discussed)
    - Correction of optical overlap
    - Absolute calibration
  - consistent CBH across diverse sensor network
  - Qualitative use - e.g. cloud base or layer detection
    - Target categorization / classification
    - Liquid water content
  - Quantitative use
    - Drizzle products
    - Ice water microphysical quantities from radar-lidar algorithms
    - Precipitation profiling
    - Liquid water microphysical quantities
- CCRES is supporting ABL testbed at AERIS-ESPRI (PROBE, ACTRIS, ICOS, E-PROFILE) → automatic detection of ABLH and MLH across diverse sensor network

CCRES perspective

Support for RI-URBANS



CARS perspective

What CARS can provide:

- CARS has a long history and experience in QA/QC/homogenization of high power lidar instruments (AHL) and data
- This experience can help to improve the quality of ALC measurements
- Existing AHL procedures and tools can be adopted to ALC measurements
- During the setup phase of ACTRIS it was decided that CARS is responsible for ACTRIS ALCs, even if they are operated as part of CCRES NFs
- CCRES should thus benefit from the knowledge within CARS

Benefit for CARS:

- Exchange of expertise (mainly concerning applications) with user community (e.g. ABL retrievals, cloud screening…)
- Long-term goal: fill observational gaps (time and space) in AHL network with ALC observations

CARS perspective

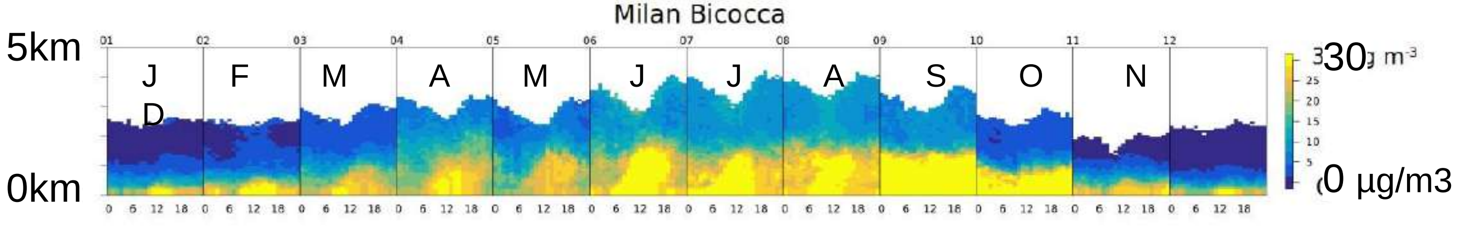
- CARS-ALC is running an evaluation-platform with commonly used ALC models in ACTRIS from different manufacturers (Vaisala CL31 & CL51 & CL61, Lufft CHM15k & CHM8k, Campbell SkyVUE PRO, miniMPL) together with AHL-reference systems
- Following tasks are foreseen to be carried out in close cooperation with CCRES/CLU, E-PROFILE, PROBE and other ALC operators
  - Development and testing of new methods for the QA/QC of ceilometers
  - Application, development and testing of ALC calibrations (including overlap correction, water vapor absorption correction)
  - Application, development and testing of different ABL algorithms
  - Testing of existing ALC products (e.g. PARAFOG)
  - Support the formulation of guidelines (SOPs)
  - Provide tools, methods and training to the community

RI-URBANS perspective

Products from ALC & P-ALC (24/7)

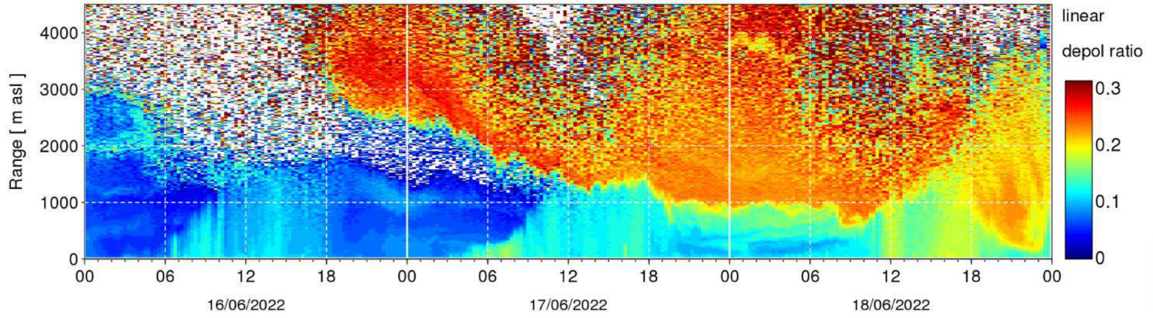
- Atmospheric Boundary Layer Height (ABLH)
- Aerosol type
- Aerosol optical properties and mass concentration profiles

Aerosol mass concentration profiles climatology (2016-2021) - ALICEnet



(Bellini et al., 2022)

Aerosol type profiles



Advanced ALC products

	CCRES/CLU	CARS/ARES	RI-URBANS
Corrected and calibrated attenuated backscatter	● Being discussed at CLU ● Initial implementation at AERIS-ESPRI, methods under development	Operations could be adopted from research lidar tools (SCC, ATLAS)	Initial implementation at AERIS-ESPRI
Atmospheric boundary layer heights	ABL testbed @ AERIS-ESPRI	Product of interest	ABL testbed @ AERIS-ESPRI
Cloud base height	CLU has algorithms to determine consistent estimate	Product of interest	
Target categorization / classification **Liquid water content** **Drizzle/precip**	Implementation in CLU		
Aerosol type profiles		To complement AHL network	First tests with P-ALC
Aerosol optical property profiles		To complement AHL network	Implementations identified at ALICEnet, Met Office, Met Norway, AERIS-ICARE
Aerosol mass concentration profiles		To complement AHL network	Implementations identified at ALICEnet, Met Office, Met Norway, AERIS-ICARE

Processing: RCS → attenuated backscatter

Corrections/processing

- **Optical overlap**, e.g. temperature-dynamic model for Lufft CHM15k (Hervo et al. 2016)
- Vaisala: near-range artefacts & instrument-related **background** (Kotthaus et al. 2016)
- Water vapour effects ALC ~910 nm (Wiegner and Gasteiger 2015; Wiegner et al. 2019)

- **Absolute calibration** necessary based on atmospheric quantities

Rayleigh method (e.g. Wiegner and Geiß 2012)

- Reference: Rayleigh scattering profile in upper atmosphere
- Careful selection of profiles is key
- Sensitivity to molecular scattering is required!
- Not suitable for e.g. Vaisala CL31

Liquid cloud method (O'Connor et al. 2004, Hopkin et al. 2019)

- Reference: liquid clouds (lidar ratio 18.8 sr)
- Careful selection of profiles is key
- Special care must be taken if signal saturates in thick clouds (e.g. Lufft CHM15k)

ACTRIS CCRES

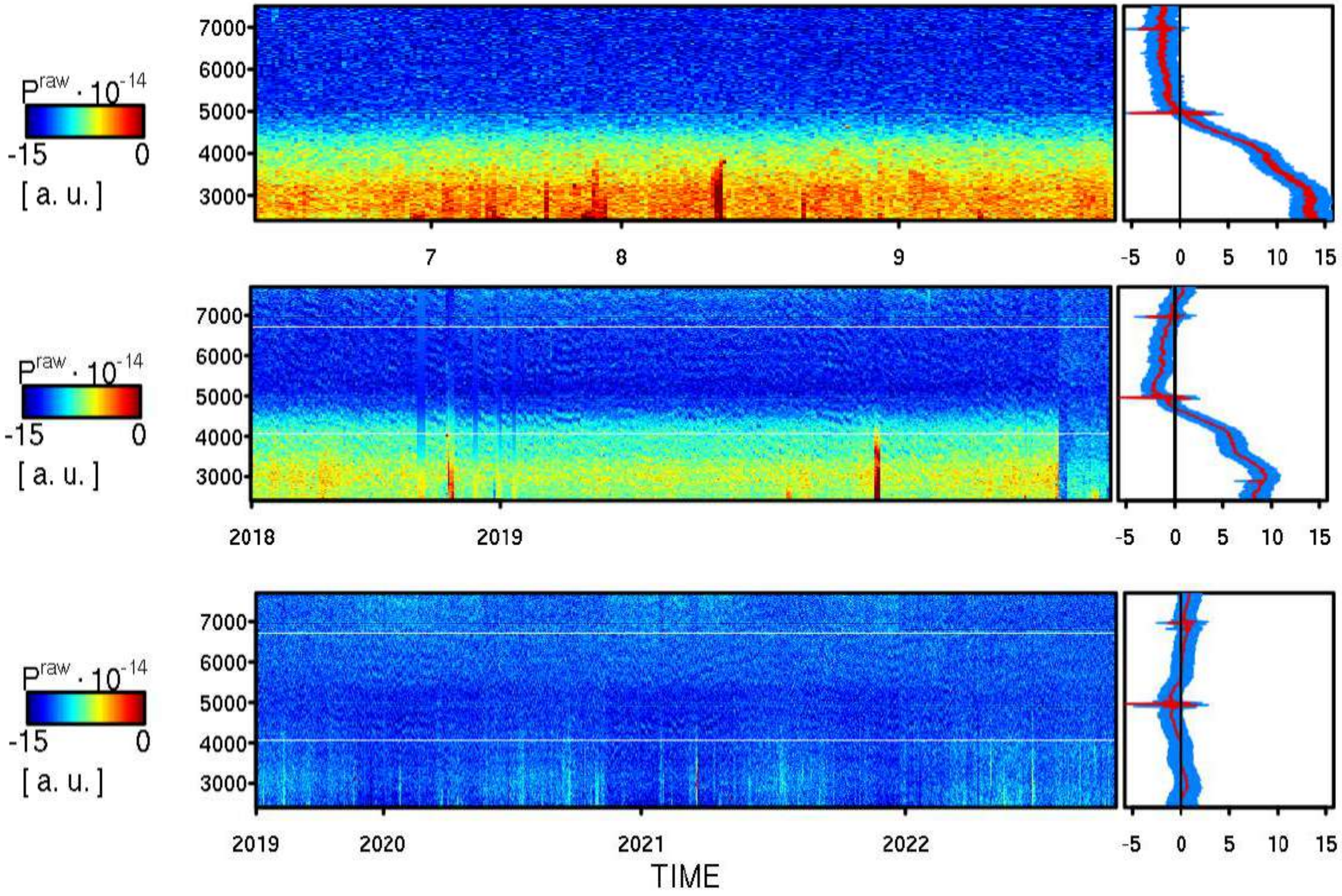
ALC Attenuated backscatter harmonisation

Harmonised attenuated backscatter at European scale (ACTRIS, E-PROFILE)

- Diverse sensor network
- Required for multiple applications: ABL height detection, retrieval of aerosol optical properties and mass profiles

https://www.dwd.de/EN/research/projects/ceilomap/ceilomap_node.html

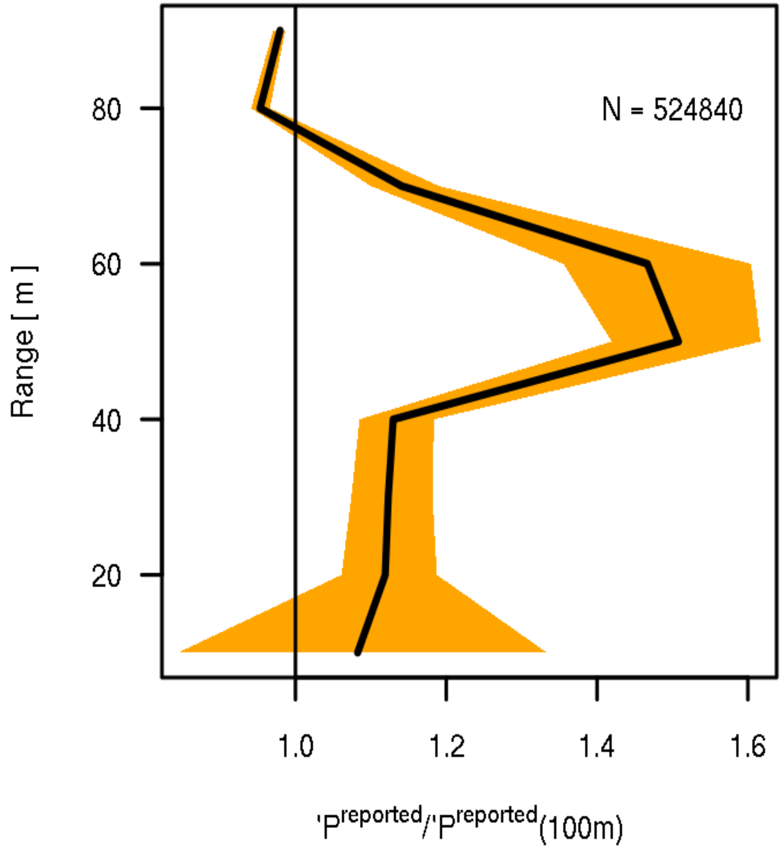
Instrument-related background



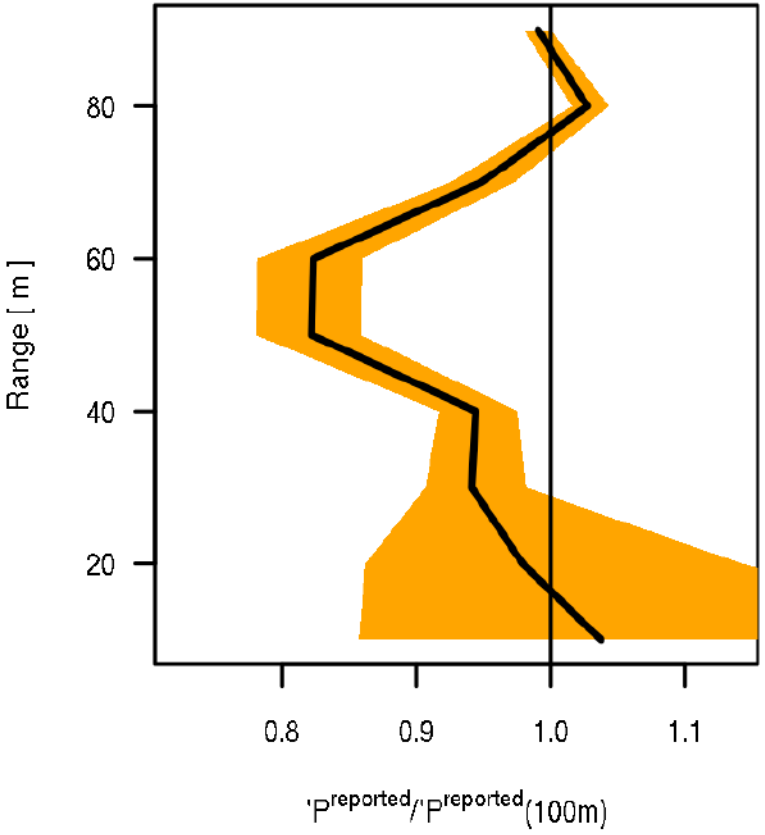
- Instrument-related background (Kotthaus et al. 2016)
- Can change with transmitter CLT, settings, and firmware
- Background correction should at least include a few months of data (cloud-free nights)

Near-range artefact

CL31



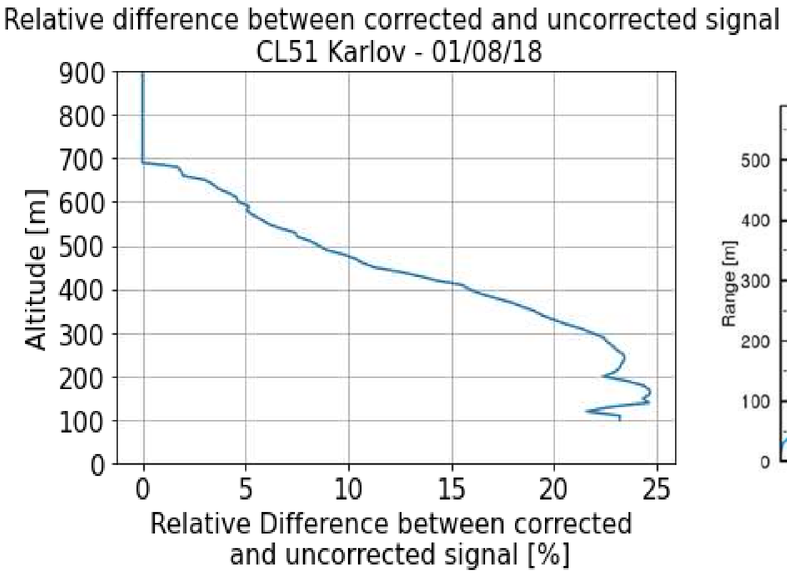
CL51

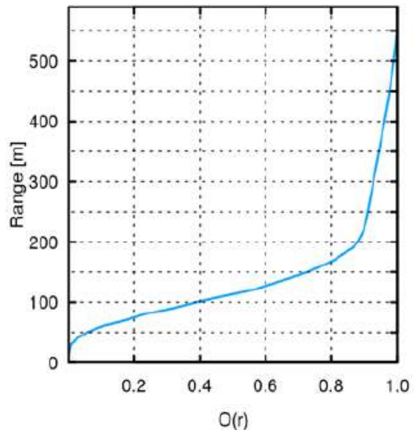


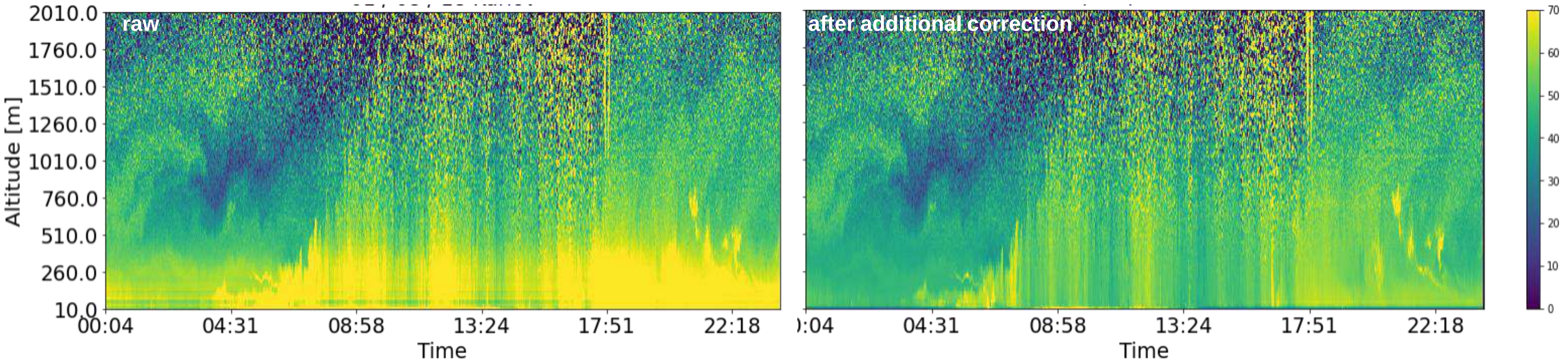
- Near-range artefact correction (Kotthaus et al. 2016)
- For both Cl31, and CL51 (CL61 to be checked)
- Requires a few days (cloud-free afternoon with well-mixed conditions)

CL51 optical overlap correction bias

- CL51 assessment in ABL testbed
- Systematic overestimation < 500 m
- Uncertainty in overlap correction?

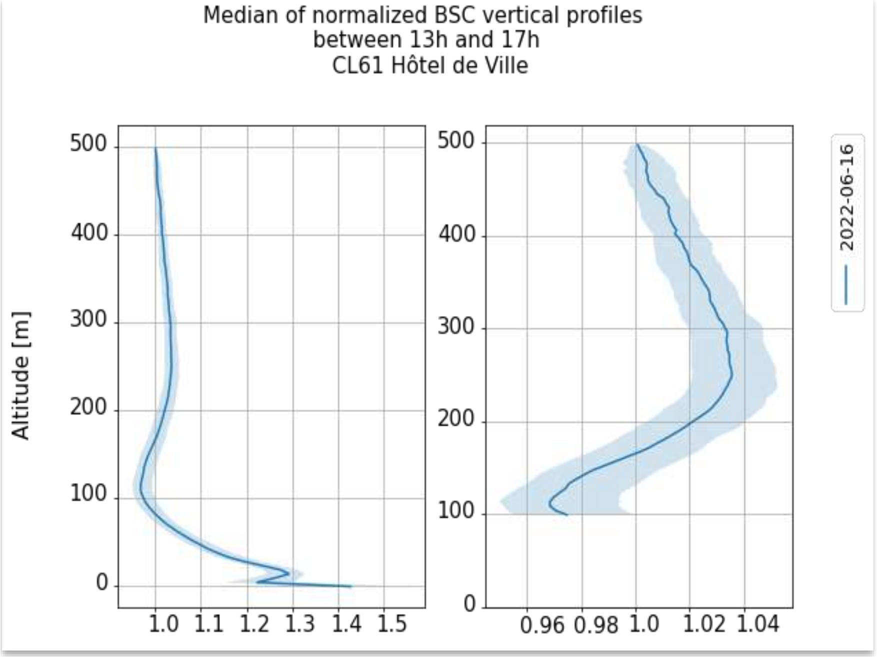


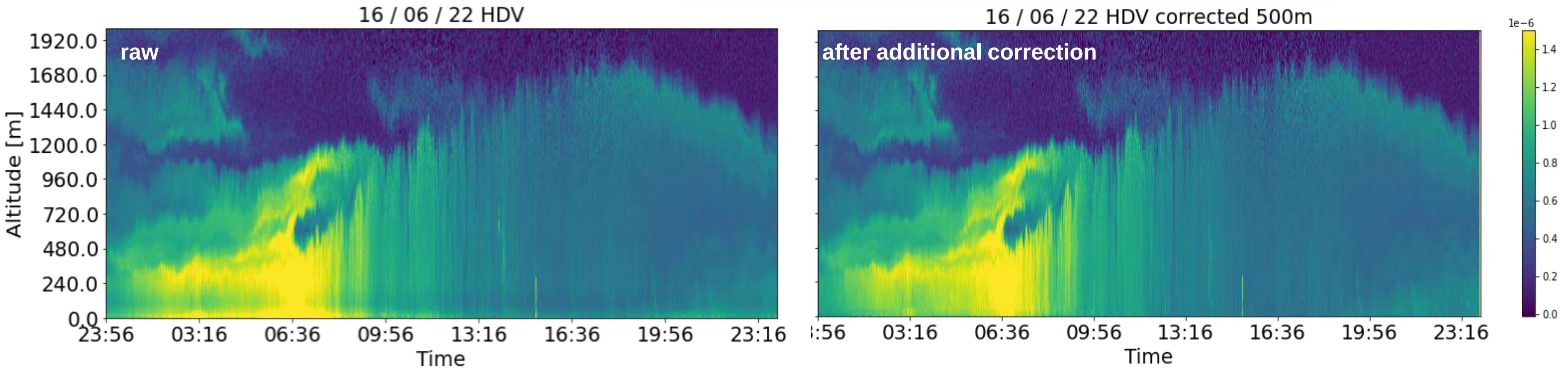




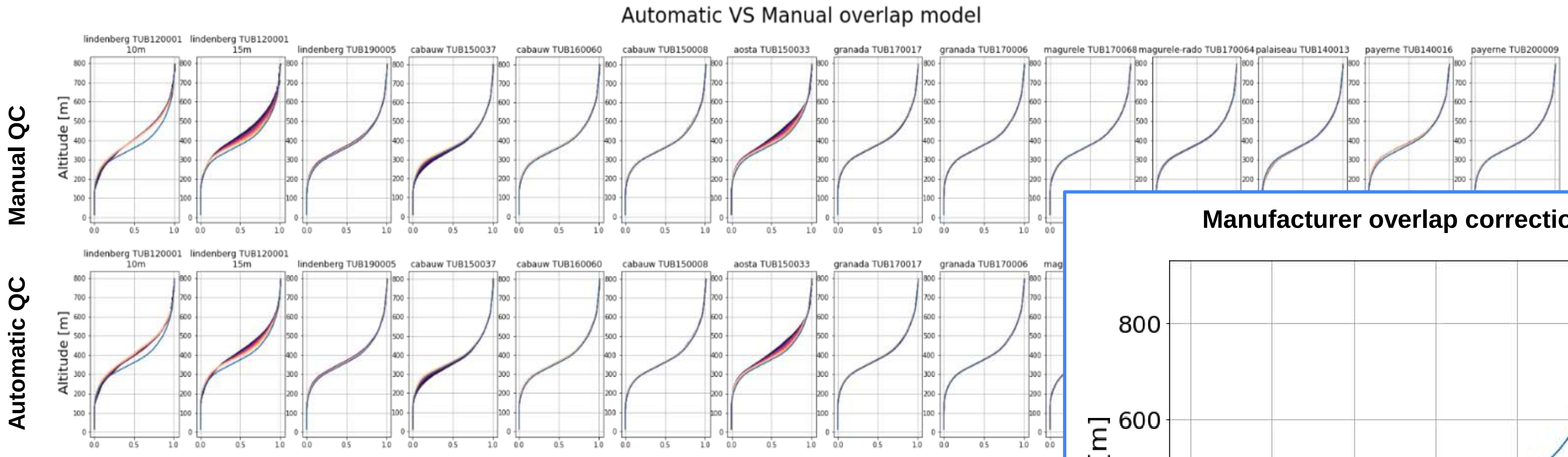
CL61 optical overlap bias?

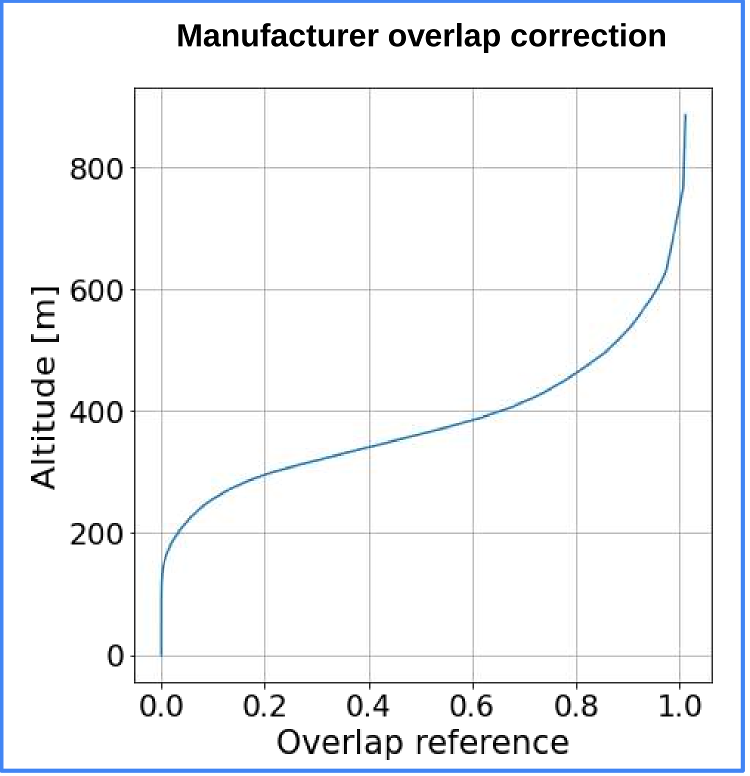
- CL61 operated in central Paris Hotel de Ville in summer 2022 as instrument loan from Vaisala
- Systematic underestimation ~ 80-160 m of **about 3 %** and overestimation above
- Uncertainty in overlap correction?





CHM15k overlap correction





Optical overlap correction CHM15k

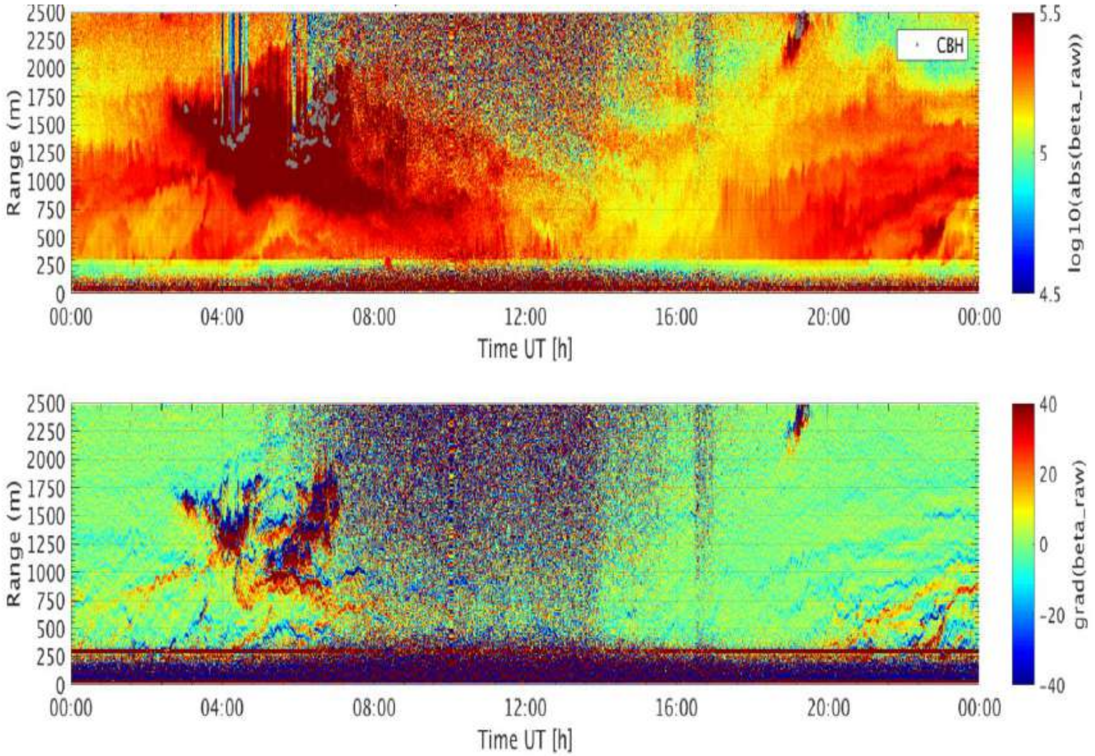
- Correction of the incomplete optical overlap between transmitter and receiver.
- Manufacturer: constant correction function, but overlap varies with internal temperature (Hervo et al. 2016)
- Hervo approach requires manual QC. This is now achieved automatically.

ACTRIS CCRES

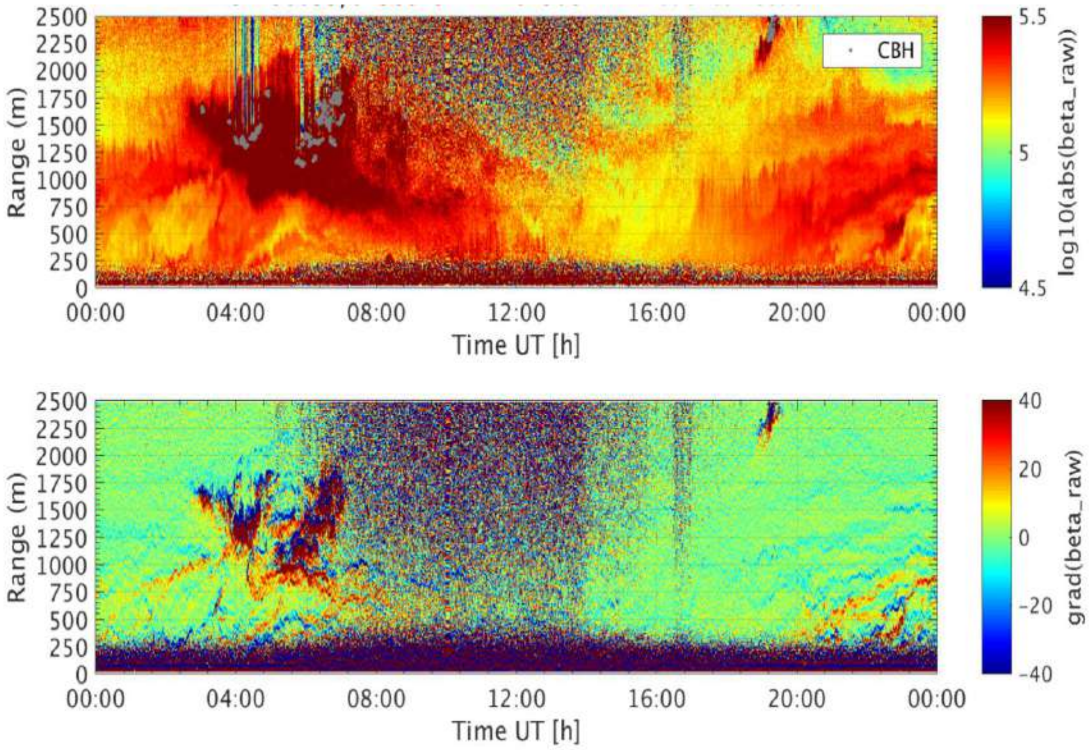
CHM15k overlap correction

Example : Aosta (ALICEnet site) - 22/08/2019

Considering all data



After applying automatised correction

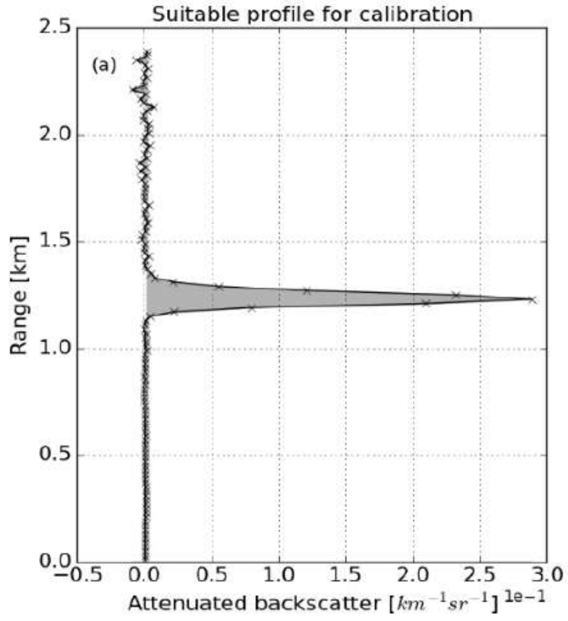


ACTRIS CCRES

Calibration : attenuated backscatter

<u>CL31, CL51</u>

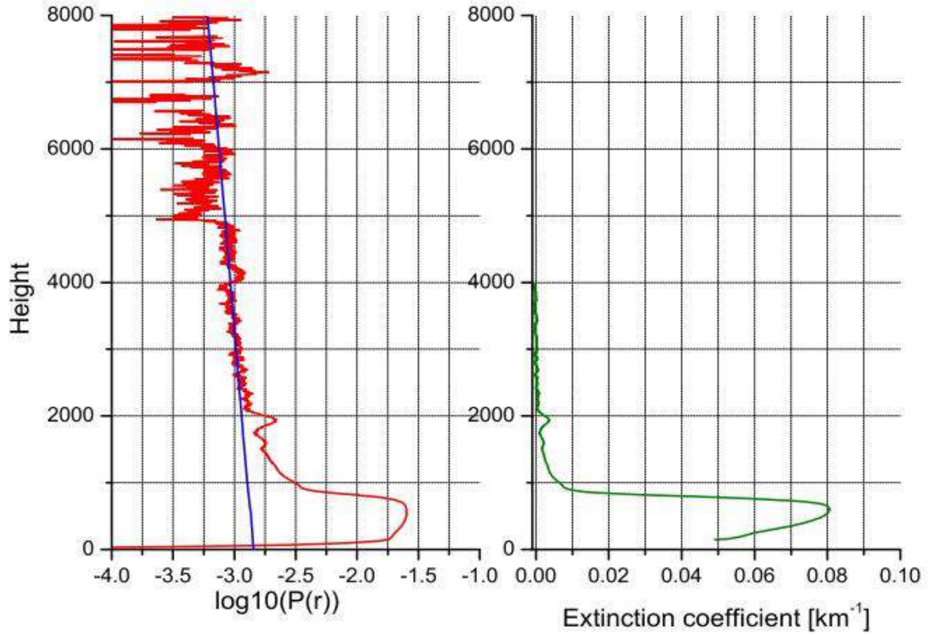
Liquid cloud method
- Reference: liquid clouds (lidar ratio 18.8 sr)
- Careful if signal saturates in thick clouds (photon counting sensors)
- Careful selection of profiles is key



(Hopkin et al. 2019)

<u>CHM15k, CL61</u>

Rayleigh method
- Reference: Rayleigh scattering profile in upper atmosphere
- Sensitivity to molecular scattering required
- **Careful selection of profiles is key**



(Wiegner and Geiß 2012)

Rayleigh calibration implementation

CARS (ATLAS & SCC)

- incl detailed steps for selection of molecular zone
- Volker Freundenthaler & Victor Nicolae currently developing stand-alone python tool
- Primary application: research-grade lidars
- Application to ALC possible but will require additional testing (e.g. to determine noise thresholds)

E-PROFILE

V1

@ MeteoSwiss

steps to find molecular zone:

- average time>=3h in clear nights
- minimum SNR required
- rolling windows to find the best fit real-synthetic signal
- search zone 2-6 km
- quality controls

V3

@ ALICEnet (Italy)

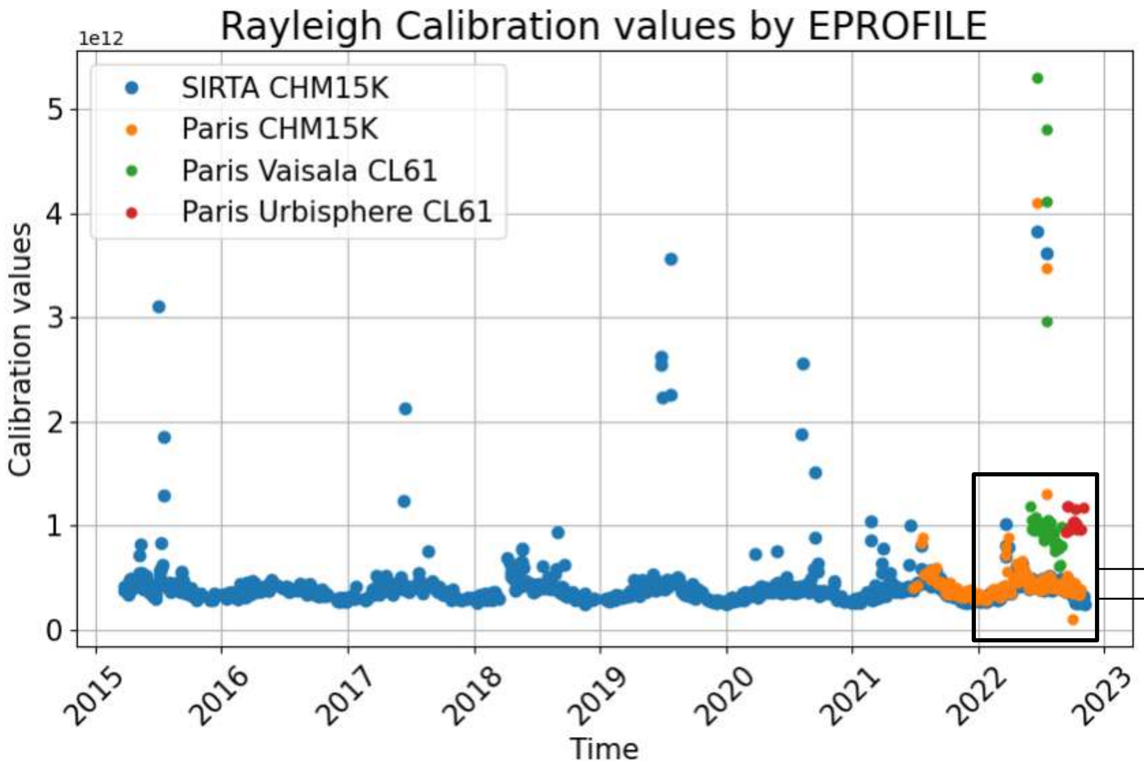
steps to find molecular zone:

- average time>=3h in clear nights
- minimum SNR required
- rolling windows to find the best fit real-synthetic signal
- search zone 3-7 km
- improved quality controls (BG test and cumulative sign in residuals) to filter aerosol layer

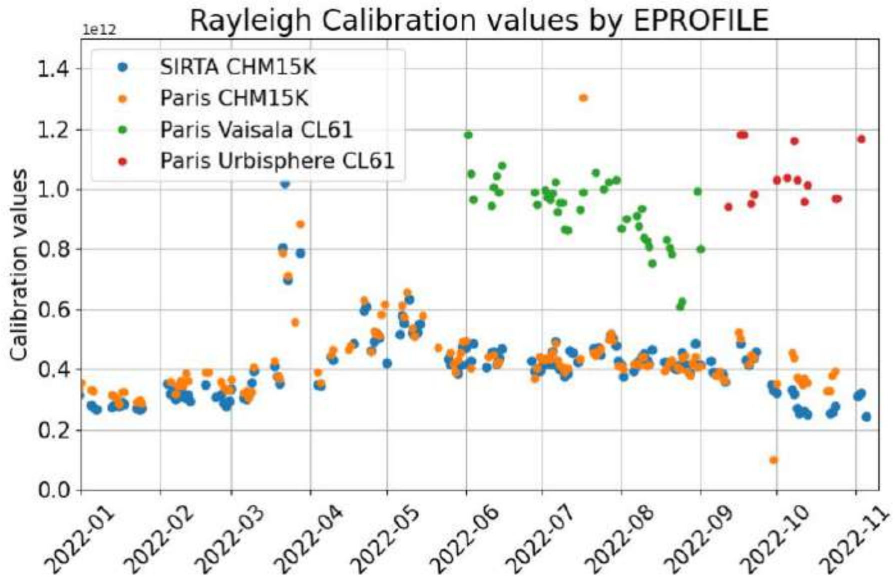
ACTRIS CCRES

Results E-PROFILE Implementation (V1)

- Outliers mostly associated with elevated aerosol layers
- More careful selection of molecular zone necessary - as done by CARS and ALICEnet



Zoom on 2022, without outliers

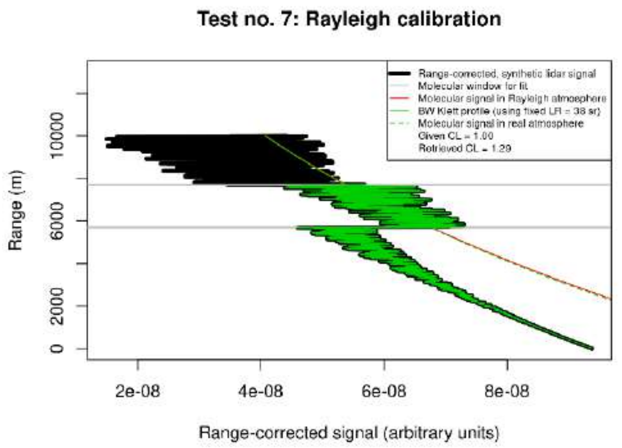


N.B. CL61 values $*10^{12}$

Seasonal cycle CHm15k Rayleigh calibration : instrument or atmosphere?

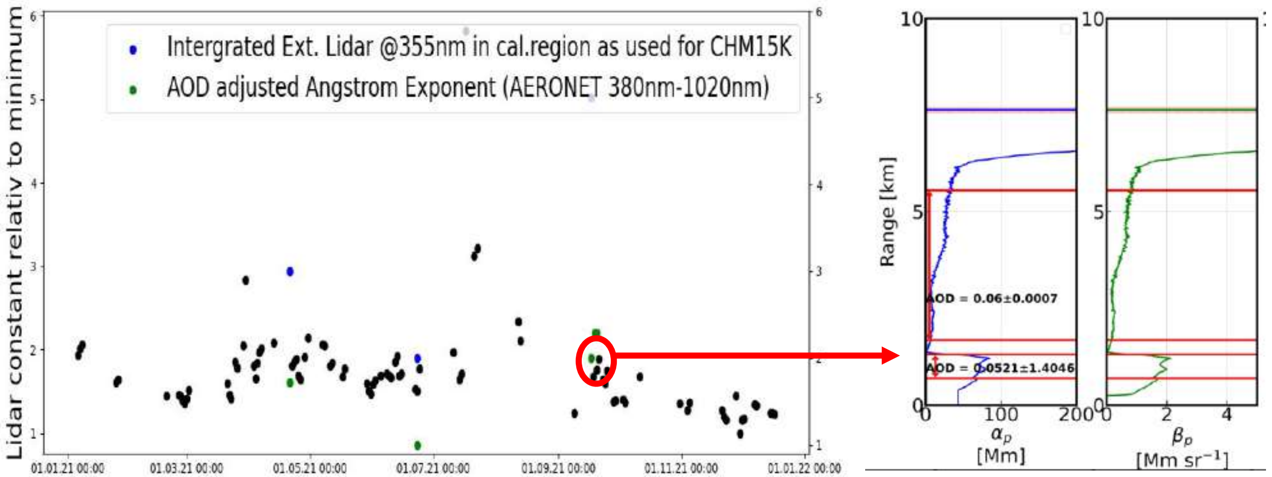
PROBE research study by Joelle Buxmann (Met Office) with Ina Mattis (DWD), Henri Diemoz (ARPA Aosta), Rolf Ruefenacht (Meteo Swiss), Francesca Barnaba (ISAC-CNR), Annachiara Bellini (ISAC-CNR), Martin Osborne (Met Office)

1. Generate synthetic profiles to show theoretical feasibility



- Synthetic profiles show that even very small amounts of aerosol (AOD~0.01) can sufficiently change cal. constant
- Additional influenced by boundary layer aerosols

2. Look at the long-term seasonal variation-comparison between the calibration of the lidar (example Nottingham)



- no clear correlation with lidar constant directly
- Aerosol layers can be detected by the Raymetrics lidar within the calibration window of e-profile CHM15K calibration

⇒ those aerosol layers will artificially increase the calibration constant

Summary

- The European ALC networks are generally diverse (manufacturers, models)
- Different ALC models have varying capabilities and limitations (overlap, SNR)
- Careful corrections are required for most ALC, often determined during post-processing using time series of historic data
- Corrections depend on individual components (mostly laser module)
- Housekeeping data are essential

Implementation

- Often long time series are required for robust corrections/calibrations
  - “Online” processing
  - History data treatment (capability “to-rerun”?)

ACTRiS CCRES

Perspectives

Step 1) RCS conversion to attenuated backscatter profiles

- Determine corrections and calibrations
- Apply corrections and calibrations

Step 2) Advanced products

- Cloud base height
- Liquid water content / target classification / drizzle / precipitation/ ...

- Aerosol type
- Aerosol optical properties & mass concentrations
- ABL heights

ACTRIS data centres
- CLU
- ARES

CNRS data centres
- AERIS-ICARE
- AERIS-ESPRI

Coordination with E-PROFILE?
- Meteo Swiss
- MetOffice hub

ACTRIS CCRES

ACTRIS
CCRES

Thank you