Retrieval of atmospheric backscatter and extinction profiles with the ALADIN airborne demonstrator (A2D)

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Motivation

ESA mission Aeolus

- Satellite mission Aeolus will be ready for launch in January 2018
- The atmospheric laser Doppler instrument (ALADIN) carried by the satellite is a direct detection Doppler wind lidar operating at 355 nm

Mission objectives

- Obtaining global observations of HLOS wind profiles
- Improving numerical weather predictions and climate studies

ALADIN will be the first high spectral resolution lidar (HSRL) in space
➡ Accurate vertical profiles of aerosol and cloud optical properties as a secondary product

An important tool for the development, testing, validation and optimization of the hardware and data processors is the ALADIN airborne demonstrator (A2D)

- Same fundamental concepts and design but slightly different specifications compared to ALADIN
- A2D was operated during several campaigns in 2006, 2007, 2009, 2015 and 2016
- Important information about instrument characterisitc, calibration and data processing were gained with real atmospheric signals

But: Focus was so far only on wind retrievals
➡ For the validation and optimization of the aerosol retrieval of ALADIN with real atmospheric measurements an retrieval of particle backscatter and extinction coefficient profiles is necessary

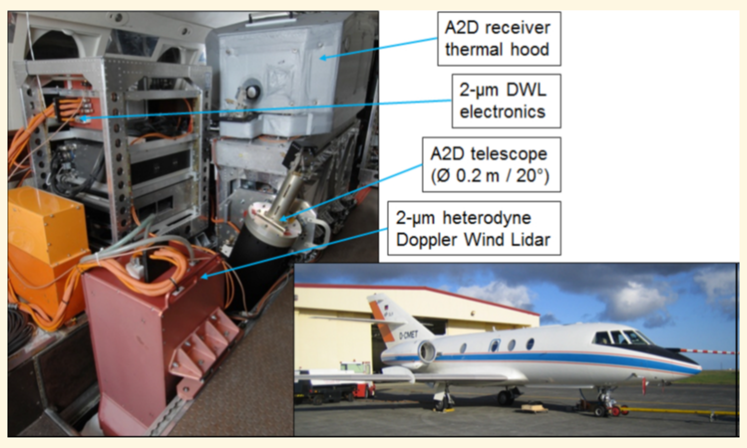
The ALADIN Airborne Demonstrator A2D

Platform

- DLR research aircraft Falcon
- 20 degree LOS pointing

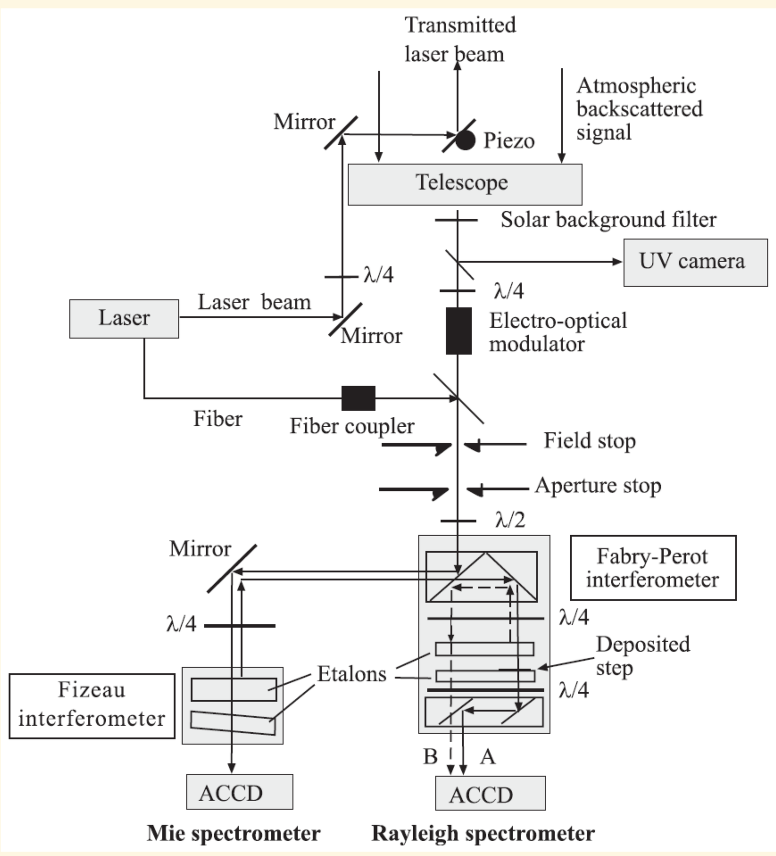
Transmitter

- Frequency tripled diode pumped Nd:YAG
- Pulse energy of 50-60 mJ at 355 nm
- Pulse repetition frequency of 50 Hz
- Circularly polarized light is emitted
- Co-alignment loop of transmit-receive path



Receiver

- Telescope with 0.2 m diameter and secondant mirror
- Near field signal is suppressed
  ➡ Full overlap at around 2000-3000 m distance
- Only parallel polarized light is detected
- Mie receiver: Fizeau interferometer
- Rayleigh receiver: dual Fabry-Pérot interferometer
- ACCDs to capture signals
  ➡ 25 range bins of which 20 are atmospheric
  ➡ variable vertical resolution of 296-2370 m
  ➡ around 80 m horizontal resolution
- Vertical crosstalk of ACCD leads to overlapping range bins



Data pre-processing

An aerosol retrieval needs the correct overall signal intensities
➡ Different steps in the signal pre-processing must be performed

Raw signal corrections and outlier elimination

- Detection chain offset subtraction
- Background subtraction
- Range correction
- Normalization to shortest range bin length
- Summation over 16 ACCD pixels

➡ Mie and Rayleigh signal intensities

Mie signal corrections

- Rayleigh signal on Mie channel

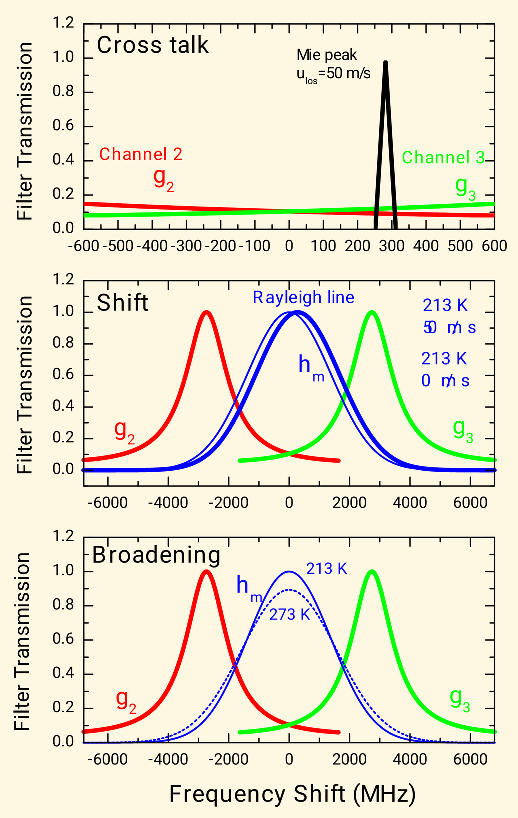
➡ A telescope obscuration correction is necessary by using so called Mie out of useful spectral range measurements

Rayleigh signal corrections

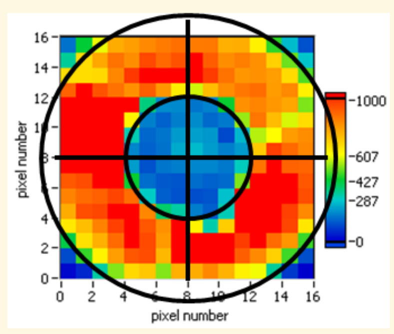
- Mie signal on Rayleigh channel
- Wind-induced shift of the Rayleigh-Doppler backscatter spectrum
- Temperature-induced Rayleigh line broadening

Ground return

Ground bin determination by using a digital elevation model based on SRTM data with 3 arcsec resolution
➡ Ground range bins at highest horizontal resolution



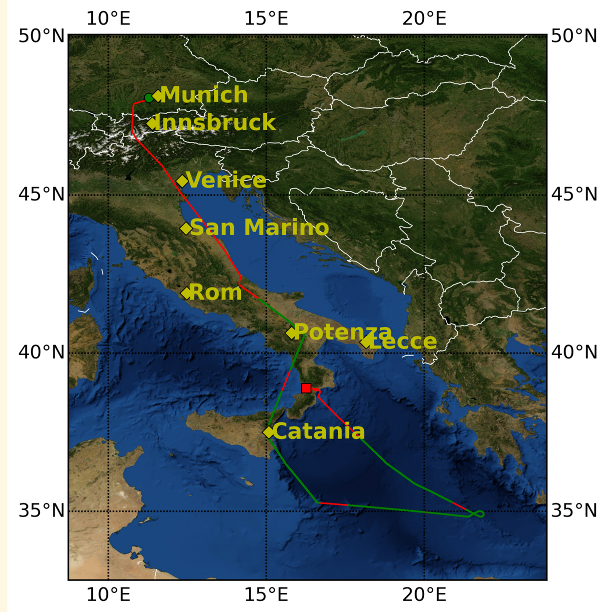
Albert Ansmann, Aeolus L2A final report 2007



Results from the aerosol flight on 22nd October 2016

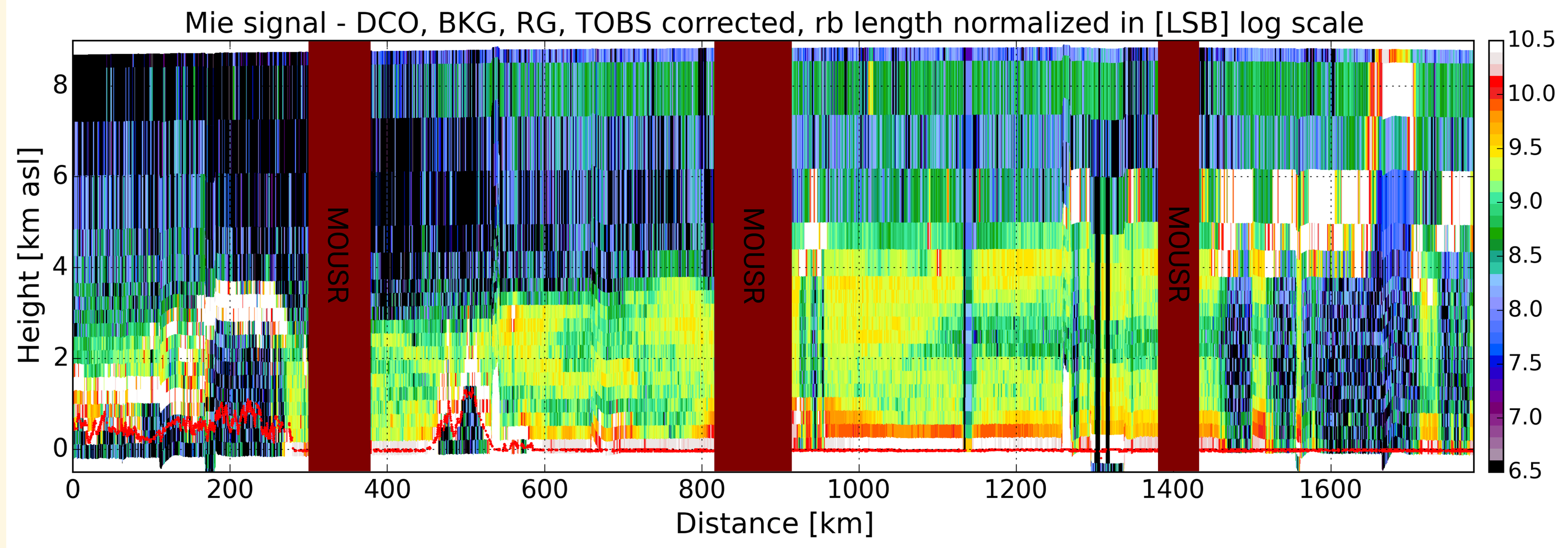
Aerosol flight in the Mediterranean region

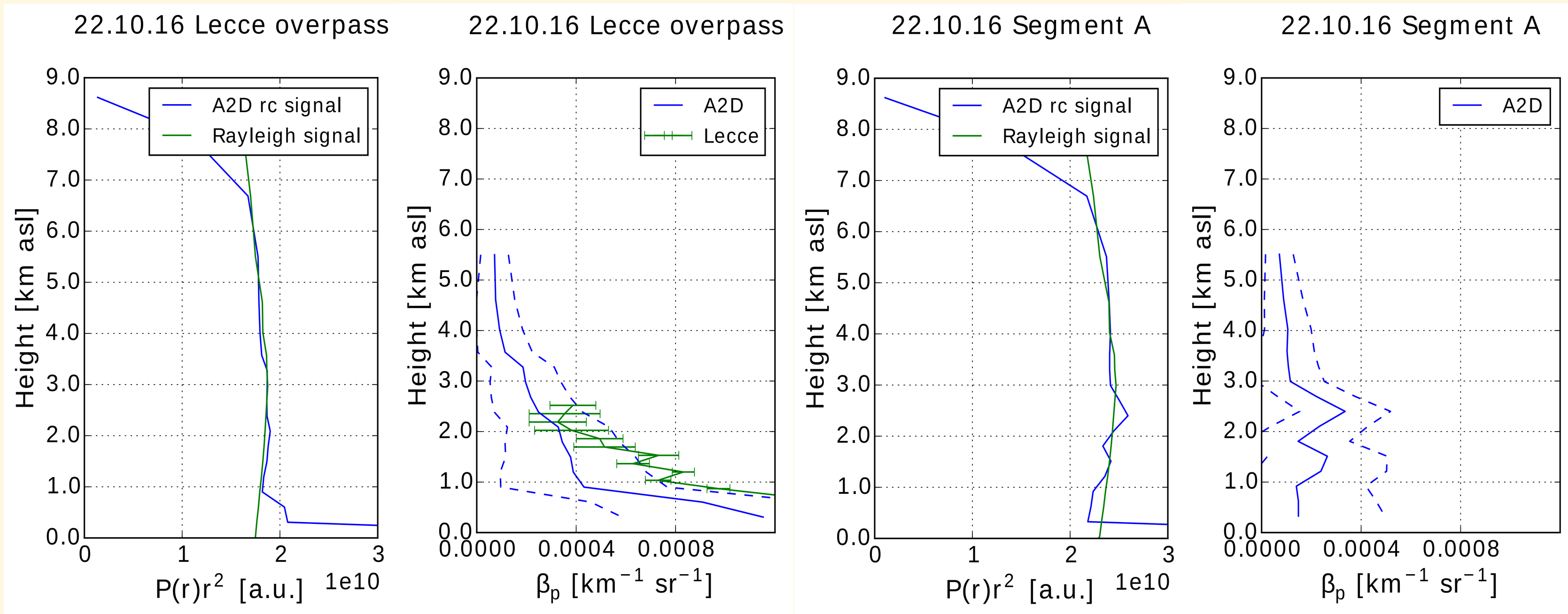
- Start in Oberpfaffenhofen (GER) at 08:02 UTC
- Arrival at Lamezia Terme (ITA) at 12:08 UTC
- Measurement from 09:08 until 11:30 UTC
- Elevated Saharan dust was forecasted by the MACC model
- Segment A averaged from 395-400 km
- Lecce overpass on the second flight leg back to Munich



Retrieval of particle backscatter coefficient profiles

- Klett-Fernald algorithm applied to Mie channel signals
- Assumption of aerosol free region at 5.5 km
- Lidarratio of 50±10 sr
- Backscattering ratio at reference height of 1.01 and 1.08
- Radiosonde data 40 km northwest of Lecce





Conclusion

With first results from an aerosol flight in the Mediterranean region, it could be shown that the retrieval of particle backscatter coefficient profiles with A2D is in principle possible when applying the Klett-Fernald algorithm to uncorrected signals from the Mie channel only.
A comparison with results from a ground based lidar shows similar results within the uncertainties. The structure of the elevated aerosol layer could be resolved in regions with short range bin length.

Main problems are caused by the coarse vertical resolution, what makes a Rayleigh fit in order to find a reference height difficult. In case of high aerosol layers the overlap region must be considered.
In the next step, the HSRL retrieval must be applied and the influence of the different signal corrections has to be quantified.

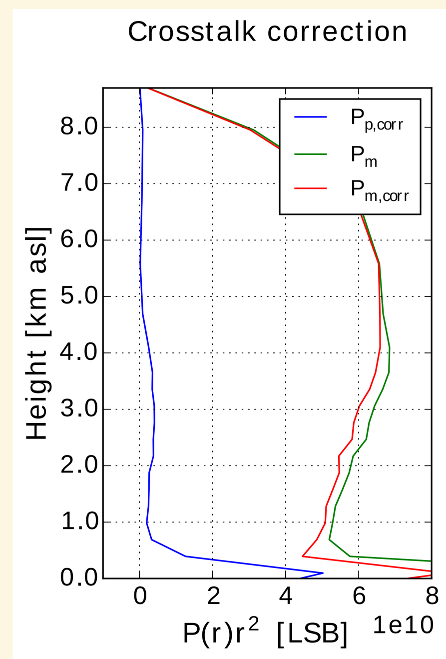
Outlook

HSRL retrieval

- Preliminary crosstalk correction

$$P_{m,corr} = P_m - ct_{fac} * P_{p,corr}$$

ct_{fac} determination by maximization of summed up negative gradients from all measurement profiles



- Correction for wind shift
- Correction for temperature induced frequency shift

Validation

- Comparison with ground based stations (lidars, ceilometer network)
- Comparison with CALIPSO data

Uncertainties

- Quantification of depolarization effects
- Multiple scattering
- Influence of telescope obscuration correction
- Influence of different crosstalk corrections

Acknowledgments:
Special thanks to the DLR team for providing A2D data and performing an extra aerosol flight in the Mediterranean region after the NAWDEX campaign.
Thank you to the Aerosol & Climate Laboratory of the University of Salento, Lecce, for providing us with aerosol optical properties retrieved from their ground based lidar for the Falcon overpass.
The research leading to these results was done within an ESA Internal Research Fellowship.