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 HLOD 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)
- Some 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 characteristics, 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 aerosol retrieval of ALADIN with real atmospheric measurements 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, 355 nm
- Pulse repetition frequency of 50 Hz
- Circularly polarized light is emitted
- Co-alignment of transmission/reception path

Receiver:
- Telescope with 0.3 m diameter and secondary mirror
- Near field signal is suppressed
- Full overlap at around 2000-2000 m distance
- Only parallel polarized light is detected
- Mix receiver: Fizeau Interferometer
- Rayleigh receiver: dual Fabry-Perot Interferometer
- ACCOs to capture signals
- 25 range bins of which 20 are atmospheric
- Vertical resolution of 296-2570 m
- Approximately 80 m horizontal resolution
- Vertical cross-talk of ACCs to overlapping range bins

Results from the aerosol flight on 22nd October 2016

Aerosol flight in the Mediterranean region
- Start in Oberpfaffenhofen (Germany) at 08:02 UTC
- Arrival at Lampedusa (ITA) at 12:08 UTC
- Measurement from 09:06 until 11:30 UTC
- Elevated Saharan dust was forecasted by the MACC model
- Segment A averaged from 335-400 km
- Lecce overpass on the second flight leg back to Munich

Retrieval of particle backscatter coefficient profiles
- Klett-Fernald algorithm applied to Mic channel signals
- Assumption of aerosol free region at 0.5 km
- Lidar ratio of 60±10 sr
- Backscattering ratio at reference height of 1.01 and 1.08
- Radiosonde data 40 km northwest of Lecce

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

Mix signal corrections
- Rayleigh signal on Mic channel
- A telescope obstruction correction is necessary by using so-called Mix out of usable spectral range measurements

Rayleigh signal corrections
- Mix 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

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 Mic 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, which 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 cross-talk correction
- $P_{	ext{mic,corr}} = P_{	ext{mic}} - c_{	ext{mic,corr}}$
- $c_{	ext{mic,corr}}$ 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, colimator network)
- Comparison with CALIPSO data

Uncertainties
- Quantification of depolarization effects
- Multiple scattering
- Influence of telescope obstruction correction
- Influence of different cross-talk corrections

Acknowledgements
- Special thanks to the DLR team for providing A2D data and performing an extra aerosol flight in the Mediterranean region after the MASTEx campaign
- Thanks to the German Climate Laboratory at the University of Saarbrücken, Lecce, for providing us with aerosol optical properties retrieved from the ground-based data for the Fuego campaign
- This research leading to these results was done within an ESA Internal Research Fellowship.