Lidar-based technique for the observation of microphysical properties of liquid water clouds: Dual-FOV Polarization lidar

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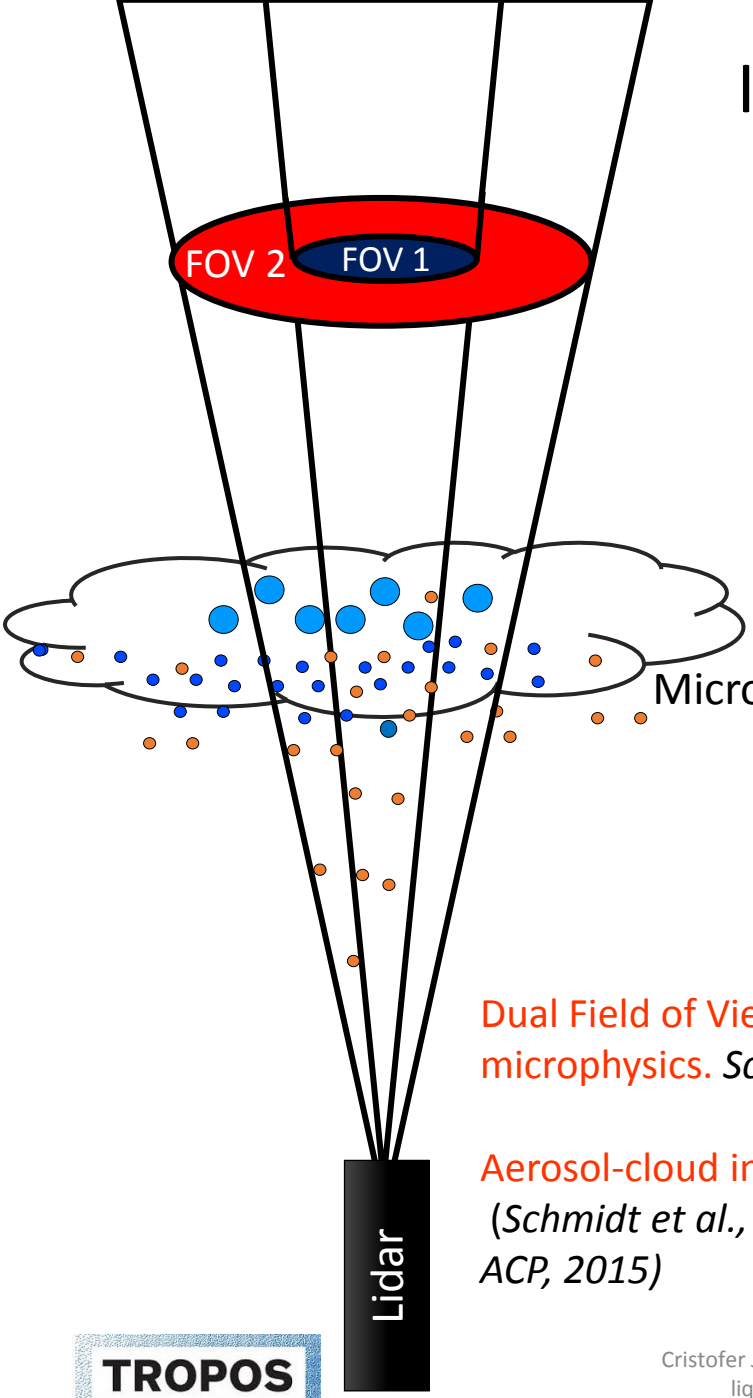
HD(CP)²
High definition clouds and precipitation for advancing climate prediction

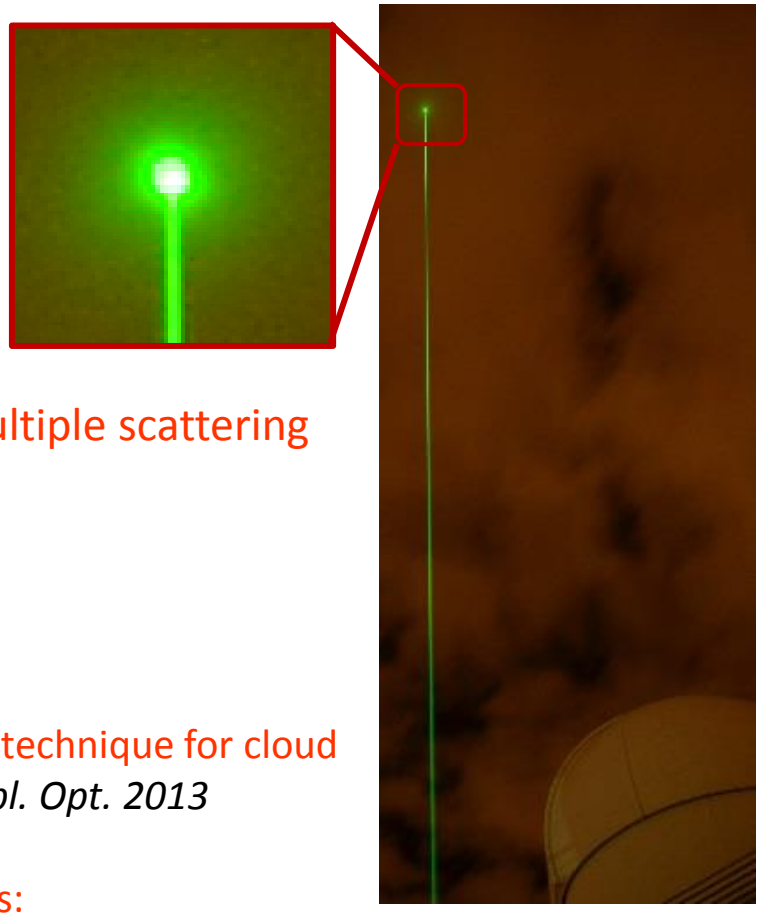
Contents

- Retrieval capabilities of a DFOV-Polarization lidar.
- Instrument and calibration.
- Measurement case.
- Contrast: Leipzig (Germany) vs. Punta Arenas (Chile)

Introduction



Lidar system MARTHA, Leipzig



Multiple scattering

Dual Field of View (FOV) Raman technique for cloud microphysics. *Schmidt et al., Appl. Opt. 2013*

Aerosol-cloud interaction studies:
(*Schmidt et al., J.G.R. Atm. 2013; Schmidt et al. ACP, 2015)*

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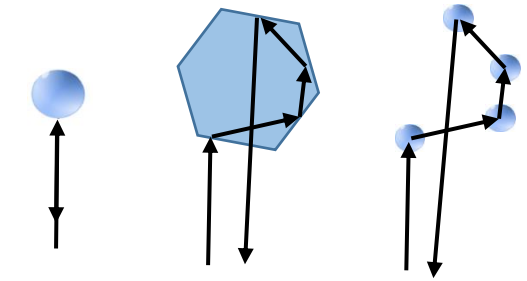
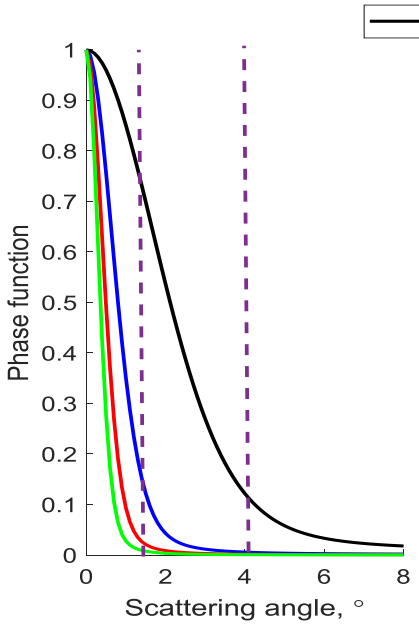
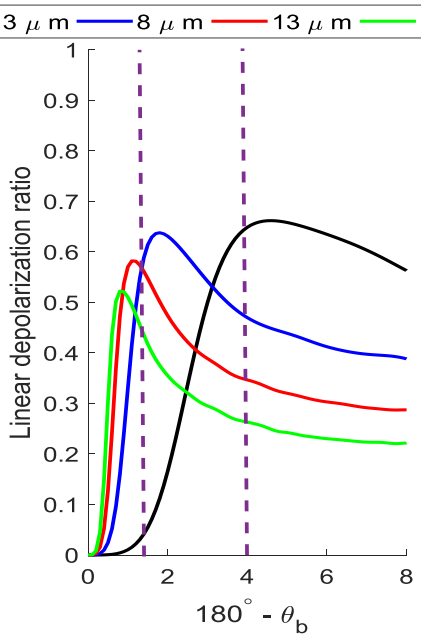
New measurement principle: Dual-FOV Depolarization



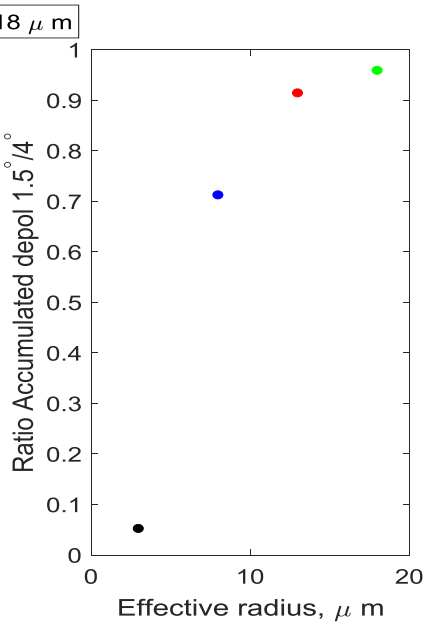
$\frac{P_\perp}{P_{II}} = 0$ $\frac{P_\perp}{P_{II}} > 0$ $\frac{P_\perp}{P_{II}} > 0$



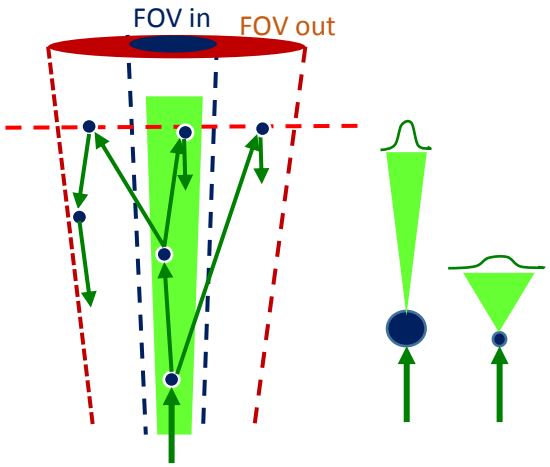
Forward scattering



Backscattering



Combined



The smaller the droplets, the more different the depolarization ratios measured by two FOVs

New measurement principle: Dual-FOV Depolarization

Simulation results for a cloud at 2 km height

Analytical multiple scattering model *(Chaikovskaya and Zege, JQSRT, 2004):*

∥ and ⊥ backscatter components.

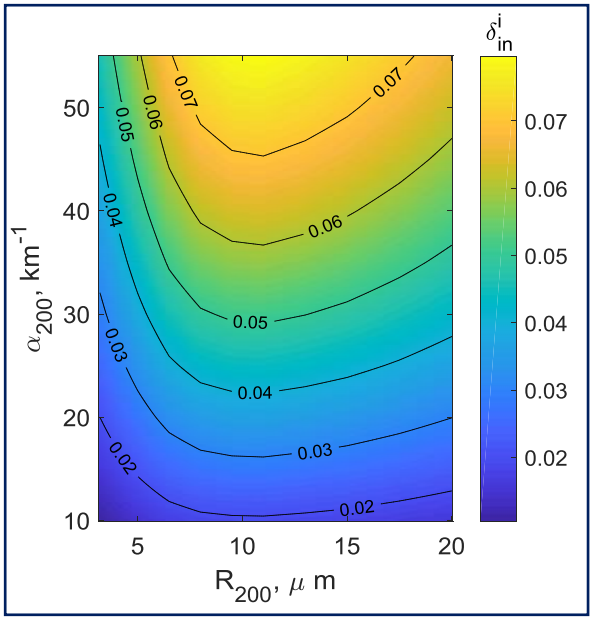
two Fields of view "*in*" and "*out*":

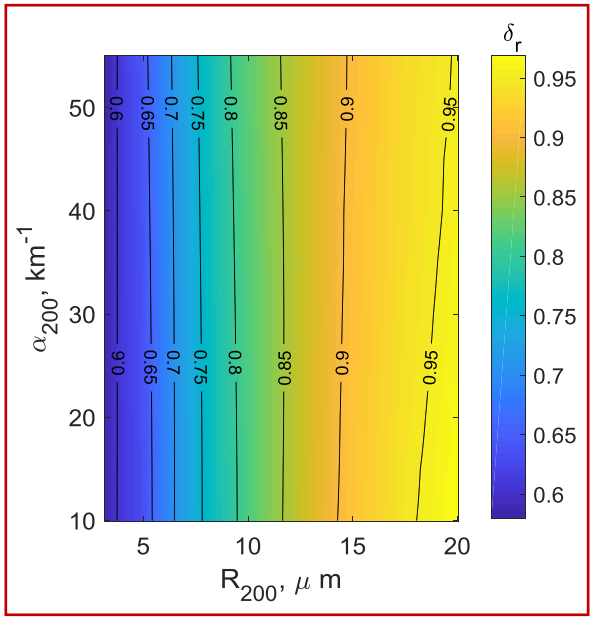
Linear depolarization ratio

$\bar{\delta}_{in}(z)$ at $\theta_{in} = 1$ mrad

$\bar{\delta}_{out}(z)$ at $\theta_{out} = 2$ mrad

Relative depolarization: $\delta_r = \frac{\bar{\delta}_{in}(z)}{\bar{\delta}_{out}(z)}$





Jimenez et al., AMT 2019 (to be submitted)

Best estimate up to 75 meters above cloud base:

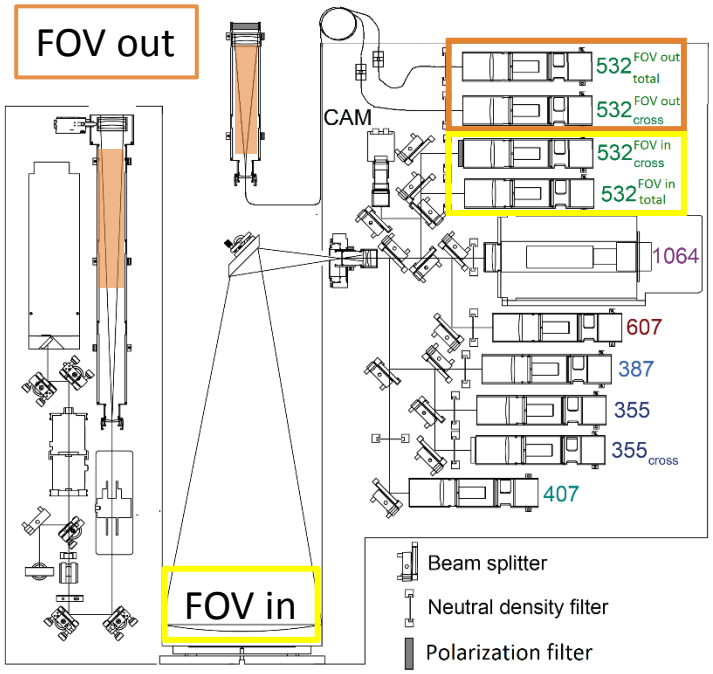
Extinction coefficient: α_{75}

Effective radius: R_{75}

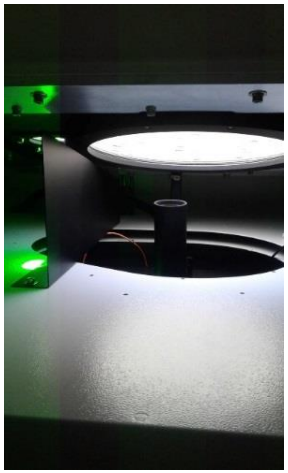
Liquid water content: $LWC_{75} = \frac{2}{3}\rho_l \alpha_{75} R_{75}$

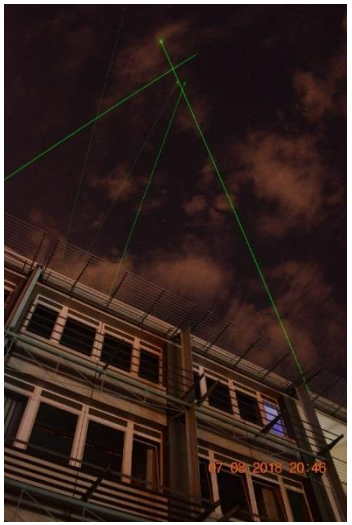
Droplet number concentration: $N_d = \frac{1}{2\pi k}\alpha_{75} R_{75}^{-2}$

Implementation: Dual-FOV Depolarization



LACROS station





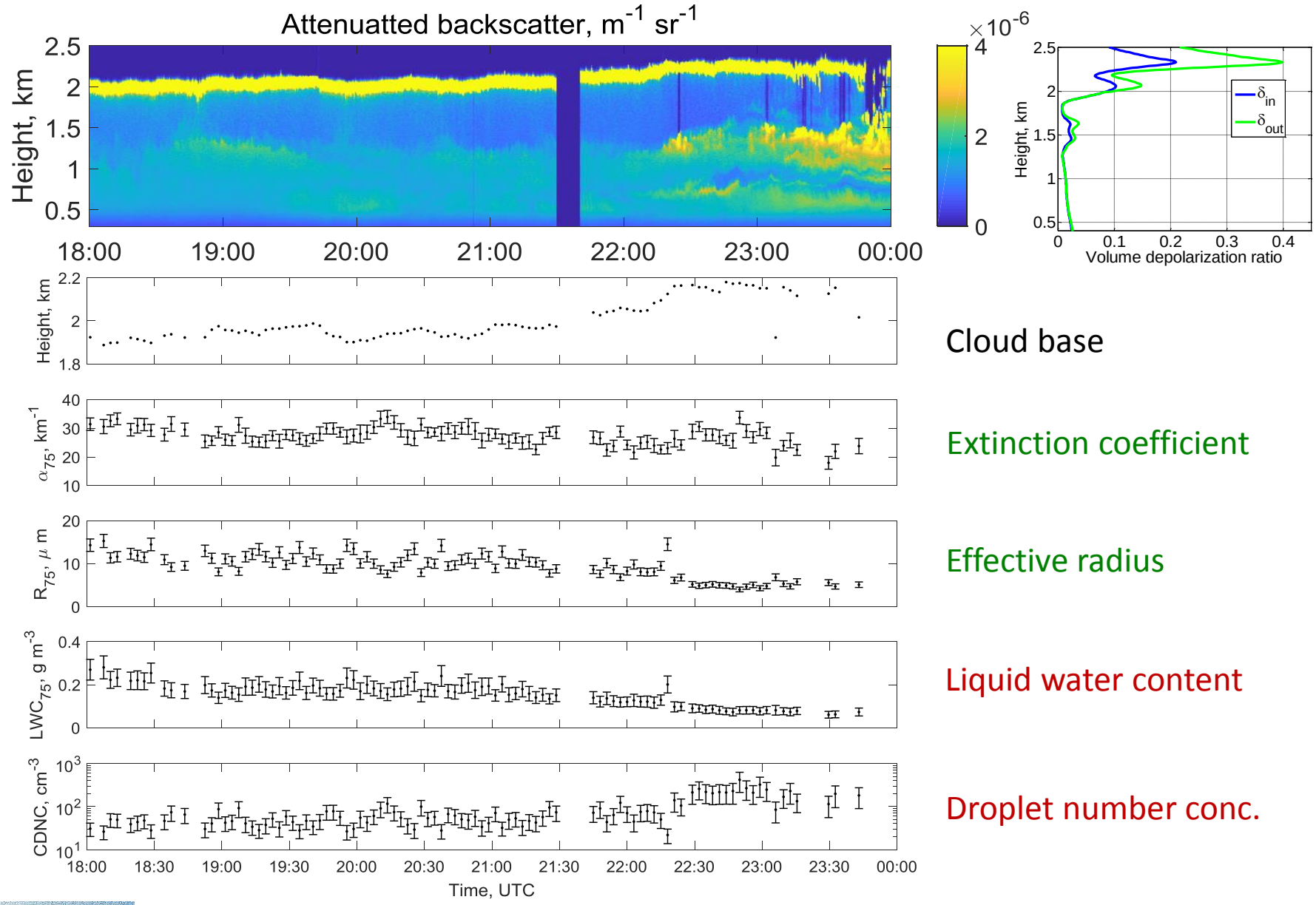
Calibration methods:

- MARTHA: Three-channel approach (*Jimenez et al., AMT 2019)*
- Polly XT: $\Delta 90$ *rotation (Engelmann et al., 2016)*

Relative calibration

$$\delta_{in} \equiv \delta_{out} \quad \text{(cloud-free)}$$

Measurement case: Leipzig, 20-08-2018



Cloud base

Extinction coefficient

Effective radius

Liquid water content

Droplet number conc.

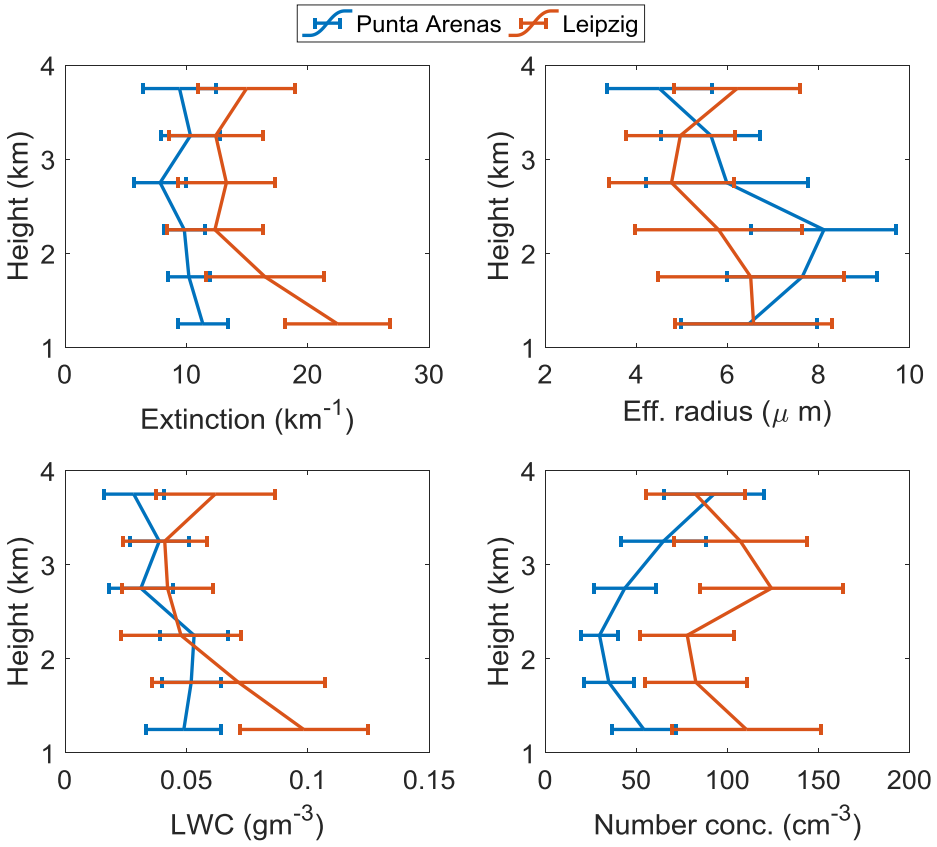
Statistical analysis: comparison Leipzig and Punta Arenas

MARTHA system, Leipzig (51.3°N 12.4°E):
40 Hours, Spring-Summer-Autumn 2017

Polly system, Punta Arenas (53.2°S, 70.9°W):
55 Hours, Summer 2019
Measurement campaign: DACAPO-PESO

Values 75 above cloud base!

	Leipzig	Punta Arenas
Extinction (km^{-1})	15.81 ± 6.35	9.82 ± 3.35
Eff. Radius (μm)	5.80 ± 2.18	6.38 ± 1.91
LWC ($g\ m^{-3}$)	0.06 ± 0.03	0.04 ± 0.02
Nd (cm^{-3})	97 ± 46	53 ± 29



Height-range averaged: 0.5 km step

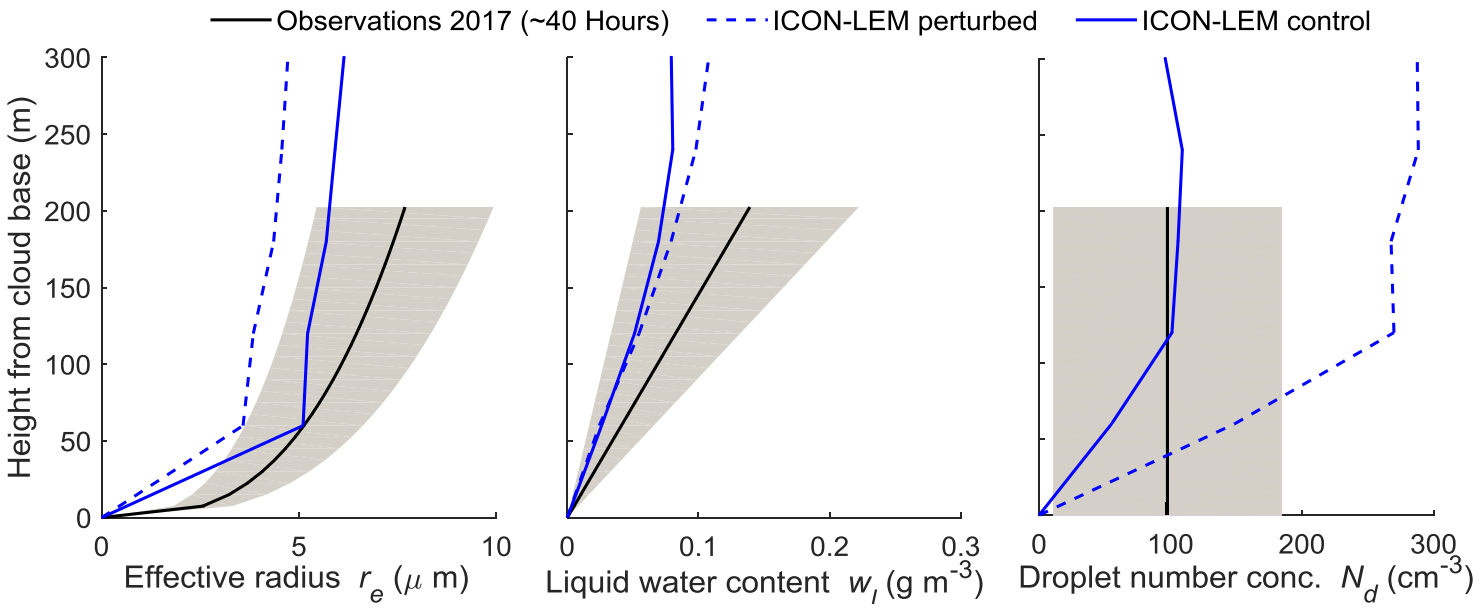
Summary

- A new dual-FOV depolarization approach was developed and implemented on two lidar instruments. Small instrumental upgrade is required
- High temporal resolution retrievals are possible with this technique.
- Strong contrast between Punta-Arenas and Leipzig in terms of cloud microphysics. Clouds in the continental conditions at Leipzig exhibit double amount of droplets than in the marine conditions at Punta Arenas.

Next steps:

- Validation by comparison with other techniques.
- ACI considering vertical wind information: Downdraft and Updraft regime
- statistical analysis of the aerosol properties

Thank you for your attention!

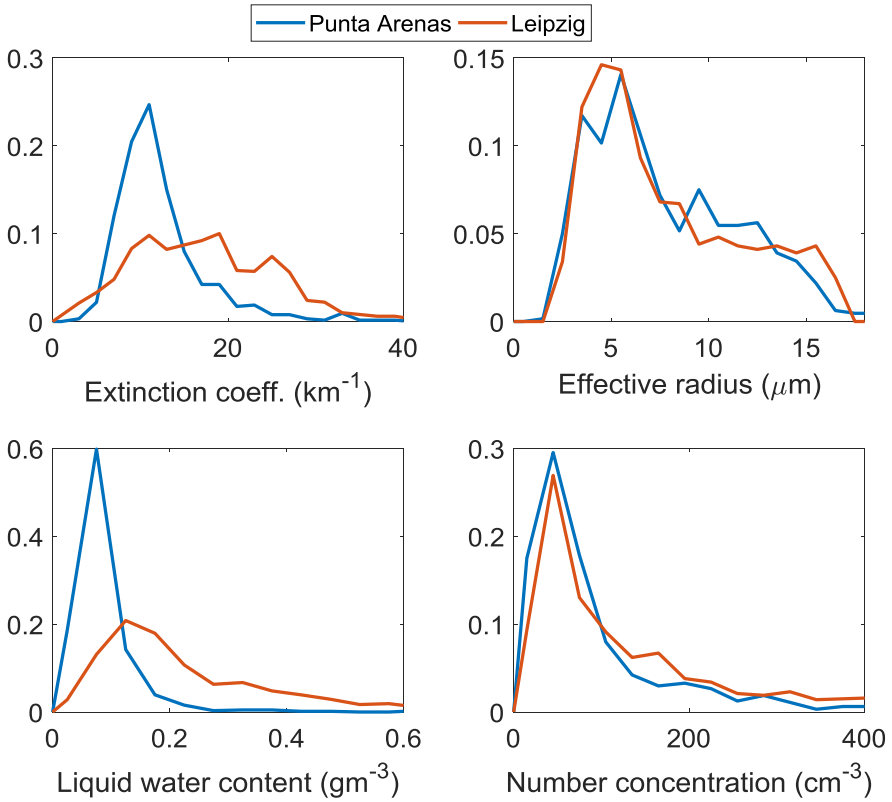

Observations 2017 (~40 Hours)
ICON-LEM perturbed
ICON-LEM control
Height from cloud base (m)
300
250
200
150
100
50
0
0
5
10
Effective radius r_e (μ m)
0
0.1
0.2
0.3
Liquid water content w_l (g m^{-3})
0
100
200
300
Droplet number conc. N_d (cm^{-3})

Statistical analysis: comparison Leipzig and Punta Arenas

MARTHA system, Leipzig (51.3°N 12.4°E):
40 Hours, Spring-Summer-Autumn 2017

Polly system, Punta Arenas (53.2°S, 70.9°W):
55 Hours - Summer 2019
measurement campaign: DACAPO-PESO

Histograms: Values 75 meters above C.B.



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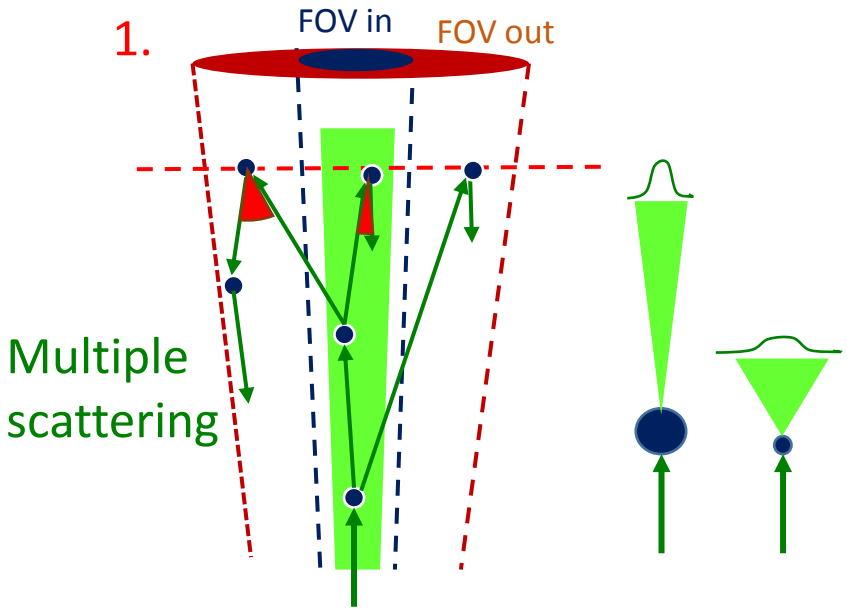
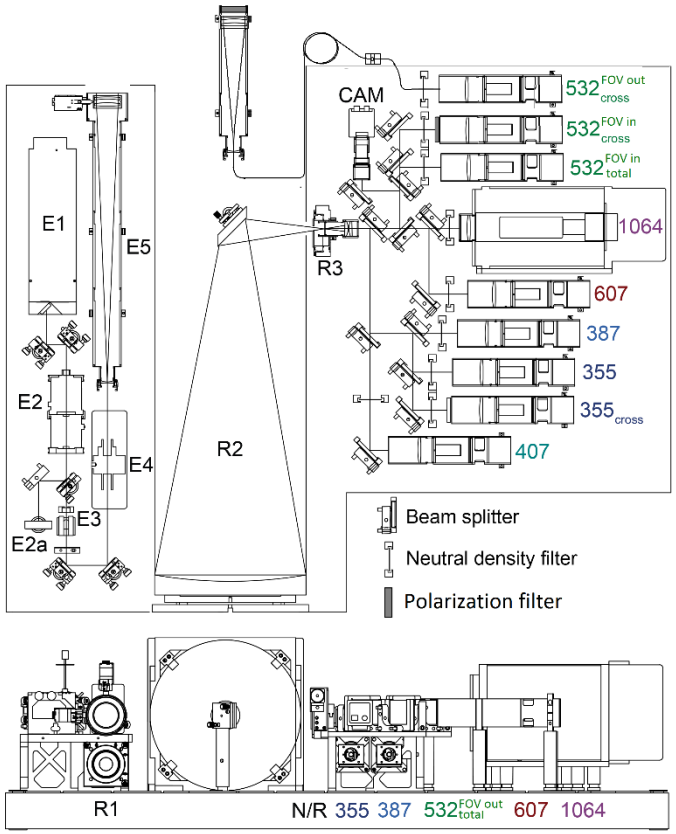
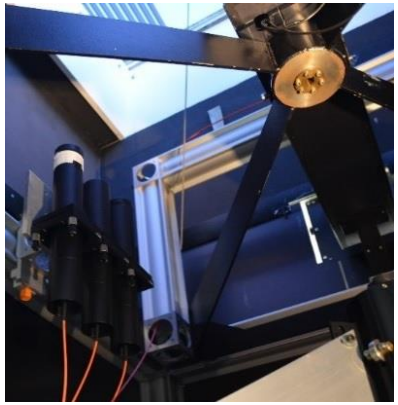
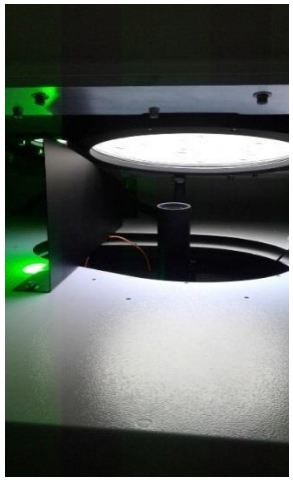


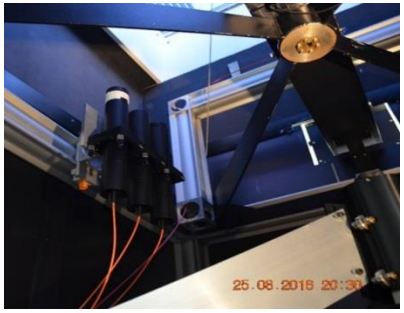




At MARTHA



At Polly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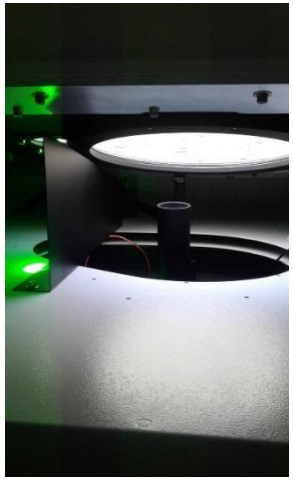


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