Retrieval of cloud droplet size distributions from polarimetric specMACS observations

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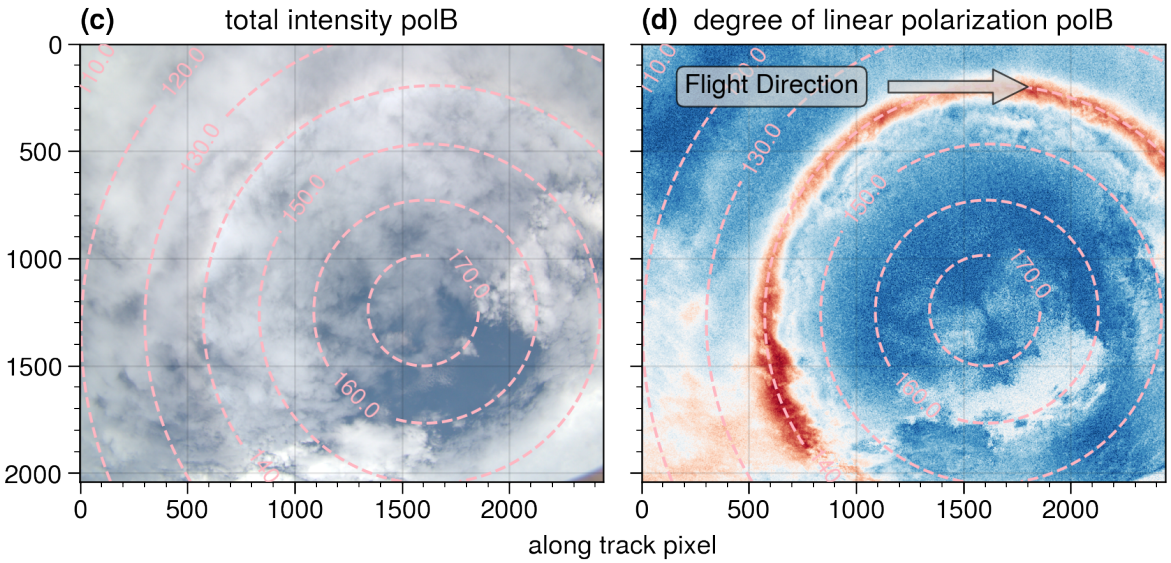
How big are the droplets in such clouds?

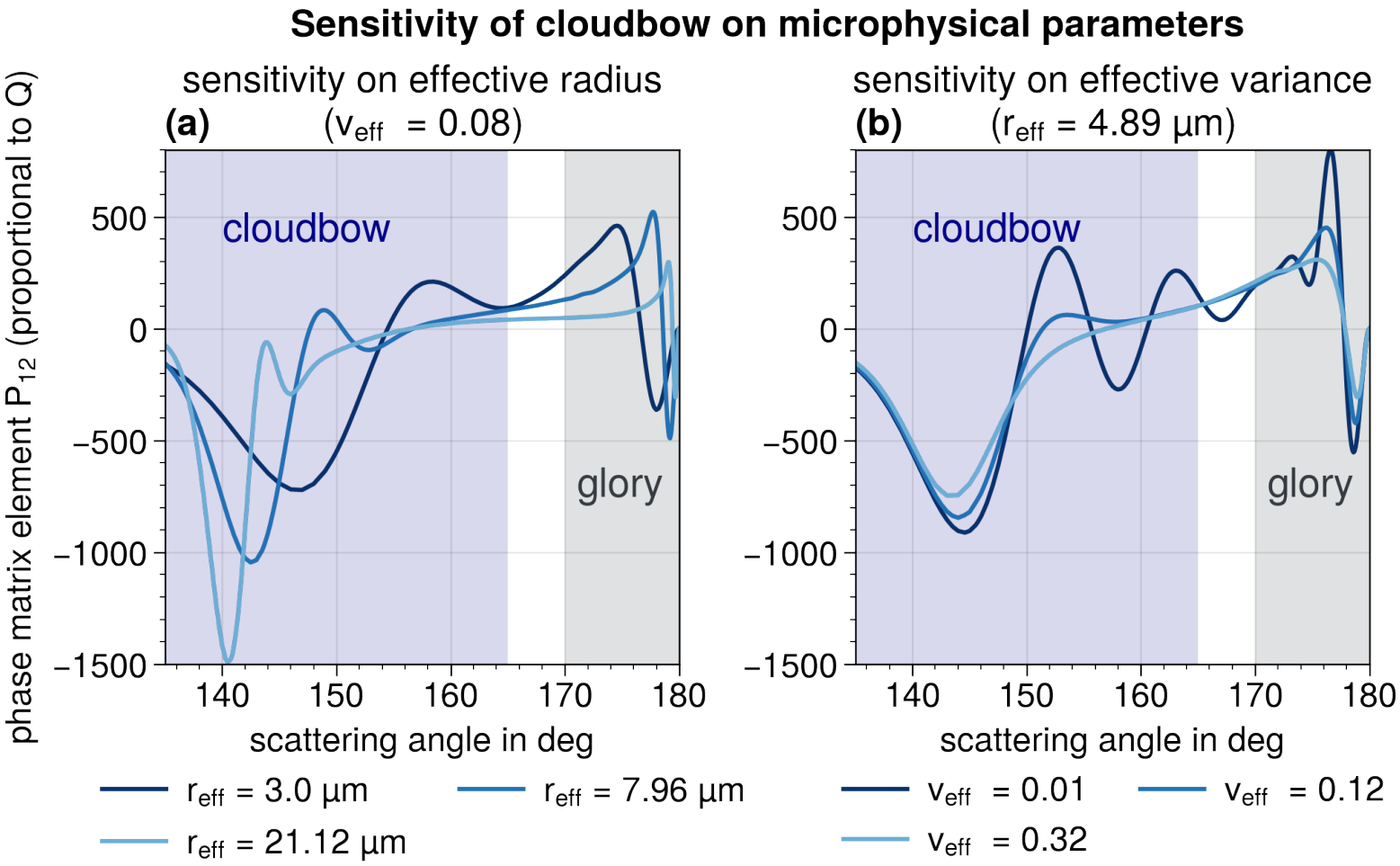
CAMERA SYSTEM *SPECMACS*

- two hyperspectral line cameras (400 nm – 2500 nm wavelength range)
- two polarization resolving 2D cameras
- mounted onboard German research aircraft *HALO*
- nadir measurements



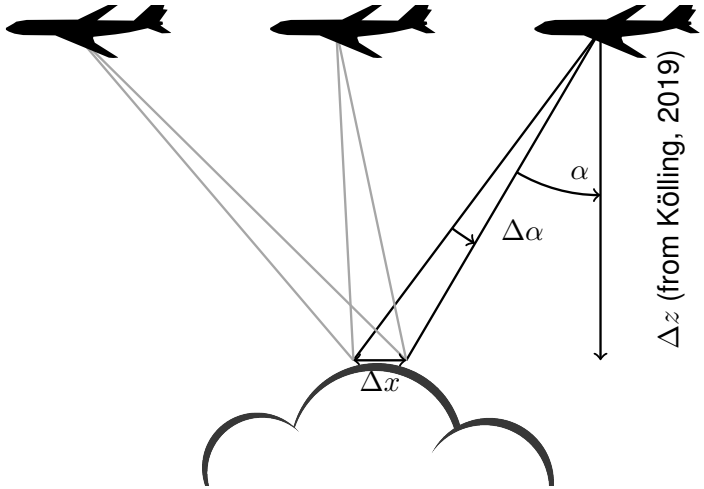
Measurement from polarization camera; red circle = cloudbow

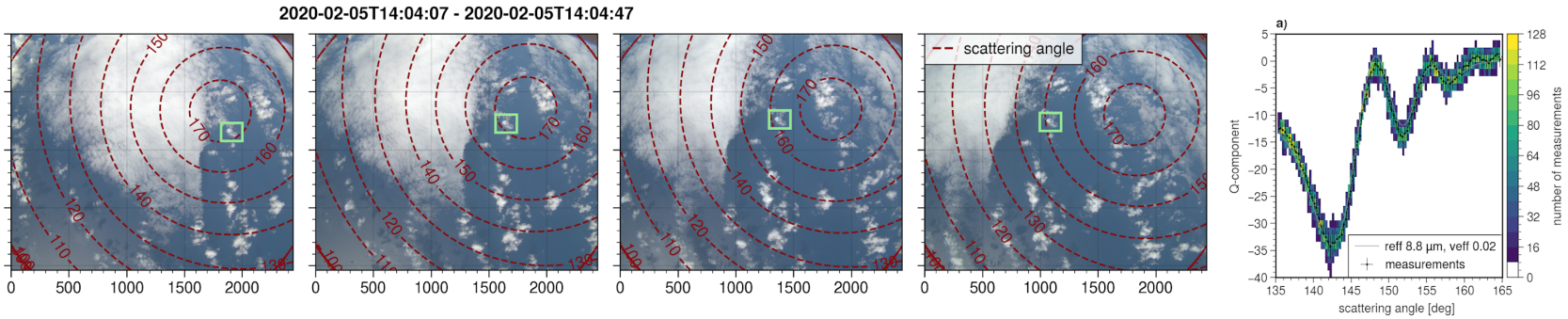
WHY DO WE MEASURE THE CLOUDBOW?



Aggregation of observations

- observation of same cloud element in successive images
- cloud element: 100 m by 100 m
- necessary: cloud top height → stereographic method from Kölling et al. (2019)





Observation of same cloud (green box) from different angles and aggregated angular measurement (right)

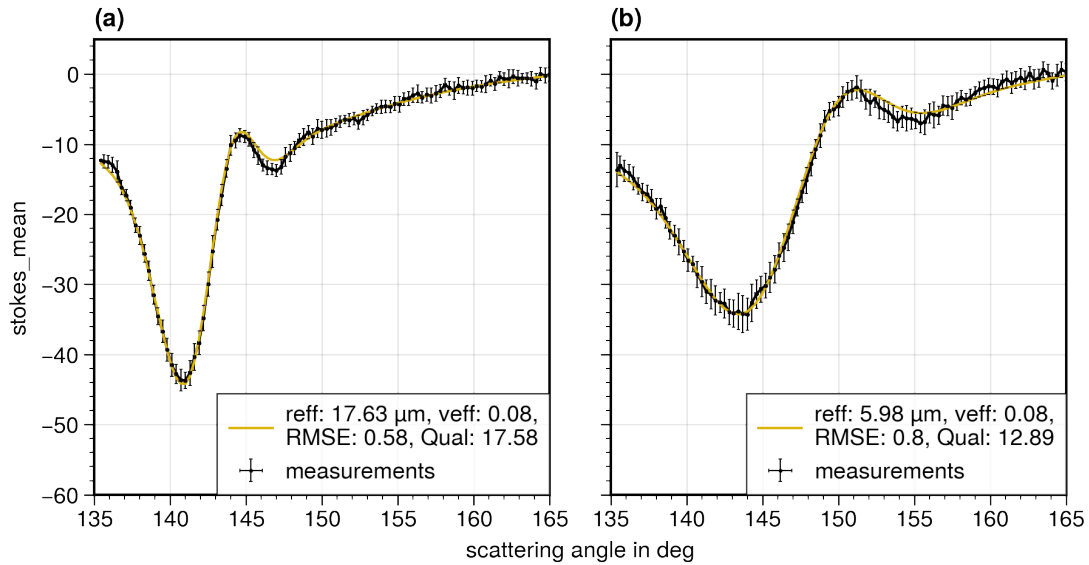
Find matching drop size distribution

- Look-up table of simulated cloudbow signals for different cloud droplet size distributions (CDSDs)
- Assumption: CDSD has a gamma distribution shape (defined by effective radius and effective variance)
- Fit look-up table against observations [1]

$$y_{\text{fit}}[r_{\text{eff}}, v_{\text{eff}}](\theta) = \underbrace{a * cos(\theta)^2 + b}_{\text{multiple scattering residual, Rayleigh scattering...}} + \underbrace{c * P_{12}[r_{\text{eff}}, v_{\text{eff}}](\theta)}_{\text{cloudbow signal (single scattering)}}$$

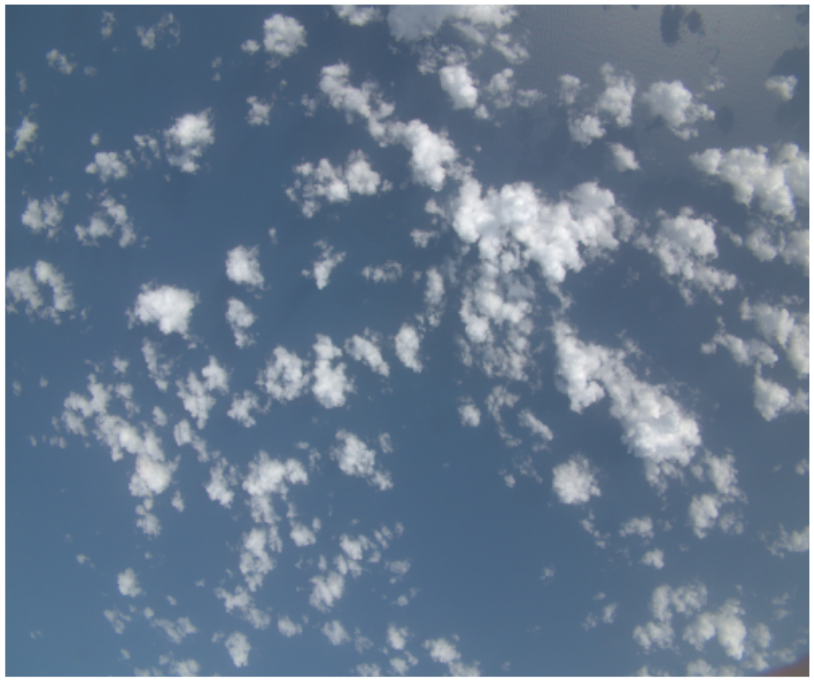
$y_{\text{fit}}[r_{\text{eff}}, v_{\text{eff}}](\theta)$: fitting function
θ: scattering angle

P_{12}: polarized phase function
a, b, c: fitting parameters



[1] see e.g., Mayer et al. (2004); Alexandrov et al. (2012)

CASE STUDY

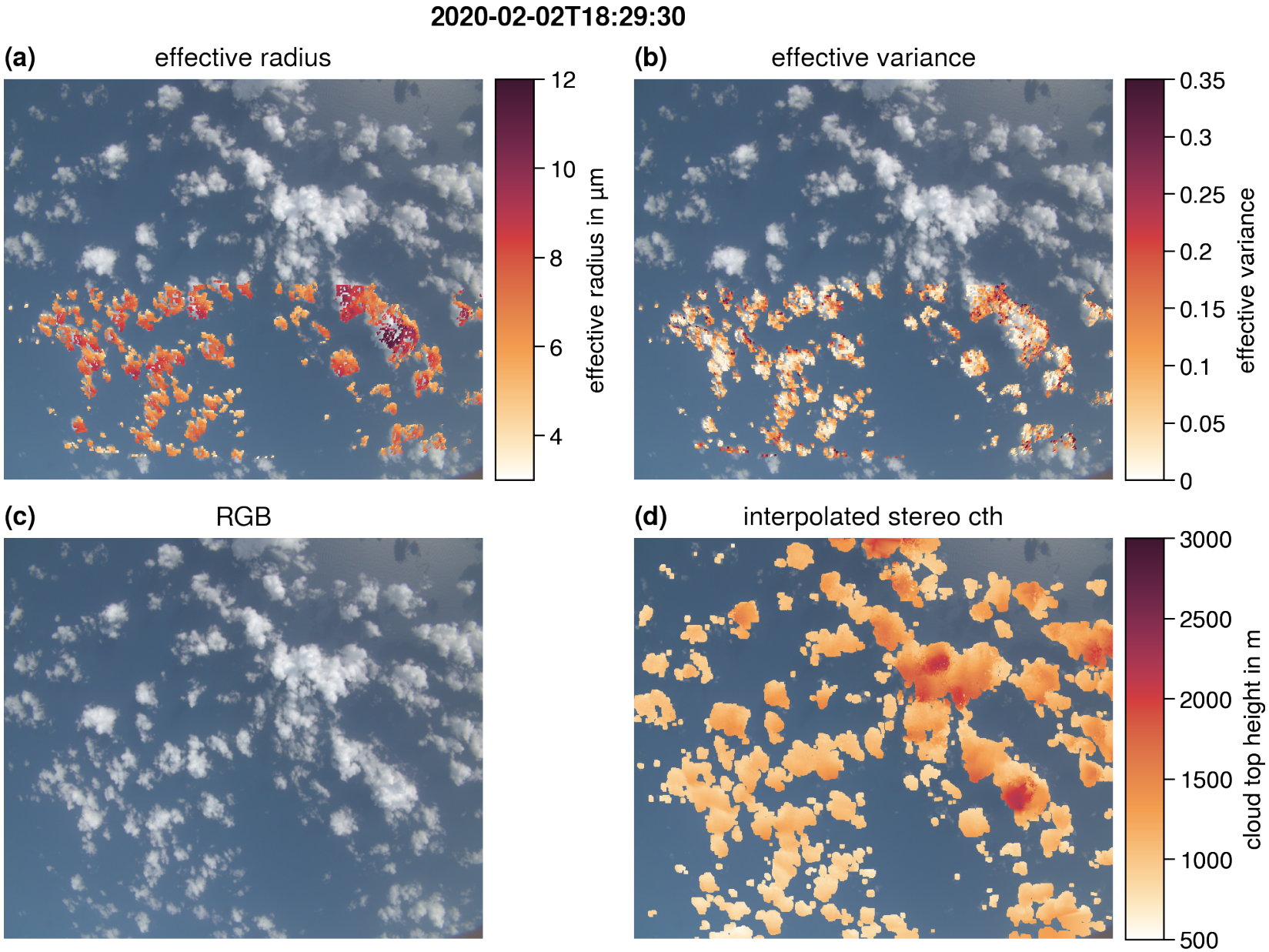


specMACS measurement

View from aircraft (by Felix Ament)

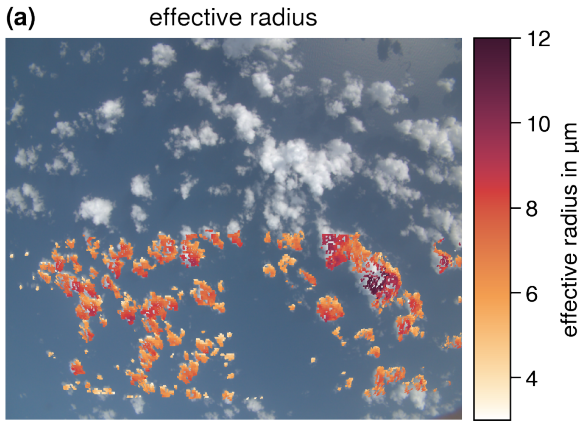
- cloud field of small trade wind cumulus clouds
- diameters typically 1 km to 3 km
- case study published in Pörtge et al. (2023)

CLOUDBOW RETRIEVAL RESULT



specMACS retrieves spatial distributions of cloud microphysical properties ...

- ... at high spatial resolution
- ... for a very large field-of-view
- ... even for small cumuli.
- Published in AMT: Pörtge et al. (2023)



Ongoing work

- Estimation of retrieval uncertainty based on simulated images
- Statistical evaluation of all EUREC^{4}A measurements
- Comparison with in-situ data and bi-spectral droplet size retrievals

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EGU abstract QR code

Alexandrov, M. D., Cairns, B., Emde, C., Ackerman, A. S., and van Diedenhoven, B. (2012). Accuracy assessments of cloud droplet size retrievals from polarized reflectance measurements by the research scanning polarimeter. Remote Sensing of Environment, 125:92–111.

Kölling, T., Zinner, T., and Mayer, B. (2019). Aircraft-based stereographic reconstruction of 3-d cloud geometry. Atmospheric Measurement Techniques, 12(2):1155–1166.

Mayer, B., Schröder, M., Preusker, R., and Schüller, L. (2004). Remote sensing of water cloud droplet size distributions using the backscatter glory: a case study. Atmospheric chemistry and physics, 4(5):1255–1263.

Pörtge, V., Kölling, T., Weber, A., Volkmer, L., Emde, C., Zinner, T., Forster, L., and Mayer, B. (2023). High-spatial-resolution retrieval of cloud droplet size distribution from polarized observations of the cloudbow. Atmospheric Measurement Techniques, 16(3):645–667.