Two-Year Analysis of Aerosol-Cloud-Interaction from Cloud-Radar and Ceilometer Observations at JOYCE

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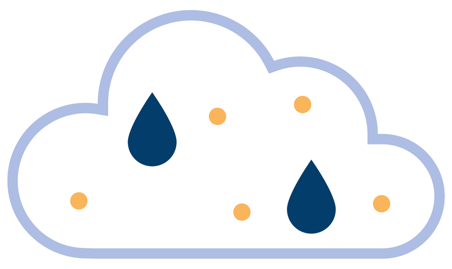
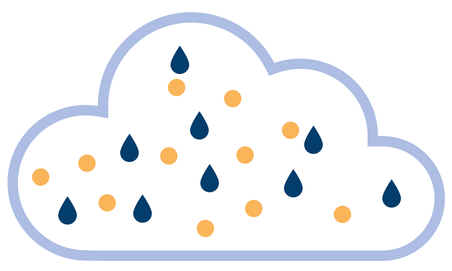
1. Motivation

Aerosols are key ingredients for cloud formation and influence the global radiation budget directly and indirectly. Aerosol cloud interaction (ACI) creates the largest uncertainty in the estimation of anthropogenic radiative forcing. Ground based remote sensing instruments are a key tool to address this problem. In this study, the instrumentation of the JOYCE cloud remote sensing site was used to establish a synergistic ACI monitoring algorithm.

2. The Twomey-Effect and Indirect Effect Indices

It was shown by Feingold et al., 2003, that the aerosol indirect effect (Twomey-effect) can be observed with ground-based remote sensing instruments (cloud radar and high power lidar) and quantified by the indirect effect (IE) indices.





$$IE_r = -\frac{\mathrm{d}\ln(r)}{\mathrm{d}\ln(\alpha)} \qquad IE_N = \frac{\mathrm{d}\ln(N)}{\mathrm{d}\ln(\alpha)}$$

N: cloud droplet number concentration
r: cloud droplet effective radius
α: aerosol proxy (aerosol extinction coefficient or aerosol optical depth)

3. Jülich Observatory for Cloud Evolution

The Jülich Observatory for Cloud Evolution (JOYCE) is a cloud remote sensing site and a cooperative project with University of Cologne. JOYCE is part of the pan-European Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS) .

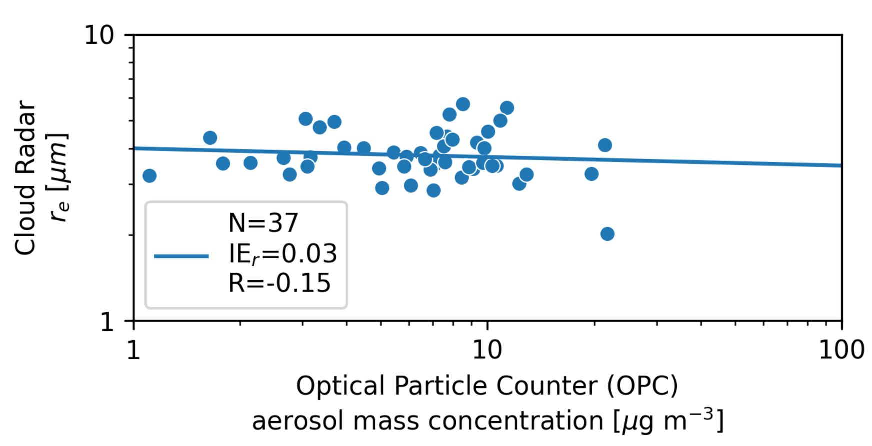
Microwave Radiometer
→ liquid water path (LWP)

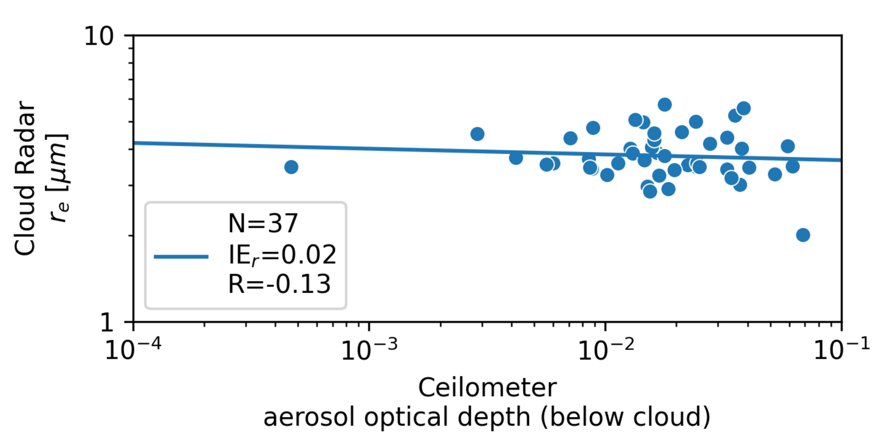
Wind Lidar
→ boundary layer classification (Manninen & Marke, 2018)

Cloud Radar
→ cloud droplet effective radius (Frisch et al, 2002)

Ceilometer
→ aerosol optical depth (AOD) (A-Profiles - Mortier, 2022)

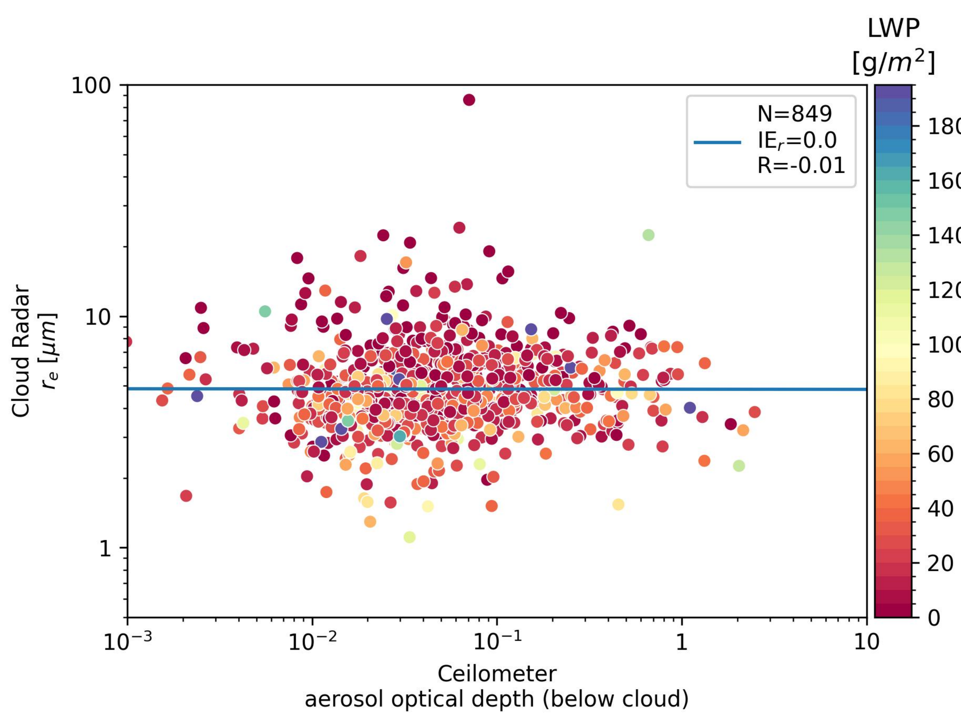
4. In-Situ & Ceilometer ACI Analysis





- Dataset: 2023-02-01 - 2023-08-01
- Cloud radar and OPC measurements show negative correlation and positive IE_r
- Uncertainty is too high to confirm the Twomey-effect
- Results were reproduced using cloud radar and ceilometer AOD
- Literature: IE_r = 0.1 (Feingold et al., 2003)

5. Two Year ACI Analysis



- Dataset: 2021 & 2022
- Cloud radar & ceilometer measurements show no correlation and no IE_r
- No effect of LWP on IE_r
- Unknown aerosol and cloud properties:
  - Size distribution
  - Composition
  - Cloud intrusion
  - Optical properties

6. Summary

- First IE-index studies based on **radar** and **ceilometer** measurements did not confirm the **Twomey-effect** within the uncertainty of the method.
- The potential influence of additional parameters on IE_r is currently investigated:
  - **cloud liquid water path** from a microwave radiometer
  - **weather information** from the Jülich meteorological tower
  - **boundary layer classification**

7. Outlook

- Implementation of **JOYCE Raman Lidar** for aerosol remote sensing (aerosol extinction coefficient retrieval and calculation of IE-indices)
- Comparison of IE-indices of JOYCE Raman Lidar to Ceilometer IE-indices.
- Comparison of IE-indices for arctic (**Ny-Ålesund**, Svalbard) and mid-latitude (**JOYCE**) environment.