Assessing Arctic low-level clouds and precipitation from above - a radar perspective

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1. Motivation

- most Arctic clouds occur below 2 km altitude
- they have a large impact on the radiative surface energy budget
- to improve low-level cloud representation in climate models using CloudSat, its limitations must be known

➡evaluation of CloudSat by high-resolution airborne observations

2. Data

- **Which variable?** low-level cloud fraction: amount of cloudy points relative to all points with height derived from radar reflectivities
- **Where?** over the Fram Strait
- **When?** 4 aircraft campaigns within (AC)³ between March and September from 2017 to 2022
- **Instruments?**
  - cloud profiling radar on CloudSat
  - Microwave Radar/radiometer for Arctic Clouds (MiRAC) on Polar 5

3. Method

Comparison of CloudSat and MiRAC cloud fractions:

1) forward simulation of MiRAC (Fig. 1a) to synthetic CloudSat radar reflectivities:
   I. along track convolution (Fig. 1b)
   II. along-track integration (Fig. 1c)
   III. along-range convolution (Fig. 1d)
   IV. application of sensitivity threshold (-27 dBZ; Fig. 1e)
2) comparison with original CloudSat data for 4 underflights (Fig. 1f)
3) comparison with original MiRAC observations over all campaigns

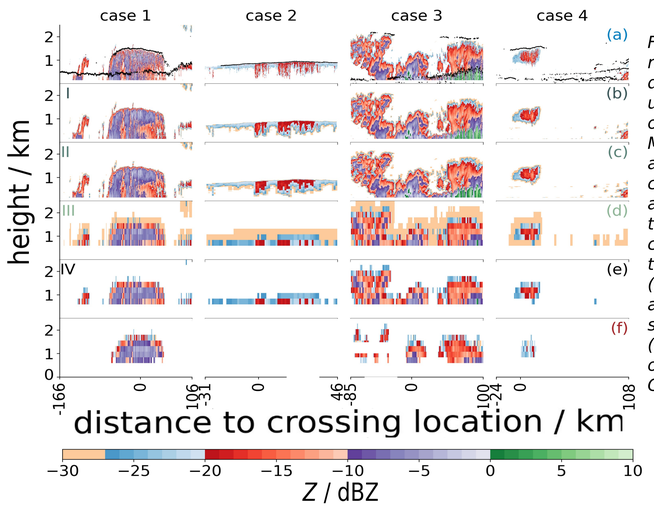

Fig. 1: Profiles of radar reflectivity (Z) during 4 underflights as obtained from MiRAC (a), after along-track convolution (I; b), additional along-track integration (II; c), further along-track convolution (III; d), after applying a sensitivity threshold (IV; e), and as obtained from CloudSat (f).

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ABSTRACT

4. Results and conclusions

- **Above CloudSat's blind zone** (1 km) **and below 2.5 km**, simulations reveal that CloudSat would
  - overestimate MiRAC cloud fraction by 6 percent points (pp) due to its **horizontal resolution** (Fig. 2a; MiRAC→II),
  - overestimate it by 12 pp due to its **range resolution** (II→III),
  - underestimate it by 10 pp due to its **sensitivity** (III→IV).
  - In total, CloudSat would **overestimate** MiRAC cloud fraction (Fig. 2d).
- CloudSat's **blind zone** misses a cloud fraction of 32 % (Fig. 2a) and half of the total (mainly light) precipitation.
- CloudSat's limitations depend on cloud fraction and shape of the profile rather than season (Fig. 2e).
- Especially during **cold air outbreaks over open water**, clouds below 1.5 km are stretched by CloudSat's pulse length that increases the simulated cloud fraction compared to MIRAC by 16 pp (Fig. 3a, c).
  Cold air outbreaks affect the profiles over different surfaces (Fig. 2c, f) and circulation weather types (Fig. 3b, d).

CloudSat's relatively coarse spatial resolution, low sensitivity, and blind zone limit its assessment of Arctic low-level clouds. These limitations depend on synoptic and surface conditions.

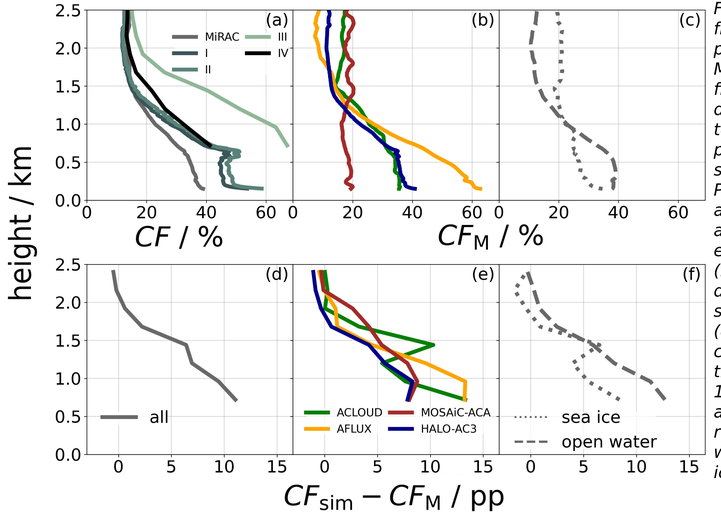

Fig. 2: Cloud fraction profiles from MiRAC (CF_M; first row) and difference to simulated profiles (CF_{sim}; second row). Profiles are averaged over all data (a, d), each campaign (b, e), and different surface covers (c,f). Sea ice concentrations below 15 % and above 90 % represent open water and sea ice.

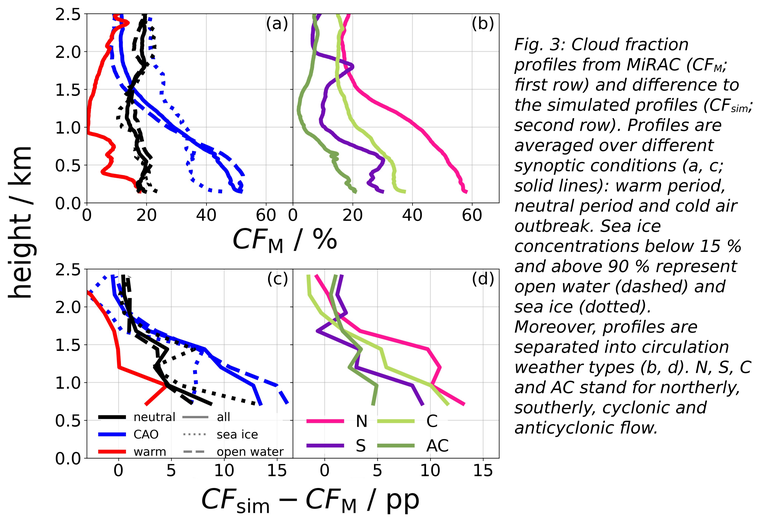

Fig. 3: Cloud fraction profiles from MiRAC (CF_M; first row) and difference to the simulated profiles (CF_{sim}; second row). Profiles are averaged over different synoptic conditions (a, c; solid lines): warm period, neutral period and cold air outbreak. Sea ice concentrations below 15 % and above 90 % represent open water (dashed) and sea ice (dotted). Moreover, profiles are separated into circulation weather types (b, d). N, S, C and AC stand for northerly, southerly, cyclonic and anticyclonic flow.