Statistics on clouds and their relation to thermodynamic conditions at Ny-Ålesund using sensor synergy

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1. Abstract

Cloud formation strongly depends on meteorological conditions that have pronounced seasonality in the Arctic. High occurrence of temperature and humidity inversions over the Arctic can provide additional moisture for clouds and have a strong impact on cloud lifecycle and precipitation efficiency. This study presents statistics of clouds (pure ice, liquid and mixed-phase) at the AWIPEV observatory at Ny-Ålesund (Svalbard, Norway) where a novel 94 GHz cloud radar has been operating since June 2016. The atmospheric conditions under which clouds form and develop at Ny-Ålesund are analyzed. Such a dataset can be also used for NWP model evaluation. As an example, a comparison to the global NWP model ICON is shown.

2. Characterization of the atmospheric conditions

Temperature and humidity are key factors for cloud formation and development

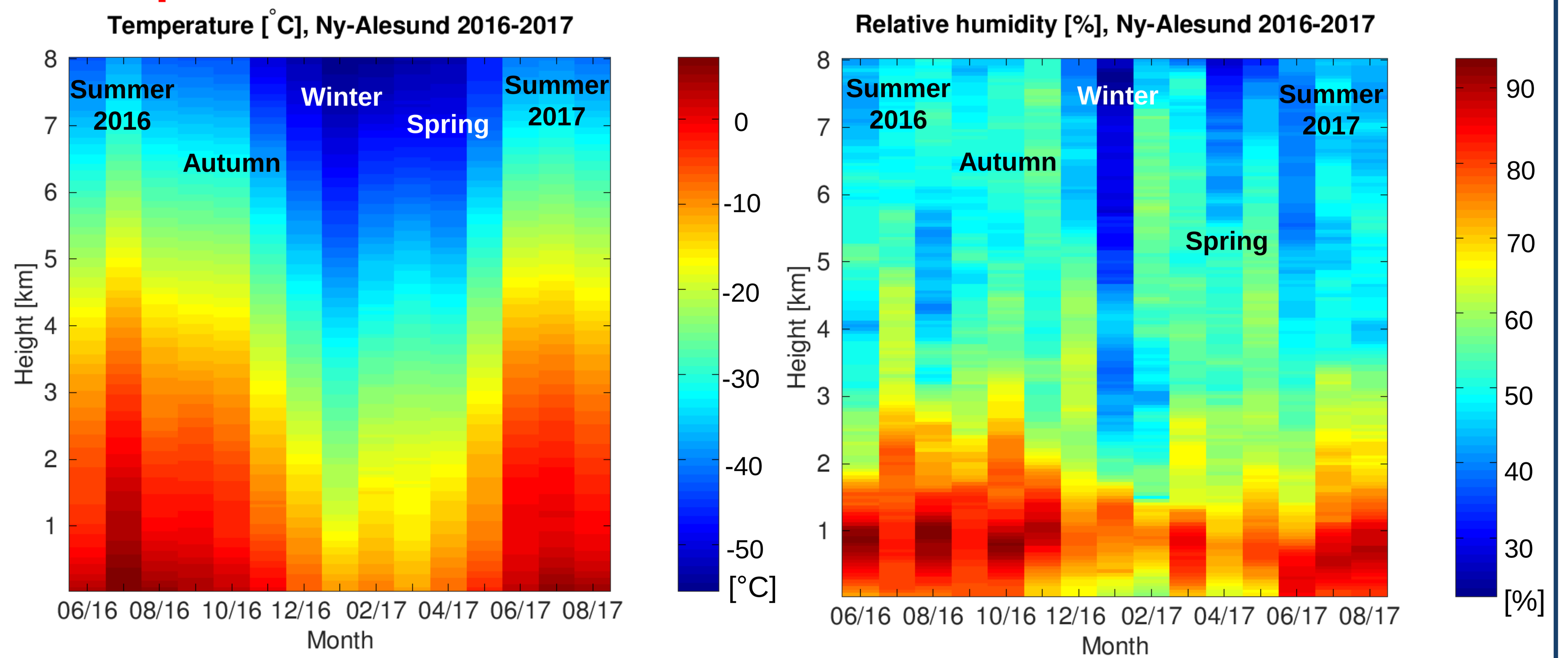

Fig. 1: Annual cycle of tropospheric temperature (left) and relative humidity (right) from radiosonde observations at Ny-Ålesund from June 2016 to August 2017.

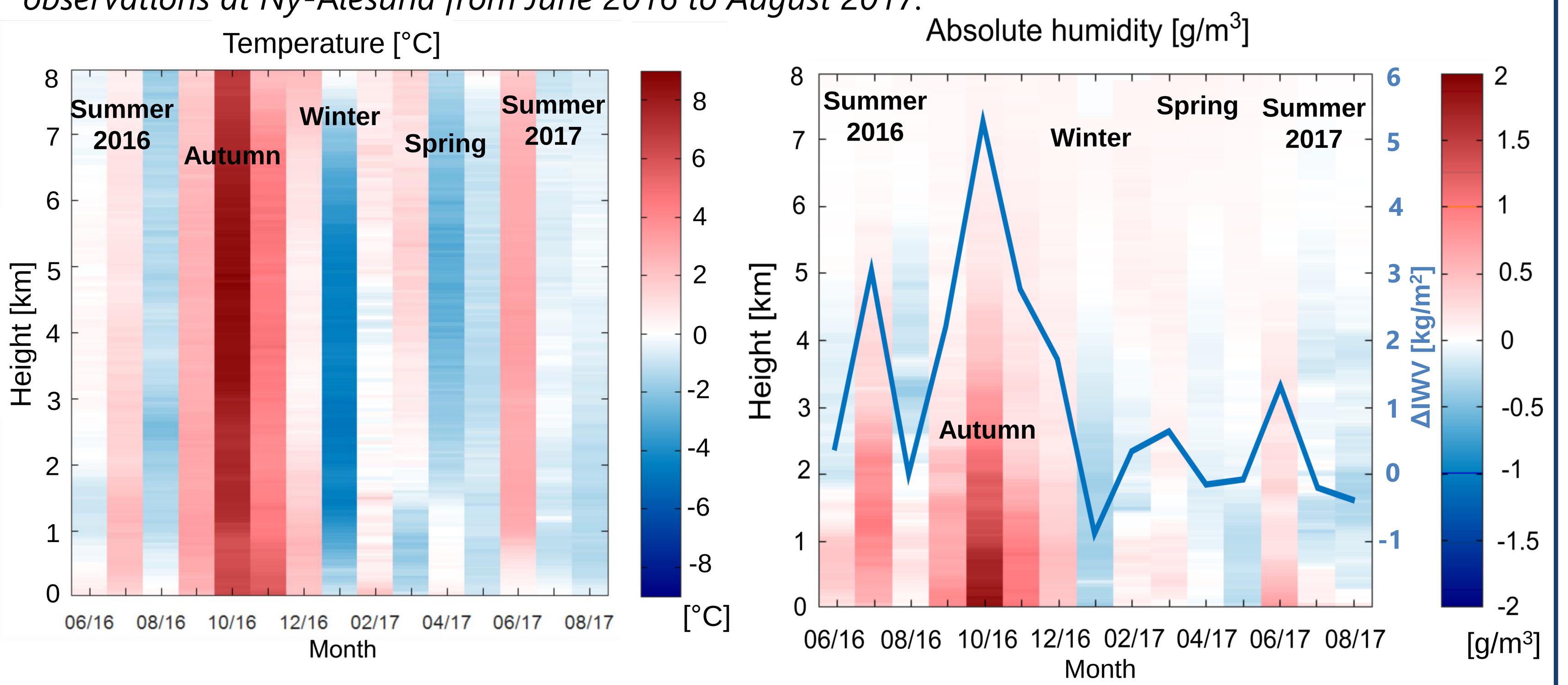

Fig. 2: Anomalies of tropospheric temperature (left) and absolute humidity (right) from radiosonde observations at Ny-Ålesund from 2016 to 2017 compared with the previous 23 years homogenized radiosonde dataset (1993-2015) [1]. Blue line corresponds to the IWV anomaly for the same time period.

References:

1. M. Maturilli, M. Kayser, 2016: Arctic warming, moisture increase and circulation changes observed in the Ny-Ålesund homogenized radiosonde record, Theoretical and Applied Climatology, doi: 10.1007/s00704-016-1864-0.
2. A. Illingworth, R. Hogan, E. O'Connor, and D. Bouniol, 2007: Cloudnet, Bulletin of the American Meteorological Society, 88(6), 883.

3. Vertical occurrence of hydrometeors

Cloudnet categorization [2] was used to vertically characterize hydrometeors at Ny-Ålesund.

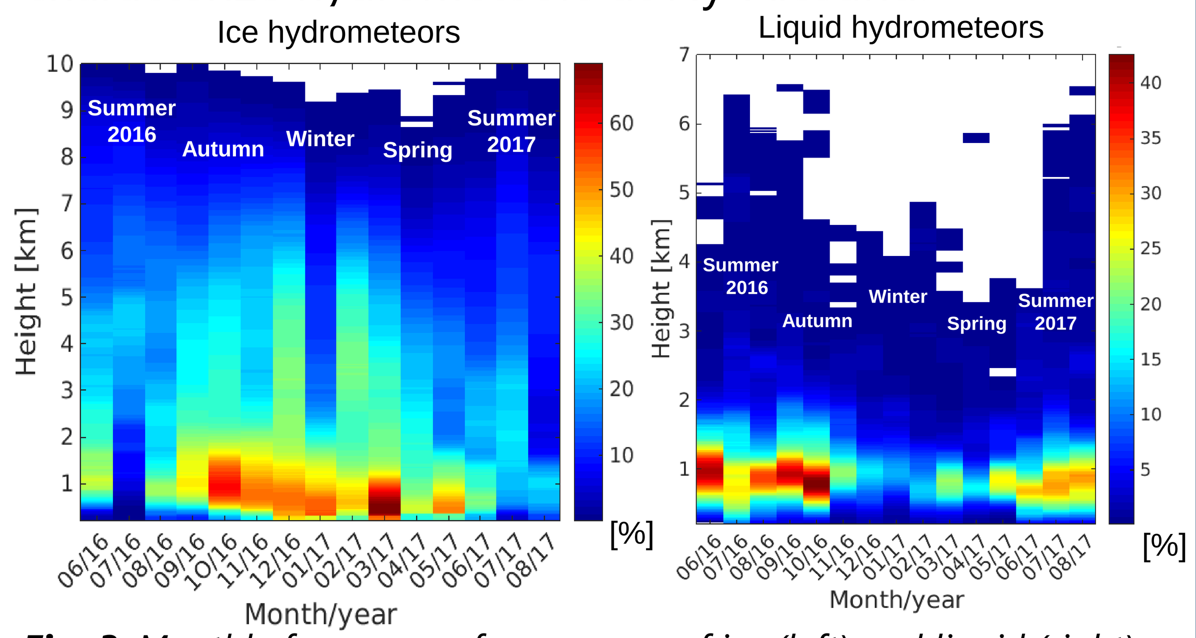

Fig. 3: Monthly frequency of occurrence of ice (left) and liquid (right) hydrometeors as a function of height. Frequency of occurrence is normalized to the total number of Cloudnet profiles for each month.

- Ice and liquid mostly occur in the lowest 2 km with a max. at 40% and 25%, respectively, at 800 m (whole time period).
- Almost no liquid at heights > 3km.
- High occurrence of liquid and ice in October (>50%) which is connected to high temperature and humidity this month.

4. Occurrence of cloud types

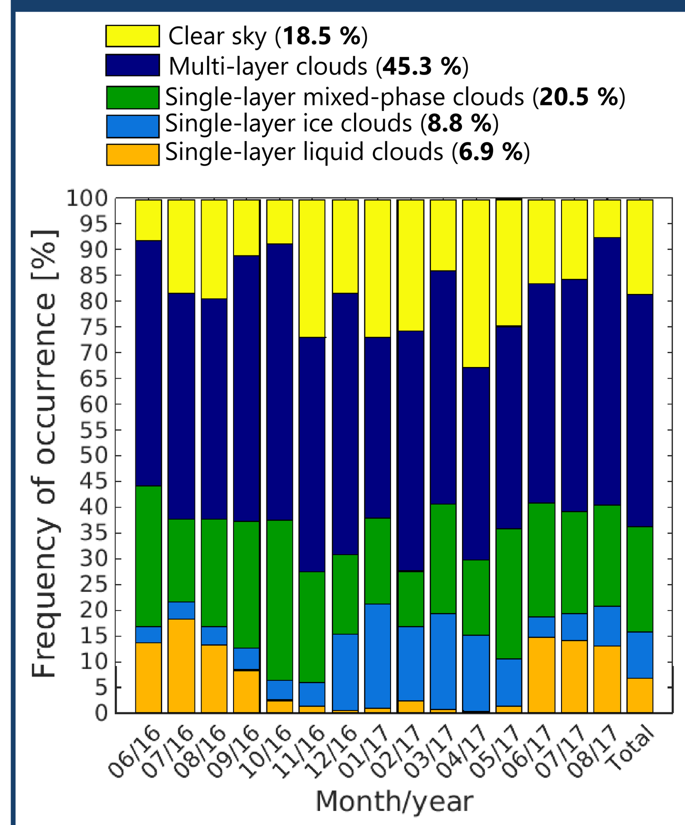

Fig. 4: Monthly frequency of occurrence of cloud types from June 2016 to August 2017.

- More multi-layer (**45.3%**) than single-layer clouds (**36.2%**)
- **Single-layer liquid**:
  - often in summer (**10-18%**)
  - rare in winter (**3%**)
- **Single-layer ice**:
  - rare in summer and autumn (**3-8%**)
  - often in winter (**15-22%**)
- High occurrence of **single-layer mixed-phase** clouds in October (**30%**)

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We gratefully acknowledge DWD service for providing the data of the global NWP ICON model.

5. Microphysical properties of single-layer clouds

Observations

Cloud type	Median (mean) LWP [g/m²]	Median (mean) IWP [g/m²]	Mean cloud geometrical thickness [m]
Liquid	10 (30)	-	300
Ice	-	4.7 (110)	1200
Mixed-phase	32 (68)	6.9 (58)	1500

Higher LWP in mixed-phase clouds

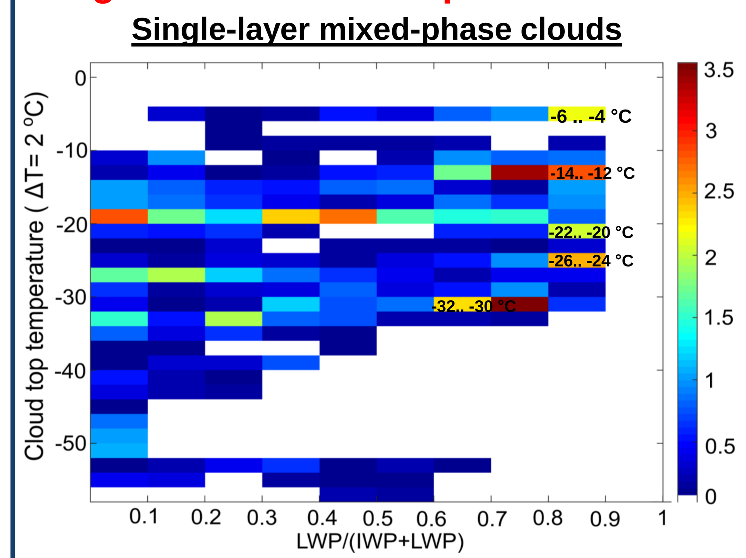

Fig. 5: Two-dimensional histogram of liquid fraction as a function of cloud top temperature for observed mixed-phase clouds.

Global NWP ICON model

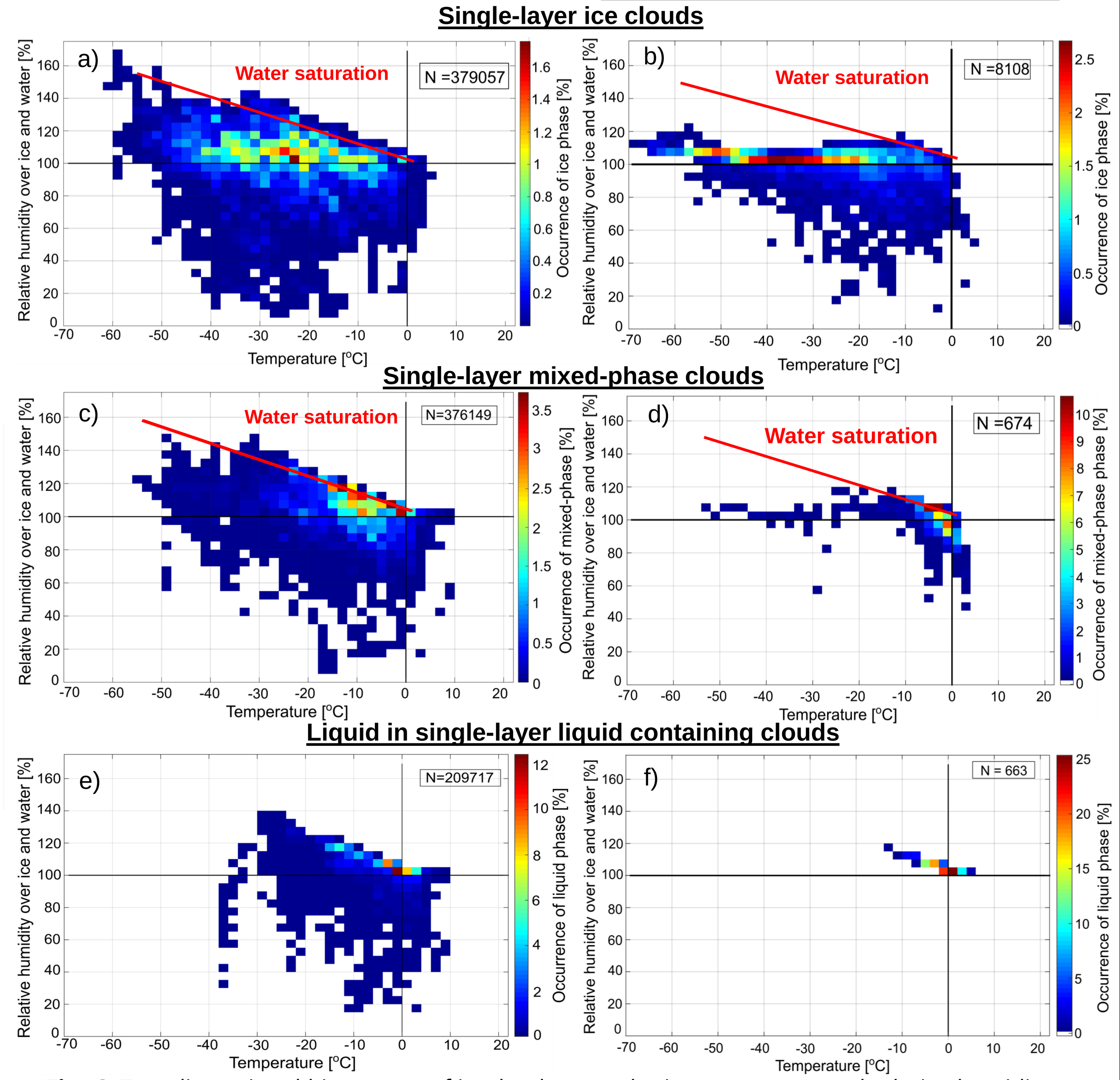

Fig. 6: Two-dimensional histograms of in-cloud atmospheric temperature and relative humidity (over ice and water) for observations (a),(c),(e) and global NWP ICON model (b),(d),(f). Distributions for observations include cases within of 1 hour before and after a radiosonde launch.

Observations

- Liquid clouds are typically thin.
- Most liquid in mixed-phase clouds with relatively high LWP/TWP occur at CTT from -24…4 °C (Fig.5).
- Lower LWP/TWP ratios are shifted to smaller CTTs (Fig.5).
- Almost no liquid at CTT<-35 °C (Fig.5).
- Liquid fraction of 0.4 to 0.5 is frequent at -20..-18 °C and rare at CTT<-34 °C (Fig.5).
- Ice clouds mostly occur below water saturation line (Fig.6a).
- Mixed-phase clouds occur near water saturation as well as at supersaturation with respect to ice at T_{obs}= **-24..+6 °C** (Fig.6c).
- Liquid mostly occurs near water saturation at T_{obs}= **-28..+6 °C** (Fig.6e).
- Supercooled liquid observed at **-38 °C** while pure liquid clouds limited by T< **-30 °C** (Fig.6e).
- Three most common temperature ranges for cloud observations **-22..-26 °C (ice)**, **-14..-12 °C** (**mixed-phase**) and **-2..0 °C** (**liquid**) (Fig.7, left).

Single-layer clouds

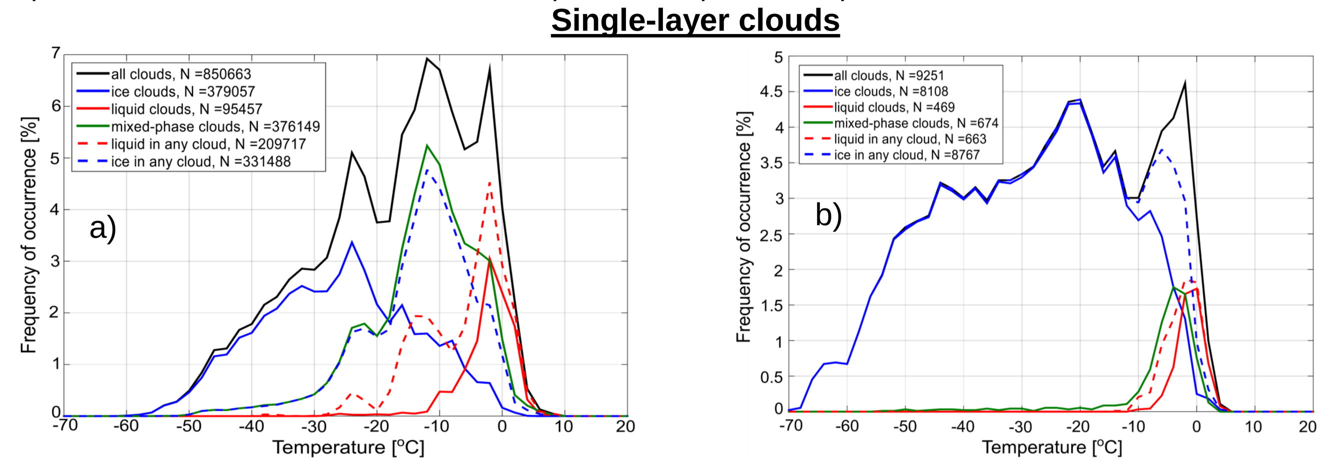

Fig. 7: Distributions of in-cloud atmospheric temperature for different types of single-layer clouds, liquid and ice phase for observations (a) and global NWP ICON model (b).

Global NWP ICON model

- A broad T range for ice clouds starting at T<**-70 °C** at which clouds were not observed (Fig.6b).
- Narrow T range for mixed-phase clouds (Fig.6c).
- Mixed-phase clouds occur near water saturation as well as at supersaturation with respect to ice at T_{icon}= **-12..+6 °C** (Fig.6d).
- Mostly liquid occurs near water saturation at T_{icon}= **-10..+6 °C** (Fig.6f).
- Seems to the global ICON NWP model underestimate conditions for mixed-phase clouds (Fig.7, right).

6. Outlook

- Comparison of LWP, IWP statistics from observations with global ICON NWP model.
- Retrieving cloud microphysical properties (LWC, r_{eff}, IWC, D_{mean}) and their analysis.

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