# Characterization of the cloud conditions at Ny-Ålesund using sensor synergy and representativeness across Arctic sites

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## 1. Abstract

Clouds are one of the crucial components of the hydrological and energy cycle and thus affecting the global climate. Their special importance in Arctic regions is defined by cloud's influence on the radiation budget. This study presents a first analysis of clouds properties at Ny-Ålesund including cloud occurrence, cloud geometry (cloud base, cloud top, and thickness) and cloud type (liquid, ice, mixed-phase) (Svalbard, Norway).

## 2. Instrumentation and products

| Instrument | Specification | Observations |
|---|---|---|
| Radiosonde | Dataset of 10 years, RS92 since 2007, RS41 after 1 April 2017 | Temperature, pressure, humidity, and wind profiles |
| Microwave radiometer (passive instrument) | 22.24 – 31.4 GHz, 51.0 – 58.0 GHz Temporal resolution ~ 1 s | Continues temperature, humidity profiles, LWP, IWV |
| Ceilometer CL51 (active instrument) | Max range 15 km, range resolution 10 m Temp. resolution 6-120s, wavelength 910 nm | Cloud base, detection of supercooled liquid |
| 94 GHz FM-CW Cloud radar (active instrument) | range resolution up to 10 m, Doppler resolution ~1cm/s, passive channel at 89 GHz, since June 2016 | Cloud geometry, cloud microphysics |

Cloudnet retrievals

The Cloudnet categorization ([1], see example in Fig.6) is used to find profiles of different types of clouds at Ny-Ålesund.

The total number of available profiles between June 2016 and August 2017 is 1,209,303 (288,853 clear sky, 920,450 cloudy).

Clouds in general were present ~70 % of the time.

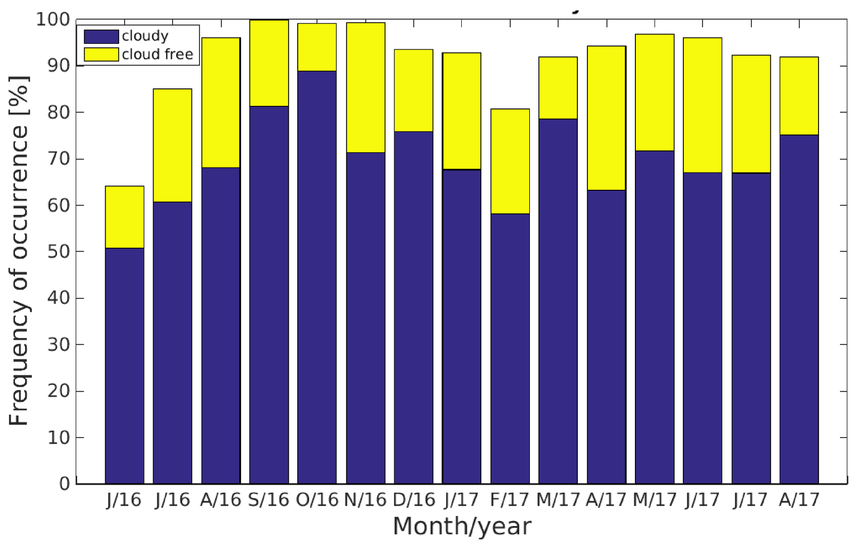


*Fig. 1: Cloudnet availability*

## 3. Cloud statistics at Ny-Ålesund

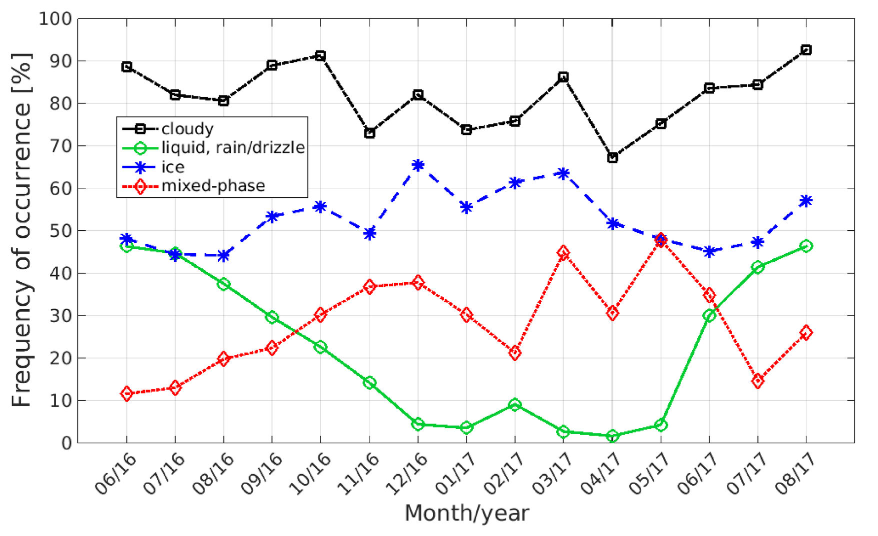


*Fig. 2: Frequency of occurrence of ice, liquid, mixed-phase and any hydrometeors in an atmospheric column based on Cloudnet categorization data.*

The phase of the clouds significantly influences the radiative forcing -> analysis of different types of clouds.

- Ice was present ~60 % of the time.
- Liquid phase occurred ~50 % during summer time mostly due to precipitation and <5 % in winter.
- Mixed-phase was present ~30 % with max 50 % and 45 % in May 2017 and March 2017 (the coldest month), respectively.

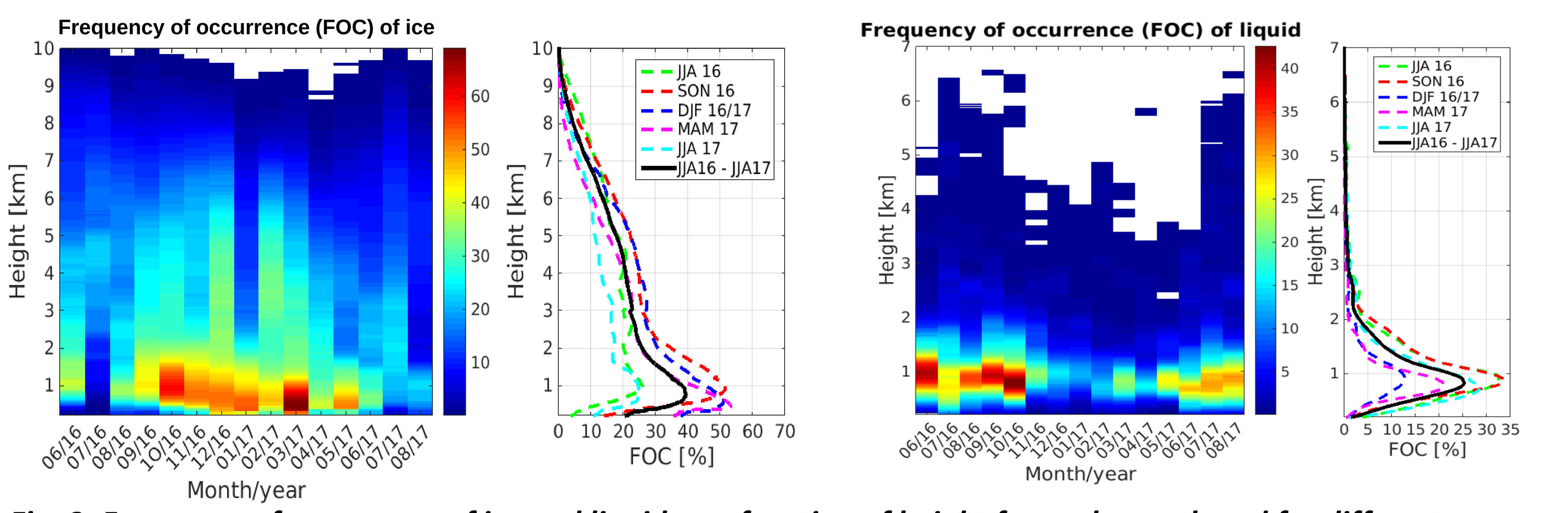


*Fig. 3: Frequency of occurrence of ice and liquid as a function of height for each month and for different seasons. White areas correspond to cases where clouds are not present.*

- Occurrence of clouds in general is largest in lowest 2 km (more than 70% in October 2016 and March 2017).
- Presence of ice is highest during autumn and winter with max >70 % in March 2017 at 800 m, lowest in January 2017 above 2 km;
- Occurrence of liquid was larger in summer and fall in 2016 than in 2017, with max >45 % for June, August-October 2016 and 25 % for July 2016.
- Occurrence of multilayer clouds is more than twice larger than single layer clouds;
- Multilayer liquid and mixed-phase cases are likely to be underestimated due to the attenuation ceilometer signal in the first liquid layer.

Single layer ice containing clouds

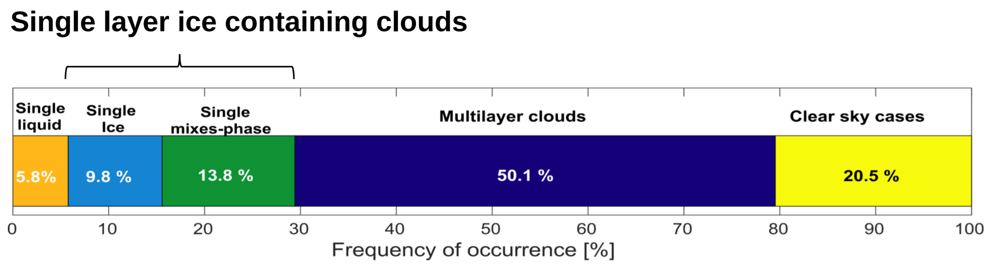


*Fig. 4: Total frequency of occurrence of different types of clouds for the whole period from June 2016 to August 2017.*

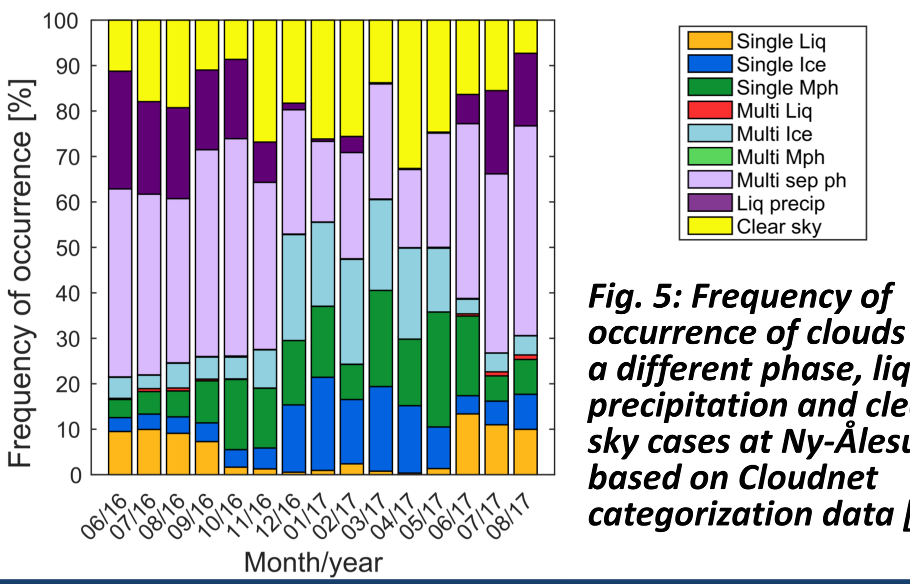


*Fig. 5: Frequency of occurrence of clouds with a different phase, liquid precipitation and clear sky cases at Ny-Ålesund based on Cloudnet categorization data [1].*

## 4. Cloudnet classification

As a first step, all non-precipitating single-layer clouds were chosen for futher analysis.

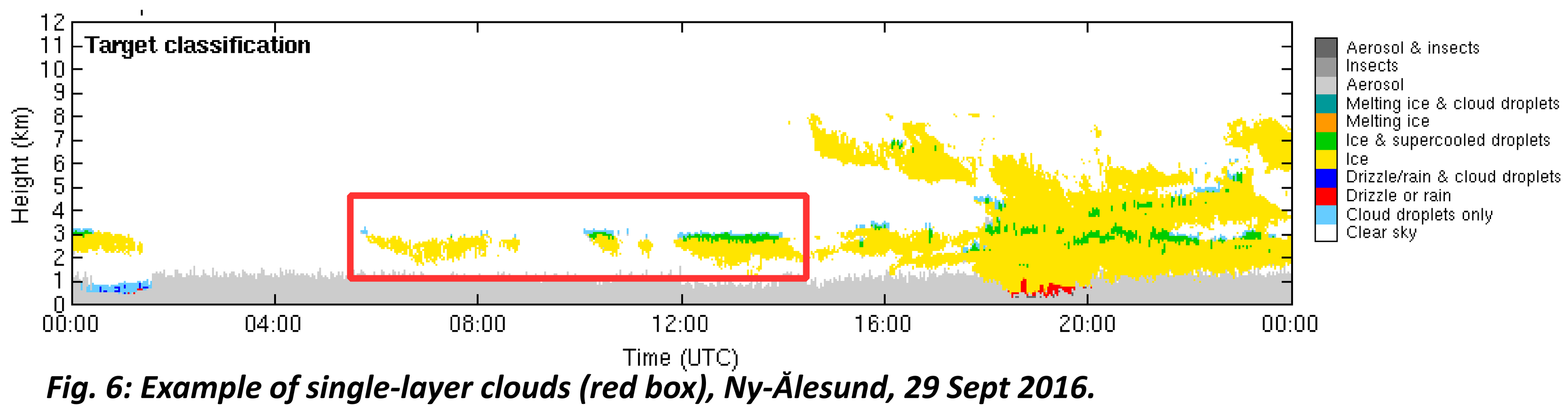


*Fig. 6: Example of single-layer clouds (red box), Ny-Ålesund, 29 Sept 2016.*

## 5. Single layer cloud macrophysical properties

- Mean cloud base height on average for single layer ice clouds is ~3 km, liquid and mixed phase clouds ~1.5 km.
- Liquid single layer clouds occur at the lowest 2 km and are very thin with median values of ~200 m.
- For ice and mixed-phase single layer clouds mean cloud tops are ~4 km and ~2 km, mean cloud bases ~2.5 km and 1.5 km, respectively.

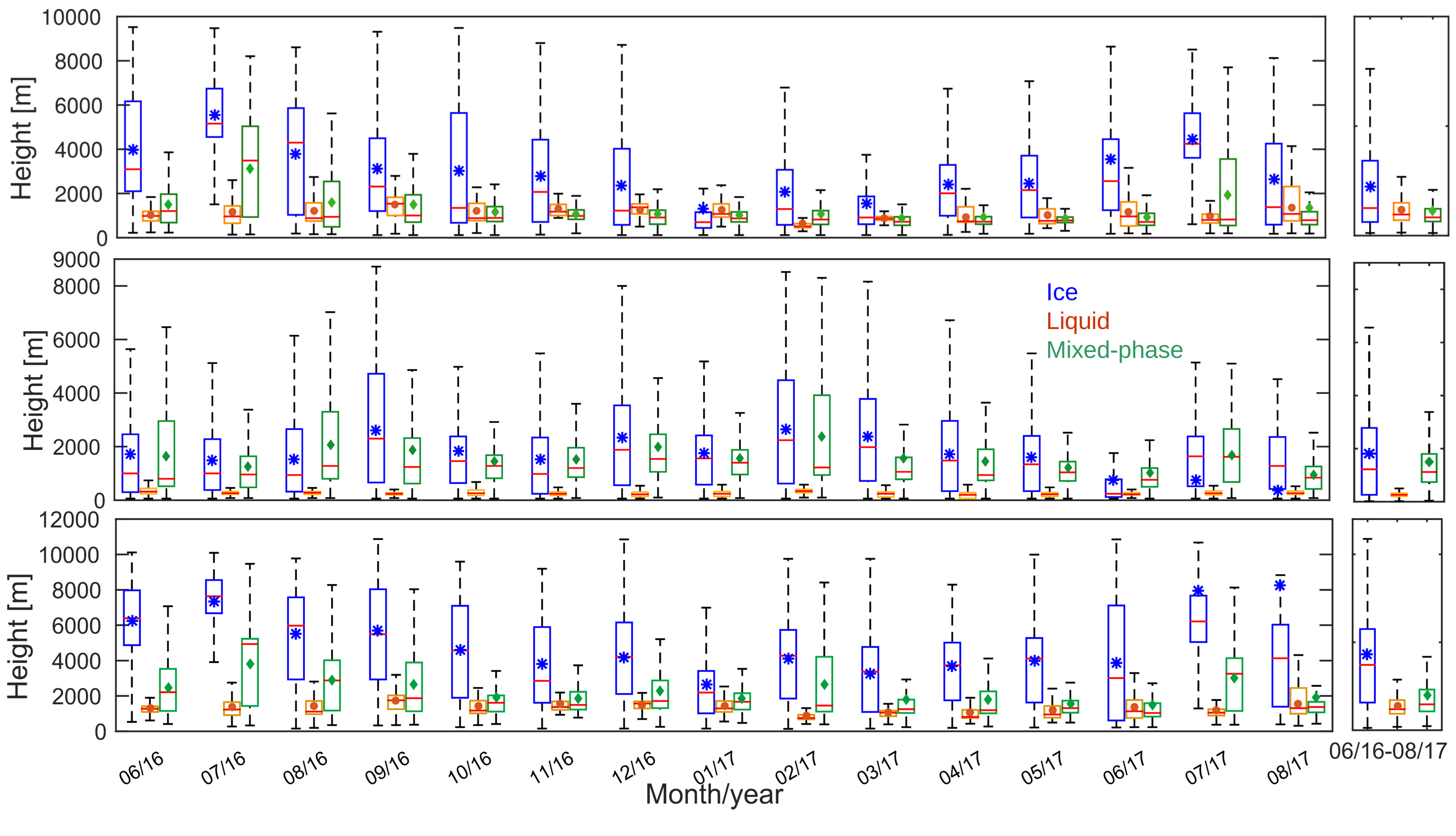


*Fig. 7: Cloud base height (upper panel), cloud thickness (middle panel) and cloud top (lower panel) for different types of single layer clouds. Mean values are shown as symbols. Boxes (blue – ice, orange – liquid, green – mixed-phase clouds) and whiskers diagrams include the median (red line in a bar), 25th and 75th percentiles (end of box), 5th and 95th percentiles (end of whiskers). Mean total cloud base height, cloud thickness and top for the whole period is shown in the right columns, respectively.*

## 6. Summary and Outlook

- Preliminary analysis of occurrence of clouds with different phase at Ny-Ålesund
- 15 month period gives an overview on seasonal and monthly variability of clouds at Ny-Ålesund.
- Clouds were present ~ 70% of the time with ~50 % multilayer clouds and ~ 20% single layer clouds.
- Cloud occurrence decreases with height with a max of ~70 % at 2 km (October 2016 and March 2017).
  1. Cloud microphysical properties of single layer ice and mixed-phase clouds exhibit a high month-to-month variability.
  2. Single layer liquid clouds were very thin (median ~200 m) and less variable throughout the year.
- LWP and IWP analysis will be done as a next step.
- Representativeness across other Arctic sites will be analyzed.

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*References:*

*[1] A. Illingworth, R. Hogan, E. O'Connor, and D. Bouniol, Cloudnet, 200: Bulletin of the American Meteorological Society, 88(6), 883 (2007).*