Cloud vertical structure studied with synergtic measurements of Radiosonde, ceilometer and Ka-band radar in Munich

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Outline

- Instruments: miraMACS, YALIS, and radiosonde;
- Relative humidity with respect to ice derived with radiosonde and compared with miraMACS;
- Cloud base heights compared between the simultaneous obs. with radiosonde and YALIS;
- Statistics of cloud layers and their thicknesses with radiosonde data in 2018;
- Summary;

MIRA-35 Cloud radar and YALIS CHM15kx ceilometer at MIM

- ⇒ Millimeter cloud radar (35 GHz, 30 kw)
- ⇒ Range res.: 60m, max: 30 km
- ⇒ 1-meter antenna with 0.6 ° beam width
- ⇒ Linear depolarization ratio LDR.

- ⇒ Single-wavelength lidar at 1064 nm
- ⇒ Range res.: 5-15 m, max: 15.30 km
- ⇒ Bandwidth: 0.1 nm, laser power: 50 mW
- ⇒ Pulse repetition rate: 5-7 kHz.

Radiosonde at Oberschleißheim, 15 km away from Munich

Relative humidity with respect to ice from Radiosonde

To care for saturation effects in the troposphere, saturated regions are identified with the method described by Zhang et al. [2010]. A layer is regarded as saturated, if the relative humidity exceeds an altitude-dependent threshold RH_{min} within the whole layer and if additionally somewhere within the layer $RH \geq RH_{\mathrm{max}}$. The thresholds RH_{min} and RH_{max} are piecewise linear functions of altitude defined by Zhang et al. [2010]. As the relative humidity of radiosondes is computed with respect to liquid water, it is corrected for $T < 0\,°\mathrm{C}$. To this end, RH is multiplied by the ratio $e_{\mathrm{w}}/e_{\mathrm{i}}$ of the saturation pressure of water vapour over liquid water e_{w} and over ice e_{i}. e_{i} is estimated by the empirical expression

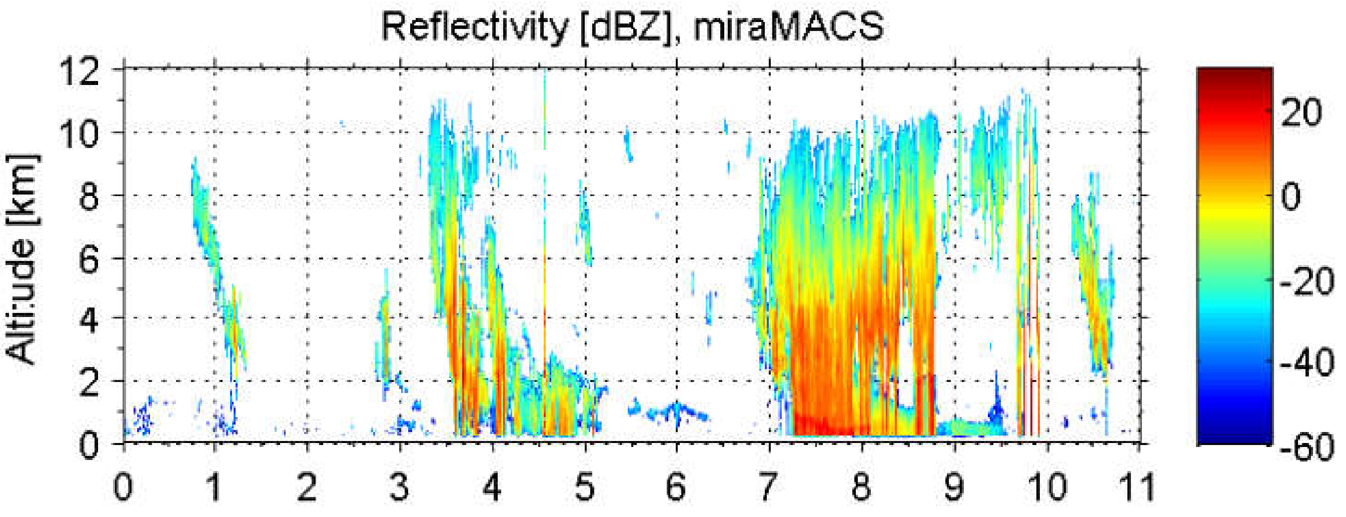
$$e_{\mathrm{i}} = \frac{1\,\mathrm{hPa}}{100} \exp\left(28.9074 - \frac{6143.7\,\mathrm{K}}{T}\right) \tag{4.10}$$

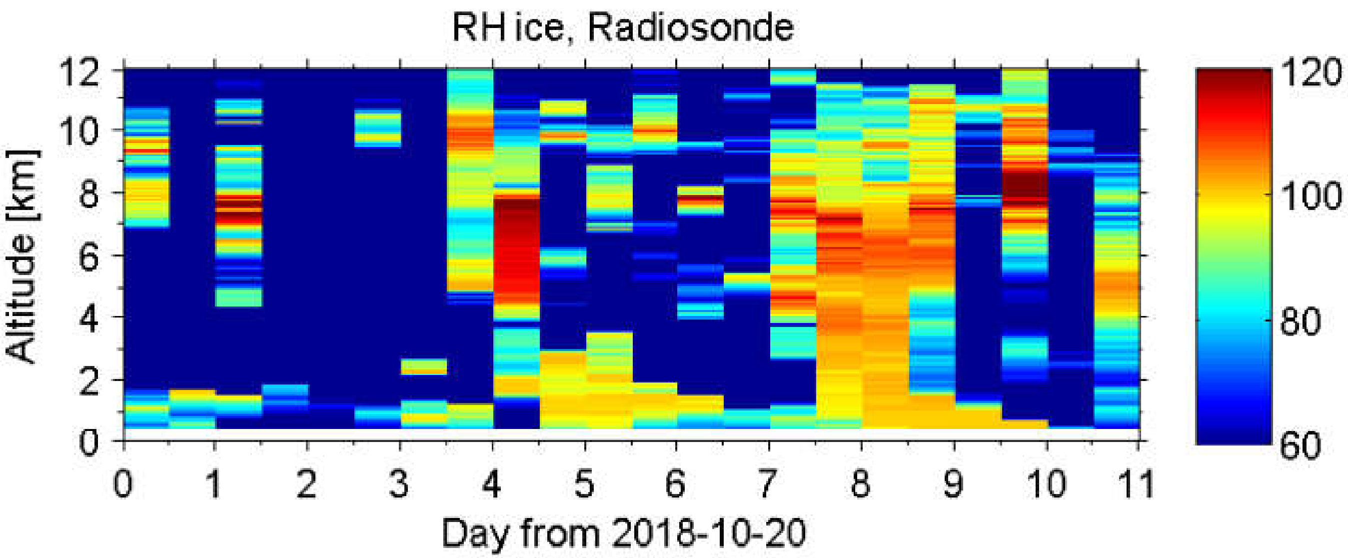
[Murphy and Koop, 2005, (2); Wilson et al., 2013, (9)], and e_{w} by the WMO recommended formula[1]

$$\begin{aligned} \log_{10} e_{\mathrm{w}} = {} & 10.79574\,(1 - 273.16\,\mathrm{K}/T) - 5.02800 \log_{10}(T/273.16\,\mathrm{K}) \\ & + 1.50475 \cdot 10^{-4}\,(1 - 10^{-8.2969(T/273.16\,\mathrm{K}-1)}) \\ & + 0.42873 \cdot 10^{-3}\,(10^{4.76955(1-273.16\,\mathrm{K}/T)} - 1) \\ & - 2.2195768 + \log_{10}(1013.25) \end{aligned} \tag{4.11}$$

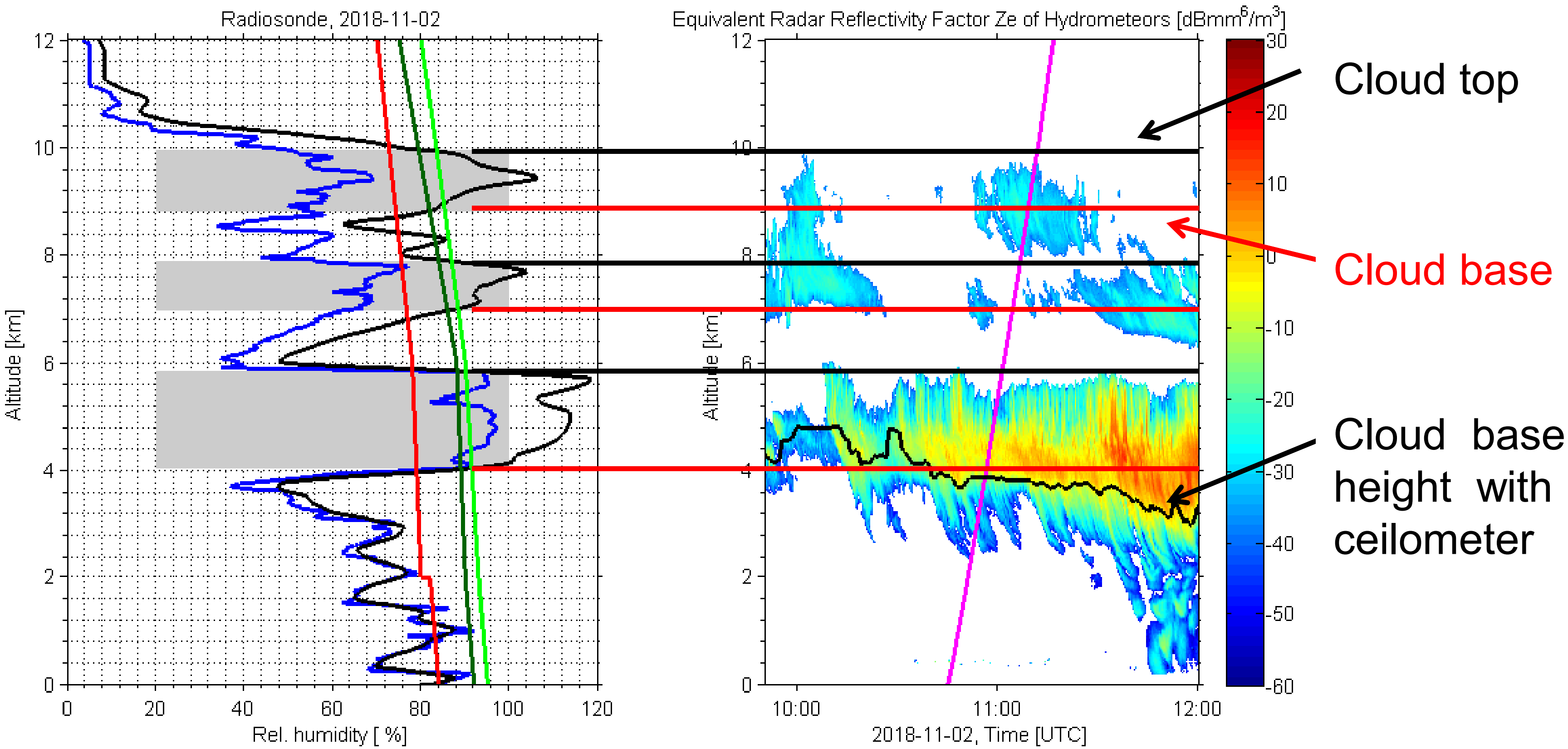
[Goff, 1957, (6)], where e_{w} and e_{i} are in Hectopascal.

Comparison: Reflectivity (radar) and relative humidity (ice)



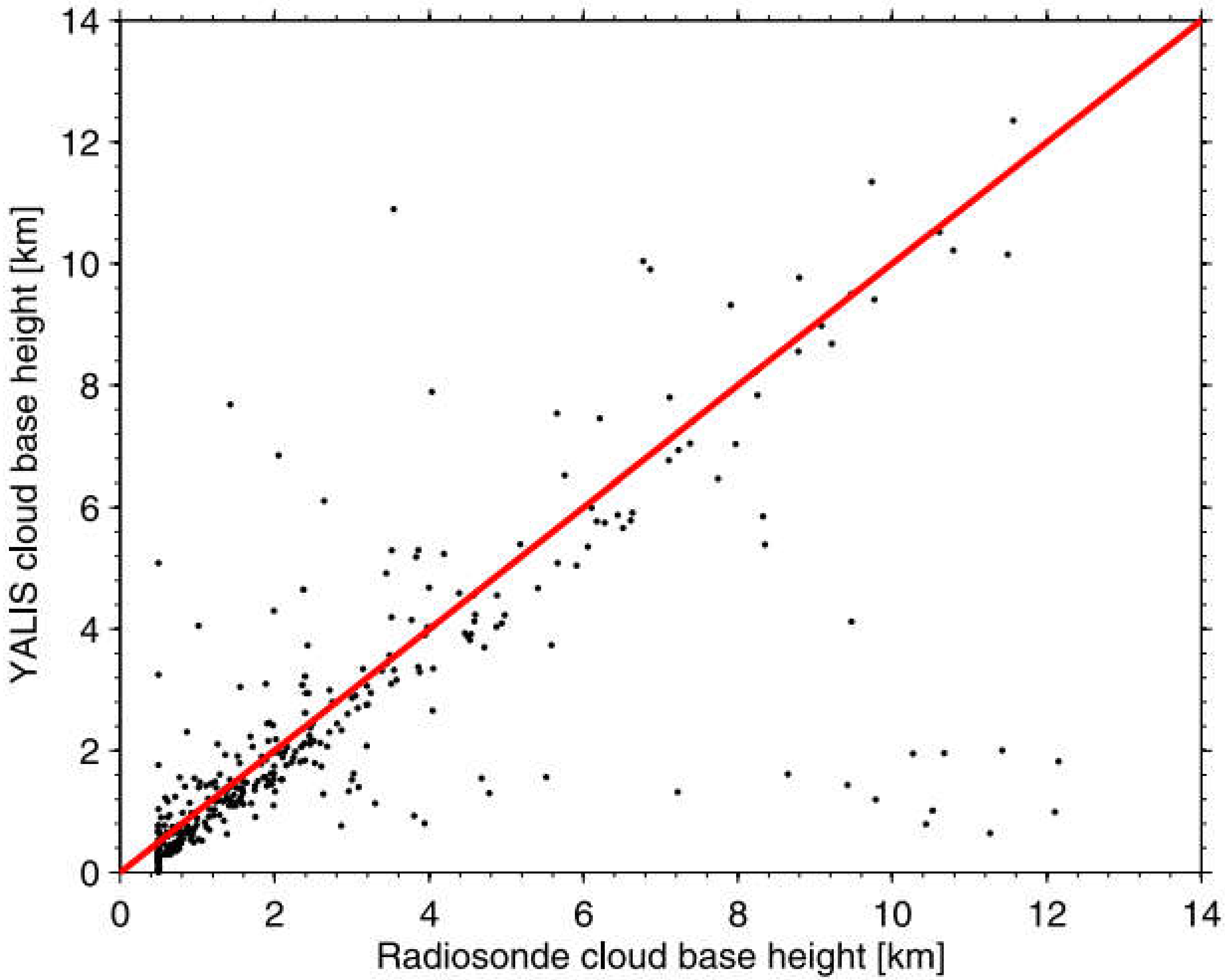


Cloud layer comparison with cloud radar and radiosonde



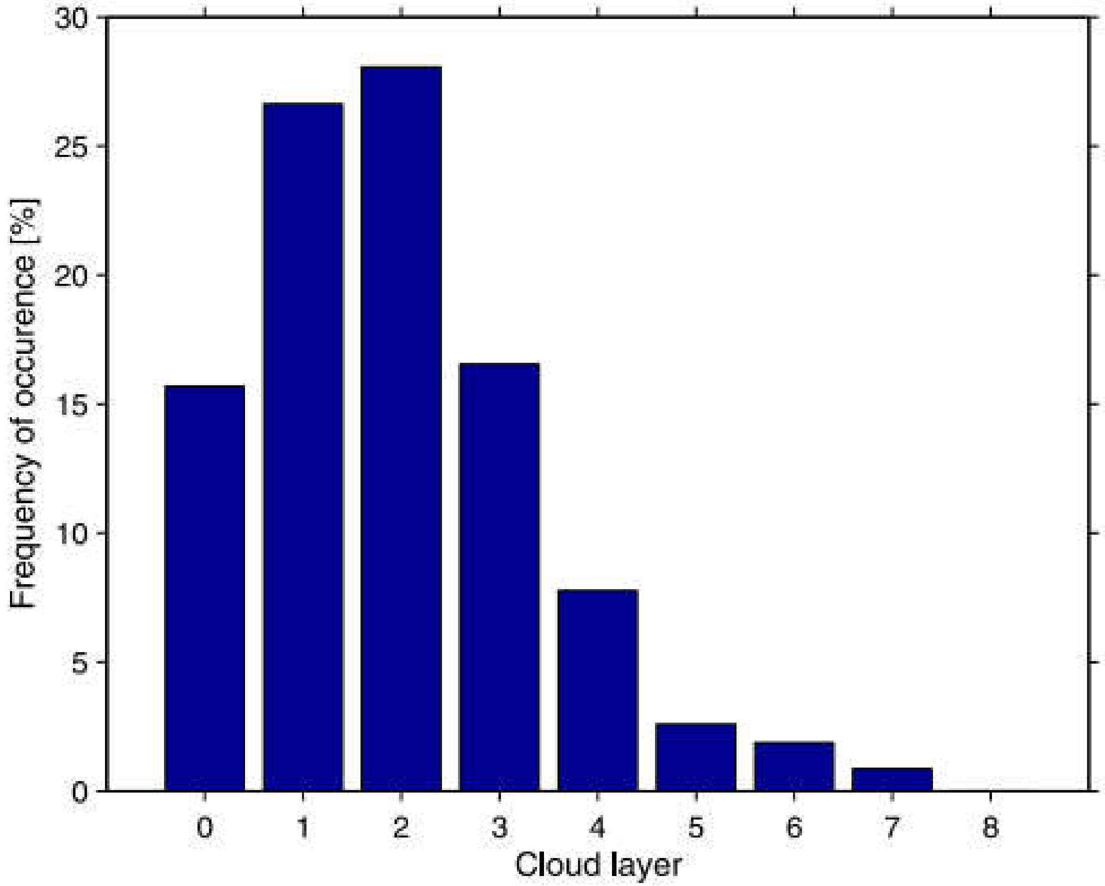
⇒ The three-layer clouds determined with radiosonde in term of relative humidity with respect to ice are in good agreement with the miraMACS results

Cloud base height comparison with YALIS and radiosonde



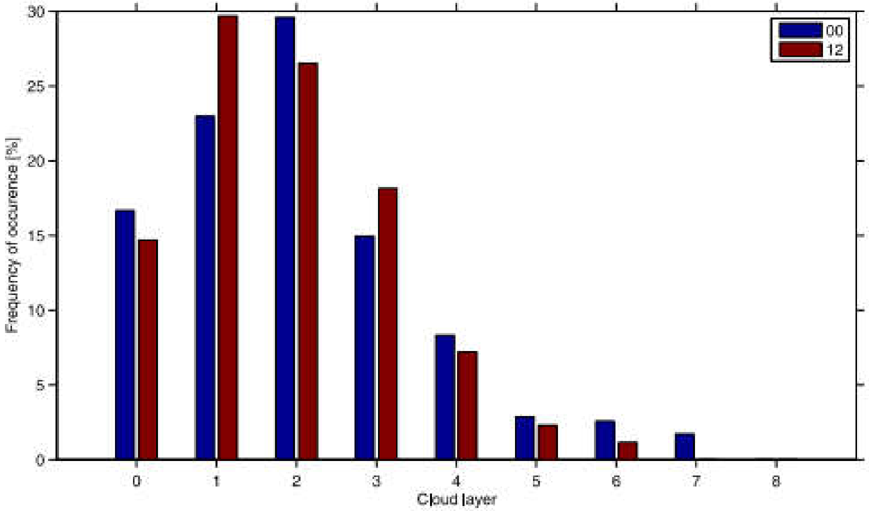
⇒ An overall agreement between the cloud base height is reached from both instruments with a correlation coefficients of 0.73.

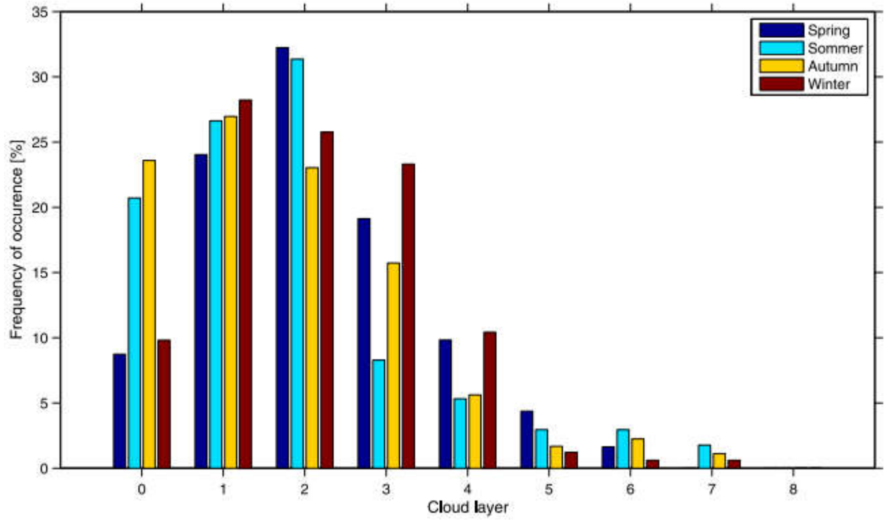
Distribution of cloud layers derived with radiosonde in 2018



⇒ From one-year Radiosonde measurements of 2018, cloud-free cases and one to three cloud layers are 15.7%, 26.3%, 28.1%, and 16.6%, respectively. About 13.3% of all cases with more than three cloud layers.

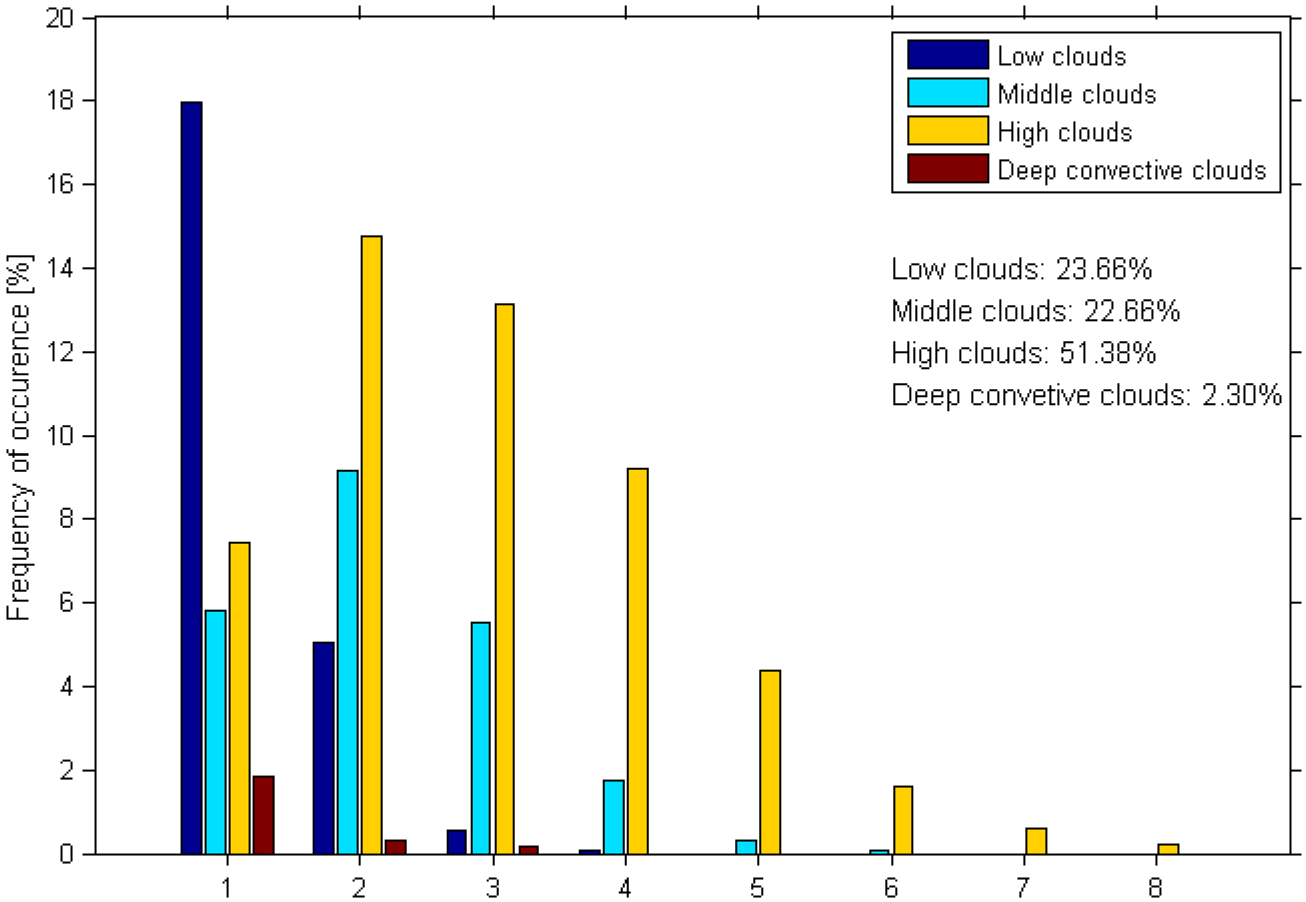
Daily and seasonal variations of cloud layers





⇒ There is no significant difference for cloud layers at noon or midnight;
⇒ For both the one-layer and two-layer clouds occurred most frequently.
⇒ Cloud-free cases occurred mostly in summer and autumn;
⇒ In spring and winter, clouds with more than two layers occurred more frequently.

Four types of clouds: High clouds occurred most frequently

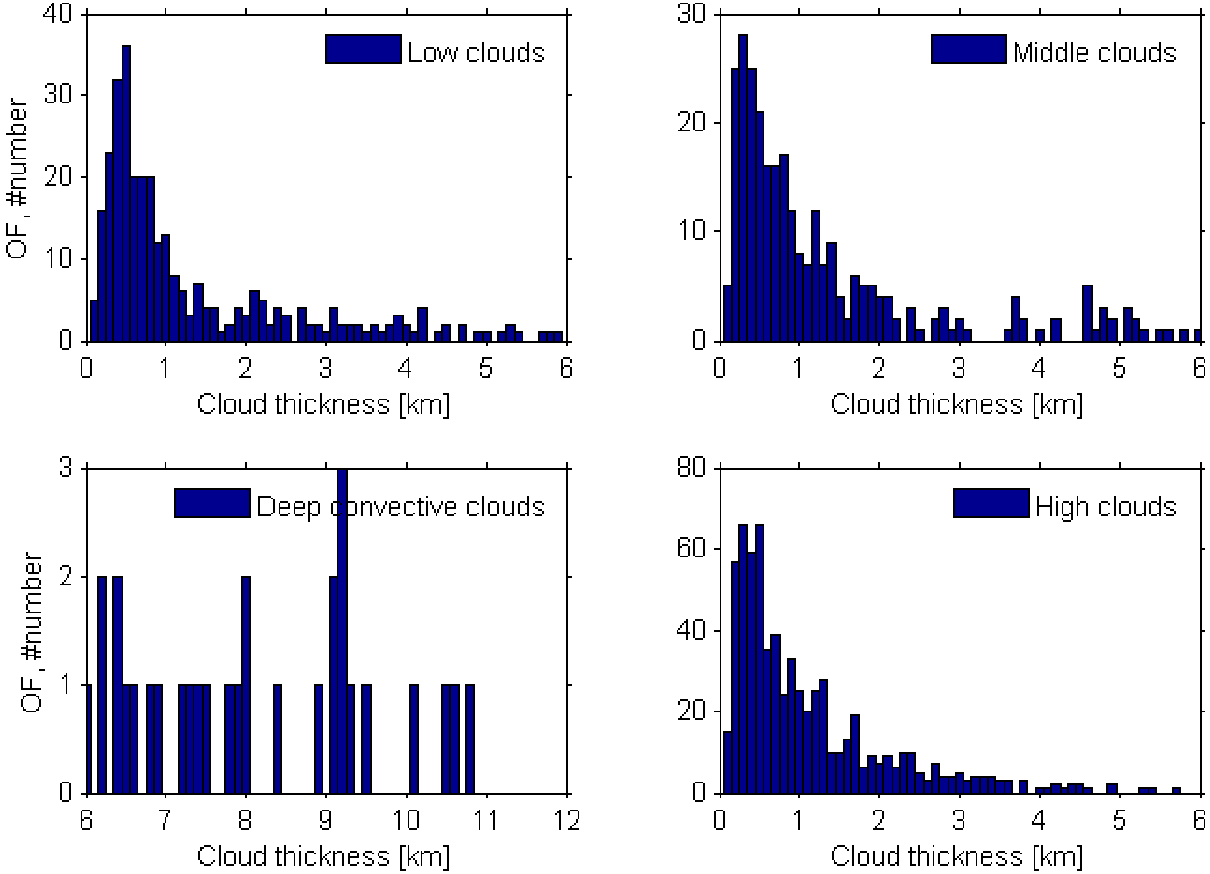


Low clouds: with base lower than 2 km and thickness less than 6 km;

Middle and high clouds: with base between 2-5 km and higher than 5 km, respec.;

Deep convective clouds: with base lower than 2km and thickness greater than 6km;

Four types of clouds: Middle clouds are thickest (ex. DCC)



⇒ Cloud layers with thickness <1.5 km occurred most frequently for all clouds;

⇒ The average of cloud thickness for low, middle, high and deep convective clouds are 1.31, 1.54, 1.10, and 8.10 km, respectively.

Summary

- Cloud layers determined with radiosonde are compared with the results of cloud radar, resulting in a good agreement;
- Cloud base height with radiosonde are compared with ceilometer results;
- Based on one-year radiosonde measurements, the statistics of cloud layer and their thickness are derived;
- From this study, one-layer and two-layer clouds occurred most frequently;
- High clouds occurred most frequently;
- For all clouds, the thicknesses are mostly < 1.5 km; except for deep convective clouds, middle clouds are thickest with average of 1.54 km.

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Thank you!

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Table 1. Summary of Height-Resolving RH Thresholds

	Height-Resolving RH Thresholds		
Altitude Range	min-RH	max-RH	inter-RH
0–2 km	92%–90%	95%–93%	84%–82%
2–6 km	90%–88%	93%–90%	80%–78%
6–12 km	88%–75%	90%–80%	78%–70%
>12 km	75%	80%	70%

Zhang et al., JGR 2010