Temperature profiles under cloudy conditions retrieved from Microwave Radiometers during the SOFOG3D experiment

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The SOuthwest FOg 3D experiment for processes studies (SOFOG3D), taking place in the south-west of France during the fall-winter period of 2019/2020, aims to deepen the understanding of fog physical processes in the Atmospheric Boundary Layer (ABL), by providing a 3D characterization of fog layer properties with a special focus on the role of fog microphysics. With the given insight into micro-physical processes, current parametrization schemes and forecasts of Numerical Weather Prediction (NWP) models may be improved. Generally, the upper atmosphere is well covered by satellite observations, but the ABL is difficult to observe with satellites due to obstruction from clouds and less suited weighting functions (Illingworth *et al*., 2019). This problem can be overcome with suited ground-based ABL profilers. In order to capture the dynamics, radiation and surface fluxes in the ABL, multiple networks of ground-based in-situ and remote sensing instruments have been set up for the SOFOG3D campaign. One of those networks consists of eight Microwave Radiometers (MWRs) over a domain of 300 x 200 km. MWRs passively measure the atmospheric brightness temperature (TB) spectra, obtained from naturally emitted downwelling radiance by the 22.24 GHz water vapour and 60 GHz O2 absorption lines. In order to retrieve temporally highly resolved profiles of humidity and temperature in the ABL, TBs have to be inverted with a suited retrieval algorithm.

This study will evaluate the impact of clouds on the performance of the microwave retrieval and specifically how the retrieval performs within clouds. Synthetic observations for two elevation scanning microwave radiometers, the Humidity and Temperature profiler (HATPRO, Rose *et al.*, 2005), which uses 14 frequency channels for profiling the troposphere, and the Meteorological Temperature Profiler-5 (MTP-5, Kadygrov 2015), which relies on one static frequency and is only suited for heights up to 1000 m, were created by forward modelling of TB spectra from the reanalysis of Cosmo-Rea2 (Bollmeyer *et al.,* 2015). The Cosmo-Rea2 reanalysis has a spatial resolution of 2 km and the forward model consists of a non-scattering radiative transfer model. Multi-variate regression retrievals for both MWRs were derived for SOFOG3D locations. Afterwards, the observations are split into three different cases, i.e. clear sky cases, cases with liquid clouds only and all sky conditions. Figure 1 shows the root-mean-square error (RMSE) between the retrieved temperature profile and the original temperature profile. In the lowest 1000m the HATPRO shows a slightly lower RMSE than the MTP-5 and with similar performance for all cases and better performance under clear sky conditions for both MWRs at higher altitudes. Next, the performance of the retrieval was investigated in liquid cloud layers only (Figure 2). For this, cloud base height and cloud top height have been identified and normalized to a grid ranging from 0 (cloud base height) to 1 (cloud top height), with missing values in between linearly interpolated. It shows, that the overall temperature profile in-cloud of the HATPRO has a lower RMSE than the MTP-5. Additionally, for both MWRs retrievals using elevation scans, which perform multiple measurements at different elevation angles, were found to have a lower overall RMSE than zenith only retrievals. Therefore, the retrieval of temperature profiles in-cloud shows relatively small RMSEs (0.7 K at cloud base – 1.1 K at cloud top), suggesting, that it may be well suited for further cloud studies. The next steps are to apply the tested retrieval algorithm to real MWR observations during the SOFOG3D campaign, compare the results with different retrieval methodologies, especially the 1D-VAR algorithm (Martinet *et al.*, 2017, Martinet *et al*., 2020) and evaluate the performance with radiosoundings.

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APPENDIX

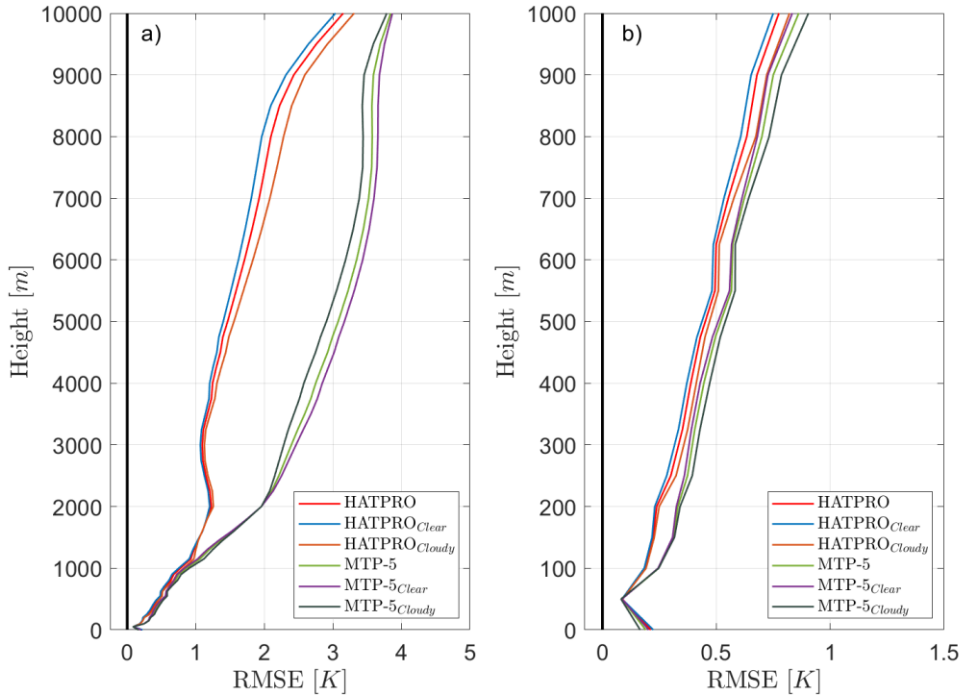

Figure 1: Comparison of retrieval performance of the HATPRO and MTP-5, applied to the troposphere ranging from 0 to 10km height in a) and ranging from 0 to 1000 m in b).

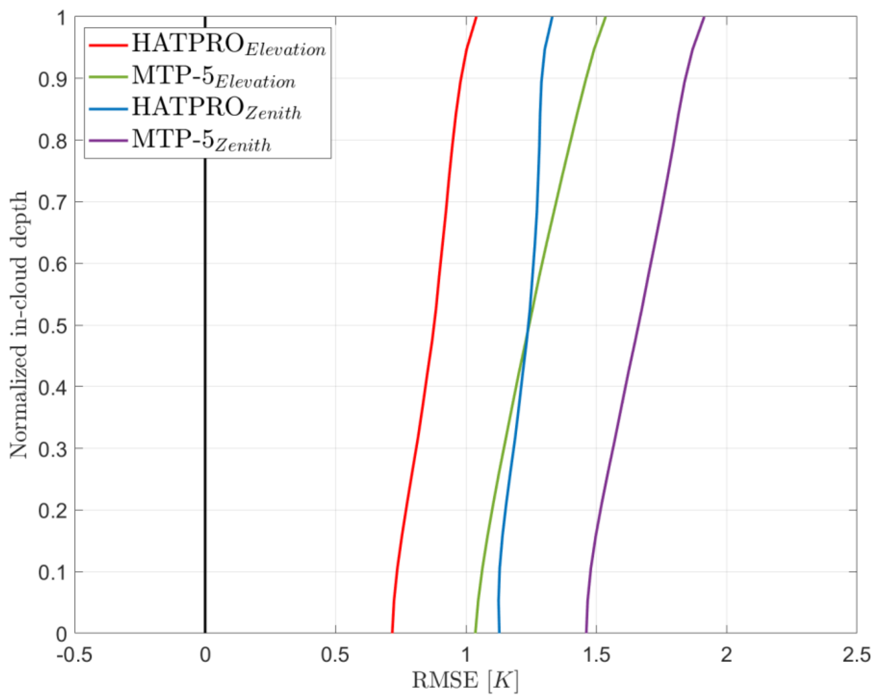

Figure 2: Comparison of retrieval performance of the HATPRO and the MTP-5, applied to clouds only. The cloud thickness is normalized from 0 (cloud base height) to 1 (cloud top height).