



Supplement of

Boundary layer dynamics after rain fronts: high-resolution reconstruction and model validation using ground- and drone-based measurements

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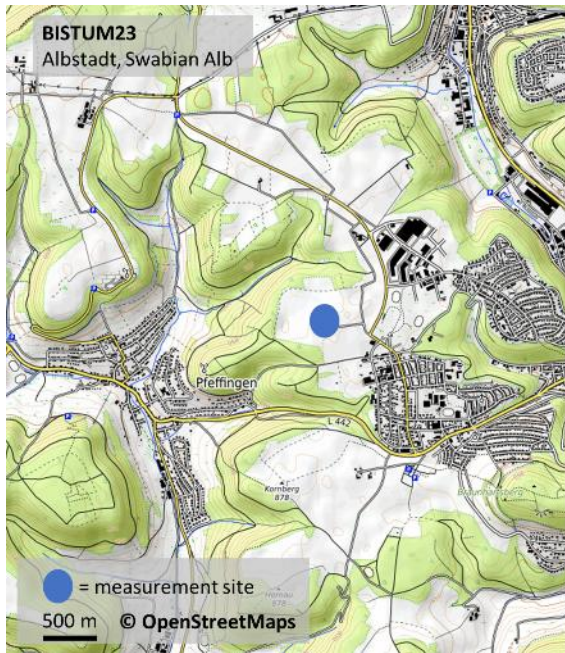


Figure S1: Topographic map of the rural measurement sites during BISTUM23 (Sect. 4) and BISTUM24 (Sect. 3) © OpenStreetMap contributors 2025. Distributed under the Open Data Commons Open Database License (ODbL) v1.0.

NOAA HYSPLIT MODEL
 Backward trajectories ending at 1400 UTC 12 Aug 23
 GFSQ Meteorological Data

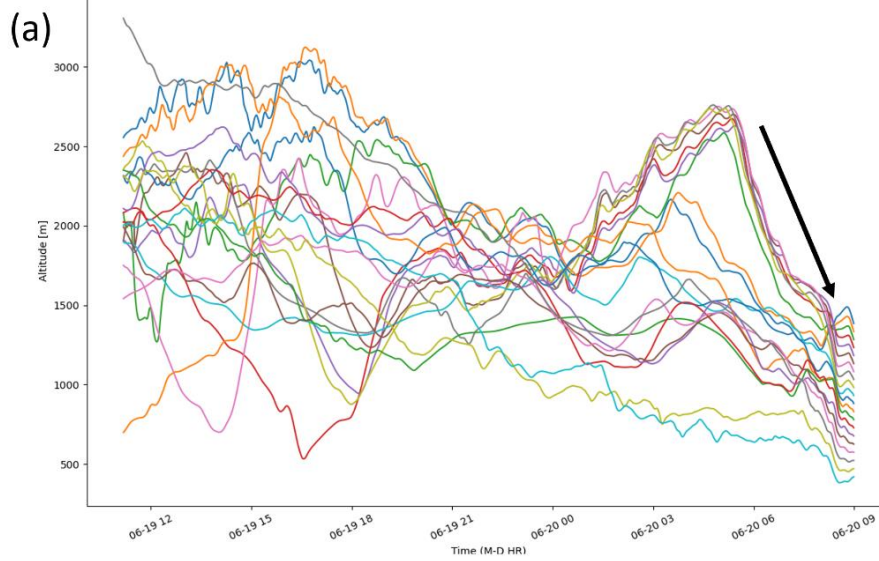


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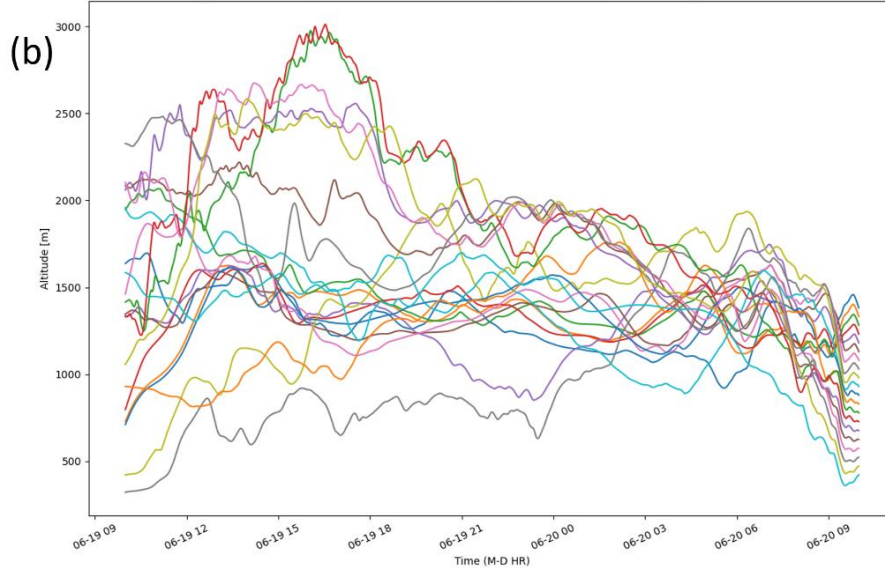
Figure S2: 24 h-backward-trajectories reaching the measurement site at 12:00 local time on 12 August 2023 reveal south-westerly aspiration from rural areas. The trajectories were calculated with the HySplit analysis tool and were started from 0 m, 120 m and 500 m above ground level (Stein et al., 2015). The near surface trajectories are influenced stronger by the underlying surface, leading to a more westerly flow at the Northern flank of the high-pressure system ~18 h before arrival, but are then partially deflected by the Alps and additionally get further into the influence of the cyclonic system over the British islands. The trajectory at elevated altitude is able to follow the free tropospheric flow more closely, such that the eastward flow, which is more driven by the free tropospheric wave pattern is less dominant.

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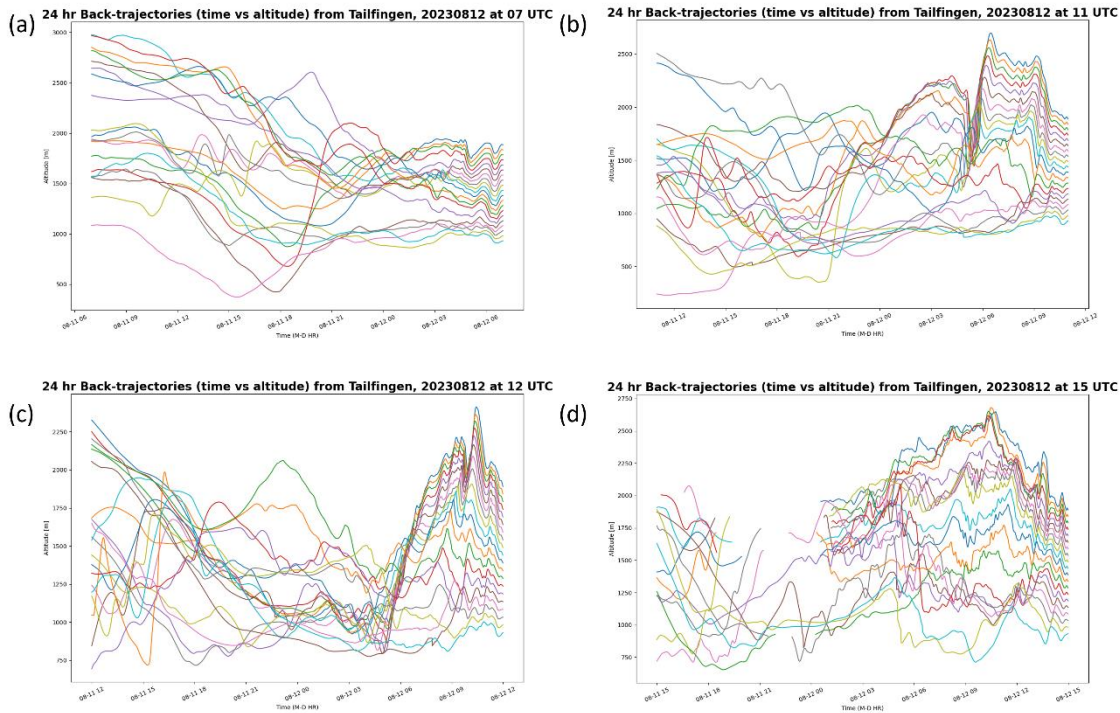
24 hr Back-trajectories (time vs altitude) from Spielberg, 20240620 at 09 UTC



24 hr Back-trajectories (time vs altitude) from Spielberg, 20240620 at 10 UTC



15 **Figure S3: During the rain event, 24-h backward trajectories show a strong downdraft from 3000 m a.s.l. from 6 h before reaching the measurement site for arrival altitude levels down to 150 m a.g.l., whereas the ground-near trajectories are isolated and do not reveal strong vertical movement (a). After the rain event, the aspiration level is more than 1000 m lower and trajectories are homogenously distributed (b). Note that altitude levels are denoted as above mean sea level, and the measurement location is at 391 m a.s.l.**



20 **Figure S4: 24-h backward trajectories for the BISTUM23 measurement site show a shallow aspiration height in (a) at 09:00 between the first and second rain event. A strong updraft, followed by a downdraft movement were found for 13:00 and 14:00 (before the third (b) and fourth rain event (c)), whereas after the thunderstorm trajectories at 17:00 show a low downdraft, with rather parallel trajectories (d). Note the different scaling of the y-axes; altitudes shown are in m a.s.l., the measurement site was located at 886 m a.s.l. LT (local time) is given in UTC + 2 h.**

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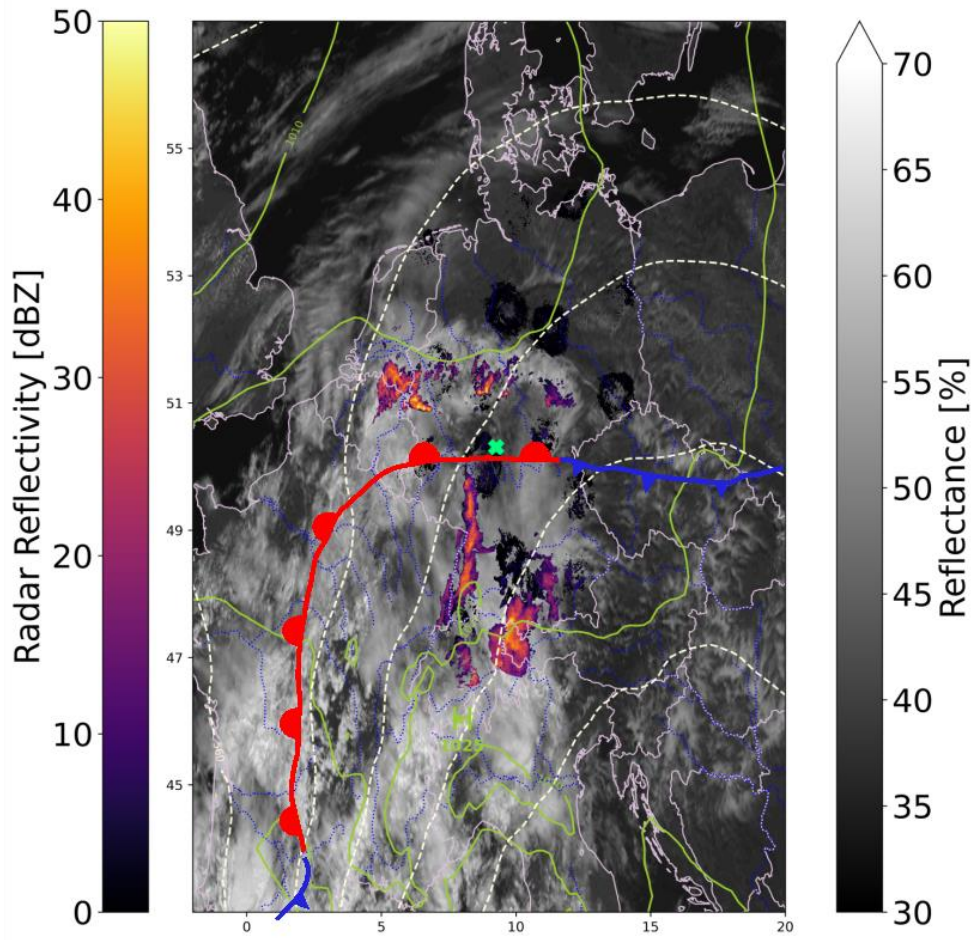


Figure S5: Synoptic map for 12:00 on 20 June 2024 including the radar reflectivity (colorscales) shows the measurement site (green) in a large high-pressure system close to a warm front (red line). Lines represent the surface pressure (lime) and the 500 hPa geopotential (dashed white).

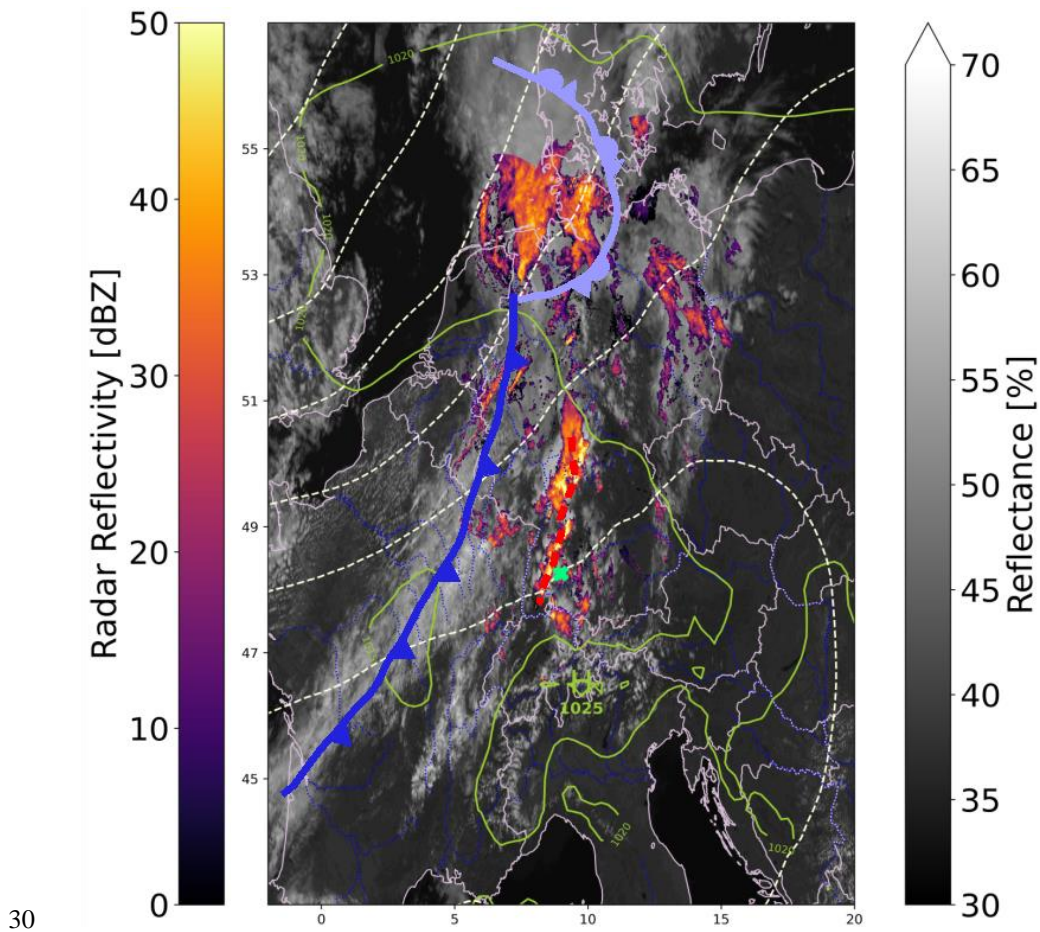
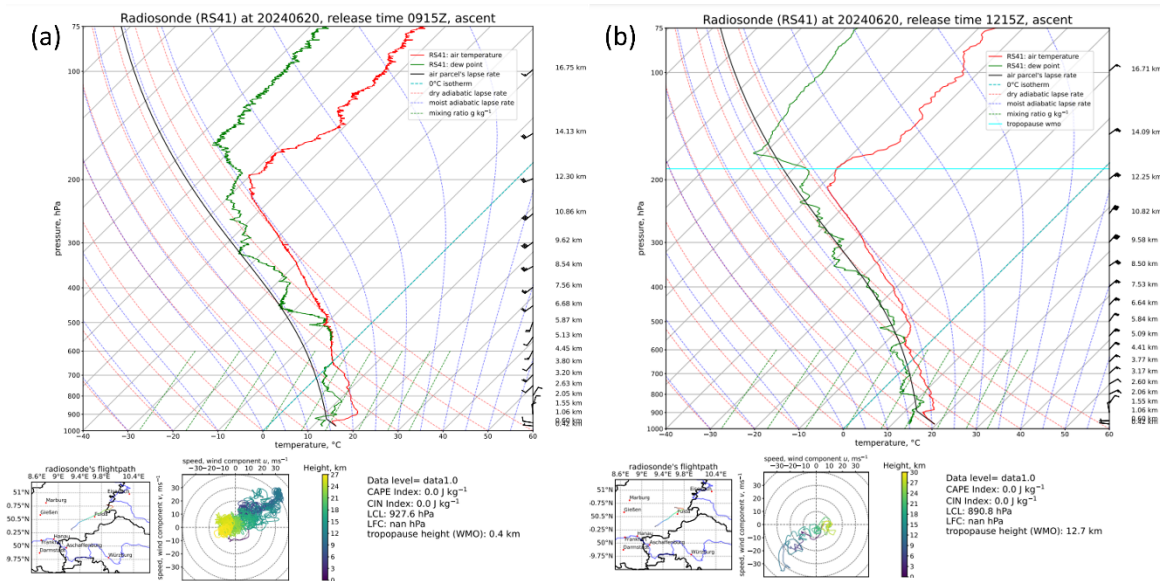
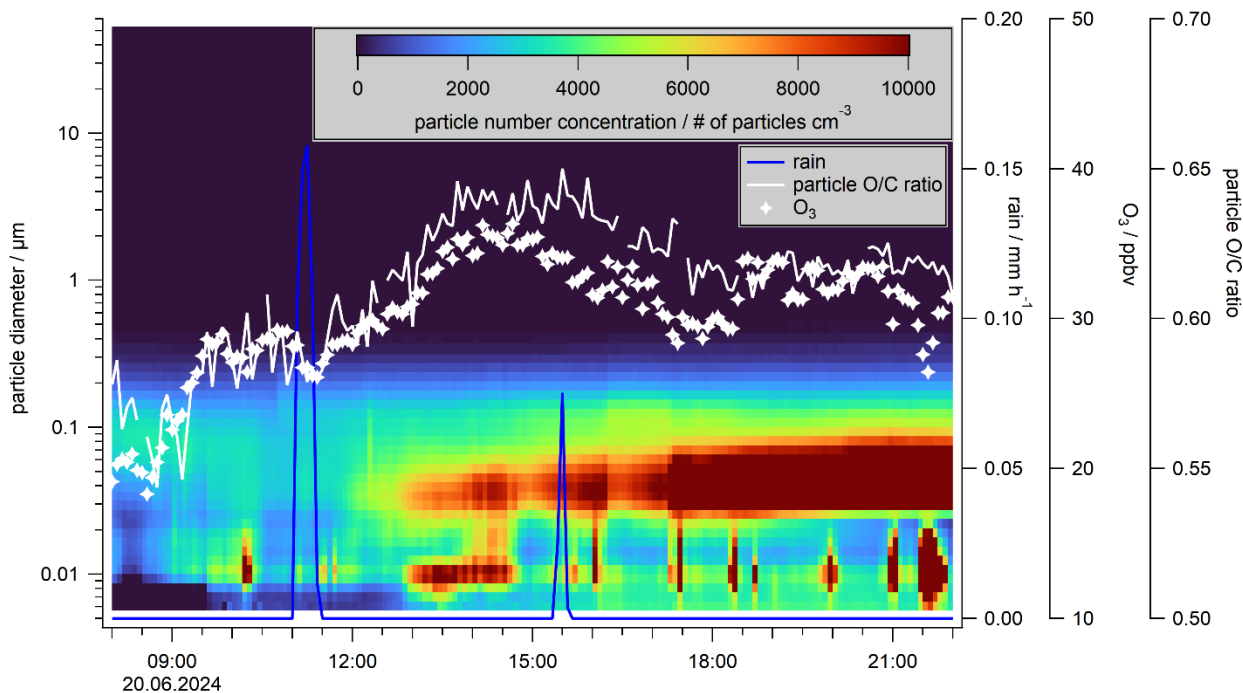


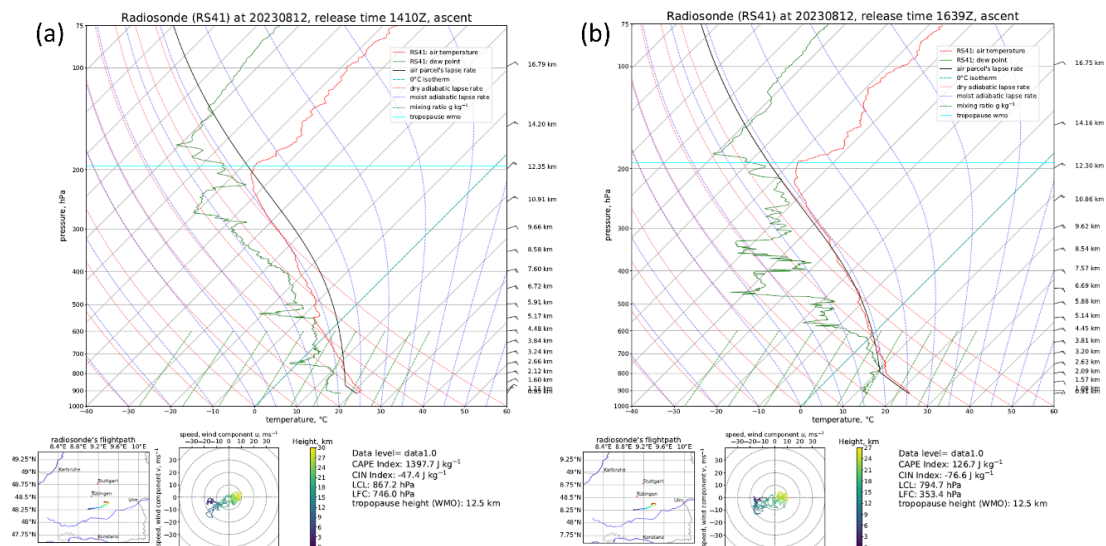
Figure S6: Synoptic map from 12:00 on 12 August 2023 including the radar reflectivity (color scales) shows a convergence line (red) at the measurement site (green) in vicinity to a large cold front (blue). Lines represent the surface pressure (lime) and the 500 hPa geopotential (dashed white).



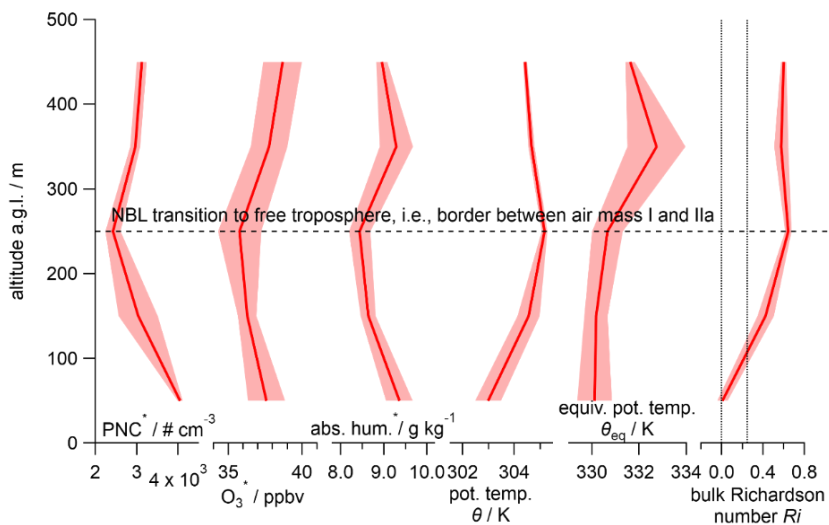
35 **Figure S7: Radiosonde ascents on 20 June 2024 indicate stable pre- and post-rain conditions (a) at 09:15 and (b) at 12:15).**



40 **Figure S8: The good agreement of time series of O₃ (white stars) and the O/C ratio of organic particle components (white trace) measured at ground level in MoLa show an increase of oxidized aerosol particles along with oxidizing reagent. Therefore, particles form and grow as indicated by increasing mode sizes of the particle number concentration for the nucleation and Aitken mode (image plot) after the rain at 11:00 (blue).**



45 **Figure S9: Radiosonde ascents on 12 August 2023 show the unstable accumulation of CAPE before rain ((a), 14:10) and release of CAPE afterwards ((b), 16:39). Altitude is given in km a.s.l.**



50 **Figure S10: Medians of vertical profiles (100 m altitude increments) of the particle number concentration (PNC), O_3 mixing ratio, absolute humidity, potential temperature θ , equivalent potential temperature θ_{eq} and the bulk Richardson number Ri on 12 August 2023 at 08:00. Variables marked with * are corrected for temporal variation over the measurement period using the corresponding MoLa data. Error ranges represent the standard error. Dotted vertical lines indicate $Ri = 0$ and $Ri = 0.25$.**

References

Stein, A. F., Draxler, R. R., Rolph, G. D., Stunder, B. J. B., Cohen, M. D., and Ngan, F.: NOAA's HYSPLIT Atmospheric Transport and Dispersion Modeling System, Bulletin of the American Meteorological Society, 96, 2059-2077, 10.1175/bams-d-14-00110.1, 2015.

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