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Supplement of

Hectometric-scale modelling of the mixed layer in an urban region evaluated with a dense LiDAR-ceilometer network

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Supplemental Materials

S1. Vertical spacing comparison

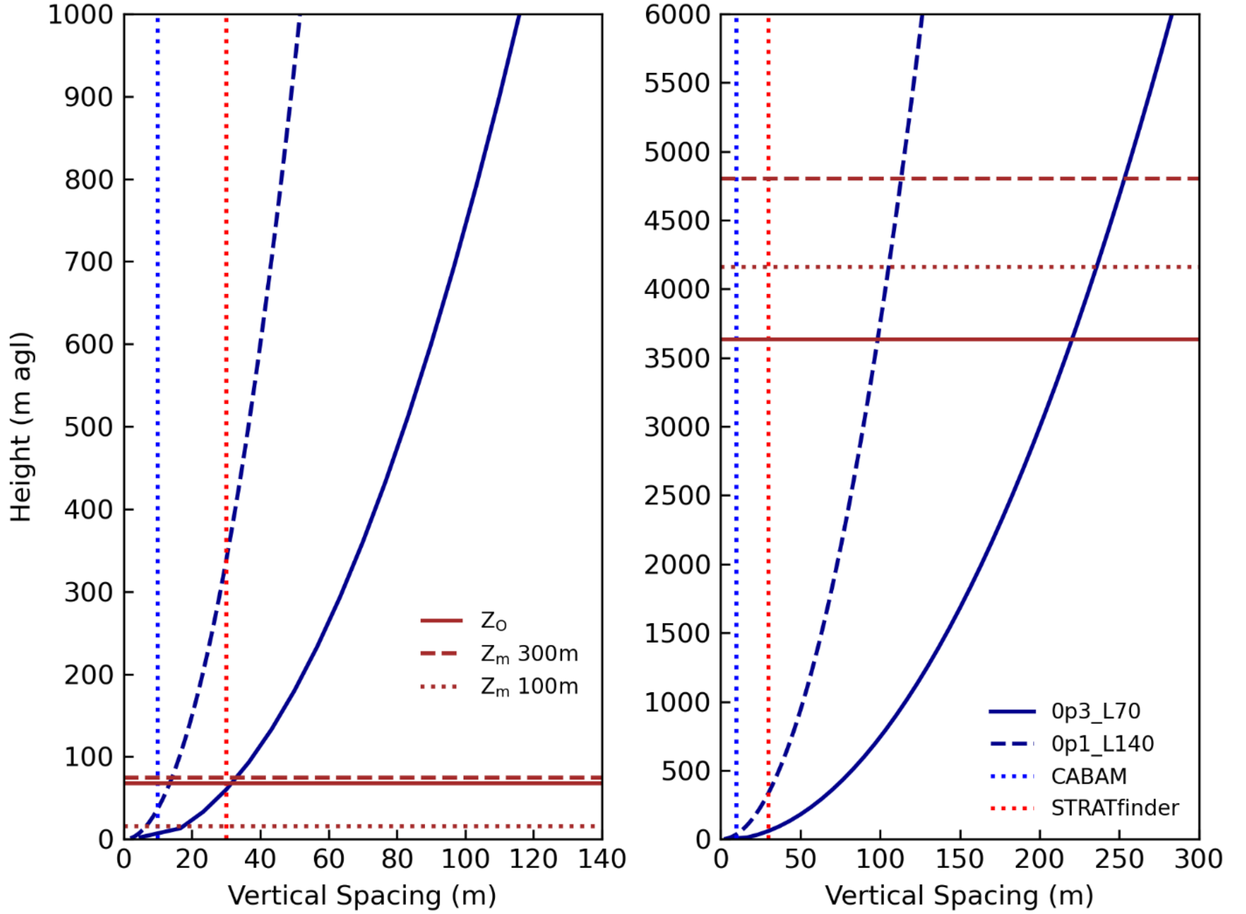

Figure S1. A comparison of the vertical spacing of data used for MLH in this study for (left) the first 1000 m in CABAM (dotted blue), STRATfinder (dotted red), the 300 m domain (‘0p3_L70’, solid dark blue), and the 100 m domain (‘0p1_L140’; dashed dark blue). Brown lines indicate the minimum MLH detected at any site by MMLH (Z_M) in the 300 m (dashed brown), and 100 m domains (dotted brown), and for all ALC observations (Z_O, solid brown). (Right) Vertical spacing with height up to 6000 m with brown lines indicating the same as in the left but now showing the height of the 99th percentile of MLH among all sites.

S2. Soil moisture modifications for 4 August 2022

Biases present in the soil moisture initial state result in built-up areas having unrealistically wet soil in the city. To ameliorate this, the median soil moisture is determined within a box (Fig. S1) which is large enough such that the median soil moisture inside the box is similar to the soil moisture outside of the city. Within this box, model grid points with values greater than the median are replaced by the median. The box is kept small so the replaced soil moisture remains similar to the immediate surrounding area, and not impacted by the larger spatial variations outside the city. As the soil moisture is greater to the southwest of the city, the box is drawn to ensure we do not remove this trend. We have additionally followed guidance in Hall et al. (2024) that found removal of soil moisture stress downscaling at intialisation resulted in reduced spatial variability of soil moisture introduced by soil properties (Fig. S1, S2), and improves near-surface air temperature.

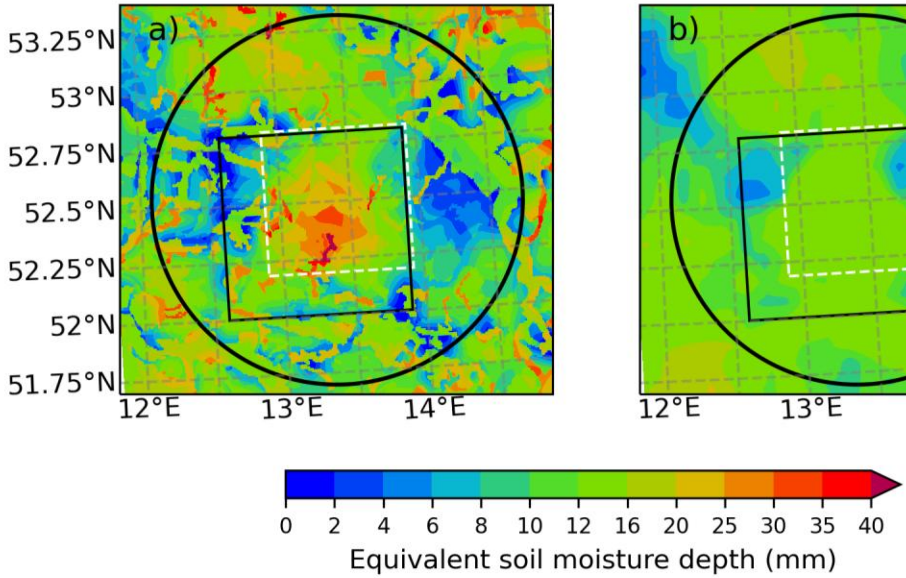

Figure S2. Equivalent soil moisture depth (mm) of the top most soil layer (0 to 0.01 m) from the 300 m domain at intialisation in the 4 August 2022 simulation (a) before and (b) after modification, with rural ring C (90 km, black), boundaries of the 100 m domain (white dashed box), and the region where urban grid points soil moisture are replaced by (black box) the median. The soil moisture stress initialisation is also removed as in Hall et al. (2024).

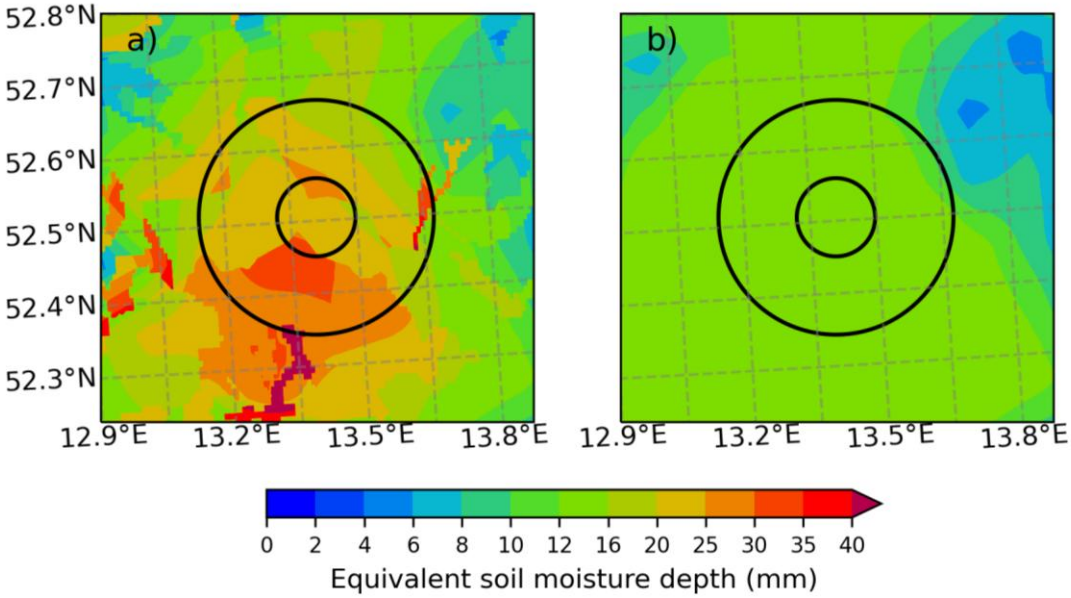

Figure S3. As Fig. S1, but for the 100 m domain, with ring A and B (radius 6 and 18 km respectively, black circles).

S3. List of Observation sites

Table S1. *urbisphere*-Berlin ALC instrument sites for 18 April (Ap) and 4 August (Au) 2022. Modelling domains available for each site for comparison to the ALC are indicated in the 'Model domains' column. Site operators are *urbisphere* (primarily University of Freiburg, UFR), and partners Deutscher Wetterdienst (DWD), Technische Universität Berlin (TUB), and Freie Universität Berlin (FUB).

Site	Ring	Latitude (° N)	Longitude (° E)	Model domains (300 m ,100 m)	ALC type	Operator	Case (Ap, Au)
ALTL	C	52.557283	13.727988	300,100	CL61	UFR	Ap
ANGE	C	53.031631	13.990849	300	CHM15k	DWD	Ap, Au
BARU	C	52.061375	13.499704	300	CHM15k	DWD	Ap
FICH	B	52.457794	13.310898	300,100	CHM15k	FUB	Ap, Au
FOGR	B	52.473253	13.225099	300,100	CHM15k	TUB	Ap
GENT	C	52.387 542	12.160 061	300	CHM15k	DWD	Ap, Au
GRGL	C	52.465286	13.102737	300,100	CL61	UFR	Ap, Au
GRKR	C	52.403896	12.785645	300	CL31	UFR	Ap, Au
HELL	B	52.548064	13.585989	300,100	CL61	UFR	Ap, Au
KYRI	C	52.936310	12.409355	300	CHM15k	DWD	Ap, Au
LIND	C	52.208532	14.118009	300	CHM15k	DWD	Ap
MANS	C	52.546856	14.545148	300	CHM15k	DWD	Ap, Au

MARI	B	52.398415	13.368076	300,100	CL31	UFR	Ap, Au
MAVI	B	52.592138	13.355699	300,100	CL31	UFR	Au
NEUR	C	52.903729	12.807121	300	CHM15k	DWD	Ap, Au
PLAN	A	52.483590	13.479983	300,100	CL31	UFR	Ap, Au
POTS	C	52.381108	13.062117	300,100	CHM15k	DWD	Ap, Au
REIC	C	52.650763	14.067637	300	CL31	UFR	Ap, Au
TEMP	A	52.467502	13.402222	300,100	*CL31/ CL61	DWD, UFR	Ap, Au
TUCC	A	52.512238	13.327804	300,100	CHM15k	TUB	Ap, Au
WEDD	A	52.540129	13.368945	300,100	CL61	UFR	Ap, Au
WEIS	A	52.552620	13.436642	300,100	CL31	UFR	Ap, Au
WEST	B	52.524105	13.269433	300,100	CL31	UFR	Ap, Au
WIES	C	52.120703	12.458597	300	CHM15k	DWD	Ap, Au
WITT	C	51.889181	12.644598	300	CHM15k	DWD	Ap, Au

*CL31 during April case and CL61 during August case

S4. WEDD backscatter timeseries

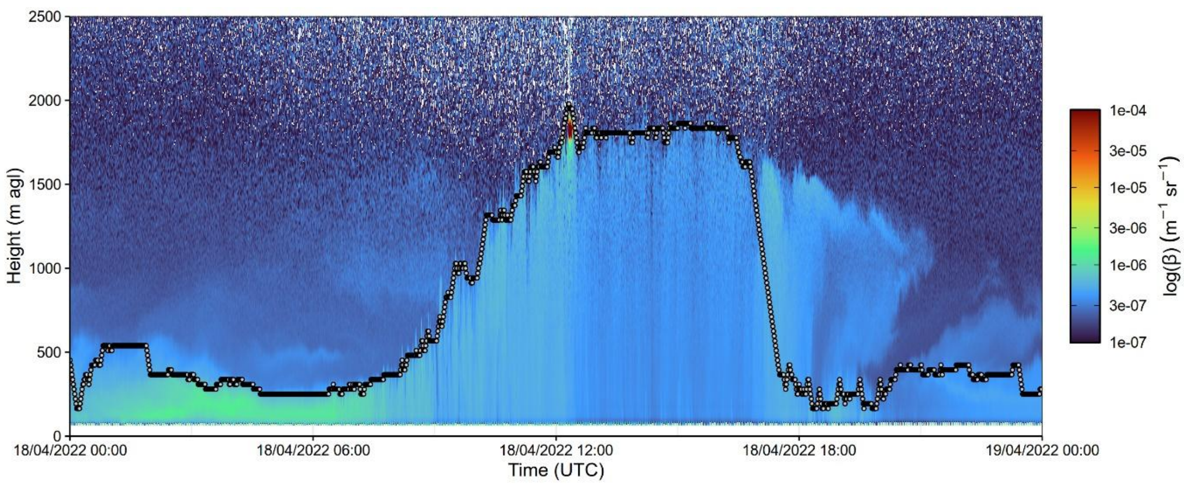

Figure S4. Timeseries of attenuated backscatter (colour bar) from the Vaisala CL61 at site WEDD (Fig. 2b) The solid black line traces the interpreted STRATfinder (Kotthaus et al. 2020; 2023) derived MLH for 18 April 2022. Note that the instrument base height is at 65.5 m above ground level.

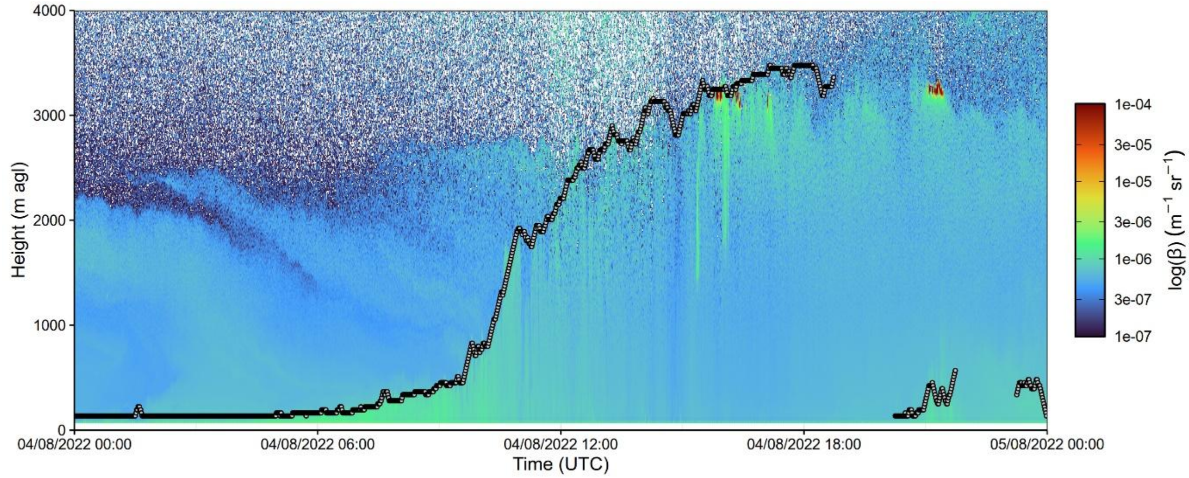

Figure S5. As Fig. S4, but for 4 August 2022.

S5. WEDD Lapse rate

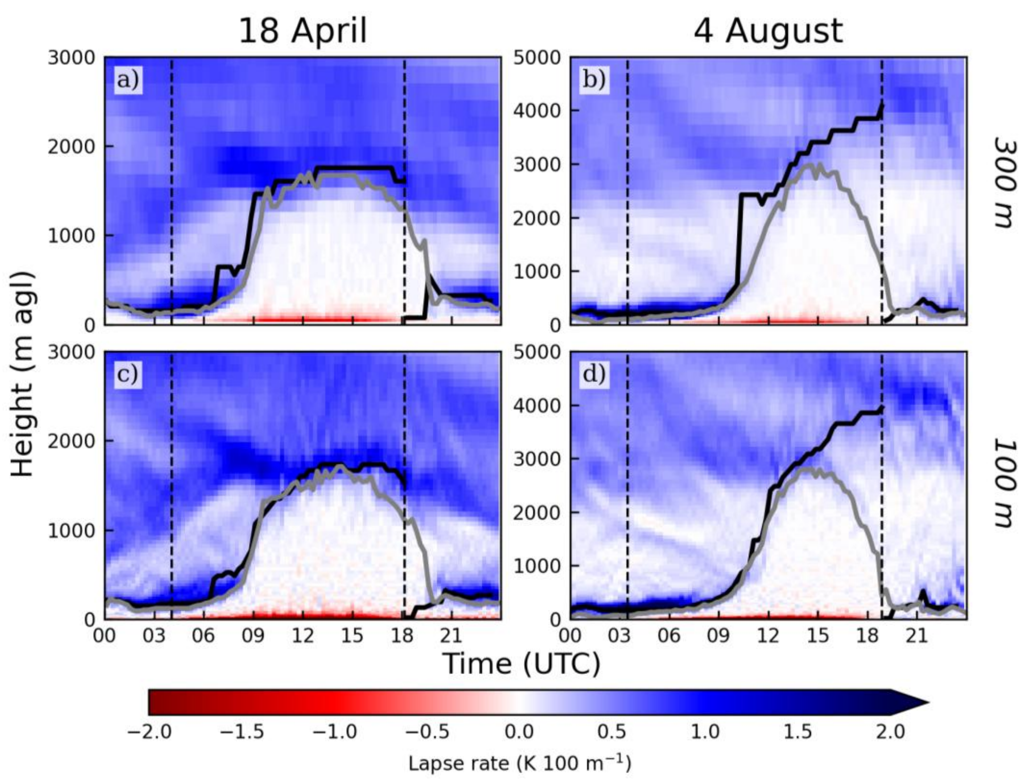

Figure S6. As Fig. 4, but showing the modelled environmental lapse rate per 100 m averaged to 15-minutes (colour bar), with BLD diagnostic (grey lines), ZM (black lines), and sunrise and sunset (dashed lines).

S6. WEDD vertical velocity

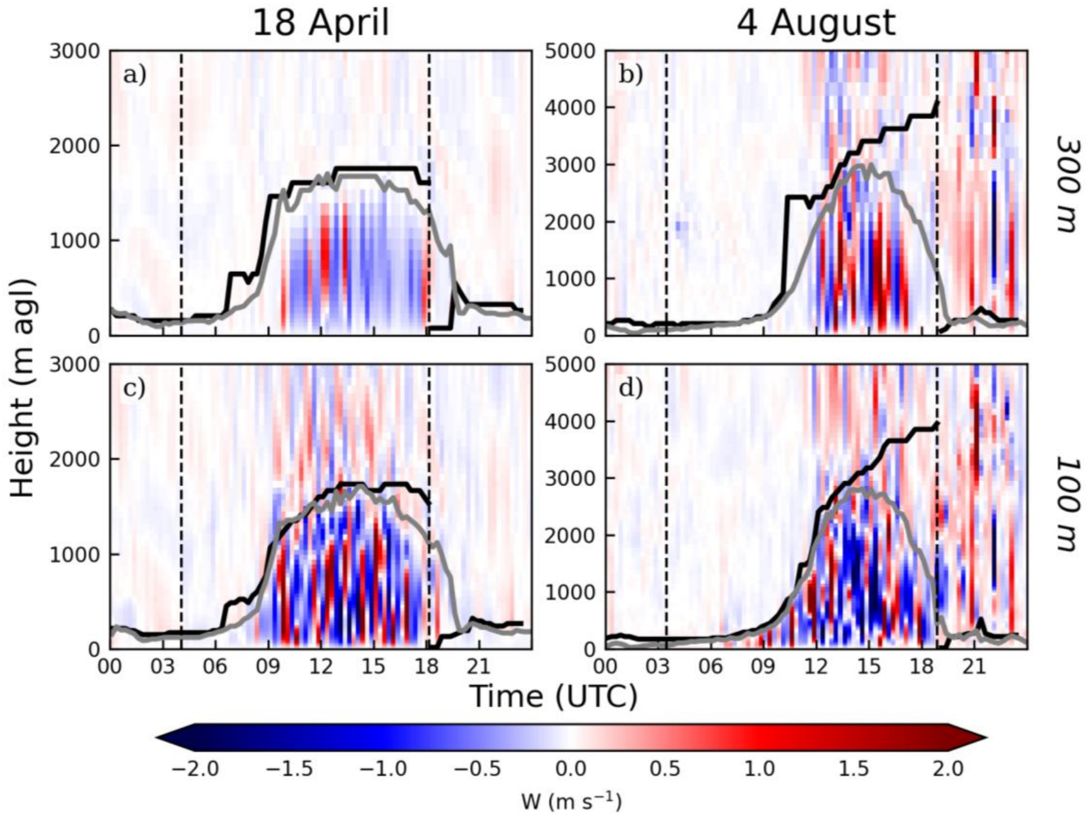

Figure S7. As in Fig. S8 but showing the 15-minute instantaneous vertical velocity (W [m s^{-1}]).

S7. Normalised hit rate

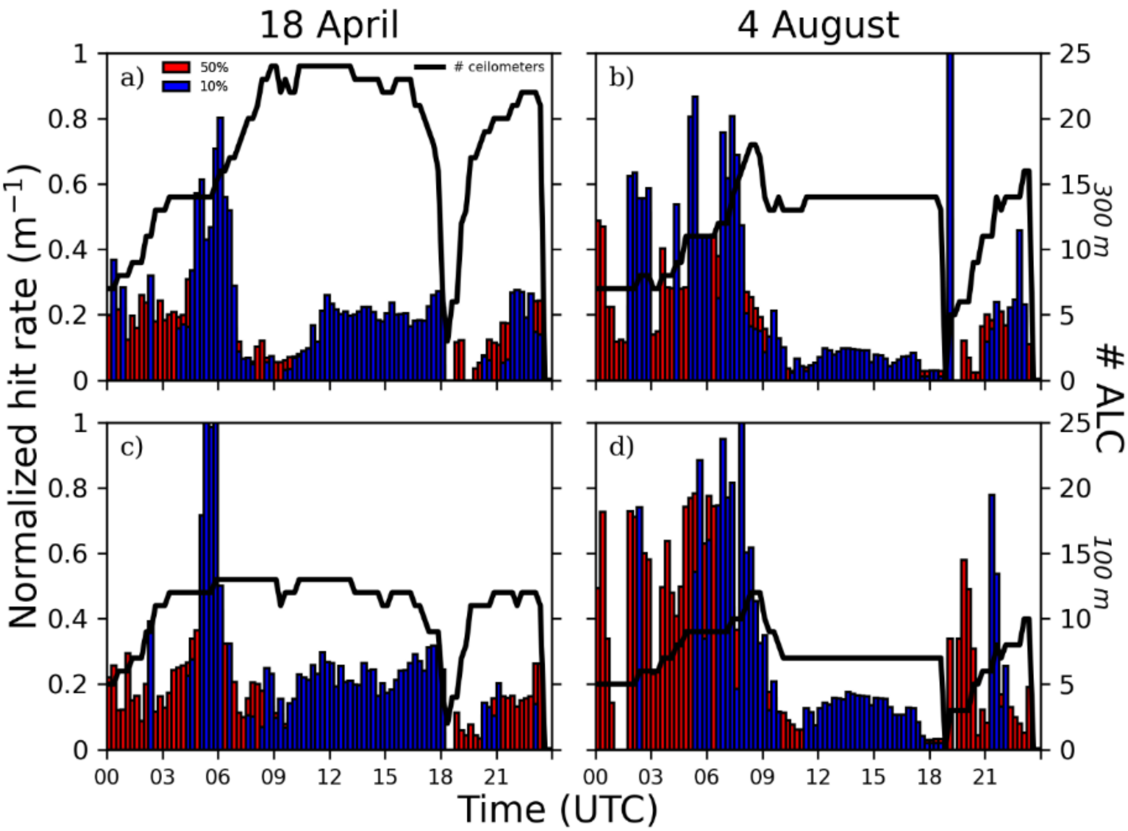

Figure S8. Normalised hit rate (nHR, Appendix A2) for 50% (red) and 10% (blue) of the observed value. ±50% and ±10% of the observed value defines the hit window for the 50% and 10% hit rate respectively.

S8. 4 August 2022 soil moisture profile

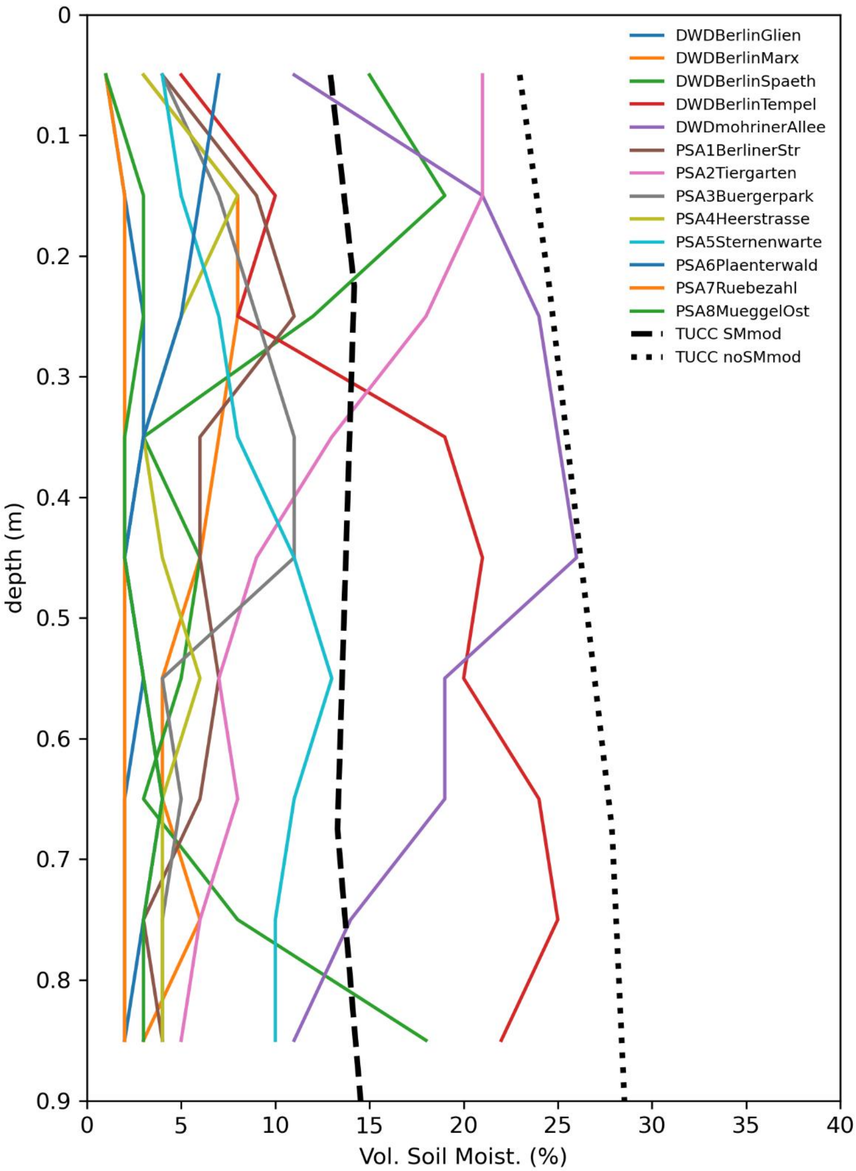

Figure S9. Volumetric soil moisture (%) profile at 12:00 UTC 3 August at various sites (Data source: Berlin Senate 2023) in and around Berlin on 4 August 2022 compared to the profile modelled at the TUCC site (Figure 1, near city centre) with profile before (dotted black) and after (dashed black line) modifications. Observational data are calculated in nine 0.10 m thick layers to 0.90 m, whereas JULES' 4 layers start with a 0.10 m thick layer, and increasing to 0.25 m, 0.65 m and 2 m respectively.

References

Berlin Senate: Messungen der Bodenfeuchte, https://www.berlin.de/pflanzenschutzamt/stadtgruen/beratung/messungen-der-bodenfeuchte/, date accessed: 27 October 2023.