SUPPLEMENTARY INFORMATION

Investigating the efficacy of a fast urban climate model for spatial planning of green and blue spaces for heat mitigation

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S1. TARGET modelling approach

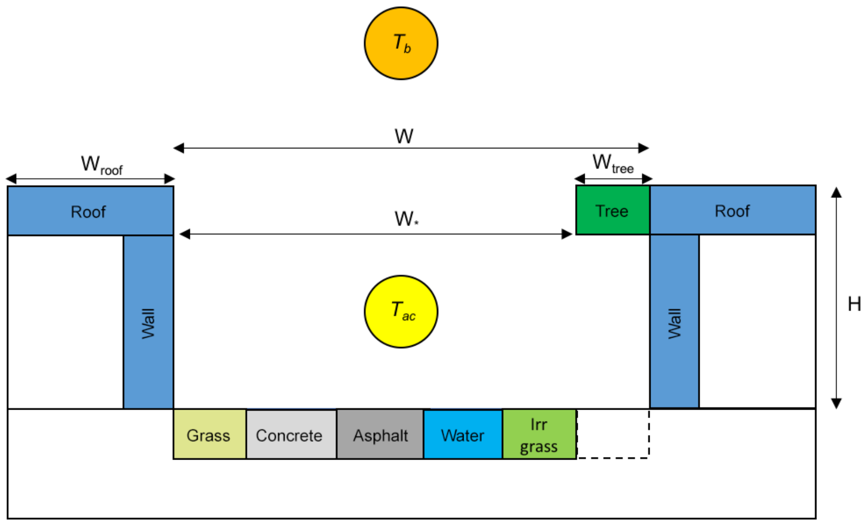

***Figure S1a**. Schematic of TARGET urban canyon set-up. Tac is the canopy layer air temperature, and Tb is the above-canopy air temperature, which is a uniform value across the whole domain. Wroof is the roof width, Wtree is the tree width, W is canyon width, and W*= W - Wtree. The surface beneath trees is assumed to be representative of canyon ground-level surfaces. Figure reprinted from Broadbent et al., The Air-temperature Response to Green/blue-infrastructure Evaluation Tool (TARGET v1.0): an efficient and user-friendly model of city cooling, Geoscientific Model Development, 2019, under the terms of the Creative Commons Attribution 4.0 License.*

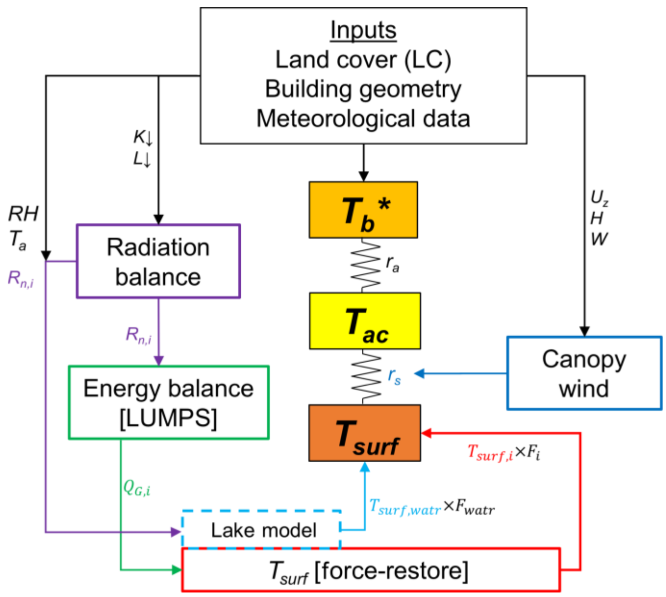

Figure S1b. *Overview of approach used in TARGET. Tac is street-level (urban canopy layer) air temperature (C), Tb is the air temperature above the urban canopy layer (C), Tsurf,i is the surface temperature for surface type i, K is incoming shortwave radiation (W/m2), L is incoming longwave radiation (W/m2), Ta is reference air temperature (C), Rn is net radiation (W/m2), RH is relative humidity (%), Fi is the fraction of land cover type i (%), QH,i is the sensible heat flux for surface i from LUMPS (W/m2), QG,i is the storage heat flux for surface type i from LUMPS (W/m2), Uz is the reference wind speed (m/s), H is the average building height (m), W is the average street width (m), rs is the resistance from the surface to the canopy (s/m), and ra is the resistance from urban canopy to the atmosphere (s/m). Tb is the above-canopy air temperature, which is a uniform value across the whole domain. Figure reprinted from Broadbent et al., The Air-temperature Response to Green/blue-infrastructure Evaluation Tool (TARGET v1.0): an efficient and user-friendly model of city cooling, Geoscientific Model Development, 2019, under the terms of the Creative Commons Attribution 4.0 License.*

S2. Pictures of Netatmo stations and optional shield

Figure S2a. Netatmo private weather stations, consisting of an indoor and an outdoor module. Source: https://shop.netatmo.com/en-us/weather/smart-weather-station/weatherstation

Figure S2b. Shield for the outdoor module. Source: https://shop.netatmo.com/en-us/weather/accessories/weather-station-shield?s=shield

S3. List of parameters used for simulations

Table S3. *Parameter values used in simulations*

	Roof and wall	Road	Water	Soil	Concrete	Dry grass	Irrigated grass	Tree
α	0.15	0.08	0.10	n/a	0.20	0.19	0.19	0.10
ε	0.9	0.95	0.97	n/a	0.94	0.98	0.98	0.98
C ($\times 10^6$)	1.25	1.94	4.18	3.03	2.11	1.35	2.19	n/a
κ ($\times 10^{-6}$)	0.05	0.38	0.14	0.63	0.72	0.21	0.42	n/a
T_m	25.0	26.0	24.5	n/a	26.0	22.4	21.5	n/a
OHM [a_1, a_2, a_3]	[0.12, 0.24, -4.5]	[0.50, 0.28, -31.45]	n/a	n/a	[0.61, 0.28, -23.9]	[0.27, 0.33, -21.75]	[0.32, 0.54, -27.4]	[0.11, 0.11, -12.3]
α_{pm}	0.0	0.0	n/a	n/a	0.0	0.2	1.2	1.2
β	3.0	3.0	n/a	n/a	3.0	3.0	3.0	3.0

α is the surface albedo, ε is the surface emissivity, C is the volumetric heat capacity ($\times 10^6$) (J m^{-3} K^{-1}), κ is the thermal diffusivity ($\times 10^{-6}$) (m^2 s^{-1}), T_m is the initial ground temperature (°C), OHM [a_1, a_2, a_3] are LUMPS empirical coefficients, α_{pm} is the LUMPS empirical alpha parameter, and β is the LUMPS empirical beta parameter.

S4. List of case-specific constants used for simulations

Table S4. *Explanations and values of constants specific to Zurich case study*

Constant	Explanation	Value (m)
zavg	Average building height in domain	10.73
z_TaRef	Height of reference air temperature measurements	2.0
z_URef	Height of reference wind speed measurements	28.05

S5. Impact of meteorological input on modelling results

The study also investigated the impact of meteorological inputs from different meteorological stations. Data from Kloten station, which is located next to the Zurich airport, and the Fluntern station, which sits in a more urbanised area and is much closer to the study area, were compared.

As shown in Figure S6, with meteorological data from either station, TARGET replicated the temperature peaks well. However, it generated better results during the night with Fluntern data. Therefore, better agreement with observed data is achieved with Fluntern data, as indicated by the r-squared and error metrics. For the urban case, Fluntern has higher r-squared and lower errors. Although Kloten's r-squared is 0.01 better for the less urban case, Fluntern's error terms are considerably lower. Conformity with observed data is slightly better in urban areas than in less urban areas. As a result, Fluntern data were used as the default meteorological input in all simulations in this study.

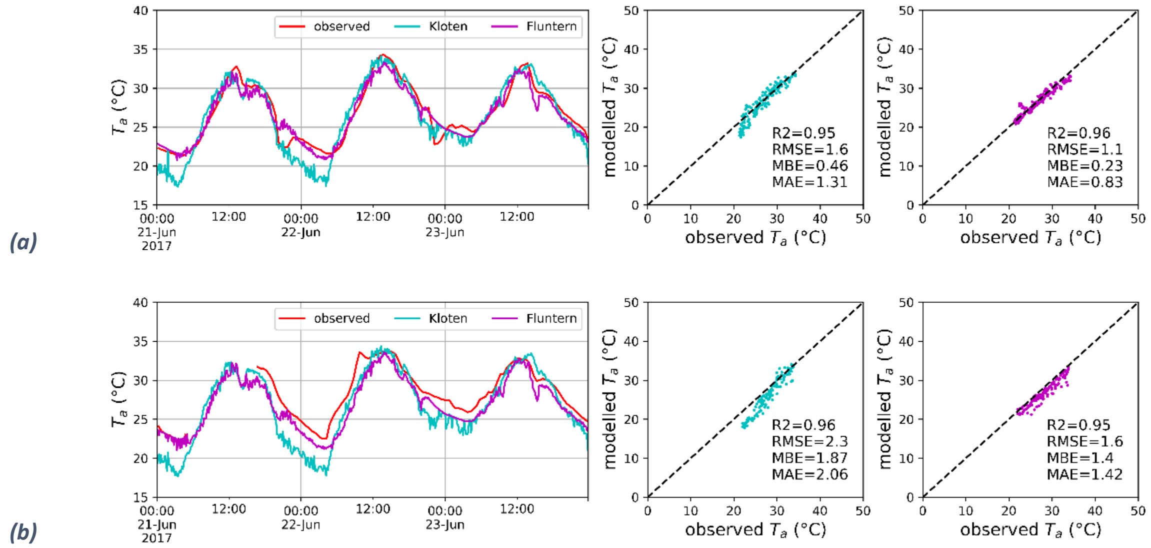

Figure S5. *Time-series comparison of Kloten and Fluntern results with Netatmo observed data, complemented with scatterplots for Kloten and Fluntern separately, for (a) an urban case and (b) a less urban case.*

Although not typically recommended for TARGET meteorological input, there are reasons why Fluntern achieved better results compared to Kloten. The Fluntern station is located right next to the study area, so its meteorological measurements might be more alike with the actual conditions in the region of interest. On the contrary, the Kloten station is farther away and is very likely to have different meteorological conditions due to the two hills between the station and the study area. Besides, located in the city, the Fluntern station measures a higher night-time incoming longwave radiation, capturing the night-time temperature better. TARGET does not account for warm air advection or heat generation from buildings due to energy use, so it is expected to have underestimated night-time temperature with meteorological data from a rural area like Kloten.

Testing of different meteorological inputs is encouraged for similar studies with TARGET. As TARGET forces the meteorological input to the whole simulation area, it is essential to find a meteorological station that can best estimate the temperature while conforming to TARGET's requirement of open space. In the future, TARGET may be improved to use data from multiple meteorological stations simultaneously, which means forcing spatially distributed meteorological data to the area of interest. This improvement will allow TARGET to generate more accurate results and potentially be applied to larger areas.

S6. Parameter sensitivity analysis results

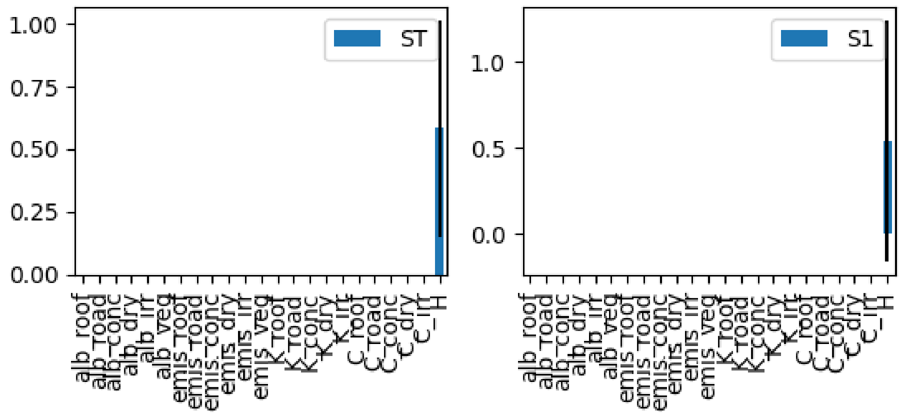

Figure S6a. Total and first order sensitivities for parameter sensitivity analysis including H/W.

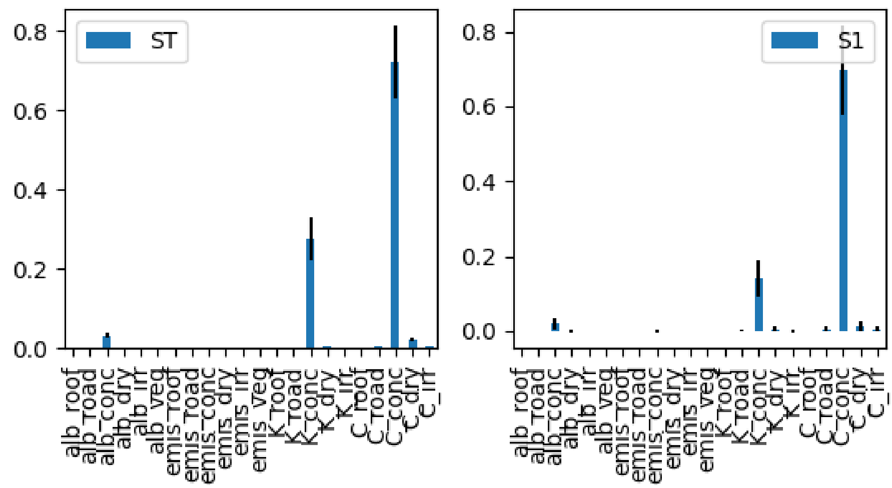

Figure S6b. Total and first order sensitivities for parameter sensitivity analysis excluding H/W.

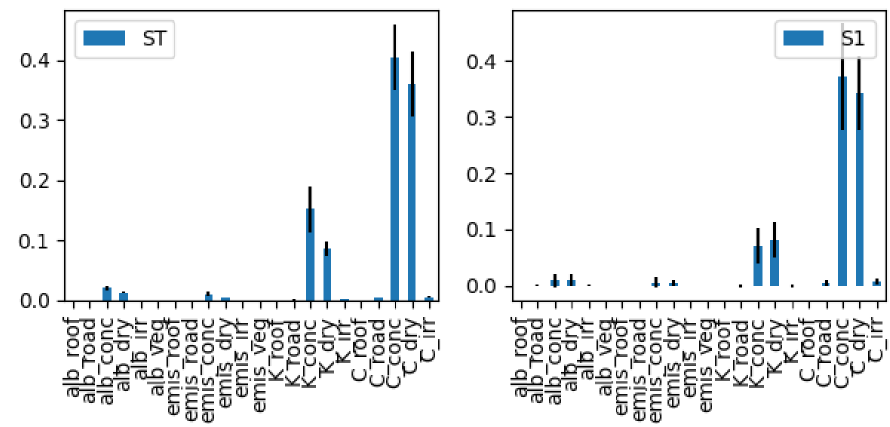

Figure S6c. Total and first order sensitivities for parameter sensitivity analysis excluding H/W, at 06:00.

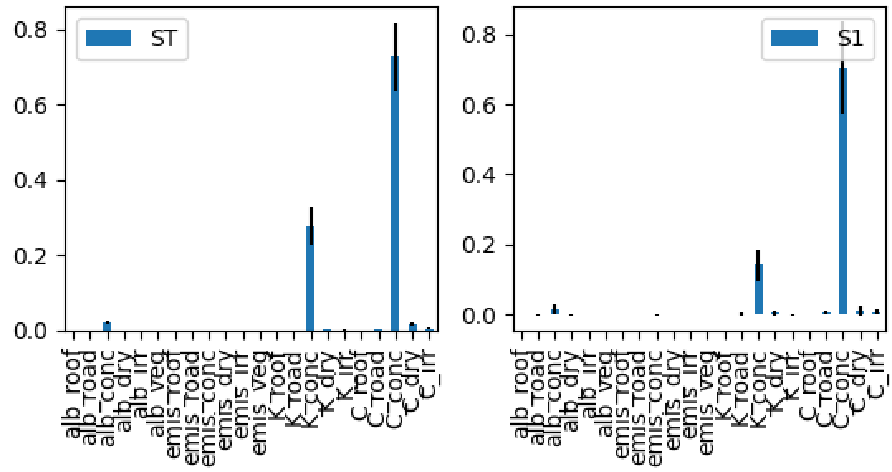

Figure S6d. Total and first order sensitivities for parameter sensitivity analysis excluding H/W, at 14:00.

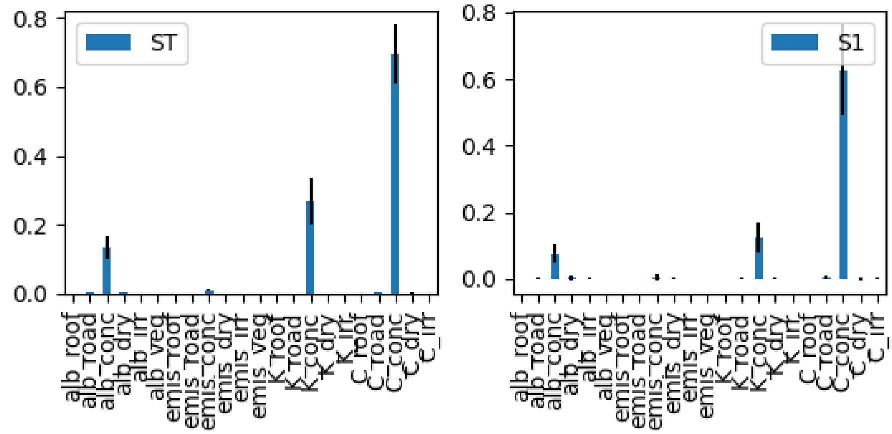

Figure S6e. Total and first order sensitivities for parameter sensitivity analysis excluding H/W, at 22:00.

Figure S6f. Extreme values for air and surface temperatures obtained in simulation results for parameter sensitivity analysis excluding H/W, average. Unit: °C

Min Ta	Max Ta	Min Ts	Max Ts
23.50	23.56	23.84	23.90

S7. Overall point-to-point comparison of modelled and observed air temperatures

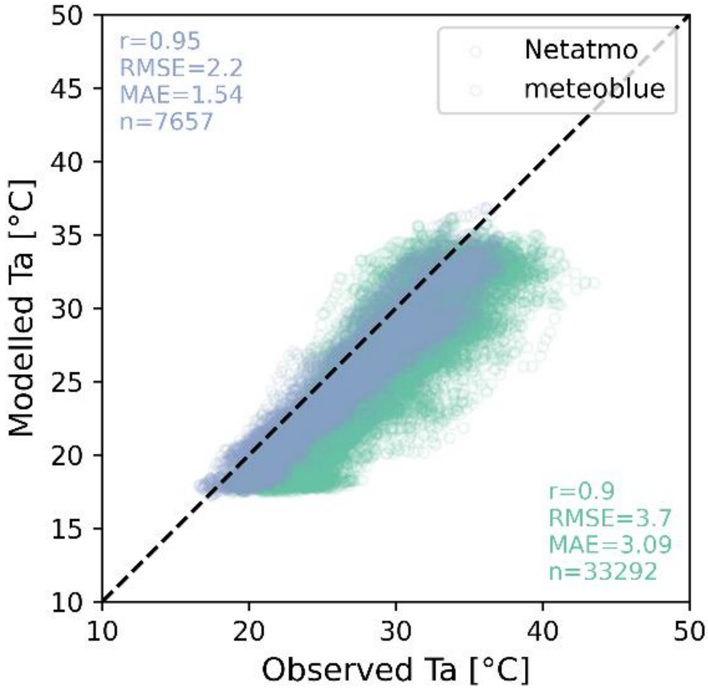

Figure S7. *Point-to-point comparison of observed and modelled air temperatures for all NetAtmo stations for the period 21/06/2017 00:00 – 24/06/2017 00:00.*