Supplemental Material

Supplementary Material

In our study, we set the emissivity value of the tall grassland site to be 0.97, which is 0.04 higher than that of the short grassland site, and the results show that the tall grassland site is on average cooler by 4-5 K. The emissivity values prescribed here are from standard textbooks (Oke et al. 2017) since there are no emissivity measurements. To quantify the effects of the prescribed emissivity values on the derived surface temperature for the grassland sites, sensitivity tests are conducted and the results are shown in Table S1. If we use the same emissivity value for both sites (e.g., 0.93 or 0.97) (see Tests 1-2 in Table S1), we observe a decrease in the average surface temperature difference between the two grassland sites from 5 K to 1-2 K during the day and from 4 K to 1 K at night. These sensitivity tests show that as long as the emissivity of the tall grassland site is higher or even the same, its surface temperature is on average lower (Table S1). Hence the sign of the surface temperature difference between the two grassland sites is not entirely caused by the different emissivity values.

Table S1 Sensitivity tests on the emissivity at the grassland sites.

	Original value		Test 1		Test 2	
	ε (-)	T_s (K)	ε (-)	T_s (K)	ε (-)	T_s (K)
DS	0.93	315	0.93	315	0.97	312
DT	0.97	310	0.93	314	0.97	310
NS	0.93	305	0.93	305	0.97	302
NT	0.97	301	0.93	304	0.97	301

Note. ε is emissivity; T_s is surface temperature. DS = daytime at the short grassland site; DT = daytime at the tall grassland site; NS = nighttime at the short grassland site; NT = nighttime at the tall grassland site. The value is the mean of the results at the hourly scale.

Moreover, we examine the impacts of the prescribed emissivity values on the attribution results. When we change the emissivity value of the short grassland site from 0.93 (Figure S1 a&c) to 0.97 (Figure S2 a&c), the daytime surface urban cool islands (SUCIs) become much smaller while the nighttime surface urban heat islands (SUHIs) become much larger. This is because when the emissivity value increases, the derived surface temperature decreases with a given outgoing

longwave radiation. As a result, the aerodynamic resistance calculated using the derived surface temperature decreases according to Eq. (2) with a given sensible heat flux, leading to a smaller urban-rural aerodynamic resistance difference in terms of magnitude. This further causes a decrease in the negative contribution from aerodynamic resistance and thus the daytime SUCI effect is damped while the nighttime SUHI effect is strengthened. For the same reason, the SUHIs decrease and even turn into SUCIs during the daytime when we reduce the emissivity value of the tall grassland site from 0.97 (Figure S2 b&d) to 0.93 (Figure S1 b&d). It is again the contribution from aerodynamic resistance that is mostly affected by this change of emissivity value. However, for both sensitivity tests, the relative importance of each contributor to the urban-rural surface temperature difference is not altered fundamentally. It is still the aerodynamic resistance that dominates the daytime SUCIs when using the short grassland site as the reference site (Figures S1a & S2a), and the nighttime SUHIs are still predominantly caused by the stronger release of heat storage at the urban site (Figures S1 c&d and S2 c&d). Although the daytime urban-rural difference in surface temperature when using the tall grassland site as the reference site changes from positive to negative, the dominant factors that contribute to the observed urban-rural temperature difference remain unchanged (Figures S1b & S2b).

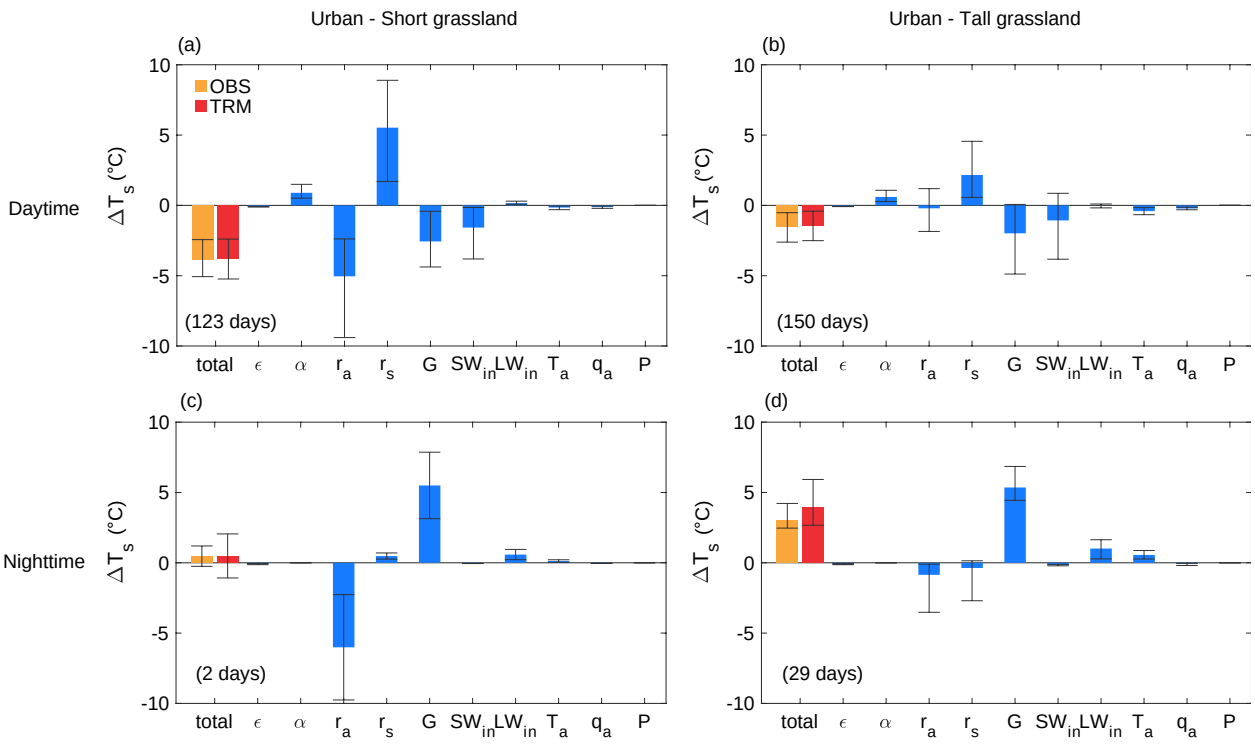

FIGURE S1 Attribution results of surface urban heat islands using the Two Resistance Mechanism (TRM) model during (a, b) daytime (10am-4pm) and (c, d) nighttime (10pm-4am). The emissivity value is set as **0.93** for both grassland sites. The sample size is noted in the bracket in the bottom left corner of each panel. The column indicates the median of the results at the daily scale, and the upper and lower error bars are the 80th and 20th percentiles of the results, separately, representing the day-to-day variability of the attribution results.

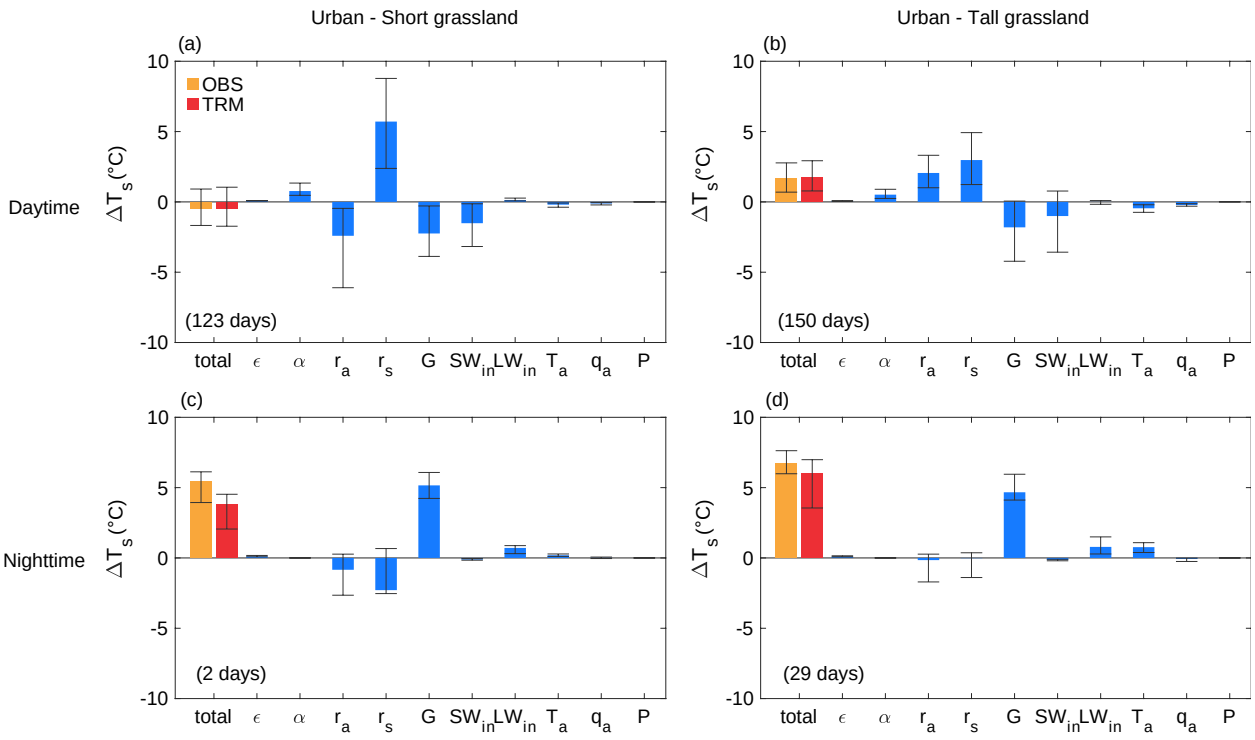

FIGURE S2 Attribution results of surface urban heat islands using the Two Resistance Mechanism (TRM) model during (a, b) daytime (10am-4pm) and (c, d) nighttime (10pm-4am). The emissivity value is set as **0.97** for both grassland sites. The sample size is noted in the bracket in the bottom left corner of each panel. The column indicates the median of the results at the daily scale, and the upper and lower error bars are the 80th and 20th percentiles of the results, separately, representing the day-to-day variability of the attribution results.

References:

Oke, T.R., Mills, G., Christen, A., Voogt, J.A., 2017: *Urban Climate*. Cambridge University Press, 546 pp.