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Geoscientific
Model Development
Discussions

Interactive comment on "An urban ecohydrological model to quantify the effect of vegetation on urban climate and hydrology (UTC v1.0)" *by* Naika Meili et al.

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We thank the reviewer for his/her time, precise summary, and positive evaluation of the manuscript.

Specific referee comments and author replies:

1. Line 97: "The anthropogenic heat flux Qf is directly added to the sensible heat budget of the canyon air." The anthropogenic heat flux should be on the LHS of Eq. (1) instead of RHS.

Thank you for your comment, we have now clarified this point in the manuscript in Eq.

(1). Previously we separated the "surface budget" from the "canyon air" budget, but that was indeed confusing.

2. Line 101: "hourly time steps". Is this enough to ensure numerical stability?

The code has been modified to accommodate shorter time steps (e.g. $\frac{1}{2}$ or $\frac{1}{4}$ h) if the meteorological forcing data are available (see also reply to referee 1). Equations for which a finer temporal resolution is required to ensure numerical stability, such as the soil moisture equations, are internally solved at a much finer time step determined by an ordinary differential equation solver that is based on a modified Rosenbrock formula of order 2 (ode23s, Shampine and Reichelt, 1997). We have clarified this in the revised manuscript (Line 100-102) and in Sect. "6.2 Vadose zone dynamics" in the TRM.

3. Lines 151–152: "The air volume within the canyon is subdivided into two layers with a height of 4 m for the first layer and a height of (HCanyon - 4) m for the second layer." This geometry setting will largely limit the application of the proposed model if the height (4 m) is fixed.

Thank you for the feedback. The height of 4 m is chosen to calculate the portion of sensible heat flux from the wall that is contributing to the 2 m air temperature. In the case when the mean building height is lower than 4 m, it is assumed that the sensible heat flux from the total wall area is contributing to the air temperature at 2 m. We have now clarified this in the manuscript (Line 151-156).

4. Lines 172–173: ": : :interior building temperature Tb, which is set equal to the atmospheric forcing temperature within the range of a specified minimum Tb;min and maximum temperature Tb;max." Is there any specific reason for such setting? The interior building temperature is usually distinct from outside temperature (forcing) when H/AC is used (as mentioned in line 174).

The interior building temperature is set to a prescribed minimum temperature Tb,min if the outdoor temperature drops below Tb,min and building interiors are heated. Similarly, if outdoor temperatures exceed Tb,max, the interior building temperature will be fixed to Tb,max and building interiors are air-conditioned. In between these two set-points, the interior building temperature is prescribed equal to the forcing temperature under the assumption that minimal heating or air-conditioning is applied during periods with pleasant outdoor temperatures. We believe this is a reasonable assumption as building occupants are likely to open windows during comfortable outdoor conditions. The interior building temperature can also be set to one single prescribed value Tb if the building interior is assumed temperature controlled under all outdoor conditions. We have modified the manuscript to clarify this point in line 178-179 and TRM Line 984-985.

5. Lines 380–381: “The simulation time series length is : : : mean daily cycles averaged over the whole year”. Did the authors observe any seasonal variability?

The sensitivity analysis of 2 m air temperature and relative humidity to an increase in vegetated ground cover λveg, LAI and Vc,max is performed for the urban set-up of the eddy-covariance measurement site in Telok Kurau, Singapore. Singapore experiences a relatively uniform climate throughout the year and hence, we did not analyse seasonal variability. There is an exceptional dry period (15.2.2014 - 16.3.2014) in the modelled time series for which we have now separately analysed the mean 2 m air temperature decrease and relative humidity increase caused by the change in λveg, LAI and Vc,max. See modifications in the manuscript at line 385-388 and line 527-535.

6. Figure 5(i): Sensible heat flux is generally overestimated by the model during daytime. Please provide some possible reasons.

As shown in Figure 5, the sensible heat flux is mainly overestimated in Melbourne, while the model appears to better simulate the sensible heat fluxes in Singapore and Phoenix. As shown in Figure 5 of Coutts et al. (2007a), the spatial heterogeneity of the urban landscape combined with the variability in wind direction has an impact on the fluxes. The model lumps these heterogeneities into a handful of variables, which

of course represent a simplification of the true process. In general, uncertainties in parameter values, such as urban morphology, and thermal and radiative characteristics, can influence model performance (Demuzere et al. 2017). Additionally, uncertainties in model structure and parametrizations might also lead to simulation-observation differences. Uncertainties are also introduced in the amount of anthropogenic heat and water added to the system, and the prescribed interior building temperature used. Furthermore, tower based eddy-covariance measurements do not close the energy budget which is attributed to the conductive heat fluxes and change in heat storage in the urban fabric as well as measurement uncertainties, since the lack of energy balance closure is also observed in the long-term averages. In other words, some difference between model simulations and observations are expected. Because the sensible heat flux is typically one of the major energy fluxes in the urban environment, model and measurement discrepancies are likely emphasized. All of these reasons can contribute to the observed difference; however, it is hard to pinpoint the main reason with only flux-tower estimates of sensible heat and this will likely require different observations as fields of surface temperature and vertical profiles of wind speed.

7. Section 4.1.3: Probably the observed discrepancy can also be attributable to the assumption of irrigation water use.

Thank you for the comment, we have added this point to the manuscript. Modification in line 445-447 of the revised manuscript.

8. Figure 10: The dynamics of soil moisture over time are very interesting. Can this be evaluated with field measurements (of moisture)?

Unfortunately, we do not have soil moisture measurements in the ground underneath the Telok Kurau eddy-covariance site in Singapore during the simulation time period shown in the manuscript. The evaluation with field measurements is also difficult as soil texture and soil moisture are often heterogeneous and measurements are usually performed at the point scale and, hence, unlikely representative of a larger area, while the model and the eddy-covariance measurements simulate/measure at the neighbourhood scale.

9. Lines 569–570: “Higher air temperature decrease in drier climates is often linked to urban irrigation though as shown by Broadbent et al. (2018b) in Melbourne....” and lines 30–37 about the advantages of urban vegetation: please note that using nature-based solutions for cooling should also consider the trade-off between irrigation water use and the cooling effect the urban vegetation can provide, especially in dry areas like Melbourne or Phoenix, see Yang and Wang (2017) (https://doi.org/10.1016/j.landurbplan.2017.07.014) for a regional simulation in Phoenix and Wang et al. (2019) (https://doi.org/10.1016/j.compenvurbsys.2019.101397) for a continental simulation in U.S.

Thank you for the comment which we have now included in the manuscript. Modification in line 588-590 of the revised manuscript.

Technical corrections

1. Line 81: please add “,” after “accounted for”.

Corrected.

2. Line 515: “The sensitivity to maximum Rubisco capacity (Vc,max), as indicative of plant photosynthetic capacity, leads to an average reduction of T2m by 0.3 °C and an increase of RH2m and ETcanyon by 1.6

Changed.

3. Figure 13: Please move the legend to the right side (outside subplot c).

Changed.

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