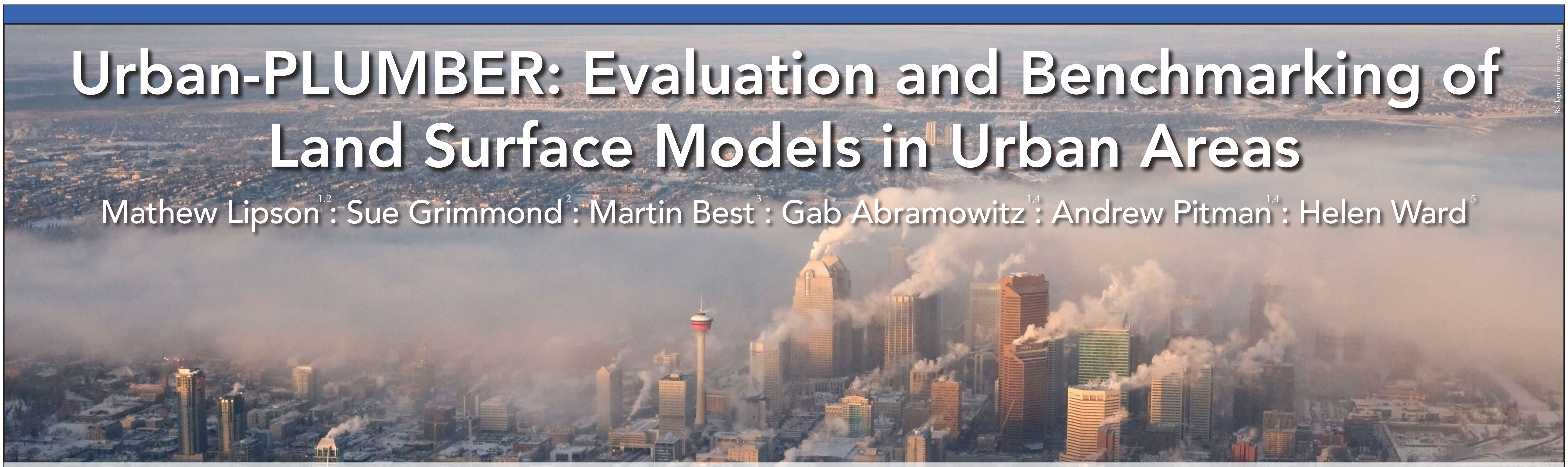
Urban-PLUMBER: Evaluation and Benchmarking of Land Surface Models in Urban Areas

Mathew Lipson[1,2] : Sue Grimmond[2] : Martin Best[3] : Gab Abramowitz[1,4] : Andrew Pitman[1,4] : Helen Ward[5]



Urban-PLUMBER is a multi-model, multi-site offline evaluation project in two phases:

1: Initial evaluation at one suburban site to refine experiment design, and

2: Evaluation across a wide range of urban types and climate.

1. UNSW THE UNIVERSITY OF NEW SOUTH WALES
2. University of Reading
3. Met Office
4. ARC CENTRE OF EXCELLENCE FOR CLIMATE EXTREMES
5. universität innsbruck

Project aims:

The project will:

- assess both specialised urban and general land surface models together
- examine performance at many sites, from highly urbanised to highly vegetated
- assess where on the urbanised/vegetated continuum models are more skillful
- use benchmarking methods to set *a priori* minimum performance expectations.

Why benchmarking?

Benchmarking sets an *apriori* minimum expectation of performance. A minimum expectation may be that a complex or specialised model should perform better than a simple model with fewer parts or inputs.

Building on the PLUMBER project for land surface models (Best et al., 2015), three types of benchmarks are proposed:

1. Out-of-sample linear regressions (e.g. shortwave radiation/ air temperature).
2. A simple physically-based model (e.g. modified Penman-Monteith equation).
3. A universally-available non-urbanised model (e.g. ERA5 from ECMWF).

The aim is not to declare a "best" model among participants, but to find where models are performing below benchmarks and help focus future developments.

Get involved:

We can work with you through:

- providing meterology spinup and observational forcing in your preferred units,
- helping set up an appropriate model configuration for the initial site and automate the generating of multi-site configuration files from simple csv inputs,
- to produce a simple schematic description of your model for the community.

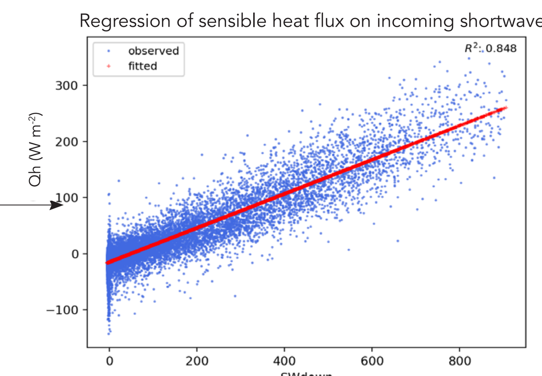
Be part of the project by providing modelling and/or observational data.

Initial results: (indicative only - may change)

1. Define simple benchmarks that models should beat, e.g. out-of-sample linear regression on shortwave radiation.

Swindon site is surrounded by 1-2 story residential buildings with 40-50% vegetated area, located in South West England, UK.

Observations: Ward et al., (2013). Image: Google Maps 2019.

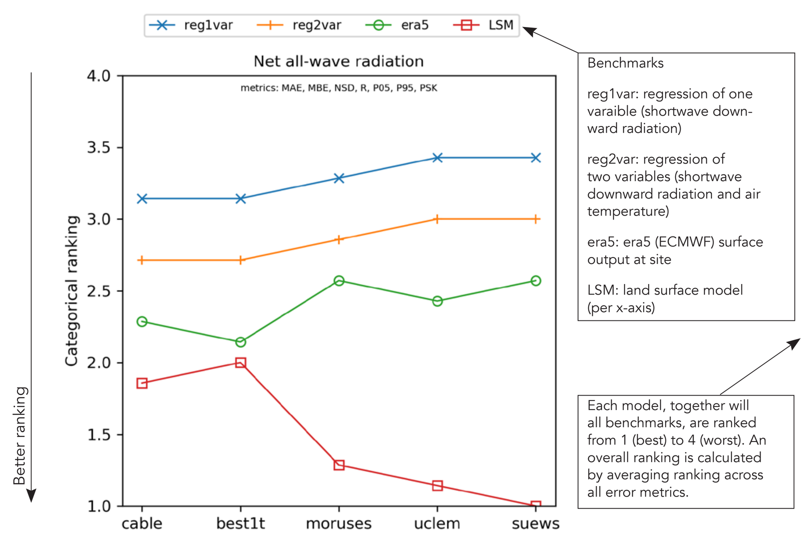


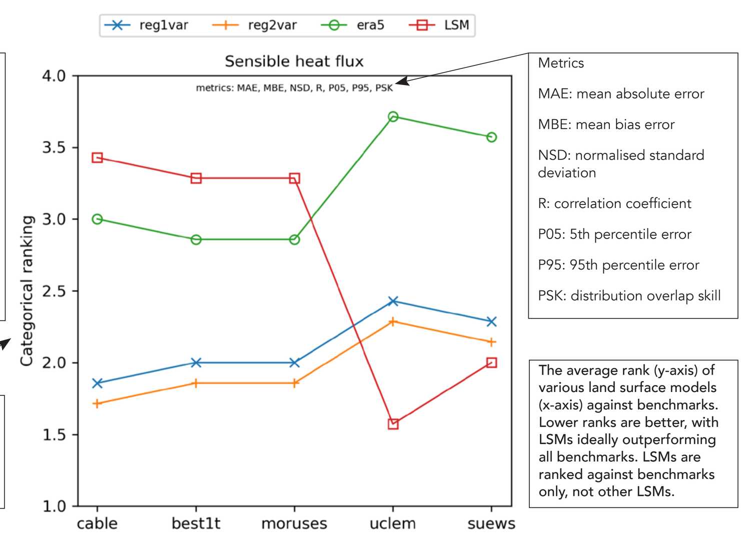
Simple linear regressions of various fluxes (Qh: sensible heat flux shown) using one or two variables (SWdown: incoming shortwave radiation shown).

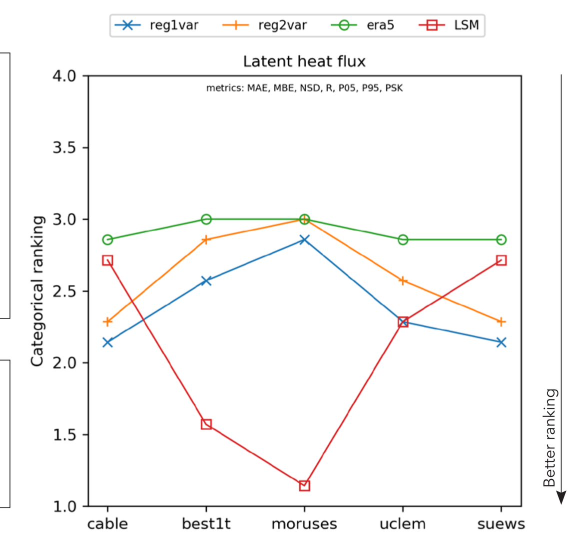
Regression used to predict fluxes at a different site: Preston, in suburban Melbourne, Australia, previously used in the PILPS-Urban comparison project (Grimmond et al., 2011).

Observations: Coutts et al., (2007). Image: Apple Maps 2019.

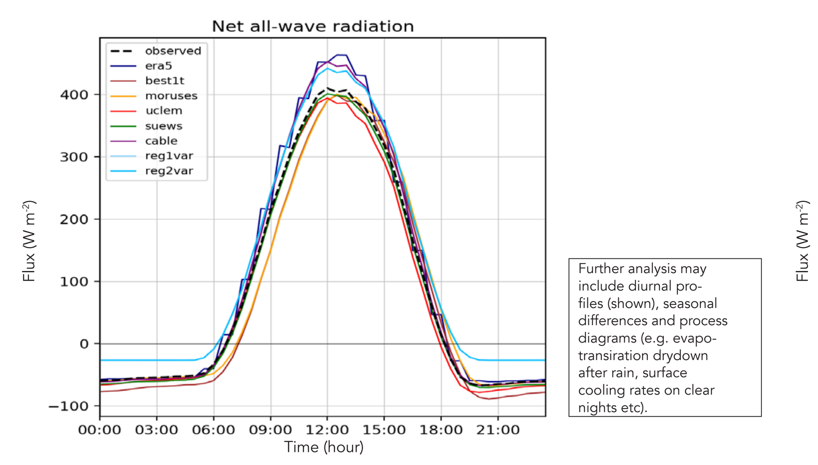
2. Compare and rank model against various benchmarks across various error metrics.

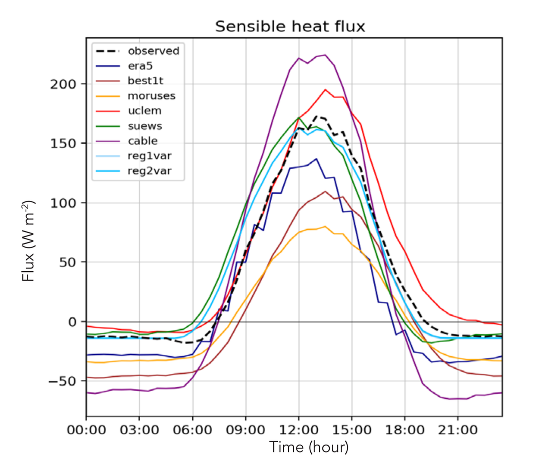


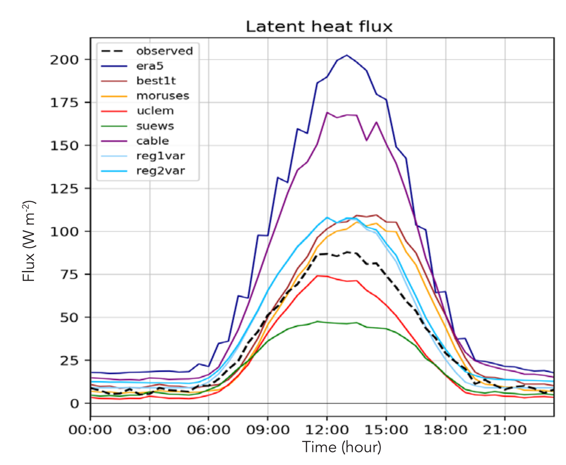




3. Analyse results, looking at where and how various models underperform simple benchmarks.







Diurnal profiles over analysis period (15 months).

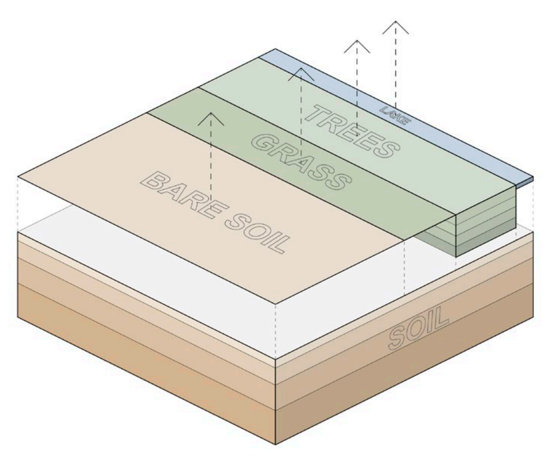
CALLING FOR PARTICIPANTS!

Can your urban model beat a linear regression on one variable?

Current participants:

CABLE

(Harverd et al., 2018)



Urban scheme: none (bare soil)

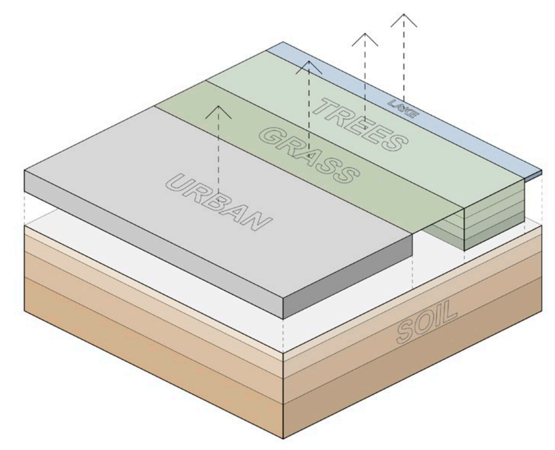
Vegetation: eleven types, multi-level canopy and dynamic LAI and carbon.

Soil: multi-level, complex hydrology.

Primary use: global/ regional climate and vegetation responses.

BEST1T + JULES

(Best et al., 2005)



Urban scheme: 1 facet slab scheme with prescribed anthropogenic heat fluxes. Run within JULES.

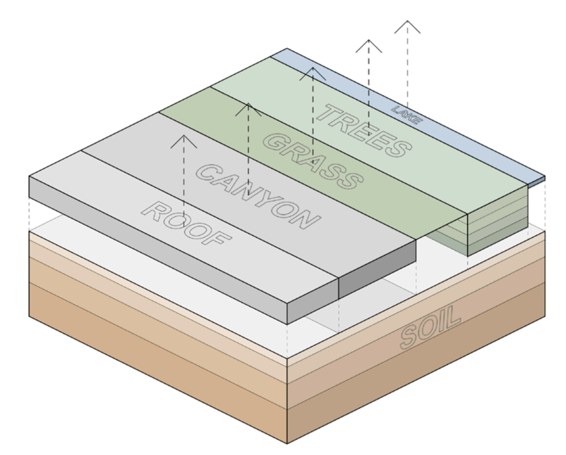
Vegetation: five types, multi-level canopy, dynamic vegetation.

Soil: multi-level, complex hydrology.

Primary use: global/ regional NWP and climate projections.

MORUSES + JULES

(Porson et al., 2009)



Urban scheme: 2 facet slab scheme with morphologically determined canyon characteristics and prescribed anthropogenic heat fluxes.

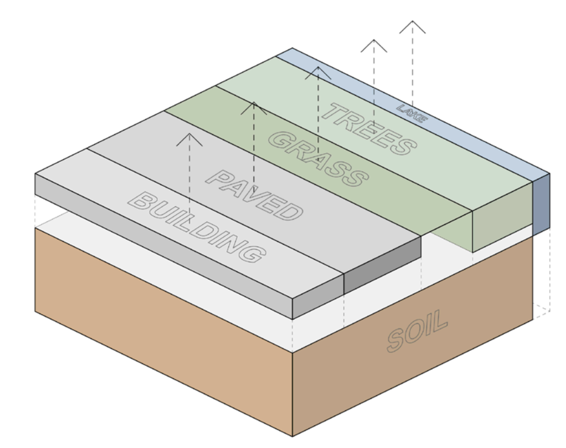
Vegetation: five types, multi-level canopy, dynamic vegetation.

Soil: multi-level, complex hydrology.

Primary use: global/ regional NWP and climate projections.

SUEWS

(Ward et al., 2016)



Urban scheme: 2 facet slab scheme with dynamic anthropogenic heat fluxes dependent on meterology.

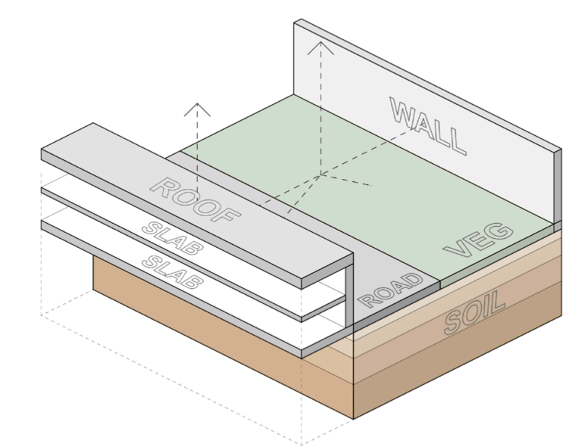
Vegetation: three types, single layer canopy and dynamic LAI.

Soil: single level, complex hydrology.

Primary use: regional/ urban climate and hydrology.

UCLEM

(Lipson et al., 2018)



Urban scheme: canyon scheme with roof, 2x wall, road and vegetation facets with dynamic anthropogenic fluxes from a building energy model

Vegetation: two types (canyon and roof) using big leaf, static LAI.

Soil: multi-level, bucket hydrology.

Primary use: global/ regional/ urban climate and building energy use.

Contacts:

Mathew Lipson: m.lipson@unsw.edu.au
Martin Best: martin.best@metoffice.gov.uk

References:

Best, M.J., 2005. Representing urban areas within operational numerical weather prediction models. Boundary-Layer Meteorology 114, 91–109. https://doi.org/10.1007/s10546-004-4834-5

Best, M.J., Abramowitz, G., Johnson, H.R., Pitman, A.J., Balsamo, G., Boone, A., Cuntz, M., Decharme, B., Dirmeyer, P.A., Dong, J., Ek, M., Guo, Z., Haverd, V., van den Hurk, B.J.J., Nearing, G.S., Pak, B., Peters-Lidard, C., Santanello, J.A., Stevens, L., Vuichard, N., 2015. The Plumbing of Land Surface Models: Benchmarking Model Performance. J. Hydrometeor 16, 1425–1442. https://doi.org/10.1175/JHM-D-14-0158.1

Coutts, A.M., Beringer, J., Tapper, N.J., 2007. Impact of increasing urban density on local climate: spatial and temporal variations in the surface energy balance in Melbourne, Australia. Journal of Applied Meteorology and Climatology 46, 477–493. https://doi.org/10.1175/JAM2462.1

Grimmond, C.S.B., Blackett, M., Best, M.J., Baik, J.-J., Belcher, S.E., Beringer, J., Bohnenstengel, S.I., Calmet, I., Chen, F., Coutts, A., Dandou, A., Fortuniak, K., Gouvea, M.L., Hamdi, R., Hendry, M., Kanda, M., Kawai, T., Kawamoto, Y., Kondo, H., Krayenhoff, E.S., Lee, S.-H., Loridan, T., Martilli, A., Masson, V., Miao, S., Oleson, K., Ooka, R., Pigeon, G., Porson, A., Ryu, Y.-H., Salamanca, F., Steeneveld, G. j., Tombrou, M., Voogt, J.A., Young, D.T., Zhang, N., 2011. Initial results from Phase 2 of the international urban energy balance model comparison. International Journal of Climatology 31, 244–272. https://doi.org/10.1002/joc.2227

Haverd, V., Smith, B., Nieradzik, L., Briggs, P.R., Woodgate, W., Trudinger, C.M., Canadell, J.G., Cuntz, M., 2018. A new version of the CABLE land surface model (Subversion revision r4601) incorporating land use and land cover change, woody vegetation demography, and a novel optimisation-based approach to plant coordination of photosynthesis. Geoscientific Model Development 11, 2995–3026. https://doi.org/10.5194/gmd-11-2995-2018

Lipson, M.J., Thatcher, M., Hart, M.A., Pitman, A., 2018. A building energy demand and urban land surface model. Quarterly Journal of the Royal Meteorological Society 144, 1572–1590. https://doi.org/10.1002/qj.3317

Porson, A., Clark, P.A., Harman, I.N., Best, M.J., Belcher, S.E., 2010. Implementation of a new urban energy budget scheme in the MetUM. Part I: Description and idealized simulations. Q.J.R. Meteorol. Soc. 136, 1514–1529. https://doi.org/10.1002/qj.668

Ward, H.C., Evans, J.G., Grimmond, C.S.B., 2013. Multi-season eddy covariance observations of energy, water and carbon fluxes over a suburban area in Swindon, UK. Atmospheric Chemistry and Physics 13, 4645–4666. https://doi.org/10.5194/acp-13-4645-2013

Ward, H.C., Kotthaus, S., Järvi, L., Grimmond, C.S.B., 2016. Surface Urban Energy and Water Balance Scheme (SUEWS): Development and evaluation at two UK sites. Urban Climate 18, 1–32. https://doi.org/10.1016/j.uclim.2016.05.001