A multi-model and -namelist ensemble for a tropical urban energy balance

Matthias Demuzere,ab, Harshan, S.,b Jarvi, L.,b Velaso, E.,d Roth, M.a

(a) K.U. Leuven, Department of Earth and Environmental Sciences, Celestijnenlaan 200E, 3001 Leuven, Belgium; (b) Department of Geography, National University of Singapore (NUS), Singapore
(c) University of Helsinki, Department of Physics, Helsinki, Finland. (d) Singapore-MIT Alliance for Research and Technology (SMART), Center for Environmental Sensing and Modeling (CENSAM), Singapore

*Contact: Matthias.Demuzere@ees.kuleuven.be - Tel: +32 16 326424 @MaffieMuis

Key Findings

The main (preliminary) findings of this work can be summarized as follows:

- Overall, the skill of each model depends on the flux of interest, the namelist used and the prevailing atmospheric conditions. No model performs better overall compared to any other model, and all models generally perform best for Qrad and worst for Qc.
- CLM and SURFEX almost behave identical when the same namelist is used. And while TERRA-URB is the most simple scheme, its performance is as good compared to the more complex schemes.
- During the exceptional dry period, some models' behavior changes compared to the other models (eg. the modelled outgoing longwave radiation by SURFEX during the dry periods. For most models, the normalized bias for upward long-wave radiation (latent heat flux) increases (decreases) as a function of “hours after a rainfall event” (not shown).
- The inter-model and inter-namelist variability often depict a similar magnitude in interquartile range. Also here, no model or namelist combination outperforms the others on all accounts. Thus results very much depend on the choice of model and namelist used, and the flux being considered.

1. Site & data

The climate and flux data used to force and evaluate the models were measured at a flux tower located in the suburban area Telok Kurau (TK) of Singapore. TK is a low-density residential neighborhood located about 3 km north of Singapore’s south-eastern coastline. The study area is flat and characterized by low-rise buildings (2-3 story row and semi-detached houses and a few 5 story condominiums). Surface cover in the same area is 85% impervious (30% buildings, 12% roads, 34% parking lots, etc) and 15% pervious (11% tree crowns, 4% grass) (See Figure 1). The area corresponds to local climate zone (LCZ) 3 or “compact low rise” (Stewart and Oke, 2012). This site was chosen because of its directional homogeneity in surface cover and the data here used extends from June 2013 to April 2014.

The micro-meteorological tower supported various meteorological sensors at a height of 23.7 m above the surface: radiative fluxes (CN12), turbulent fluxes of sensible and latent heat (CSAT3/LI-7500), temperature & humidity probe (HMP45C) and rain gauge (HOBO RG; Onset Computer Corporation, Bourne, MA, USA).

2. Methods

Four land-surface models are used in the current study, with a focus on their urban parameterizations. All models are forced with atmospheric data observed above the canopy layer (see 1. Site & Data), hereby removing a potential source of error produced by the atmospheric model.

Four different models are used, each characterized by a varying degree of complexity:
- CLM (Oleson et al., 2008), SURFEX (Masson et al., 2013), SUEWS (Järvi et al., 2011) and TERRA-URB (Wouters et al., 2015).

The latter – probably least known model – is a recent development within TERRA-ML, the default land-surface scheme of the numerical atmospheric model COSMO-CLM. TERRA-URB is a simple bulk scheme in which urban land cover is characterized by a specific thermal inertia, roughness length, albedo and emissivity and accounts for surface layer stability and the roughness sub-layer (Demuzere et al., 2008; Wouters et al., 2015).

While all models are forced with the same meteorological boundary conditions, each LS generally has a native set of external parameter values. E.g. SURFEX used the ECCLIMAP database (nJa03, Masson et al., 2003), while CLM uses the Jackson et al. (2010) database for its urban parameters. For this study, all models are run with three namelists (REF, mA03 and mA10), with varying values for the land cover fractions and the thermal, radiative and morphological properties (see Table 1).

3. Preliminary results

The Phase I general evaluation uses all four models with the reference namelist REF. All performance metrics are based on the hourly output for the whole period (as in Figure 3) or further sub-divided sub-periods (eg. day and night in Figure 4). A temporal evolution of the normalized bias is shown in Figure 5.

A first result on the Phase II multi-namelist and -model experiment is shown in Figure 6. Here one can clearly see the sensitivity of using one model with different namelists or one namelist for all different models.

Context

Impervious (urban) surfaces only cover a small percentage of the Earth’s land surface, but their representation in land-surface (LS) models and numerical weather prediction / climate models is nevertheless of great importance. Where the range of available LS schemes is considerable, the number of available urban parameterizations embodied in those schemes - as revealed by the intercomparison study by e.g. Grimmond et al. (2010, 2011) – might be even higher. The intercomparison study also outlined that models with various complexities have various strengths and weaknesses, while all models have a varying performance across the energy balance components. Besides the varying model complexities (physics), LS schemes also differ in the amount and characteristics of their external parameters describing the surface characteristics. The amount of parameters is generally associated with a models’ complexity.

Against this background, this study aims at 1) a general evaluation of the capacity of 4 urban canopy models (see 2. Methods) in simulating a tropical urban surface energy balance (see 1. Site & data) and performing a multi-namelist and model mini-ensemble indicating the role of and interaction between the models’ complexity and the external parameter settings (See 2. Methods and 3. Preliminary results).

Selected references


