The influence of COSMO model developments and parameters affecting the boundary layer on urban climate Modelling with TERRA_URB

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Motivation

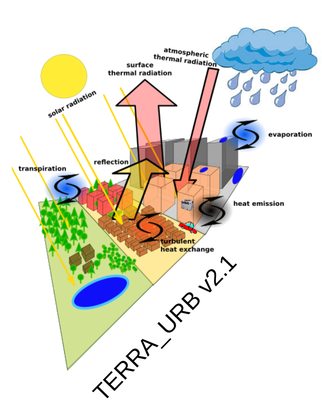
- A substantial underestimation of nocturnal urban heat islands with an out-of-the-box setup of COSMO-CLM coupled to TERRA_URB is experienced for cities in Belgium[1]
- This is despite TERRA_URB's satisfactory results of reproducing the urban surface energy balance during intensive urban observation campaigns for Toulouse, Basel and Singapore[2,3]
- Idealized boundary-layer model demonstrates that urban heat island intensities depend on the stable stratification of the vertical temperature profiles[4]
- The question rises what's the role of an apparent underestimation of the stable stratification and overestimated nocturnal rural temperatures on the underestimation of the urban heat island intensity

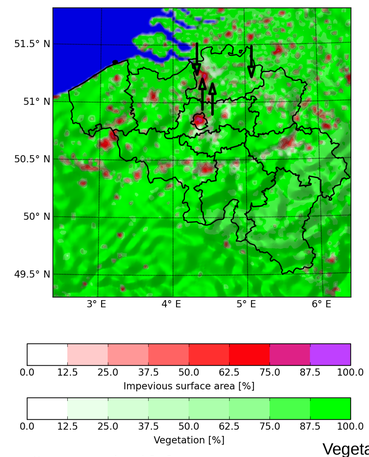
Objectives

- Investigate sensitivity of urban heat islands to model parameters affecting the boundary layer through:
  - ➔ changes in the model parameters of boundary-layer turbulent vertical transport
  - ➔ inclusion of an implicit vegetation effects parameterization[5]
- Provide recommendations for improved urban-climate modelling with COSMO

Experiments

- Belgian domain, 2.8km horizontal spacing
- Nested in ECMWF forecasts, 12.5 km grid spacing
- Using COSMO5.0_clm8 + TERRA_URB v2.1
- Mid-summer: 2012/07/21 → 2012/08/20 with 3 weeks of spin-up





Length scale of subscale surface patterns over land [m], which scales the tke circulation term

Minimal diffusion coefficients of vertical turbulent transport

Vegetation skin effect is turned on for the natural tiles using a skin-layer conductivity of $10 Wm^{-2}K^{-1}$, which agrees with observations over grassland[5]. It is switched off for the urban tiles where no vegetation is present.

Experiment ID	`tkmmin` and `tkhmin` [m^2s^{-1}]	`pat_len` [m]	Vegetation skin effect
TKDEF_PLDEF	0.4 (default)	500 (default)	no
TKDEF_PL010	0.4	10	no
TK002_PL500	0.02	500	no
TK002_PL010	0.02	10	no
TKDEF_PLDEF_SK	0.4	500	yes
TKDEF_PL010_SK	0.4	10	yes
TK002_PLDEF_SK	0.02	500	yes
TK002_PL010_SK	0.02	10	yes
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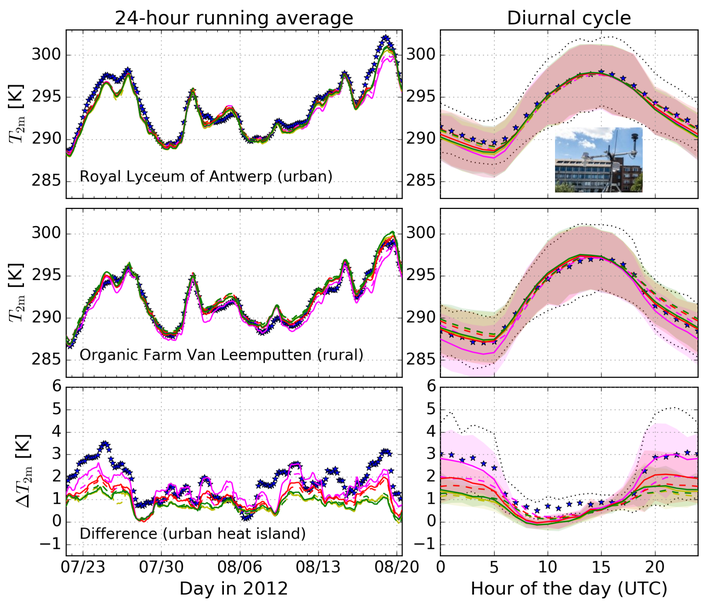
Results and discussion

Urban climate observations

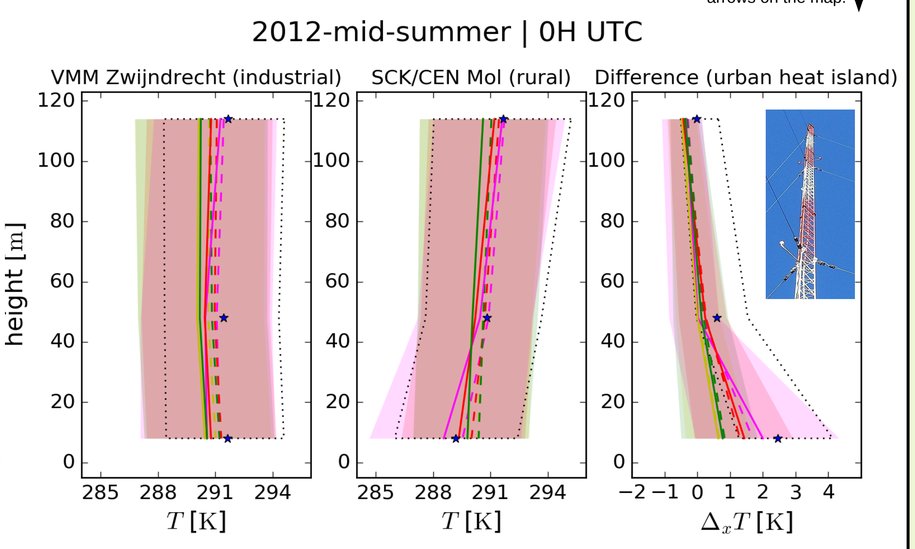
The two stations are indicated with upwards arrows on the map: ↑



- Both the vegetation insulation effect and turbulence parametrization influence nocturnal temperatures and stability of the nocturnal boundary layer temperature profiles
- The effect is mainly established in the rural areas and it is much smaller extent in the urban areas
- As a consequence, they affect (NBL and CL) urban heat islands – confirming previous idealized studies – by up to a factor 3
- Non-linear responses: the different parameters sensitivities intensify each other
- Results are consistent with sensitivity experiments over Moscow[6]

Tower observations

The two towers are indicated with downwards arrows on the map: ↓



Conclusions and outlook

– Results suggest that optimisation of boundary-layer representation in COSMO has large potential in improved urban-climate modelling, especially the alleviation of underestimated nocturnal heat islands
– In order to avoid overtuning, a physical basis of optimized parameters needs to be investigated
– Remaining underestimation of urban heat islands needs to be tackled by considering:
(1) improved consistency between observed and modelled temperatures
(2) additional detail in surface and urban morphological information
(3) improved model physics (urban, rural, upper air…) of the coupled model system
– Tests with additional COSMO developments need to be done regarding the new TKE turbulence scheme[7,8] and explicit vegetation shading

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[8]*Cerenzia, I., Raschendorfer., M., 2016. Diagnostics and Revision of the COSMO Surface Layer Formulation under Stable Conditions (COSMO/CLM/ART User Seminar 2016.*