“Test Version” (TV) of the Urban land-surface scheme TERRA_URB for the COSMO(-CLM) model

Hendrik Wouters, Matthias Demuzere, Ulrich Blahak, Jürgen Helmert, Jan-Peter Schulz, Matthias Raschendorfer, Gianluca Mussetti, Nicole van Lipzig

Details, see appendix new paper

TERRA_URB

"Intrinsic representation of urban physics in the COSMO(-CLM) model with modifications to the input data, soil module and land-atmospheric interactions"

– *Version 1 → Development Version COSMO* [*May 2014*] –

- Bulk representation of the urban canopy (De Ridder et al., 2012; Demuzere et al., 2008)
- Anthropogenic heat emission (Flanner, 2009)
- 'Bluff-body' thermal roughness length parametrization (Brutsaert et al., 1982; Kanda et al., 2006)
- Impervious water storage based on a density distribution of water puddle depths (Wouters et al., 2015)
- Poorman's tile approach

– *Version 2 → Test Version in COSMO* [*February 2016*] –

- Application of SURY (Wouters et al., in submission)→ next slide
- Application of TURBTRAN
- **Buildings and pavements** are represented **on top of natural soil** instead of seperate 'paved soiltype' → Consistent representation of **urban tile consisting of impervious surfaces, bare soil, vegetation and snow**

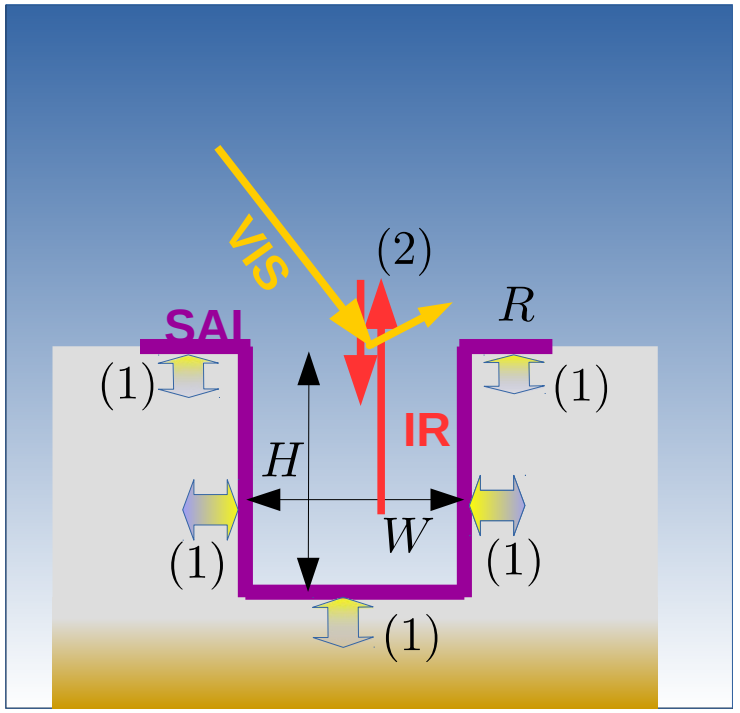
Since workshop "implementation of TERRA_URB into the COSMO-CLM model" (2014/11)

Switches TERRA_URB v.2

- l_urb: &!general urban parameterization switch that activates:
  &!luf = 1; itype_eisa = 2; itype_ahf = 1; itype_tile = 1
- luf : switch for taking into account the urban fabric (true is default)
- itype_kbmo_uf : kB-1 (= ln[z0/z0h]) - parametrization in turbulence_tran for the urban fabric; 0: standard from the turbran model; 1 (default): external parametrization according Brutsaert/Kanda; 2: external from Zilitinkevich
- itype_tile = 0/1 : 0 means no tiles; 1 (default) is poor-man's tile approach for the seperate treatment of the urban fabric alongside the natural land
- itype_ahf = 0/1: 0 means no anthropogenic heat flux; 1 (default) means anthropogenic heat according to Flanner, 2009 (latitudinal, annual, and diurnal-dependent anthropogenic heat flux based on an annual-mean dataset)
- itype_eisa ,& ! type of evaporation from impervious surfaces:
  0: evaporation just like bare soil;
  1: no evaporation
  2 (default): densitity of puddle depths (Wouters et al., 2015)

```
IF (l_urb.and.luf) THEN
…
ENDIF
IF (l_urb.AND.eisa) THEN
…
ENDIF
```

Semi-empirical Urban canopY parametrization SURY



Urban canopy parameters

parameter name	symbol	default value
substrate albedo	α	0.101
substrate emissivity	ϵ	0.86
substrate heat conductivity	λ_s	0.777 W m^{-1} K^{-1}
substrate heat capacity	$C_{v,s}$	1.25 10^{6}J m^{-3} K^{-1}
building height	H	15 m
canyon height-to-width ratio	$\frac{H}{W}$	1.5
roof fraction	R	0.67

SURY

"Translation of urban canopy parameters into bulk parameters"

→ Allows for intrinsic urban physics in bulk land-surface schemes

Bulk parameters

parameter name	symbol
bulk albedo (snow-free)	α_{bulk}
bulk emissivity (snow-free)	ϵ_{bulk}
aerodynamic roughness length	z_0
bulk heat conductivity	λ_{bulk}
bulk heat capacity	$C_{\mathrm{v,bulk}}$

1. 'SAI'-integrated substrate heat transport
2. Approximation of Fortuniak (2007) for albedo reduction depening on $\frac{H}{W}$
3. Surface roughness from building height (Sarkar and De Ridder, 2010)

All components are implemented in the COSMO-CLM model:
`cosmo_131108_5.00_clm6_urb_tile_dv4`

TERRA_URB

Semi-empirical Urban canopY parametrization SURY

Urban canopy parameters

parameter name	symbol	default value
substrate albedo	α	0.101
substrate emissivity	ϵ	0.86
substrate heat conductivity	λ_s	0.777 W m^{-1} K^{-1}
substrate heat capacity	$C_{v,s}$	1.25 10^{6}J m^{-3} K^{-1}
building height	H	15 m
canyon height-to-width ratio	$\frac{H}{W}$	1.5
roof fraction	R	0.67

Local Climate Zones classification (Stewart and Oke, 2012) – WUDAPT.org

"Translation of urban canopy parameters into bulk parameters"

→ Allows for intrinsic urban physics in bulk land-surface schemes

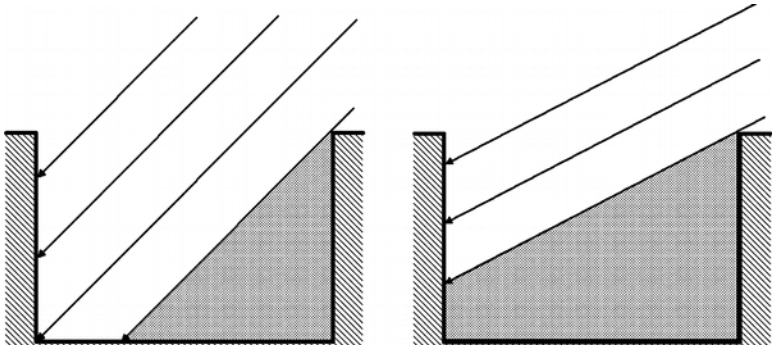
Bulk parameters

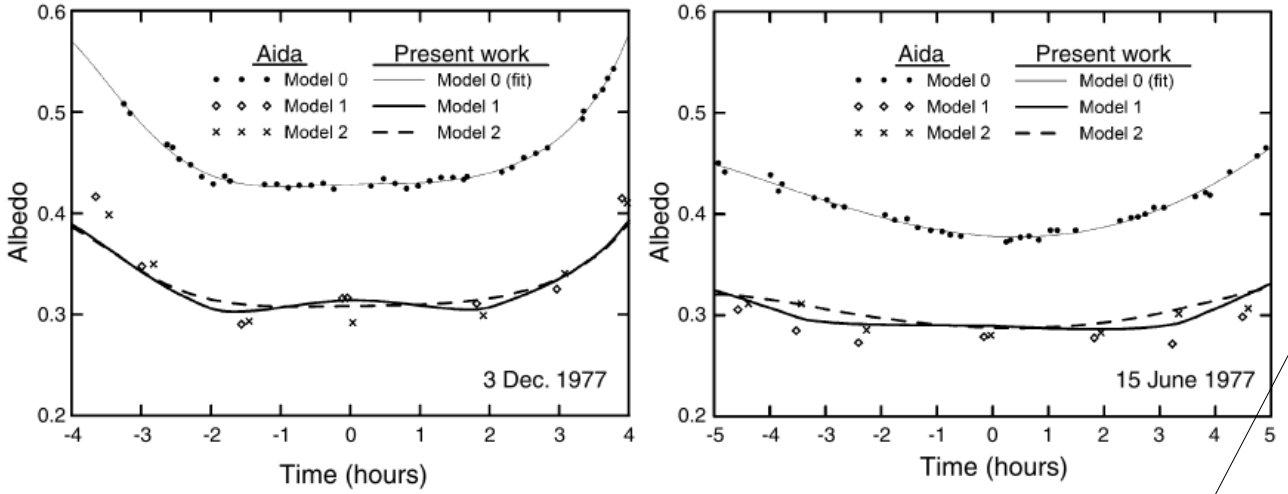
parameter name	symbol
bulk albedo (snow-free)	α_{bulk}
bulk emissivity (snow-free)	ϵ_{bulk}
aerodynamic roughness length	z_0
bulk heat conductivity	λ_{bulk}
bulk heat capacity	$C_{\text{v,bulk}}$

1. 'SAI'-integrated substrate heat transport
2. Approximation of Fortuniak (2007) for albedo reduction depening on $\frac{H}{W}$
3. Surface roughness from building height (Sarkar and De Ridder, 2010)

All components are implemented in the COSMO-CLM model:
`cosmo_131108_5.00_clm6_urb_tile_dv4`

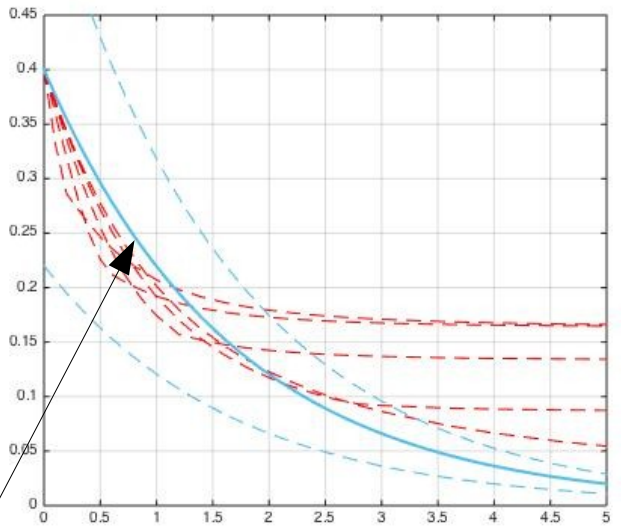
TERRA_URB





Fortuniak, 2007

$$\alpha_s \times \psi_{\text{canyon}}$$



Error between 7% to 45% depending on sun height

$$\psi_{\text{canyon}} = \exp^{-0.6H/W}$$

EXTPAR

– In DWD version 2.4 and COSMO consortium version 3.0 –

- New field: Impervious Surface Area (ISA)
- New field: Annual-mean Anthropogenic Heat Flux (AHF)

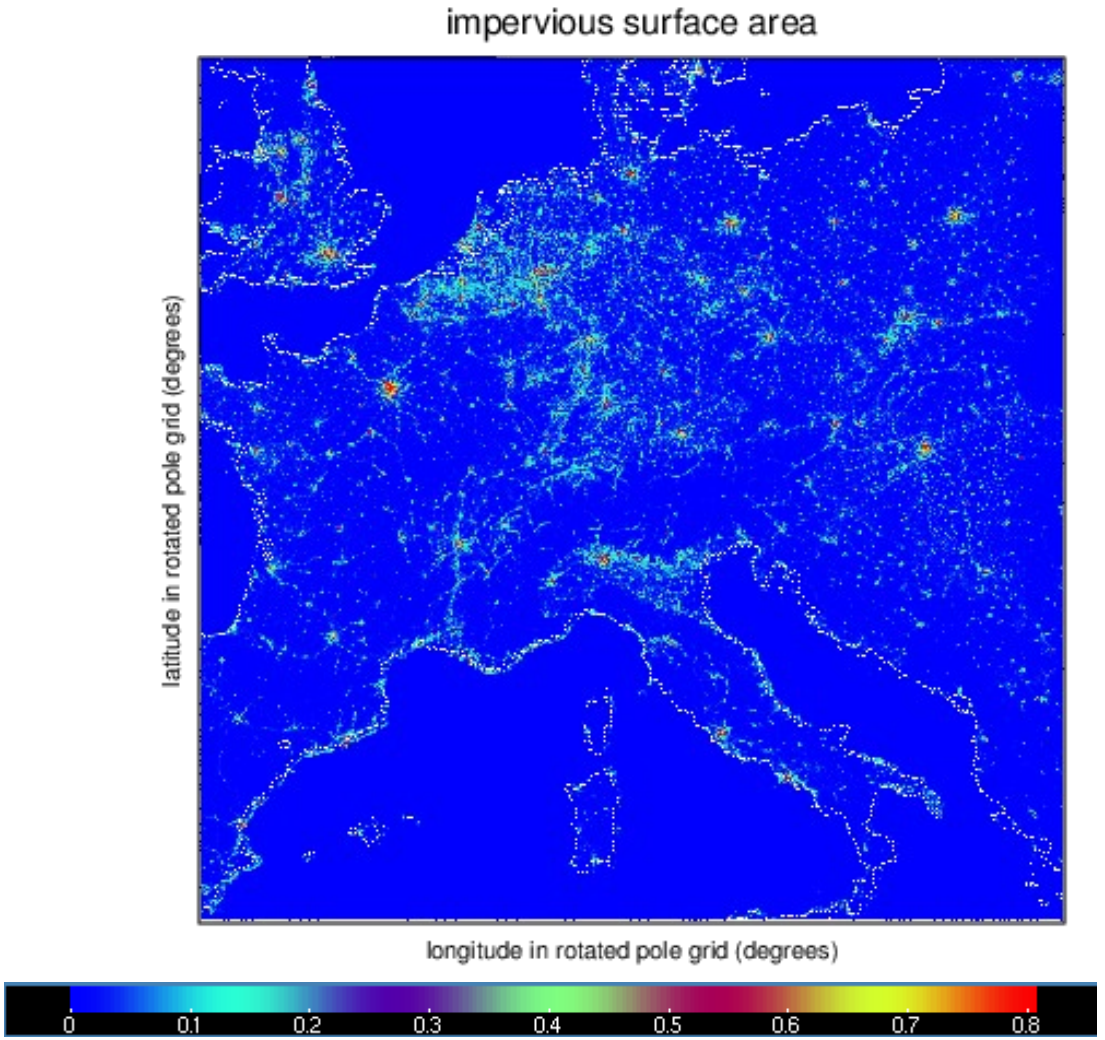
NCID	long name	Units	Res	Area	Filename	Source	recommended
ISA	impervious surface area	-	10”	90 °N - 12.5 °N 60 °W - 60 °E	EEA_ISA_4_16bit.nc	European Environmental Agency (Maucha et al., 2010)	*
ISA	impervious surface area	-	30”	75 °N - 65 °S 180 °W - 180 °E	NOAA_ISA_16bit.nc	NOAA	
AHF	annual-mean anthropogenic heat flux	W m^{-2}	2.5’	90 °N - 90 °S 180 °W - 180 °E	AHF_2006_2.5min_latreverse.nc	Flanner (2009)	
AHF	annual-mean anthropogenic heat flux	W m^{-2}	30”	75 °N - 65 °S 180 °W - 180 °E	AHF_2006_NOAAISAredistr.nc	Flanner (2000) and redistributed to NOAA ISA	*

http://www.eea.europa.eu/data-and-maps/data/eea-fast-track-service-precursor-on-land-monitoring-degree-of-soil-sealing/

http://www.cgd.ucar.edu/tss/ahf/

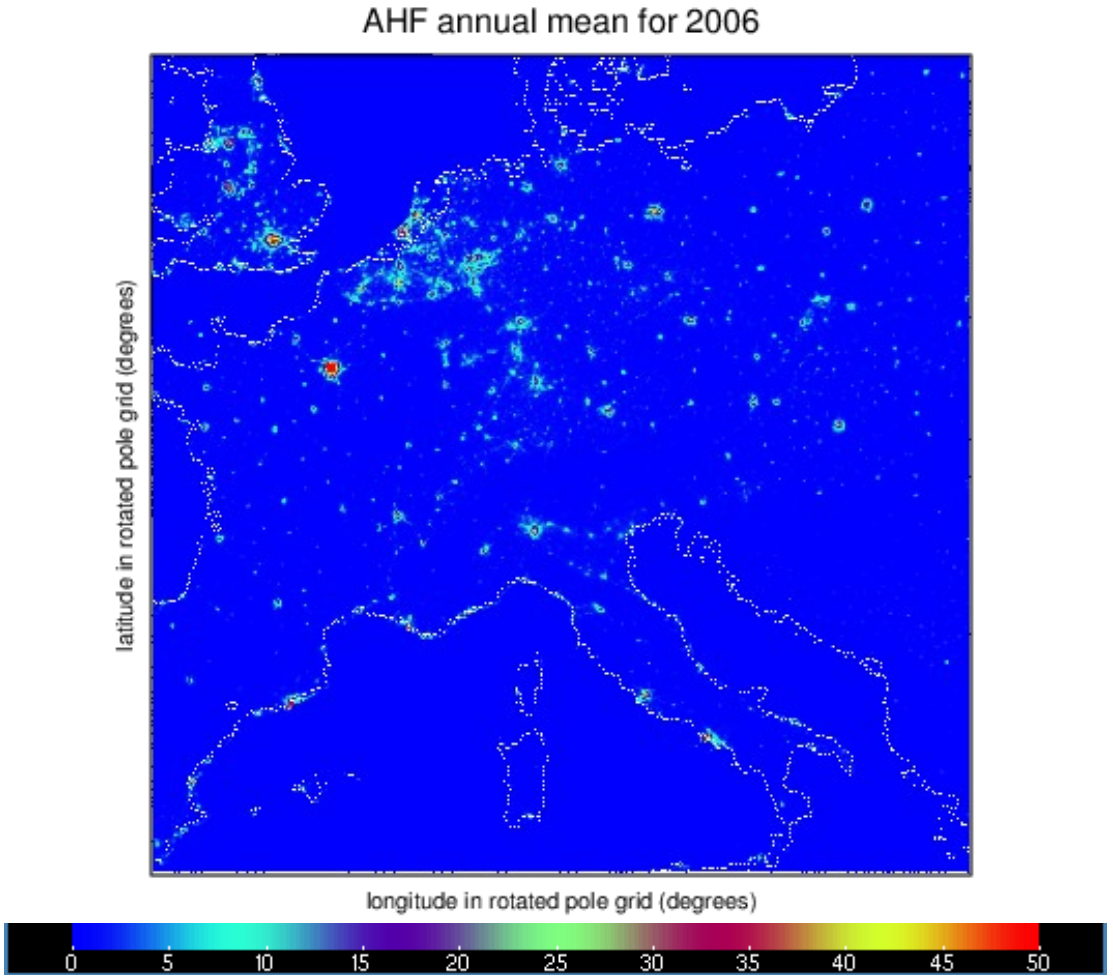
Adapted from slides Daniel Lüthi (COSMO GM last 09/2015)

ISA (example europe)



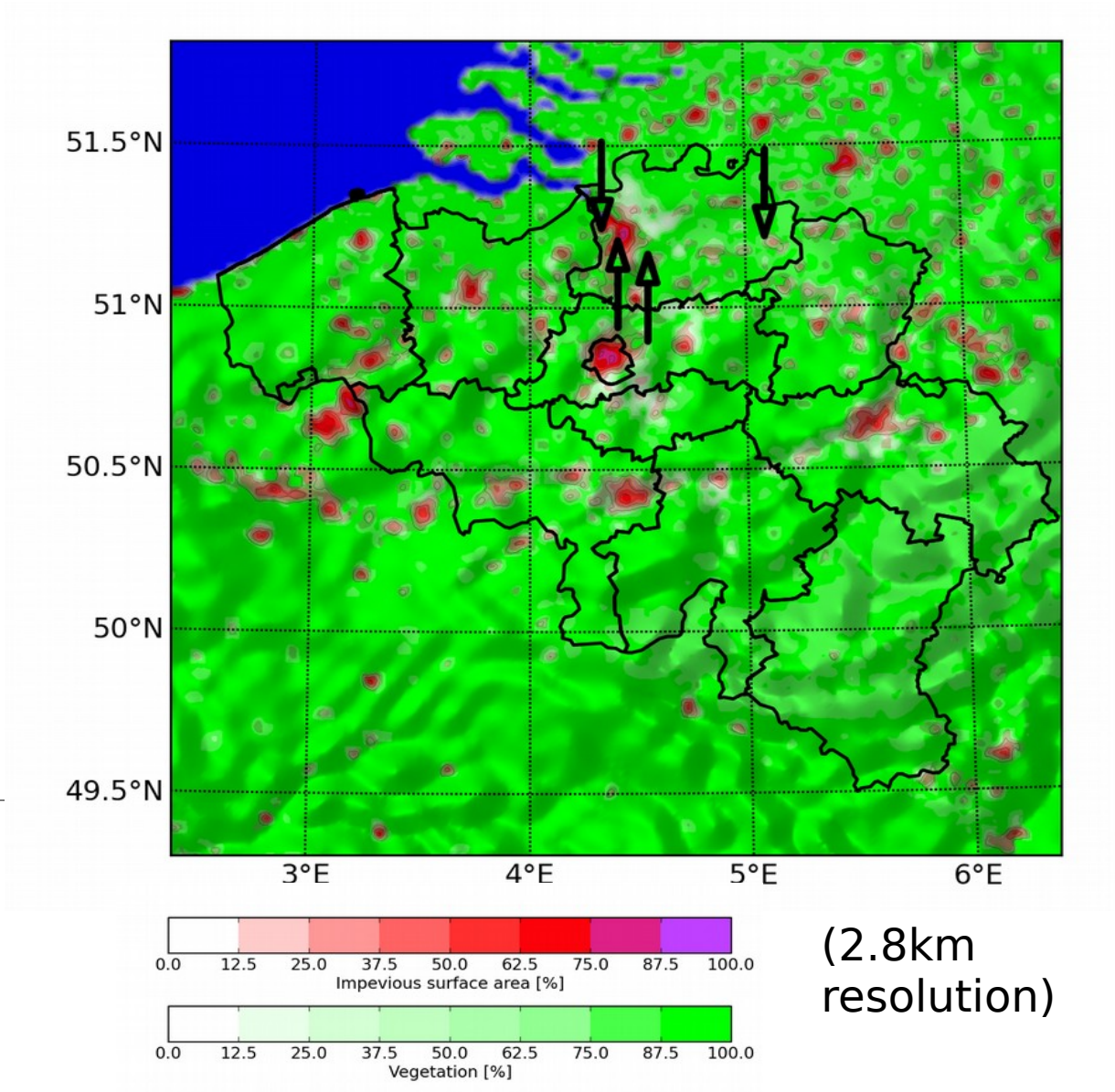
Adapted from slides Daniel Lüthi (COSMO GM last 09/2015)

AHF (example Europe)



Adapted from slides Daniel Lüthi (COSMO GM last 09/2015)

Example Belgium



(2.8km resolution)

– for the Belgian area and the city of Antwerp –

Evaluation

TERRA_URB

REF, STD

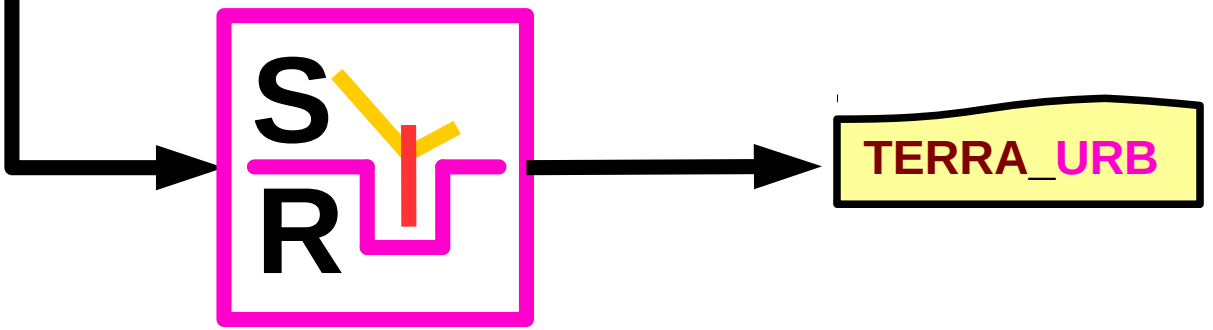
~~TERRA_URB~~

Urban canopy parameter sensitivity

AL, AH, BL, BH, …, GL, GH

Experiment ID	urban canopy parameter	L	H
A	α	0.10	0.25
B	λ_s [W m^{-1} K^{-1}]	0.200	0.968
C	$C_{\mathrm{v,s}}$ [10^6J m^{-3} K^{-1}]	0.321	1.56
D	$\frac{H}{W}$	0.75	2.0
E	H [m]	3	30
F	R	0.40	0.70
G	AHF	0	2 × FL09

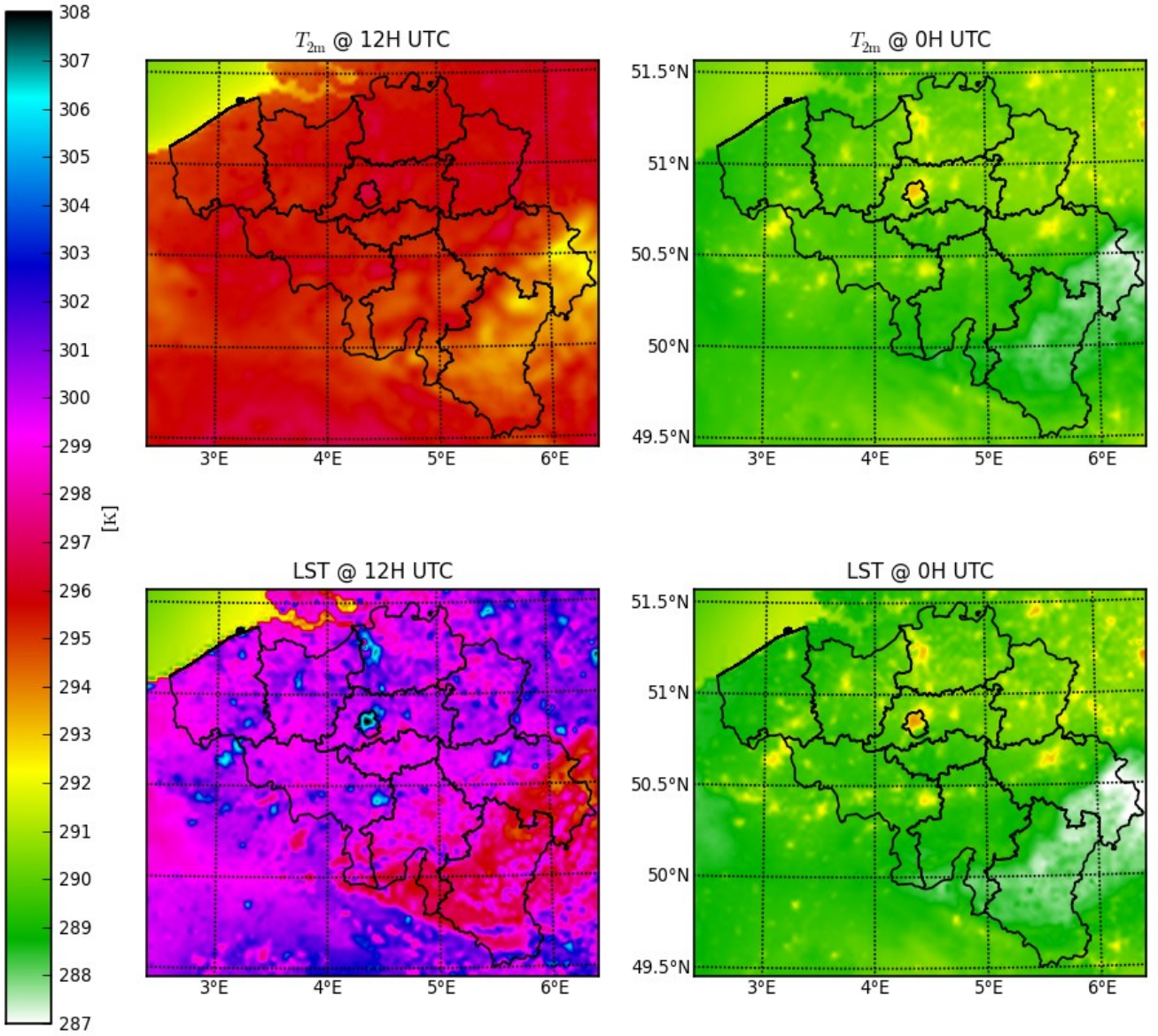
Ranges are adopted from the Local Climate Zones of 'compact mid-rise' and 'compact low rise' (Stewart and Oke, 2012)



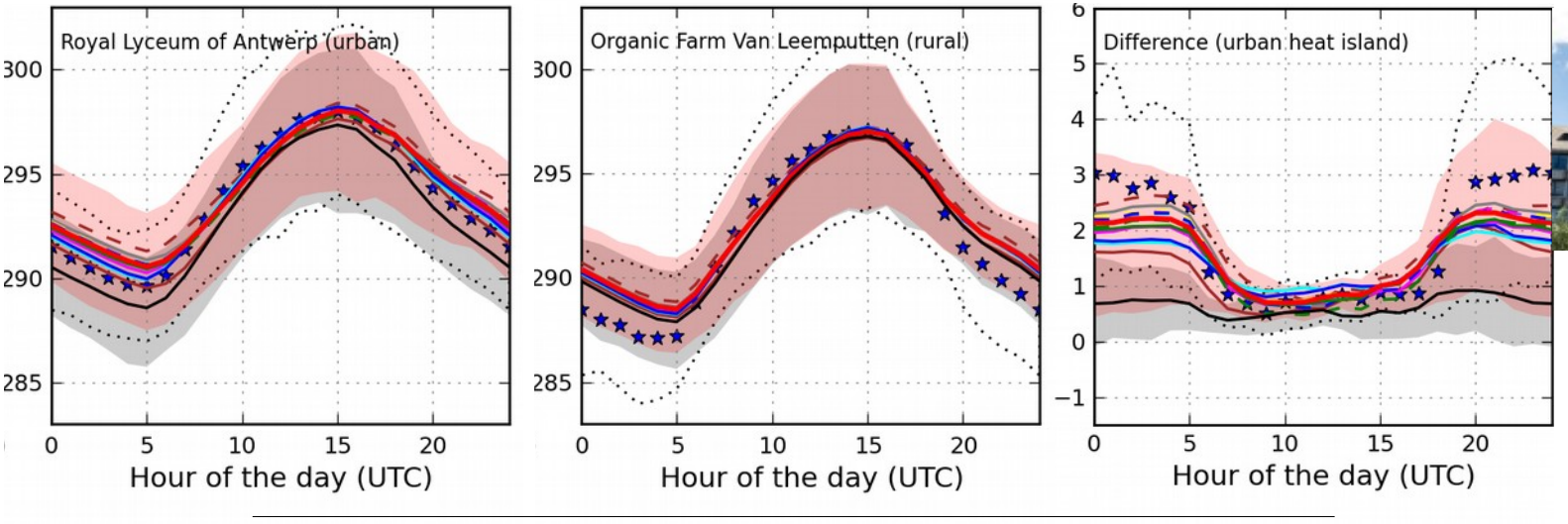
Evaluation for the Belgium summer 2012

TERRA_URB

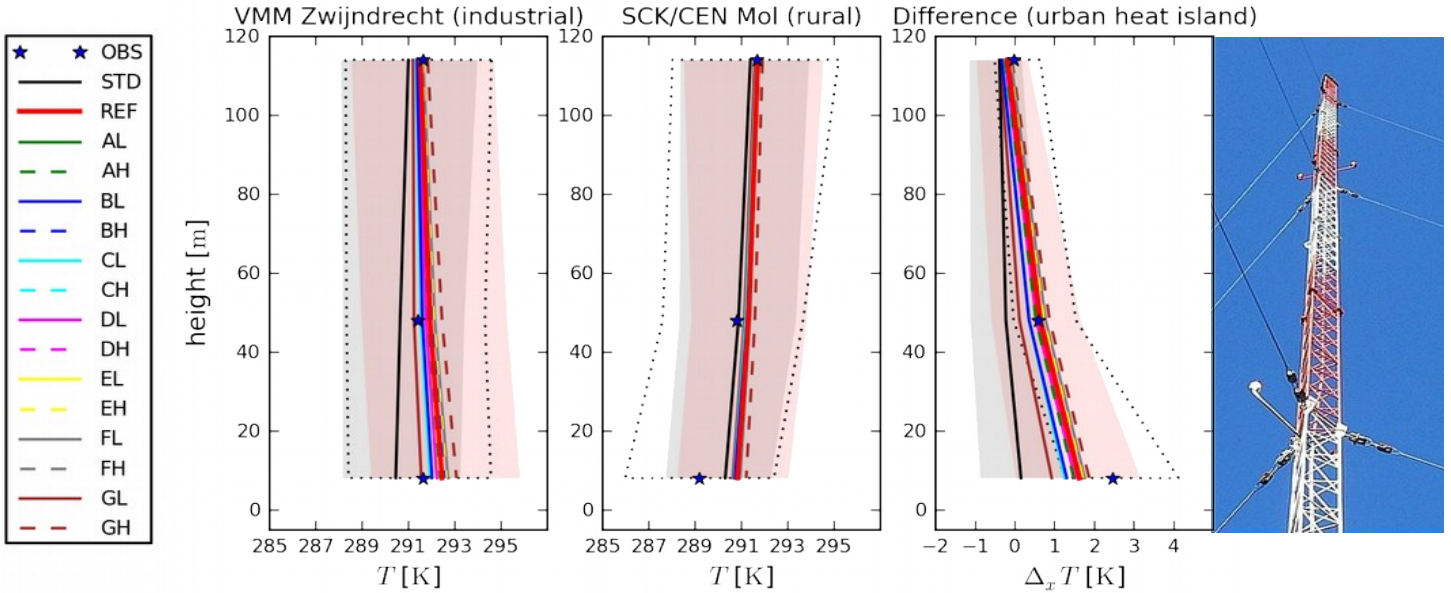
REF

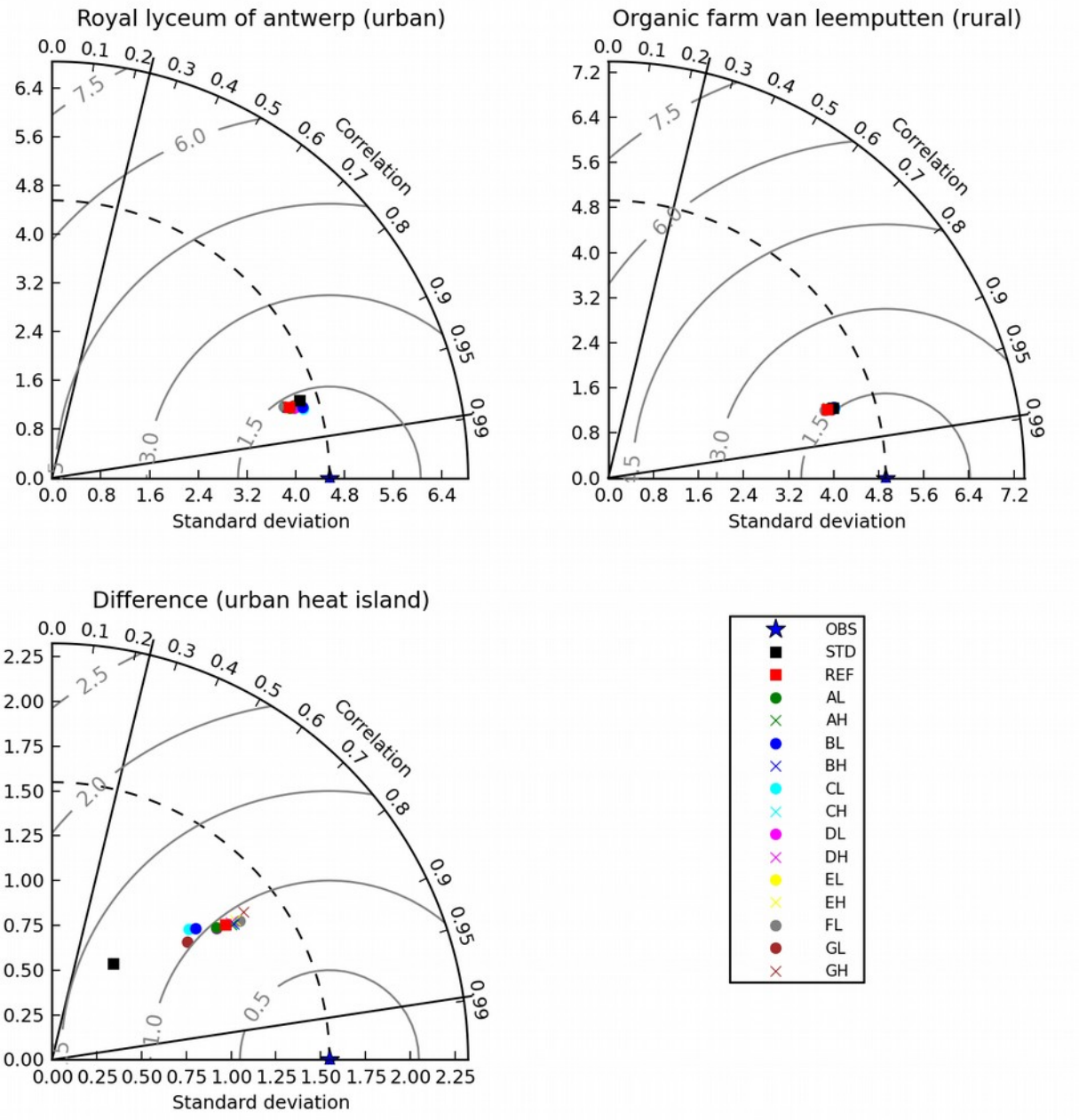


Canopy-Layer Urban Heat Island (CLUHI) – Antwerp

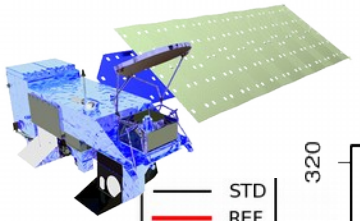


Nocturnal Boundary-Layer Heat Island (BLUHI) – Antwerp

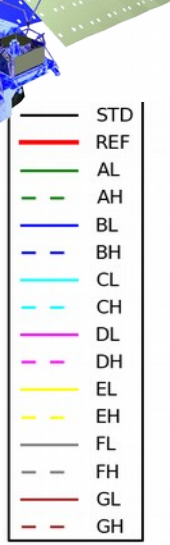


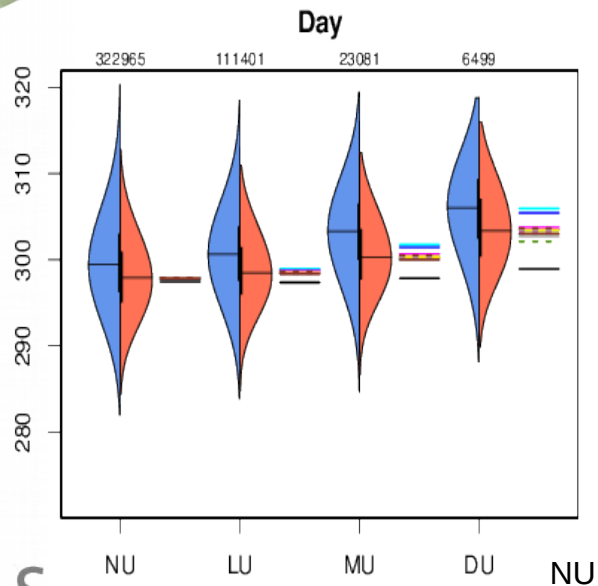

Royal lyceum of antwerp (urban)
Organic farm van leemputten (rural)
Difference (urban heat island)
Correlation
Standard deviation
OBS
STD
REF
AL
AH
BL
BH
CL
CH
DL
DH
EL
EH
FL
GL
GH

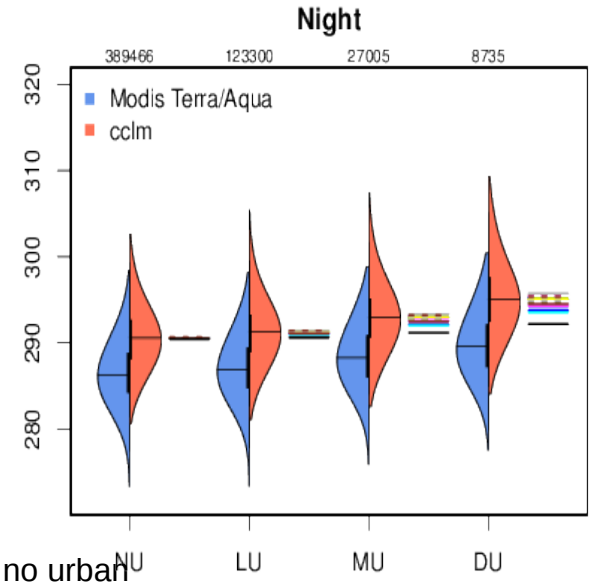
Surface Urban Heat Island (SUHI) – Belgium



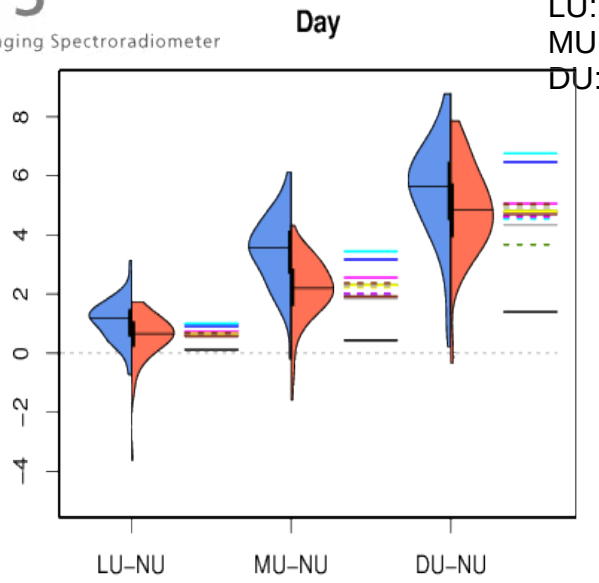
MODIS
Moderate Resolution Imaging Spectroradiometer

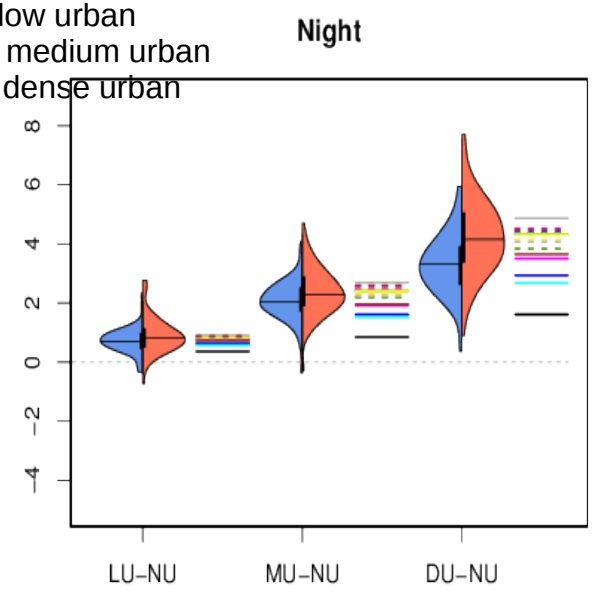






NU: no urban
LU: low urban
MU: medium urban
DU: dense urban





Discussion and conclusions TERRA_URB

- Underestimation of urban temperatures is alleviated with TERRA_URB v.2; **Variability of urban heat islands are well reproduced**; **Effect** on temperature compared to the standard COSMO(-CLM) model in the **rural areas is minor**.
- Overall model **overestimation** is found in **nocturnal temperatures**, particularly in night-time land-surface temperatures; Systematic **underestimation** is found for the **nocturnal heat islands**.
- Model sensitivity study by changing the **urban canopy parameters** in SURY show a **city-scale effect**: Additional urban canopy information has potential for improving regional atmospheric modelling.
- Land-surface temperatures and SUHI show the largest sensitivity for the substrate thermal parameters; $T_{2\mathrm{m}}$, nocturnal boundary-layer temperatures and associated UHI show the largest sensitivity for the anthropogenic heat emission.
- **Model errors overrule the model uncertainty range** with regard to the **urban canopy parameters**. This demonstrates that the majority of the model uncertainty is not related to such parameter uncertainty, but from uncertainties in the land-surface scheme and other aspects of the atmospheric model system.
- **Ambiguity in performance and its sensitivity** with regard to the **different temperature quantities** demonstrate that multi-variable evaluation is a requirement for improving and comparing online urban atmospheric modelling strategies.

Next steps

- Submission the SURY/TERRA_URBv.2 paper, probably to Geosci. Mod. Dev.
- Implementation in the standard COSMO model → COSMO5.5
  - this will be done be the DWD / COSMO source code management team (Uli et al.)
  - Based on ICONs tile parallellization interface and the TERR_URB's poor-man's tile approach

    → may take some time until the changes are propagating in official versions of COSMO and COSMO-CLM versions
- Testing with in NWP mode

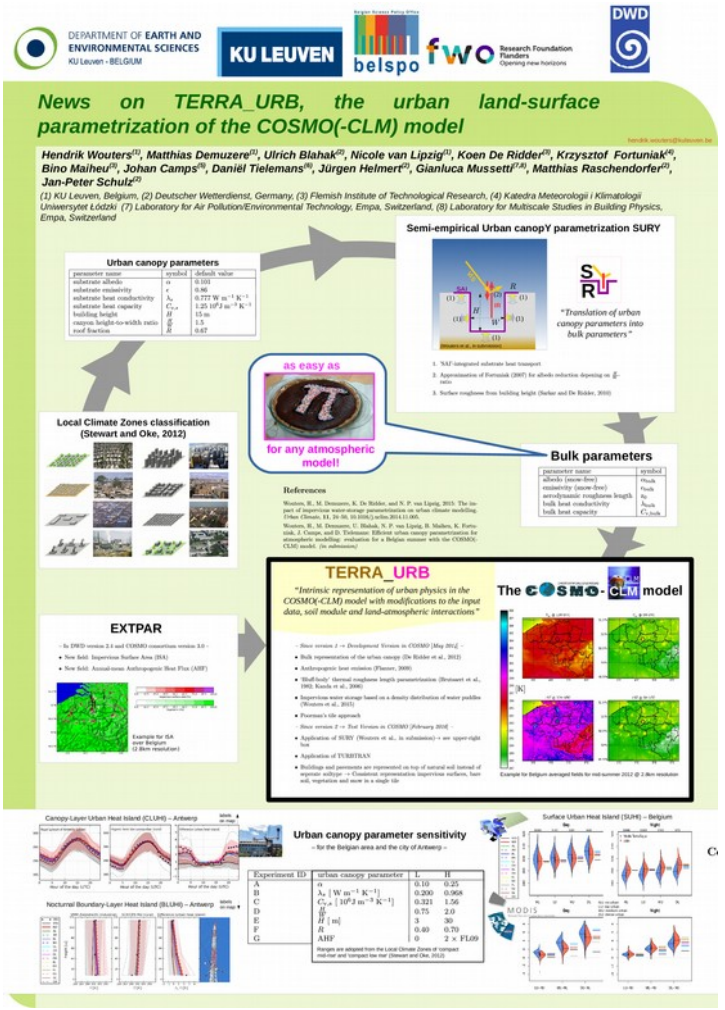
More advances? Feed for discussion...

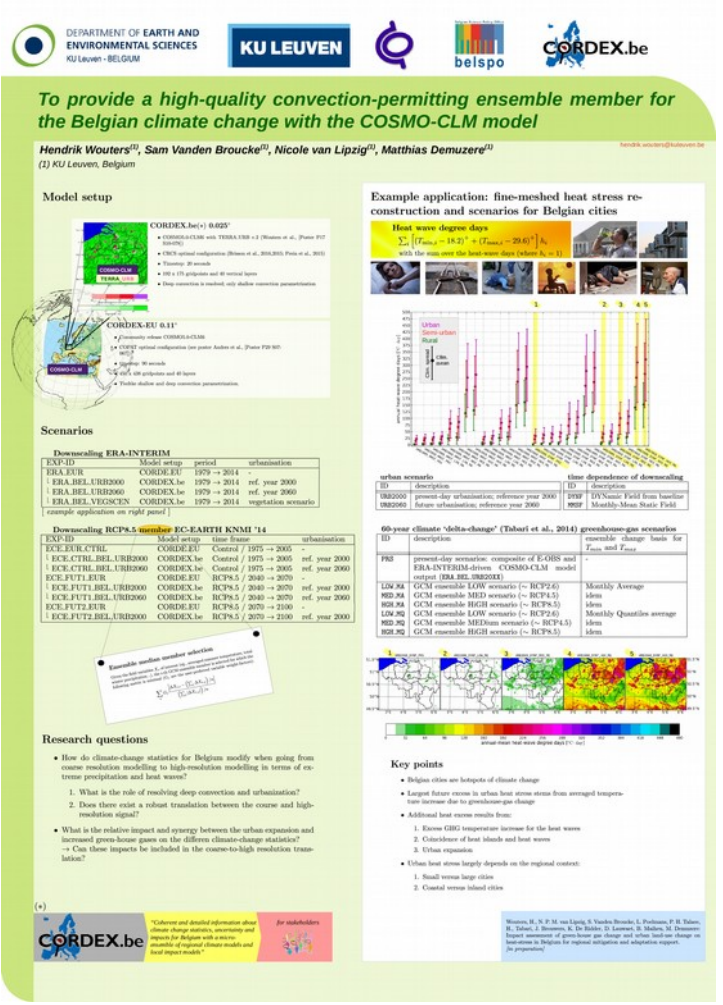
- Documentation (from the appendix from the paper to be submitted)
- Model tuning (→ in SOILVEG_URB / URBMIP)
- testing of vegetation (shading) and (multi-layer) snow in the urban tile
- TERRA_URB version 3?
  - make 2-D input fields for urban canopy parameters (now, they are domain-wide fixed variables)
  - more explicit representation of canopy morphology in the surface-layer turbulence transfer scheme that should replace the (thermal) roughness length parametrization
  - Including the “sun height “
  - tile seperation between roofs and canyons
  - tile-dynamic canyon shading
  - ...

Additional discussion points

- Availability of intermediate version until official version is available (on Redc?)
- New fields ISA and AHF in EXPAR not yet available through the CLM-community Webpage WEBPEP

Thank you for your attention.





References

Wouters, H., M. Demuzere, K. De Ridder, and N. P. van Lipzig, 2015: The impact of impervious water-storage parametrization on urban climate modelling. *Urban Climate*, **11**, 24–50, 10.1016/j.uclim.2014.11.005.

Wouters, H., M. Demuzere, U. Blahak, N. P. van Lipzig, B. Maiheu, K. Fortuniak, J. Camps, and D. Tielemans: Efficient urban canopy parametrization for atmospheric modelling: evaluation for a Belgian summer with the COSMO(-CLM) model. *(in submission)*