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How much spatial details in meteorological parameters is needed for modelling urban air-quality?

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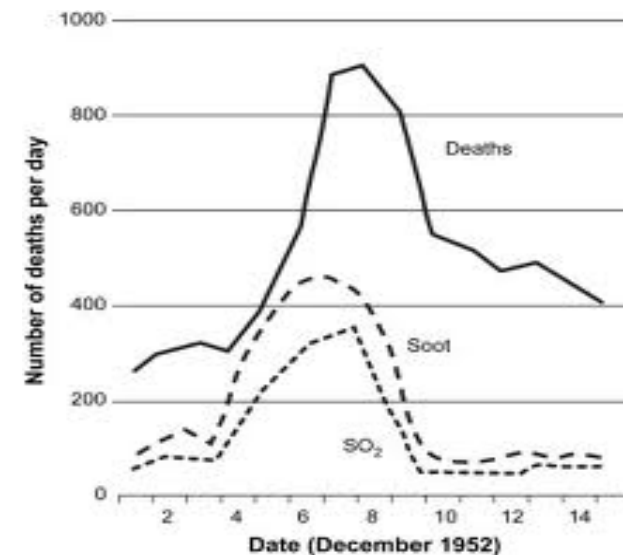
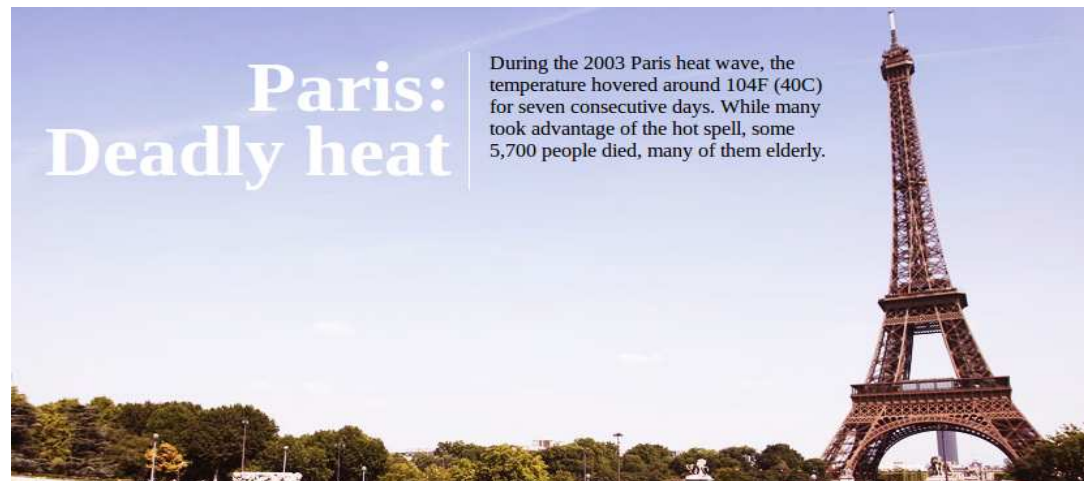
Overview

1. Motivation
2. Urban parameterization of TERRA-ML and COSMO-CLM
3. Urban climate observations
4. Model setup and configuration
5. Model evaluation
6. Conclusions
7. Outlook and applications



1. Motivation (1/2)

- » Large discrepancy exists between urban and natural areas
- » Cities: where most people of the world live!
- » Urban climate and air quality affects human health





1. Motivation (2/2)

- » How to counter these hazardous effects?
Investigate for relevant processes with urban climate and air-quality simulations
- » Representation of urban climate is needed!
This allows us to assess the impact of urban climate on air quality



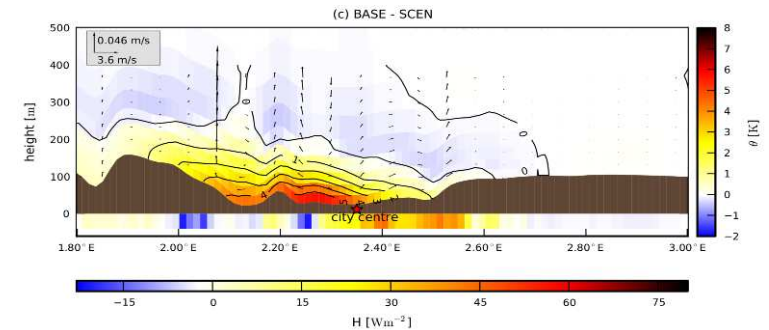
2. Urban parameterization of TERRA-ML and COSMO-CLM



2. Urban parameterization (1/4)

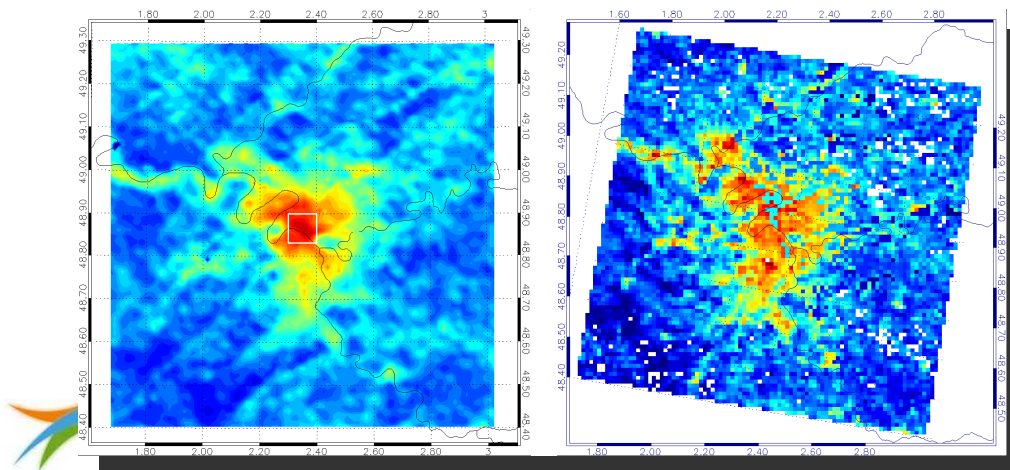
- » Based on in-depth urban climate modeling research
 - » *De Ridder, Geophys. Res. Lett., 2006*
 - » *Demuzere et al., J. Geophys. Res., 2008*
 - » *Wouters et al., Boundary-Layer Meteorol., 2012*
 - » *De Ridder et al., J. Geophys. Res., 2012*

Wouters et al. (in ACP Discussions)



Sarkar and De Ridder, Boundary-Layer Meteorol., 2011

$$kB^{-1} \equiv \ln(z_0/z_{0t})$$



516

A. Sarkar, K. De Ridder

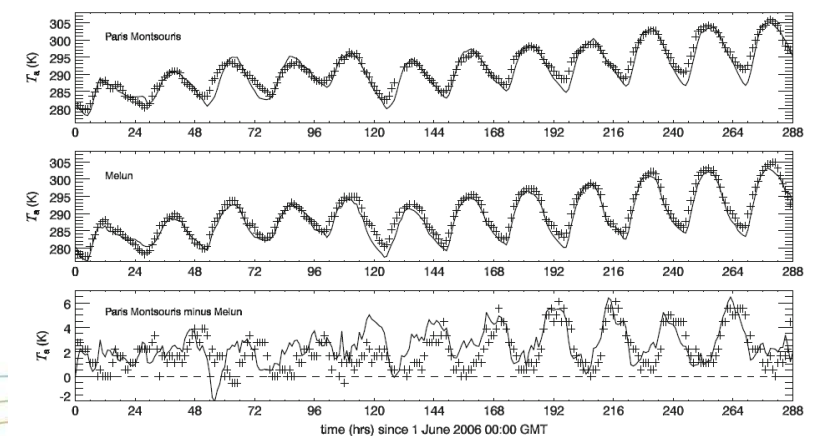
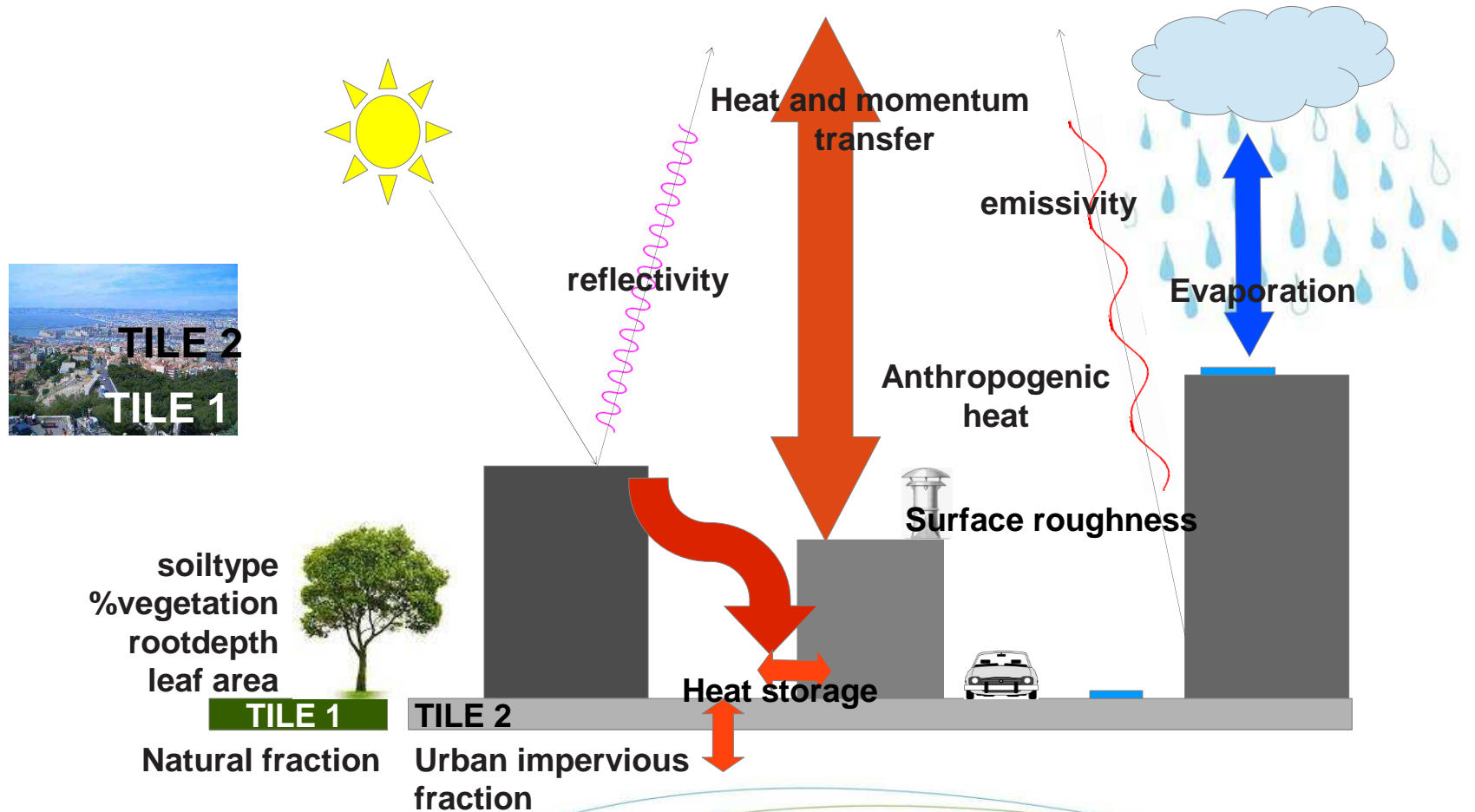


Fig. 2 Simulated (solid line) versus observed (symbols) 2-m air temperature for the period 1–12 June 2006, for the stations Paris-Montsouris (upper panel), Melun (middle panel), as well as the 2-m air temperature difference between the Paris and Melun stations (lower panel)



2. Urban parameterization (2/4)

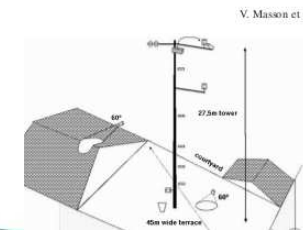
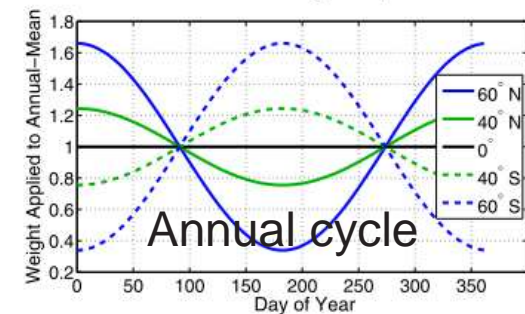
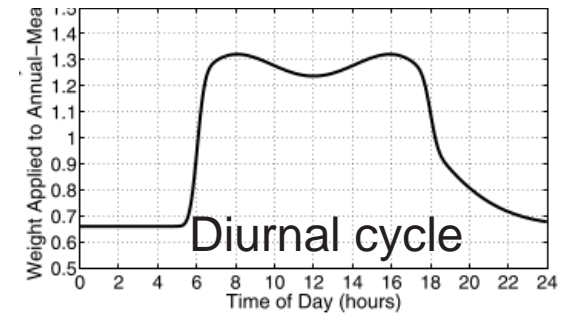
» Urban upgrade of TERRA-ML -> TERRA-MLU





2. Urban parameterization (3/4)

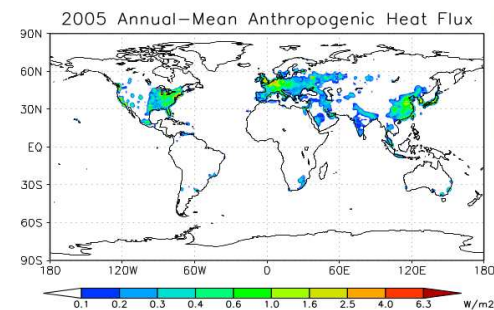
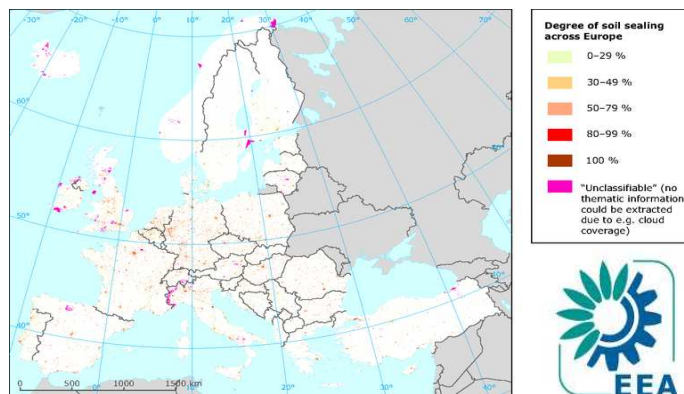
- » Urban upgrade of TERRA-ML -> TERRA-MLU
 - » **urban land-use** class with specific surface parameters (*De Ridder et al. 2012*; *Demuzere et al. 2008*) for albedo, emissivity, conductivity, heat capacity
 - » **New surface-layer transfer coefficients** (*Wouters et al., 2012*)
 - » **Zilitinkevich (1993) Bluff-rough thermal roughness parametrization**
 - » **Anthropogenic heat (Flanner 2009)**
- » It has been tested in offline mode for urban sites (**Marseille, Toulouse and Basel**)





2. Urban parameterization (4/4)

- » Integration of TERRA-MLU in COSMO-CLM
 - » **Urban fraction** determined from EEA soil-sealing database (250m res.)
 - » **Annual-averaged anthropogenic heat** (Flanner 2009)
 - » **Tile approach**



NCAR
Flanner (2009)

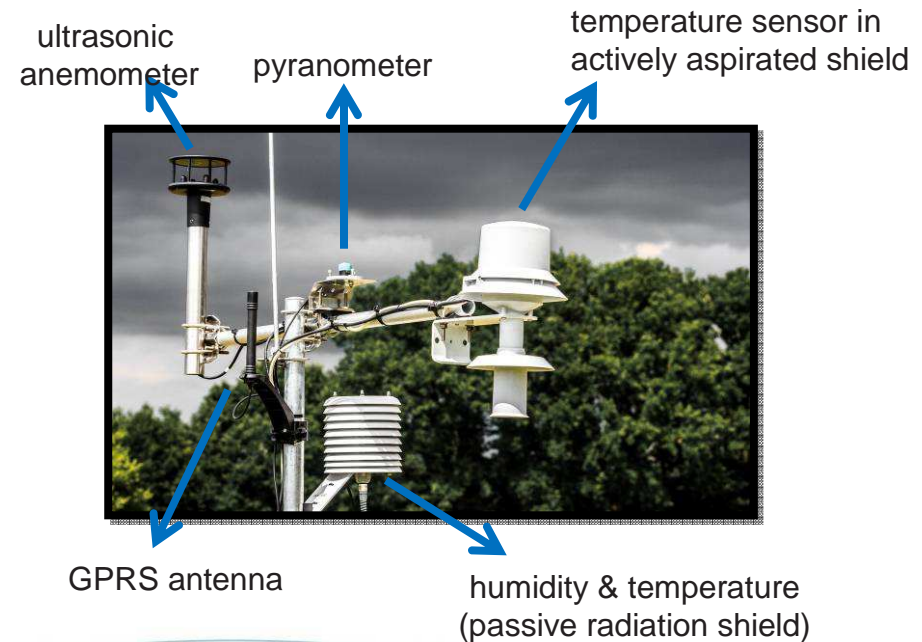


3. Urban climate observations



3. Urban climate observations (1/3)

- » Established especially for (UHI) modelling purposes:
- » high-quality measurements (T2M, RH, SW↓, wind) with **identical and calibrated** equipment at **urban** and **rural** locations



“Aren't we a bunch of modelers?”

3. Urban climate observations (2/3)



Antwerp
(Belgium)





3. Urban climate observations (3/3)

Ghent (Belgium)

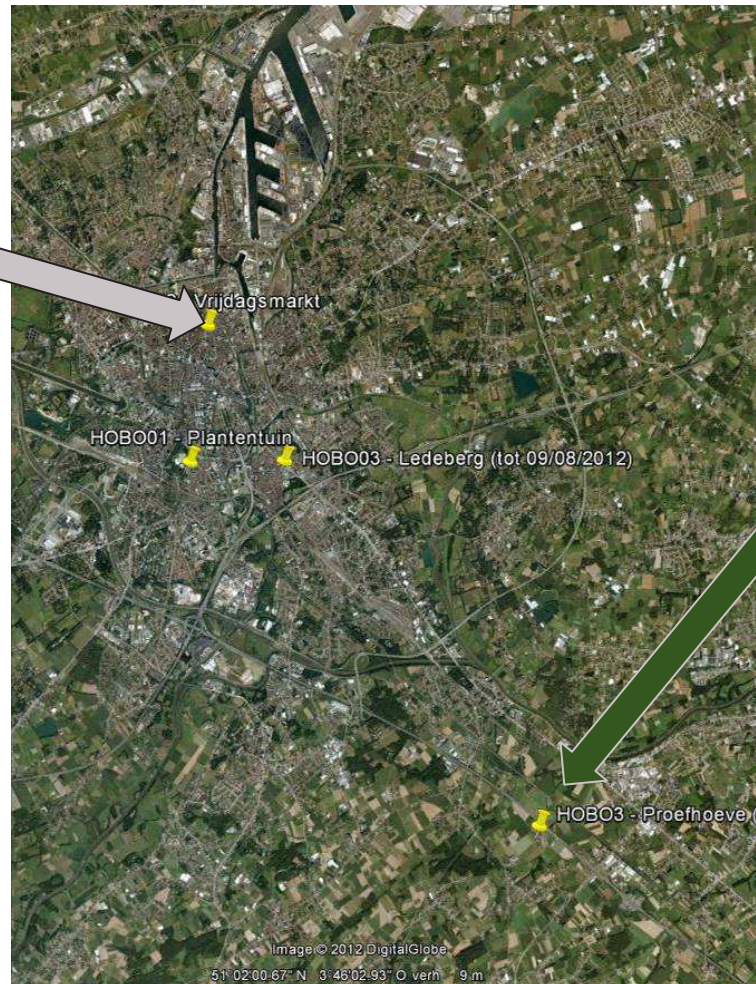


Image © 2012 DigitalGlobe
51°02'00.67" N 3°48'02.93" O vern 9 m

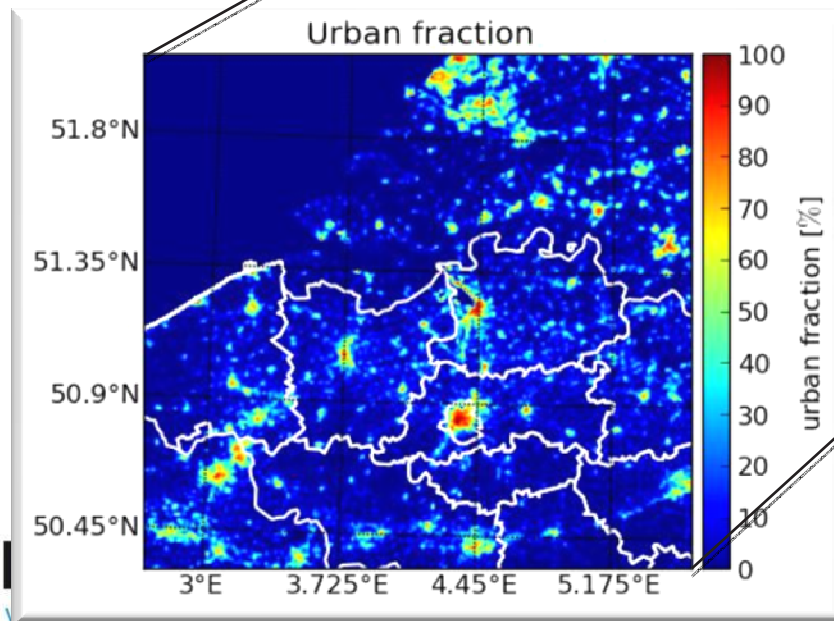
4. Model Configuration





4. Model Configuration (1/1)

- » COSMO4.8-CLM11 with urban parameterization
- » Over Belgium at 1km resolution
- » 200x200 grid cells
- » Cascade nested in ECMWF 12.5km
- » Last Summer 2012



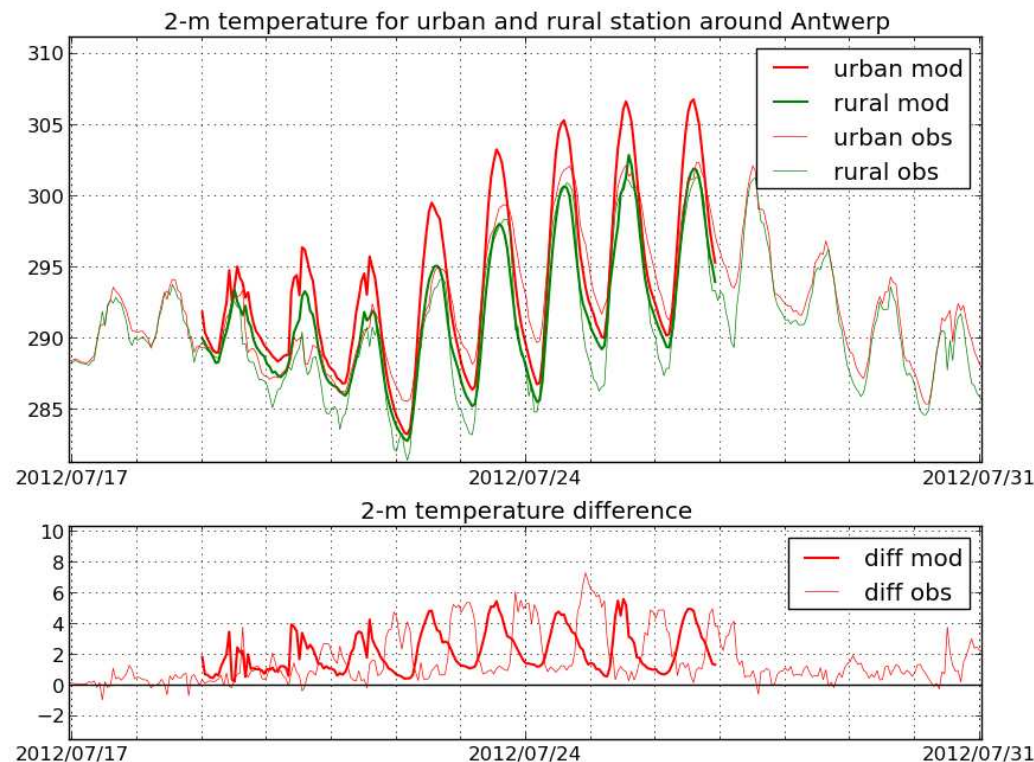
5. Evaluation and Results





5. Evaluation and Results (1/4)

- » Results Antwerp with COSMO4.8-CLM11 standard version (no urban parameterization)



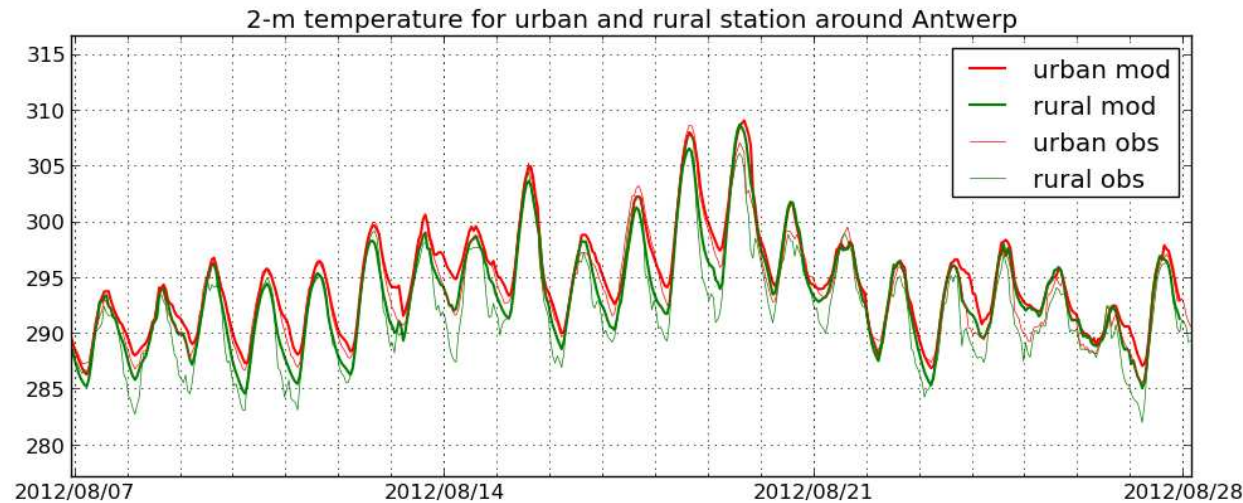
R = -0.40





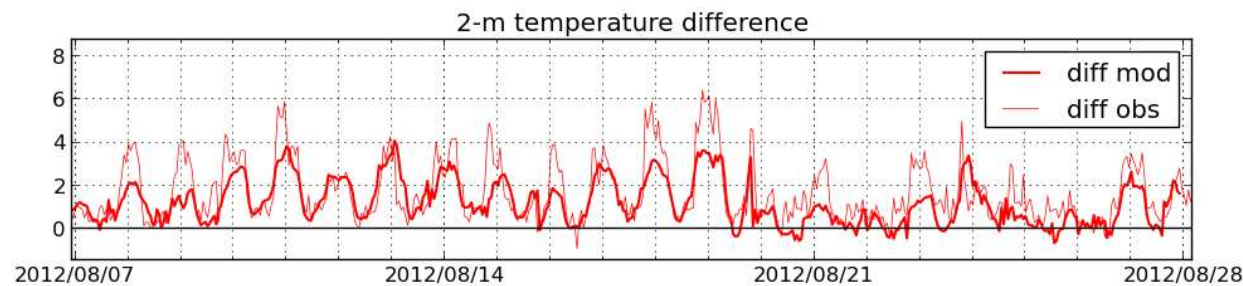
5. Evaluation and Results (2/4)

» Results Antwerp with COSMO-CLM11 + urban parameterization



RMSE: 1.14K
 MAE: 1.05K
 BIAS: 0.78K
 R: 0.97

RMSE: 1.37K
 MAE: 1.38K
 BIAS: 1.10K
 R: 0.96



RMSE: 1.01K
 MAE: 0.79K
 BIAS: -0.32K
 R: 0.60

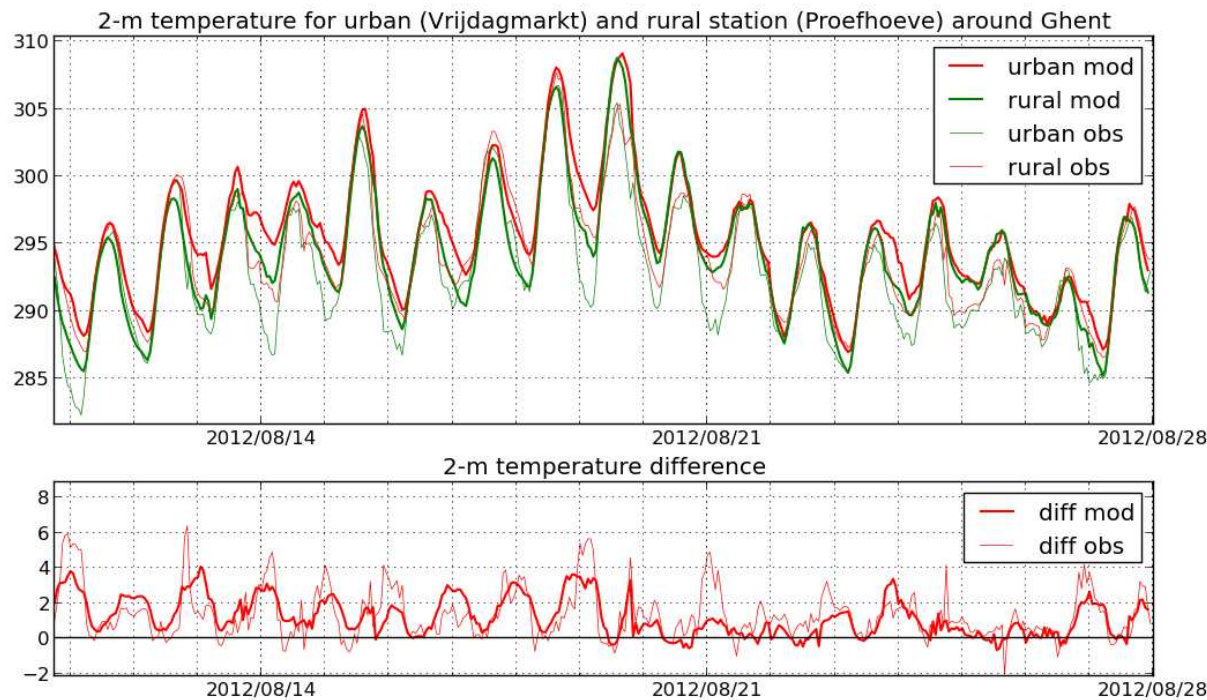
diff mean mod: 1.25K
 diff mean obs: 1.57K





5. Evaluation and Results (3/4)

» Results Ghent with COSMO-CLM11 + urban parameterization



RMSE: 1.36K
 MAE: 1.34K
 BIAS: 1.07K
 R: 0.95

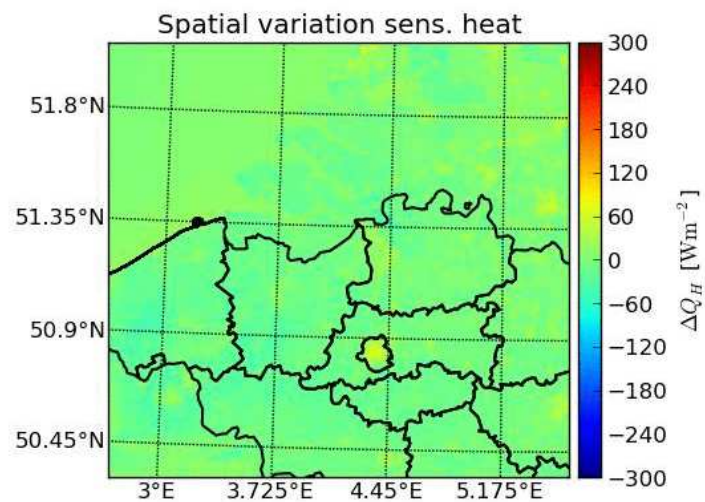
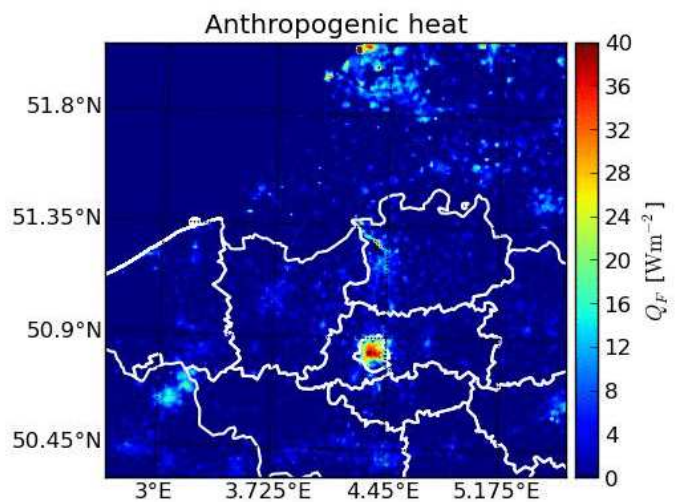
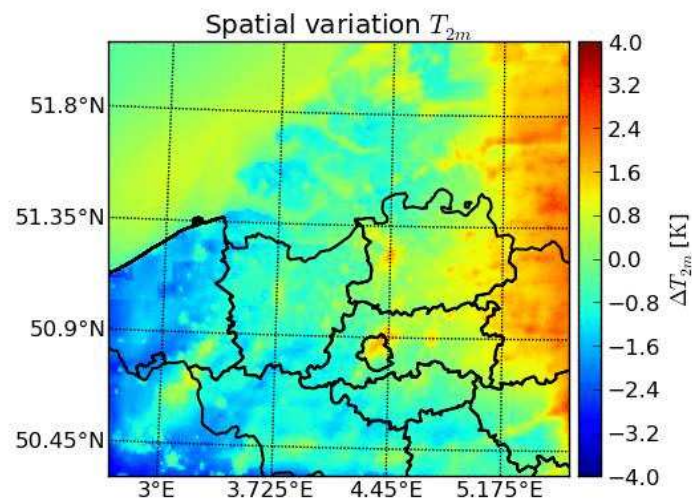
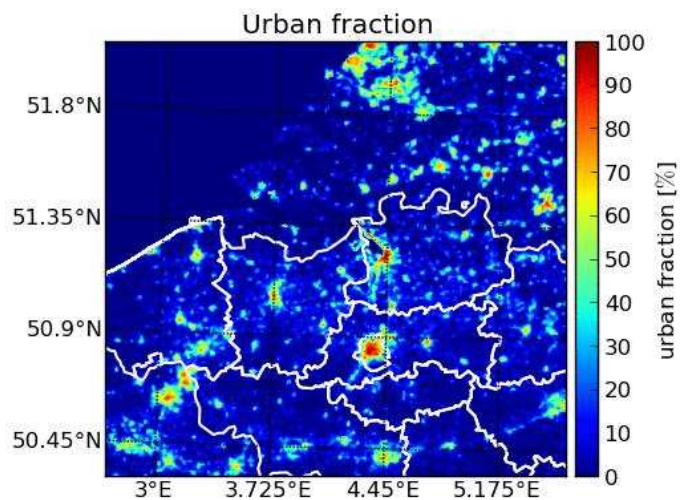
RMSE: 1.70K
 MAE: 1.70K
 BIAS: 1.30K
 R: 0.93

RMSE: 1.10K
 MAE: 0.86K
 BIAS: -0.13K
 R: 0.64

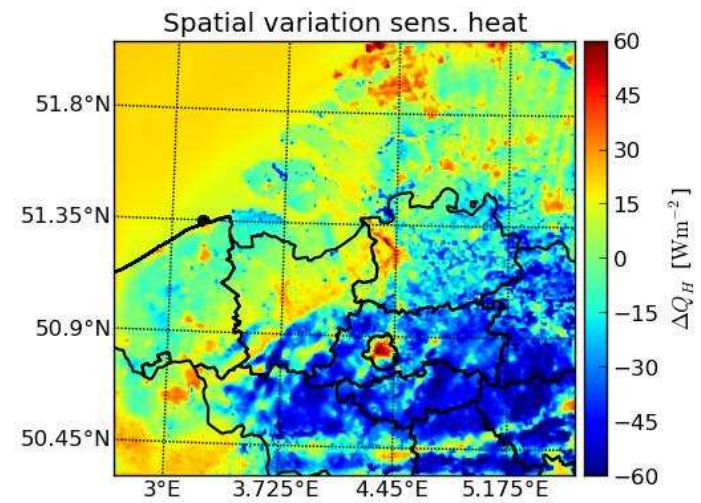
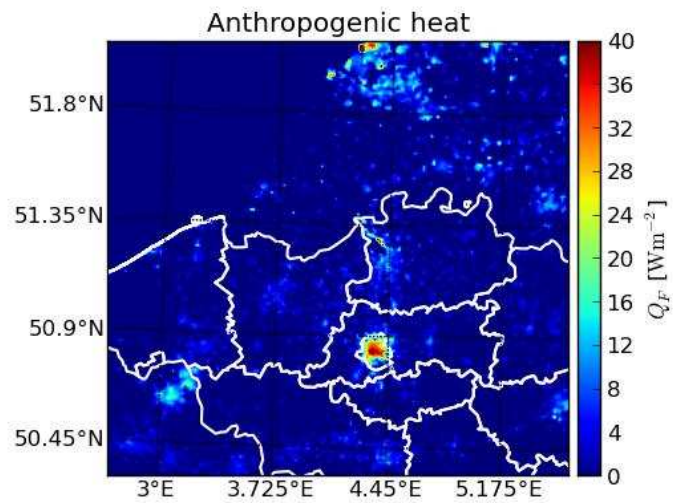
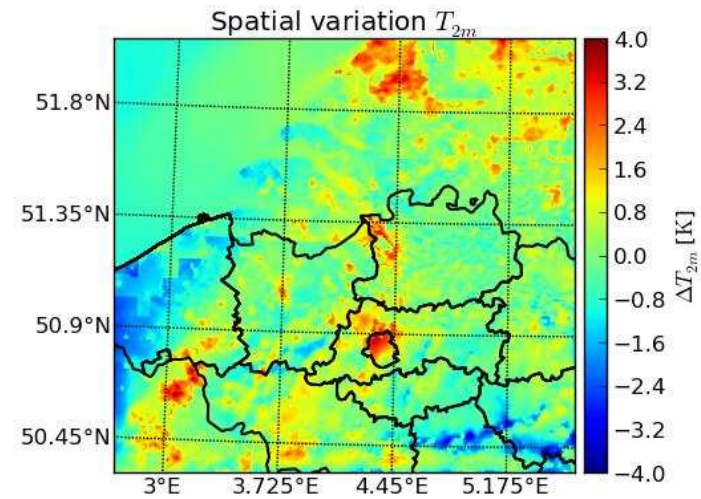
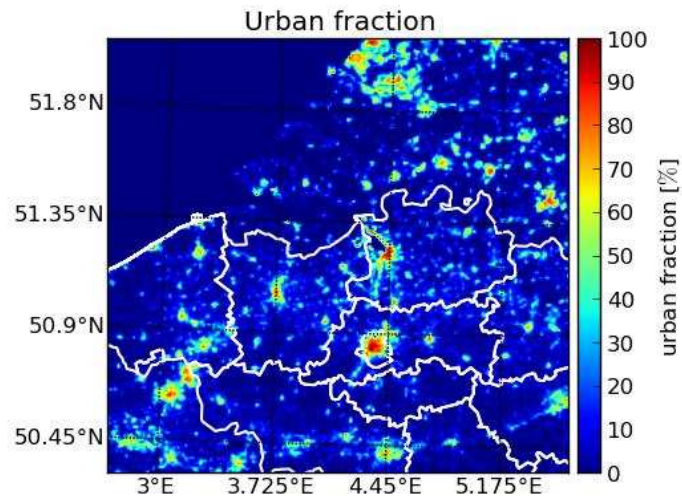
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 diff mean mod: 1.37K



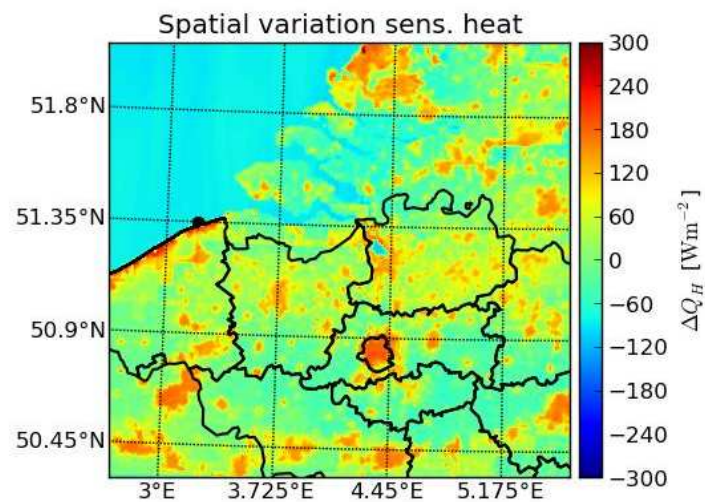
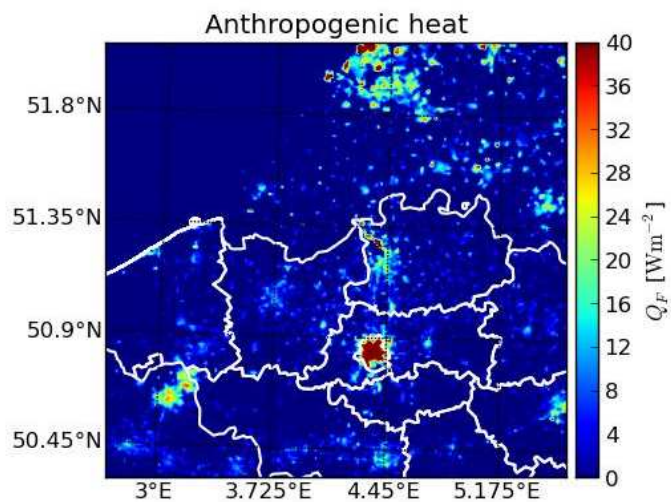
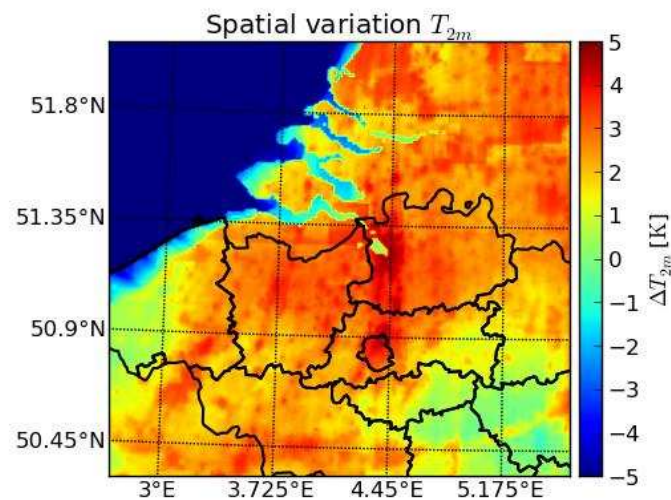
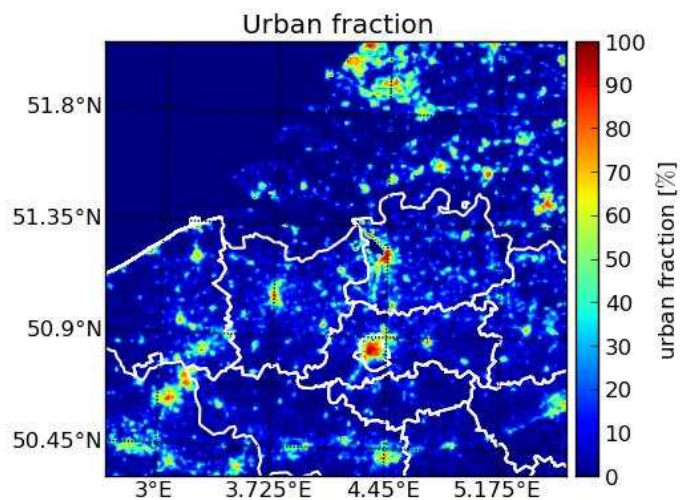
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5. Conclusions (1/1)

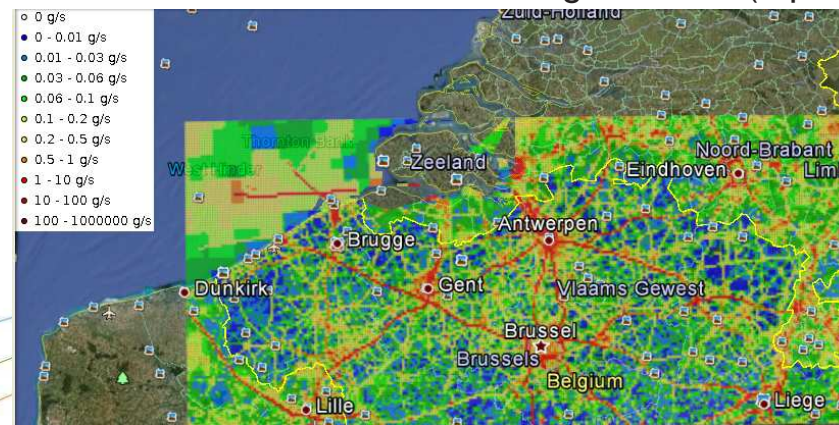
- » **urban parameterization** in COSMO-CLM/TERRA-ML was **successfully implemented and tested** on 1km resolution over Belgium
- » The temporal and spatial **variability** of the **UHI intensity** are **very well reproduced**
- » Additional computational cost was negligible (+3% CPU-time)
- » Number of needed extra parameters is small and readily available globally
- » An underestimation of the UHI may be caused by:
 - » Insufficient near-surface cooling in rural areas for nocturnal stable conditions
 - » Negligence of the sky-view factor in cities



5. Outlook and applications (1/3)

- » Air-quality modeling with AURORA (VITO NV)
 - » What are the **driving processes determining urban air quality?**
 - » **Relevance of mesoscale meteorology** (1-10km), UHI, topography
 - » **Versus mesoscale meteorology** (10–1000km)
 - » **Versus uncertainty emissions for VOC's, PM10,PM2.5,NOX**
 - » Why do we care?
 - > **to set priorities for the improvement of urban air-quality modelling**

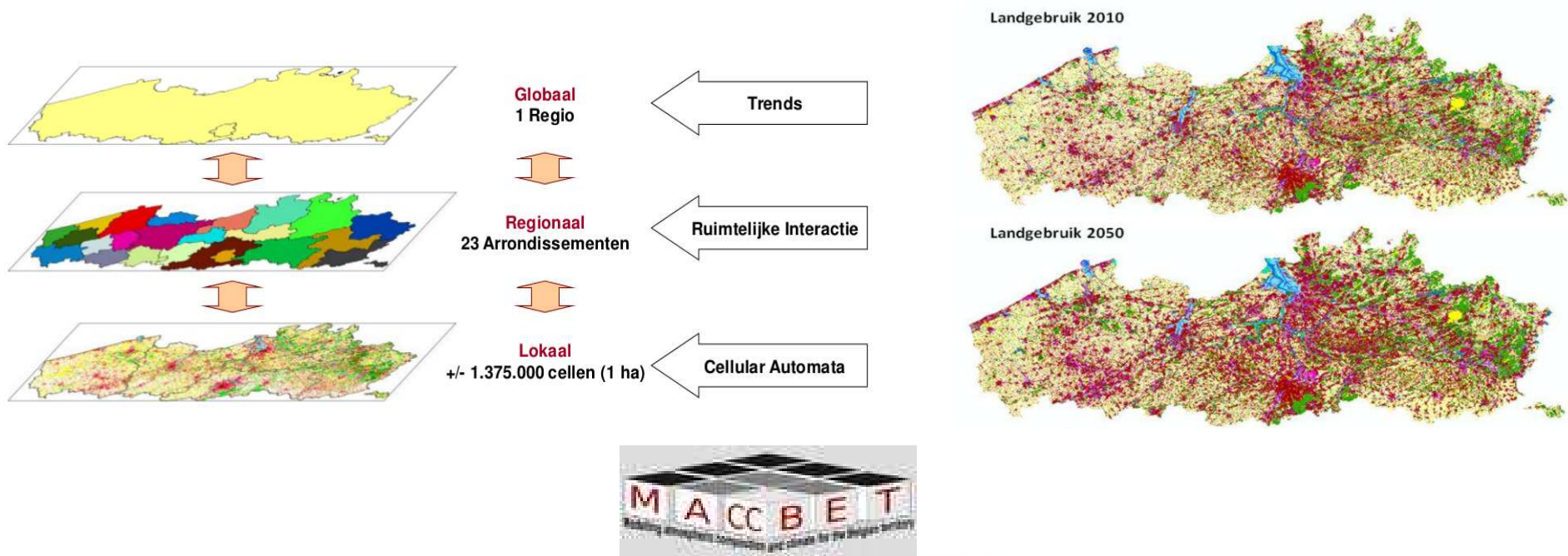
Nox emissions over Flanders/Belgium 2009 (top-down)





5. Outlook and applications (2/3)

- » Urban land-use change scenarios:
 - » Investigate the impact of land-use change and global climate change on urban climate





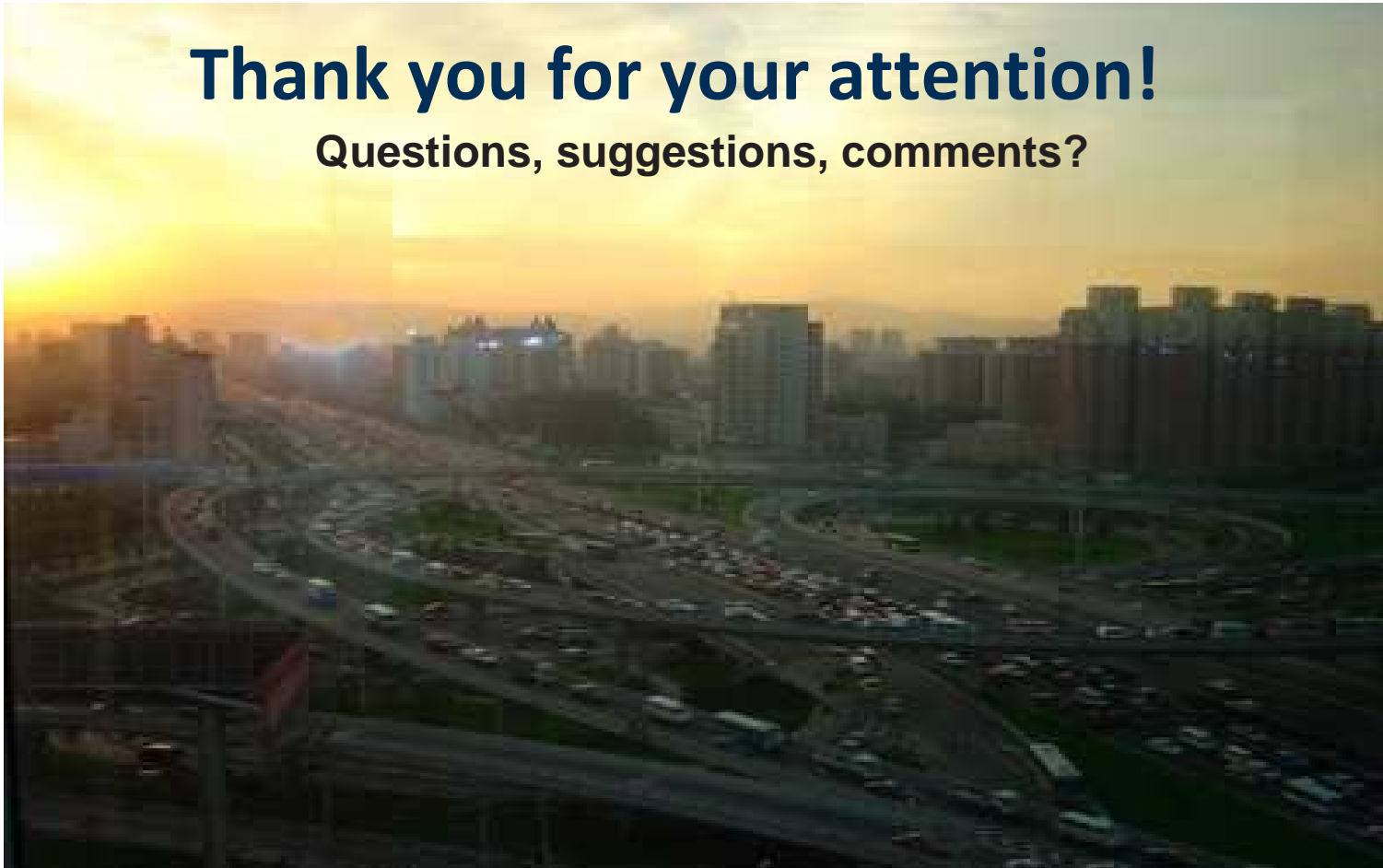
4. Outlook and applications (3/3)

- » Further developments:
 - » Urban impervious water-storage in the online coupled model
 - » Implementation of the sky-view factor



Thank you for your attention!

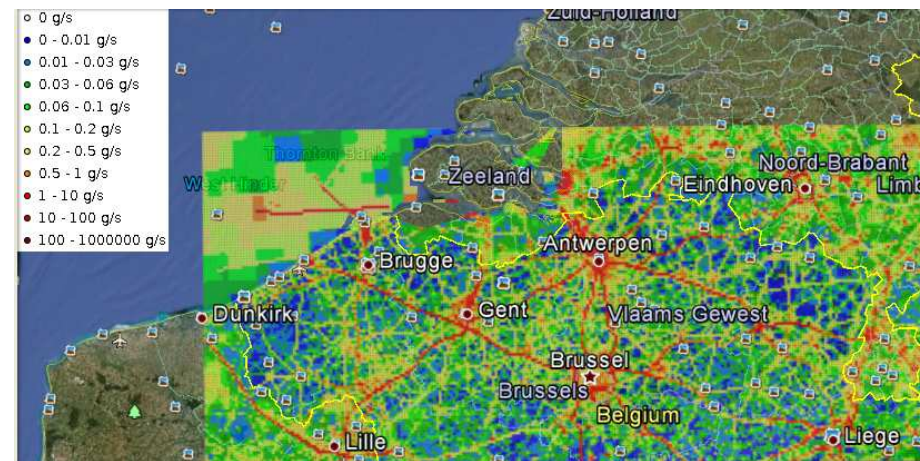
Questions, suggestions, comments?





the uncertainty on the emissions...

- » comparing bottom-up versus top-down emission datasets
- » Investigate impact of uncertainty on air-quality modelling with our in-house model AURORA



Nox emissions over Belgium 2009 (top-down)