vito
vision on technology

26/04/2013

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

Hendrik Wouters, Koen De Ridder, Matthias Demuzere, Bino Mahieu, Nele Veldeman, Peter Viaene, Felix Deutch, Erwan Brisson

CLM Community

MACCBET

DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
KU Leuven - BELGIUM

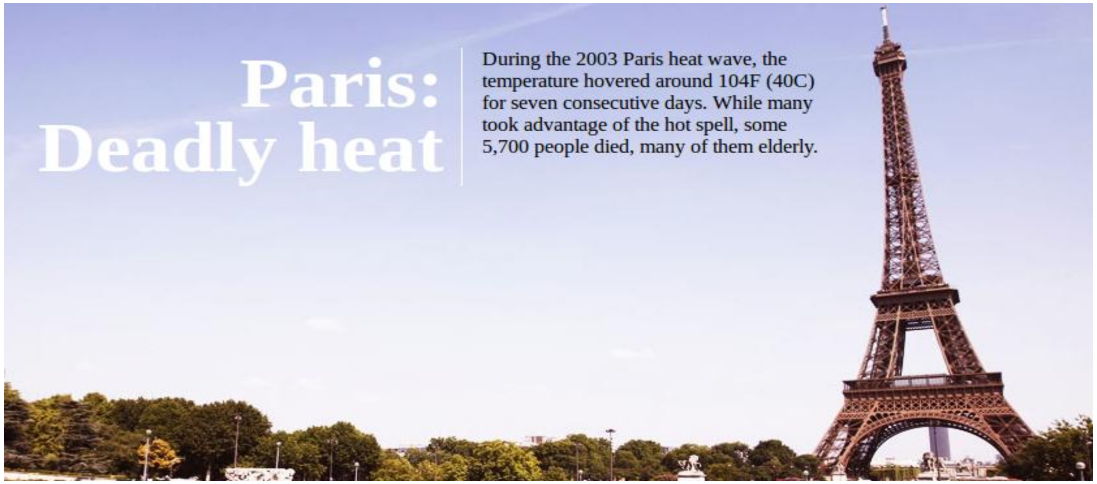
Overview

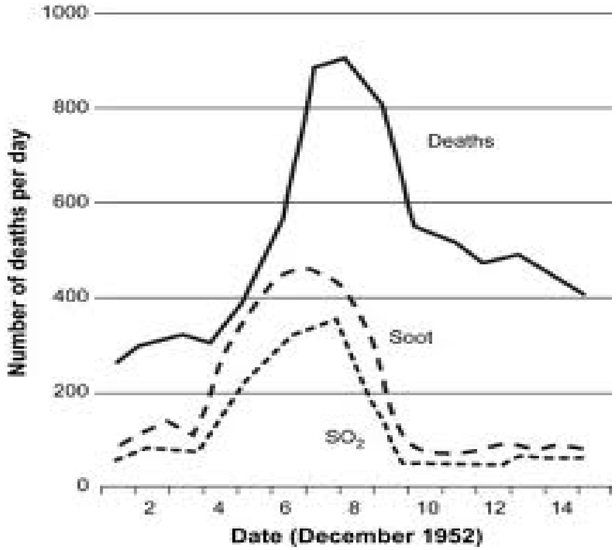
1. Motivation
2. The regional climate model COSMO-CLM
3. Urban parameterization of COSMO-CLM
4. Urban climate observations
5. Model setup and configuration
6. Model evaluation
7. Conclusions
8. Outlook and applications

DEPARTMENT OF EARTH AND
ENVIRONMENTAL SCIENCES
KU Leuven - BELGIUM

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





DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
KU Leuven - BELGIUM

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. Regional climate model COSMO-CLM

- Climate version of the NWP model COSMO (DWD, Meteoswiss…)
- Currently actively used and developed by a growing climate research community
- Horizontal resolution up to 1 km
- The standard version no urban parametrization

DEPARTMENT OF EARTH AND
ENVIRONMENTAL SCIENCES
KU Leuven - BELGIUM

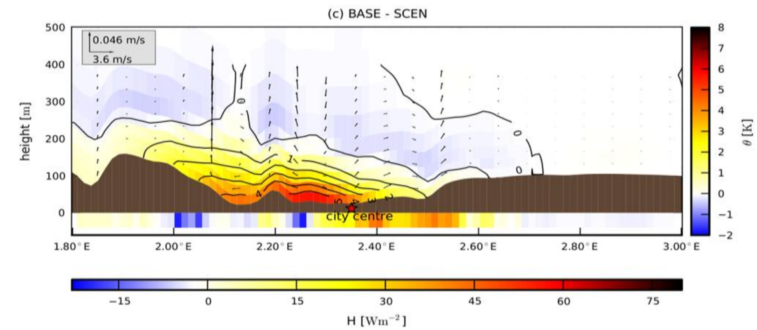
2. Urban parameterization

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

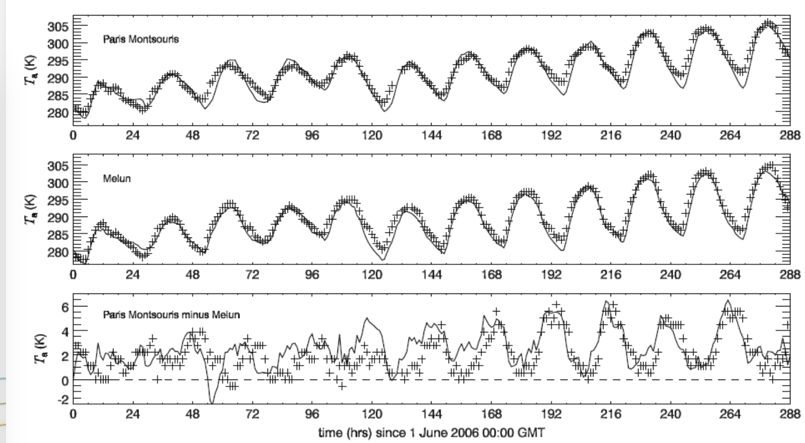
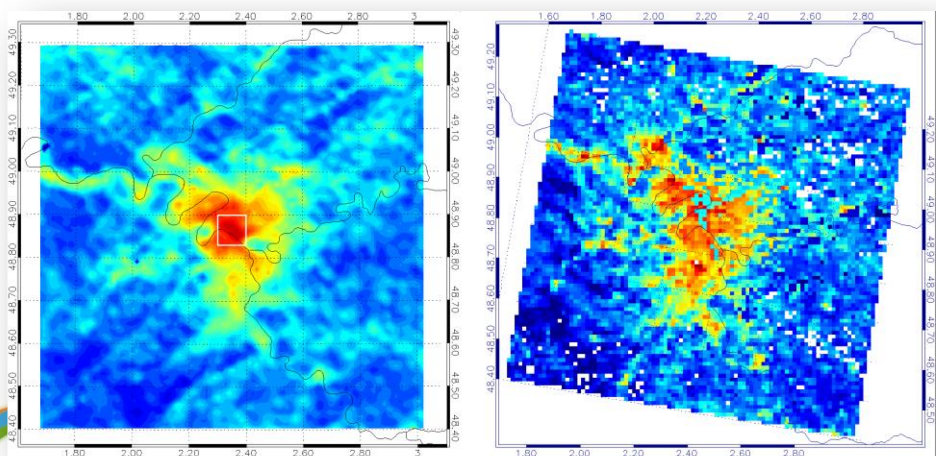

516 A. Sarkar, K. De Ridder

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*)

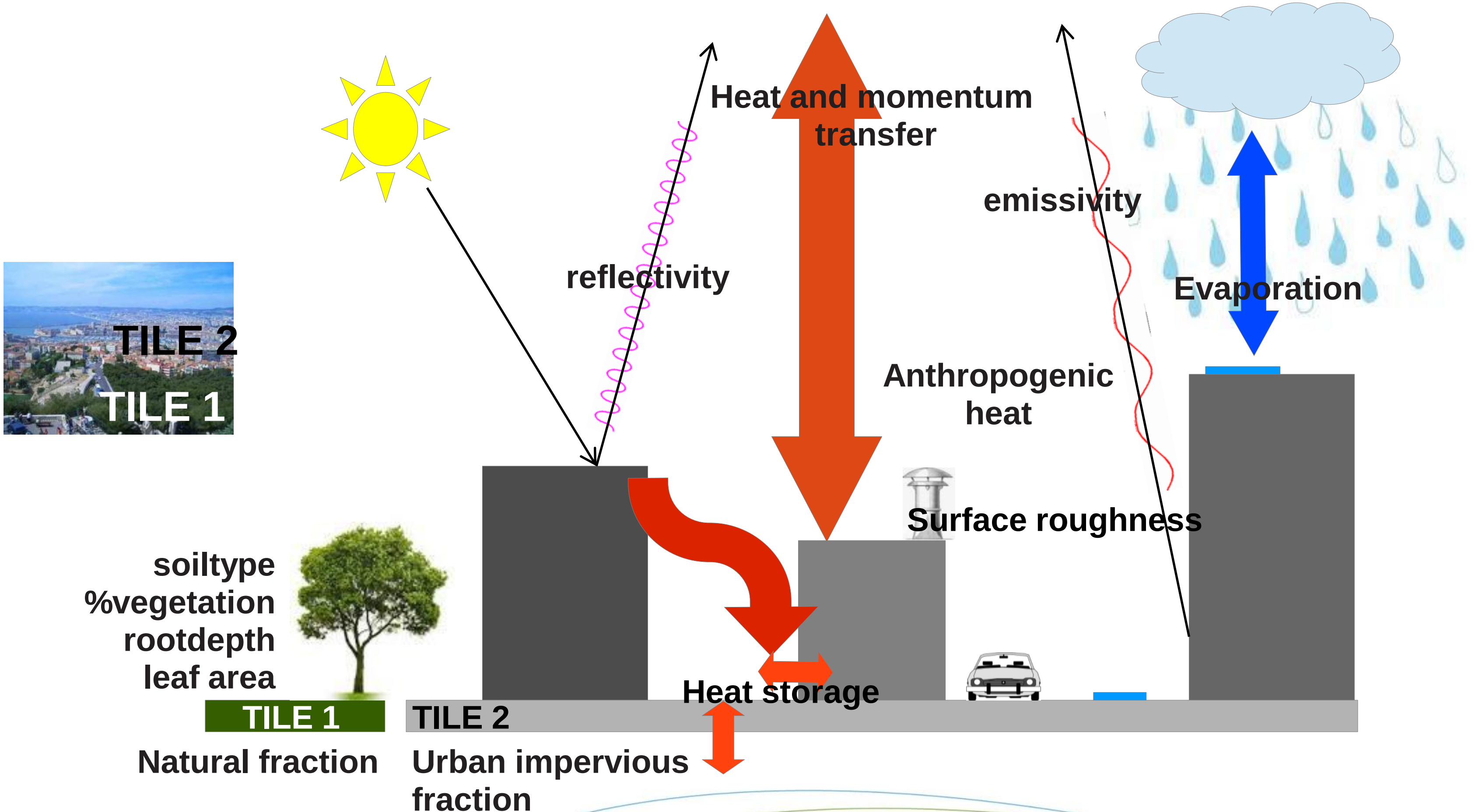
$$kB^{-1} \equiv \ln\ z_0 / z_{0t}$$



DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
KU Leuven - BELGIUM

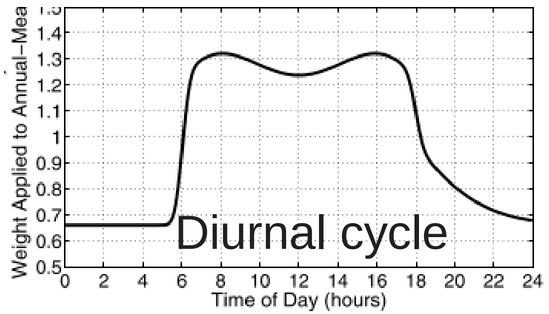
2. Urban parameterization (2/4)

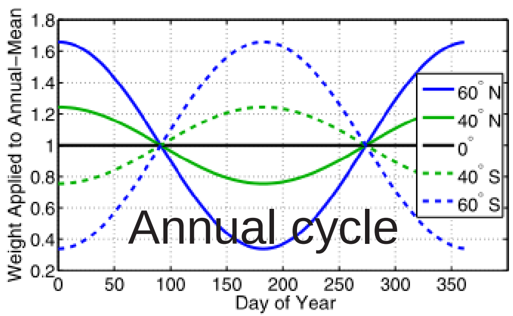
» Urban upgrade of TERRA-ML -> TERRA-MLU



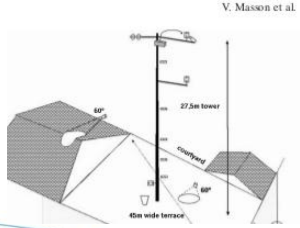
DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
KU Leuven - BELGIUM

2. Urban parameterization (3/4)





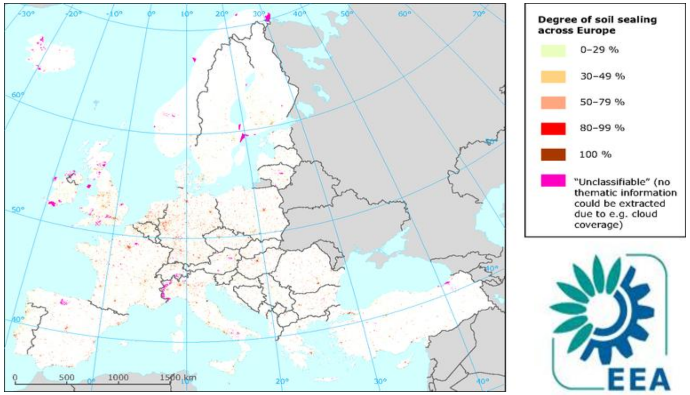
- Urban upgrade of TERRA-ML -> TERRA-MLU
  - **urban land-use** class with specific surface parameters ***(De Ridder et al. 2012; Demuzere et al. 2008)*** for albedo, emissivity, conductivity, heat capacity
  - *New **surface-layer transfer coefficients** (Wouters et al., 2012)*
  - ***Brutsaert/Kanda**Bluff-rough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



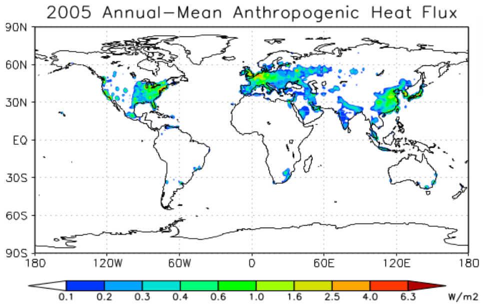
DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
KU Leuven - BELGIUM

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**



EEA



NCAR

Flanner (2009)

vito
vision on technology

3. Urban climate observations

DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
KU Leuven - BELGIUM

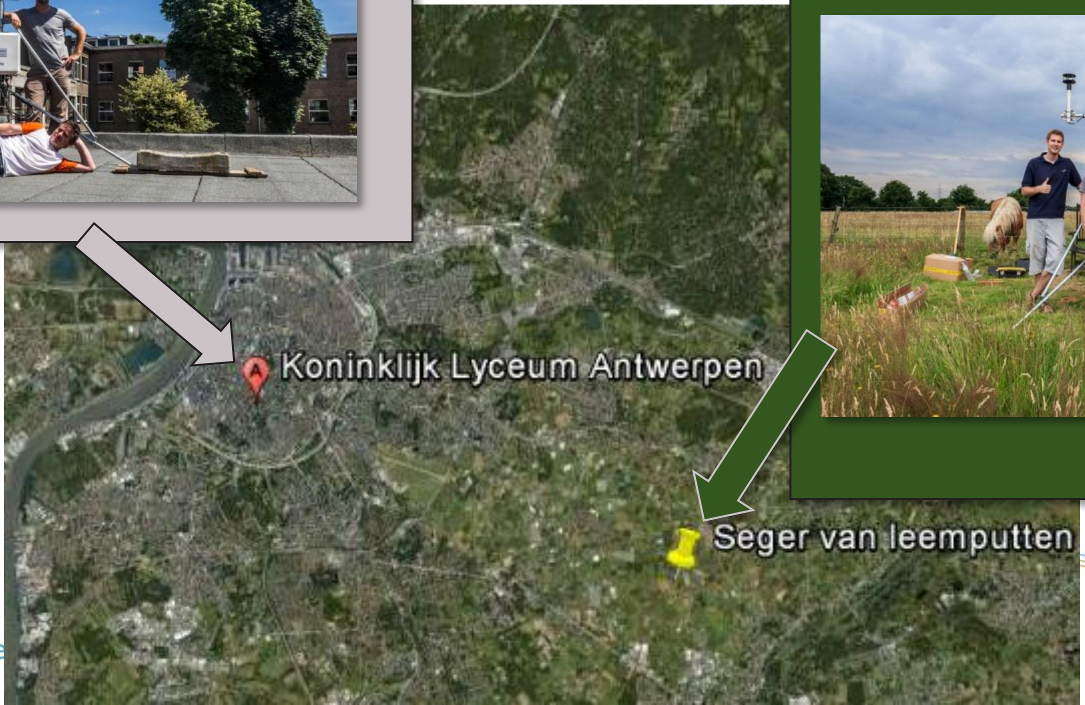
3. Urban climate observations (1/3)

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

3. Urban climate observations (2/3)

"Aren't we a bunch of modelers?"

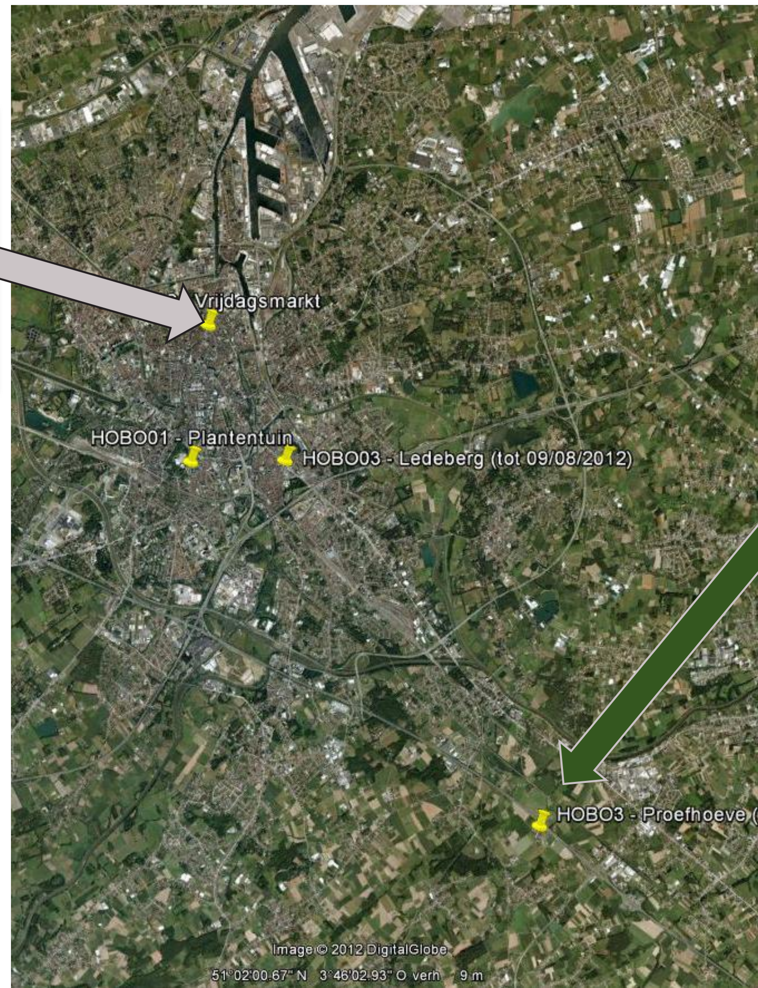
Antwerp (Belgium)



vito
vision on te

3. Urban climate observations (3/3)

Ghent (Belgium)

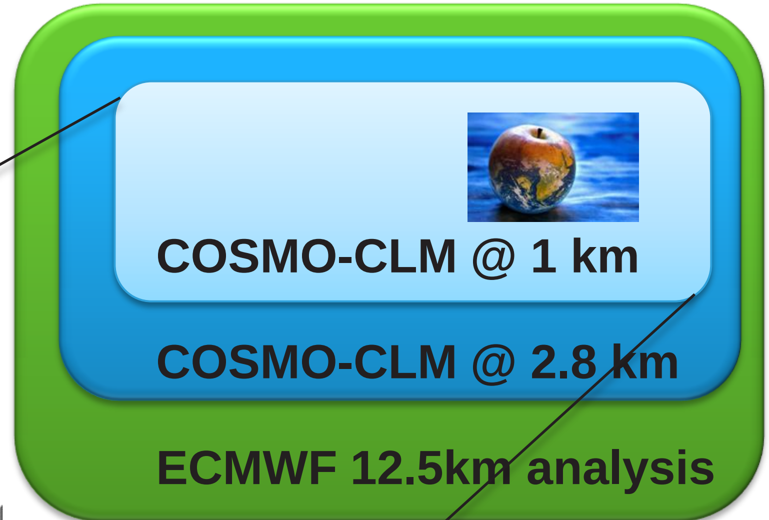


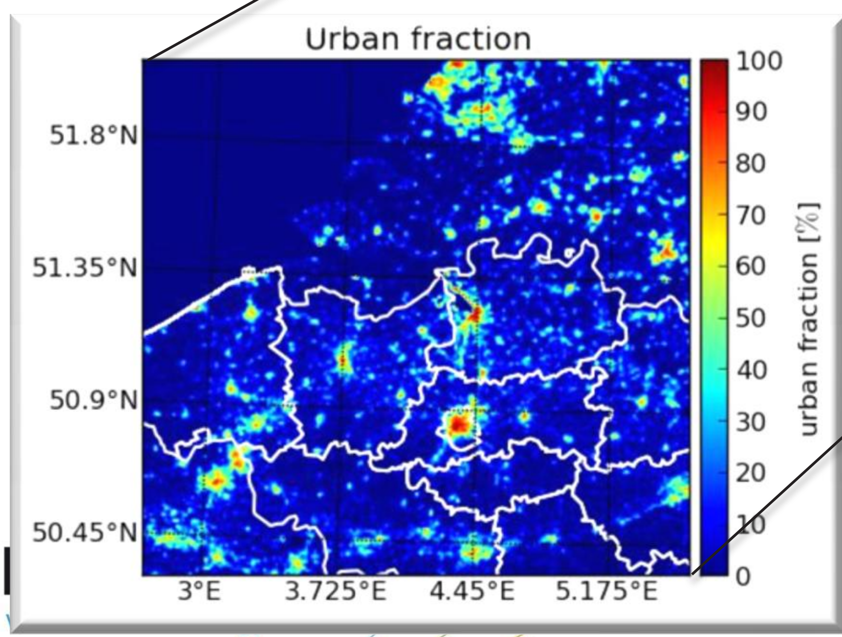
vito
vision on technology

4. Model Configuration

4. Model Configuration

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



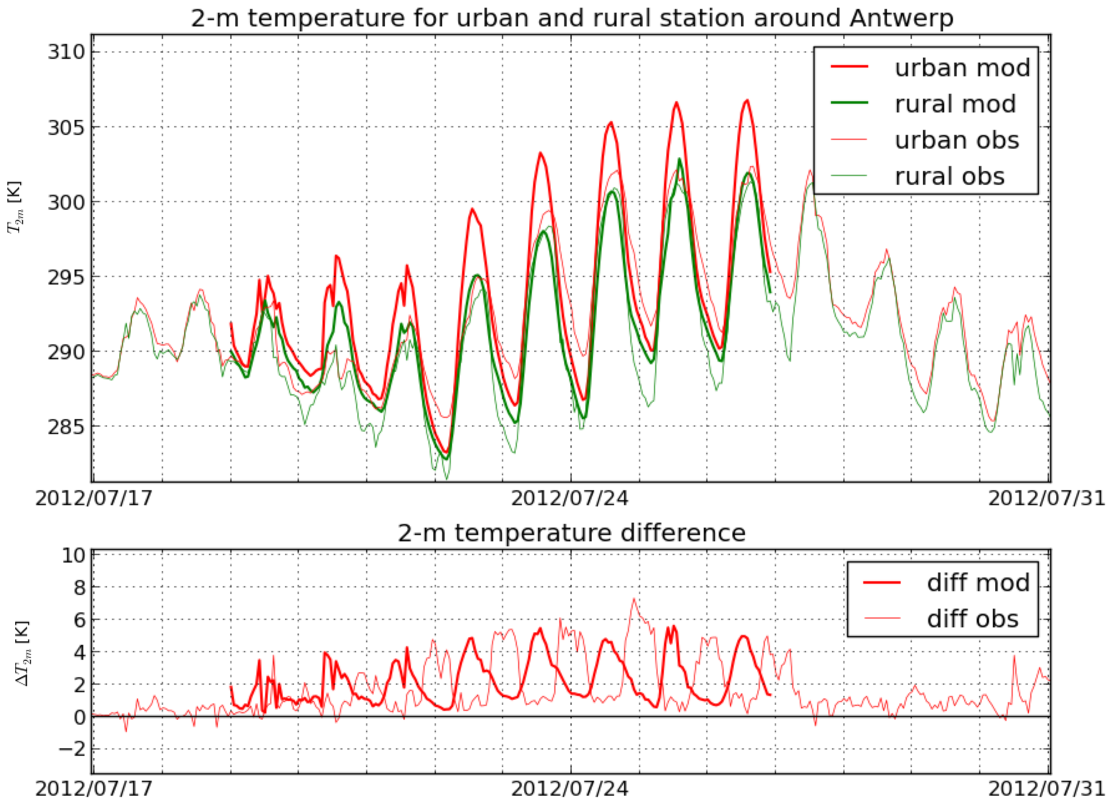


5. Evaluation and Results

DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
KU Leuven - BELGIUM

5. Evaluation and Results (1/4)

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

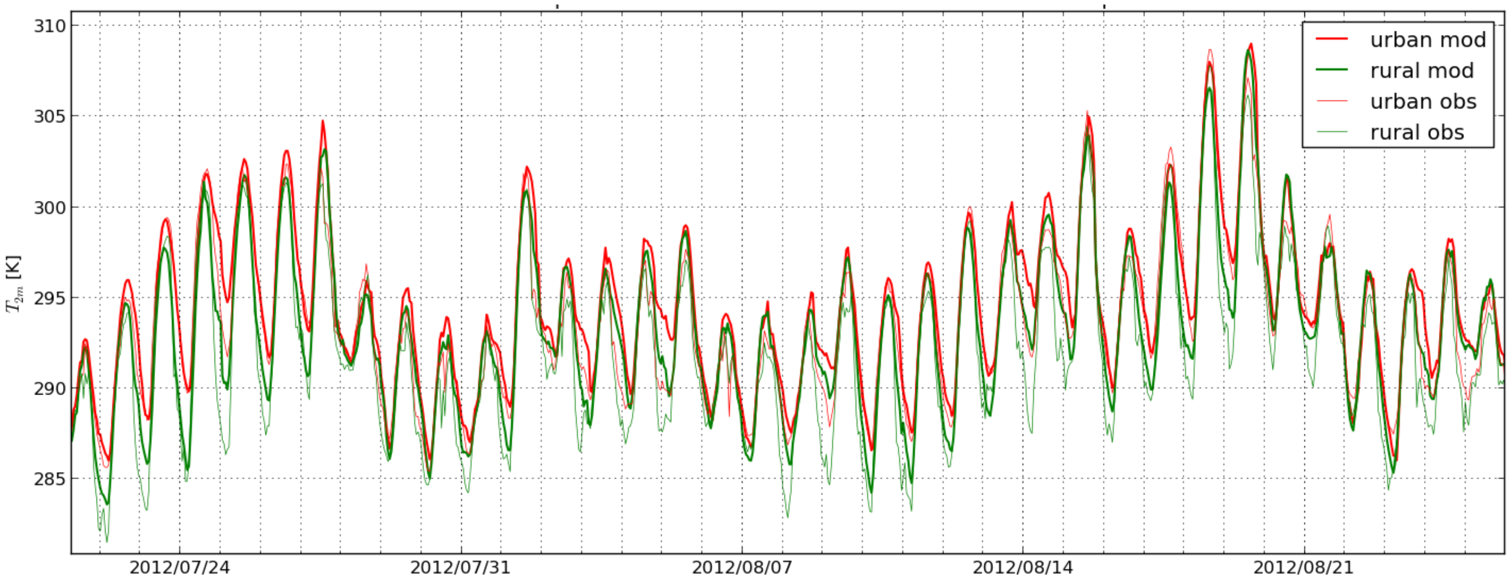


R = -0.40

DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
KU Leuven - BELGIUM

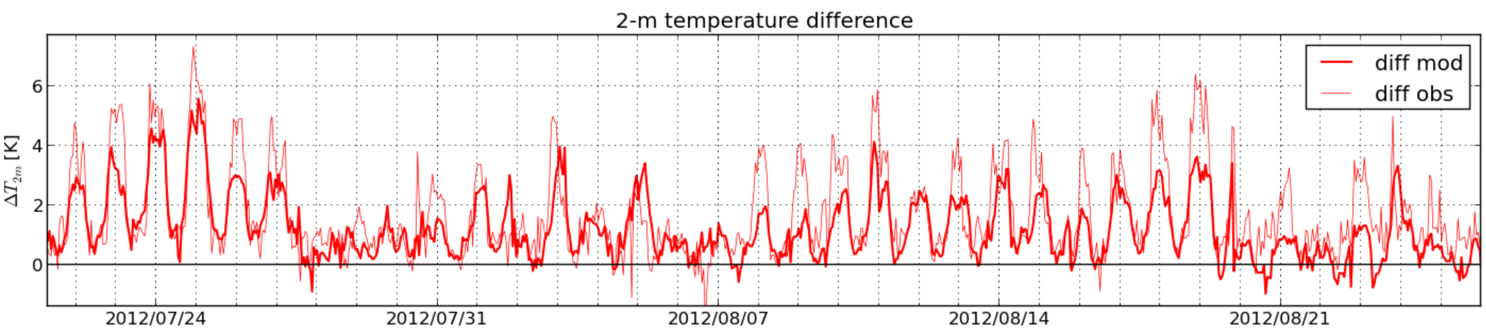
5. Evaluation and Results (2/4)

» Results Antwerp with COSMO-CLM11 **+ urban parameterization**



RMSE: 1.26K
MAE: 1.09K
BIAS: 0.75K
R2: 0.96

RMSE: 1.45K
MAE: 1.48K
BIAS: 1.20K
R2: 0.95



RMSE: 0.94K
MAE: 0.77K
BIAS: -0.45K
R2: 0.77

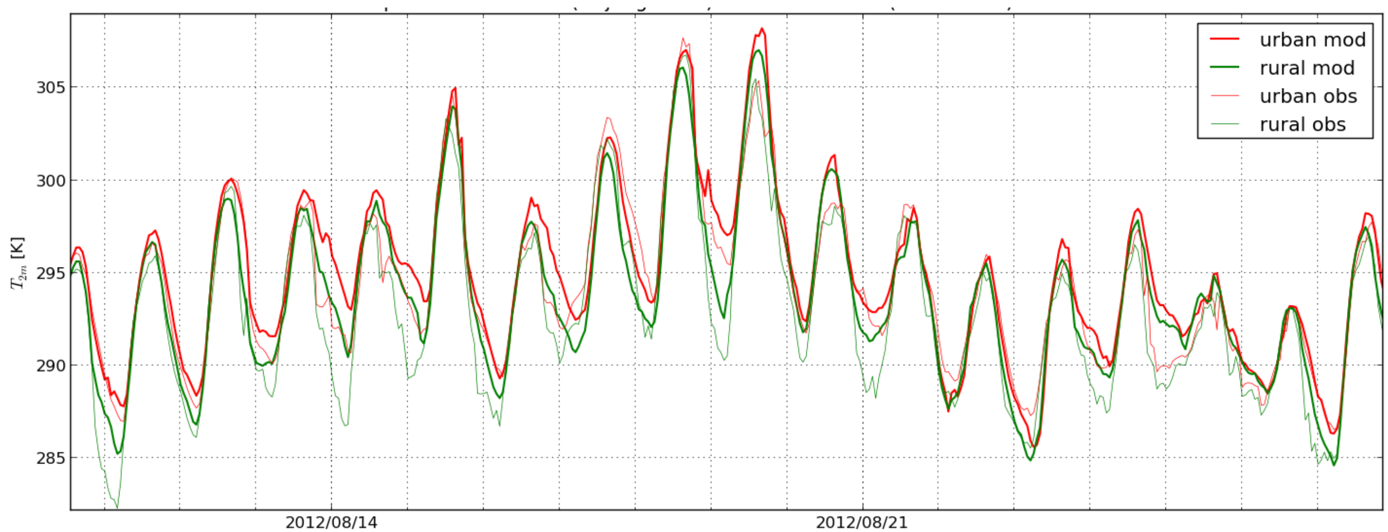
mean mod: 1.17K
mean obs: 1.62K

vito
vision on technology

DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
KU Leuven - BELGIUM

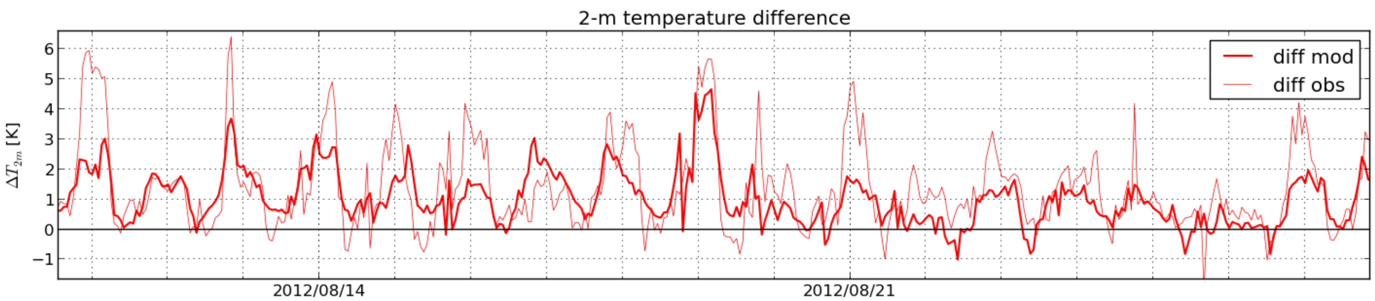
5. Evaluation and Results (3/4)

» Results for Ghent with COSMO-CLM11 **+ urban parameterization**



RMSE: 1.34K
MAE: 1.06K
BIAS: 0.60K
R2: 0.95

RMSE: 1.43K
MAE 1.31K
BIAS: 0.87K
R2: 0.95

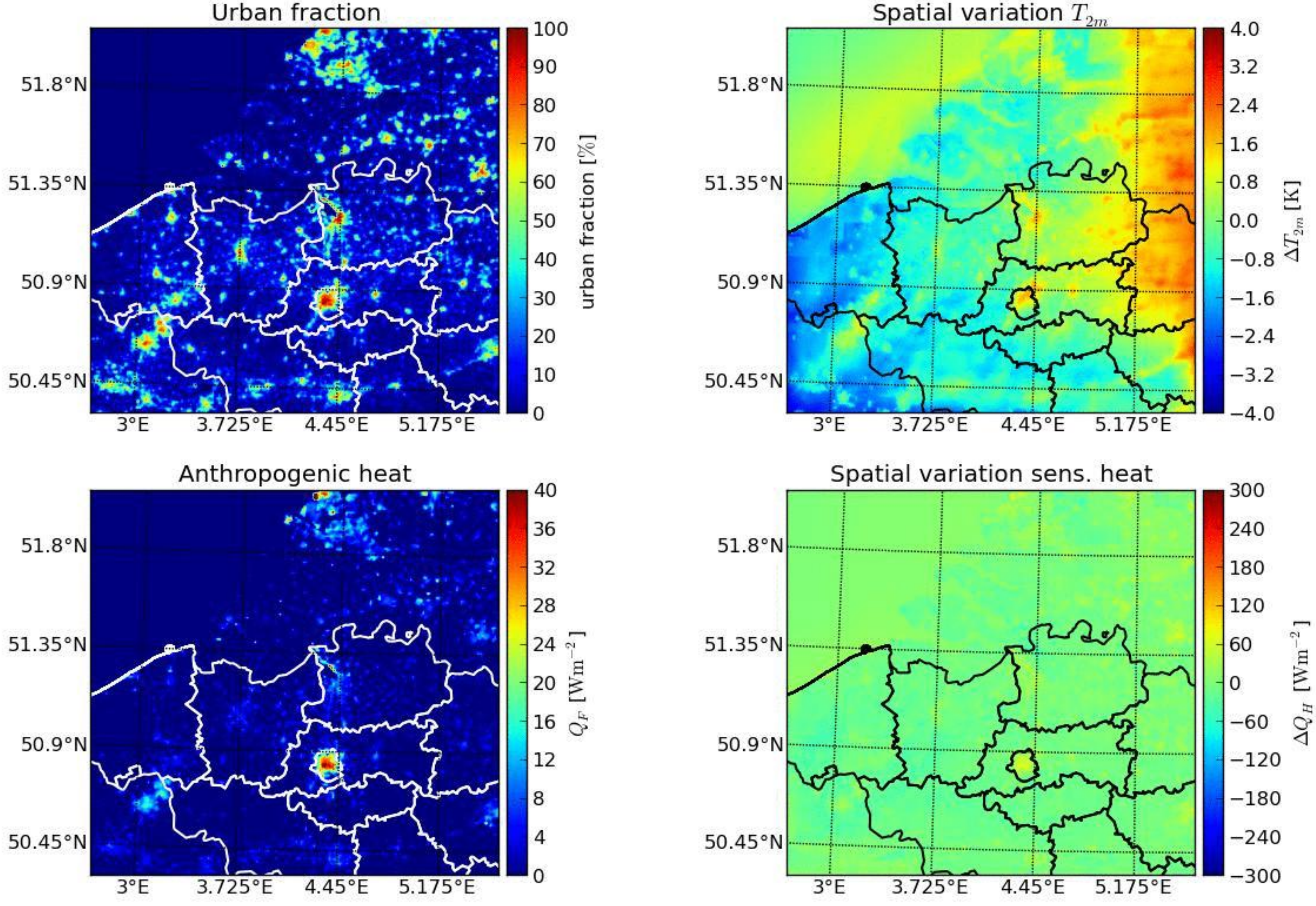


RMSE: 1.04K
MAE: 0.82K
BIAS: -0.34K
R2: 0.68

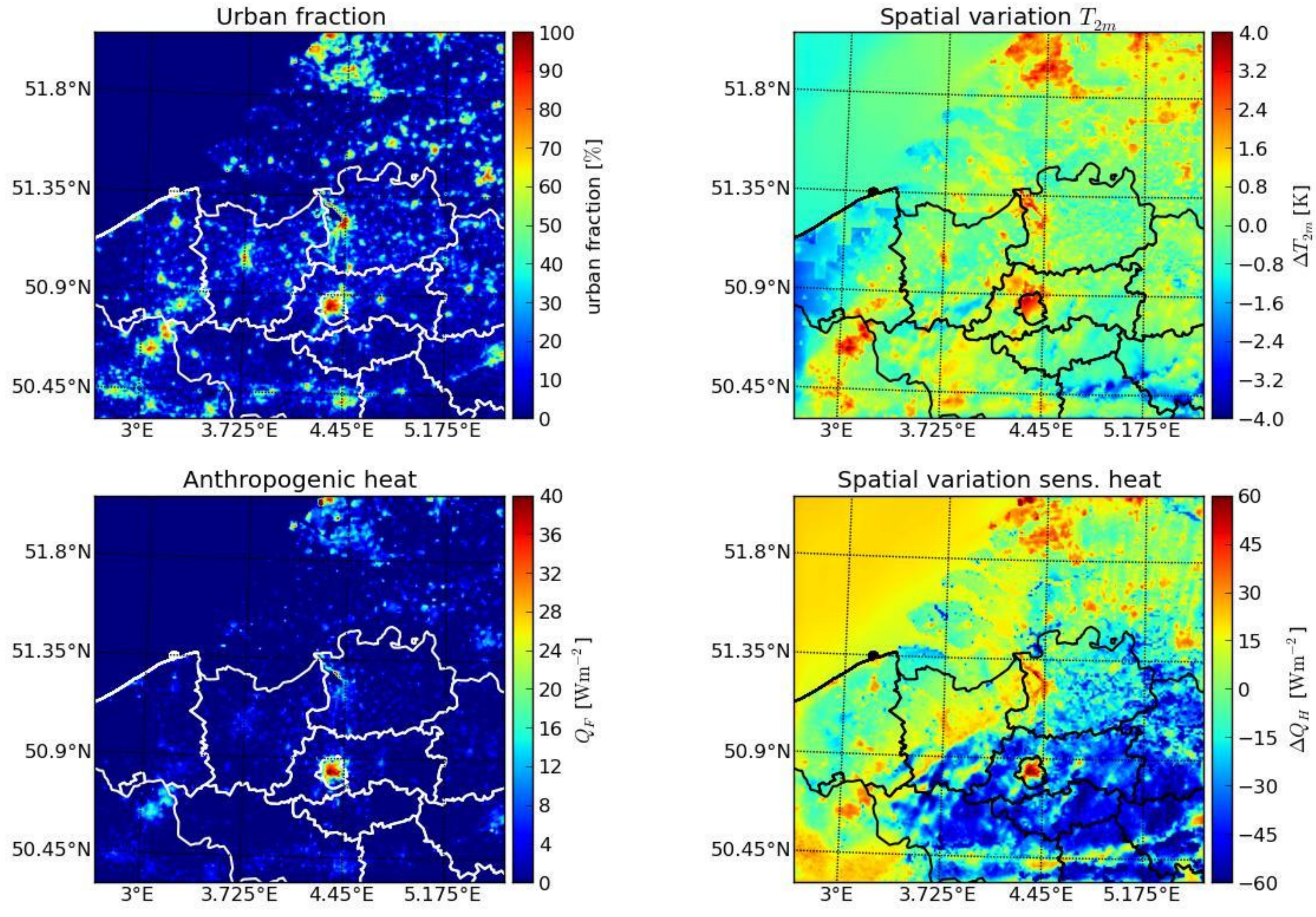
mean mod: 1.03K
mean obs: 1.37K

vito
vision on technology

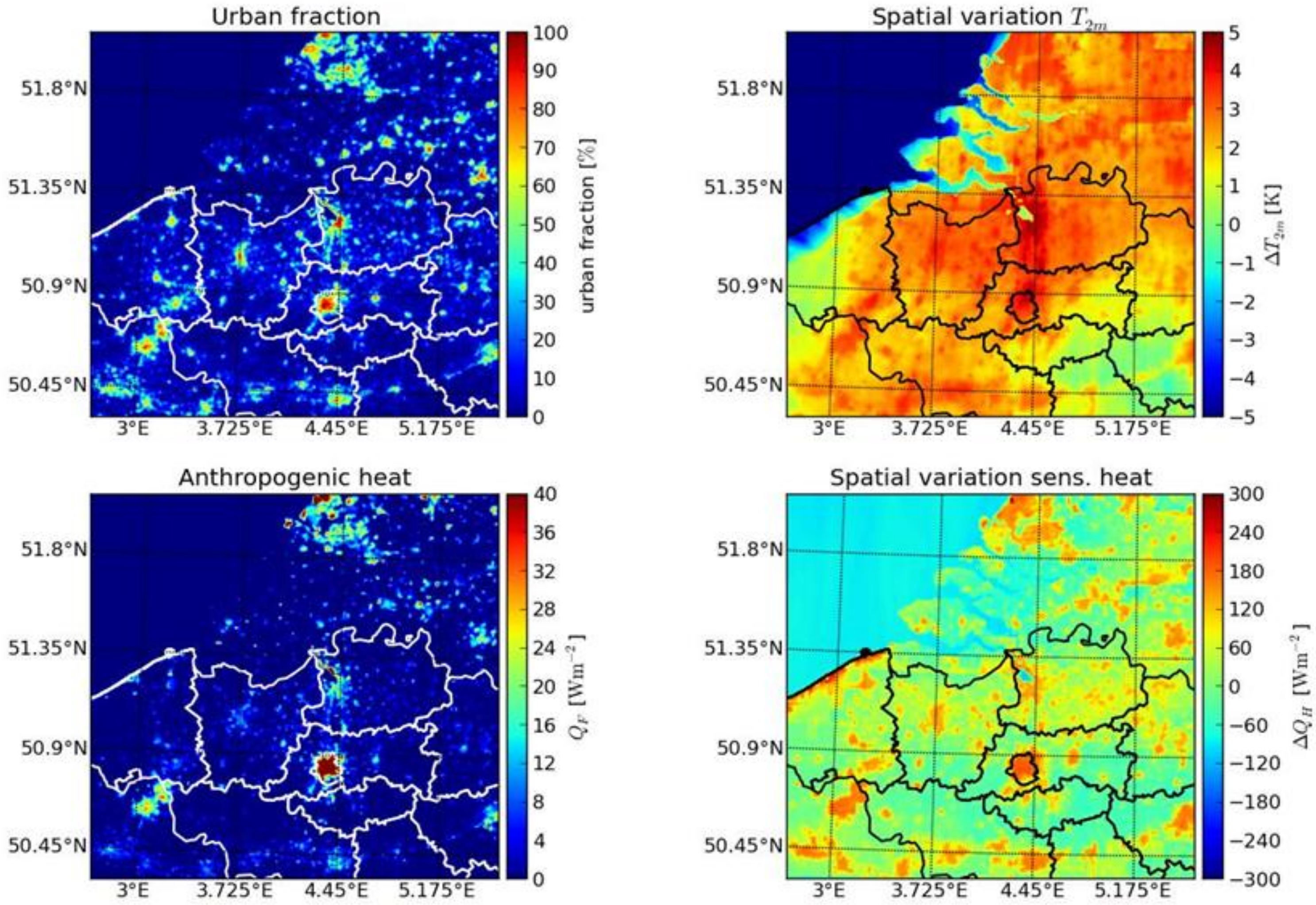
2012-08-16 00:00:00UTC



2012-08-19 00:00:00UTC



2012-08-18 15:00:00UTC



5. Conclusions

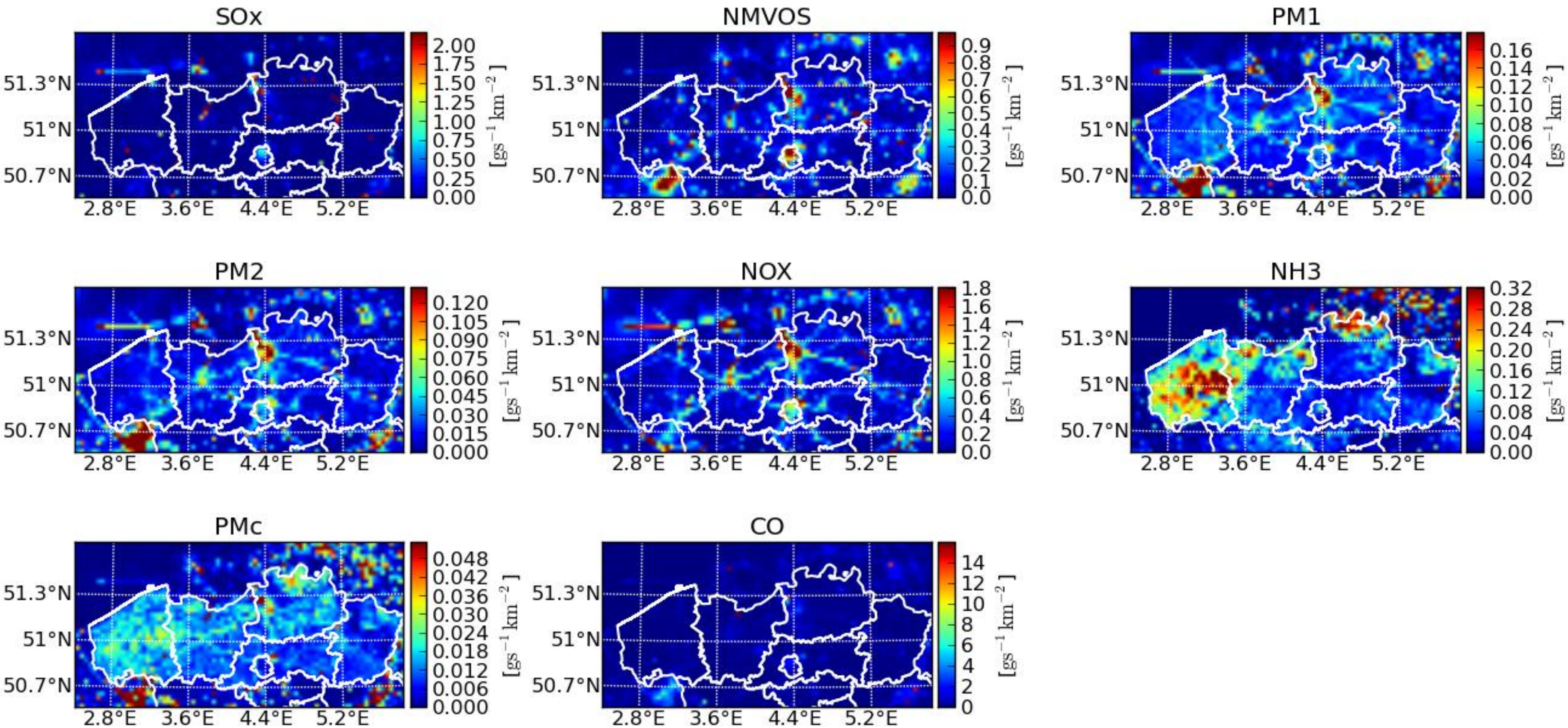
- **urban parameterization** in COSMO-CLM/TERRA-ML was **successfully implemented and tested** on 1km resolution over Belgium
- The temporal and spatial **variatiability** of the **UHI intensity are very well reproduced**
- Additional **computational cost** was **negligible** (+3% CPU-time)
- Number 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
  - unresolved radiative and turbulent flow mechanisms at the stations

DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
KU Leuven - BELGIUM

5. Outlook and applications

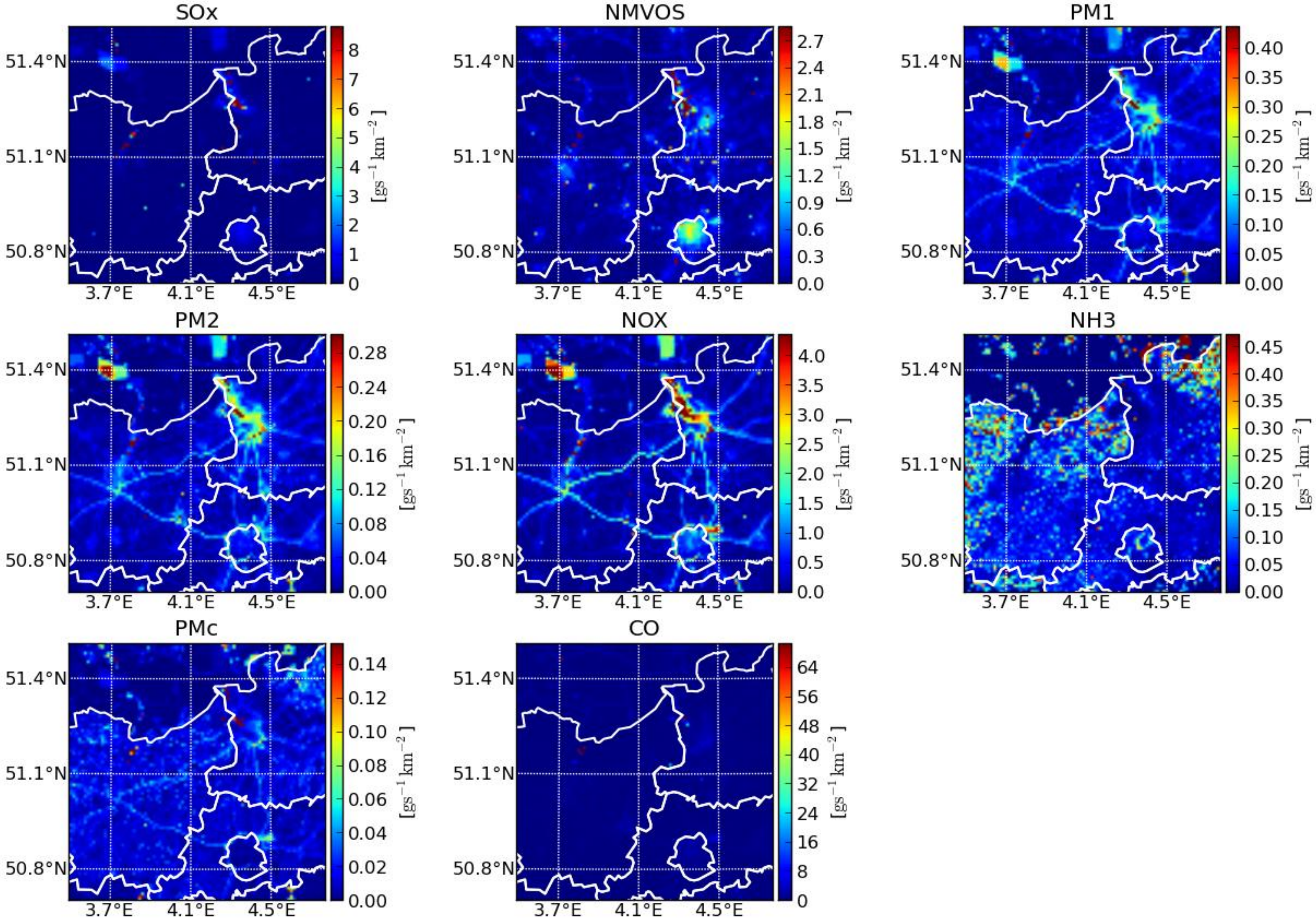
- Air-quality modeling with AURORA (developed at VITO)
  - What are the **driving processes determining urban air quality**?
    - **Relevance of micro-scale meteorology** (1-10km): UHI, topography
    - **Versus large-scale meteorology** (10–1000km)
    - **Versus** uncertainty **emissions** (top-down versus bottom-up)

Emissions at 3km resolution over Flanders



vito
vision on technology

Emissions at 1km resolution over Brussels/Ghent/Antwerp



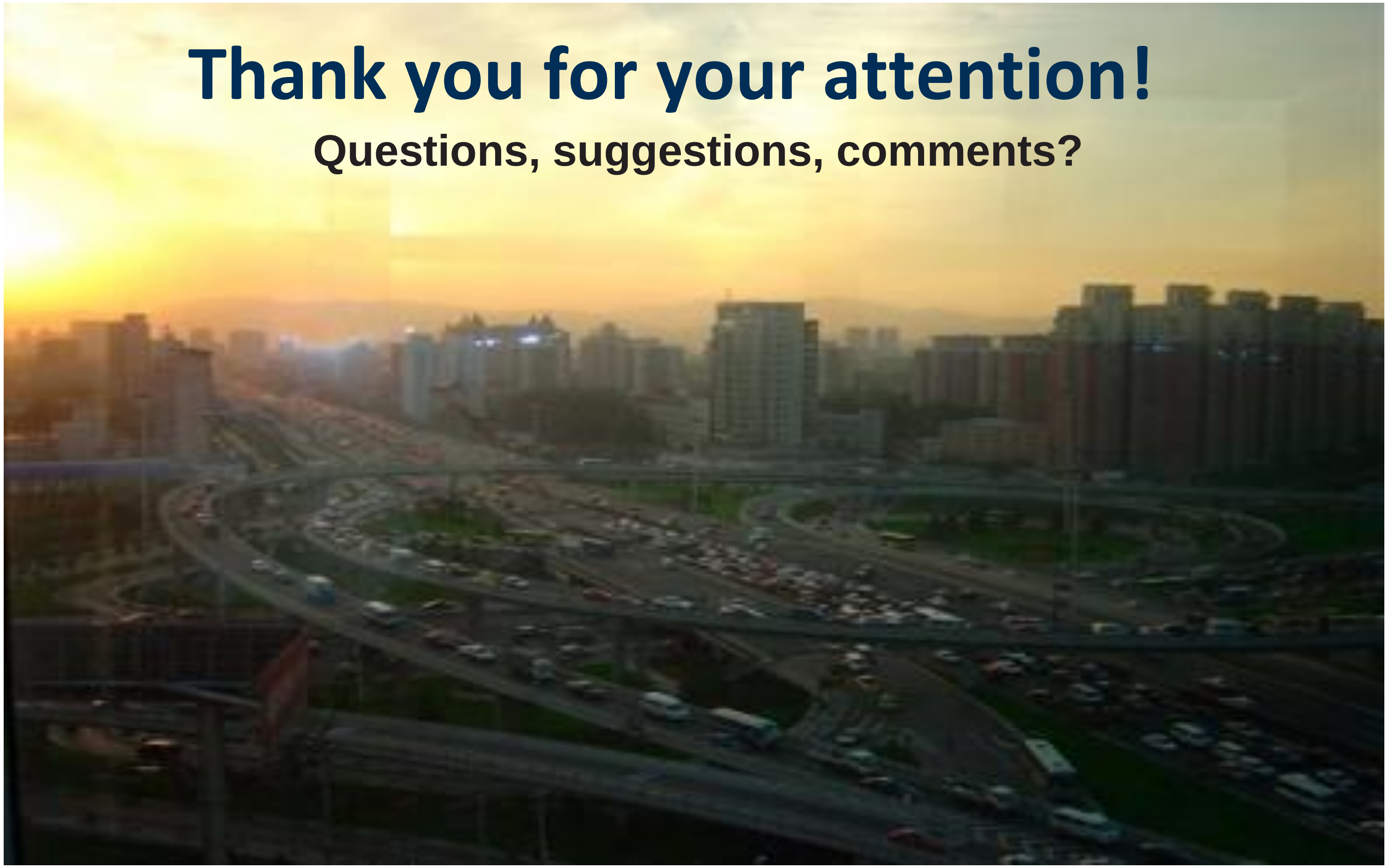
5. Outlook and applications

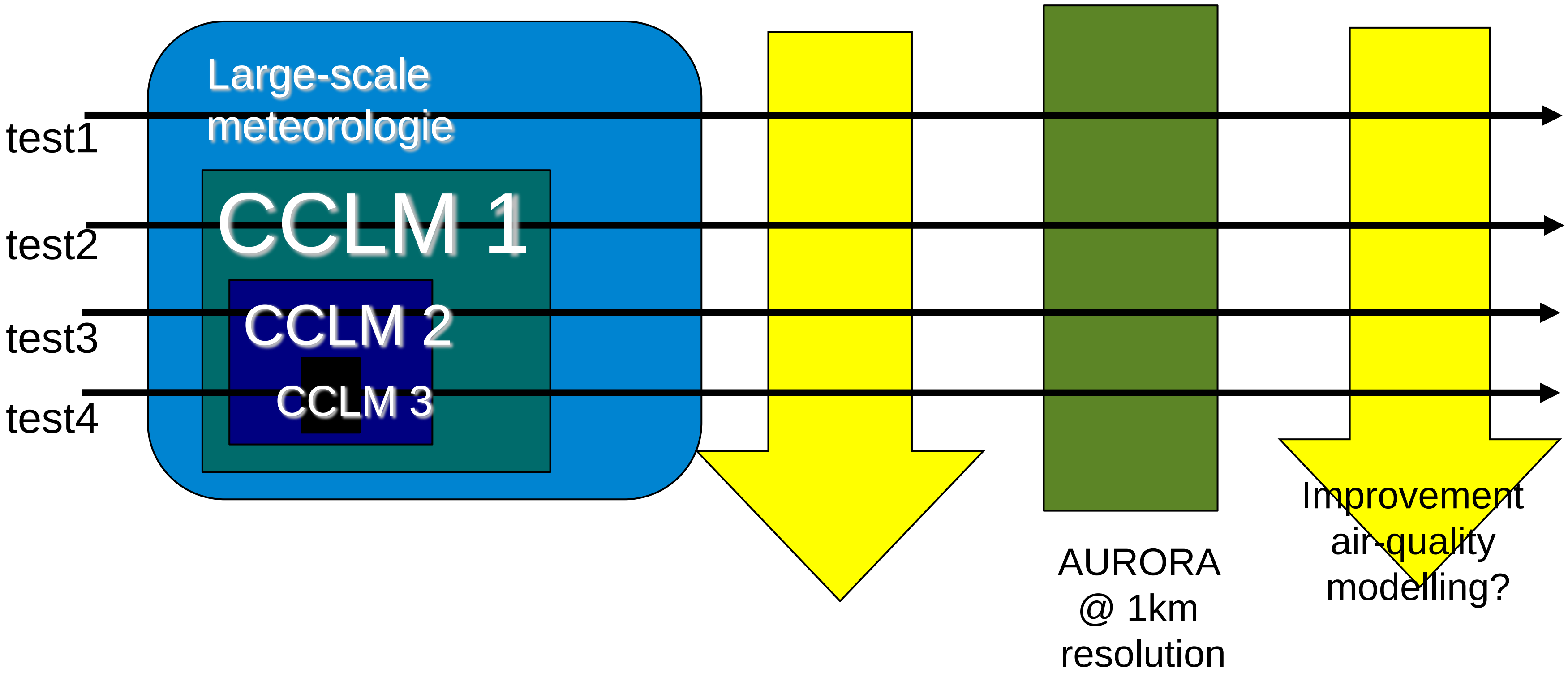
- Air-quality modeling with AURORA (VITO NV)
  - What are the **driving processes determining urban air quality**?
    - **Relevance of micro-scale meteorology** (1-10km): UHI, topography
    - **Versus mesoscale meteorology** (10–1000km)
    - **Versus** uncertainty **emissions for** VOC's, PM10,PM2.5,NOX (top-down versus bottom-up)
  - Why do we care?

    -> to set priorities for the **improvement** of **urban air-quality modelling**

Thank you for your attention!

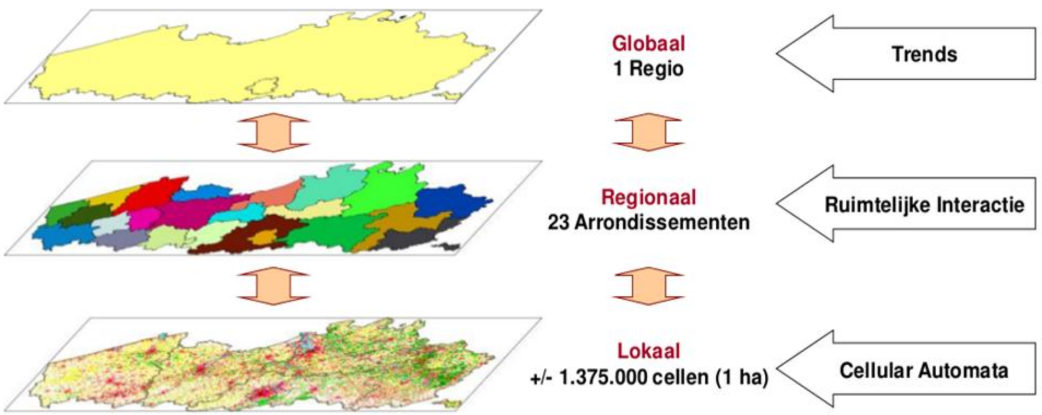
Questions, suggestions, comments?

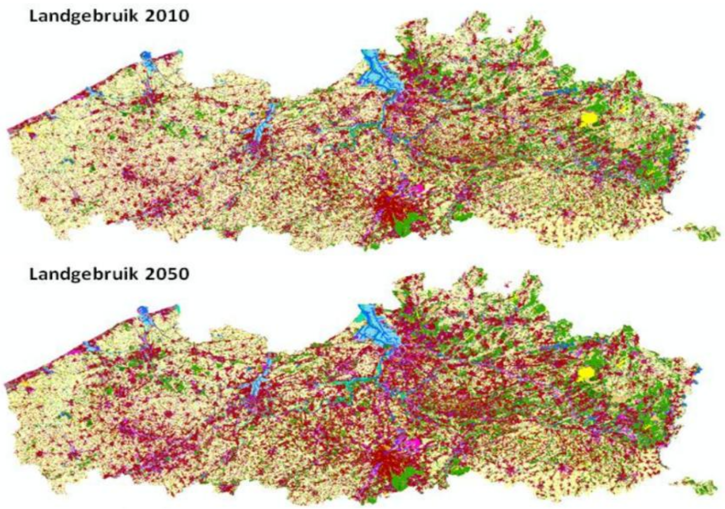



Large-scale
meteorologie
test1
test2
test3
test4
CCLM 1
CCLM 2
CCLM 3
AURORA
@ 1km
resolution
Improvement
air-quality
modelling?

5. Outlook and applications (2/2)

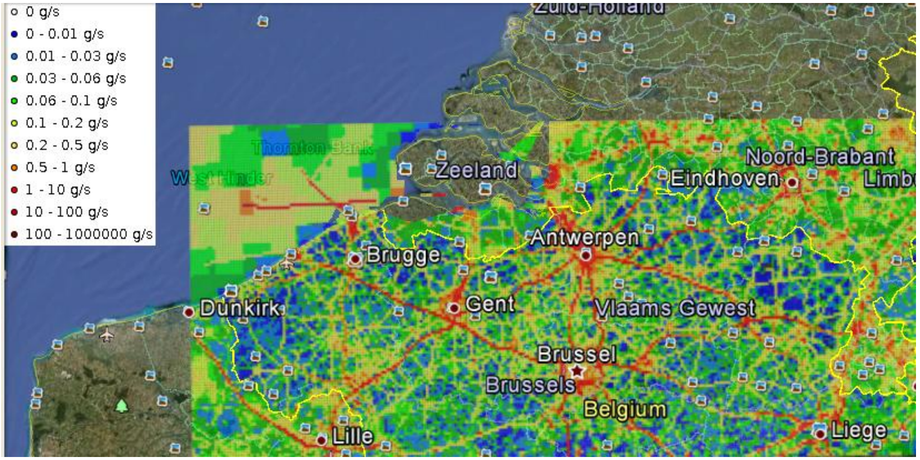
- Urban land-use change scenarios:
  - Investigate the impact of land-use change and global climate change on urban climate





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)