Adapting to heat stress in Antwerp (Belgium) based on detailed thermal mapping

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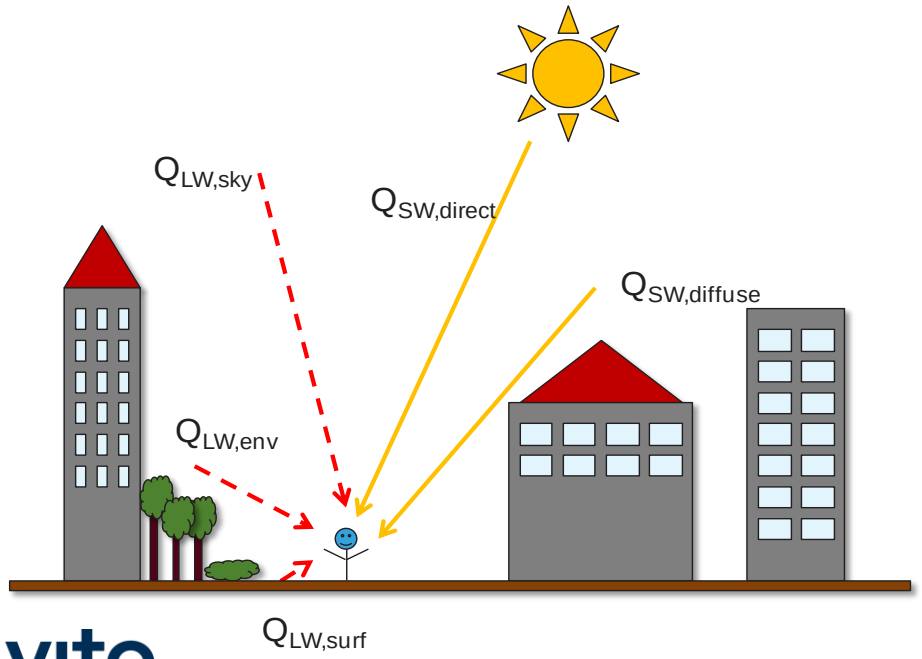
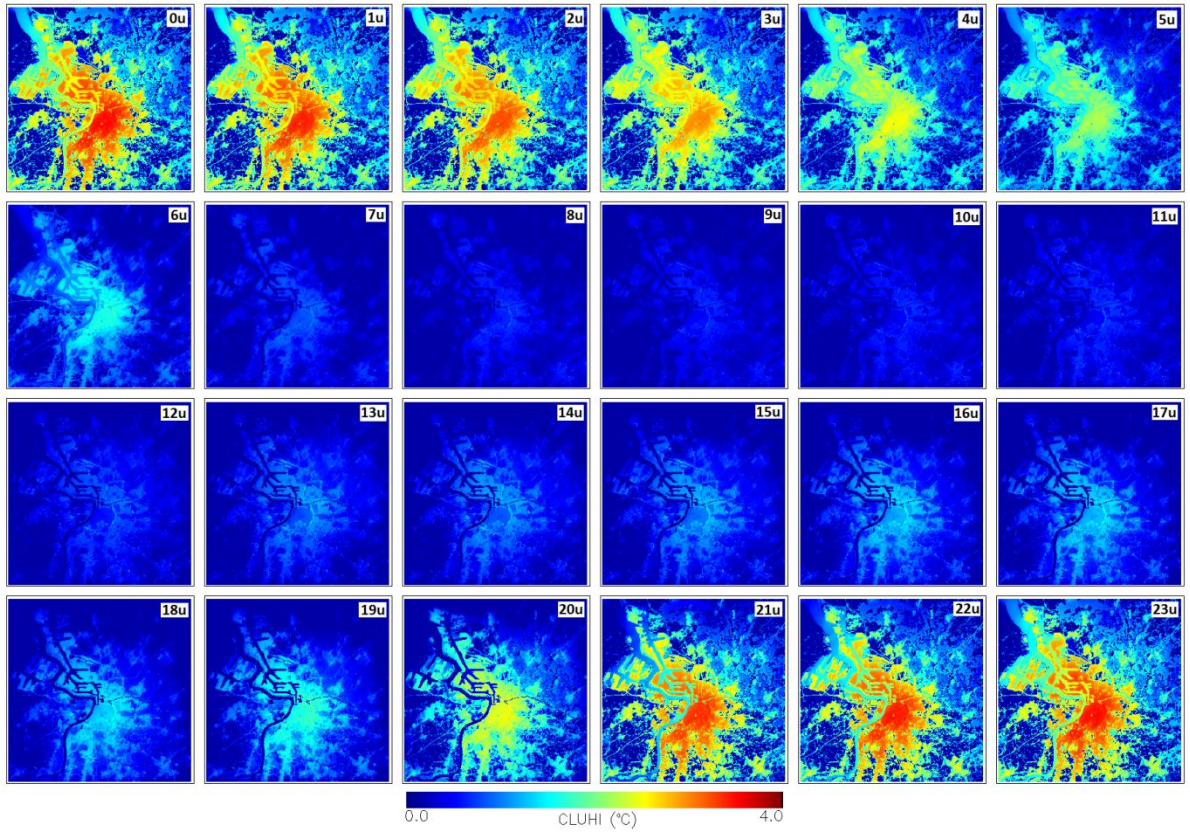
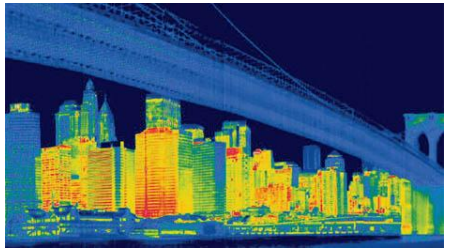
Background

- Heat stress is a problem that will only get worse in the future
- Negative impact on sleep, productivity, health and mortality
- Impact is felt hardest in cities:
    - Cities tend to be warmer than local surroundings
    - Effect both during daytime (higher radiation) and nighttime (Urban Heat Island effect)





Urban Heat Island



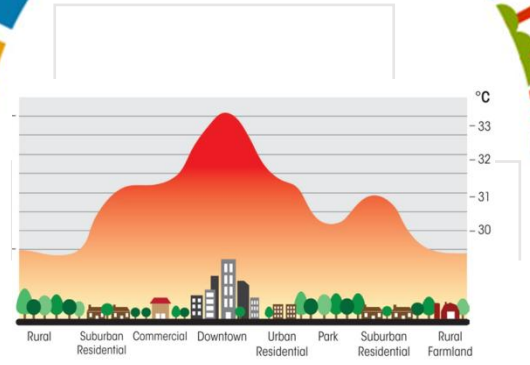
Lack of vegetation: less evaporation

Anthropogenic heat:
- Cooled / heated buildings
- (traffic) exhausts

Heat stored by buildings and paved roads released at night

Reduced ventilation in street canyons

Radiation reflected by walls



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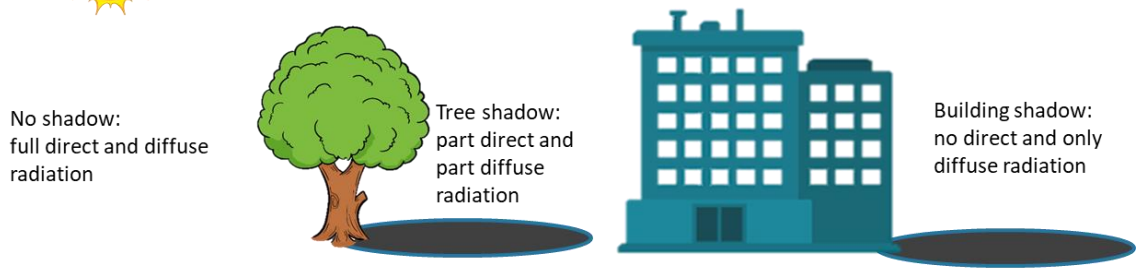
Daytime heat stress

- Air temperatures don't tell the complete story
- Important factors for thermal comfort
  - Wind speed
  - Humidity
  - Radiation load
- Many indicators exist to analyse these effects
  - ⇒ Wet Bulb Globe Temperature (ISO standard)

$$WBGT = 0.7 \times Tw + 0.2 \times Tg + 0.1 \times Ta$$

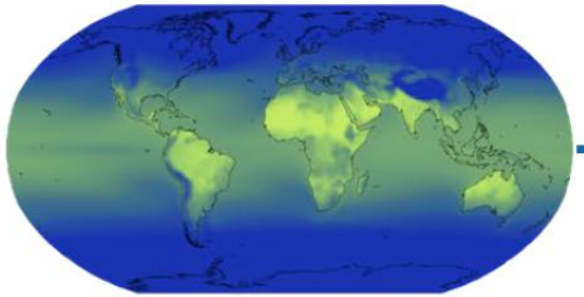
- Incorporated in legislation in several countries (incl Belgium)



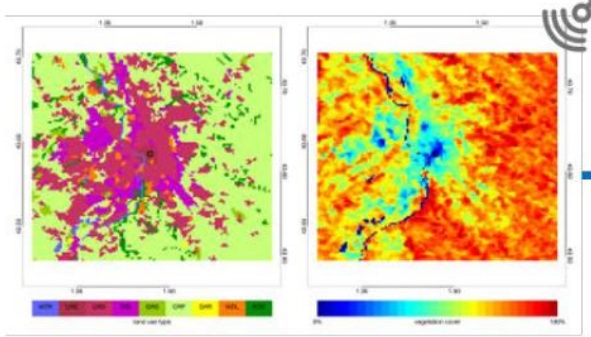
WBGT temperature (°C)	Categorie	Stress Categorie
> 31	4	extreme heat stress
29.5 to 31	3	very strong heat stress
28 to 29.5	2	strong heat stress
25 to 28	1	moderate heat stress
< 25	0	no heat stress

U.S. Army (2003)

VITO's UrbClim model

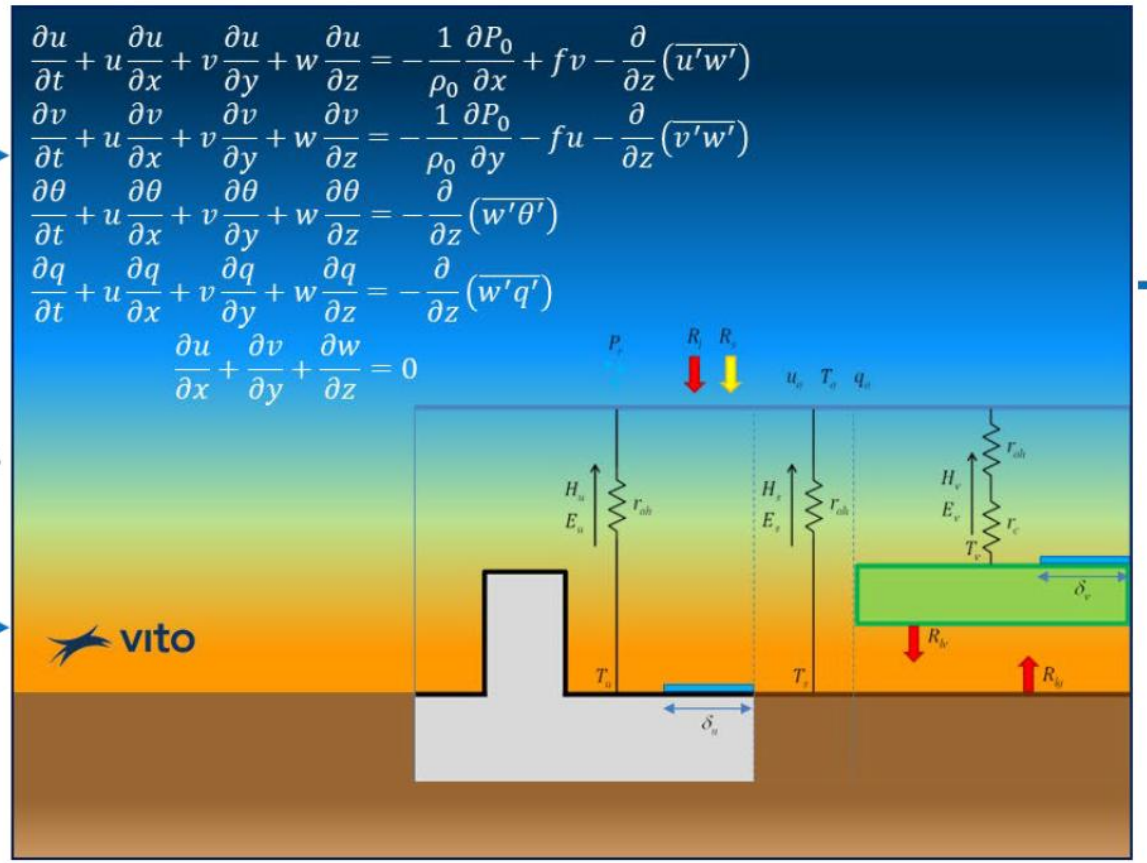


large-scale atmospheric forcing (re-analysis, climate projection)

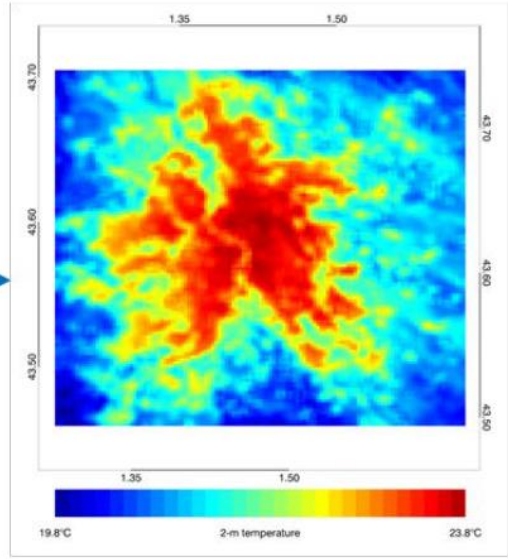


terrain parameters (land cover, vegetation %, ...)

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\rho_0}\frac{\partial P_0}{\partial x}+fv-\frac{\partial}{\partial z}\left(\overline{u'w'}\right)$$
$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{1}{\rho_0}\frac{\partial P_0}{\partial y}-fu-\frac{\partial}{\partial z}\left(\overline{v'w'}\right)$$
$$\frac{\partial \theta}{\partial t}+u\frac{\partial \theta}{\partial x}+v\frac{\partial \theta}{\partial y}+w\frac{\partial \theta}{\partial z}=-\frac{\partial}{\partial z}\left(\overline{w'\theta'}\right)$$
$$\frac{\partial q}{\partial t}+u\frac{\partial q}{\partial x}+v\frac{\partial q}{\partial y}+w\frac{\partial q}{\partial z}=-\frac{\partial}{\partial z}\left(\overline{w'q'}\right)$$
$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$



De Ridder et al., 2015. https://doi.org/10.1016/j.uclim.2015.01.001



hourly gridded (100-m)

- air & land surface temperature
- air humidity
- wind speed
- energy & water fluxes
- plant water stress
- soil moisture content
- ...

inputs — URBCLIM® — ouputs

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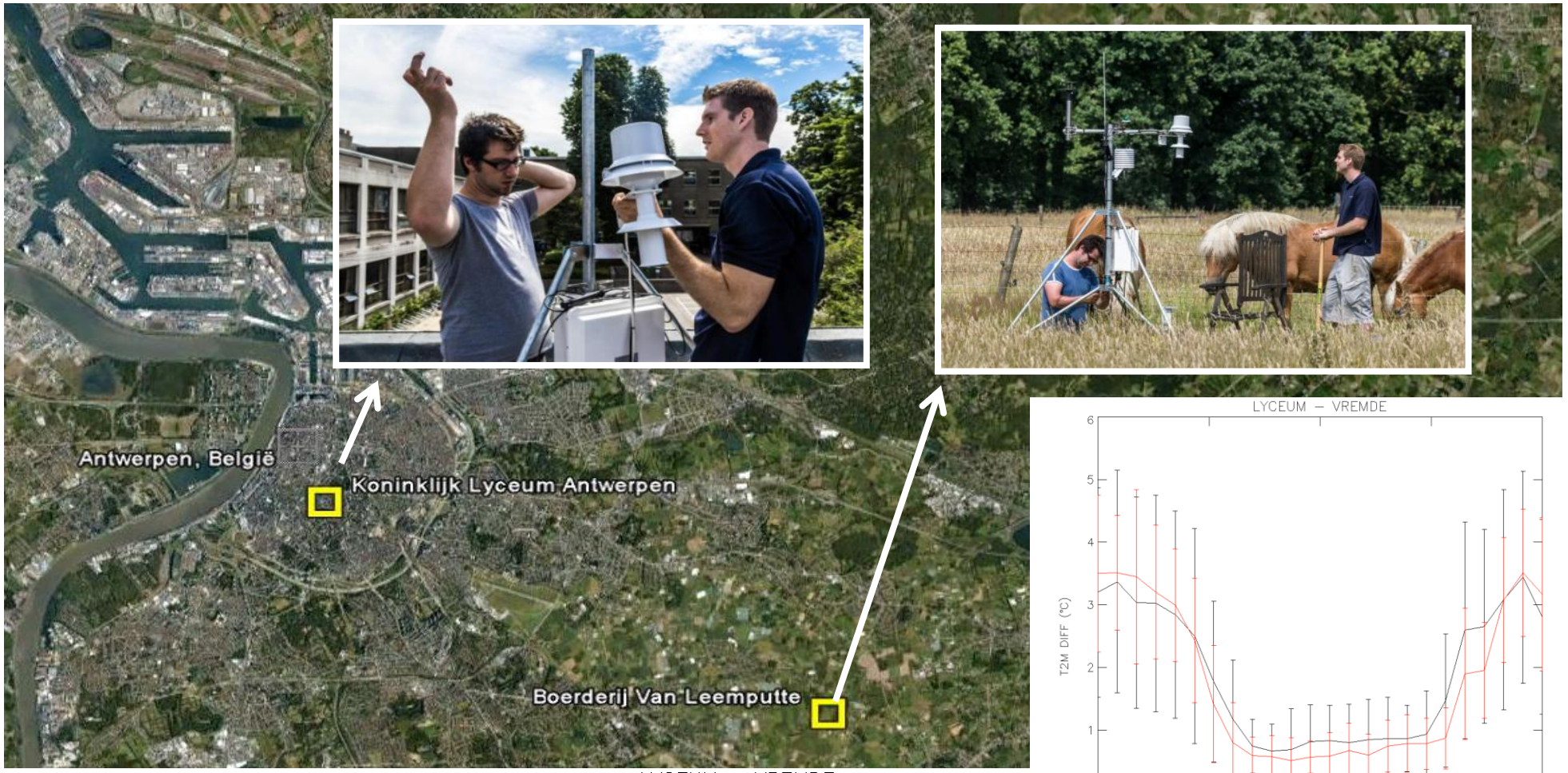
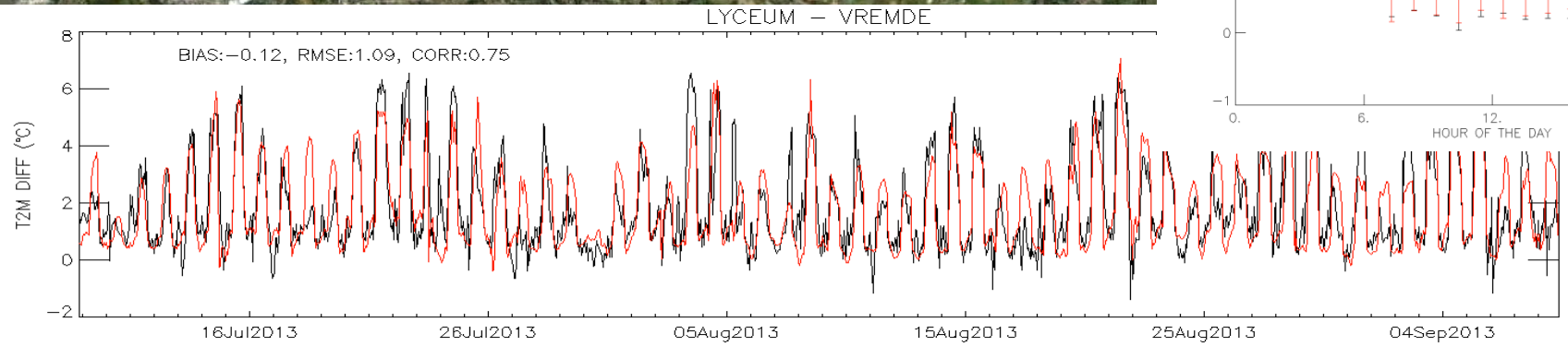
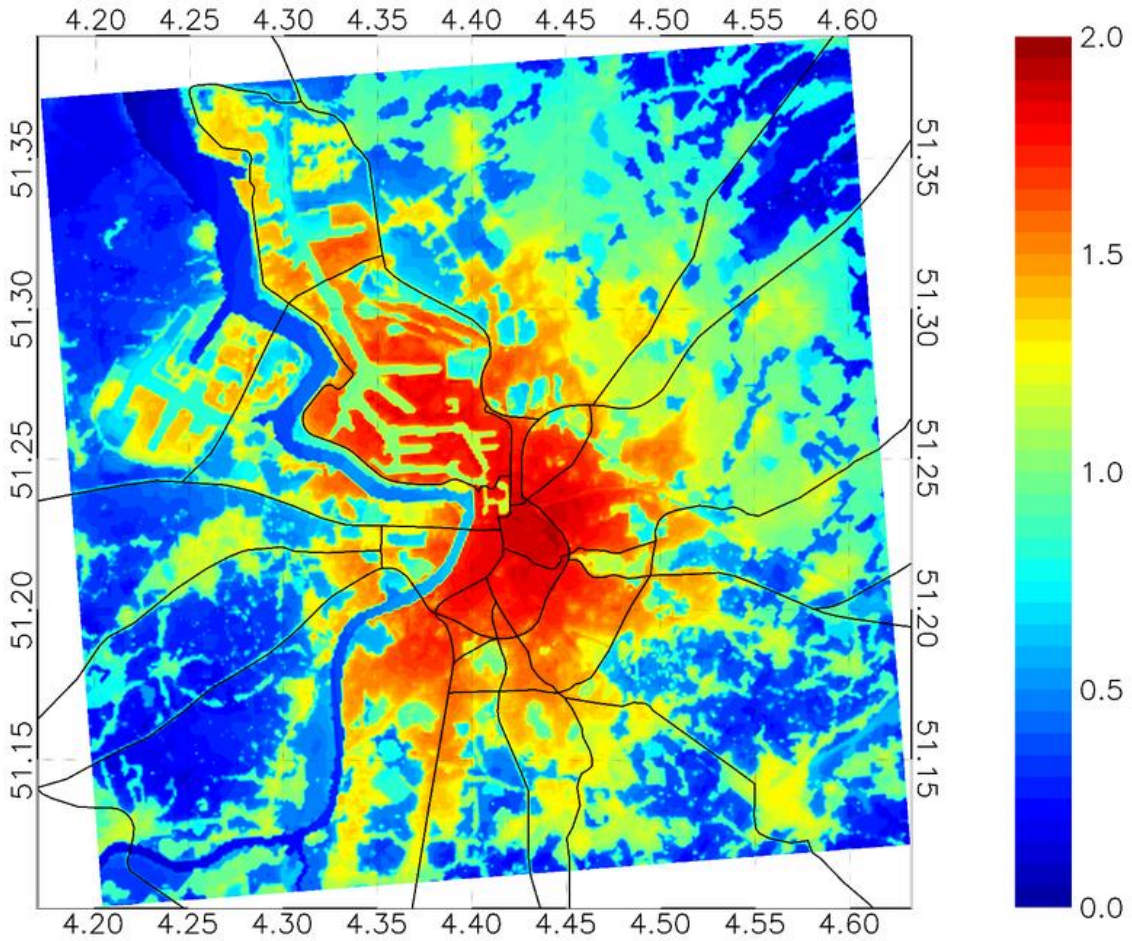
Model validation

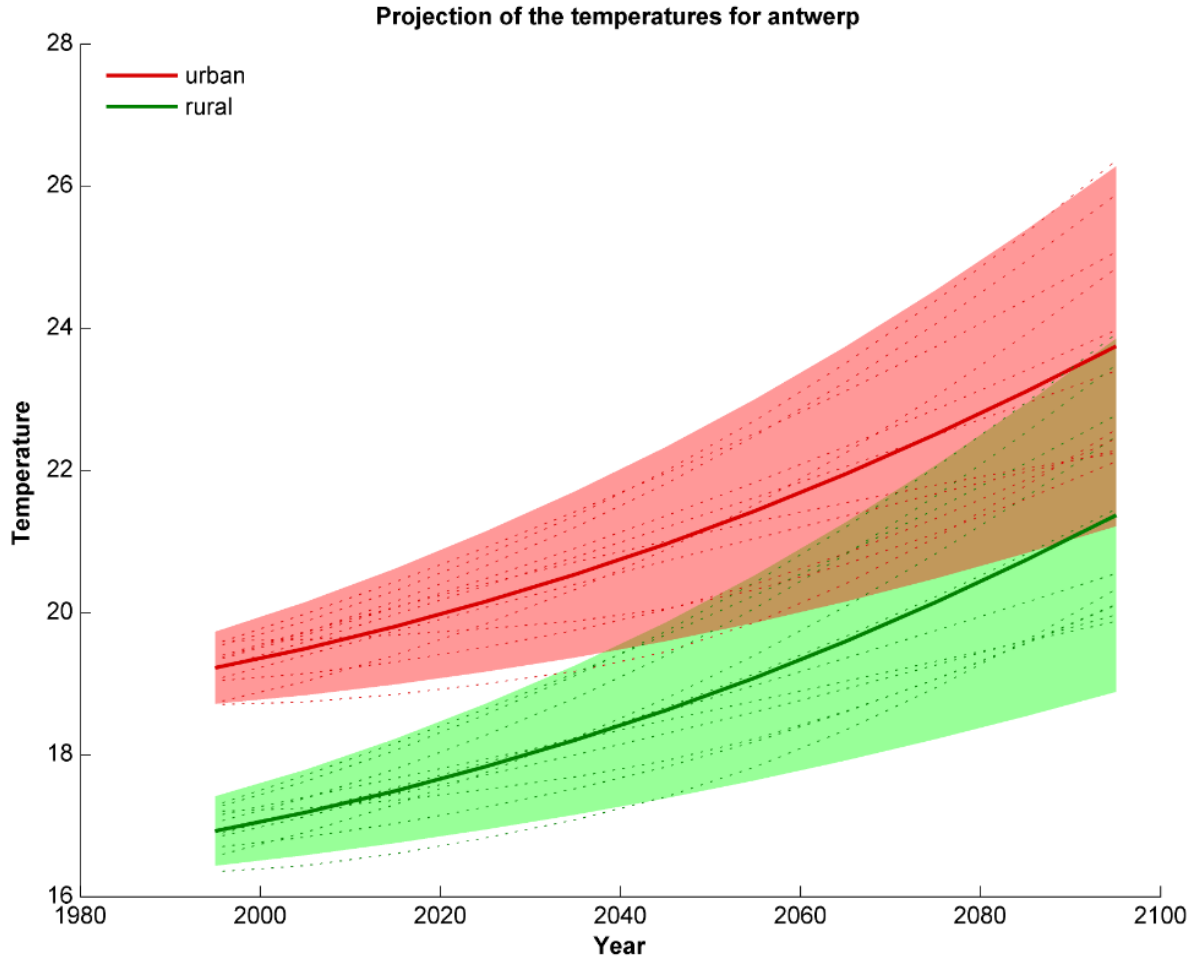




Antwerp results



Daily average UHI during summer



Projected temperature increases (RCP8.5)

Antwerp results

Modelled 1m resolution daily maximum WBGT during selected hot day

Citizen science measurement campaign (H2020 Groundtruth project)

sealed surface in the sun	grass surface in the sun	small street, sunny side	green garden, half shadow	small street, shadow side	under small trees
27,6	26,1	25,3	23,7	23,5	23,5
					

City objectives

- reduce the local heat stress as much as possible through changes in the built environment
- inform citizens about the problem
- engage them through citizen science campaigns
- minimize the health impacts with a heat forecast and warning system, targeting vulnerable groups

Website to inform citizens about heat stress

Implemented heat stress adaptation measures

- City-wide scale (building code)
  - All new or renovated roofs with a slope of less than 15% and a surface area of more than 20m², compulsory green roof installation
  - All new installed private gardens and open parking lots need to be green and permeable
  - Building fronts need to be painted in light, preferably white colour

- Local scale (urban planning)
  - When renovating large squares, parks and neighbourhoods, the optimisation of the thermal comfort situation needs to be considered
  - Several detailed modelling studies were performed by VITO to quantify the local WBGT values and assess the potential impact of planned adaptation measures
  - Inclusion of green-blue infrastructure measures (e.g. trees, permeable surfaces, water ponds, fountains) in renovation plans

- Individual scale (heat-health action plan)
  - Targeted heat stress forecast for Antwerp, taking into account the urban heat island effect
  - Development of a web platform to issue heatwave warnings to health aid workers

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Conclusions

- Main success of the research was to raise awareness about this topic at the political level, generating the political will (and funding) to tackle this problem
- Communication emerges as key issue in collaboration between researchers and city practitioners, among individual city departments involved, and suitable forms of communication between city officials or scientists and citizens
- The research on heat stress and climate change has been mainly funded by European projects (FP7 RAMSES and NACLIM, H2020 Climate-fit.city and Ground Truth 2.0), which also covered a part of the in-kind costs for the city of Antwerp
- Research on heat stress and climate change for the city of Antwerp started in 2013 and is still ongoing
- The implementation of adaptation measures at the local scale proves to be a slow process, and most realizations at the city-wide scale have yet to materialize
- Full implementation and city-wide results are only expected to be completed by 2030

VITO's CLIM TEAM

Climate adaptation services for cities, agriculture and nature

Thanks for your attention!