

# Investigating the impact of anthropogenic heat on urban climate using a top-down methodology

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University of Hamburg, Germany

# Introduction

Importance of anthropogenic heat (AH) studied for the **local** (Ichinose, 1999) up to the **global** climate (Zhang, 2013)

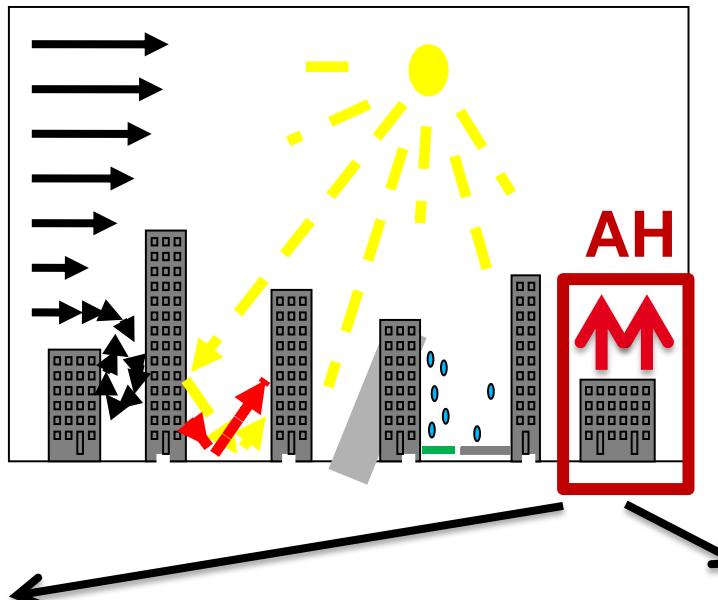
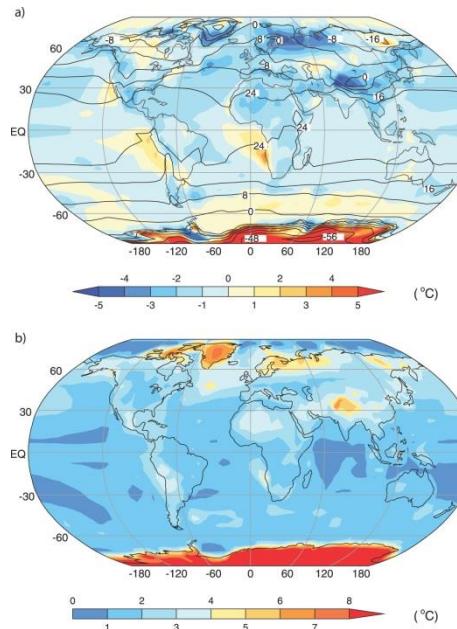
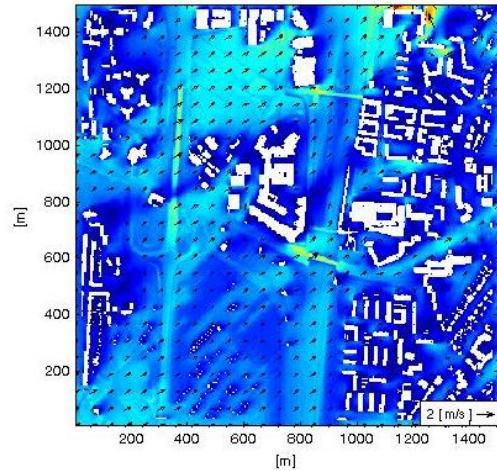


Fig 8.2 of IPCC AR-4 report



MITRAS simulation

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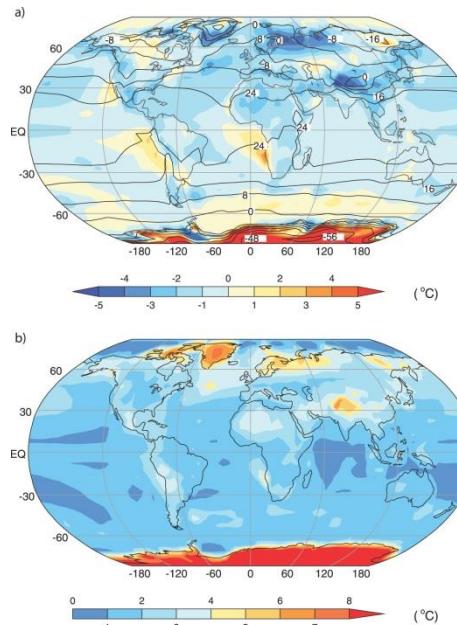
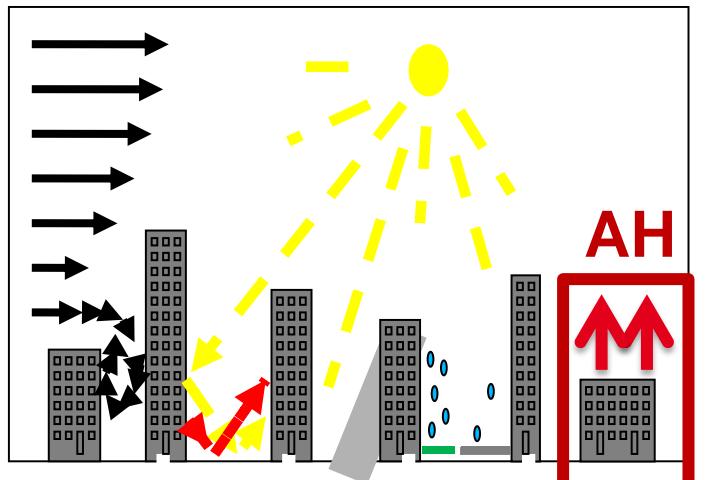
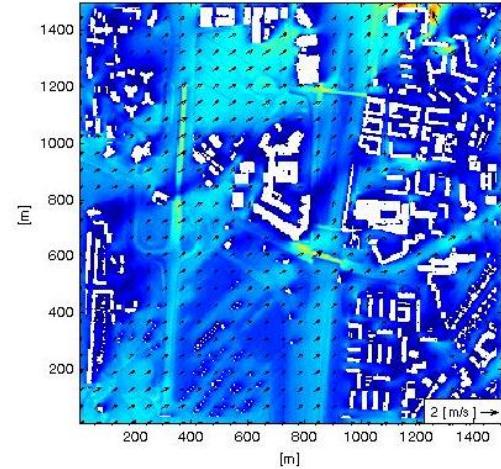


Fig 8.2 of IPCC AR-4 report



How to derive AH?  
(mesoscale models)



MITRAS simulation

# Determination of anthropogenic heat fluxes



Google Maps, satelite data

Indirect measurement  
(budget closure  
concepts)



Energy building  
models



Inventory  
approaches

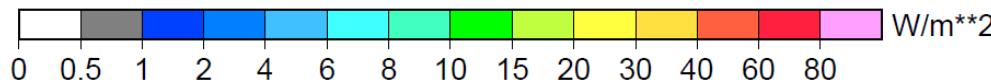
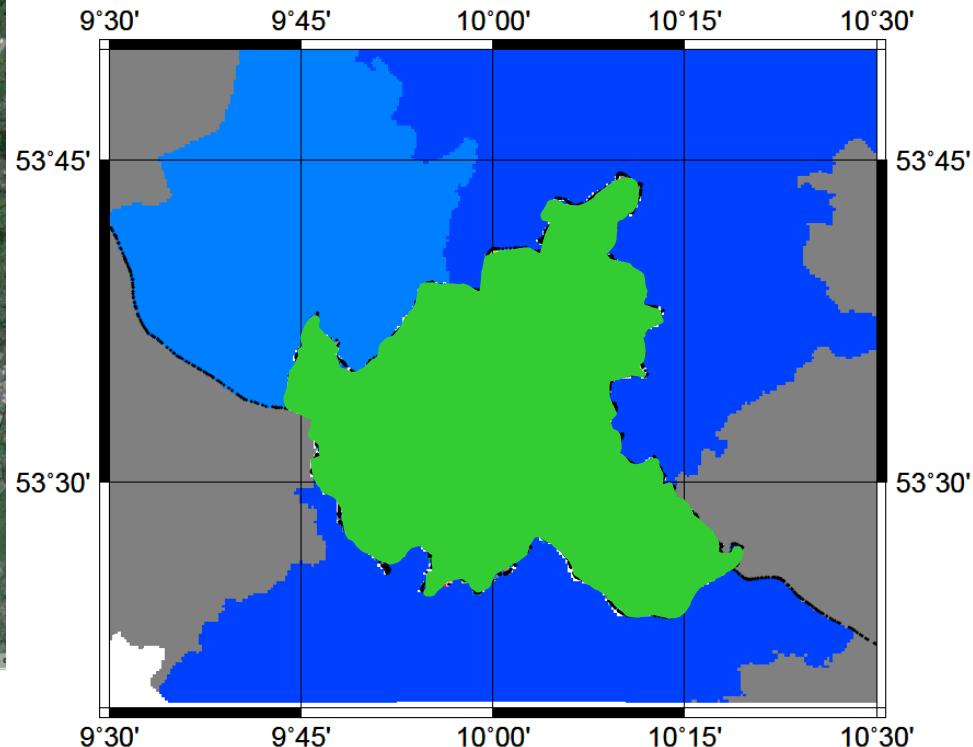
# Determination of anthropogenic heat fluxes

LUCY

(Allen and Grimmond, 2011)



Google Maps, satelite data

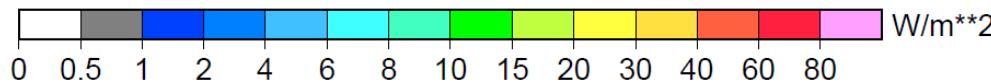
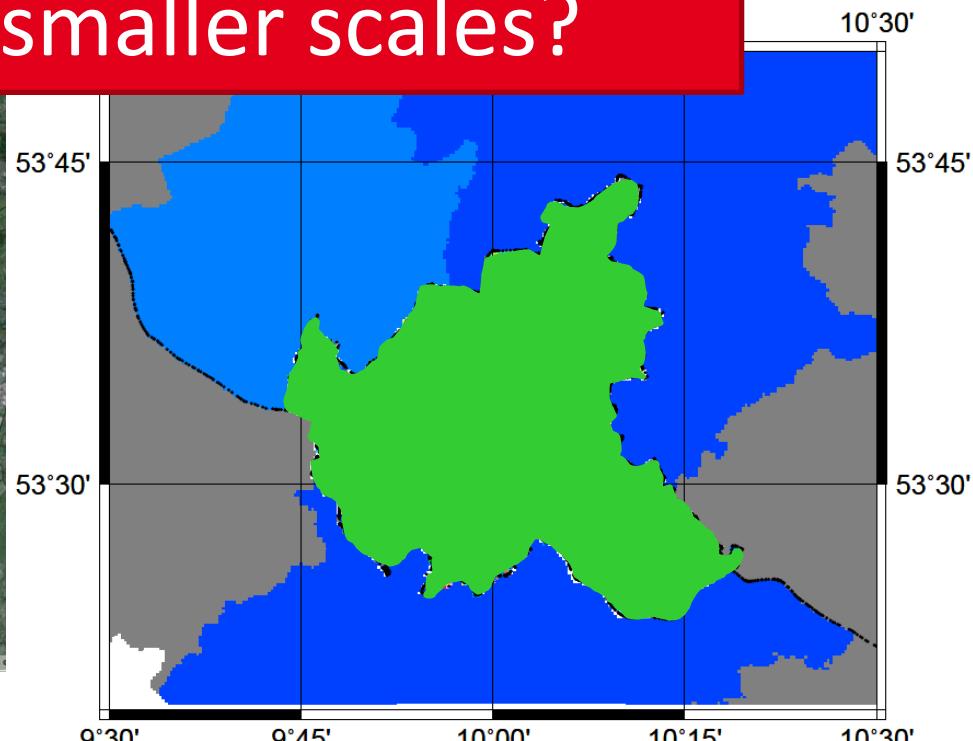


# Determination of anthropogenic heat fluxes

Are there estimates more properly representing smaller scales?

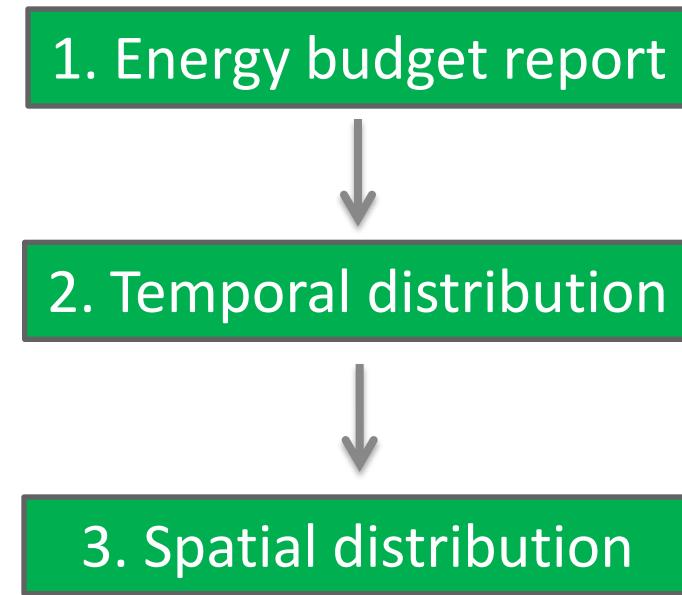


Google Maps, satellite data



# Top-Down methodology approach for Germany

Determination of anthropogenic heat emissions based  
on a three-steps procedure using SNAP classes



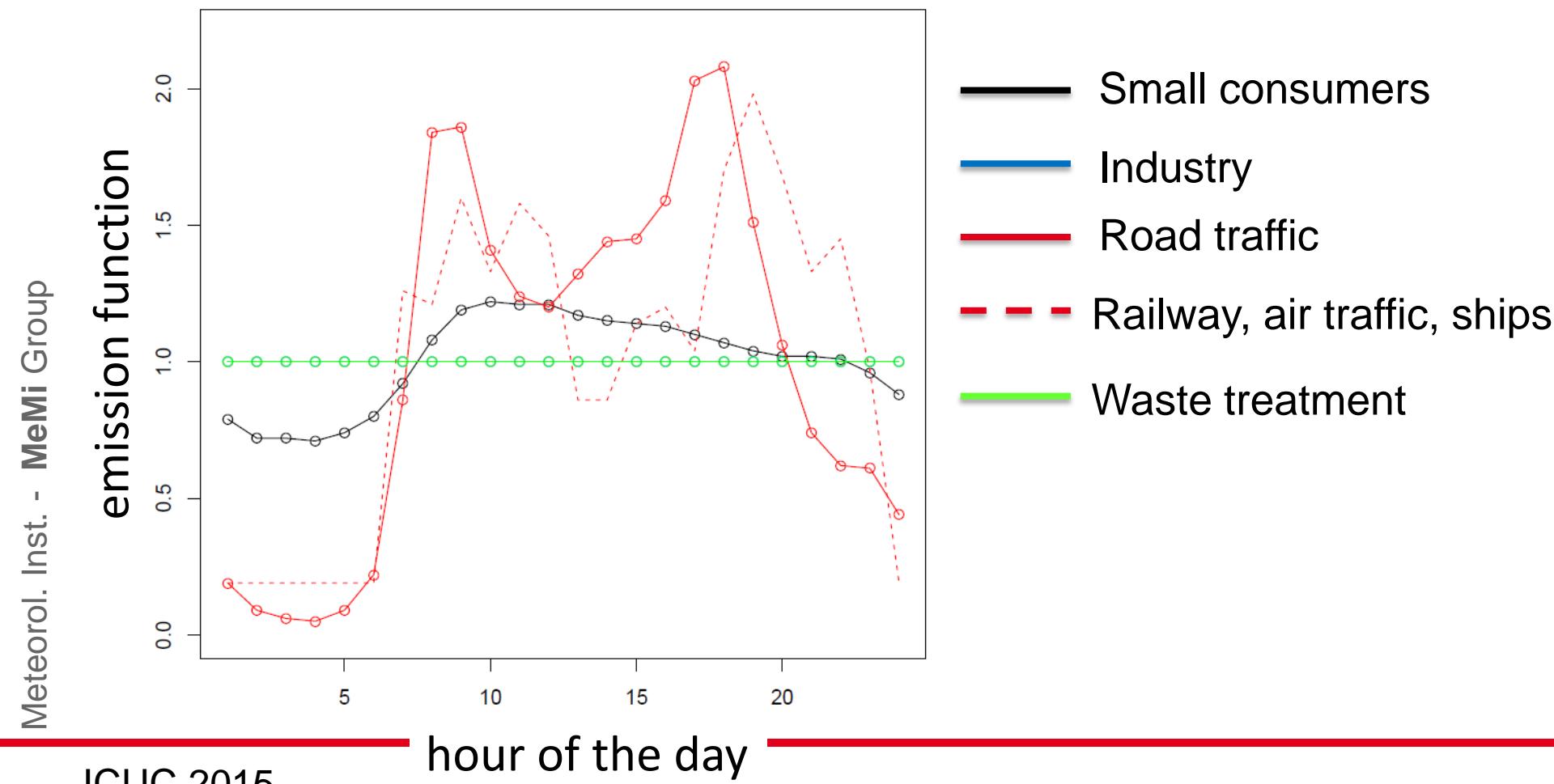
# SNAP based Top-Down methodology

annual energy budget report for the German state Hamburg,  
EC = energy consumption, SNAP classes following McInnes (1996)

SNAP class	explanation	EC [TJ]
SNAP 1	power plants	3504
SNAP 2	Small consumers	88126
SNAP 4	Industry: power generation and production processes	57456
SNAP 7	road transport	45293
SNAP 8	other mobile sources: shipping, aircrafts and rail transportation	20084

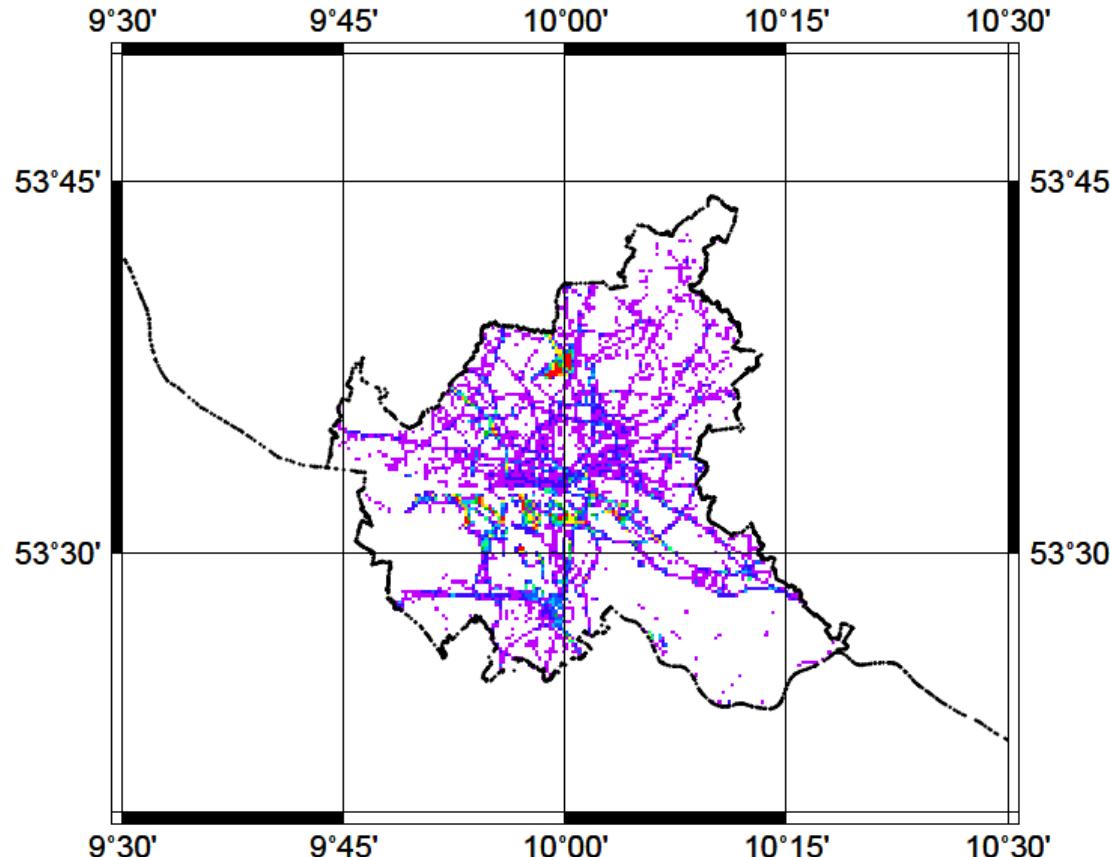
# SNAP based Top-Down methodology

temporal distribution of SNAP related emissions provided by the TNO (Kuenen et al., 2010)

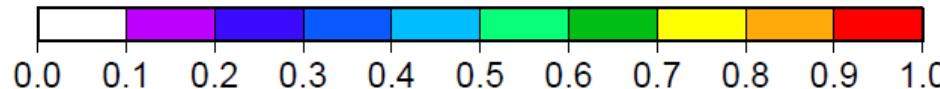


# SNAP based Top-Down methodology

Spatial mapping using high-resolution land-use data (data basis:  
BIOTOP and ATKIS mapping of BSU and BKG)

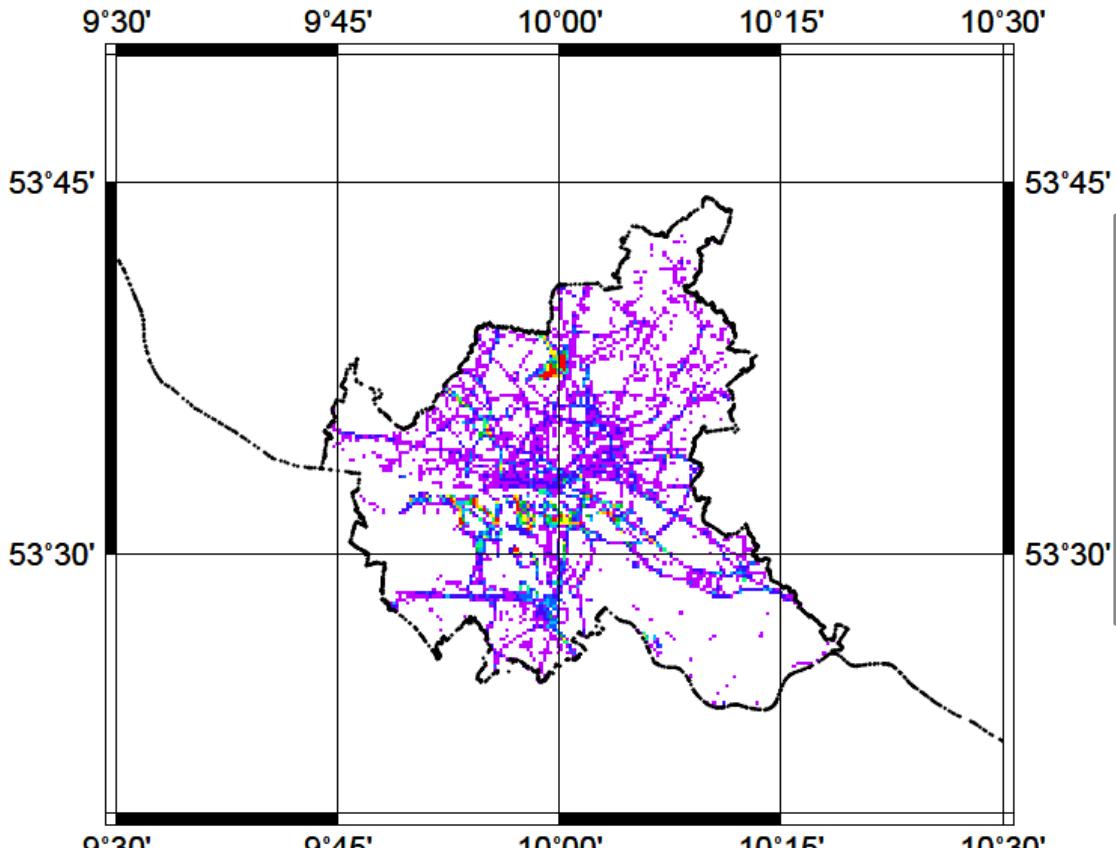


SNAP7  
(Road traffic)  
+  
SNAP8  
(other mobile  
Sources)



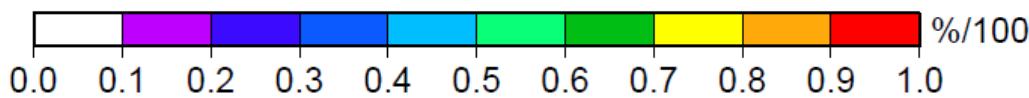
# SNAP based Top-Down methodology

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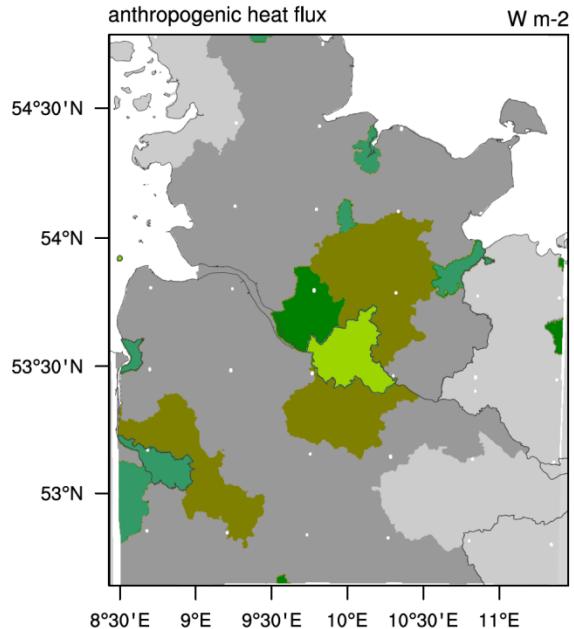
#### Drawbacks:

- often equally distribution of energy consumption
- overall energy consumption considered as sensible heat release

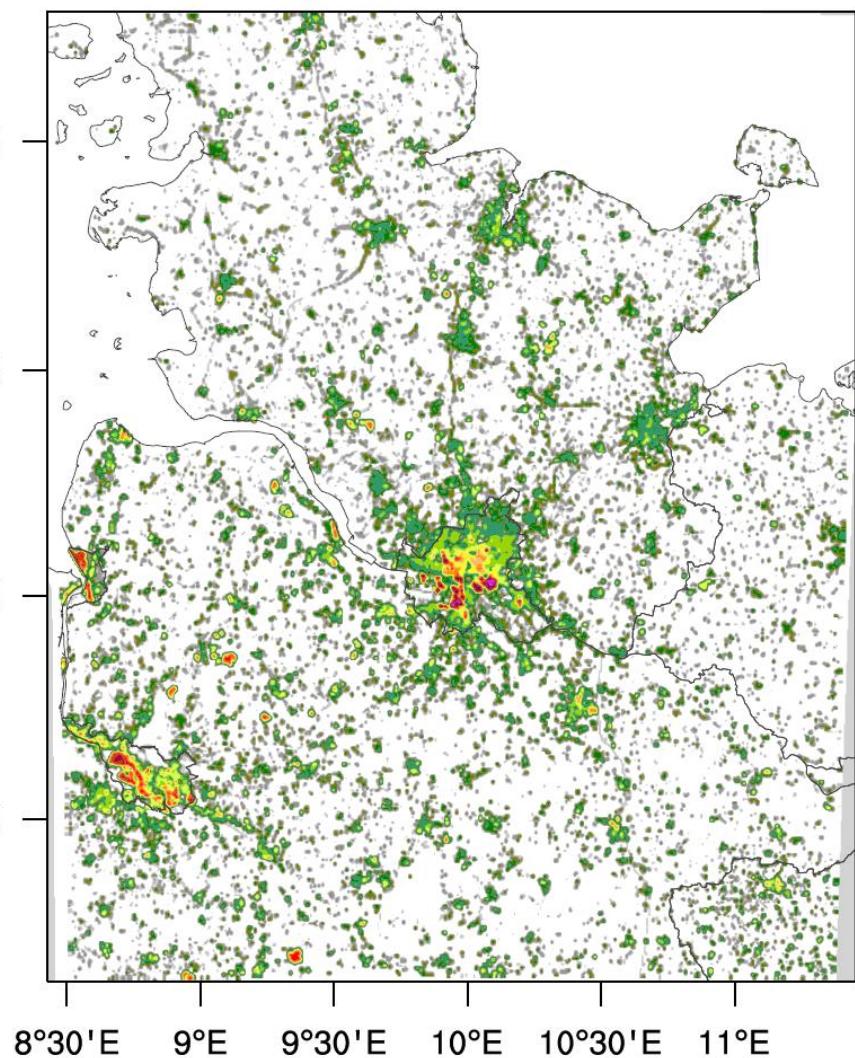


# Anthropogenic heat forcing in Northern Germany - 15th of August, 00 LT

LUCY

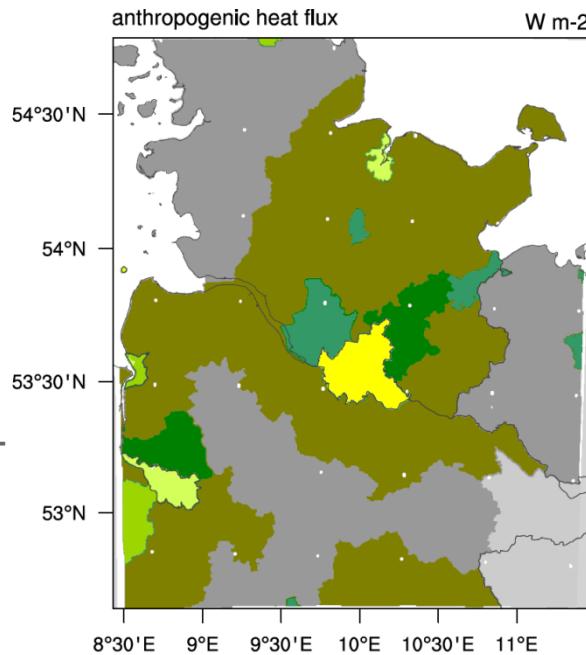


anthropogenic heat flux

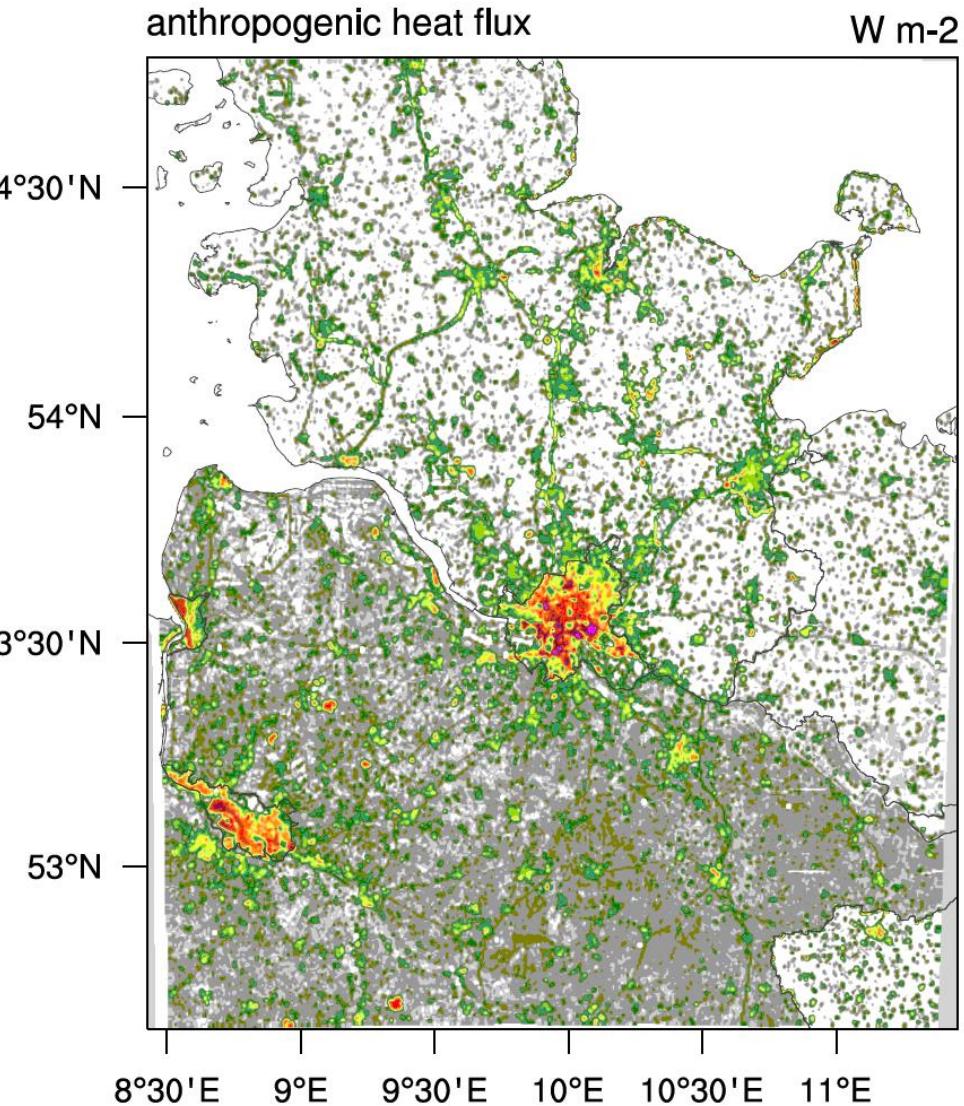


# Anthropogenic heat forcing in Northern Germany - 15th of August, 08 LT

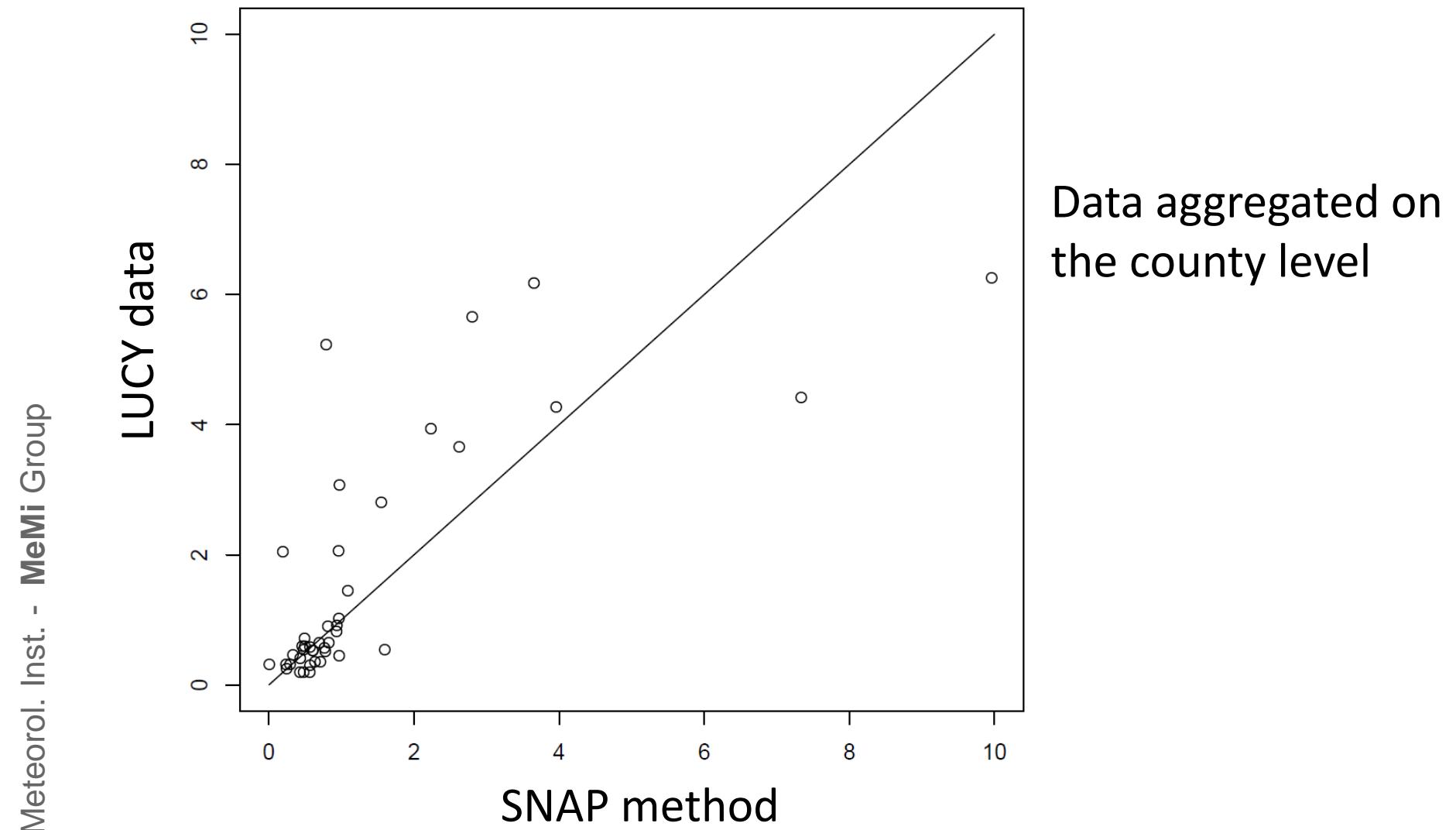
LUCY



anthropogenic heat flux



# Validation of the SNAP based Top-Down Methodology, heat fluxes



Data aggregated on  
the county level

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# **Application of the SNAP based TOP-DOWN methodology**

# Anthropogenic heat and the summer climate of Hamburg

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Simulations / sensitivity study performed with Mesocale transport model METRAS (Schlünen et al., 2012):

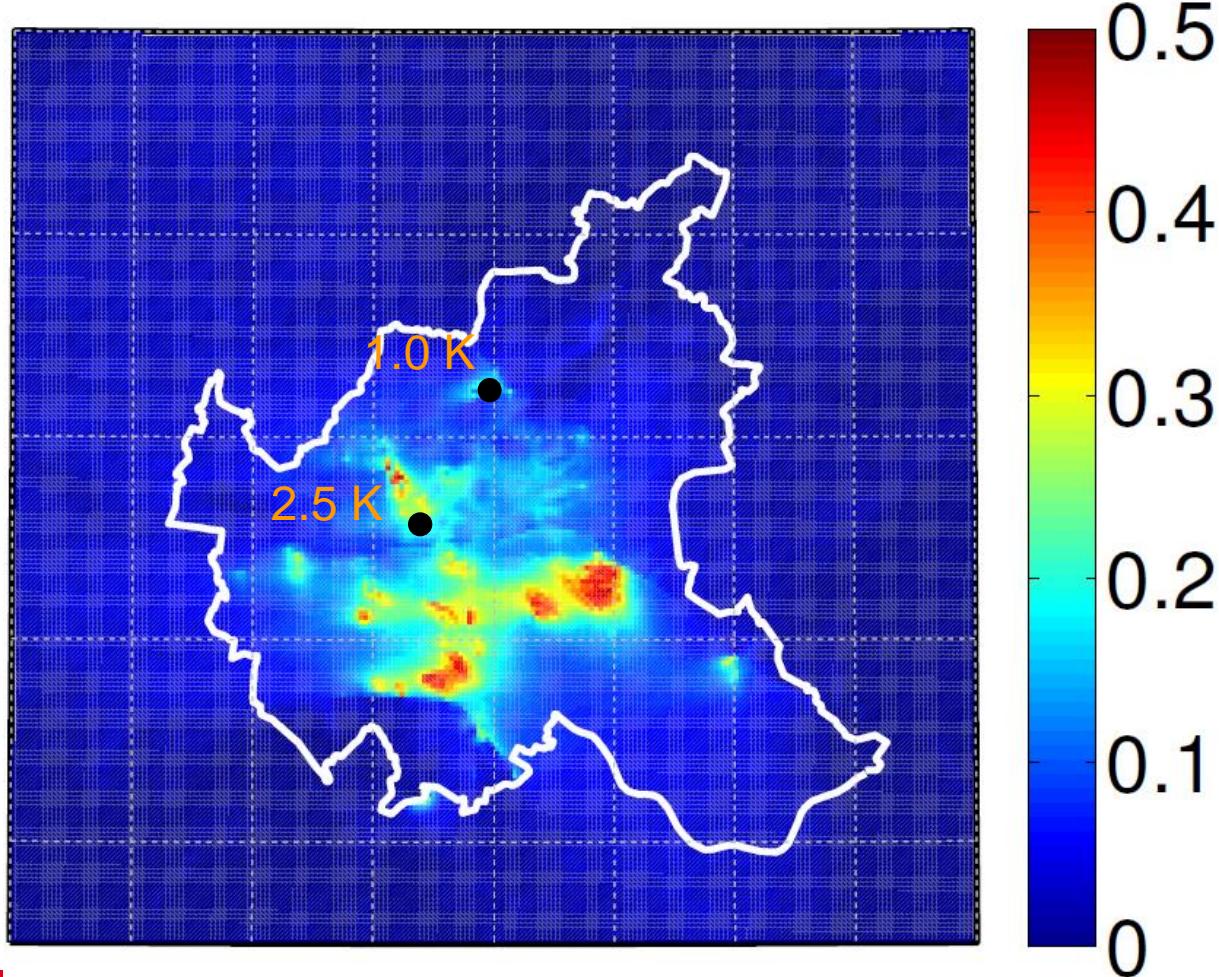
- nonhydrostatic model system with anelastic approximation
- radiation physics and cloud microphysics (warm rain)
- surface scheme using a tile approach and nearly 50 surface cover classes (Flagg, 2012)
- various turbulence parameterizations

Model setup:

- forcing with ECMWF analysis data (wind, temperature, humidity quantities)
- three nesting steps with finest nest at horizontal resolution of 250 m, vertically stretched levels
- 13 different summer runs according to Hoffmann (2012)

# Impact of anthropogenic heat, 10 p.m. to 2 a.m.

mean impact of anthropogenic heat on 10 m temperature



# Conclusions

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- The SNAP related top-down methodology provides high-resolution maps for anthropogenic heat release in the German region
- Differences to the LUCY data base originate from energy budget statistics and the related spatial resolution

Which portion of the urban heat island can be attributed to the anthropogenic heat emissions?

- nearly 0.3 K at the residential districts
- nearly 0.5 K at the industrial sites
- metabolic heat considerably small
- expecting a smaller contribution to the urban heat island in summer time compared to the winter season

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Thank you for your attention

- UNFPA (2007), State of World Population 2007: Unleashing the Potential of Urban Growth, UNFPA, 108 pages
- Schlünzen, K. H., Flagg, D. D., Fock, B. H., Gierisch, A, ... (2012): Scientific Documentation of the Multicsale Model System M-SYS (METRAS, MITRAS, MECTM, MICTM, MESIM), Meteorologisches Institut der Universität Hamburg, MEMI Technical Report 4., 138 p
- Sailor, D.J. (2011): A review of methods for estimating anthropogenic heat and moisture emissions in the urban environment, International journal of Climatology, Vol. 31
- Quah and Roth (2012): Diurnal and weekly variation of anthropogenic heat emissions in a tropical city, Singapore Anthropogenic heat emissions, Atmospheric Environment, Vol. 46
- Ichinose et al. (1999): Impact of anthropogenic heat on urban climate in Tokyo, Atmospheric Environment, Vol. 33
- Sailor and Lu (2004): A top-down methodology for developing diurnal and seasonal anthropogenic heating profiles for urban areas, Atmospheric Environment, Vol. 38
- Kuenen et al. (2010): A Base Year (2005) MEGAPOLI European Gridded Emission Inventory (Final Version). Deliverable D1.6, MEGAPOLI Scientific Report 10-17, MEGAPOLI-20-REP-2010-10
- Allen and Grimmond (2011): Global to city scale urban anthropogenic heat flux: model and variability, International Journal of Climatology, Vol. 31





# LUCY vs. Snap based fluxes, State Hamburg

W/m <sup>2</sup>	Year	Summer	Winter
Total	8.8 (97)	11.8	7.8 (88) 12.0 9.5 (108) 12.7
Small cons.	3.6 (68)	2.6 (50)	4.6 (87)
Industry	2.5 (92)	2.4 (88)	2.5 (92) 12.2
Traffic	2.7 (33)	0.2	2.4 (29) 0.2

## Understanding the differences

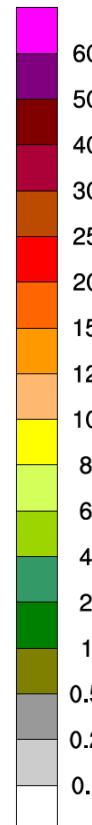
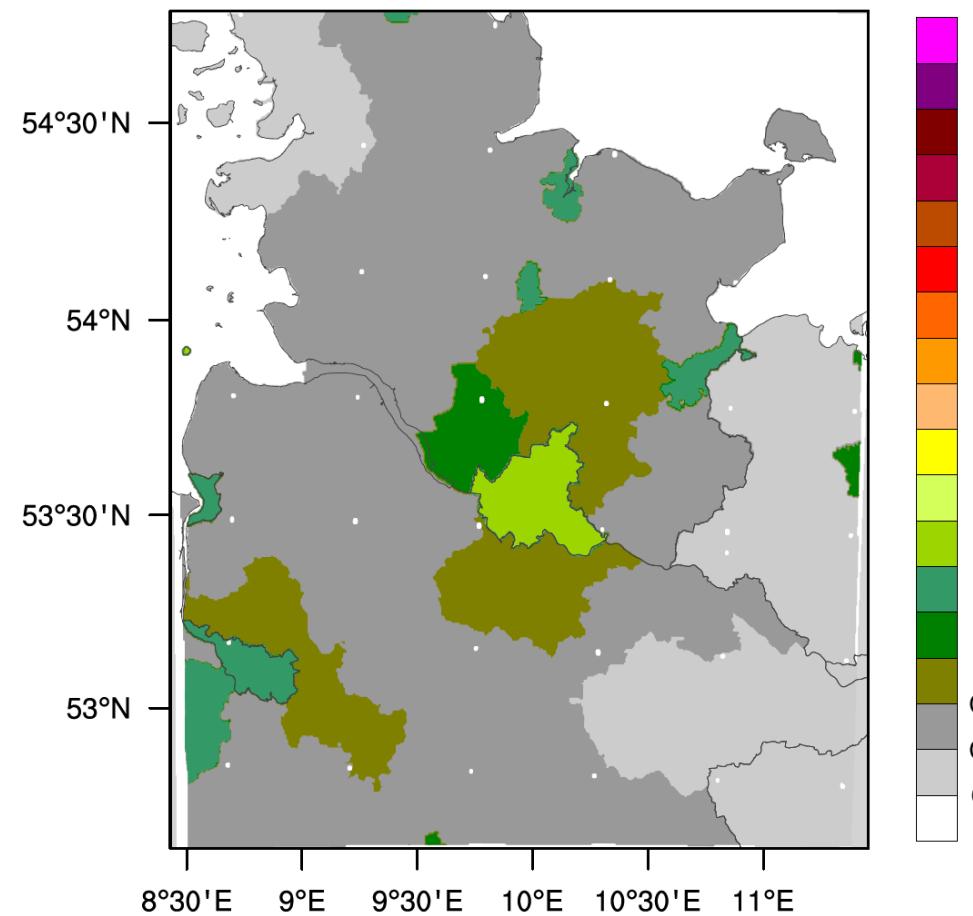
2009	LUCY	SNAP based
EC Germany	15.1 Mio. TJ	13.5 Mio. TJ
EC per person, Hamburg	167 GJ	128 GJ

# Anthropogenic heat forcing in Northern Germany - 15th of August, 00 LT

LUCY

anthropogenic heat flux

W m<sup>-2</sup>



# Determination of anthropogenic heat

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Indirect measurement  
(budget closure concepts)  
(Quah and Roth, 2012 and  
Zhang 2013)

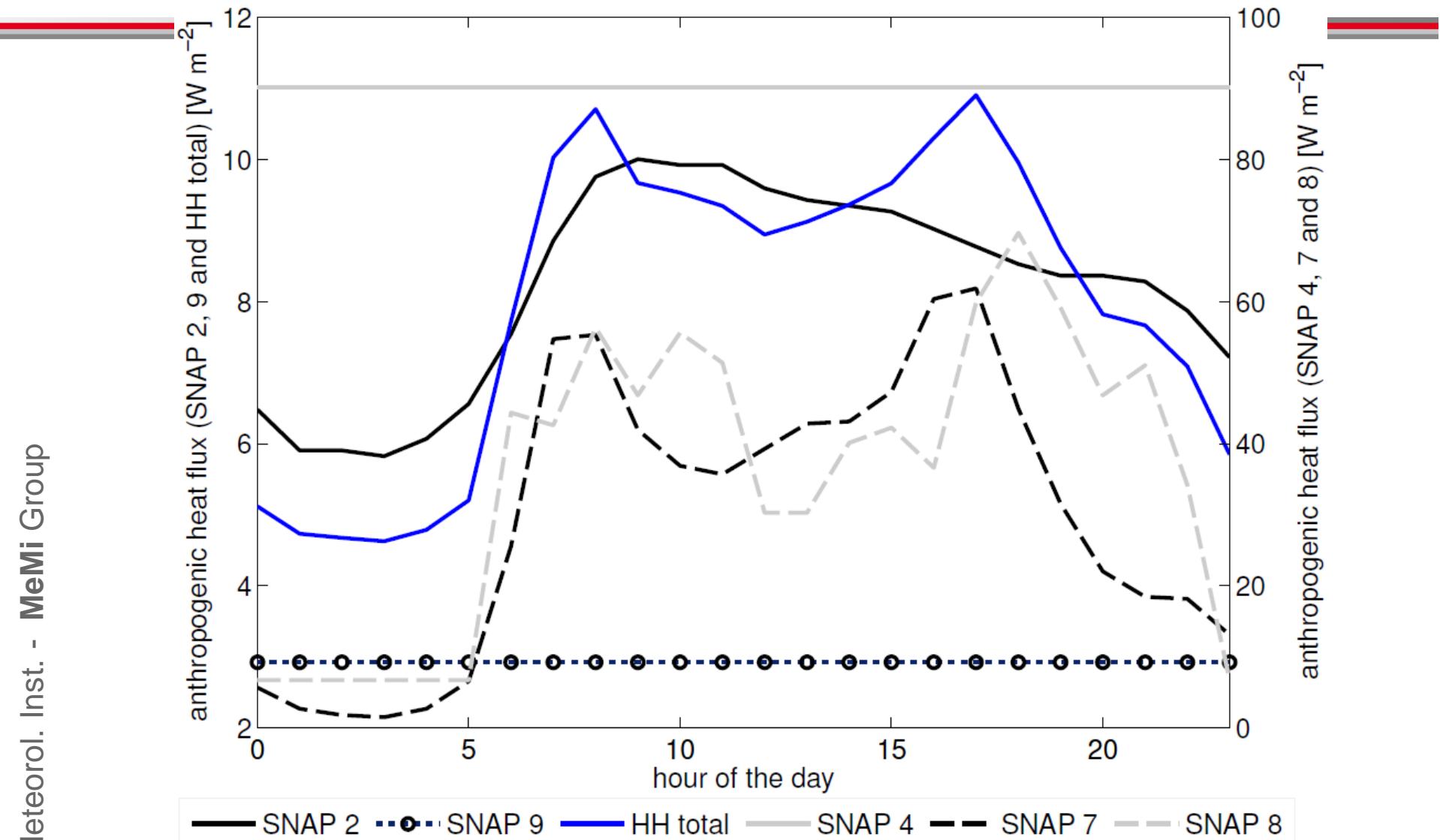


Energy building  
models (Sailor, 2011)



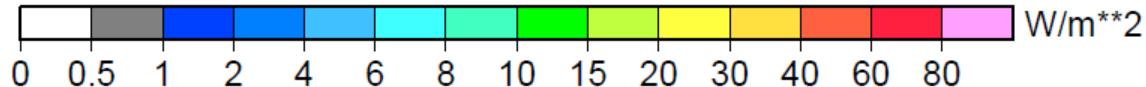
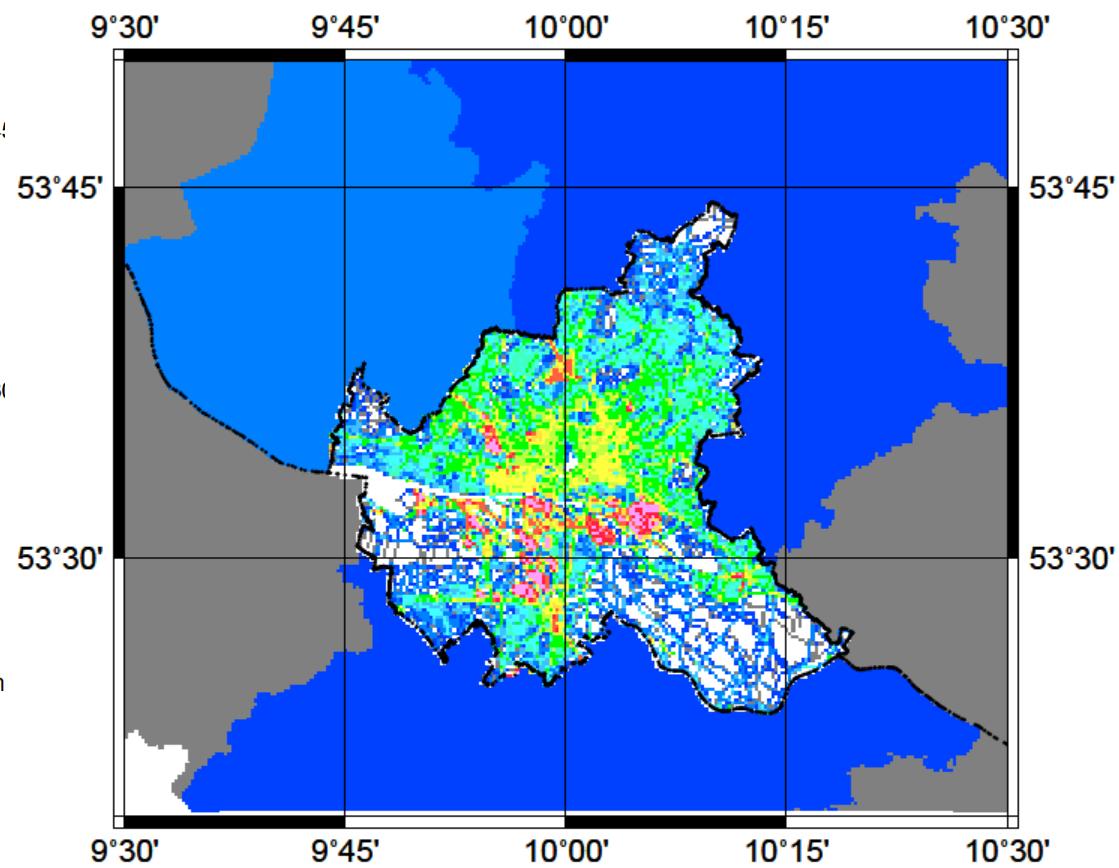
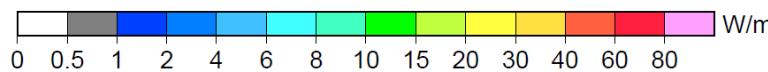
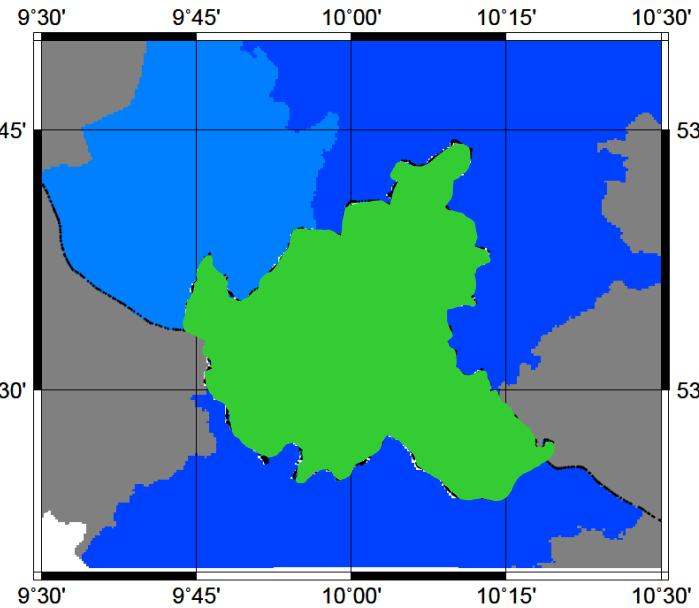
Inventory approaches  
(Sailor and Lu, 2004)

# Area-averaged anthropogenic heat flux at Hamburg for the summer season



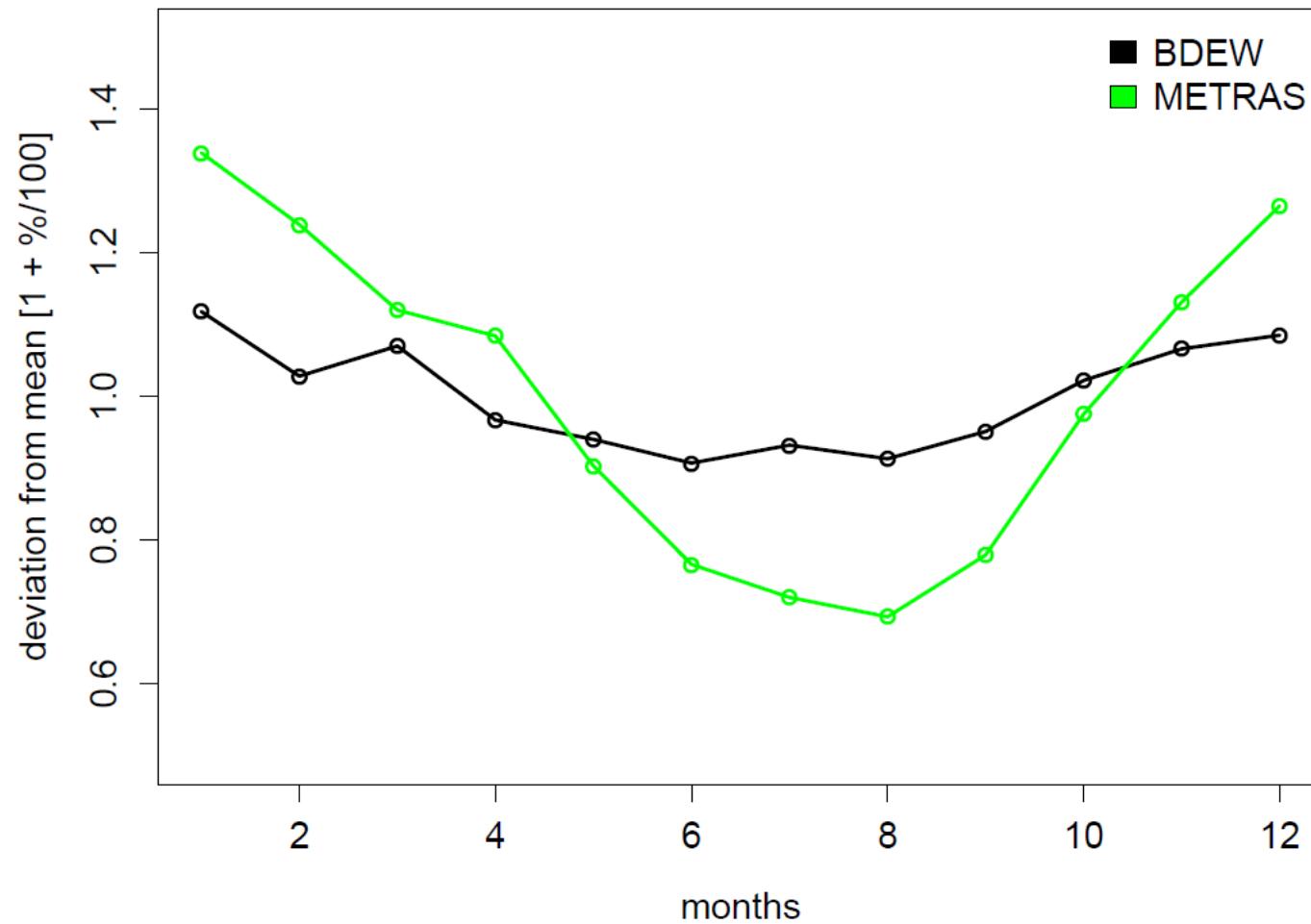
mean value of  $8 \text{ W/m}^2$  in summer (LUCY data base:  $10 \text{ W / m}^2$ , Allen et al. (2013))  
ICUC 2015

# Anthropogenic heat fluxes for Hamburg - 15th of August, 08 LST



# Evaluation time functions

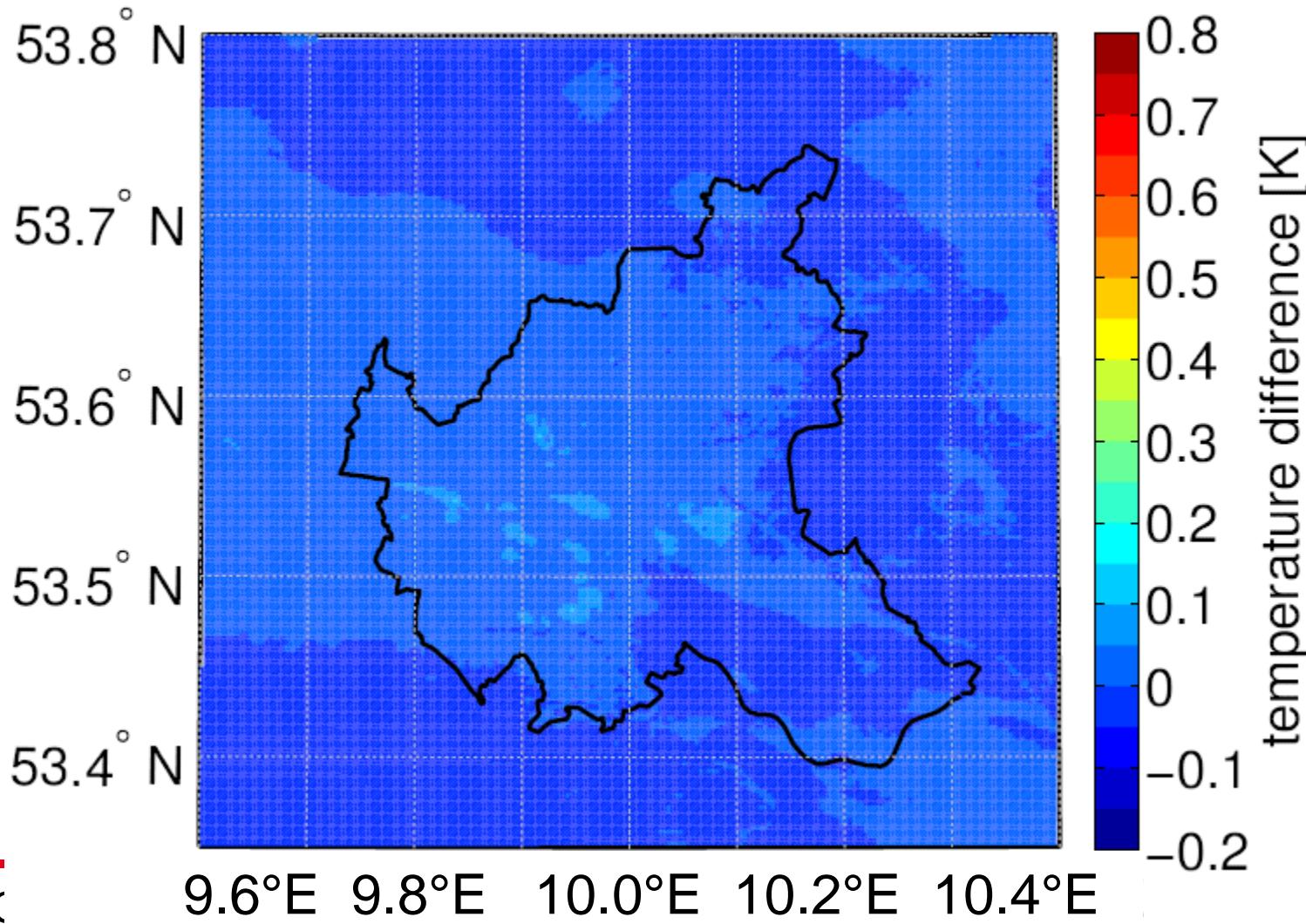
energy consumption in SNAP class 2 for single months



# Impact of anthropogenic heat I

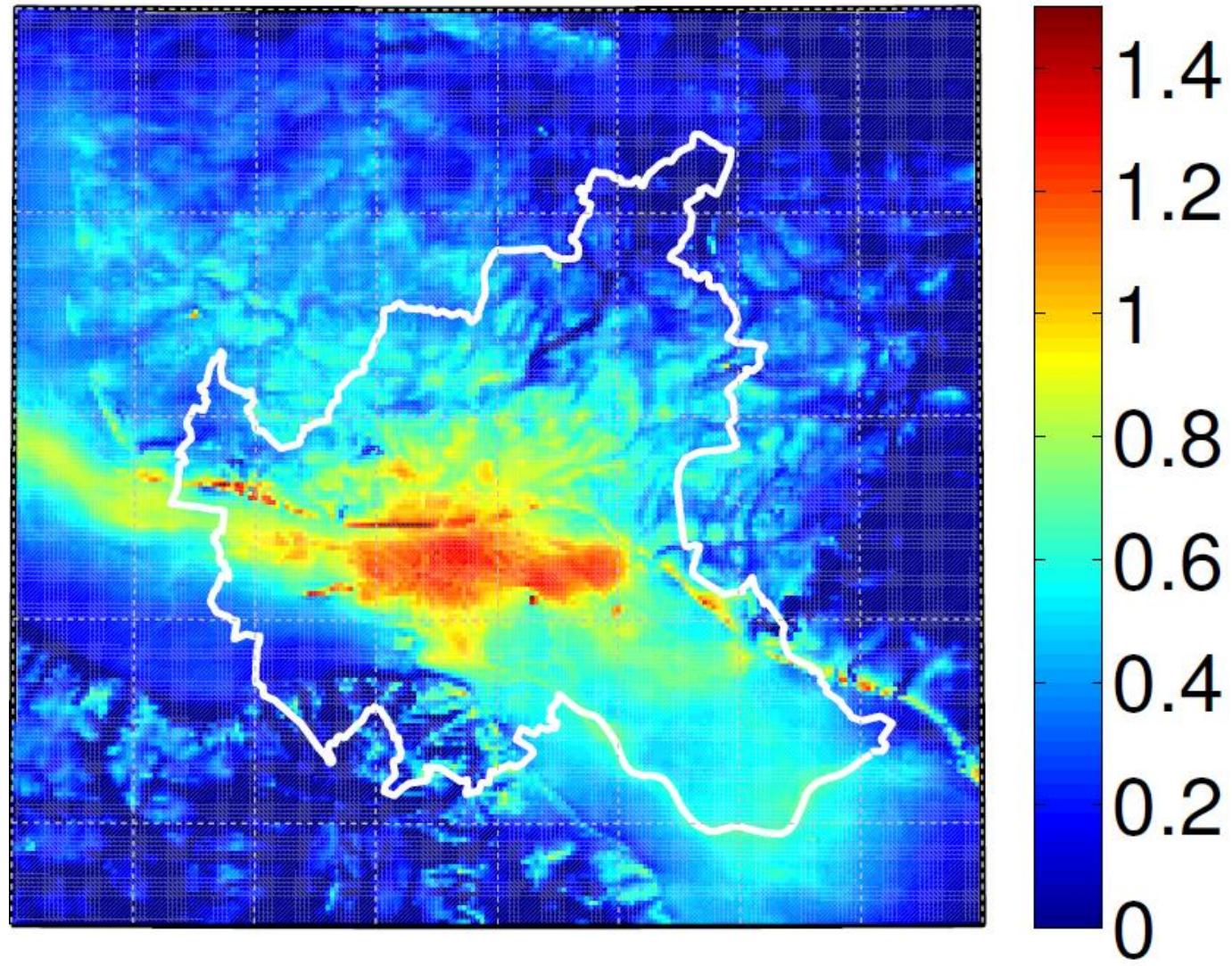
mean impact of anthropogenic heat on 10 m temperature during day-time

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# Urban heat island with anthropogenic heat [K]



# Urban heat island without anthropogenic heat [K]

