Evaluating three urban canopy models against in-situ observations for a heat-wave case in Amsterdam

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Introduction

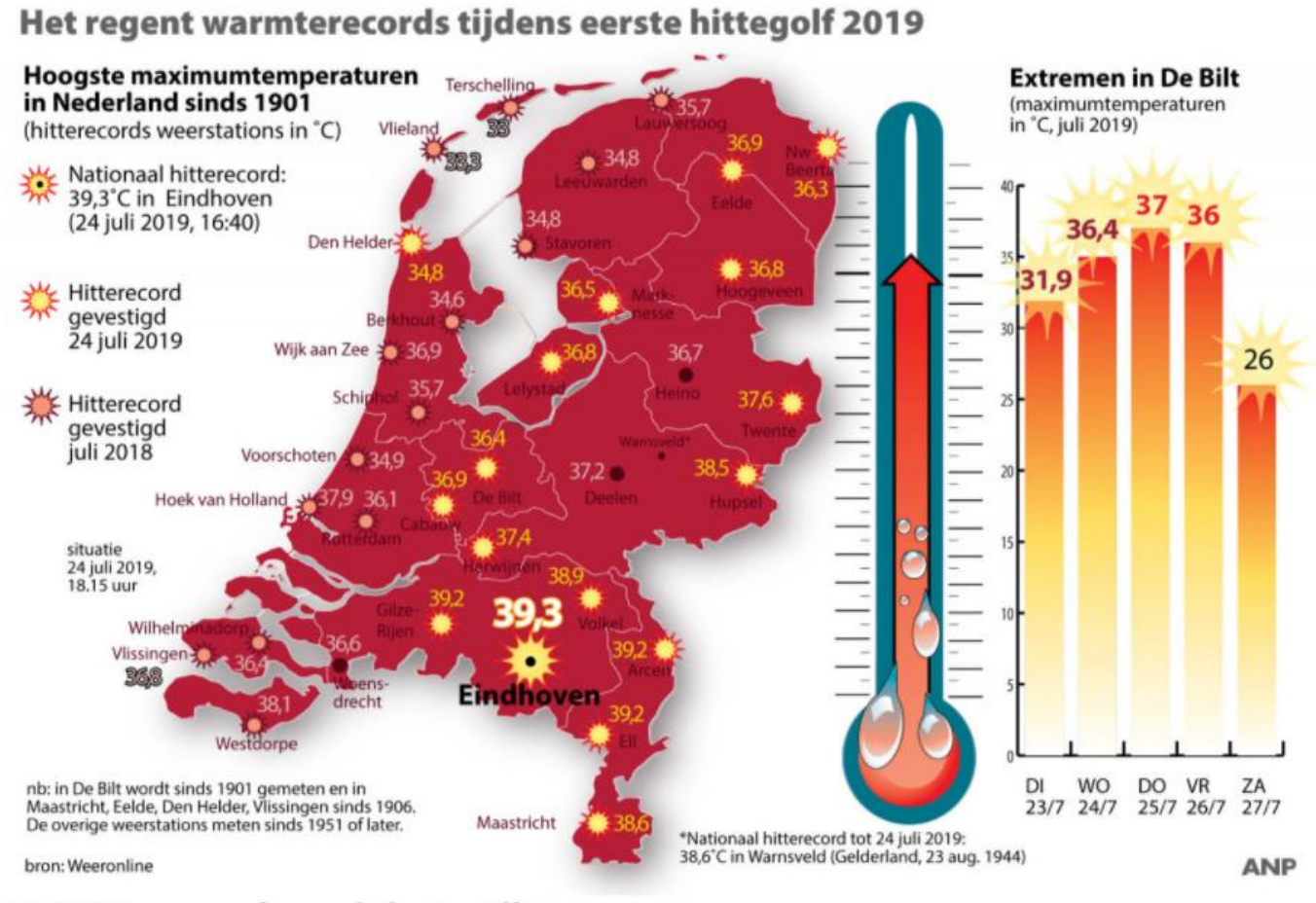
Introduction

WETENSCHAP - 24 JULI 2019

Weerballonnen brengen Amsterdamse stadsklimaat in kaart

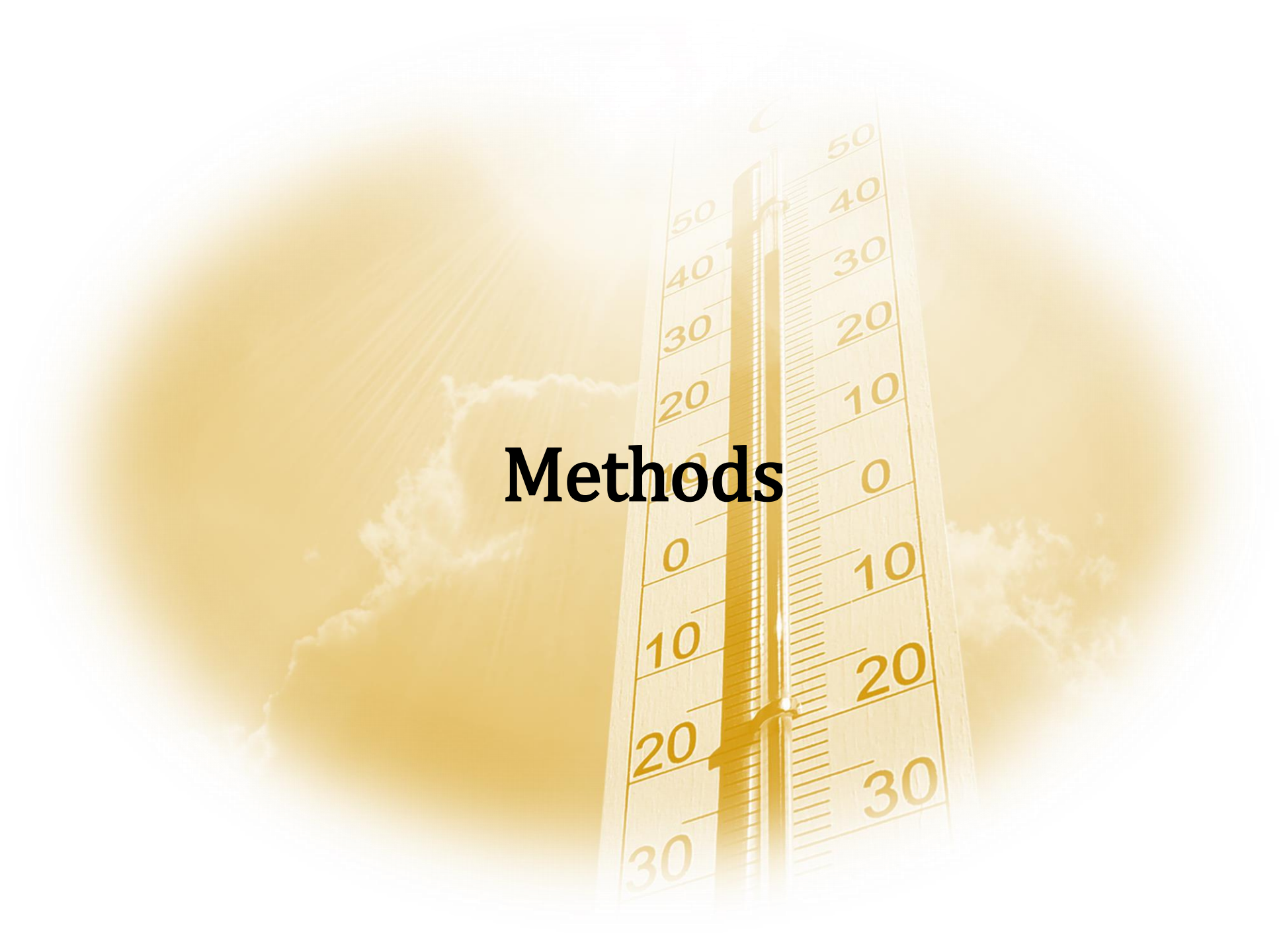
tekst: Tessa Louwerens

Om het stadsklimaat beter te begrijpen en voorspellen, lieten onderzoekers van WUR samen met het Amsterdam Institute for Metropolitan Solutions woensdag 24 juni weerballonnen op vanaf onder meer de Dam in Amsterdam. Een uniek experiment: de laatste keer dat er verticale waarnemingen zijn verzameld was met een helikopter, meer dan vijftig jaar geleden in New York.



Research questions

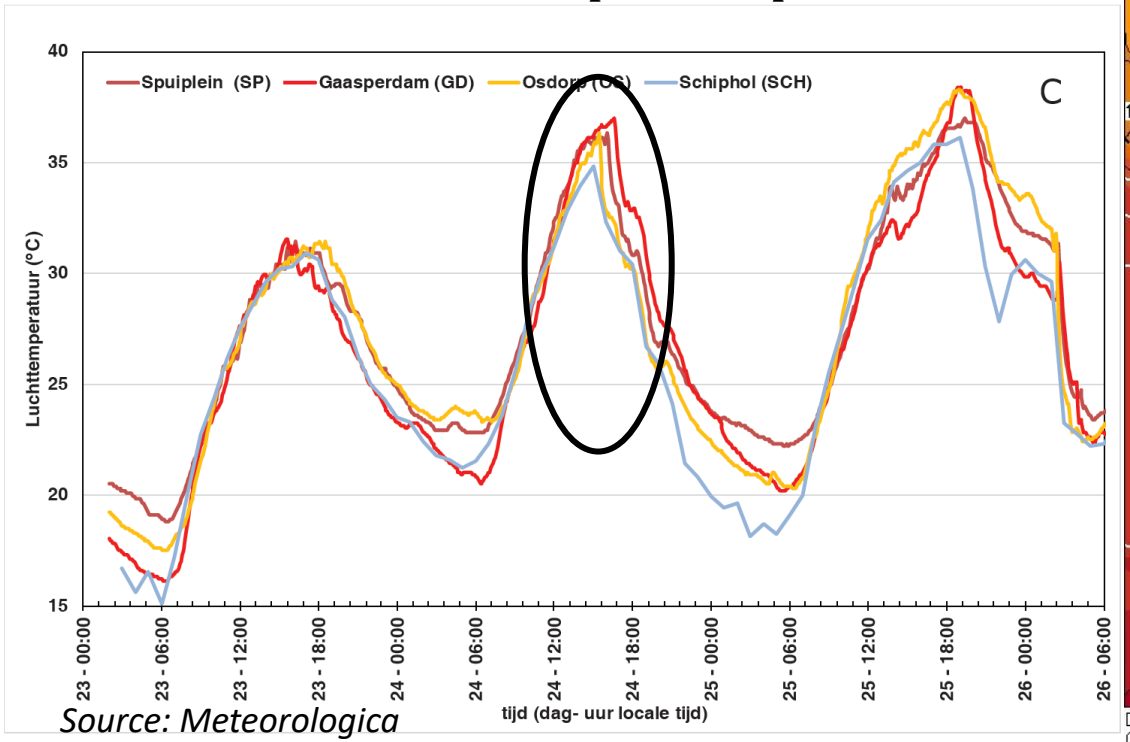
1. Is WRF able to simulate the UHI for 24 July 2019 considering at least one of the three urban physics schemes (SLUCM, BEP or BEPBEM)?
2. How will affect air conditioning systems the temperature and energy use within the city of Amsterdam?
3. How will the UHI and energy use change in 2050 according to the KNMI climate projections?



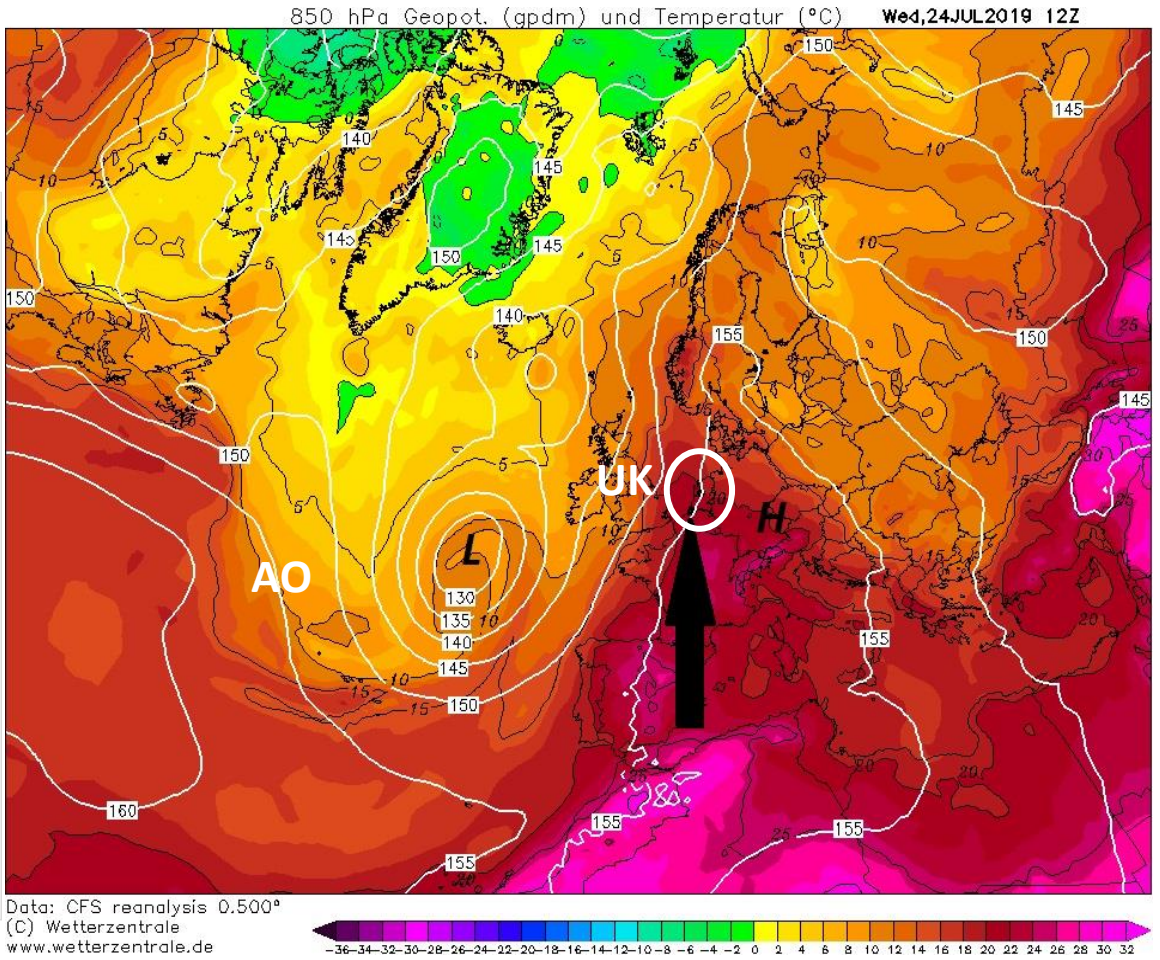
Methods

Study area and weather overview

- Focus: Amsterdam – 24 July 2019
- Synoptics
- 35.7 ºC at KNMI Schiphol Airport

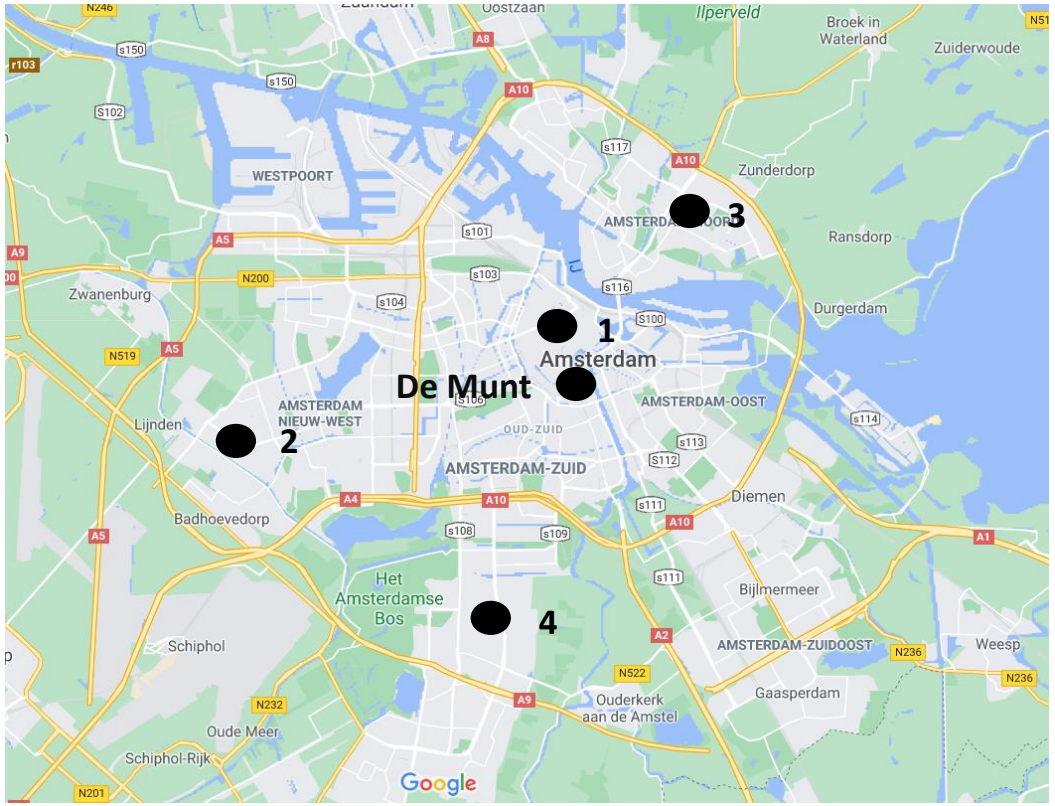


Source: Meteorologica



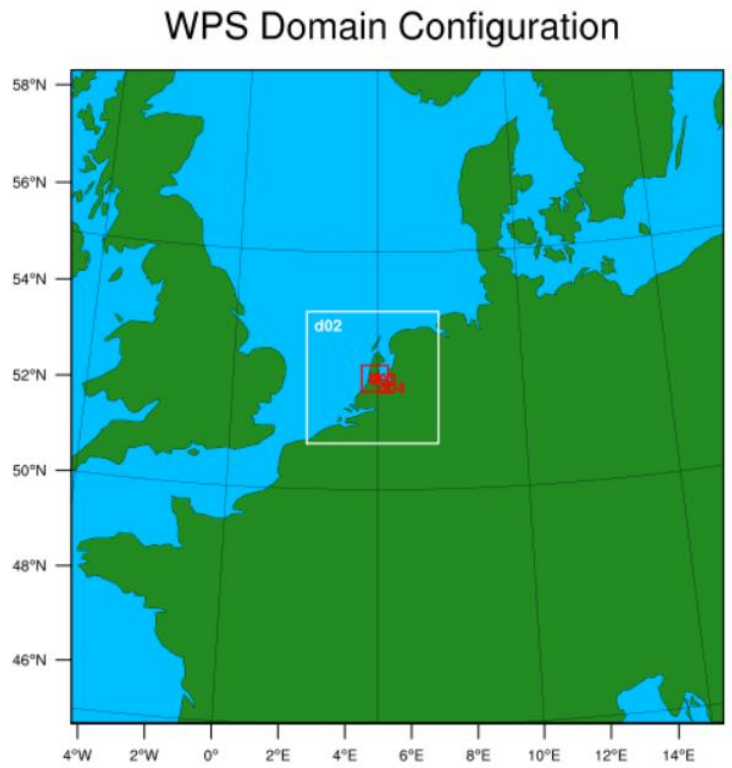
Measurement sites

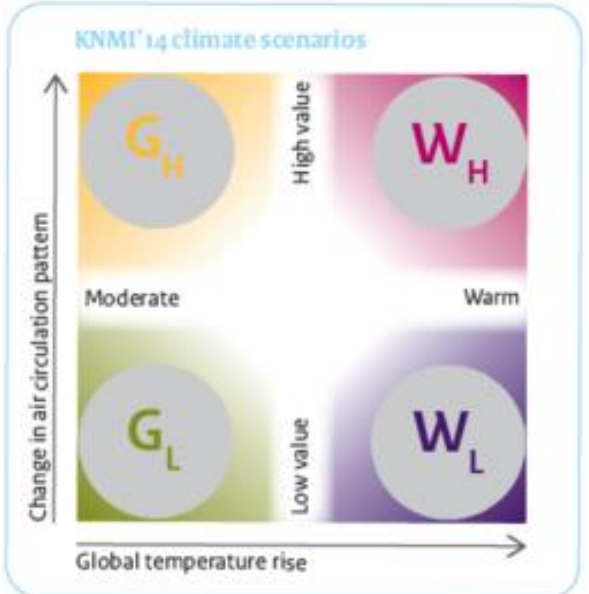
- 4 locations: Temperature
- De Munt: Atmospheric fluxes (H, LvE) measured using Eddy covariance
- Unique measurement campaign performed by the WUR
- Radiosondes at De Dam (loc: 1)



Research set-up

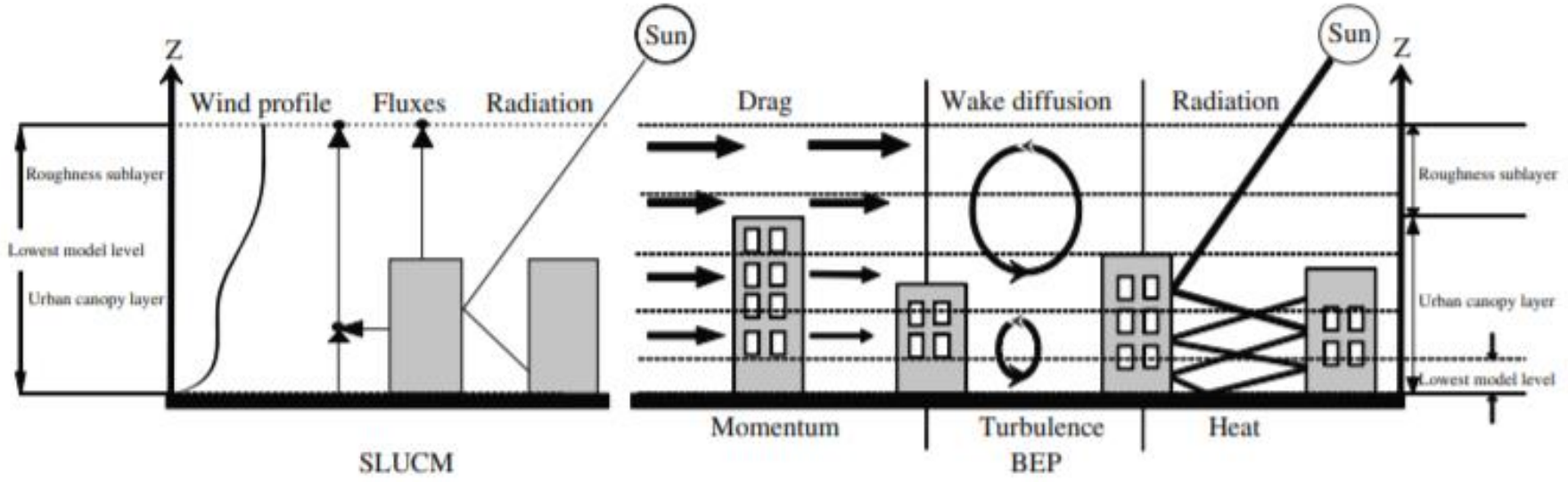
- WRF
- 4 domains (12.5 km, 2.5 km, 0.5 km, 0.1 km)
- Unique resolution
- 72 vertical layers
- Ronda et al. (2017)
- Perform 3 runs to determine which urban physics scheme is the best
- Perform additional 4 runs for each KNMI climate scenario with the best urban physics scheme
- GL (moderate low) , GH (moderate high)
  WL (warm low) , WH(warm high)





SLUCM/BEP/BEPBEM

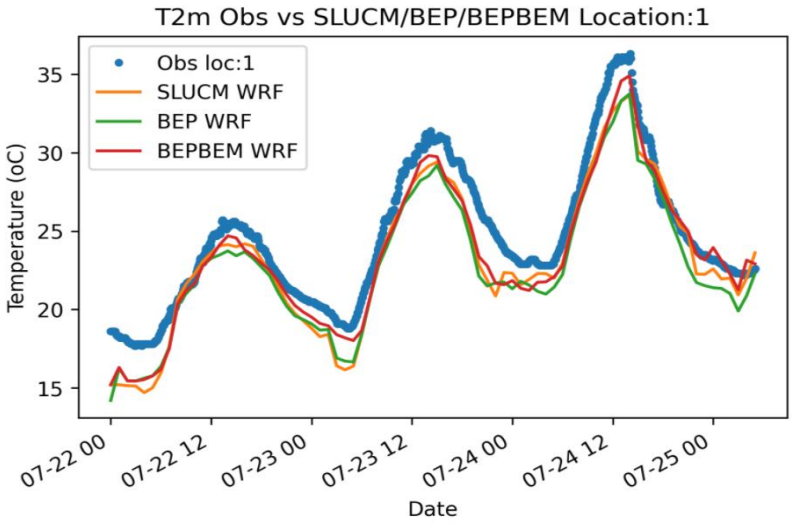
- **Three different parameterization schemes used:**
- Single Layer Urban Canopy Model (SLUCM)
- Building Energy Paramerization (BEP)
- Building Energy Paramerization + Building Energy Model (BEPBEM)

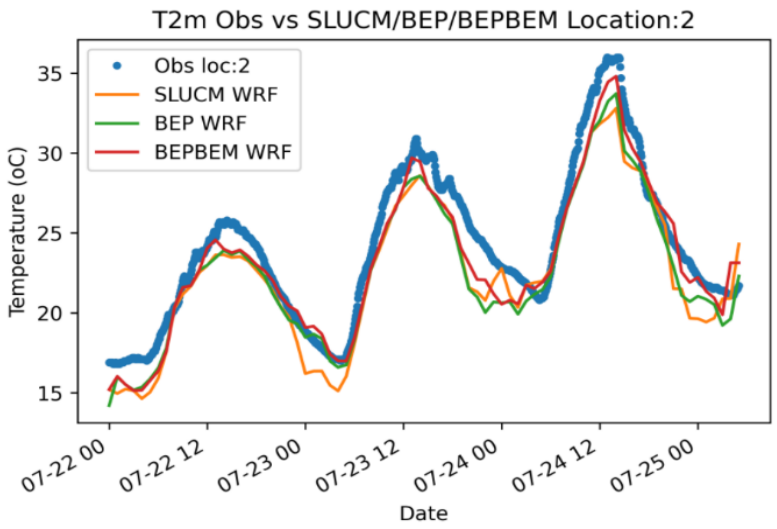


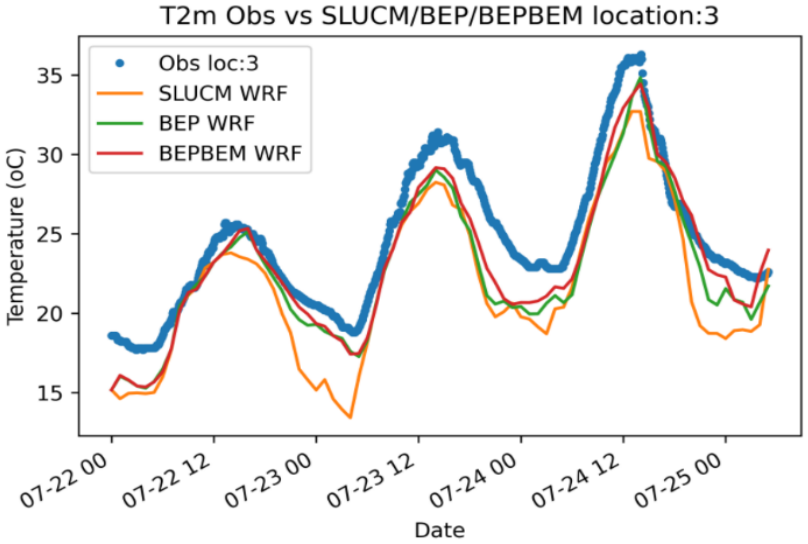
Results Research Question 1

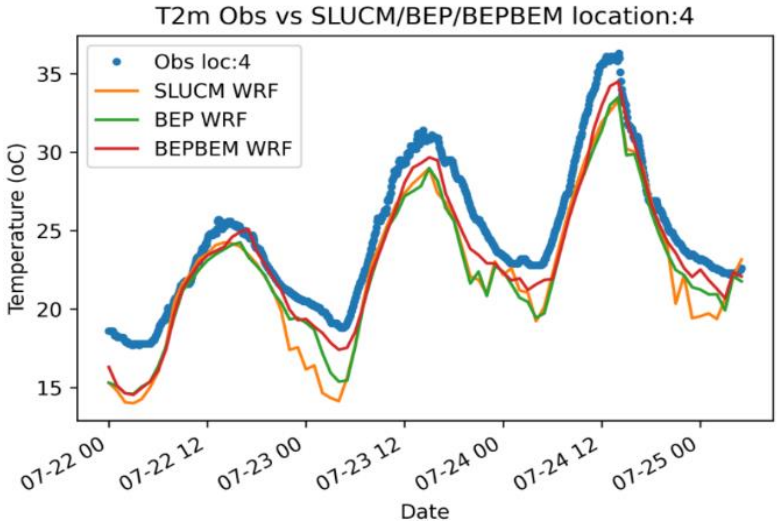
Is WRF able to simulate the UHI for 24 July 2019 considering at least one of the three urban physics schemes (SLUCM, BEP or BEPBEM)?

2m Temperature validation



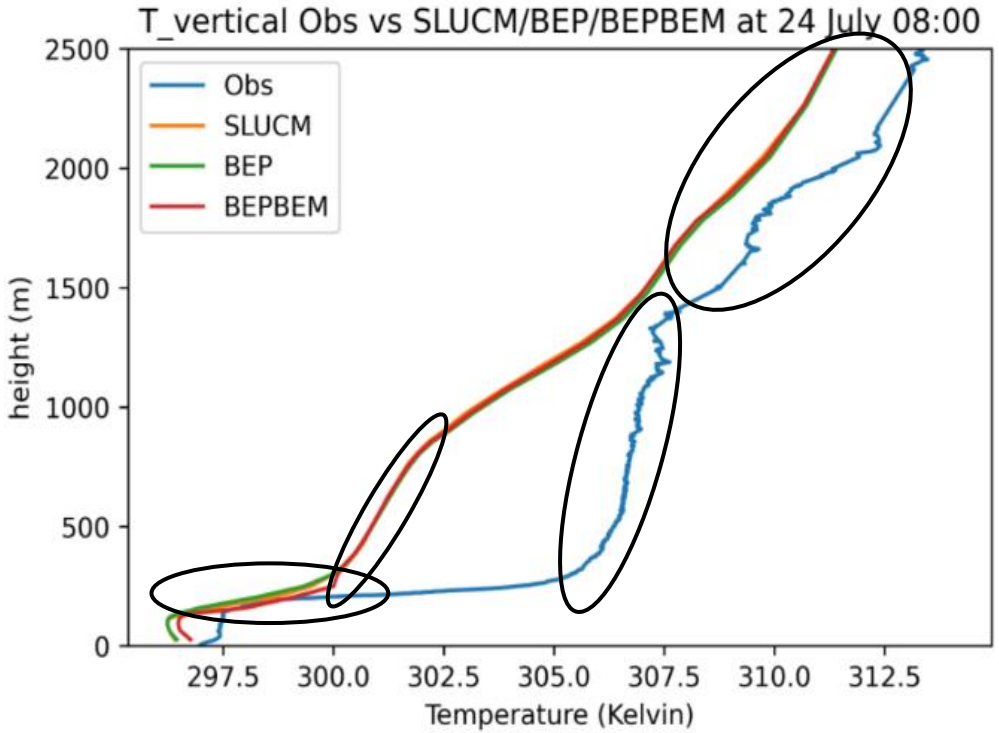


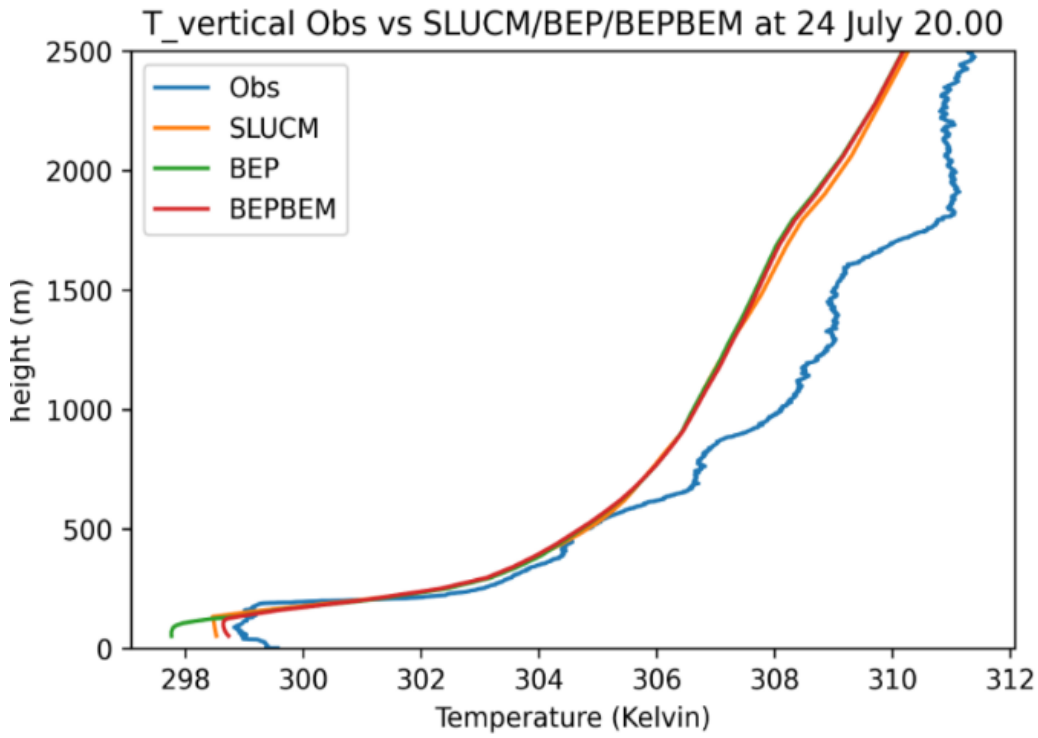




RMSE = 1.5K MB = -0.6K

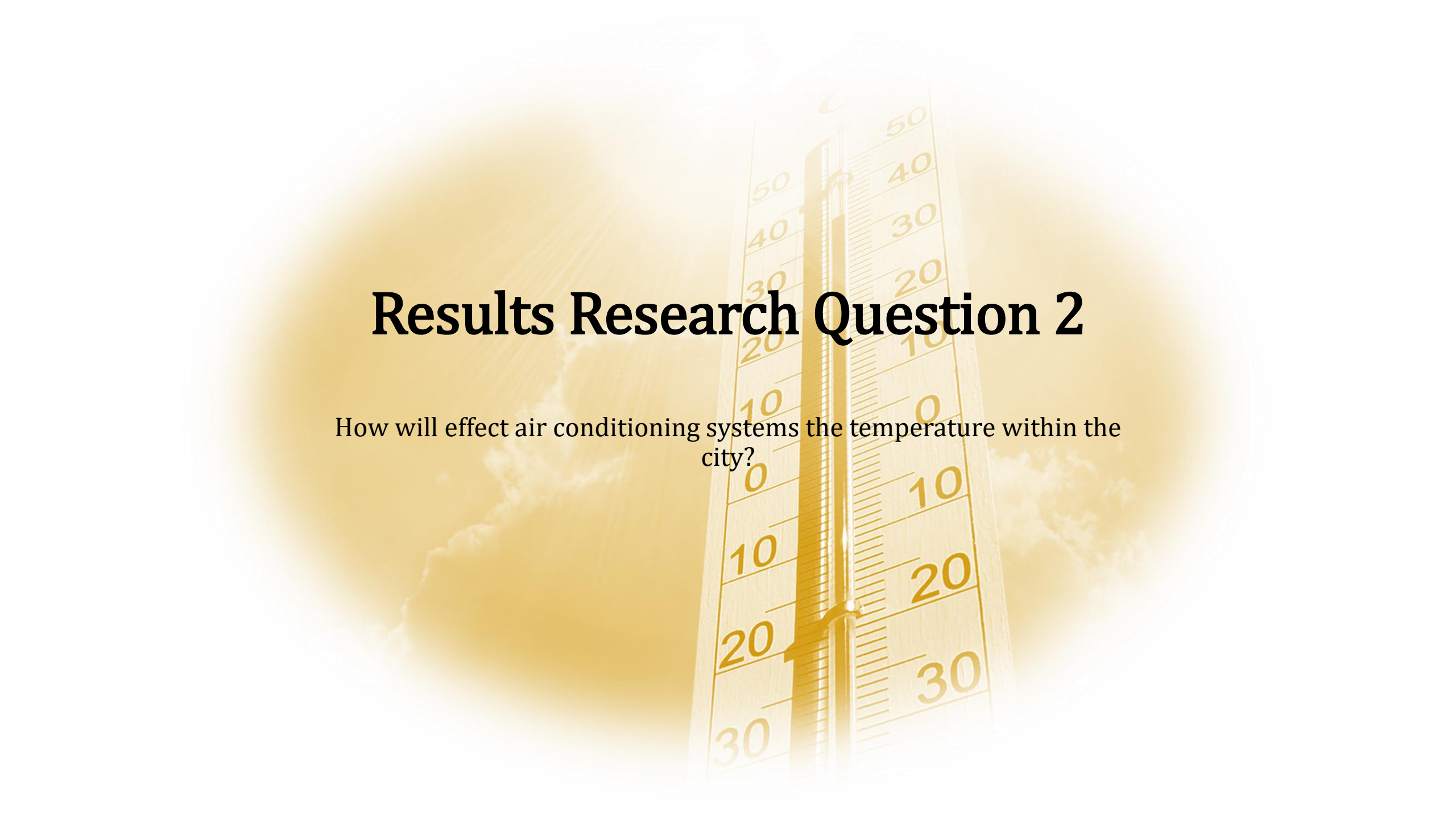
Vertical temperature validation



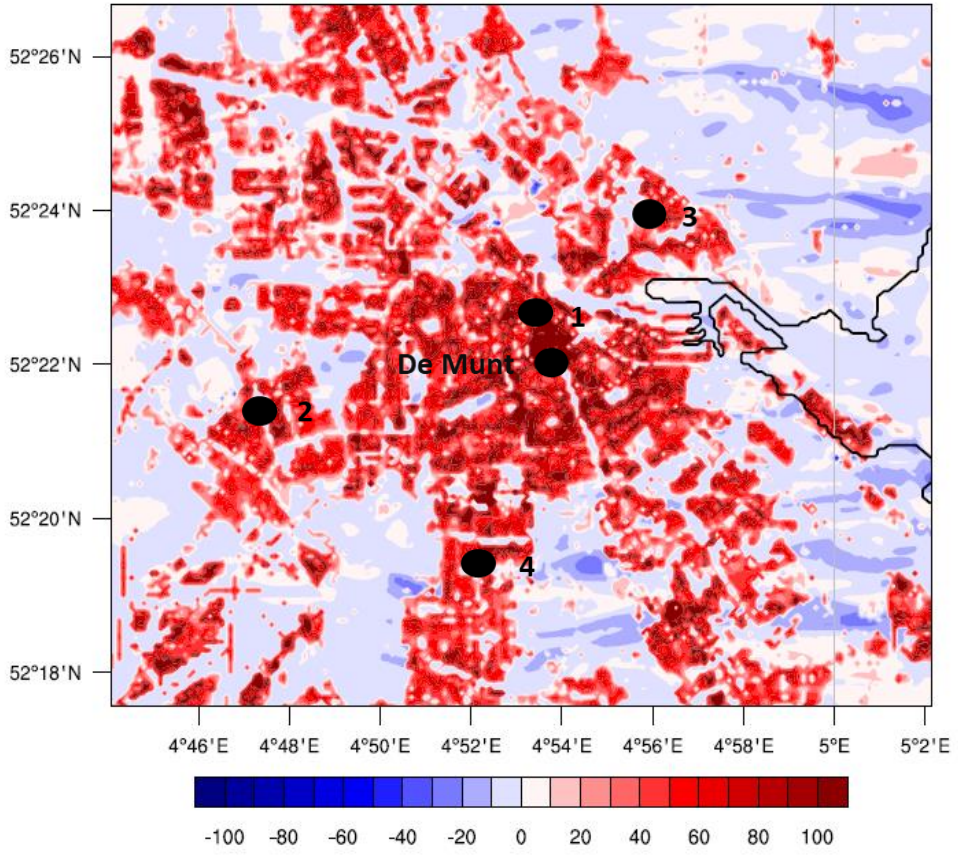


Results Research Question 2

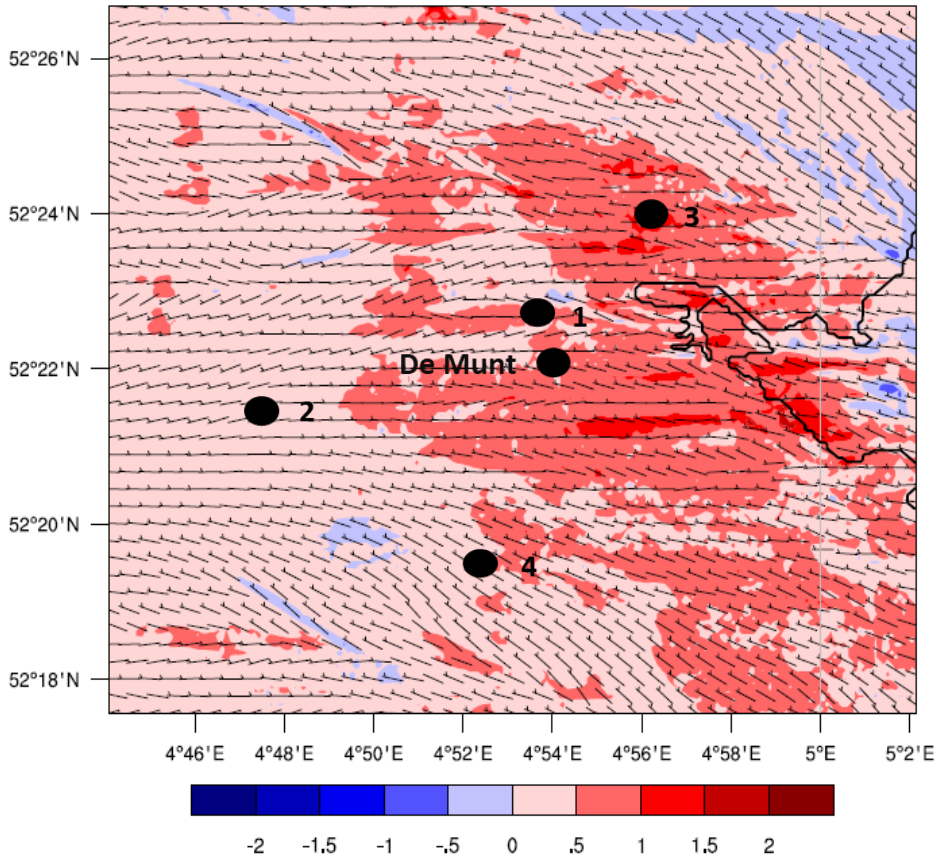
How will effect air conditioning systems the temperature within the city?



Effect of AC systems (day time)

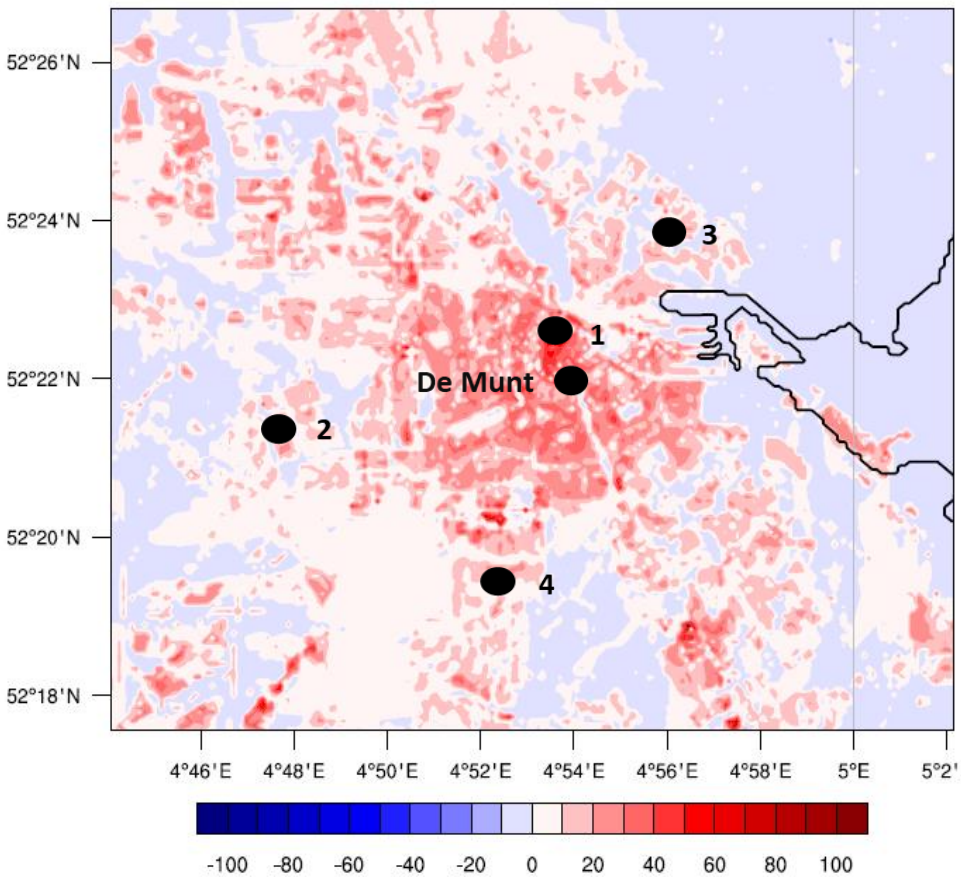


Surface sensible heat flux difference in W/m2
BEPBEM - BEP

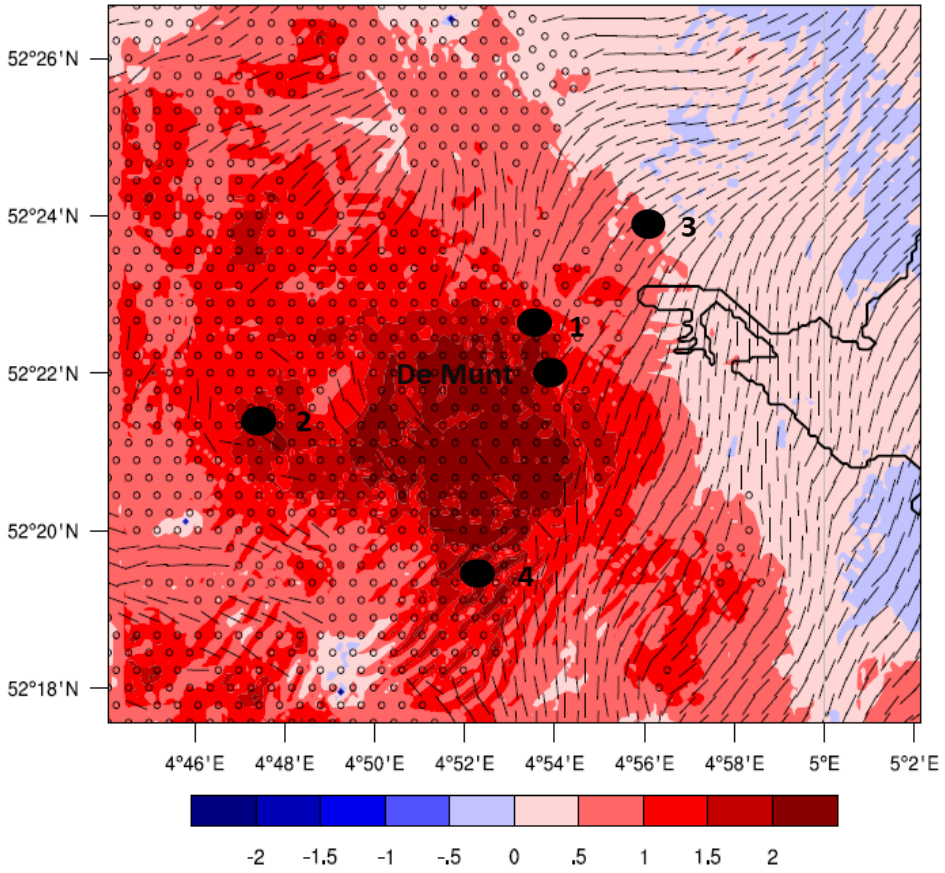


Temperature difference in degrees Celsius
BEPBEM - BEP

Effect of AC systems (night time)

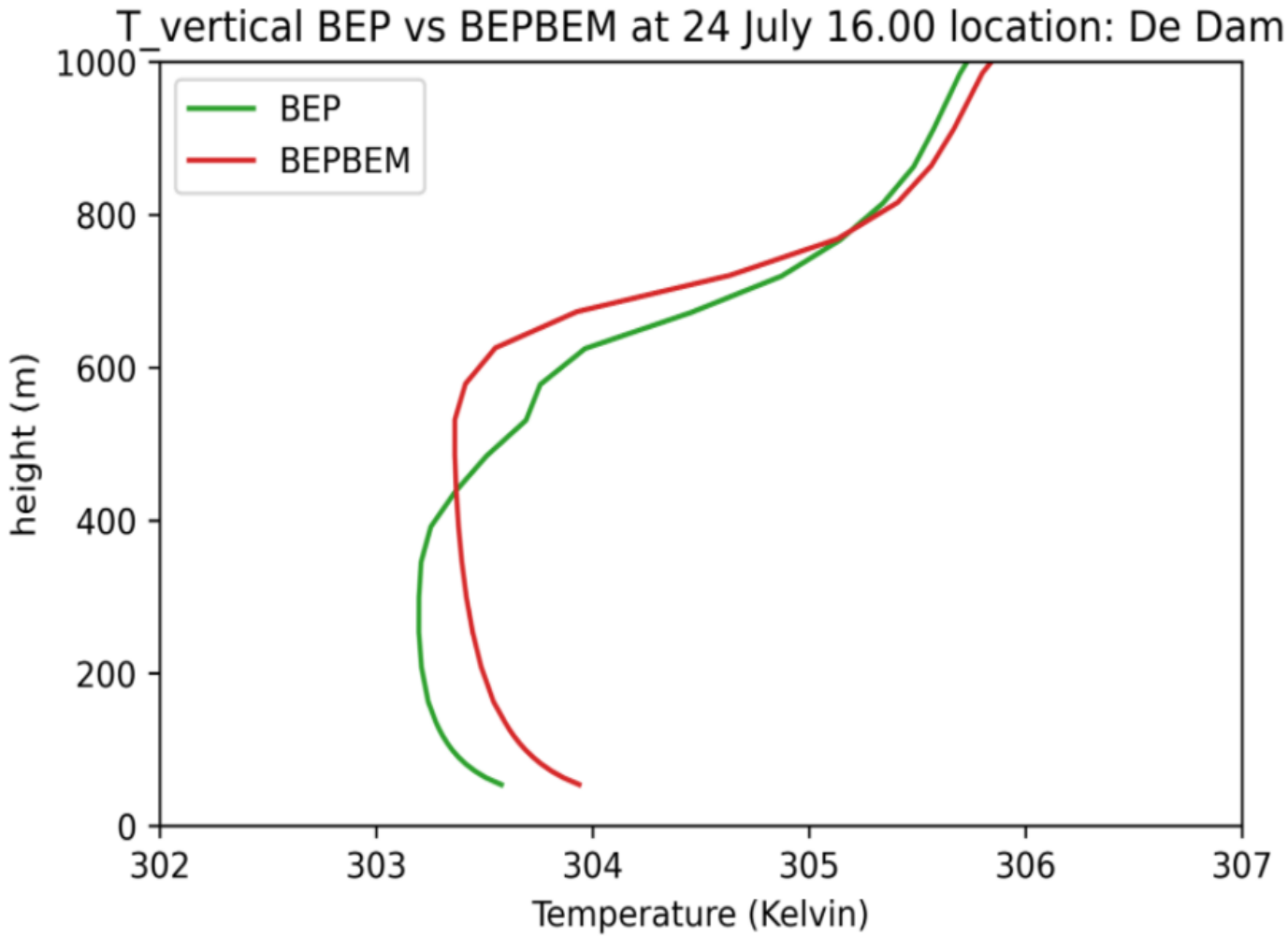


Surface sensible heat flux difference in W/m2
BEPBEM - BEP



Temperature difference in degrees Celsius
BEPBEM - BEP

Effect of AC systems in vertical direction

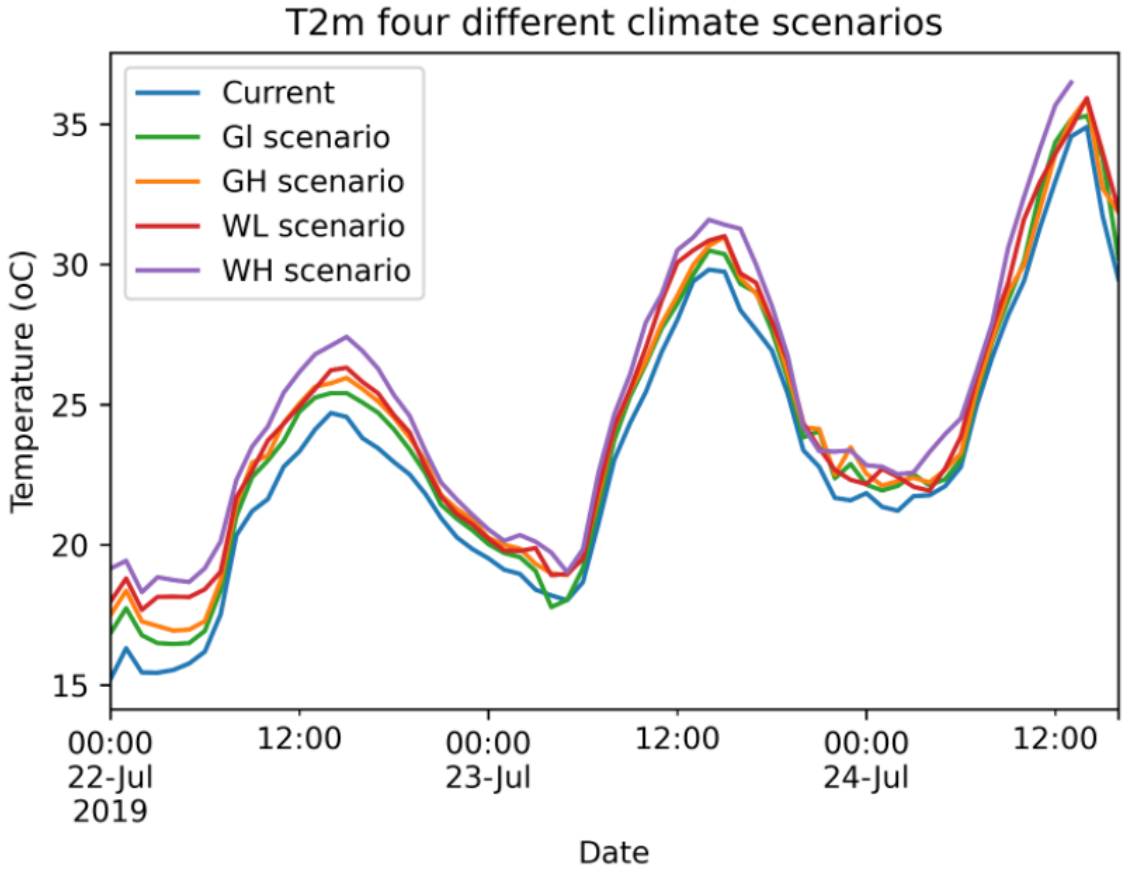


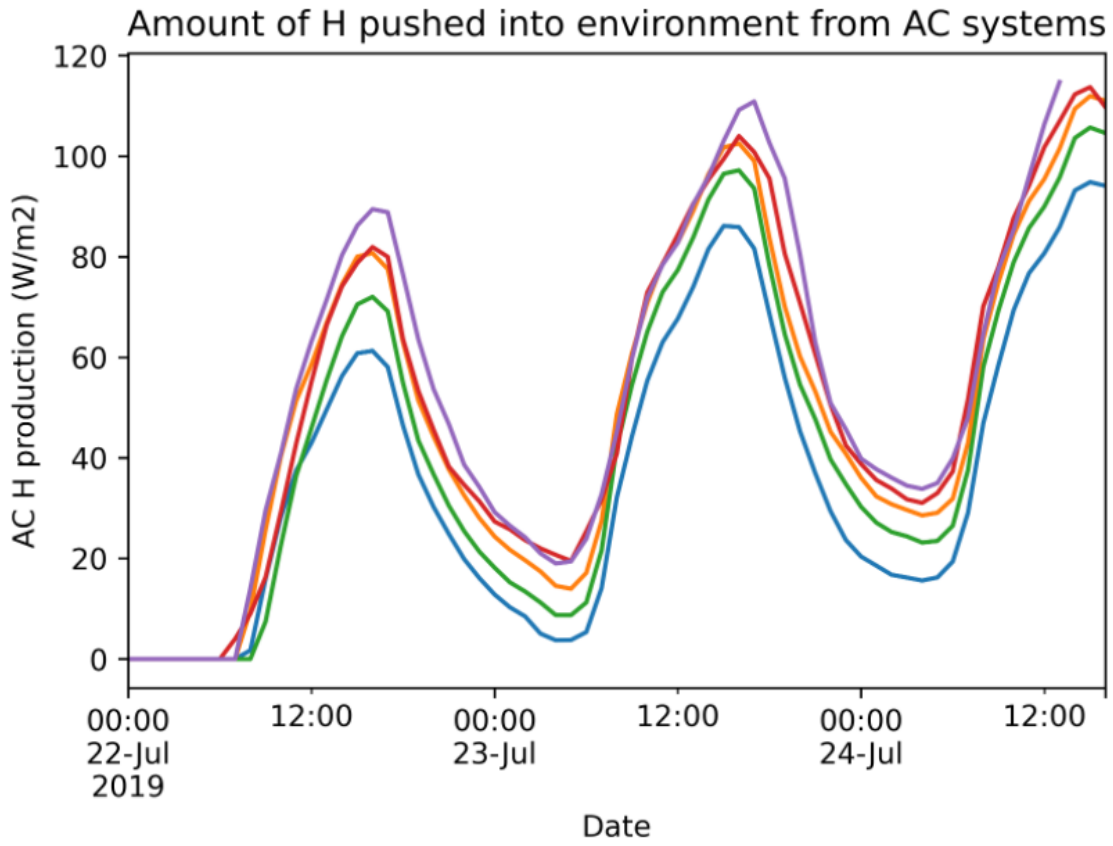
Results Research Question 3

How will the UHI change in future climate projections in 2050, according to the urban physics scheme which is able to simulate the atmospheric conditions best on the 24th of July 2019?

Climate projections

1.1K +/- 0.2K **1.5K +/- 0.2K** **2.1K +/- 0.4K** **2.9K +/- 0.6K**





Conclusions

Conclusions

- *Is WRF able to simulate the UHI for 24 July 2019 considering at least one of the three urban physics schemes (SLUCM, BEP or BEPBEM)?*

Yes, BEPBEM performs best according to observations (RMSE = 1.5K MB = -0.6K)

- *How will affect air conditioning systems the temperature and energy use within the city of Amsterdam?*

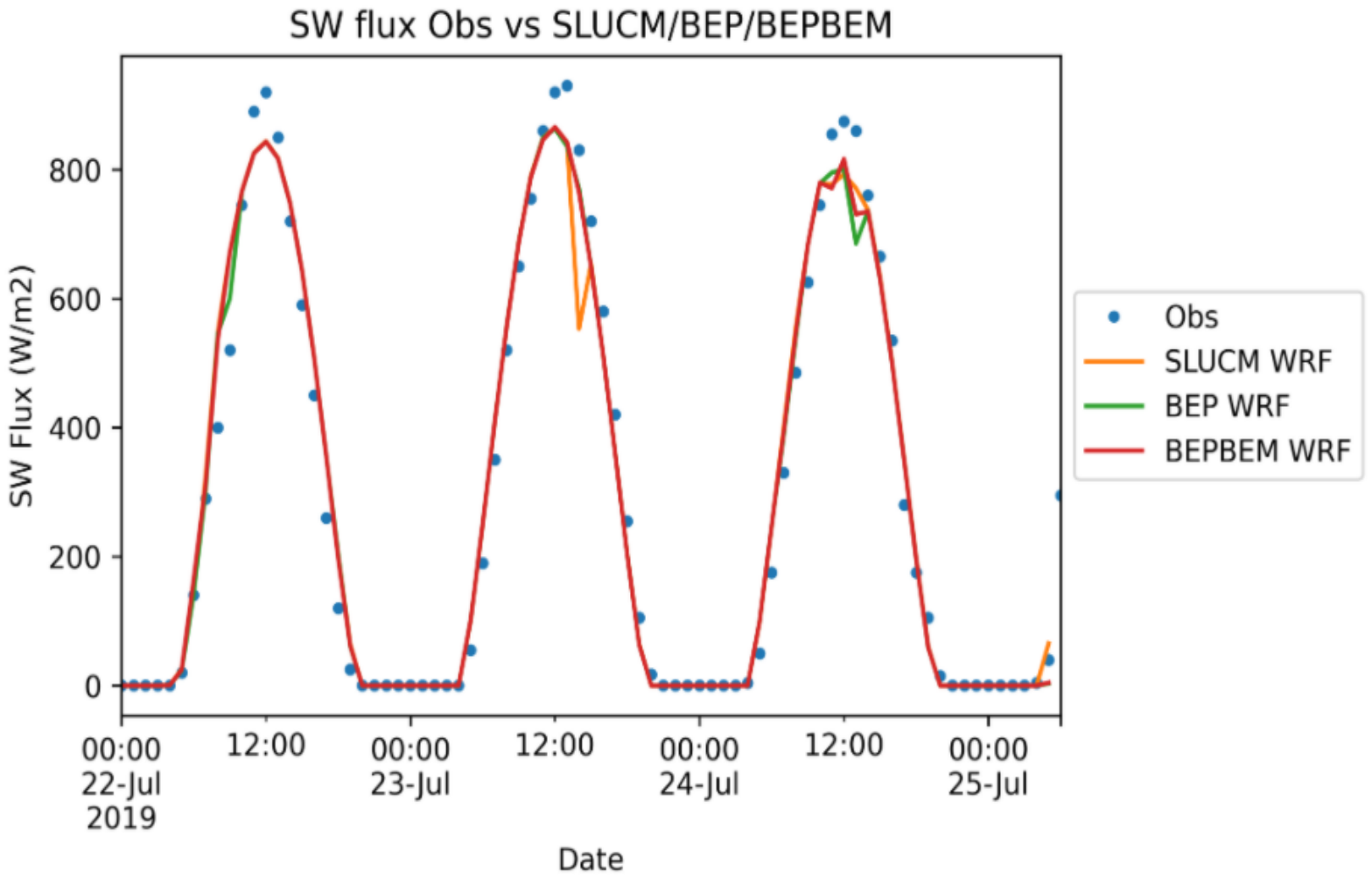
Temperature increase of 0.5-1K during daytime and 1-2.5K during night time up to 450 meters height

How will the UHI and energy use change in 2050 according to the KNMI climate projections?

	Average temperature increase during simulation period:	H increase due to AC systems:
GL-scenario:	1.1K +/- 0.2K	90 + 9 W/m2
GH-scenario:	1.5K +/- 0.2K	90 + 14 W/m2
WL-scenario:	2.1K +/- 0.4K	90 + 18 W/m2
WH-scenario:	2.9K +/- 0.6K	90 + 22 W/m2

Additional Material

Evaluation solar radiation



Formulation BEP scheme

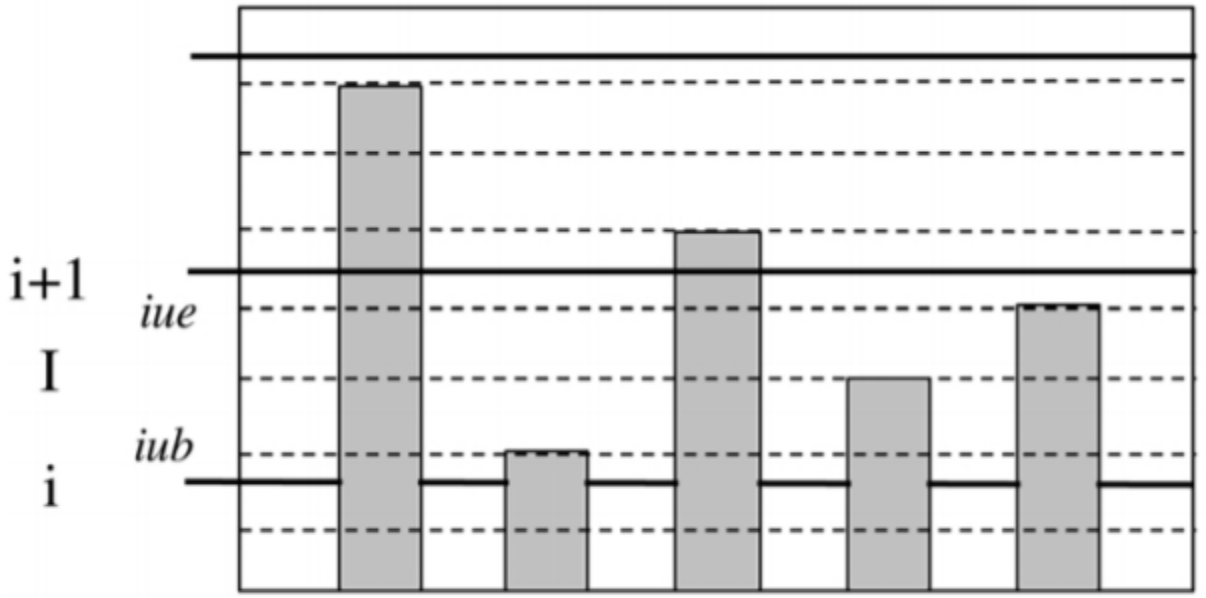


Figure 2. Representation of the connection between the urban module grid (dashed levels) and the mesoscale model grid (solid levels). *iub* and *iue* are the lowest and the highest urban model levels in the mesoscale level *I*.

Source: (Martilli et al., 2002)

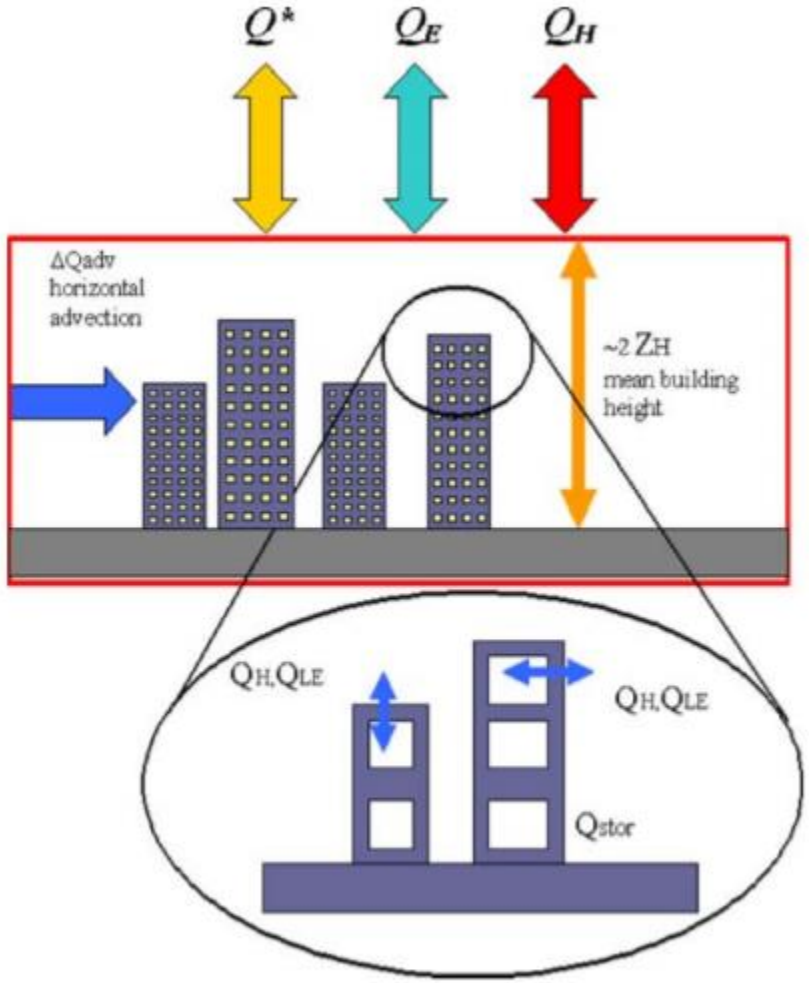


Fig. 1 Schematic picture of the heat fluxes considered in an urban environment

Source: (Salamance & Martilli 2010)

Temperature projections for 2050

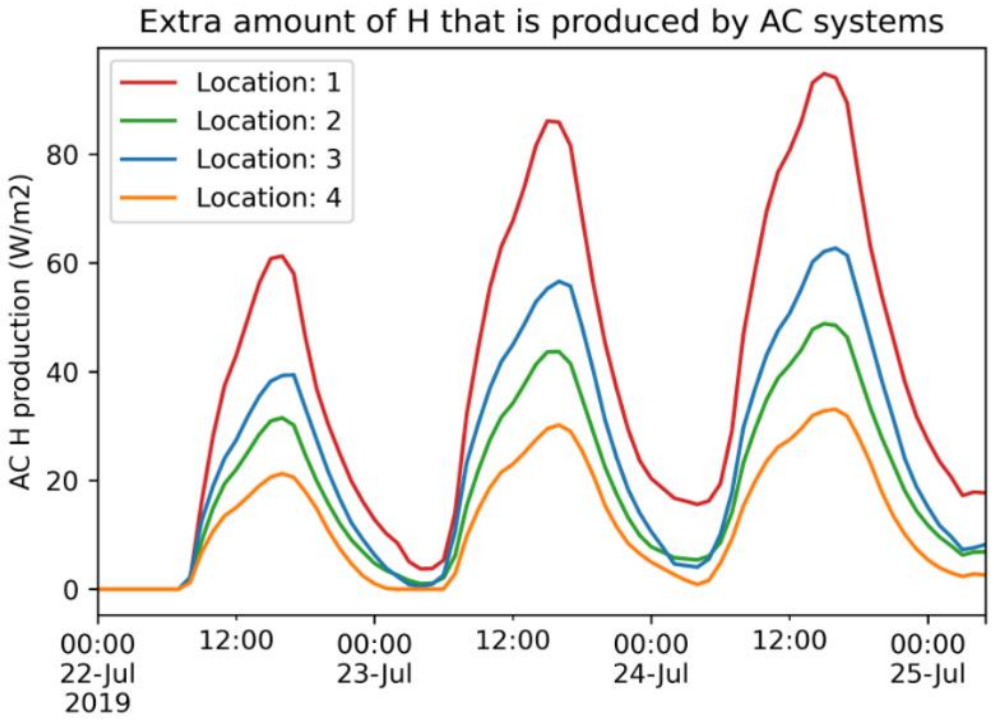
	T_gem	27.6						
	T(95)	19.9						
	T(99)	23.4						
	Gl		Gh		Wl		Wh	
	0.95	1.3	0.95	1.9	0.95	1.9	0.95	3
	0.99	1.4	0.99	2	0.99	2.2	0.99	3.3
Tf(95)	21.2		21.8		21.8		22.9	
Tf(99)	24.8		25.4		25.6		26.7	
a4	1.028571		1.028571		1.085714		1.085714	
b4	0.731429		1.331429		0.194286		1.294286	
TG_2050	29.12		29.72		30.16		31.26	
DT	1.52		2.12		2.56		3.66	

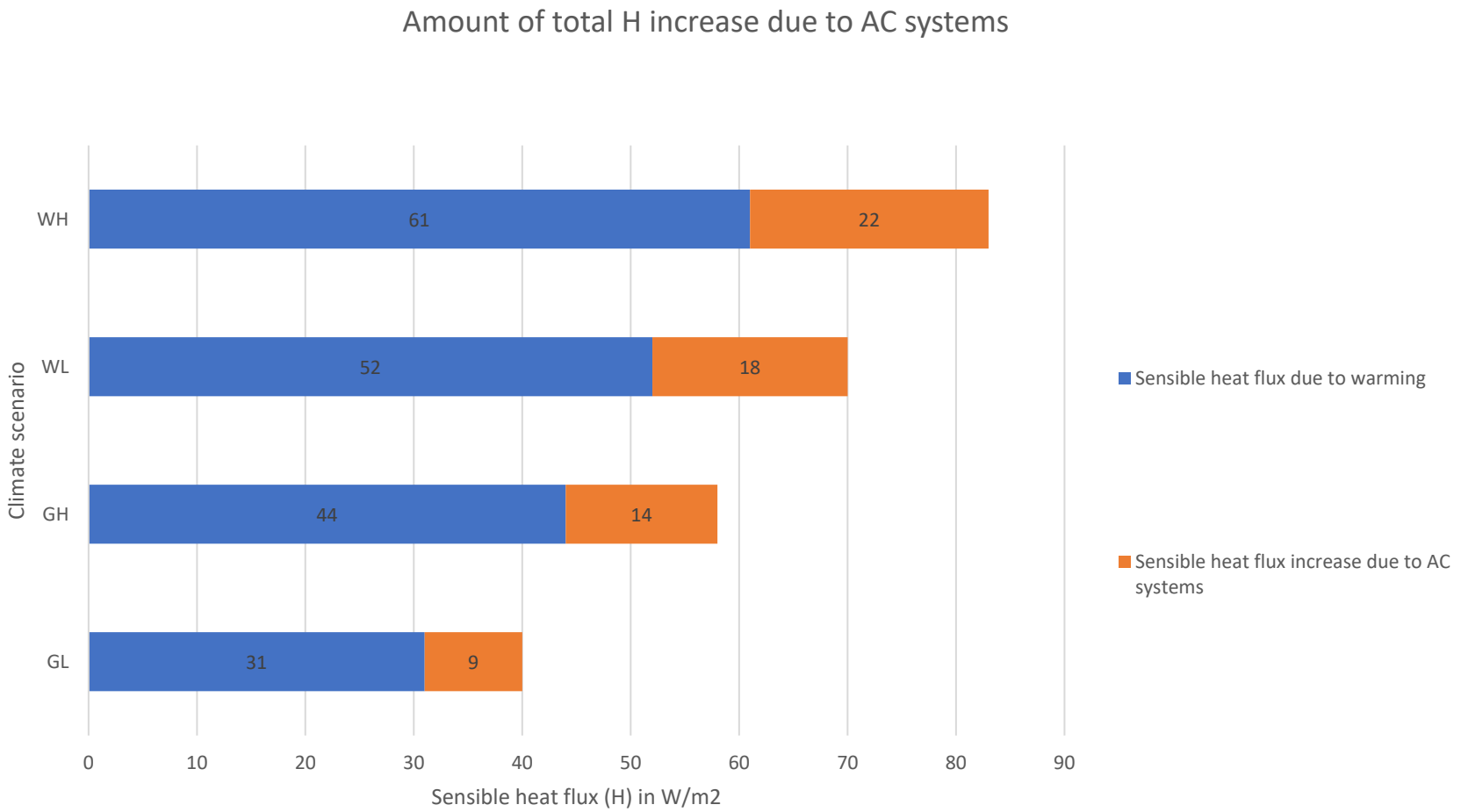
Model scores for different sites

	OBS	SLUCM			BEP			BEPBEM		
Location	Mean	Mean	RMSE	MB	Mean	RMSE	MB	Mean	RMSE	MB
1	27.6	25.7	1.7	-1.4	25.0	2.2	-1.8	25.9	1.4	-0.8
2	27.0	24.9	2.5	-1.5	24.8	2.2	-1.5	25.7	1.6	-0.6
3	25.6	23.7	3,0	-2.1	24.7	1.8	-1.4	25.3	1.6	-0.6
4	25.6	24.7	2.1	-1.3	24.6	2.0	-1.3	25.3	1.5	-0.6
AVG	26.5	24.8	2.3	-1.6	24.8	2.0	-1.5	25.6	1.5	-0.6

Effect of AC systems

- Up to 18% of total sensible heat flux in the city centre
- Up to 8-12% of total sensible heat flux in sub-urban areas




Amount of total H increase due to AC systems
WH
WL
GH
GL
61
22
52
18
44
14
31
9
Climate scenario
0
10
20
30
40
50
60
70
80
90
Sensible heat flux (H) in W/m2
Sensible heat flux due to warming
Sensible heat flux increase due to AC systems