

An assessment of current Urban Heat Island intensity in the Netherlands (with focus on Rotterdam)

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Research motivation and questions



Delft

*Many Dutch cities have
large areas of surface water*

Motivation:

- UHI intensity unknown in The Netherlands: no systematic data records last 40 years
- main future challenges are climate change and urbanization

Research questions:

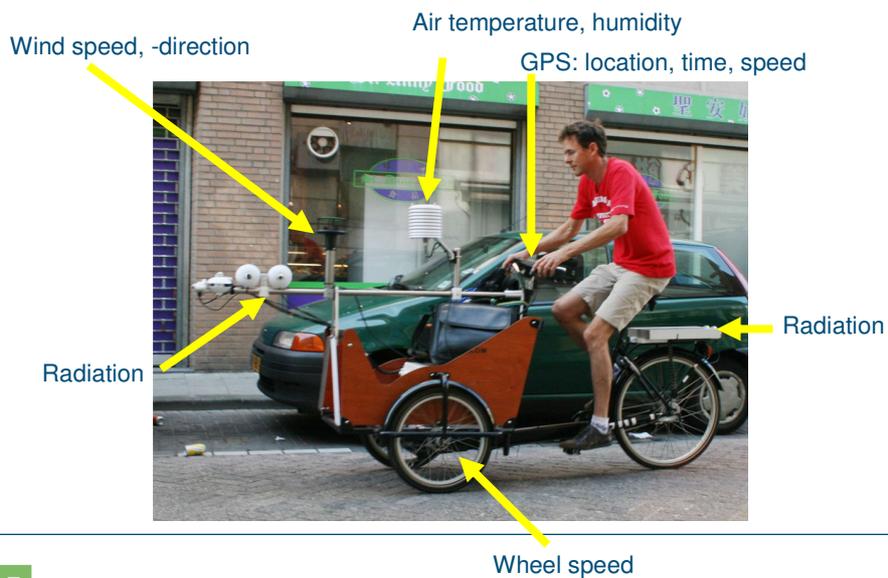
- What is the order of magnitude of the present-day UHI intensity in the Netherlands?
- Will thermal comfort (heat stress) become a critical issue?



Meteorological observations UHI intensity

1. Mobile traverse measurements → spatial patterns
2. Permanent weather stations → temporal behaviour
3. Data records hobby meteorologists → national coverage

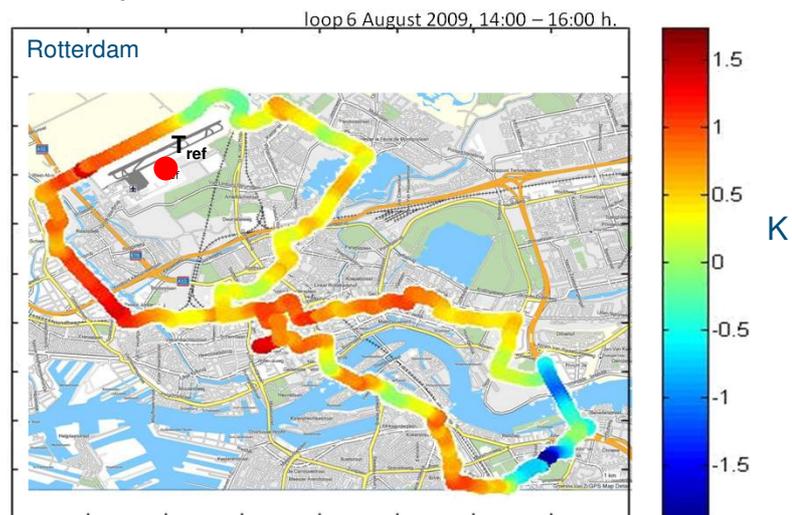
Spatial mapping of UHI with a cargo bicycle



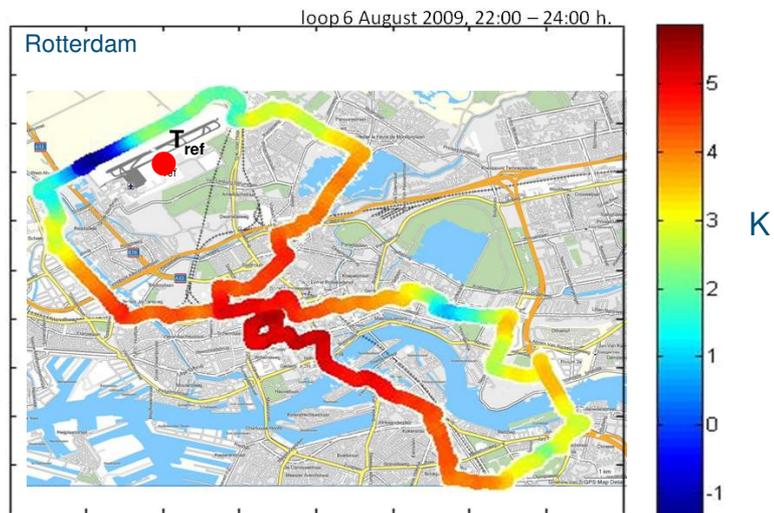
Mobile measurements golden day

- First measurements in Rotterdam (august 2009)
- Hot day (> 30 °C), low windspeed (east)
- Clear day and night
- Previous days also hot
- 3 runs per 24 hrs:
 - Midday: focus on global radiation
 - Late afternoon
 - During peak UHI (22-24 h LT)

$$\Delta T_{\text{air}} = T_{\text{bicycle}} - T_{\text{ref}} \quad \text{daytime}$$



$$\Delta T = T_{\text{bicycle}} - T_{\text{ref}} \quad \text{night time}$$

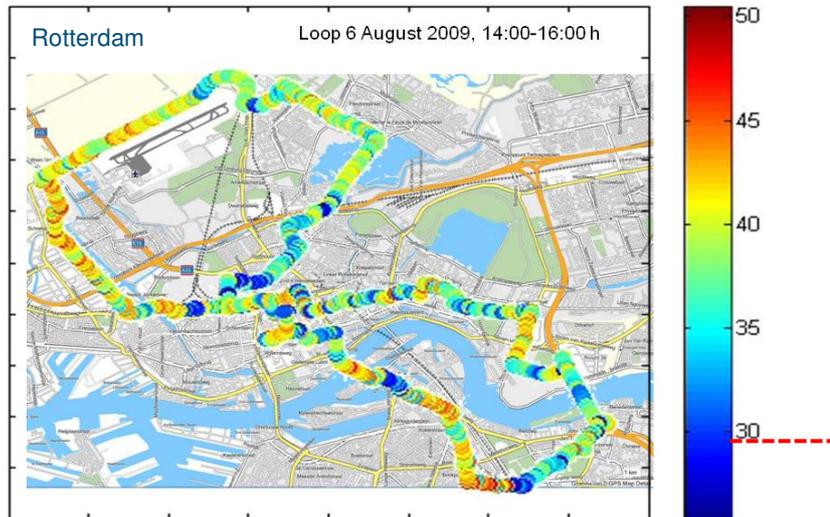


Thermal comfort and heat stress



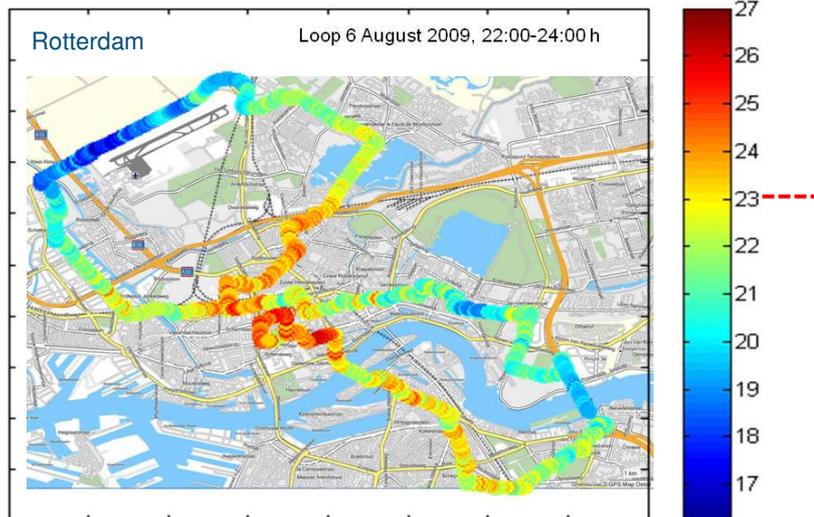
Thermal comfort index: Physiological Equivalent Temperature (PET)

Physiological Equivalent Temperature (PET) Daytime



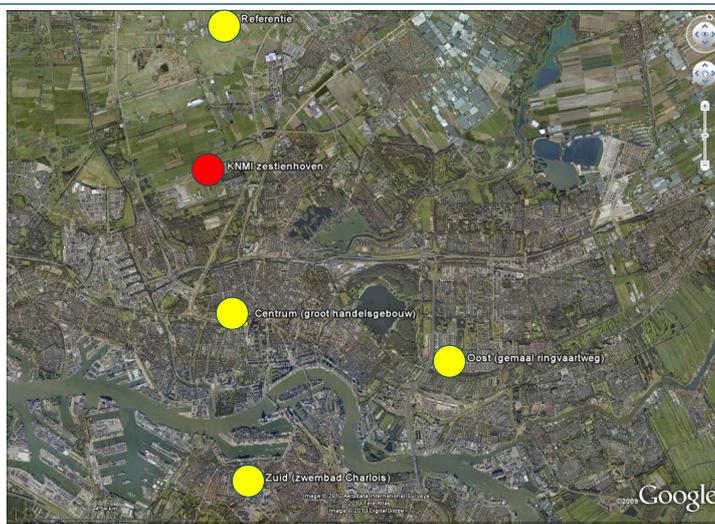
PET >29 people start to feel uncomfortable

Physiological Equivalent Temperature (PET) Night time



PET >23 difficult to sleep

Continuous observations in Rotterdam



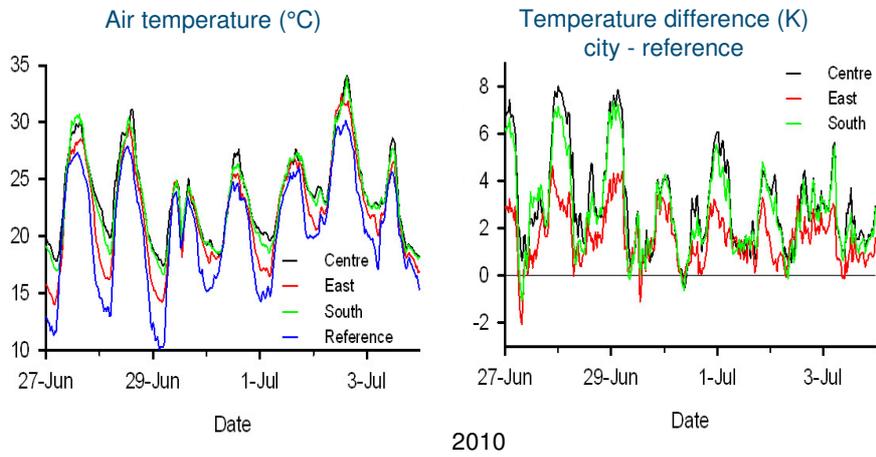
Continuous observations in Rotterdam



Rural reference (North of Rotterdam)

City centre

Continuous observations in Rotterdam



Maximum UHI-intensity in Rotterdam

First results: August 2009 – June 2010

Measurement site	N	UHI _{max}	
		median	95 percentile
Centre	263	3.3	7.3
South	201	2.9	6.6
East	224	2.2	4.6

Analysis of data from hobby meteorologists in NL

- Link each hobby station to rural KNMI weather station
- Selection based on metadata and instrumental set-up
- Typically 1.5-5 years of data
- Classification based on site description

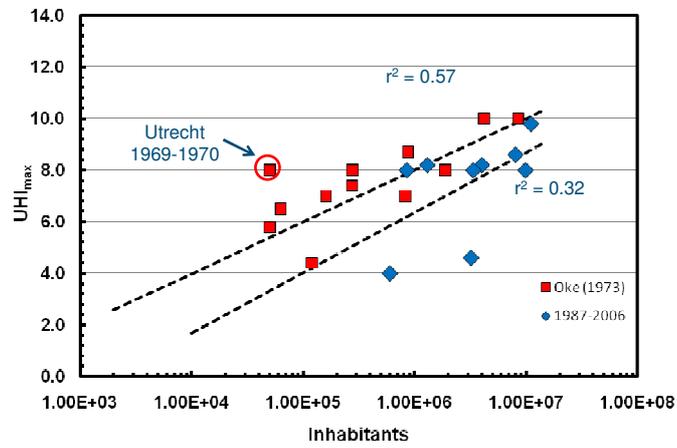


Selection of 19 cities
Inhabitants: 5500-584000

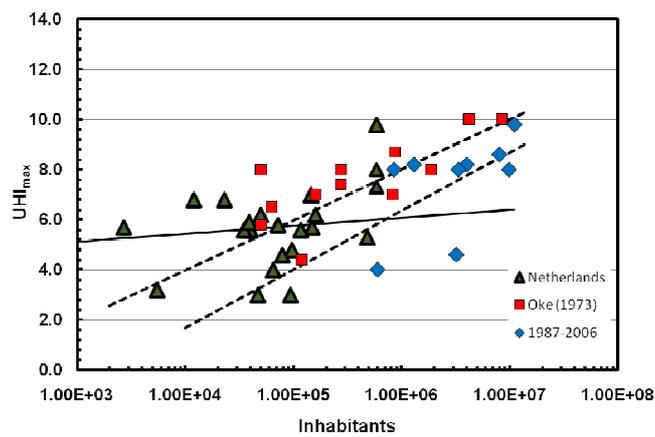
UHI intensity from observations by hobby meteorologists

City*	# inhabitants (x 1000)	Median	95 Percentile
Rotterdam	588	3.4	9.8
The Hague	483	2.2	5.3
Voorburg	40	2.4	5.6
Delft	97	1.7	4.8
Leiden	117	3.2	5.6
Haarlem	149	2.5	5.7
Purmerend	79	2.5	4.6
Heerhugowaard	50	2.4	6.2
Houten	47	1.2	3.0
Apeldoorn	160	2.9	6.2
Leeuwarden	94	1.1	3.0
Assen	65	1.8	4.0
Groningen	198	2.6	5.8

UHI_{max} intensity European cities



UHI_{max}: Dutch cities in a European perspective



Summary and conclusions

- First impressions UHI variation in space and time
- Benchmark database
- Nocturnal UHI intensity of Dutch cities is substantial (up to ~ 9 K)
- No clear link between UHI and city size (number of inhabitants)
- Impact on thermal comfort may be substantial



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Ranges of PMV and PET

PMV*	PET** (°C)	Thermal perception	Grade of physiological stress
-3.5	4	Very cold	Extreme cold stress
-2.5		Cold	Strong cold stress
-1.5	8	Cool	Moderate cold stress
-0.5	13	Slightly cool	Slight cold stress
0.5	18	Comfortable	No thermal stress
1.5	23	Slightly warm	Slight heat stress
2.5	29	Warm	Moderate heat stress
3.5	35	Hot	Strong heat stress
>3.5	41	Very hot	Extreme heat stress

Heat stress: WBGT

City*	Median	95 Percentile	98 Percentile
Rotterdam	15.1	29.7	32.3
The Hague	16.0	25.3	26.9
Voorburg	17.5	25.8	28.5
Delft	16.6	25.2	27.5
Leiden	18.5	26.6	28.2
Purmerend	14.0	23.2	24.8
Heerhugowaard	16.6	25.6	27.8
Houten	12.8	20.8	23.0
Apeldoorn	14.5	24.4	25.1
Leeuwarden	15.8	24.1	26.0
Assen	15.8	25.0	26.4
Wageningen	17.6	25.6	27.6
Groningen	16.2	26.4	28.7