

# Urban heat islands in the subsurface of German cities

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### . Introduction

Climate change and the urban heat island effect have not only caused surface temperature increase in most urban areas, but also enhanced the subsurface temperature by several degrees [1,2]. Potential natural and anthropogenic heat sources in the urban environment are manifold (Fig.1).



Besides potential negative effects on urban aquifers, this thermal anomalies in the aquifers also represent shallow geothermal energy reservoirs [3]. This study presents extensive surveys of groundwater temperatures (GWT) in several German cities.

Fig. 1: Potential anthropogenic and natural heat sources in urban areas.

## 2. Material and methods



Fig. 2: Geographical location

of studied cities

Tab. 1 Basic characteristics of the studied cities.

City Name	Population	Population density [persons/km²]	Observation wells	Measurem depth belo surface
Berlin	3,442,675	3,861	123	20 m
Munich	1,330,440	4,282	970	20 m
Cologne	679,664	2,737	52	15 m
Frankfurt	998,105	2,463	14	20 m
Karlsruhe	291,959	1,683	82	10 m
Darmstadt	143,332	1,174	16	17 m



Fig. 3: Groundwater observation well in urban area in Karlsruhe for groundwater temperature measurements.



Fig. 4: Air temperature measurements from the AERO-TRAM Project in Karlsruhe [4].

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Fig. 5: Isotherm maps of GWT in the studied German cities including locations of observation wells. For measurement depth see Tab. 1.

#### 4. Conclusions

- Existence of pronounced positive temperature anomalies in all investigated German cities.
- The distribution of groundwater temperatures appears to be spatially and temporally highly variable. · The increased heat input into the urban subsurface is controlled by very local and site-specific parameters. In
- the long-run, the superposition of various heat sources results in extensive temperature increases.
- · In most cases, the maximum temperature elevation is found close to the city centre. Regional groundwater temperature differences between the city centre and the rural background are up to 5°C.
- · Examination of the long-term variations in isotherm maps shows that temperatures have increased by about 1°C in the city of Karlsruhe, as well as in the rural background areas from 1960 until today.





Fig. 8: Correlation of city population and urban heat island intensity (UHII) in atmosphere and subsurface, respectively. Data for UHI Intensity in the atmosphere from [5] and in the subsurface from [3].

the urban heat islands.

## 5. Acknowledgements and references

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