5.8 STATISTICAL ANALYSIS OF THE DEPENDENCE OF URBAN HEAT ISLAND INTENSITY ON LATITUDE

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1. INTRODUCTION

A possible dependence of the **U**rban **H**eat **I**sland (**UHI**) on latitude and climate zone has been discussed for a long time. KRATZER already mentioned in his book about urban climatology first published in 1937 (KRATZER 1937) the assumption of increasing UHI with latitude. Since until now no comprehensive evaluation of that problem has been available this study examines a variation of UHI with latitude and climate zone on a broader global data base.

2. METHODS AND DATA

For evaluating a latitudinal dependence of UHI a statistical approach was favored. OKE (1986) for example proposed to analyse available urban climate studies to investigate the spatial transferability of urban climate information. Following that proposal the published scientific literature concerning UHI in different cities served as data source. 223 cities between latitudes 43° S and 65° N with measurements of UHI could be extracted from those publications.

Most frequently the daily maximum UHI (UHImax) occured in the publications at hand especially in tropical and subtropical zones. Choosing UHI_{max} 150 cities remained to be examined with different statistical methods such as regression, factorial and cluster analysis. In order to evaluate a possible variation of UHI_{max} with latitude and climate zone further parameters controlling the formation of UHI were included in the statistical calculations.

These parameters consisted of the size of the city population, anthropogenic heat production in form of the annual per capita consumption of primary energy, height above sea level and topographic features (coast, plain, valley). Among the large number of climate classifications the one by TERJUNG & LOUIE (1972) based on the energy balance of the earth's surface seemed most promising for proving a connection with UHI_{max} because differences in the energy balance determine the formation of UHI.

3. STATISTICAL CALCULATIONS

Bivariate, partial and multiple regression analysis were implemented to find a significant correlation between UHI_{max} and latitude. Factorial analysis should investigate to what extent a latitudinal dependence possibly determines $UHI_{max.}$ Cluster analysis on the other hand were employed to show whether parameters responsible for the formation of urban excess warming could be combined in typical groups being attached to certain latitudinal zones.

3.1 Bivariate and multiple regression

The simple linear regression shows an increase of UHI_{max} with latitude. The correlation explains 12% of the observed variance of UHI_{max} on a significance level of more than 99%. The linear regression, however, does not allow any conclusions concerning those parameters that mainly might cause such a latitudinal dependence. Therefore a multiple regression analysis with UHI_{max} as the dependent variable and size of city population, annual energy use (indicator for anthropogenic heat production), height above sea level, topography (coast, plain, valley) and climate classification by TERJUNG & LOUIE (indicator for energy balance of the earth's surface) as independent variables was performed.

The multiple regression yielded a correlation coefficient of 0.735, which means that 54% of the variance of UHI_{max} is explained by the employed set of independent variables. Table 1 contains those independent variables having a statistically significant correlation with UHI_{max}. For comparison the partial correlation of latitude ist also shown.

Table 1 Independent variables correlating significantly with UHI_{max} in multiple regression

independent variable	r	r²	P
size of city population*)	0.249	0.062	0.004
anthropogenic heat	0.155	0.024	0.082
input number **)	-0.251	0.063	0.004
latitude	0.068	0.005	0.444

*) logarithmic value of city population number
**) Input number after TERJUNG & LOUIE as indicator for radiation balance at the earth's surface
r: correlation coefficient, P: probability of chance

As can be seen from Table 1 latitude has no significant connection with UHI_{max}. Throughout this study a statistically significant correlation is assumed for P-values (probability of chance) less than 10%. The input number is defined after TERJUNG & LOUIE as the sum of the maximum monthly mean value and the annual variation of the radiation balance. Low input

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numbers are attached to high values of that sum and vice versa thus causing a negative correlation coefficient in Table 1.

If there exists a dependence of UHI_{max} on latitude it should be based on a latitudinal variation of the variables in Table 1 significantly correlating with UHI_{max}. Partial regression calculations show that latitude explains almost 6% of the observed variance concerning the input number after TERJUNG & LOUIE (indicator for radiation balance) and even 43% of the observed variance concerning anthropogenic heat production.

3.2 Factorial analysis

With the factorial analysis using a varimax rotation two factors could be extracted. Factor 1 yields the highest correlation coefficients with anthropogenic heat production, latitude and input number standing for the radiation balance after the climate classification by TERJUNG & LOUIE. Factor 2 exhibits the highest correlation coefficients with topography and height above sea level. So factor 1 was called „latitudinal energy“-factor and factor 2 was named „topographic“-factor.

Linking the two factors to UHI_{max} with bivariate regressions gave a highly significant correlation for factor 1 having a significance level of more than 99%. The „latitudinal energy“-factor describes around 6% of the observed variance of UHI_{max}. The „topographic“-factor 2, however, shows only an accidental correlation with UHI_{max} with a probability of chance around 17%.

This result hints towards a latitudinal dependence of UHI_{max} being caused mainly by anthropogenic heat production and radiation balance with their own specific dependences on latitude. It might also be assumed, that the magnitude of UHI_{max} is determined to a lesser degree (around 6% of its variance) by that latitudinal variation.

3.3 Cluster analysis

Using the parameters responsible for the formation of UHI as listed in chapter 2 three clusters could be extracted from that data set showing typical values for latitude and UHI_{max} (see Table 2).

Table 2: Typical cluster values for latitude and UHI_{max}

$\Delta\|\varphi\|$	rf($\Delta\|\varphi\|$)	$(UHI_{max})_m$	Cluster
0° - 20°	**76%**	**4.0 K**	**3**
20° - 40°	**76%**	**5.0 K**	**1**
40° - 60°	**69%**	**6.1 K**	**2**

$\Delta|\varphi|$: most frequent latitude interval (northern and southern hemisphere combined), rf($\Delta|\varphi|$): relative frequency for $\Delta|\varphi|$, $(UHI_{max})_m$: mean value of UHI_{max}

Table 2 illustrates an increase in UHI_{max} from the tropical cluster 3 over the subtropical cluster 1 to the mid latitude cluster 2. That becomes especially clear from Fig. 1 containing the cumulated frequency distribution of UHI_{max} per cluster.

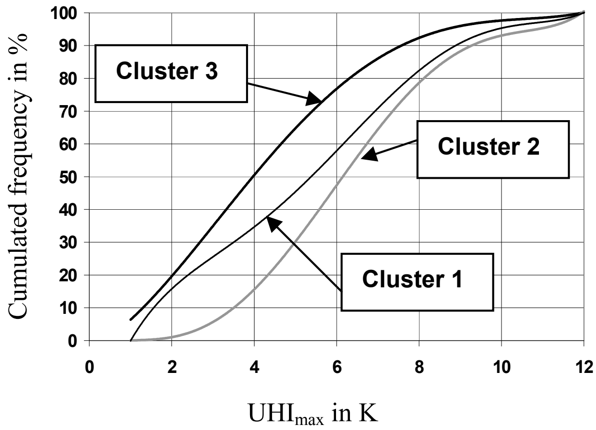

Fig. 1 Cumulated frequency distribution of UHI_{max} in different clusters

In Fig. 1 the tropical and subtropical clusters 3 and 1 show a majority of cities with values of UHI_{max} **below** 6.0 K. On the other hand around 55% of the cities in the mid latitude cluster 2 have values of UHI_{max} **above** 6.0 K.

4. RESULTS

1. UHI_{max} tends to increase from low to high latitudes.
2. The part of the observed variance of UHI_{max} being explained by the latitudinal variation, however, remains relatively small with about 6%.
3. A statistically significant dependence of the maximum urban heat island (UHI_{max}) on latitude is based mainly on the latitudinal variation of anthropogenic heat production and radiation balance. The radiation balance is used in form of the input number after TERJUNG & LOUIE with the annual variation of the radiation balance as part of the input number having like anthropogenic heat poduction a significant positive correlation with latitude.

5. REFERENCES

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