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Impact Analysis of Urbanization Process on the Urban Temperature

——A Case of Nanjing

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1. Background

In the past 100 years, the global average surface temperature increased about 0.72 ℃, and in the past 50 years climate warming rate nearly double (*IPCC,2007*). Due to pronounced warming trends, studies of how human activities influence climate change have increased dramatically in recent years.

Land cover and land use change, a combination of anthropogenic activities and changing climate, have great influence on terrestrial biogeochemical processes, and also impose feedbacks to current climate change (*Brovkin et al. 2004; Houghton 2008*).The most dramatic example is urbanization, inducing warming that overwhelms the background trend(*Motha and Baier, 2005*).

There are many approach to study urbanization process, such as remote sensing techniques (*Du Yin, 2007*)and statistic method(*Hughes, 1996*). In the past research using statistic method, single indicator such as population is often used to represent the level of urbanization. But urbanization is a comprehensive process which can reflect the level of regional economic, social and culture development. It's important to analyze the urbanization process more accurate and comprehensive.

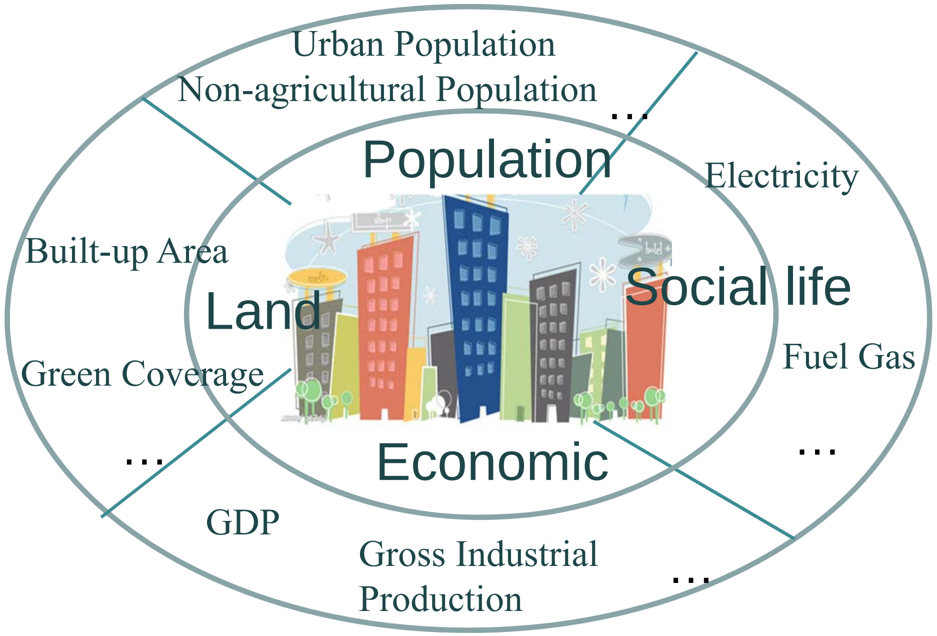

Fig.1 The performance of urbanization.

2. Data and Methods

2.1 Data

- **Meteorological Data**:

Daily temperature series observed at five meteorological stations (Nanjing,Jiangning,Jiangpu,Jurong,Liuhe),covering the period of 1985-2007, were utilized in order to investigate the variation trends of temperature.

- **Statistical Data**:

Eight urbanization indexes such as urban population, urban non-agricultural population,GDP, gross industrial production, fuel gas penetration, total electricity consumption, urban built-up area and green coverage area, have been collected from the Nanjing statistical yearbook and China Statistical Yearbook in order to study variation trends of urbanization level in Nanjing.

2.2 Methods

2.2.1 Back propagation (BP) neural network structure

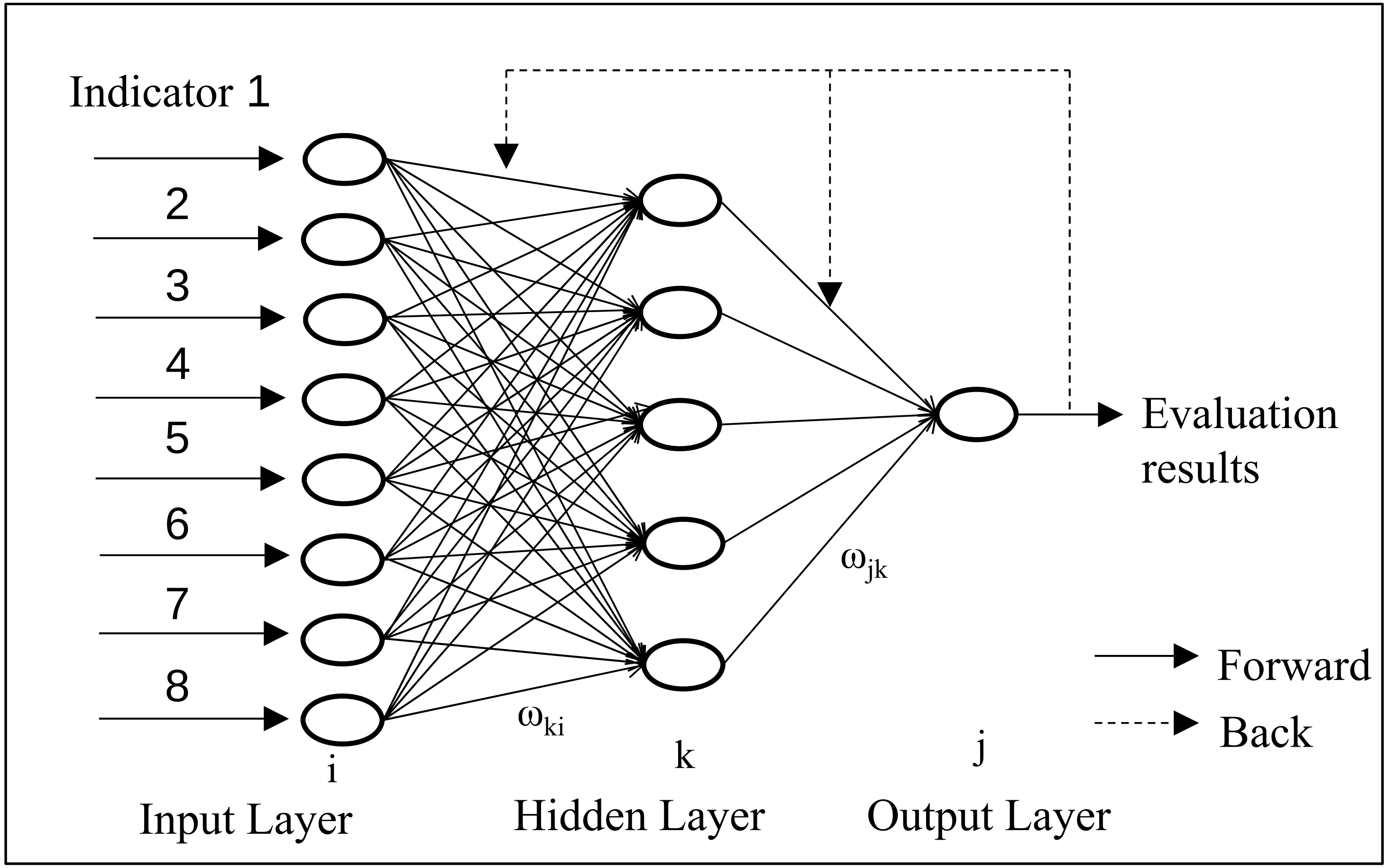

Fig. 2. BP neural network structure

2.2.2 BP neural network parameter settings

Test samples ⇨ Eight indicators of the national various cities in 2010.

Training samples ⇨ Pick up the maximums and minimums of each indicator.
According to the maximum and minimum interval of each indicator, divide the sample into five levels by linear interpolation method, and assignment 1 to 5.

Table 1. Neural network parameter settings

Input Layer Nodes	Hidden Layer Nodes	Output Layer Nodes	Initial Weight Values	Learning rate	Training algorithm	Maximum cycle Number	Maximum Training Error
8	5	1	[0,1]	0.1	trainingdm	1000	0.001

*All of the data should be normalized before calculating.

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2.2.3 Urbanization comprehensive index(UCI) calculating

Nondimensionalize $\Longrightarrow Y_{ij} = \frac{X_{ij}}{\max(X_j)}$ $\quad i = 1,2,\ldots,25;\ \mathrm{j} = 1,2,\ldots,8$ (1)

UCI $\Longrightarrow$ $Z_i = \sum_{j=1}^{n} Y_{ij} S_{ij}$ $\quad n = 1,2,\ldots,8$ (2)

i represent the year number and *j* stand for the indicator; Y_{ij} is the nondimensionalize value of the *j*th indicator in the *i*th year; *X* stand for the indicator values represent the weight to the UCI.

Related significant coefficient ⟶ $r_{ij} = \sum_{k=1}^{P} \omega_{ki}(1 - e^{-x})/(1 + e^{-x})$ (3)

$$x = \omega_{jk} \quad (4)$$

related coefficient ⟹ $R_{ij} = \left| \frac{1-e^{-y}}{1+e^{-y}} \right|$ (5)

$$y = r_{ij} \quad (6)$$

Weight ⟹ $S_{ij} = \frac{R_{ij}}{\sum_{i=1}^{m} R_{ij}}$ (7)

ω_{ki} is the weight coefficient between input layer and hidden layer; ω_{jk} is the weight coefficient between hidden layer and output layer, they all obtained by BP neural network.

3. Result

3.1 Urbanization process analysis

3.1.1 Indicator weight to UCI

Table 2. Urbanization comprehensive indicator system

System Layer	Indicator Layer	Weight
Population Urbanization	Urban Population	0.116465
	Urban non-agricultural Population	0.146861
Economic urbanization	GDP	0.291688
	Gross Industrial Production	0.180630
Social life urbanization	Fuel Gas Penetration	0.052358
	Total Electricity Consumption	0.064176
Land urbanization	Urban Built-up Area	0.090308
	Green Coverage Area	0.057981

3.1.2 Indicator growth rate variation

Table 3. The growth rate variation of urbanization indicators.

Urbanization Indicator	Growth Rate before 2000	Growth Rate after 2000
Urban Population (million · a^{-1})	4.19	10.54
Urban Non-agricultural Population (million · a^{-1})	5.31	26.85
GDP (a hundred million yuan · a^{-1})	65.97	330.78
Gross Industrial Production (a hundred million yuan · a^{-1})	100	600
Fuel Gas Penetration (% · a^{-1})	4.74	2.18
Total Electricity Consumption (ten thousand kwh · a^{-1})	47815	243489
Urban Built-up Area (square kilometers · a^{-1})	5.29	56.04
Green Coverage Area (% · a^{-1})	0.45	1.09
Civil Car Number	4927.6	51733
Industrial waste gas emissions (a hundred million standard cubic meter · a^{-1})	50.02	287.68

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3.1.3 UCI variation

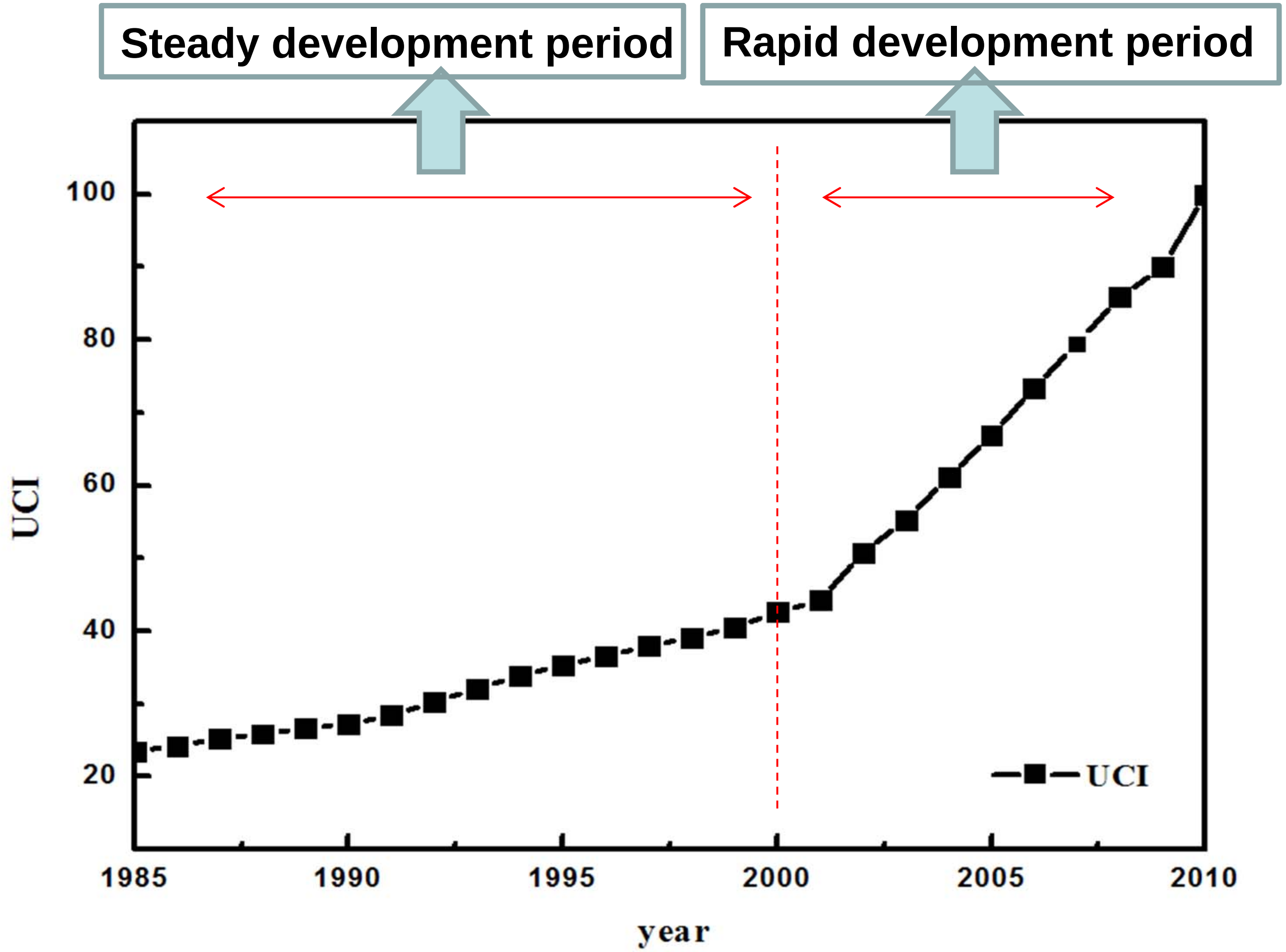

Fig.3. Changes of the Urbanization comprehensive index(UCI) in Nanjing from 1985 to 2007

3.2 Temperature variation analysis

3.2.1 Annual Mean Temperature

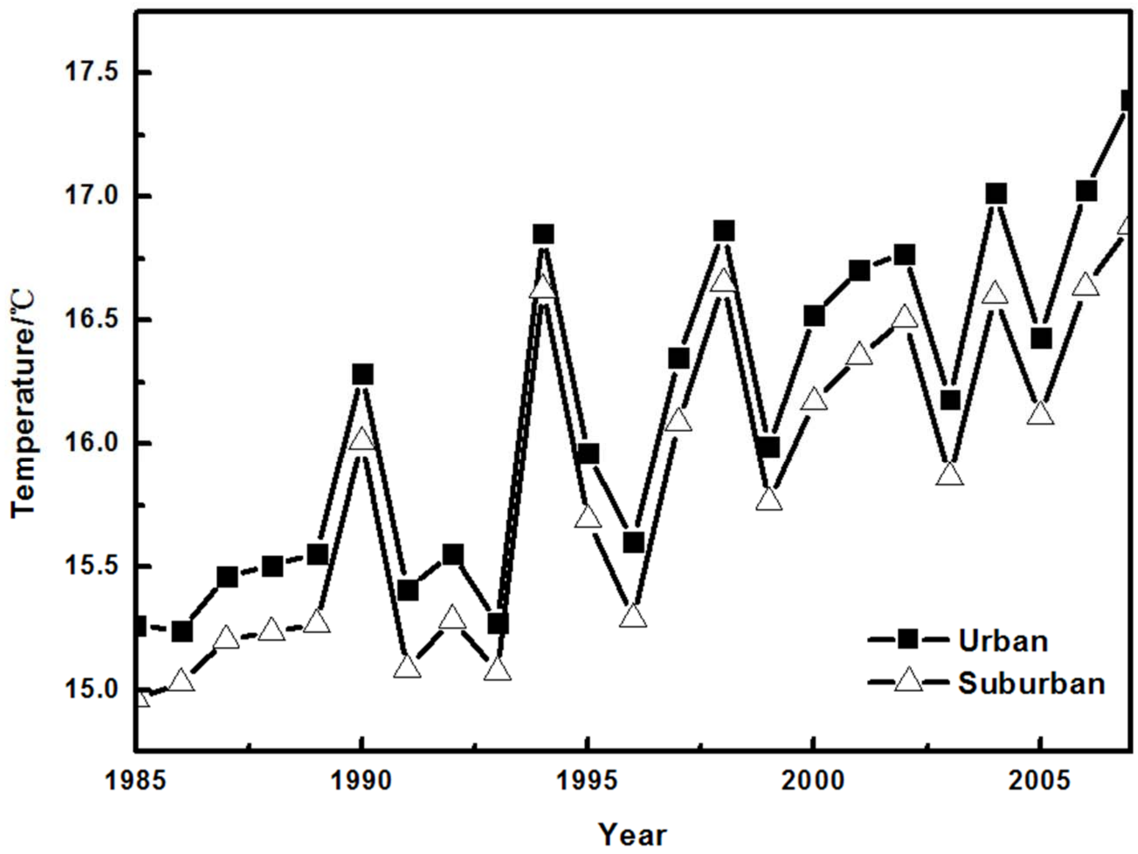

Fig.4. Temperature variation in Nanjing during 1985-2007

- Both temperature rose with fluctuations;
- The warming rate were 0.81℃/10a and 0.75℃/10a respectively;
- The warming rate before 2000: 0.80℃/10a and 0.79℃/10a;
- The warming rate after 2000: 1.14℃/10a and 0.91℃/10a.

3.2.2 Minimum and Maximum Temperature

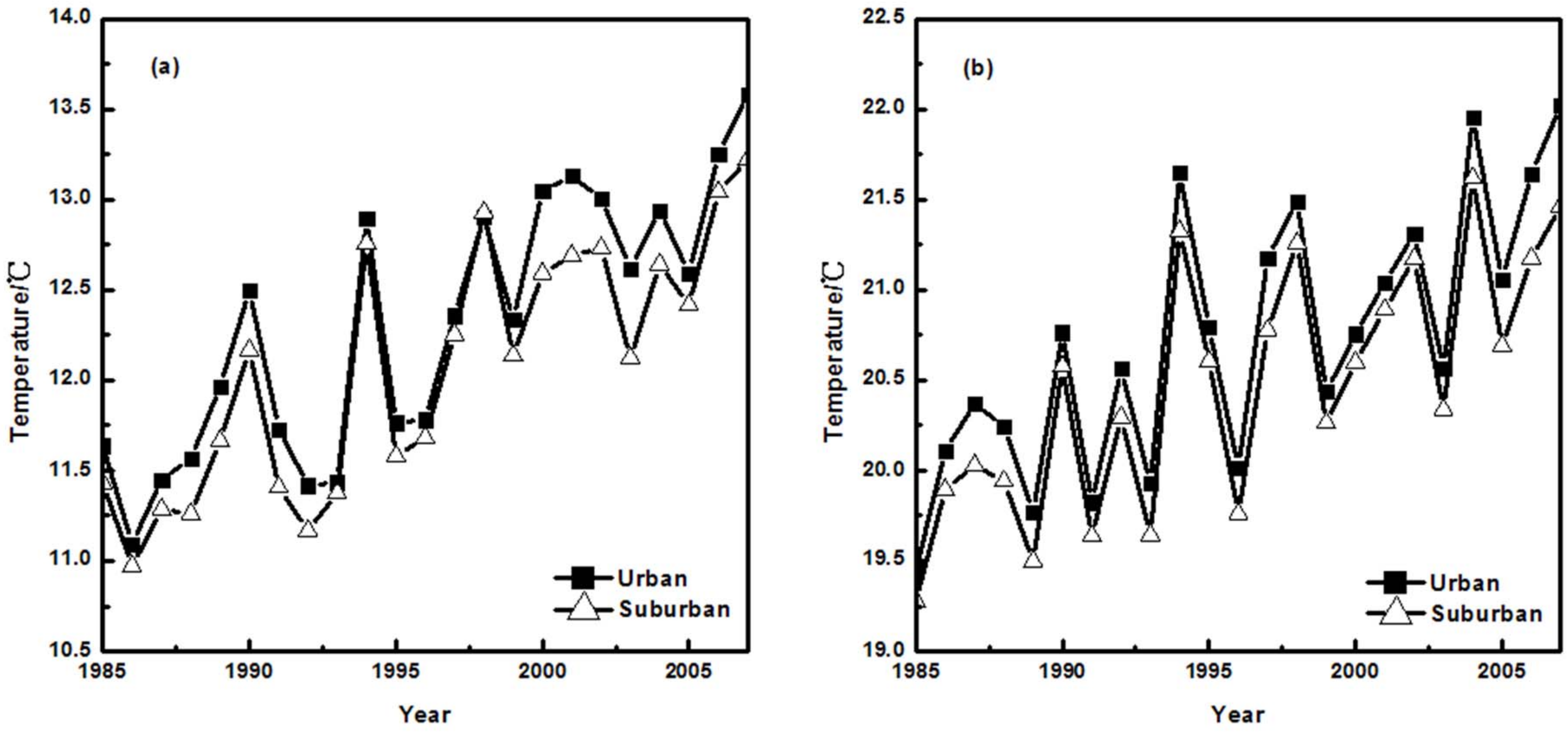

Fig.5. The minimum (a) and maximum temperture (b) variation during 1985-2007

- Warming rate of the minimum temperature : 0.88℃/10a and 0.83℃/10a in urban and suburban respectively;
- Warming rate of the maximum temperature: 0.79℃/10a and 0.74℃/10a;
- The difference between urban and suburban increased after 2000,the difference in minimum temperature was more notable.

3.2.2 Heat island Intensity

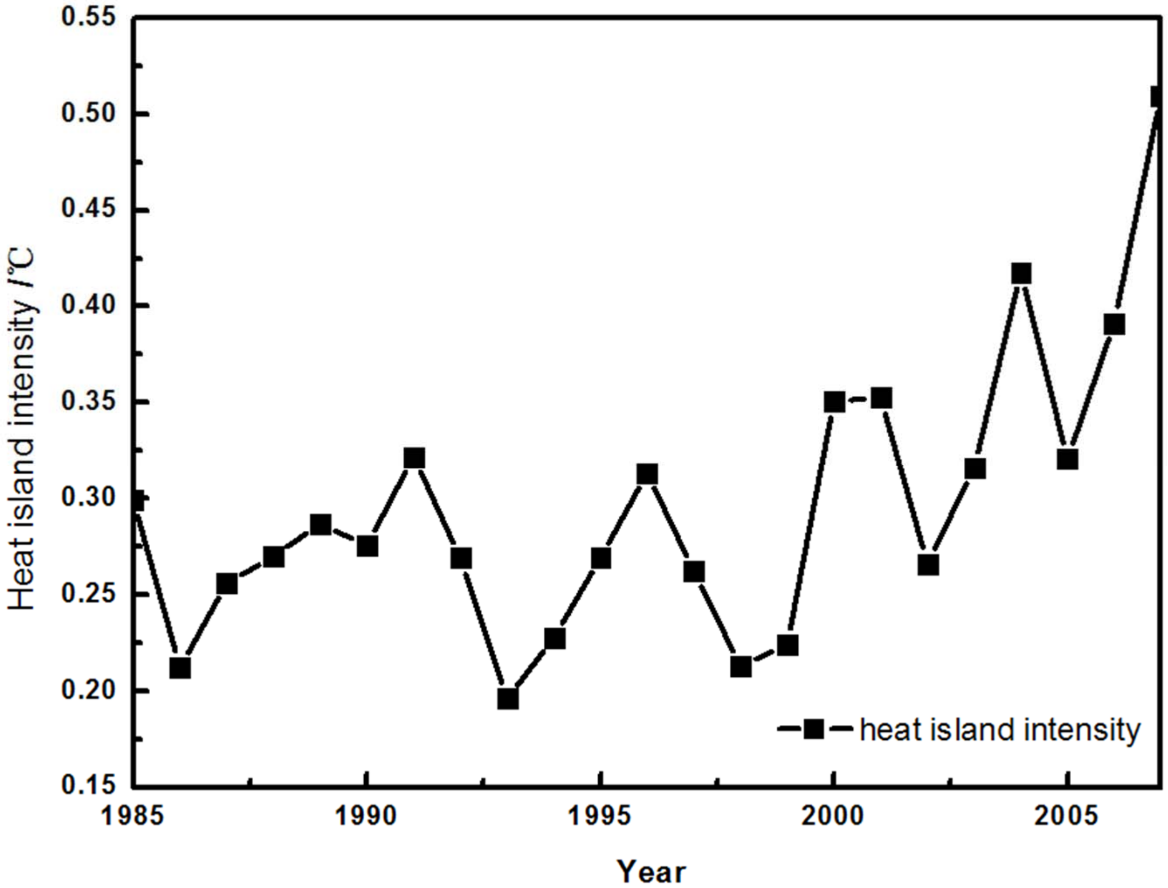

Fig.6. The heat island intensity variation during 1985-2007

- Heat island intensity rose with fluctuations;
- The trend was more close to the urbanization process;
- The warming rate after 2000: 0.19℃/10a

3.3 The influence of urbanization on the temperature variation analysis

3.3.1 Annual Mean Temperature

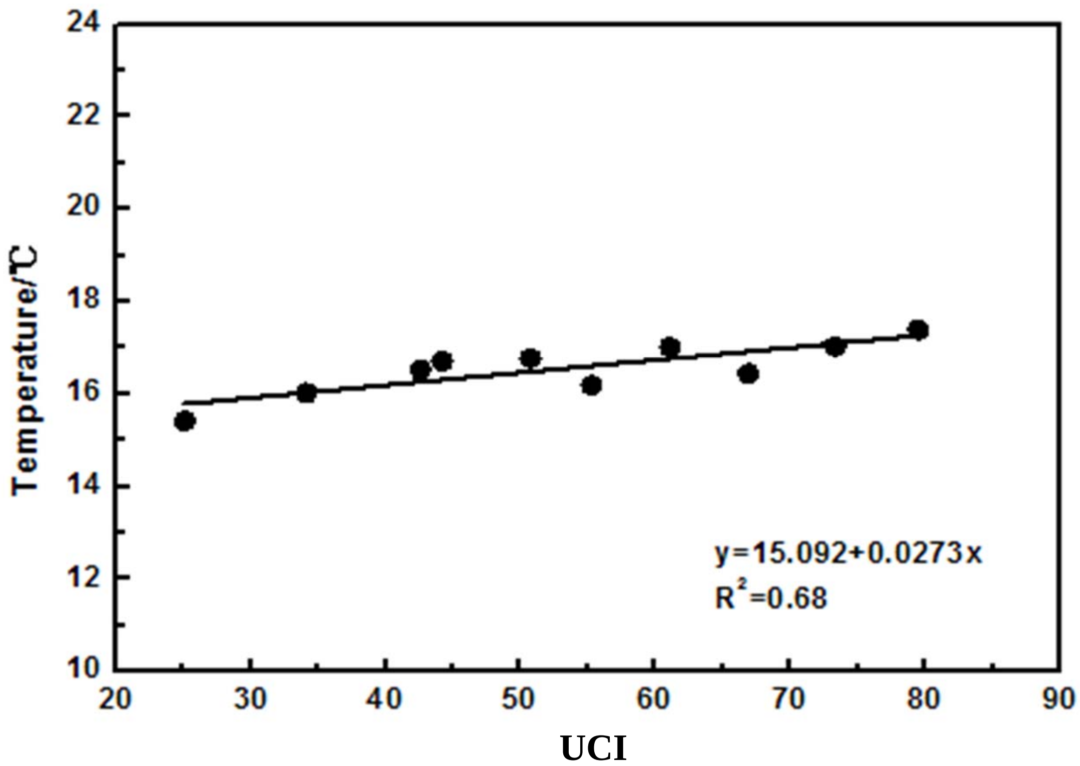

Fig.7. Relationship between UCI and annual mean temperature.

* Use the eighties average UCI value to represent 1985-1989 data, and nineties to 1990-1999 data.

- Pearson correlation coefficient:0.82

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3.3.2 Minimum and Maximum Temperature

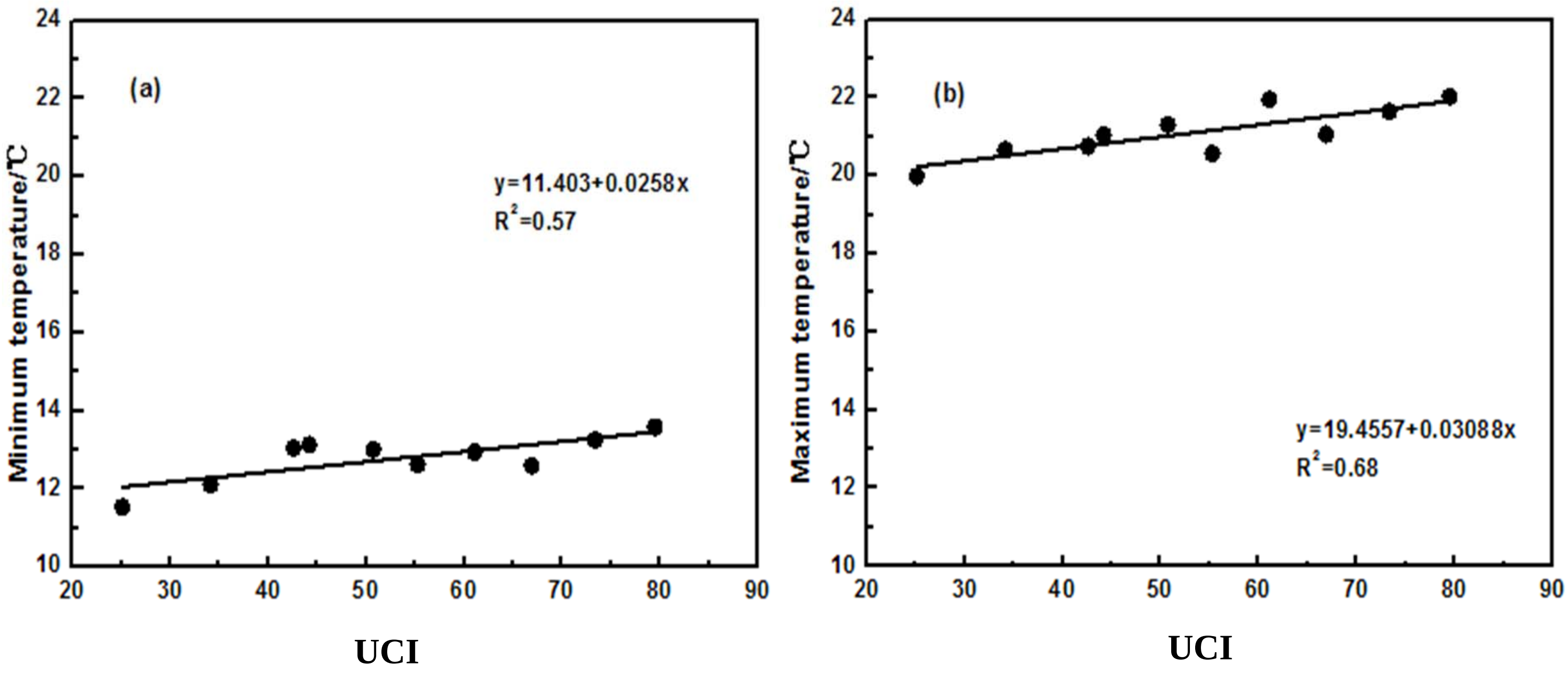

Fig.8. Relationship between UCI and extreme temperature include minimum temperature (a) and maximum temperature(b).

- Pearson correlation coefficient:0.82 and 0.83 respectively

3.3.3 Heat island Intensity

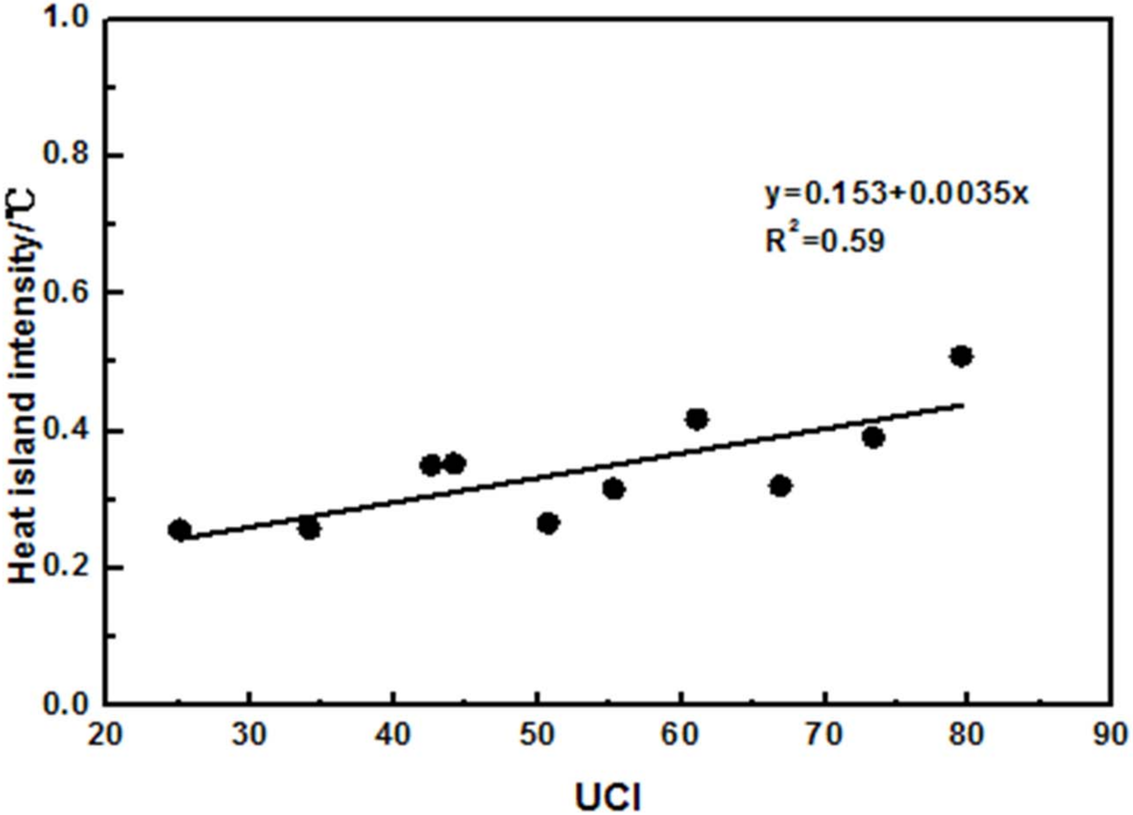

Fig.9. Relationship between UCI and heat island intensity.

- From eighties to nineties, the relationship remained unchanged;
- After 2000,the trend of increase was more obviously;
- Pearson correlation coefficient:0.77

3.3.4 Correlation between single indicators and temperature

Table 4. The Pearson correlation coefficient between urbanization indicators and temperature indicators.

Urbanization Indicator	Annual Mean Temperature	Minimum Temperature	Maximum Temperature	Heat Island Intensity
Urban Population (million · a^{-1})	0.86	0.82	0.84	0.74
Urban Non-agricultural Population (million · a^{-1})	0.80	0.73	0.77	0.77
GDP (a hundred million yuan · a^{-1})	0.82	0.75	0.83	0.81
Gross Industrial Production (a hundred million yuan · a^{-1})	0.80	0.74	0.81	0.79
Fuel Gas Penetration (% · a^{-1})	0.72	0.63	0.69	0.56
Total Electricity Consumption (ten thousand kwh · a^{-1})	0.72	0.63	0.77	0.61
Urban Built-up Area (square kilometers · a^{-1})	0.81	0.75	0.81	0.66
Green Coverage Area (% · a^{-1})	0.76	0.67	0.79	0.70
Civil Car Number	0.77	0.71	0.77	0.83
Industrial waste gas emissions (a hundred million standard cubic meter · a^{-1})	0.82	0.75	0.83	0.77

3.4 Conclusion:

Through the above analysis, we can get several conclusions:

(1) Neural network can be used to calculate CUI , the result represent well. The development of Nanjing is divided into two stages: steady development period before 2000,and rapid development period after.

(2)Four temperature indicators all showed fluctuated increase, particularly after 2000.

(3)All the temperature indicators increased with CUI, the urbanization development have a significant influence to temperature changes.

(4)Dense population, air pollution and Underlying surface type change aroused from urbanization has a dramatically influence on temperature variation.

4. Discussion

- The method of BP neural network calculating UCI is feasible, and the results showed the urbanization process of Nanjing well.
- Indicator weights to the UCI are similar to previous research. No matter in Jiangsu province(*Ou Minhao,2004*) or in the entire China(*Chen Mingxing, 2009*), economical urbanization is most noticeable, secondly is population urbanization, just like our research in Nanjing.
- It's necessary to extend the method into regional scale urbanization process study. Different city has different urbanization development process and characteristics, we need more experiment to complete the impact analysis of urbanization process on climate change.

5. Ongoing Work

5.1 Apply the method of calculating CUI to all the representatively cities in Yangtze River Delta.

5.2 Observation minus reanalysis (OMR) method for estimating the effect of urbanization on temperature variation.

Kalnay and Cai (2003)introduced a new method for estimating the effect of urbanization and other land uses on surface temperature change in the United States.

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5.2.1 Essence of OMR Method

The NCEP/NCAR Reanalysis (NNR) does not assimilate surface observations of temperature, moisture, and wind over land, and the surface temperatures are estimated from atmospheric values so that the NNR is insensitive to land surface properties and the changes in these properties *(Kalnay and Cai, 2003)*.

5.2.2 Data Preparation

- **Meteorological Data**: daily mean surface air temperature data from weather and climate stations
- **NNR Data**: the NNR 2m air temperature data download from http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html

THANK YOU