Monitoring urban change with remote sensing

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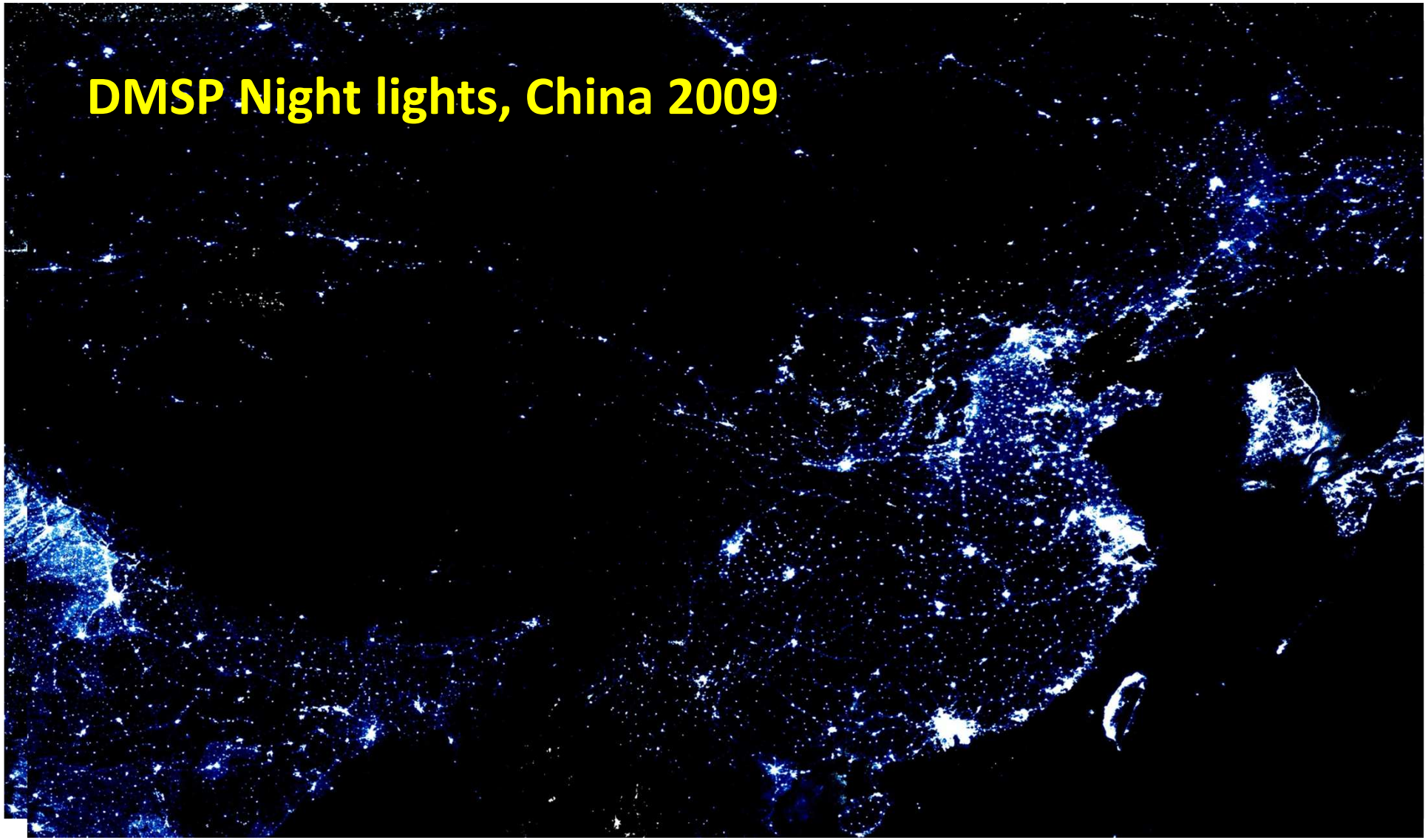
1.Introduction

- Urbanization can be defined as changes in the territorial and socio-economic progress of an area that includes a general transformation of land cover/use categories from undeveloped to developed (Weber 2001).
- China has been undergoing an accelerated process of urbanization, manifested by urban population growth, expansion of existing cities and the rapid emergence of new city centers. China had 132 cities in 1949 and it has 655 in 2004, according to official data (National Bureau of Statistics of China, 2005).
- Remote sensing provides synoptic views in space and consistent data set with high temporal and spatial resolution. It offers the capacity for dynamic monitoring of large urban agglomerations and proved to be an effect tool to map the land use and changes analysis.


DMSP Night lights, China 2009

2. Monitoring urban agglomeration expansion with remote sensing images in Jing-Jin-Tang area, China

- Study area and dataset
- Methodology
- Expansion of urban areas in Jing-Jin-Tang urban agglomeration
- Conclusion

Study area and dataset

- Urban agglomeration area around Bohai Rim(38° 30′-41° 8′N; 115° 17′-119° 30′E), covering approximately 42000 km^2 ;
- The heart of Bohai Economic Rim, plays a pivotal role in the nation's economic growth;
- Including two municipalitis(Beijing, Tianjin) and one medium-size city Tangshang.

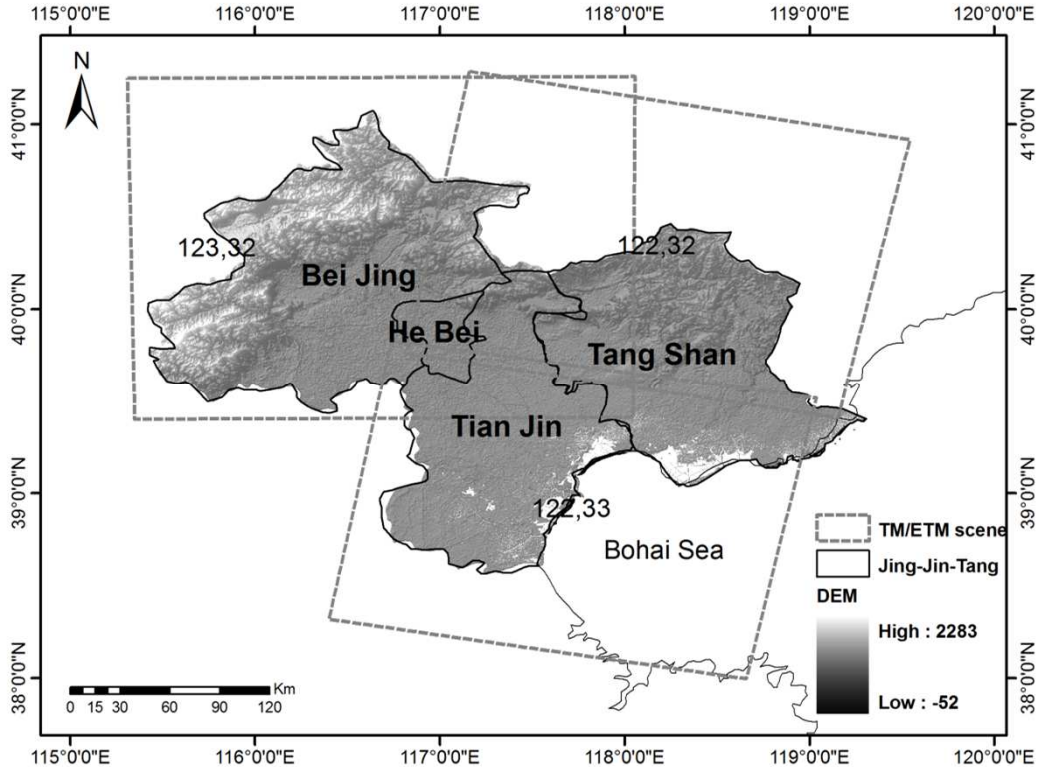


Figure 1. Location of the study area

This region experienced intense urbanization since the 1980s. The rapid growth has brought great pressure to the local environment and has led to serious environmental problems, including water shortage, air pollution and vegetation degradation especially in over populated areas.

City	1990	2000	2010
Beijing	10.819	13.819	19.612
Tianjin	8.785	10.009	12.938
Tangshan	6.628	7.120	7.577
Total	26.232	30.948	40.127

Population growth of the Jing-Jin-Tang urban agglomeration in million inhabitants

Datasets

- Landsat dataset is used to depict the urban evolution in the study area.
- Three Landsat footprints (path/row 122/32,122/33 and 123/32) cover the entire urban agglomeration region (Fig. 1).

Scene No.	Type of imagery	Date	Path/row	Nominal spatial resolution(m)
1	Landsat 5 TM	July, 1992	122/32	30
2	Landsat 5 TM	September, 1991	122/33	25
3	Landsat 5 TM	September, 1992	123/32	30
4	Landsat 7 ETM+	August, 1999	123/32	30
5	Landsat 7 ETM+	August, 1999	122/32	30
6	Landsat 7 ETM+	September, 2001	122/33	30
7	Landsat 5 TM	September, 2008	122/32	30
8	Landsat 5 TM	September, 2008	122/33	30
9	Landsat 5 TM	September, 2009	123/32	30

Characteristic of satellite data used for built up area mapping in the study area

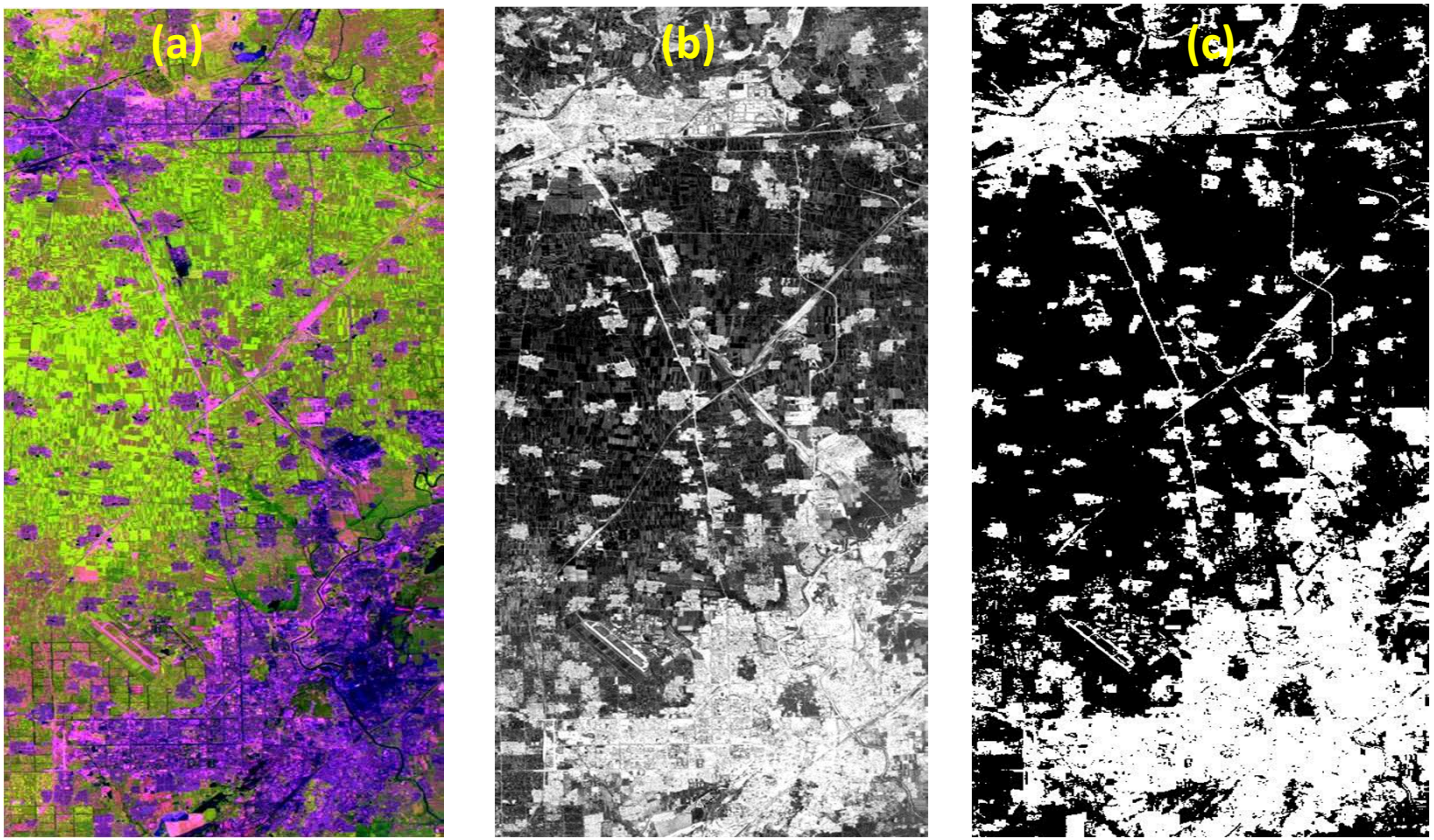
Methodology

Based on analysis of the unique spectral responses of built-up areas and other land covers in seven Landsat TM bands, an improved normalized difference built-up index methodology to extract built-up area:

$$NDVI_c = \frac{Band4 - Band3}{Band4 + Band3} \qquad NDBI_c = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4}$$

$$BU_c = NDBI_C - NDVI_C$$

The greater the value of a pixel in BU_c is, the higher is the possibility of the pixel being a built-up area.



(a)Subset of Landsat TM composition , band 5(R):4(G):3(B), (b)built-up index and (c) built-up area extracted.

Spatial metric analysis

Six class-level parameters quantifying the urban footprint at each time are calculated:

CA: absolute urban area

PLAND: Percentage of Landscape

NP: number of patches

LPI: largest patch index

LSI and **NLSI**: landscape shape index and normalized landscape index

BD: built-up density

Spatial metric analysis

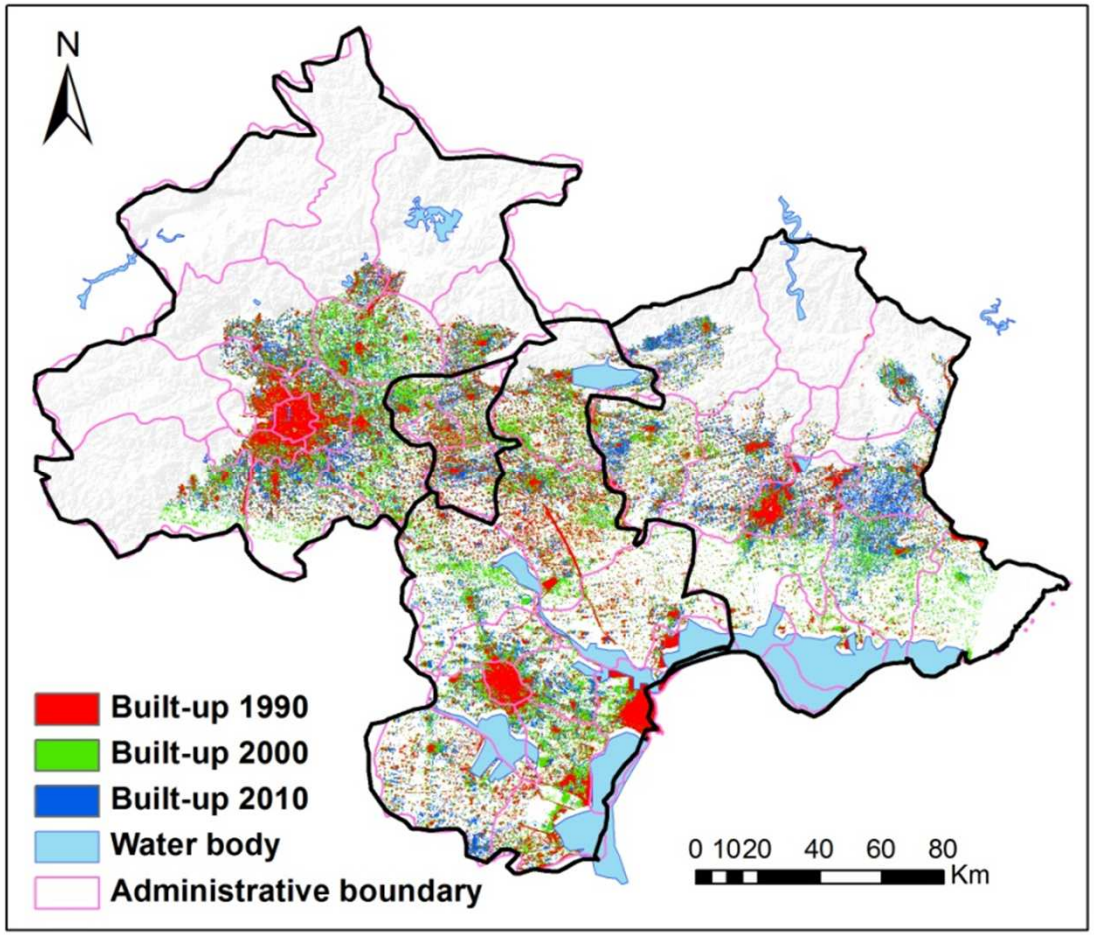
PLAND equals the percentage the landscape comprised of the built-up. They describe the growth of urban areas.

NP measures the extent of fragmentation of urban areas. NP increase indicates the conversion of non-developed land into built-up areas in the suburbs.

LPI quantifies the percentage of total landscape area comprised by the largest patch. It represents the percentage of an urban core area as a proportion of total urban land; the LPI increases when the urban areas become more aggregated and integrated with the urban cores.

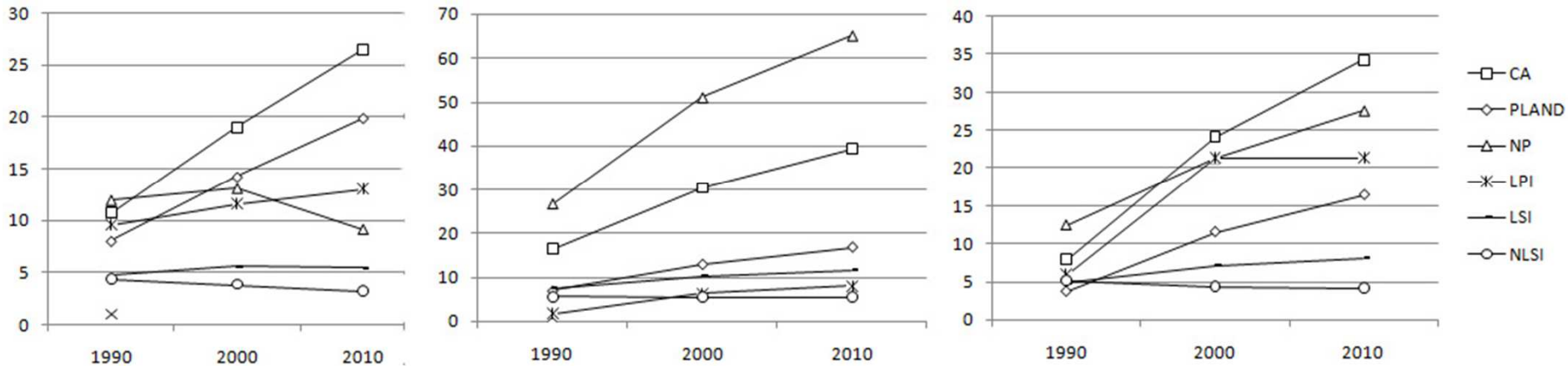
LSI provides a measure of class aggregation or clumsiness, which increases without limit as the patch type becomes more disaggregated.

Expansion of urban areas in Jing-Jin-Tang urban agglomeration



Expansion of urban areas in Jing-Jin-Tang urban agglomeration between 1990 and 2010 derived from TM/ETM+ data

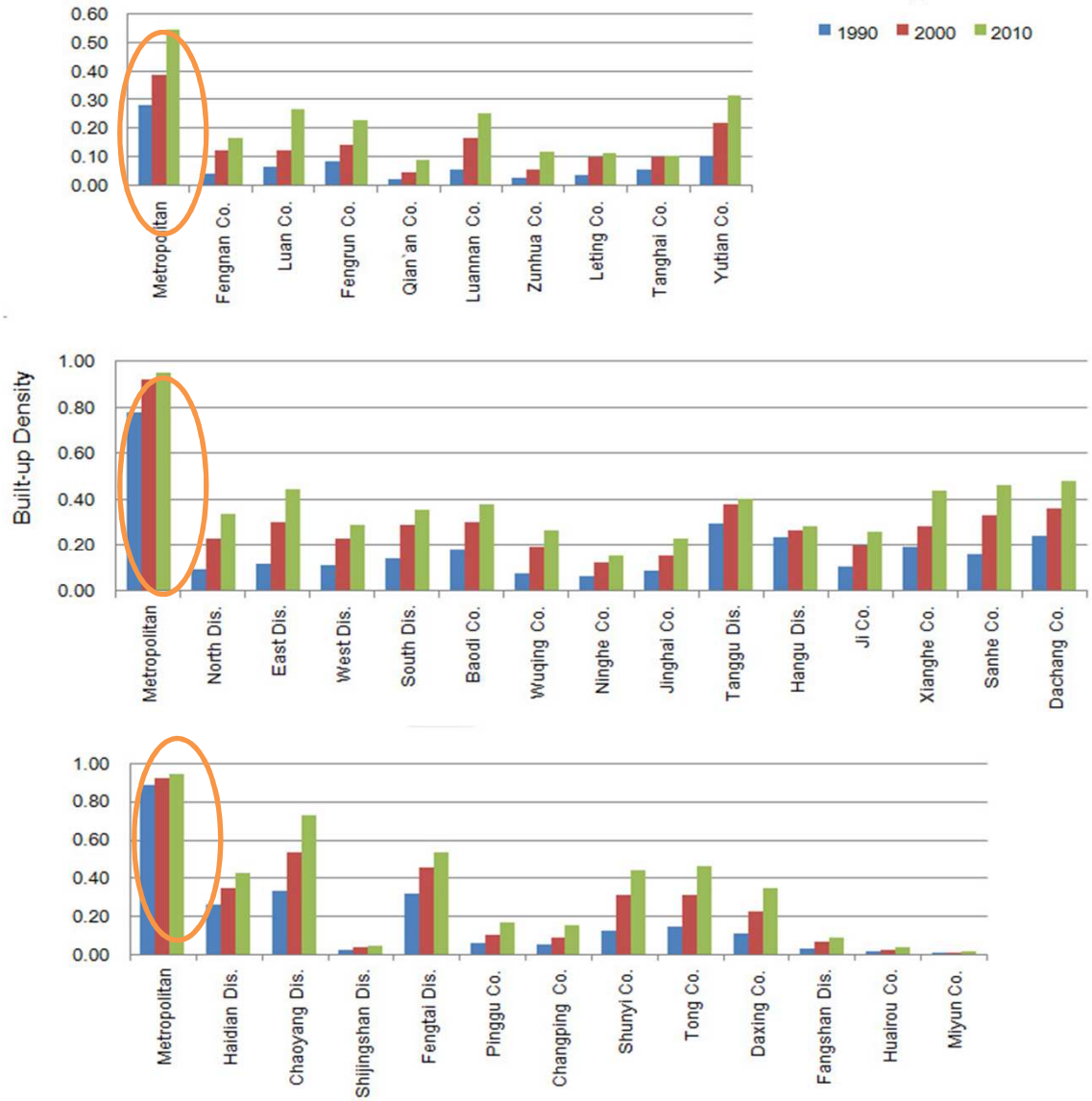
Fluctuation of six spatial parameters between 1990 and 2010 in Beijing(a),Tianjin(b) and Tangshan(c)



NP decrease indicates amalgamation between satellite towns or the urban core and individual urbanized patches in the 2000s in Beijing. NP increase in Tianjin and Tangshan the growth of new towns in the suburb area.

The decrease or stable of LSI and NLSI indicate Beijing is becoming more aggregated and a homogeneous urban patch is forming. The decrease of LSI and NLSI in Tianjin and Tangshan implies they are becoming more decentralized.

Zonal-based spatial pattern analysis at county-level



For each city, the largest built-up density exits in the metropolitan area. For Beijing and Tianjin, BD increased from 0.88 and 0.77 to higher than 0.9 respectively in the twenty years.

For Tangshan, the BD of metropolitan area increased from 0.28 to 0.55.

Conclusion

- The built-up area has a substantial increase in the urban agglomeration during last twenty years(1990-2010).
- The three cities have different development patterns. Tianjin and Tangshan is disaggregating with the increase number of satellite towns in the suburb area and Beijing is aggregating to a homogeneous region since the 2000s.

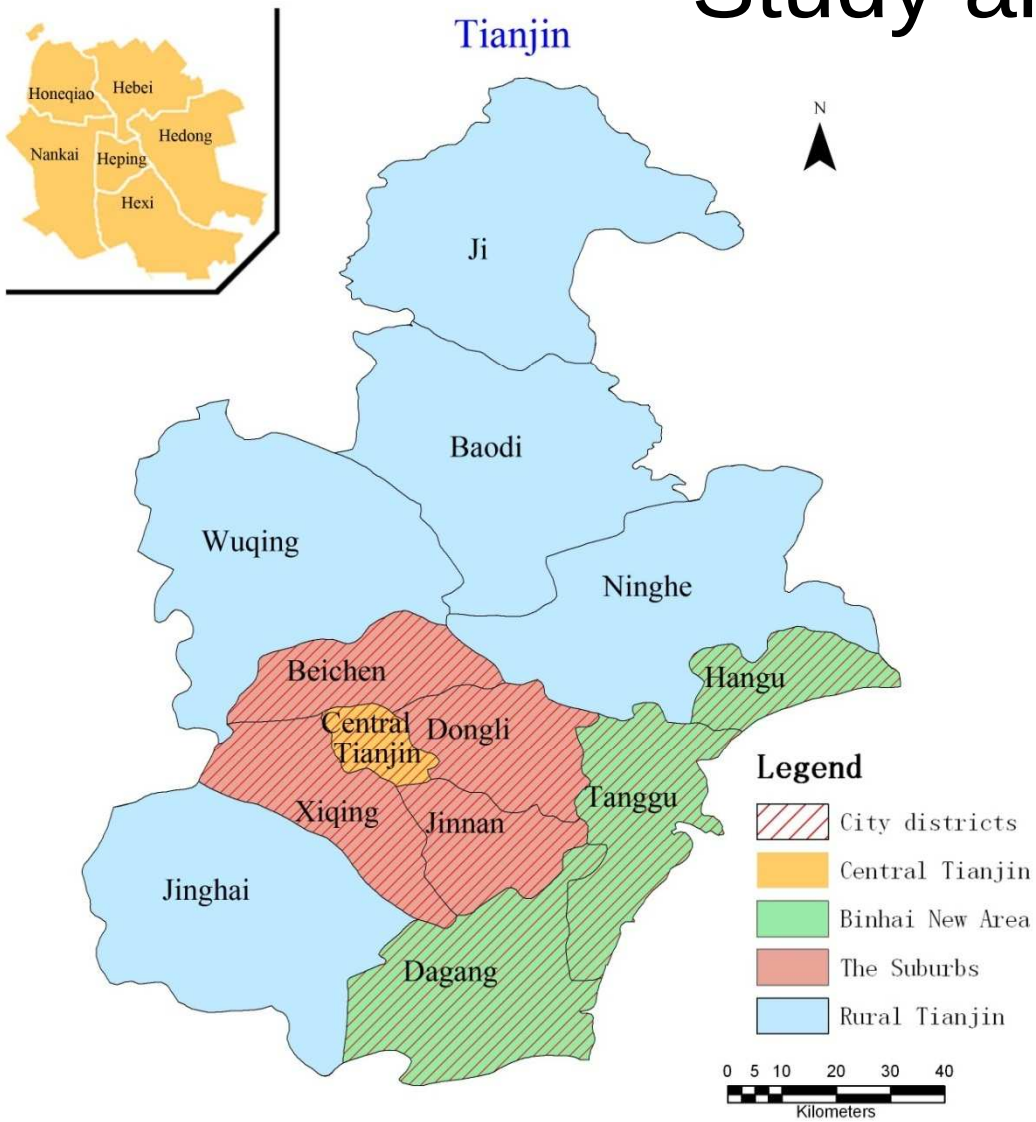
3. Comparison of Environmental Conditions in Tianjin City and Great Toronto Area

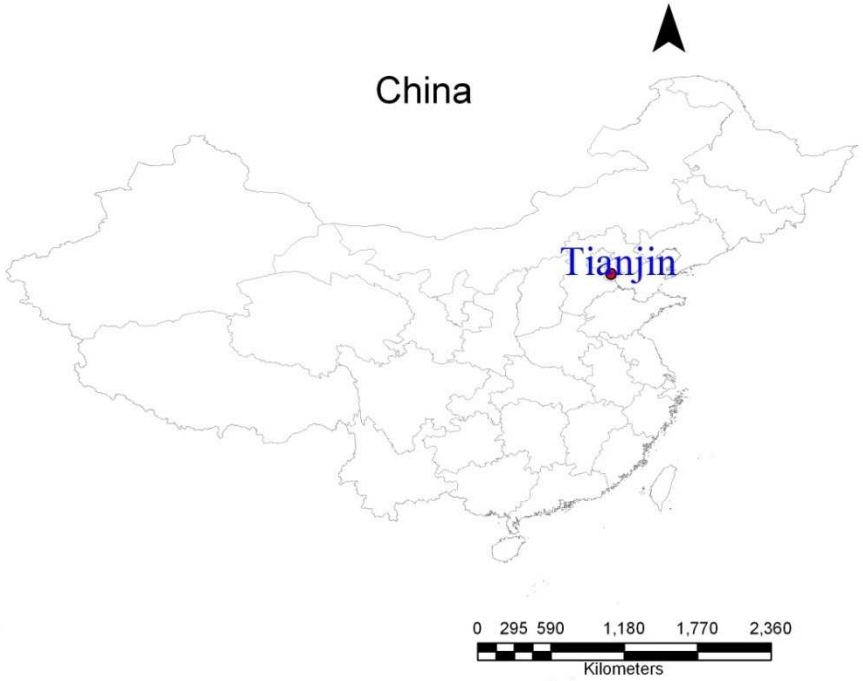
- Study area
- Datasets
- Methodology
- Data processing
- Result

- To extract urban and peri-urban land surface variables from time series TM/ETM datasets of Tianjin area and Great Toronto area based on SVM algorithm combined with hierarchy classification .
- To estimate emissivity according to the above land surface segmentation and the improved Qin approach and furthermore to retrieve land surface temperature.

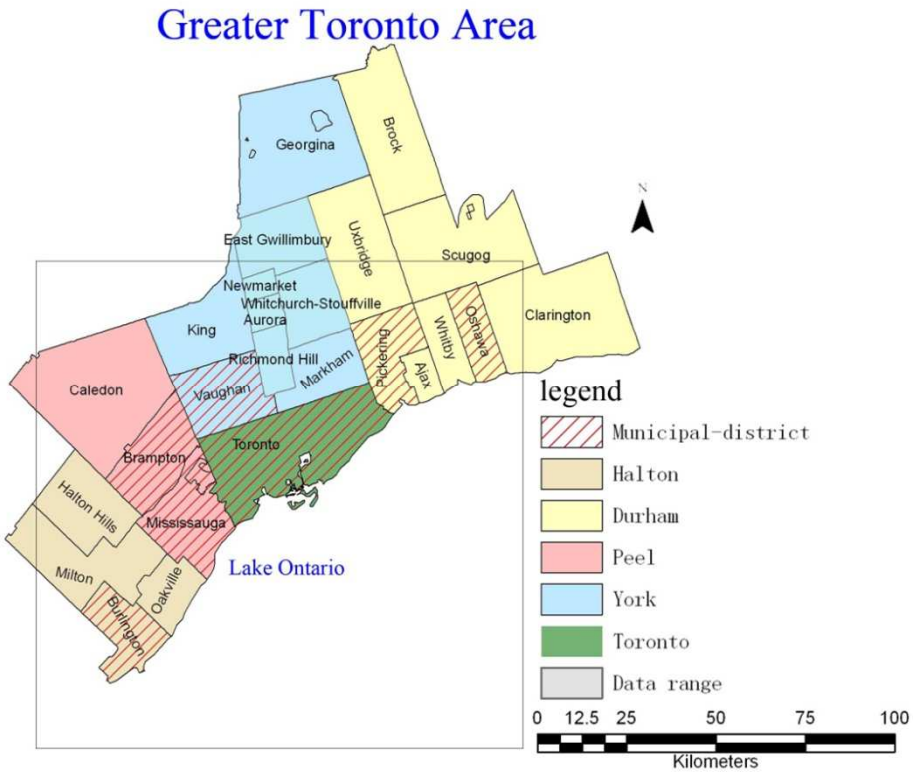
To reveal the relations and interactive mechanism between land surface variables change of urban agglomeration and regional environment; To investigate the different change characteristics of typical urban agglomeration between Tianjin and Great Toronto Area

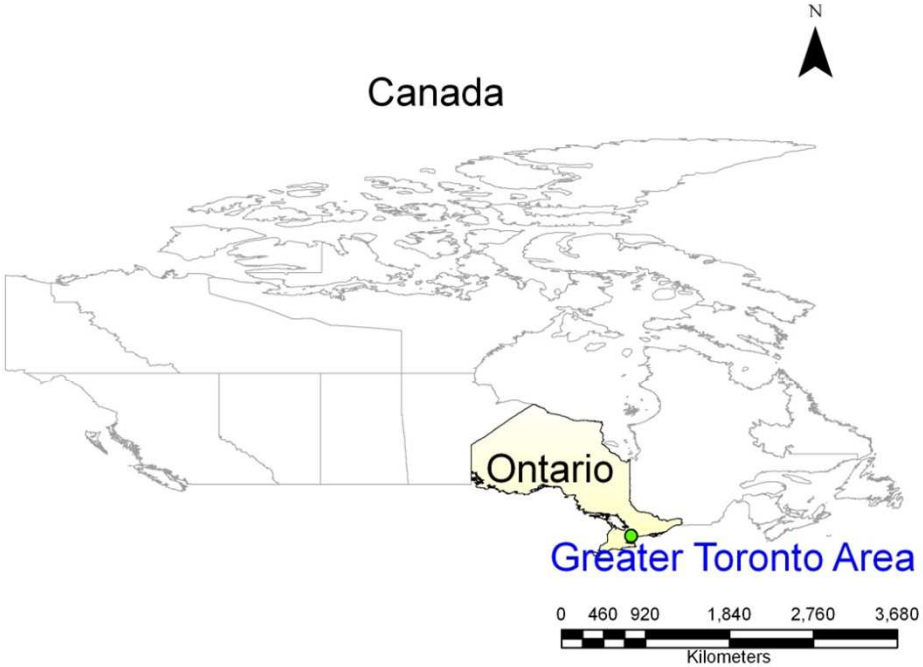
Study area





Tianjin is Located at latitude 38.57 ° N-40.25 ° N and longitude 116.72 ° E-118.32 ° E.
In terms of urban population, Tianjin is the sixth largest city of China. From 1980, the urban population proportion in Tianjin has exceeded 50% and now reached to 78.01%.





The Greater Toronto Area (GTA) is the largest metropolitan area in Canada, with a 2006 census population of 5.5 million. The GTA is composed of Toronto as the central city, surrounded by the four regional municipalities of Durham, Halton, Peel, and York. The area is at the centre of the Golden Horseshoe urban agglomeration, which contains approximately one-fourth of the population of Canada.

Datasets

Table 1. Landsat TM/ETM datasets used for the study

Area	Path	Row	Acquire Time		
			DataSet1	DataSet2	DataSet3
Southern Ontario	17	30	1984-8-25	1999-9-12	2005-9-12
	18	29	1985-9-20	1999-9-3	2005-9-11
	18	30	1985-9-20	1999-9-3	2005-9-11
Tianjin	122	33	1987-5-14	1999-8-11	2005-9-4
	122	32	1987-5-14	1999-8-11	2005-9-4
	123	32	1986-6-3	1999-8-6	2006-9-6

Methodology

VIS Model

1) That is Vegetation-Impervious surface-Soil model (Ridd,1995, International Journal of Remote Sensing),which suggests that the great variety of urban land cover types can be grouped into the three general categories – vegetation, impervious surface, and soil –plus water.

2) These basic land covers is highly related to two important factors of ecosystem: energy and moisture flux. The difference of exchange rate of energy and moisture of land cover types is used to analyze the urban environment.

Methodology

SVM and hierarchy classifier

Support Vector machines (SVM) is a non-parametric method based on the statistical learning theory. The advantage of the SVM-based classifier over traditional ones is that it solves learning problems better when only a small number of training samples is available.

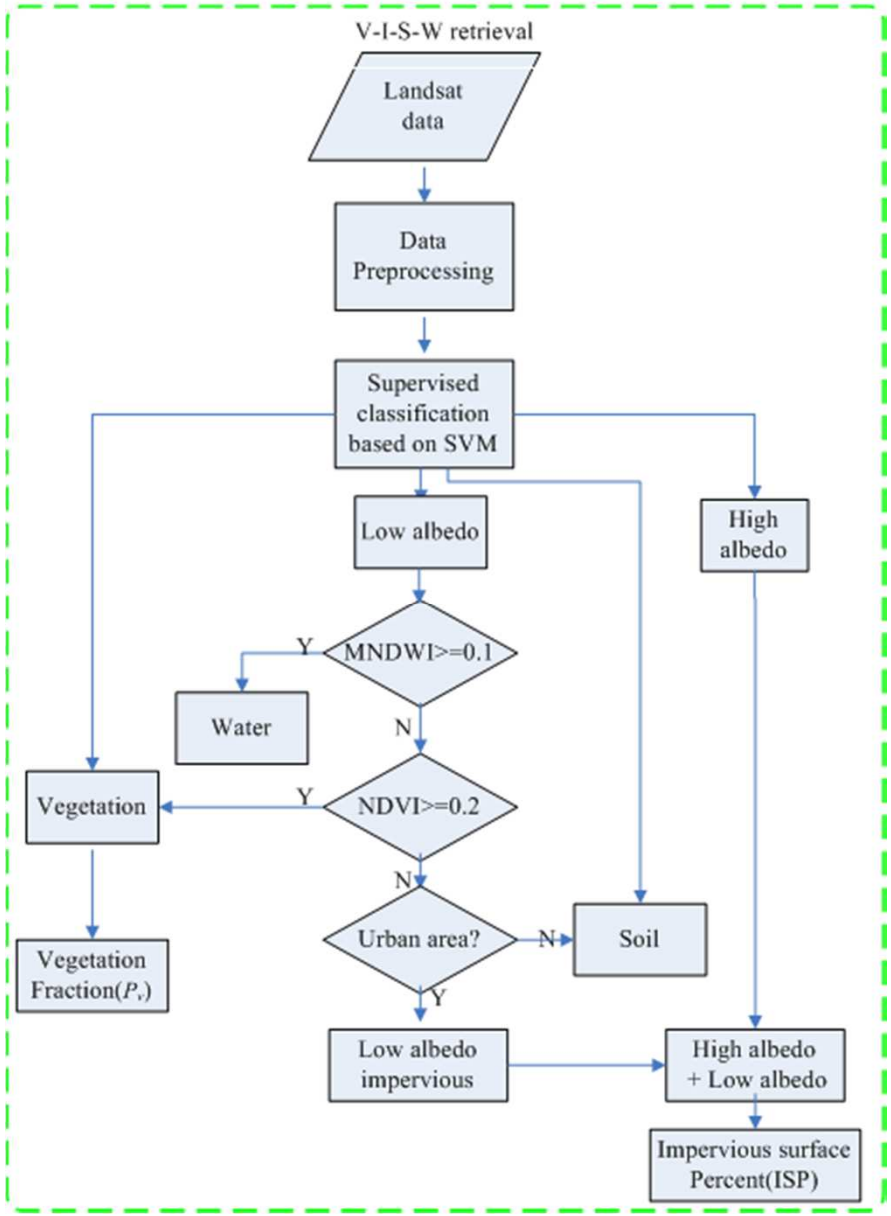
Emissivity estimation and retrieval of land surface temperature

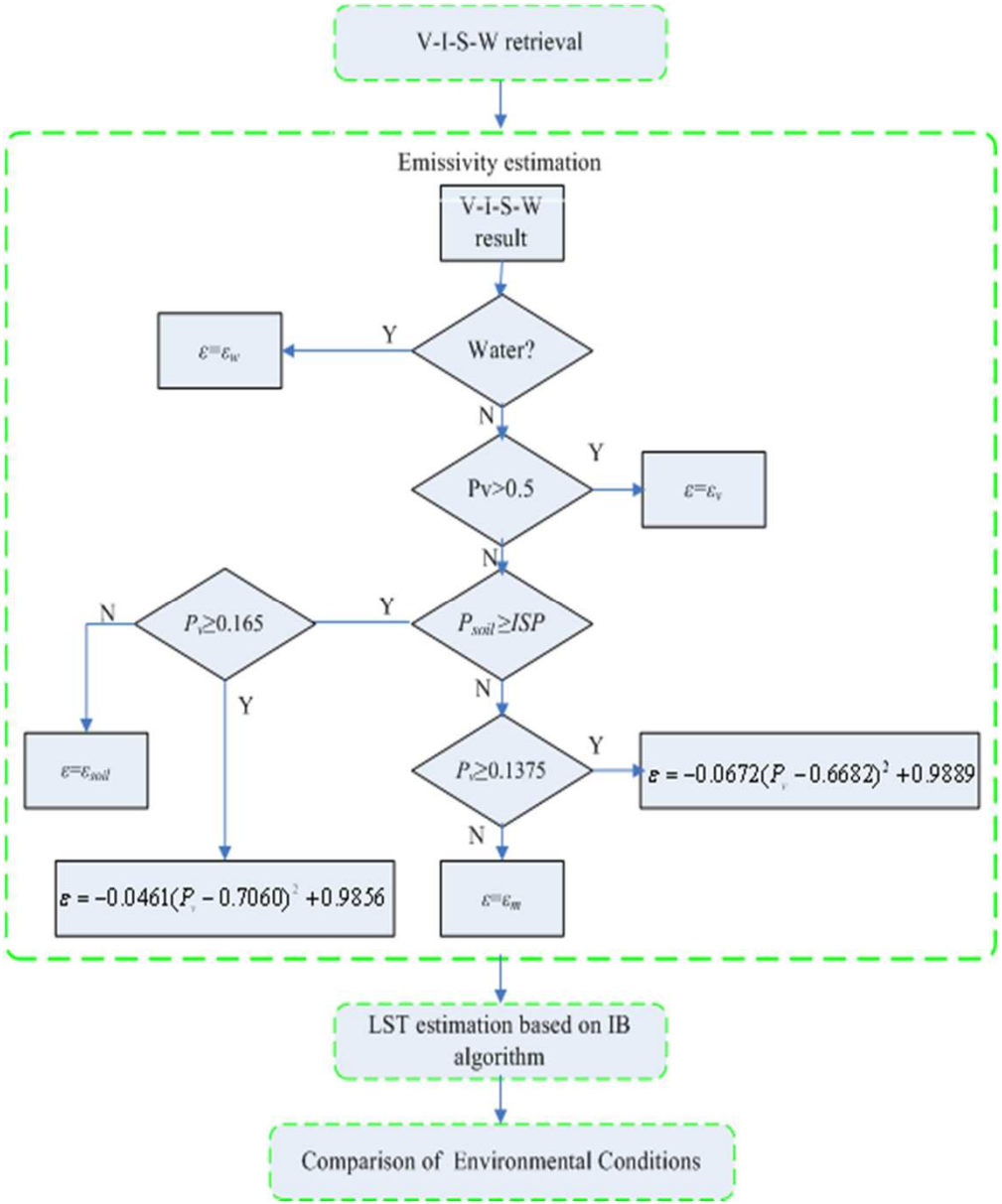
Currently, the estimation of emissivity from landsat data is largely based on the Qin's method. In this study, threshold method is used to modify the Qin's estimation model.

Retrieval of land surface temperature

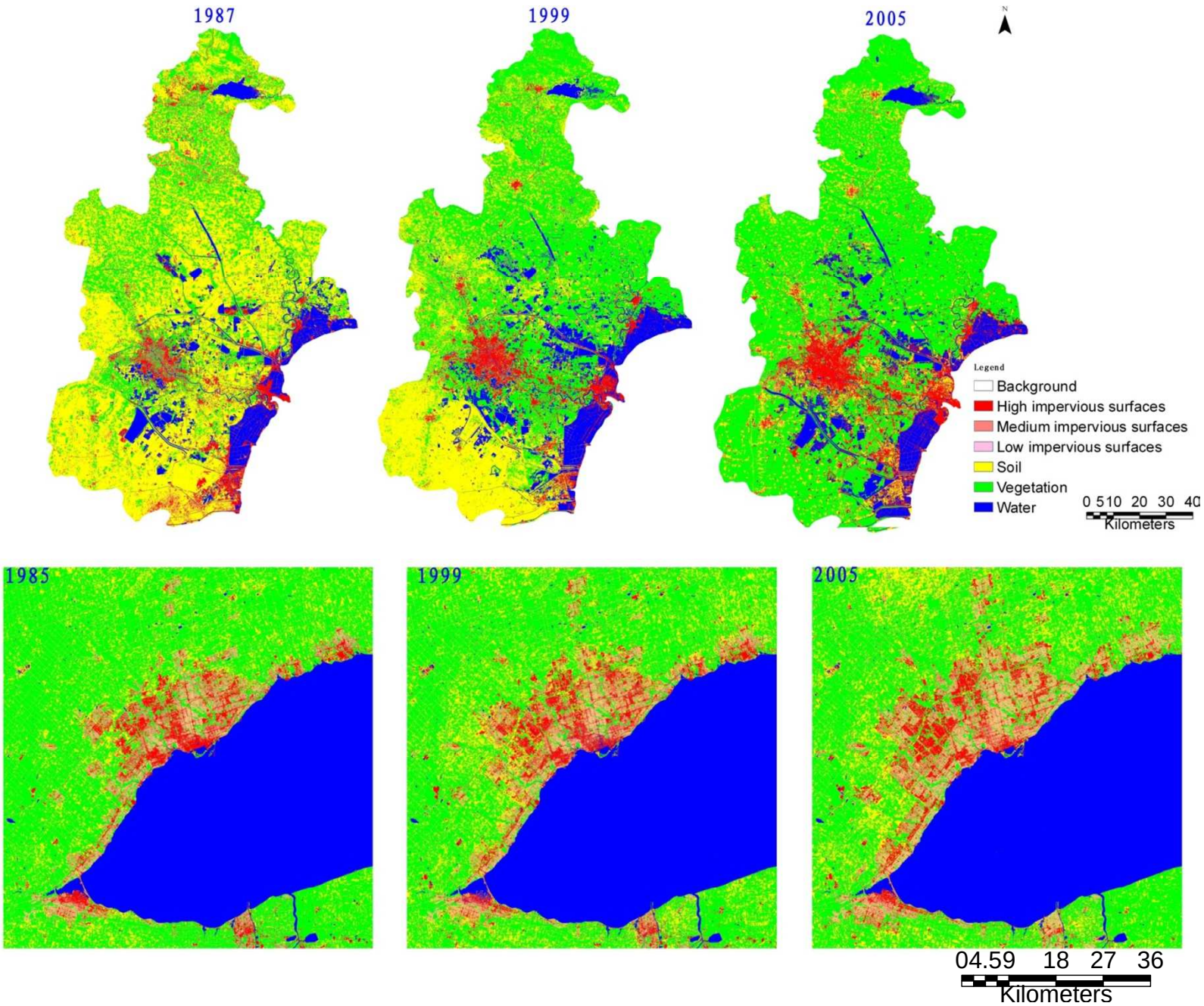
Image-based algorithm(IB) is used to retrieve land surface temperature, which just considering the emissivity influence in the clear-sky condition and not relying on any data of meteorological observation.

Data processing flowchart

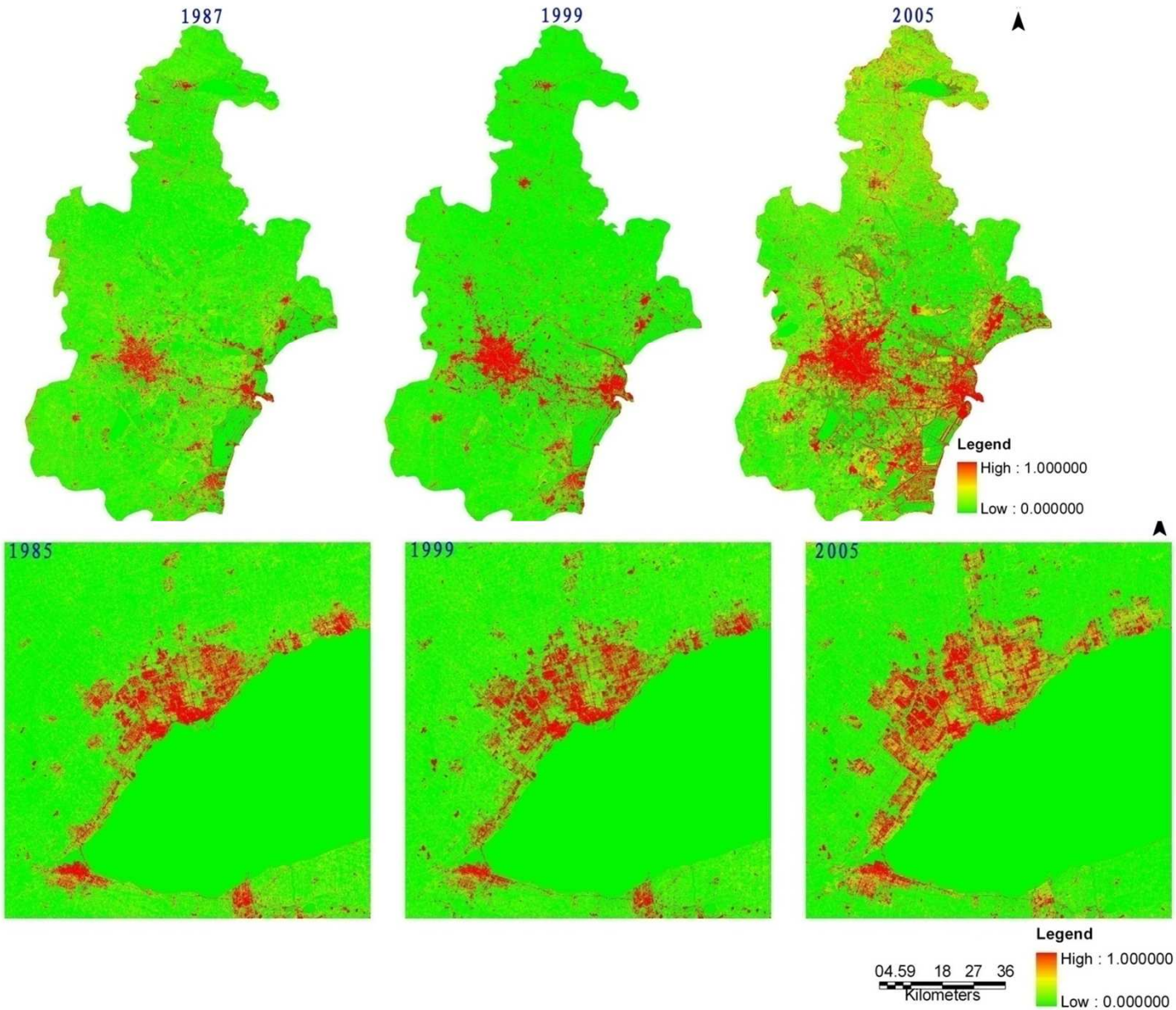




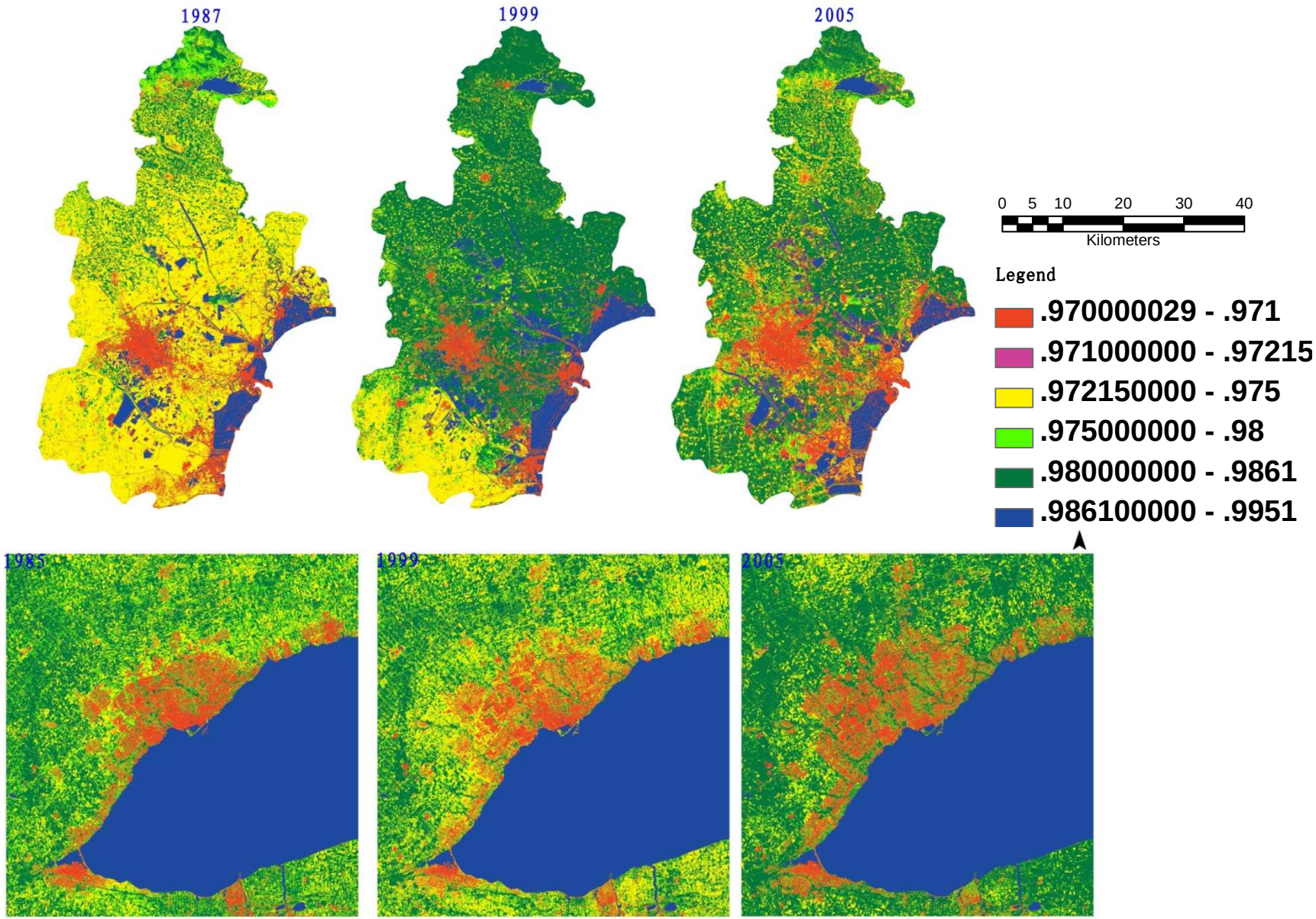
Temporal-spatial distribution of V-I-S-W of Tianjin and GTA



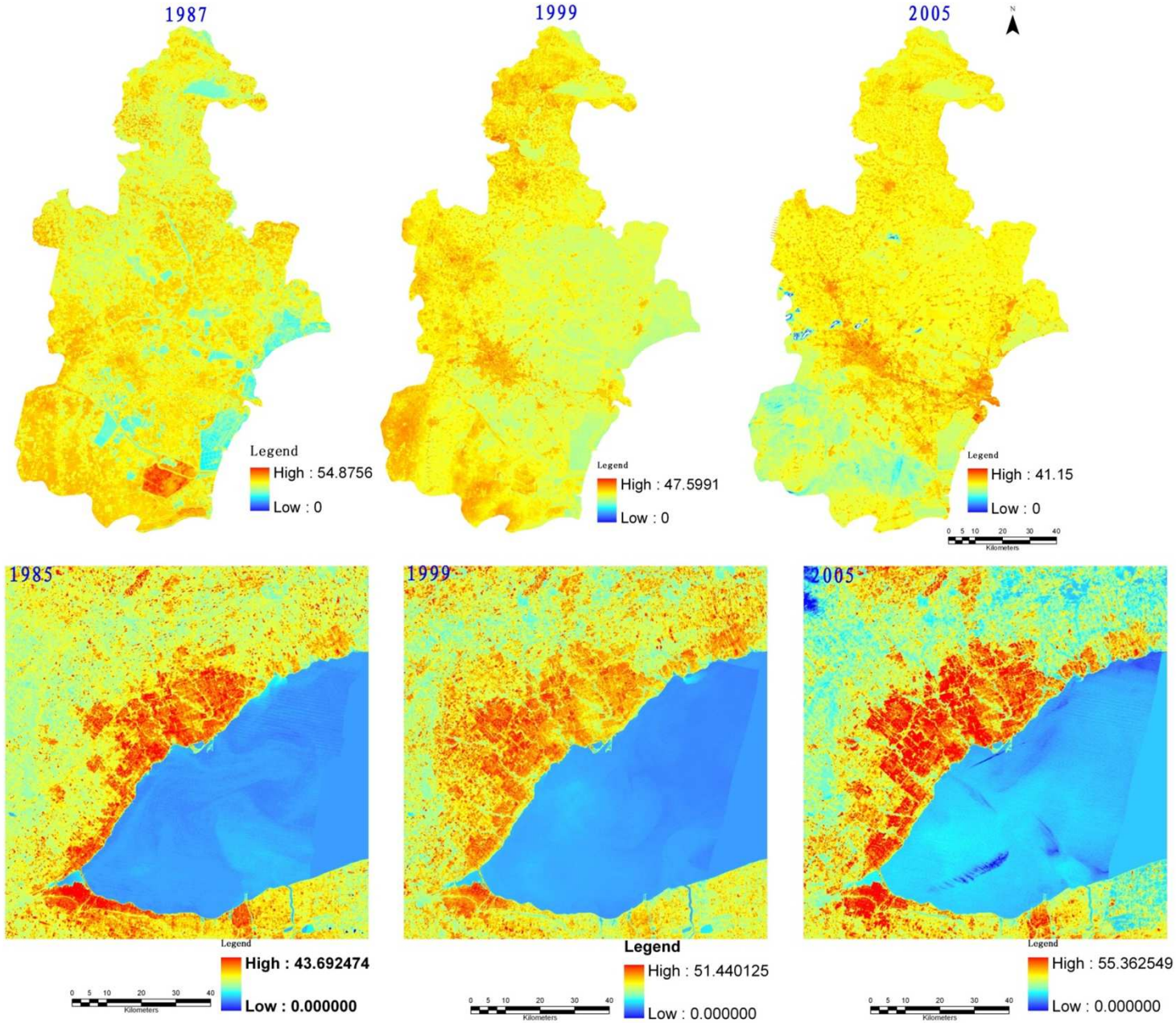
Temporal-spatial distribution ISP of Tianjin and GTA



Temporal-spatial distribution of emissivity of Tianjin and GTA



Temporal-spatial distribution of LST of Tianjin and GTA

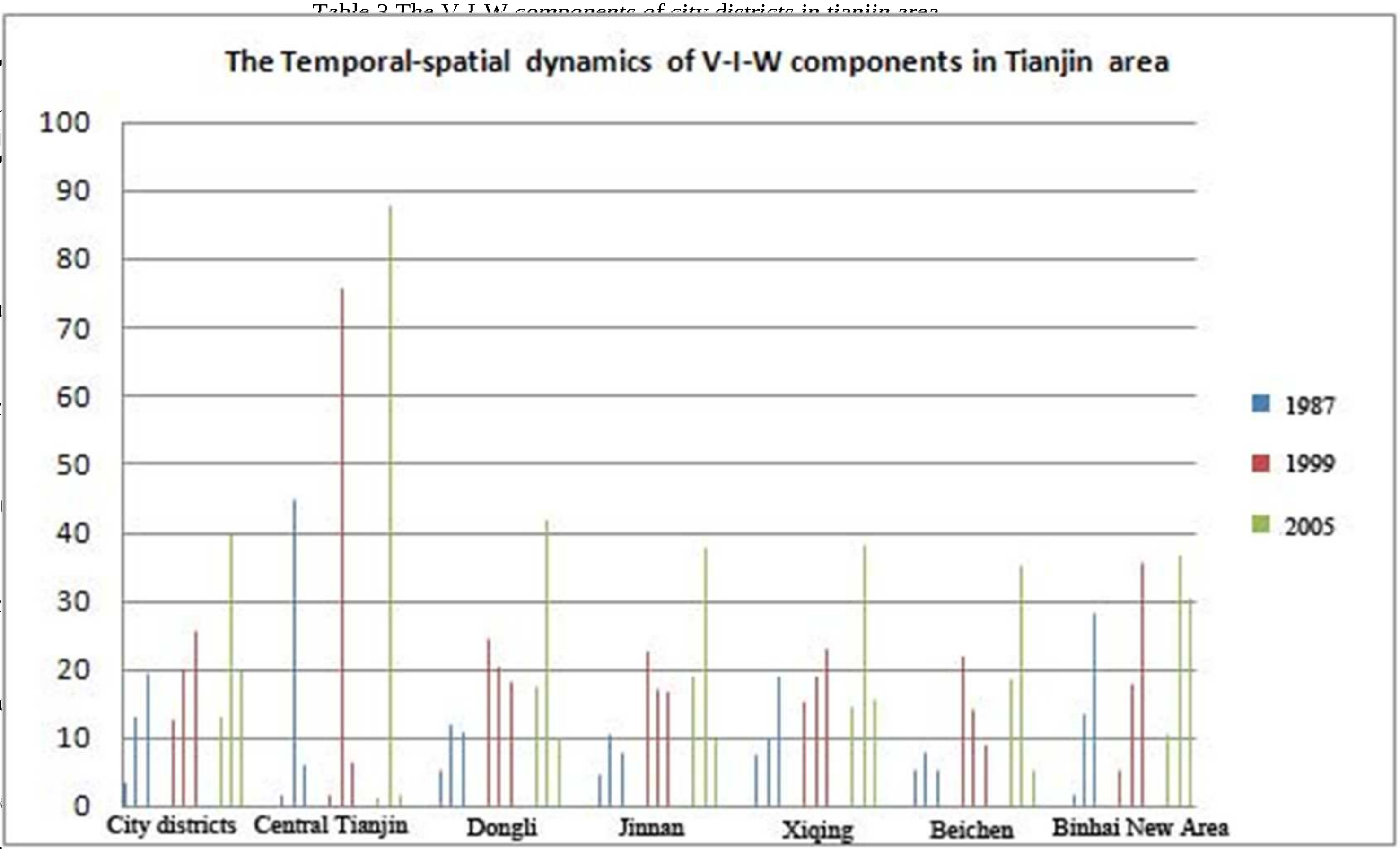


Results and analysis

➢ Tianjin area

From administrative subdivisions, the city districs is divided into urban areas(Central Tianjin, Binhai New Area) and the Suburbs(Dongli District, Jinnan District, Xiqing District, Beichen District).

Table 3 The V-I-W components of city districts in tianjin area



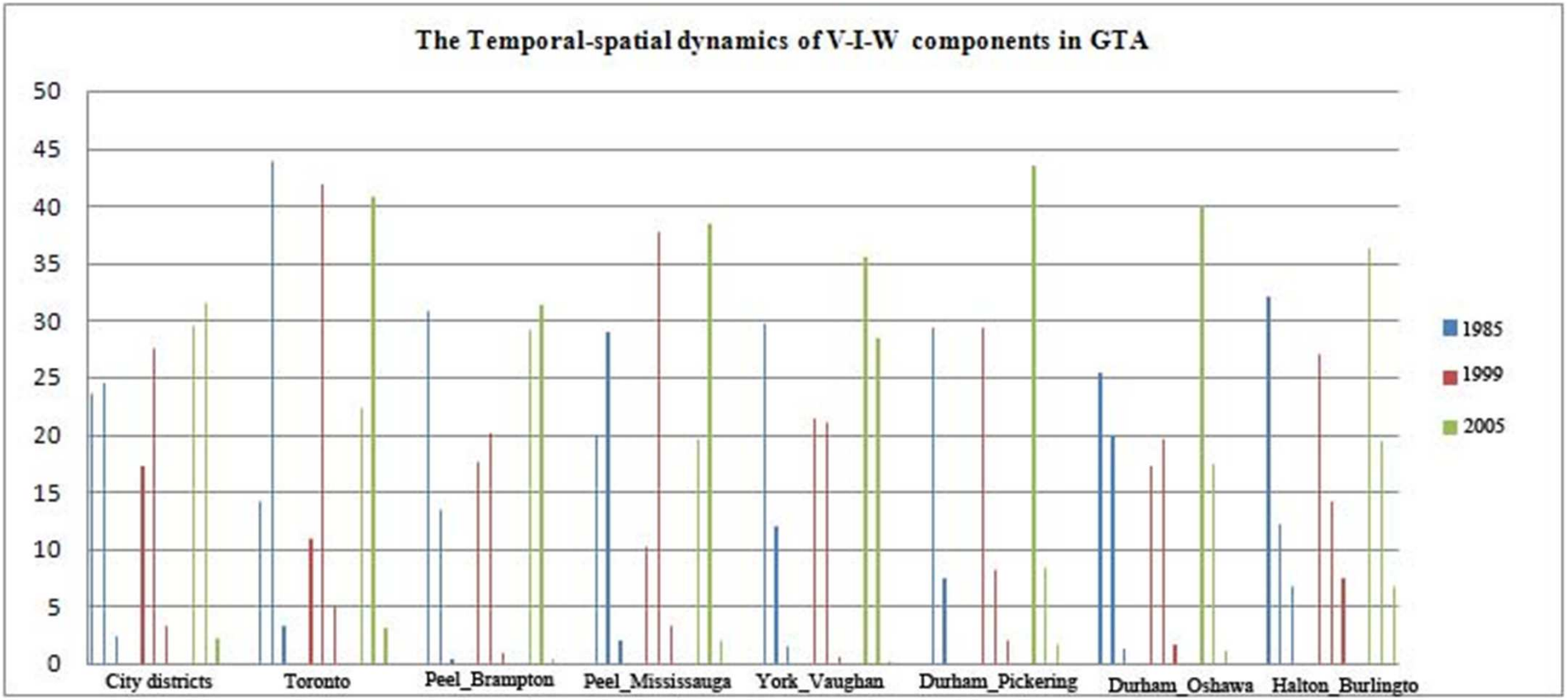
Study Site(Tianj	s	Water
City-districts	481	790.857
	318	19.696787
Central Tianji	561	2.6109
	957	1.633262
Dongli Distric	434	48.2319
	509	9.9022177
Jinnan Distric	507	38.3283
	269	9.7591101
Xiqing Distric	346	88.4394
	578	15.486887
Beichen Distri	997	23.3154
	972	5.1310999
Binhai New Ar	188	590.031
	526	30.253457

Results and analysis

- GTA

From census administrative subdivisions, The GTA is composed of Toronto as the central city, surrounded by the four regional municipalities of Durham, Halton, Peel, and York.The V-I-W components of city districts in corresponding municipality are given as follow.

Table 3 The V-I-W components of city districts in GTA

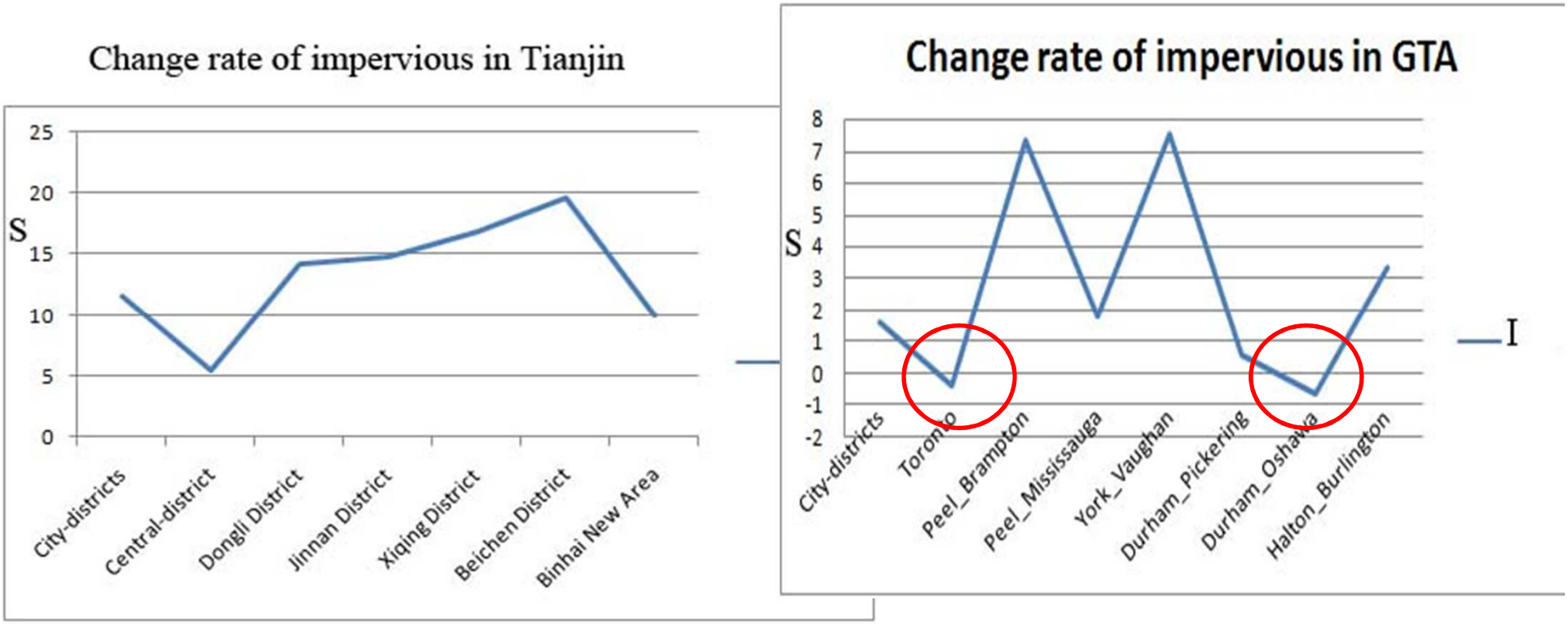


Results and analysis

➢Change rate of urban type

$$S = \frac{(S_b - S_a)}{S_a} \cdot \frac{1}{T} \cdot 100\%$$

Where S is the change rate of urban area, S_b,S_a is urban area at the beginning and the end of the study period, *t* is the study period.



Conclusion

- From the temporal-spatial dynamics of V-I-W components and the change rate of impervious surface we can see that they all have rapid increase of built-up areas in the past 20 years especially in Beichen district and Xiqing district. It can also seen that the Tianjin area is dual center development pattern.

- While in GTA, it has been highly urbanized in 1980's. And during the past 20 years, it undergone a relatively slowly urbanization. In Toronto and Oshawa city, it has negative grow rate and Brampton and Vaughan have the rapid grow speed

4. Future work

For monitoring urban agglomeration in Jing-Jin-Tang area

1. The driving forces underlying urban growth is important in studies of urbanization. A comprehensive investigation of driving forces of urban expansion can be considered in the further studies

For comparison study between Tianjin and Great Toronto area

1. The further analysis and discussion of emissivity and LST responds to V-I-W component dynamics.

2. Characterization and Monitoring of Urban Peri-urban Ecological Function and Landscape Structure based on Landscape Metrics

3. To relate these changes to regional environmental change and understand Megacity or urban agglomeration is how to drive and response to regional environment.

Thanks!